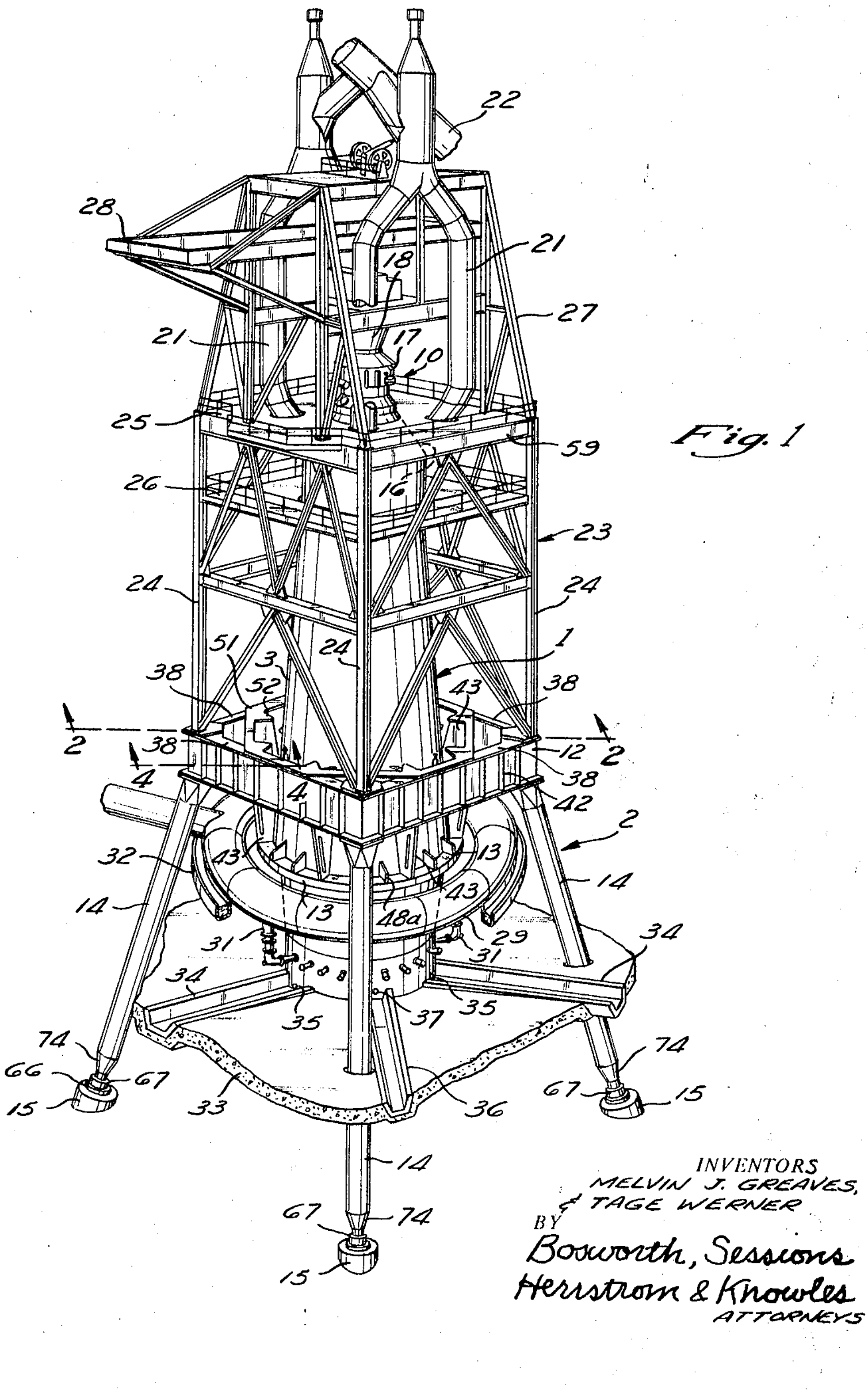
APPARATUS AND METHOD FOR SUPPORTING VESSELS

Filed Jan. 17, 1966 Sheet 1 of 6



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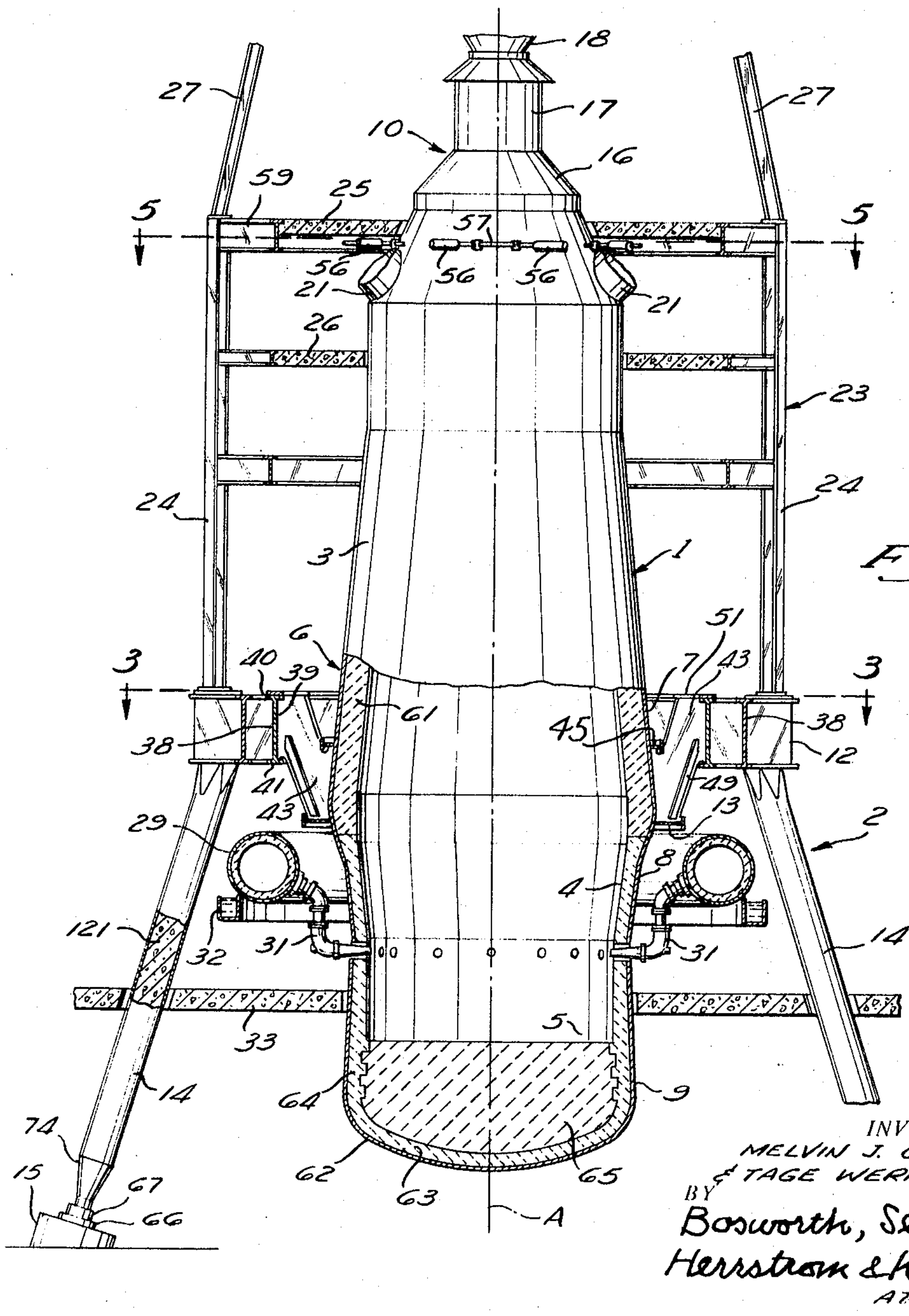

