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Greaves et al.

[11] **3,733,065**

[45] **May 15, 1973**

[54] **FURNACE APPARATUS**

[75] Inventors: **Melvin J. Greaves**, Cleveland; **Tage Werner**, Rocky River, both of Ohio

[73] Assignee: **Arthur G. McKee & Company**, Cleveland, Ohio

[22] Filed: **May 5, 1971**

[21] Appl. No.: **140,577**

Related U.S. Application Data

[60] Division of Ser. No. 811,527, March 28, 1969, Pat. No. 3,630,507, which is a continuation-in-part of Ser. No. 778,883, Aug. 29, 1968, Pat. No. 3,559,972, which is a division of Ser. No. 520,945, Jan. 17, 1966, Pat. No. 3,431,691.

[52] **U.S. Cl.** **266/43**
[51] **Int. Cl.** **C21b 7/06**
[58] **Field of Search** 266/25, 43

[56] **References Cited**

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3,371,918 3/1968 Ueshima et al. 266/43

Primary Examiner—Gerald A. Dost
Attorney—Bosworth, Sessions, Herrstrom & Cain

[57] **ABSTRACT**

Blast furnace apparatus having a shell that is lined with refractory material, and means for reinforcing the shell including gussets secured to the outer surface of the shell and companion gussets fixed to the inside of the shell substantially in alignment with the first mentioned gussets. The companion gussets preferably have openings through them to inhibit over-stressing of the companion gussets on expansion and contraction of the shell.