Fig. 2

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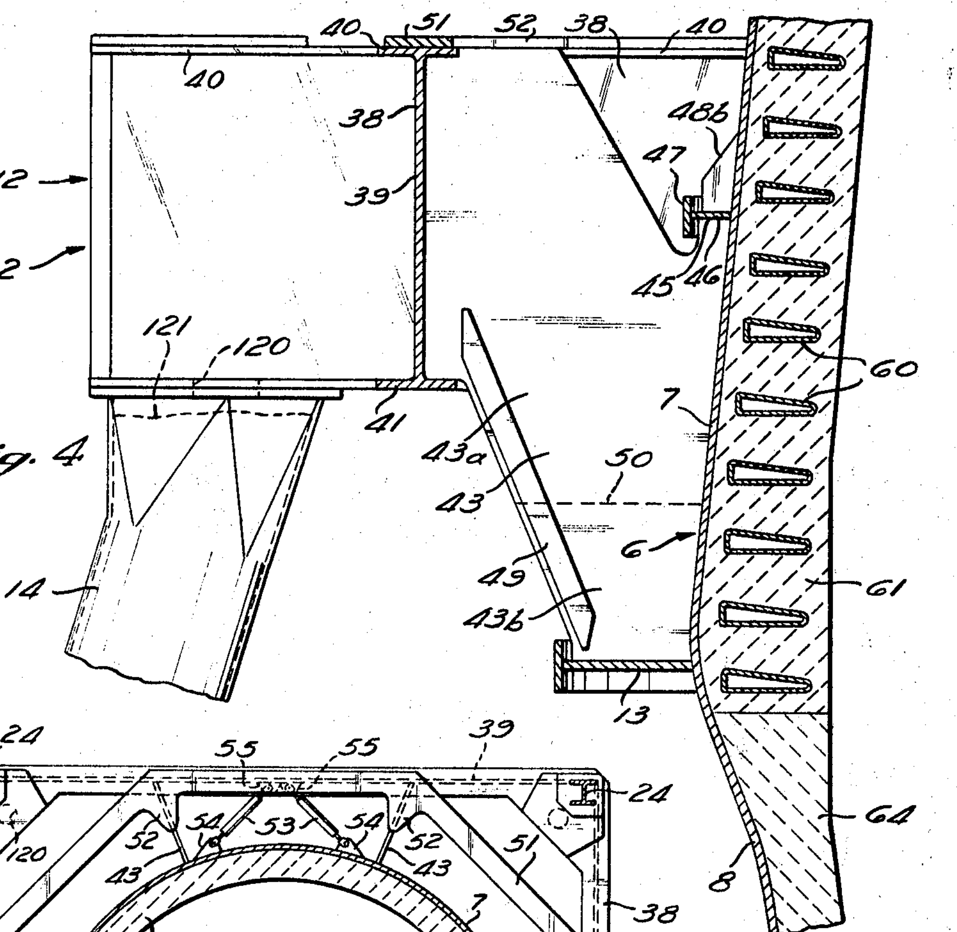

Fig. 4

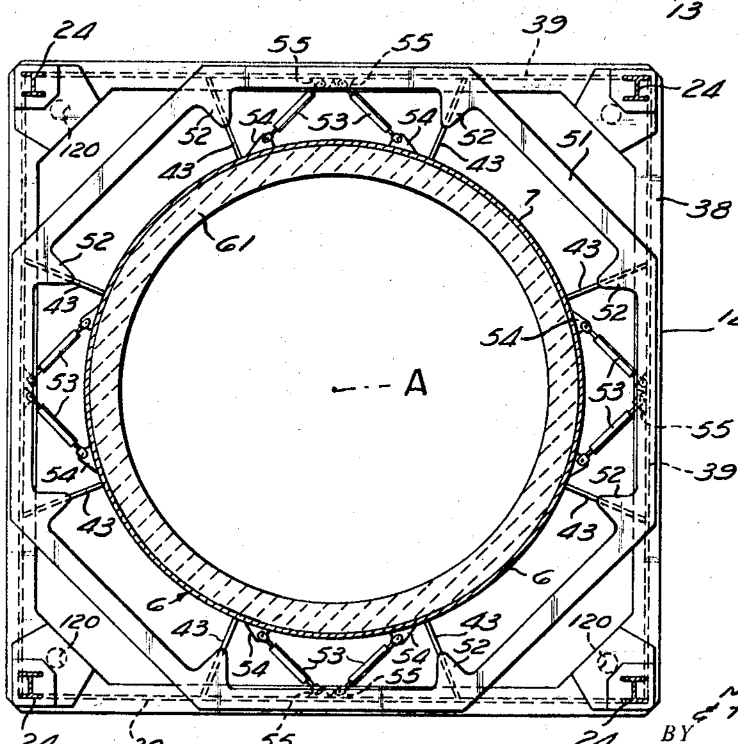

Fig. 3

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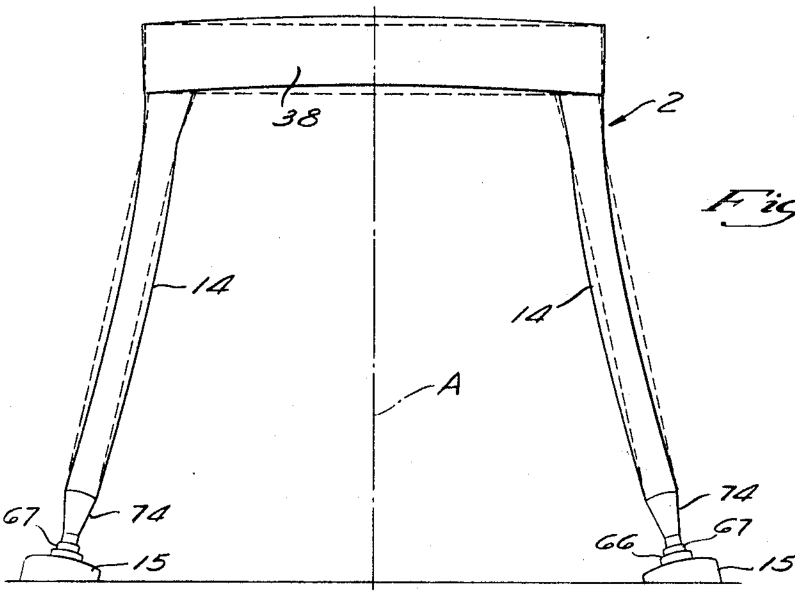

Fig. 6

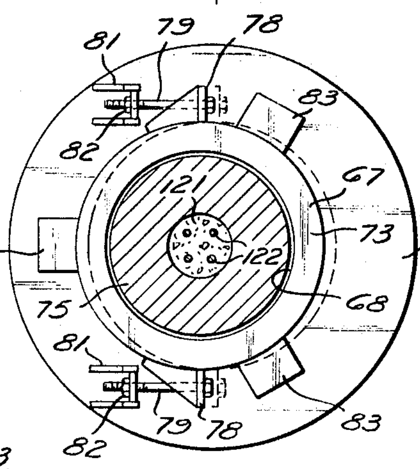

Fig. 8

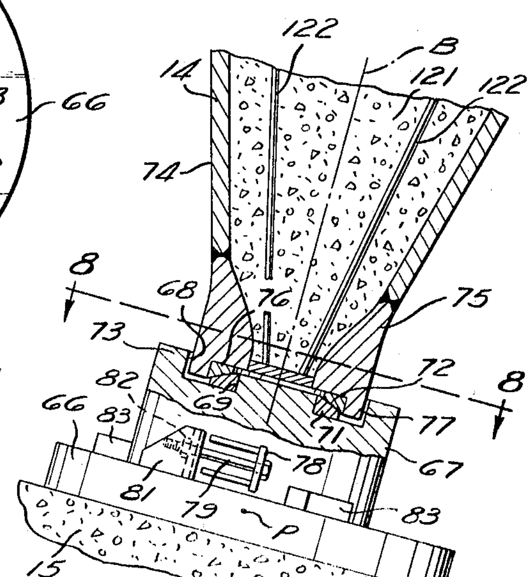

Fig. 7

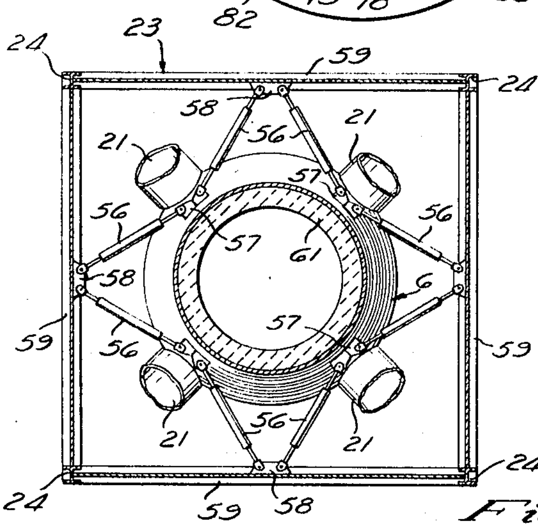

Fig. 5

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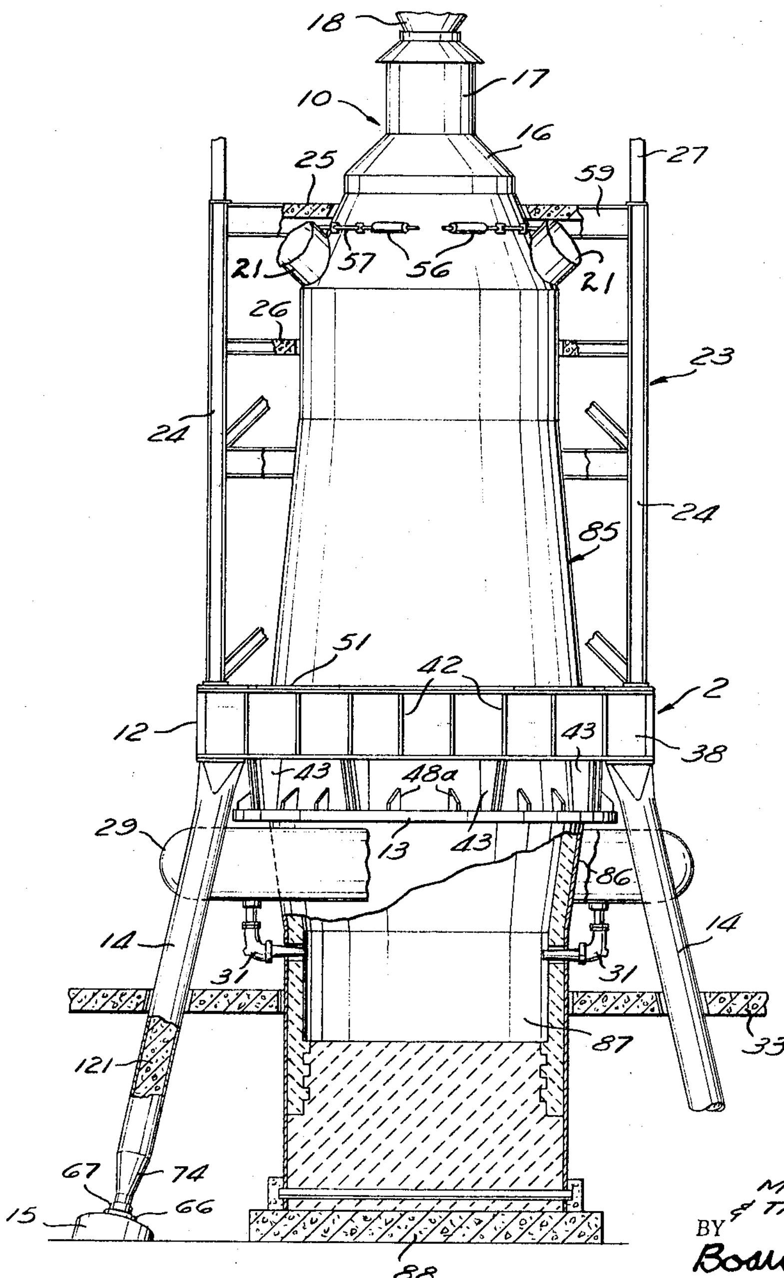

Fig. 9

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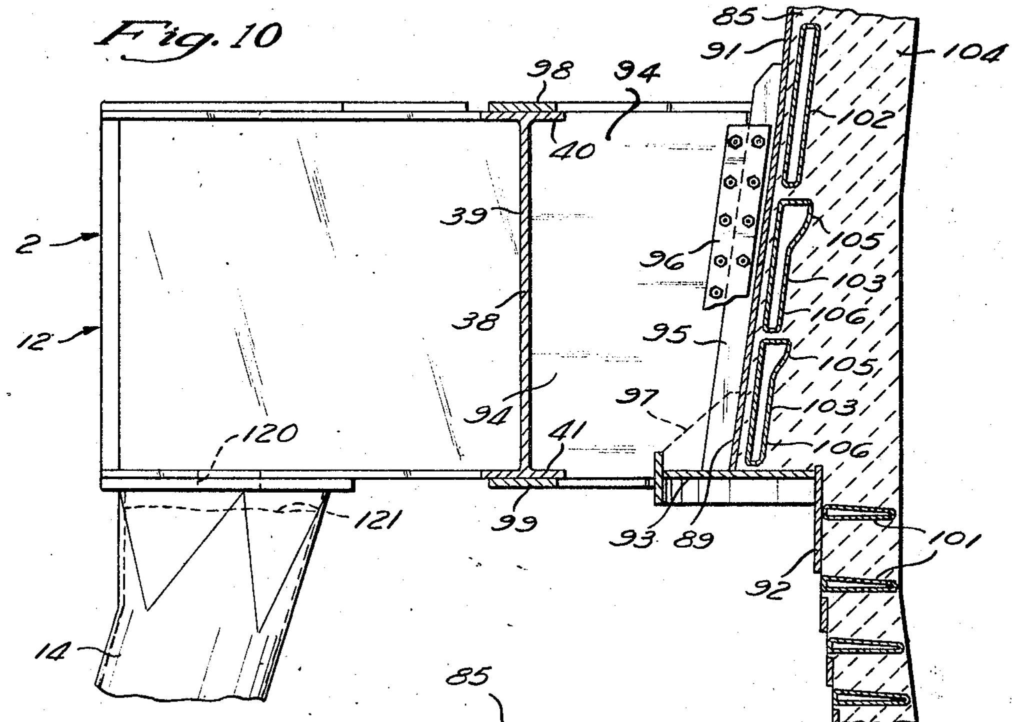
Fig. 10