8 Claims, 13 Drawing Figures

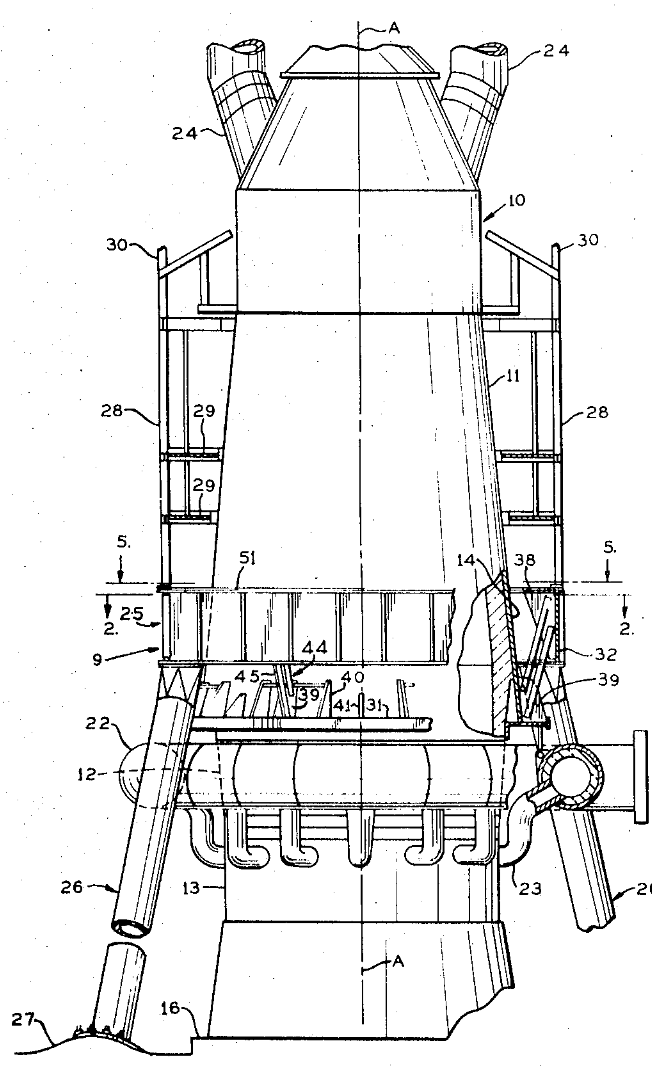
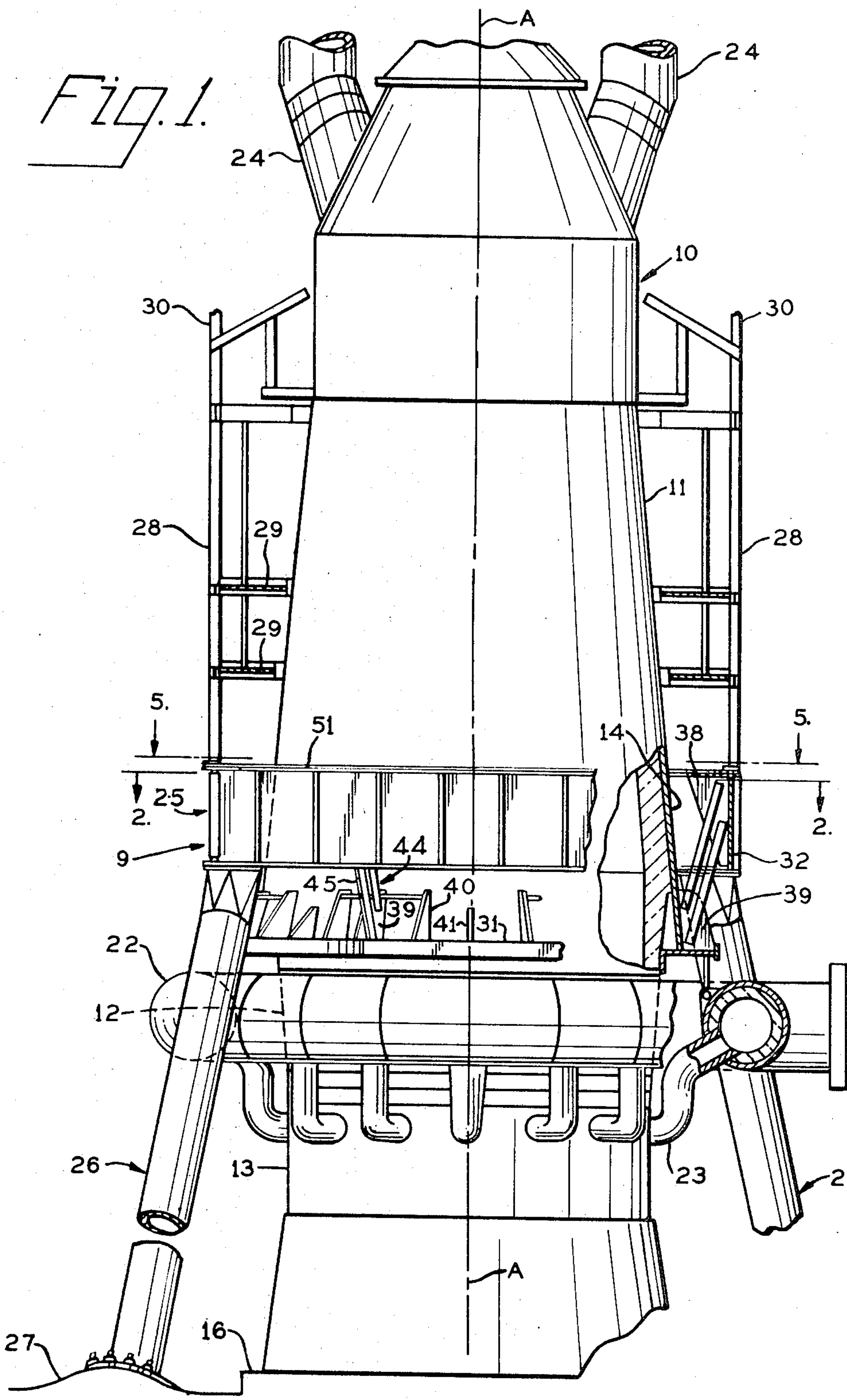