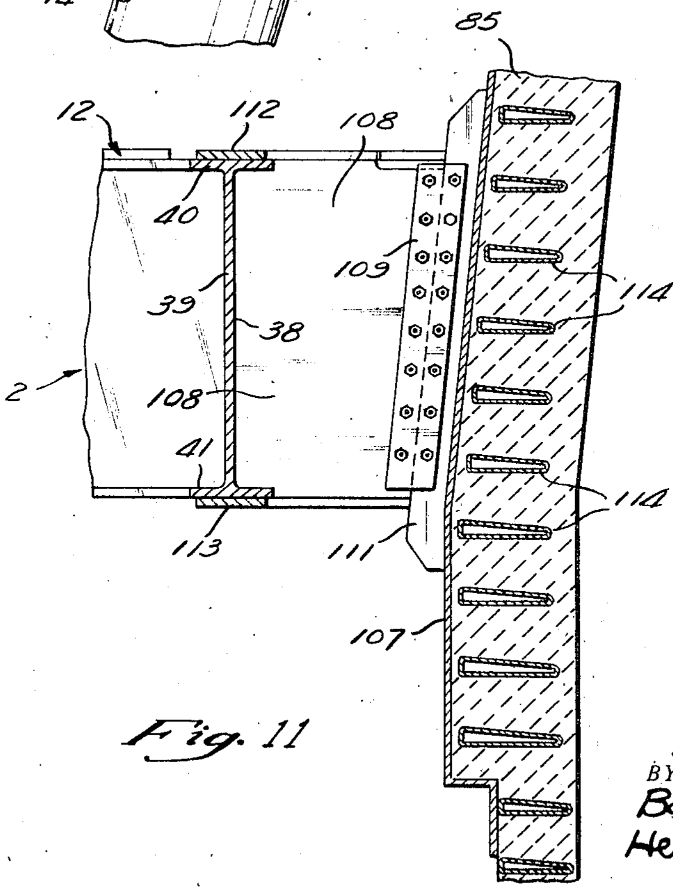


Fig. 11

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3,431,691

APPARATUS AND METHOD FOR SUPPORTING VESSELS

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U.S. Cl. 52—223 10 Claims
Int. Cl. E04c *3/30;* E04g *21/12;* C21b *7/00*

ABSTRACT OF THE DISCLOSURE

Supporting structure for supporting an upright vessel comprising transversely extending means adapted to support the vessel, outwardly inclined legs supporting the supporting means, the legs being prestressed prior to loading said supporting means by having the lower end in each of the legs positioned so it is displaced outwardly essentially in a direction and by an amount that the lower end of the leg would move if the supporting structure was subjected to a load corresponding to the vessel so that the legs are deflected when the supporting structure is unloaded and undeflected when loaded, means being provided for restraining the lower end of each of said legs against appreciable lateral movement. A method of constructing a supporting structure for an upright vessel in which the legs are deflected as indicated above to prestress them before loading.

This invention relates to blast furnace structures and more particularly to improved means for supporting blast furnaces.

In the United States, blast furnace structures heretofore conventionally used generally have included a massive foundation set into the earth; the lower portion of the furnace including the hearth and bosh has been supported by this foundation. The upper portion of the furnace, including the shaft and furnace top including the bells, distributor and upper portions of the downcomer, has been supported by a mantle that, in turn, has been supported on the foundation by numerous columns surrounding the lower portion of the furnace in close proximity to each other and to the lower portion of the furnace.

Such furnace structures have certain advantages in that the upper part of the furnace including the shaft and top supported by the mantle have been free to expand thermally as a unit on heating of the furnace. The downcomer attached to the furnace top also becomes heated during operation of the furnace, so it also expands and contracts with the portion of the furnace above the mantle, thus minimizing difficulties that might otherwise arise from thermal expansion.

However, in such furnace structures there have been substantial difficulties arising from the differences in the thermal expansions of the supporting columns and the lower portion of the furnace below the mantle. The mantle-supporting columns themselves are not subjected to sufficient heat to cause them to expand appreciably, but the lower portion of the furnace is subjected to high temperature heat; therefore, the lower portion of the furnace tends to expand substantially on heating of the furnace until it bears substantially all of the weight of the furnace above the mantle and the apparatus supported by such portion of the furnace. On cooling, the lower portion

of the furnace contracts and the entire load again is transferred to the columns. It, therefore, has necessarily been the practice to make the columns strong enough to support the upper portion of the furnace and apparatus supported thereby, and also to make the lower portion of the furnace strong enough to support the upper furnace portion and such apparatus; this has involved substantial added costs. Furthermore, the lining of the furnace in the vicinity of the mantle has been susceptible to excessive deterioration because of localized expansion and contraction arising from transfer of the load from the columns to the lower portion of the furnace and vice versa. The expansion joint often provided at this location to minimize this problem, itself has been a source of trouble.

In conventional European blast furnace structures the lower portion of the furnace including the hearth and bosh, and the upper portion of the furnace including the shaft but not the furnace top, are supported from a massive foundation set into the earth. The furnace top including the loading equipment and downcomers, is supported from this foundation by long posts or columns. This design tends to overcome the above described disadvantage of American-type structures, but introduces new problems. The bosh jacket is a structural element that supports the shaft of the furnace; consequently, a hot spot in the bosh can impair the support for the shaft; furthermore, the necessity for maintaining the bosh jacket as a structural supporting member increases the difficulties of relining the bosh. This design also make it difficult to maintain a satisfactory tight joint between the furnace top and the portion of the furnace below the top, since the portion of the furnace below the top tends to expand on heating whereas the columns supporting the top do not expand appreciably if at all; this problem is accentuated when high top pressures are used according to modern practice. Other problems arise because the downcomer, supported from the columns, expands due to heat while the columns themselves do not expand, and because a portion of the charge-distributing apparatus is usually supported by the furnace top and moves as the furnace expands, and a portion is supported from the posts and does not move from thermal expansion, so jamming of distributor parts or gas leakage at the distributor may occur.

In conventional American furnace structures, as well as in most European structures, the columns or posts that support the upper portions of the furnaces are so closely spaced in relation to the lower portions of the furnaces, as well as to each other, that they impair access to the lower portions of the furnaces for operations such as tapping, closing the tap holes and removing slag or spilled metal; they particularly impair access to these portions of the furnaces by automatic machinery for performing these functions. Moreover, since the legs are closely disposed relatively to the furnace, they can be damaged by molten metal in the event of break-outs. Furthermore, in both American and European furnace structures, it is very difficult, time-consuming and expensive to line the furnace, particularly the bosh and lower inwall portions which most frequently require lining, primarily because of the difficulties of access to the furnace caused by the closely spaced columns and by the constructions of the bosh and hearth portions which must act as supports for the upper furnace portions.

It is an object of the present invention to overcome as many of these problems and disadvantages as are desired. Another object is the provision of a blast furnace structure in which the portion of the furnace above the bosh, including the top, may be largely, or if desired entirely, supported by legs or columns at all times during heating and cooling of the furnace. This minimizes or eliminates disadvantages of American-type furnace structures such as those arising out of transfer of the support of the portion of the furnace above the mantle from the supporting columns to the lower portion of the furnace and vice versa; and also eliminates the disadvantages of European-type furnace structures such as those arising from the necessity to maintain the bosh jacket as a support for the shaft, from the difficulty of sealing the independently supported furnace top to the shaft, and from expansion of the downcomers and distributor parts relative to the non-expanding supporting posts supporting the furnace top.

A further object is the provision of a blast furnace structure in which the portions of the furnace above the mantle location, as well as the furnace top if desired, are supported by widely spaced legs that permit greatly increased access to the furnace for operations and use of automated equipment and repair or replacement of lining, and that reduces possibilities of damage to the legs in the event of break-outs of molten metal. Another object is the provision of a furnace structure of the above type in which the hearth is suspended from the furnace shell and not supported from below, so that the entire furnace is supported at all times from legs and both the upper portion and the lower portion of the furnace can freely thermally expand and contract.

These and other objects of the invention will be apparent from the following description of several embodiments of the invention in connection with the accompanying drawings in which:

FIGURE 1 is a perspective of a blast furnace structure embodying the invention and having a suspended hearth portion, parts not pertinent to the disclosure being omitted for clearness;

FIGURE 2 is a vertical cross section, along line **2—2** of FIGURE 1, parts being omitted for clearness;

FIGURE 3 is a section along line 3—3 of FIGURE 2 showing in plan the main supporting frame and lower centering means for the furnace, the scale being larger than in FIGURES 1 and 2;

FIGURE 4 is an enlarged detail along line **4—4** of FIGURE 1 showing one of the means connecting the surrounding frame of the supporting srtucture to the furnace shell;

FIGURE 5 is a cross section along line **5—5** of FIGURE 2 and to the same scale showing means for centering the upper portion of the furnace;

FIGURE 6 is a somewhat diagrammatic side elevation of the supporting structure, illustrating prestressing and preforming of the supporting structure before the load is applied;

FIGURE 7 is a vertical section to an enlarged scale of one of the supports for the legs;

FIGURE 8 is a section along line **8—8** of FIGURE 7;

FIGURE 9 is a detail of another embodiment of the invention in which the hearth is supported from the bottom but in which the remainder of the furnace structure is essentially the same as in FIGURES 1–8, parts being omitted for clearness;

FIGURE 10 is an enlarged detail, corresponding generally to FIGURE 4 in the location from which the section is taken, showing alternative means for connecting the surrounding frame to the furnace of FIGURE 9 and alternative cooling means; and

FIGURE 11 is an enlarged detail, also corresponding generally to FIGURE 4 in the location of the section, of another embodiment showing another means for connecting the furnace to a surrounding supporting frame.

In the furnace structure of FIGURES 1 to 8, inclusive, the furnace **1** is supported entirely free of the ground by supporting structure **2**. The furnace **1** comprises shaft **3**, bosh **4** and hearth portion **5**, all enclosed in a continuous steel shell **6** free of sharp bends below its connection to supporting structure **2** to provide adequate strength for the suspended portion of the furnace. Shell **6** comprises shaft shell portion **7**, bosh jacket **8** and hearth jacket **9**. The furnace top is generally indicated as **10**.

The supporting structure **2** comprises a frame **12**, surrounding and spaced from the furnace **1** in the vicinity of the ring **13**, which is preferably located in essentially the same vertical relationship to furnace shaft **3** as a mantle in a conventional furnace. Frame **12** is supported by four legs **14** from foundation members **15** set into the earth.

The furnace top **10** of the illustrated structure is conventional and includes a large bell hopper **16** containing a large bell (not shown), a superposed rotatable distributor **17**, the lower end of which is closed by a small bell (not shown), and a receiving hopper **18** above the distributor into which burden or charge material is charged. All of these parts are supported by the furnace from the top of the furnace shaft. Burden material may be conventionally charged into the receiving hopper by belts or skip cars traveling on a bridge (not shown).

Uptakes **21** are connected in conventional manner to the interior of the top portion of the furnace, and discharge into a downcomer **22** connected in the usual manner with a dust catcher, gas washer, stoves, etc., not shown. These uptakes and the upper portion of the downcomer are also supported from the top of the shaft of furnace **1**.

An auxiliary frame structure **23** is located above and rigidly supported from supporting structure **2**; it comprises upstanding legs **24** connected to the supporting structure **2** and carrying a top working platform **25** and a lower working platform **26**, the upper end of the skip or belt conveyor bridge, as well as superstructure **27** that supports the repair crane **28** and other parts usually associated with the top of a furnace.

The furnace also includes conventional bustle pipe **29** surrounding the bosh, tuyeres **31**, and associated cooling-water collecting trough **32**. A working or cast house floor **33** at the lower end of the furnace carries the iron runners **34** extending away from the iron notches **35** and a slag runner **36** extending away from the slag notch **37** in the furnace hearth. This floor is preferably supported independently of the legs **14** of the furnace structure.

In the supporting srtucture **2**, the frame **12** of the illustrated apparatus is made up of four deep steel beams **38** that are welded or bolted at their ends to form a square in plan (FIGURE 3). Each of the illustrated beams, which may be about **10** feet deep, is an I section girder having a wide vertical web **39**, top and bottom flanges **40** and **41**, and reinforcing stiffeners **42** (FIGURE 1); it may be conventionally fabricated, as by welding, from steel plates. The four legs **14** are rigidly connected to frame **12** at the four corners thereof, as by welding or bolting.

At each of eight points of equal deflection on the frame **12**, a connector member **43** connects the adjacent I-beam **38** to the blast furnace shell **6** in the vicinity of the juncture of the shaft and bosh portions of the furnace, preferably at a location such that when the furnace is empty or filled the center of gravity of the furnace is below a horizontal plane containing the center of gravity of the frame **12**.

Each of these connector members **43**, as shown in FIGURES 1 to 4, comprises a flat member, preferably formed of thick steel plate, that extends inwardly from the web **39** of the associated I-beam **38** of the frame **12** to the shaft portion **7** of the furnace shell **6** and is rigidly fixed, as by welding or bolting, to both the I-beam and the furnace shell. These members **43** are essentially located in spaced vertical planes that extend essentially radially of the furnace shell and pass through and are equiangularly spaced about a vertical axis A that is essentially coincident with the vertical axis of the furnace of supporting structure **2**. The lower portion of each member **43** extends downwardly from the bottom of the I-beam **38** to a structural ring **13** located a substantial distance below the bottom of I-beam **38** and fixed to the shell **6** of the furnace at the juncture of shaft shell portion and the bosh jacket **8**. Preferably, as shown in FIGURE 4, a structural ring **45** is fixed to the shell **6** and the inner edge of each member **43**, at a location on the shell below the top of frame **12**; ring **45** is made of a radially-extending web **46** that is welded or bolted to the shell and members **43**, and a stiffening flange **47** that is welded to the web. Rings **13** and **45** are also laterally stiffened by numerous reinforcing gussets **48*a*** and **48*b*** (FIGURES 1 and 4) welded to the shell and the rings. If desired, each connector member **43** can be made in two pieces **43*a*** and **43*b*** that are joined along line **50** to facilitate erection. Upper piece **43*a*** can be fixed to supporting frame **12**, and lower piece **43*b*** can be attached to the furnace shell **6**, after which these parts of each member **43** can be welded together in the field. Members **49** are also fixed, as by welding, to the outer edges of connector members **43** and aid in reinforcing them.

A compression ring member **51**, shown in the illustrated embodiment as octagonal with sides of equal length and equal angles between the sides, is fixed, as by welding, to top flanges **40** of the I-beams **38** of the main frame **12**, and has internally-extending projecting portions **52** that are welded or otherwise rigidly fixed to the outer top edges of the connector members **43**. This ring member **51** resists tilting of the beams **38** about their longitudinal generally horizontal axes, from the weight of the furnace or from expansion of the furnace shell on heating. As the furnace heats and its shell increases in diameter, the lower ends of the connector members **43**, which are deep enough so they themselves do not appreciably deflect, tend to move outwardly with the lower portion of the shaft shell portion **7** to which is affixed one generally vertical edge of each connector. This causes the upper ends of connectors **43** to tend to move inwardly, which tends to cause the beams **38**, to which are fixed the other spaced, generally vertical edges of connectors, to twist about their longitudinal axes so their upper flanges **40** tend to move closer to the furnace than their lower flanges **41**. However, any tendency of each I-beam thus to twist or tilt is resisted by the ring member **51** that is thus subjected to compressive forces. Reinforcing members **49**, on each side of each connector member **43**, also strengthen members **43** against buckling. Since the ring member is a symmetrical polygon with straight sides at the junctures of which the connectors are located, the member is exceptionally efficient in resisting the forces to which it is subjected.

There is a pair of divergent adjustable struts **53** connecting each of the four sides of the frame **12** to the shell (FIGURE 3). These struts are turnbuckle-types adjustable as to length. The struts of each pair are pivotally connected to widely spaced lugs **54** on the furnace shell **6** essentially equidistant from the midpoint of the adjacent frame beam **38**, and to lugs **55** on the web of such beam at locations closely adjacent to and essentially equidistant from its midpoint, preferably nearer the top of the beam than the bottom; these struts are generally tangential to shell **6**.