Fig. 1.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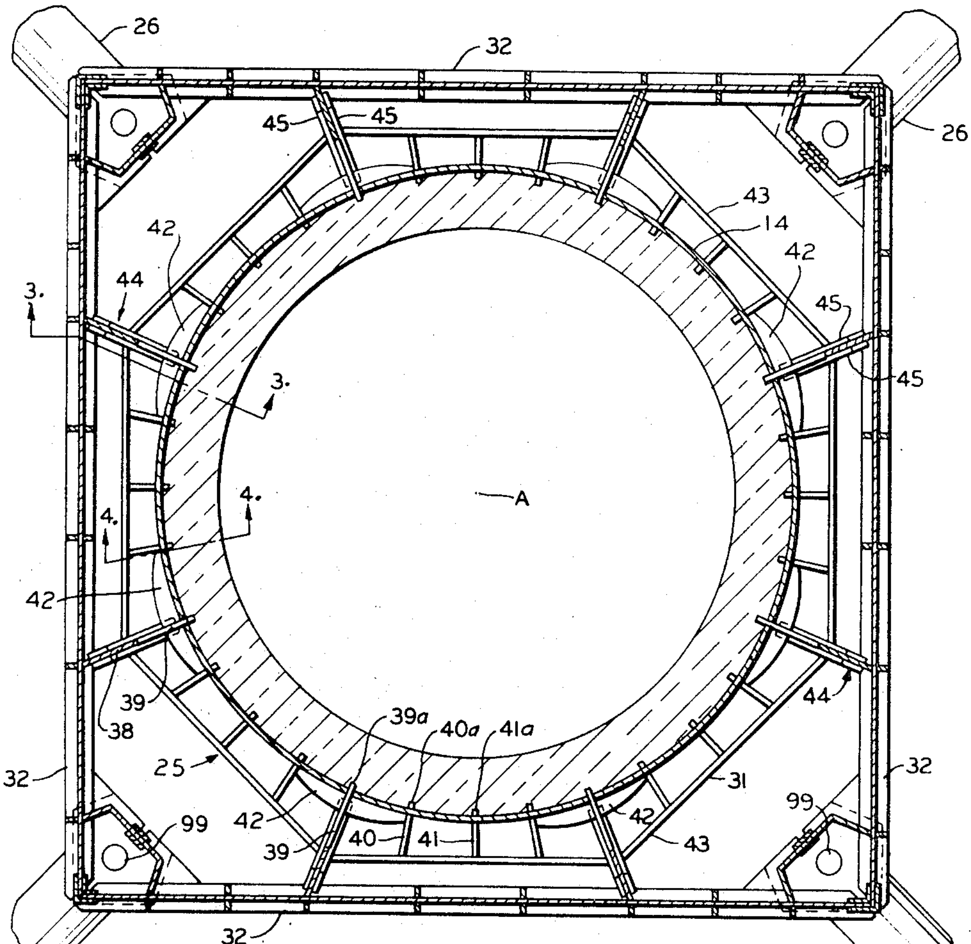
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Fig. 2.

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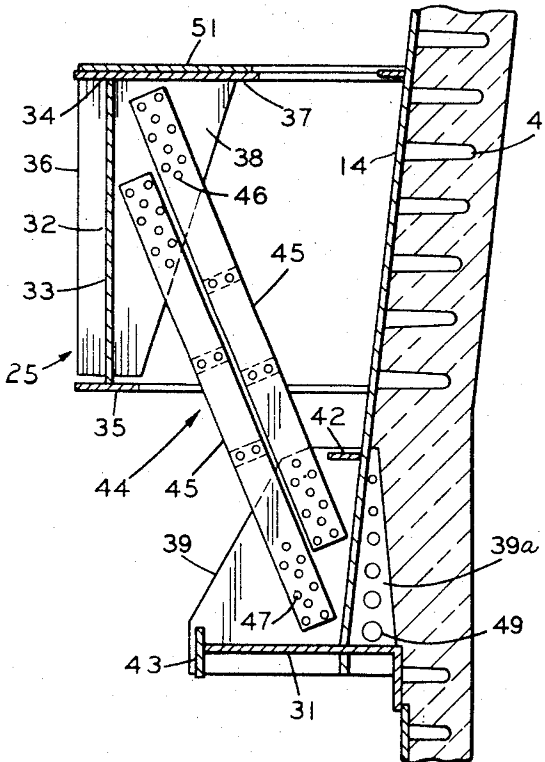
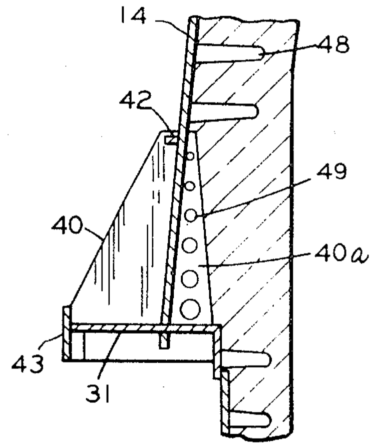


Fig. 3.



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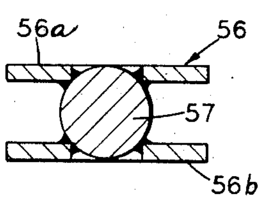

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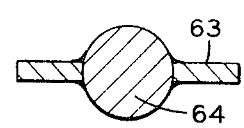


Fig. 9.