At the upper portion of the furnace pairs of divergent adjustable struts **56** similar to struts **53**, extend beween the top of the furnace shell and the auxiliary frame structure **23** (FIGURE 5). Struts **56** of each pair are pivotally connected to lugs **57** on the furnace shell **6** and to lugs **58** on the adjacent girder **59** forming the top of the auxiliary frame **23**, which is made strong enough to resist substantial lateral forces. Lugs **57** and **58** for each pair of struts are located essentially equidistantly from the center of the associated girder **59**, below the top platform **25**, and each strut **56** is generally tangential to the furnace shell.

By suitable adjustments of the lengths of struts **53** and **56** it is possible to cause them to center the furnace in the supporting structure formed of structure **2** and its attached auxiliary frame structure **23**, to prevent twisting of the furnace in such structure, and to restrain the furnace against lateral movement relative to such structure in the event of seismic or other shocks, all without preventing vertical movements of the furnace or portions thereof relative to such structure as might result from thermal expansion or contraction. The furnace is thus supported at all times by a strong, stable supporting structure.

In this embodiment, the shaft of the furnace is cooled by generally horizontal conventional cooling plates **60**, extending transversely around the circumference of the furnace in shaft inwall **61**, through which plates water is circulated by conventional means. The bosh may be conventionally cooled by water applied to its exterior.

The bottom portion **62** (FIGURES 1 and 2) of the hearth jacket **9** portion of shell **6** preferably is essentially the shape of a hemi-ellipsoid having a circular cross section, and is lined with a suitable refractory material such as a substantially uniformly thick layer **63** of carbon; the carbon lining in this embodiment continues upwardly at **64** throughout the hearth portion and the bosh up to the shaft inwall **61**. The lower portion of the hearth is filled with refractory material, such as carbon or high temperature refractory brick, to form a massive bottom **65**. The hemi-ellipsoidal shape of this portion of the hearth jacket is such that downwardly-acting forces on body **65**, resulting from the weights of the liquid metal and the charge material resting on the metal, cause substantially uniform outwardly-directed pressures on the portions **63** and **64** of the lining and the portions of jacket **9** that enclose and support the body **65**. This hemi-ellipsoidal shape also minimizes distortion of the material of body **65** on heating and cooling.

Since the hearth portion of the furnace is suspended completely free of any bottom support, numerous advantages result. The hearth portion can be cooled more readily than in conventional furnaces because of the large additional cooling area of the exposed bottom. The vertical and horizontal principal stresses in the hearth and bosh jackets are both tension stresses, so that shear in the steel jackets and their refractory linings is low; this eliminates most if not all the premature lining failure that occurs at these locations in conventional furnaces, in which the hearth and bosh support upper portions of the furnace, from the substantial shear developed in the jackets and lining material because of large horizontal ring stresses. Moreover, the suspended hearth portion facilitates repairing or replacing the lining of the furnace, with considerable savings in labor and time, and considerable reduction in furnace downtime, because accessibility is considerably greater than in conventional furnaces, and it is not necessary to dismantle large amounts of auxiliary equipment at the lower portion of the furnace as is conventionally necessary. Thus, it is a relatively simple matter to cut an opening in the wall of the furnace at floor **33** and move in men and equipment, including highly automated equipment, for relining purposes. The suspended design provides particularly important advantages in relining the lower inwall, bosh and hearth portions that most often require repair or replacement of lining. It is also possible to remove the entire lower hearth portion of the furnace, with the bosh portion if desired, and replace it with a prefabricated lined replacement portion by use of suitable jack-type dollies; it is merely necessary to attach such replacement portion to the furnace and reline a narrow belt of refractory material at the joint.

Added advantages in strength and stability of support are provided if, before loading, the supporting stucture **2** is prestressed and preformed to cause it to be formed and deflected prior to loading so that there is little if any appreciable deflection visually apparent after the furnace structure is completed. Preferably the legs **14** and also the beams **38** of the structure **2** are thus prestressed, and each beam **38** is built with a calculated camber when unloaded, so that each leg has no moment when subjected to maximum loading, and so that each beam is essentially flat when subjected to maximum loading.

FIGURE 6 shows diagrammatically the shapes of the beams **38** and legs **14** of a supporting structure **2** embodying the invention when the structure **2** is prestressed but not loaded, and when the structure **2** is loaded with the weight of the furnace and other structure carried by the furnace. The full lines show, with great exaggeration of curvature for the sake of clearness, the shape of the structure **2** from its side when the legs **14**, fabricated to have straight axes, are prestressed and curved by having the lower ends of their outer legs forced outwardly radially from the axis A of the structure **2** and the furnace, to the positions they are calculated to assume under full load. The beams **38** are also shown in full lines as cambered upwardly when the legs are prestressed. Although it might be expected that each beam would be deflected downwardly at its central portion because of the forces exerted on the ends of the beam by the rigid connections of the tops of the legs **14** to the beam ends, in the illustrated embodiment each beam **38** is fabricated so it has an upward cambered curve essentially identical to the calculated deflection that will occur when the beam is loaded with its share of the weight of the furnace and other structure supported by beams **38**; therefore the prestressing of the legs **14** will deflect the beam sufficiently to remove part, but not all, of the upward camber of beams **38**. Beams **38** and legs **14** are preferably so designed, and the prestressing of the legs is such, that after the structure is fully loaded there is no visually appreciable deflection of the legs and beams so that, as shown by broken lines of FIGURE 6, the legs and the beams are straight and can develop their maximum strength.

FIGURES 7 and 8 show means for moving the lower ends of the legs radially outwardly to prestress them as described above, and to hold the ends in such position while allowing the lower ends of said legs to rotate freely, without subjecting the lower ends of the legs to bending moments. This means comprises a metal base member **66**, fixed as by bolting to each foundation member **15** set into the earth; the upper surface of this base member is normal to the axis B of the leg **14** when the leg is straight. An adjustable member **67** rests on member **66**; it has an upwardly-open annular groove **68**, against the bottom and inner wall **69** of which is fixed an annular bearing ring **71** of hardened metal providing an upwardly-facing seat **72**, spherical about point P. The outer wall **73** of the groove **68** extends upwardly to provide a raised guard and guide.

The lower end of each leg **14** is tapered at **74** as shown and terminates in a casting **75** of thick cross section in which is fixed a seat **76** of hardened metal and shaped to mate with spherical seat **72**. Casting **75** has a flange **77** that extends into the groove **68** adjacent outer wall **73**; consequently the lower end of the leg **14** is prevented from moving laterally off the seat **72** or jumping off the base in the event of seismic shock or other large disturbances.

To draw the lower end of each leg outwardly to the desired prestressing position, each member **67** is provided with two diametrically spaced lugs **78**, each connected by a drawbolt **79** to a lug **81** fixed to the base. By tightening the nuts **82** on bolts **79** the desired amounts, each member **67** supporting the bottom of a leg **14**, can be moved from an initial position shown in broken lines in FIGURE 8 to its prestressing position shown in full lines in such figure without subjecting the leg to bending moment at its lower end, after which locking blocks **83** can be fixed, as by welding, to the base member **66** to hold the lower end of the leg in the desired prestressing position to provide the above described desirable results.

The furnace of FIGURE 9 includes a supporting structure **2** like that of FIGURES 1–3 including deep I-girders **38** joined at their ends to form a frame **12**, that is square in plan configuration, that surrounds and is spaced from furnace **85**, and that is supported from its corners by widely spaced legs **14** that, as in the previous embodiment, are prestressed during erection. This frame **12** is connected to the shell **86** of the furnace by radially-extending equiangularly spaced connector members **43** identical with, and fixed to the frame **12** and furnace shell by the same means as, connectors **43** of FIGURES 1–5. A compression ring member **51** and adjustable struts **53** at frame **12**, and adjustable struts **56** are also provided to connect the top portion of the furnace to girders **59** of auxiliary frame structure **23**, as in the previous embodiment, to perform the same or similar functions. In the embodiment of FIGURE 9, however, the hearth portion **87** of the furnace is supported from beneath by a foundation **88** that is set into the earth. The hearth portion may be conventional in design. The remainder of the furnace structure of FIGURE 9 may be identical with that of FIGURES 1–5, inclusive, and like parts bear like reference numerals. No further description is believed necessary.

FIGURE 10 shows to a larger scale alternative means for supporting furnace **85** of FIGURE 9 from supporting structure **2**, and alternative cooling means. The furnace shell **89** in this case is conventional and includes a shaft shell portion **91** and a bosh jacket **92** joined at a mantle ring **93**. The square frame **12** of the furnace supporting structure **2** is identical with that of FIGURES 1–4, being made of deep section I-girders **38** that are connected together at their ends. This frame surrounds the furnace and is supported at the four corners by four legs **14**, of which one is shown in FIGURE 10. The frame is connected to the furnace shell by connector members **94** that, as in the previous embodiment, are equiangularly radially disposed about the shell in essentally vertical planes. These connectors are connected to the beams **38** forming the frame **12** at points of equal deflection of the beams. Each connector member **94** is deep and stiff in a generally vertical direction, preferably formed of steel plate; it is fixed to the web **39** and the insides of the flanges **40** and **41** of its associated I-beam **38**, and to the furnace shell by being fixed to mantle **93**, and to a radially-projecting lug or flange **95** fixed to shell **89** by a bolted joining strip **96**. Stiffening lugs **97** are preferably fixed to the mantle for added strength. A ring member **98**, preferably of equal-sided, equiangular, octagonal plan shape like ring member **51** of FIGURES 1–4, is fixed to the top flanges **40** of the beams **38** forming frame member **12** in the same manner and location as ring member **51**. A similar ring member **99** is similarly fixed to and located on the bottom flanges **41** of the beams **38**.

The furnace of FIGURE 10 also has generally horizontally-extending conventional cooling plates **101** in the bosh section, through which plates water is circulated by conventional means. The shaft of the furnace is cooled by hollow cooling staves **102**, **103**, formed of iron or other suitable metal and extending transversely along the circumference of the furnace in the inwall **104**; water is circulated through the saves by conventional means. The upper staves **102** are conventional in that they are of rectangular cross section; the lower staves **103** differ in that the upper portion **105** of each stave is considerably wider than its lower portion **106**; preferably its exterior top width is about twice its exterior bottom width. This stave shape causes the load resulting from the weight of the brickwork or other material forming the inwall **104** of the shaft to be carried down into the reentrant corner between the shaft shell portion **91** and the inwardly-extending portion of mantle **93**; this occurs because the material forming the inwall bears on the inwardly-projecting wider upper portions of these lowermost staves to urge these staves downwardly into such corner to distribute the load through the lining material located outwardly of these staves, to the mantle and adjacent portion of the shell.

The design of FIGURE 10 permits independent assembly of the supporting structure 2 and connector members 94, independent assembly of the shell 89, and subsequent joining of the connector members 94 to the shell by strips 96. In this embodiment, moreover, the ring members 98 and 99 at the tops and bottoms of beams 38 of the frame 12 resist tilting of the beams from the weight of the furnace or thermal expansion or contraction of the furnace shell on heating or cooling of the furnace. The remainder of the furnace structure illustrated by FIGURE 10 may be like that of FIGURE 9.

In the modification of FIGURE 11 shown as applied to the furnace of FIGURE 9, the furnace 85 comprising shell 107 is supported from a supporting structure 2 identical with that of FIGURES 1–4, comprising a frame 12 that is supported by legs, not shown, like the widely spaced legs 14 of the previous embodiment. As in the previous embodiment, four deep I-girders 38 are joined at their ends to define a frame 12 that is square in plan. At points of equal deflection on the frame 12 and equiangularly spaced around the furnace shell there are radially-extending deep, stiff, generally vertical connector members 108 formed of steel plate that are fixed to the webs 39 of the beams 38 of frame 12, as by welding or bolting, and that are rigidly connected to the furnace shell above the mantle by connector strips 109 bolted to members 108 and to radially-extending lugs 111 fixed to the shell.

In the supporting structure, there is a ring member 112 which preferably is identical to member 51 of FIGURES 1–4, inclusive, and to member 98 of FIGURE 9 in that it is of equal-sided, equiangular octagonal shape in plan, fixed to the tops of upper flanges 40 of the beams of the frame 12. Another preferably identical ring member 113 is similarly fixed to and located on the undersides of the bottom flanges 41 of the beams 38.

In this embodiment, conventional generally horizontally-extending cooling plates 114 are provided, through which cooling water is circulated in the usual manner.

The ring members 112 and 113 stabilize the frame 2 and the furnace shell in the same manner as do corresponding members in the structure of FIGURE 6 by preventing harmful tilting of beams 38 of frame 12. Preferably, adjustable struts are provided, of the type and location of struts 53 and 56 of the embodiment of FIGURES 1–5, to perform the same functions. The remainder of the apparatus, not shown, may be identical with the apparatus of FIGURE 9.

The furnace structures illustrated in each of FIGURES 9, 10 and 11 provide many of the advantages indicated above in connection with the furnace structure of FIGURES 1–8 as arising from improved accessibility to the lower portion of the furnace because of the widely spaced legs, although it does not provide the advantages arising from the suspended hearth, such as rapid replacement of the suspended hearth as a whole, unimpeded downward expansion, and increased cooling area. However, in the structures of FIGURES 9 to 11, the supporting structure 2 formed of the frame 12 and the legs 14 can be designed to be stiff enough to support the load of the furnace above the connector members connecting the frame 12 to the furnace shell, but limber enough so that if the portion of the furnace below the connectors contracts on cooling, the supporting structure can permit sufficient downward movement of the upper portion of the furnace to permit the lower and upper portions of the furnace wall in the vicinity of the mantle to remain an essentially continuous wall, and thus eliminate the necessity for an expansion joint that is often located near the mantle in conventional furnaces, which expansion joint is often a source of trouble.

In the embodiment of FIGURES 1 to 8, the entire weight of the furnace and structure supported by the furnace is supported by structure 2. This, therefore, completely avoids the previously discussed problems arising in conventional American and European furnaces because the portions of the furnace above the bosh must be supported by the hearth and bosh portions, since in this embodiment the hearth and bosh are not supporting elements.

In each of the embodiments of FIGURES 9 to 11, inclusive, supporting structure 2 is so designed that at least about 25%, and preferably 50% or even more, of the weight of the furnace above the connections of the furnace above the bosh to frame 12 is at all times carried by the supporting structure 2, even when the furnace is hot and the hearth and bosh portions lengthen to positions where otherwise they would support the portion of the furnace above the bosh. Therefore, the hearth and bosh portions need not be designed to carry as much weight as in conventional American or European blast furnaces, and this substantially minimizes and can eliminate most if not all of the problems described above as arising in conventional furnaces because the hearth and bosh portions must support essentially all of the weight of the furnace and apparatus above the bosh.

Preferably, in each of the previously described embodiments, the legs 14 of the supporting structure 2 are hollow and are filled with poured concrete introduced by conventional apparatus and methods through openings 120 (FIGURES 3, 4 and 10) in the upper ends of the legs 14. Preferably the concrete 121 extends essentially from the bottom of each leg as shown in FIGURE 7 to the upper end of each leg as shown in FIGURES 4 and 10, to insure that when hardened the concrete extends throughout at least the portion of each leg that is subject to deflection. If desired, as shown in FIGURES 7 and 8, reinforcing steel 122 may be embedded in the concrete 121. Preferably the concrete is of the type that does not shrink, or that may even expand slightly, on curing to insure permanent firm contact of the concrete with the inner walls of the legs.

Maximum benefits are provided when the hollow legs 14, while empty of concrete, are, prior to loading of supporting structure 2, first prestressed by having their lower ends moved outwardly from their initial unstressed position in a direction and by an amount essentially corresponding to the direction and amount that the lower end of each leg would move outwardly from its unstressed position if the supporting structure 2 of which the leg forms a part was subjected to a load corresponding to the furnace, so that the legs are deflected as indicated by the full lines in FIGURE 6, the lower ends of the legs being then locked in such positions; structure 2 is then loaded with the furnace so the legs 14 assume positions in which they are essentially undeflected as shown in broken lines in FIGURE 6 and in full lines in FIGURES 1, 2 and 9 in which the legs are shown straight; and the legs are thereafter filled with poured concrete which is then allowed to solidify.

The concrete, after it has hardened and cured, stiffens the legs 14 and acts to maintain them in their undeflected conditions, in which they have their maximum strength. This is particularly important since the frame structure as initially designed has deep, stiff cross beams 38 and legs 14 which, while strong enough to support the load of the furnace even before the addition of the concrete, are relatively limber since they are made of steel and capable of being deflected in the prestressing operation. Addition and curing of the concrete while the legs are in their straight or undeflected positions increases the stiffness of the legs and their resistance toward bending.

The concrete in the legs also adds substantial mass to the legs which are of relatively large cross section and considerable length; for example, if the legs are circular in cross section they may be as much as five feet or even more in diameter for a furnace of modern large capacity. This large added mass and the resistance of the concrete to compressive forces provides added protection against damage from impacts on the legs, such as might occur from a derailed railroad car, thus adding to the safety of the furnace structure. The added mass of the concrete also acts to substantially absorb and dissipate the energy of either steady or transient vibrations to which the legs 14 or the furnace structure as a whole may be subjected, thus damping out vibrations which could otherwise be harmful. Steady vibrations could occur from operation of sifting machinery or unbalanced equipment which could cause undesirable resonance; transient vibrations could occur from seismic shocks or passing railroad rolling stock. The damping action of the large mass of concrete in each leg prevents undesirable resonance or harm from such vibrations.

The concrete in each leg can also act as a high capacity heat sink that can absorb and transmit away from a point of localized exposure on the leg heat from hot metal, slag or coke that might approach or contact the legs in the event of a furnace break-out. The concrete thus provides added protection for the legs in this respect.

The above advantages of the concrete filling are provided if the legs are of circular cross section as shown, or of other hollow cross sections including polygonal cross sections such as a square cross section.

It is apparent that various modifications can be made in any of the furnace structures illustrated. For example, the furnace tops in FIGURES 1, 2 and 9 could be supported from the auxiliary supporting structure **23**, instead of from the top of the furnace shaft, although when the top is supported on the furnace as in the illustrated embodiments advantages arise because the top can move upwardly and downwardly as the furnace shaft expands and contracts. The connector means of FIGURES 10 and 11 could be used in the structure of FIGURES 1–8, as well as in the structure of FIGURE 9.

While four legs of circular cross section are shown, one each corner of a four-sided supporting frame, supporting frames of different shapes, preferably polygonal, supported by a different number of legs may be used, and the legs may be of circular or other, even polygonal, cross section. In any event the number and cross section of the legs should be such that adequate support and stability are provided. It appears that for most, if not all, uses four legs and a square-sided supporting frame are most advantageous from the standpoint of stability, adequate support, economy and cost. The legs in the illustrated embodiment are diagonally inclined, for increased stability of the furnace structure; however, they may be vertically disposed, if desired.

Other modifications will be apparent to those skilled in the art. It is intended that the patent shall cover, by suitable expression in the appended claims, whatever features of patentable novelty reside in the invention.

What is claimed is:

1. Supporting structure for supporting an upright vessel comprising, before mounting of the vessel thereon a generally polygonal frame made up of spaced generally horizontal beams joined end to end, outwardly-inclined legs supporting said frame, the lower end of each of said legs being positioned so it is displaced outwardly from its initial unstressed position in a direction and by an amount essentially corresponding to the direction and amount said lower end of said leg would move outwardly from said unstressed position if said supporting structure was subjected to a load corresponding to the vessel, and means for restraining the lower end of each of said legs against appreciable lateral movement after it has been so positioned, whereby said legs are deflected when said supporting structure is unloaded and essentially undeflected when it is loaded with the vessel.

2. The supporting structure of claim **1** in which said generally horizontal beams are initially formed with an upwardly-directed camber such that after the beams are loaded when they support the vessel the beams deflect sufficiently essentially to eliminate said camber.

3. The supporting structure of claim **1** in which said legs are essentially rigid and are rigidly fixed to said polygonal frame.

4. The supporting structure of claim **3** in which said generally horizontal beams of said polygonal frame are initially formed with an upwardly-directed camber such that after the beams are loaded when they support the vessel the beams deflect sufficiently essentially to eliminate said camber.

5. In the construction of an upright vessel, the steps of constructing a supporting structure comprising an essentially rigid supporting means adapted to extend transversely of and support said vessel, which supporting means is supported by outwardly-inclined legs, and, before supporting the vessel on said supporting structure, prestressing said supporting structure by displacing the lower end of each of said legs outwardly essentially in the direction and by an amount that said lower end of said legs would move if said supporting structure was subjected to a load corresponding to the vessel, and locking the lower end of each in such displaced position.

6. The method of claim **5** in which prior to assembly into said supporting structure generally horizontal beams forming said transversely-extending supporting means are constructed with upwardly-directed cambers such that when the beams are assembled in said structure and said structure is loaded with the vessel said cambers are essentially eliminated due to deflection of the beams under the load of the vessel.

7. Supporting structure for supporting an upright vessel, comprising means extending transversely of and adapted to support the vessel, outwardly-inclined legs supporting said supporting means, said legs being prestressed prior to loading said supporting means with the vessel by having the lower end of each of said legs positioned so it is displaced outwardly essentially in the direction and by an amount that said lower end of said leg would move if the supporting structure was subjected to a load corresponding to the vessel so that said legs are deflected when the supporting structure is not loaded, and means for restraining the lower end of each of said legs against appreciable lateral movement after it has been so positioned, said legs being essentially undeflected after being loaded with the vessel, said essentially undeflected legs each comprising a hollow shell filled with poured and hardened concrete throughout at least the portion of said leg which had been deflected, the hardened concrete aiding in maintaining said legs in their essentially undeflected positions.

8. In the construction of an upright vessel, the steps of constructing a supporting structure comprising means extending transversely of and adapted to support the vessel, and hollow legs supporting said supporting means; prestressing said legs prior to loading said supporting means with the vessel to deflect them to positions to which they otherwise would deflect under the load of the vessel but so that after said supporting structure is loaded with the vessel said legs are essentially undeflected; restraining the lower portions of said legs against appreciable lateral movement thereof, loading said supporting structure with said vessel so said legs become essentially undeflected; and filling at least the portions of said legs which had been deflected with concrete while said legs are in said essentially undeflected positions.

9. Supporting structure for supporting an upright vessel, comprising means extending transversely of and adapted to support the vessel, outwardly inclined legs supporting said supporting means, said legs being prestressed prior to loading said supporting means with the vessel by having the lower end of each of said legs positioned so that it is displaced outwardly from its initial unstressed position in a direction and by an amount essentially corresponding to the direction and amount said lower end of said leg would move outwardly from said unstressed position if said supporting structure was subjected to a load corresponding to the vessel, and means for restraining the lower end of each of said legs against appreciable lateral movement after it has been so positioned, whereby said legs are deflected when said supporting structure is unloaded and essentially undeflected when it is loaded with the vessel.

10. The supporting structure of claim 9 in which said legs are essentially rigid and are rigidly fixed to said transversely extending supporting means.

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