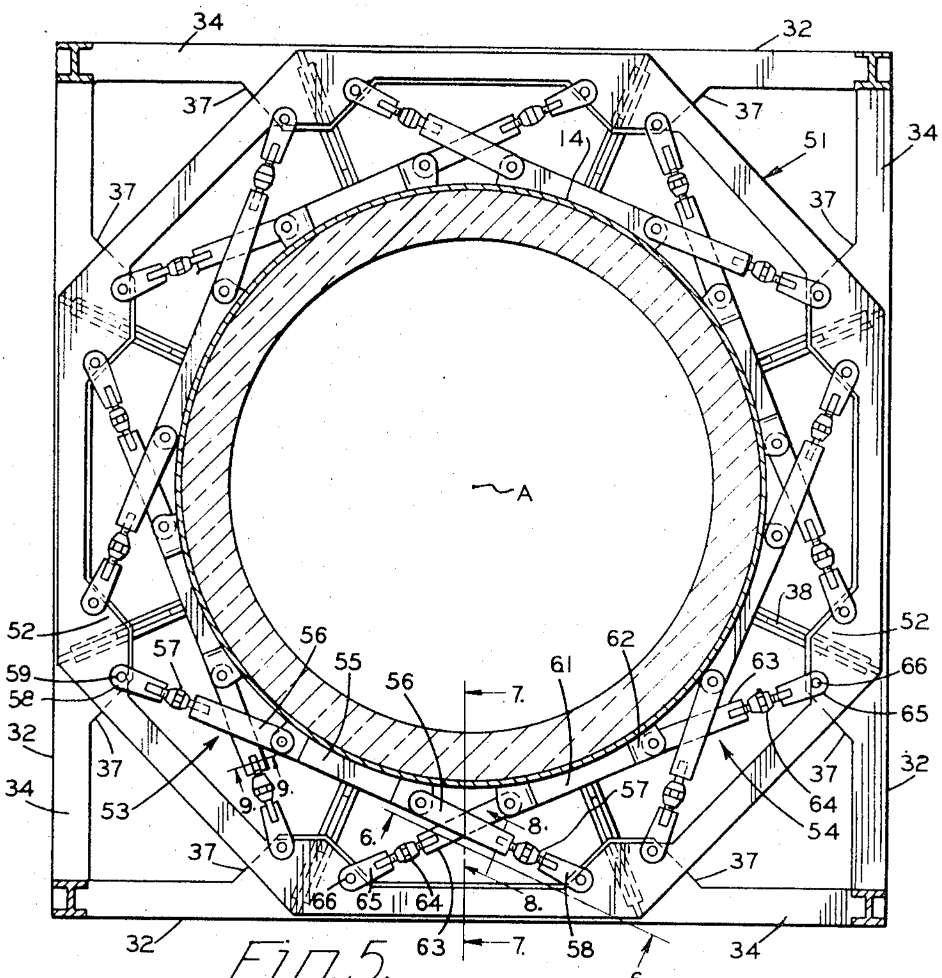
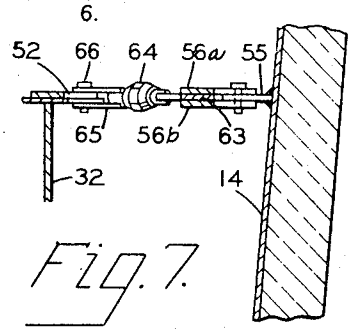


Fig. 5.



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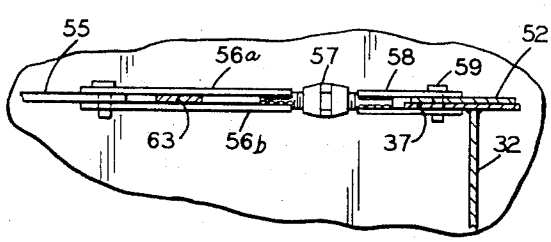


Fig. 6.

Fig. 10.

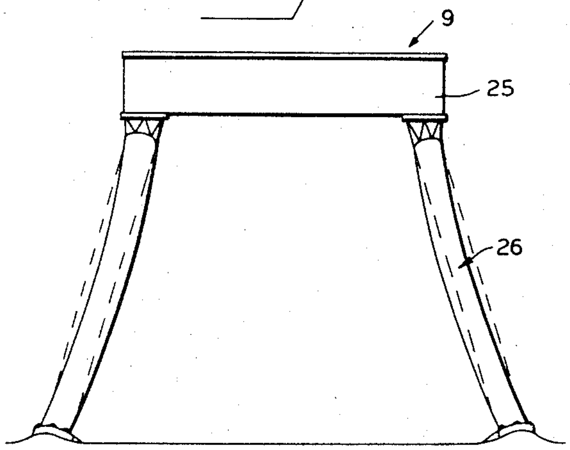
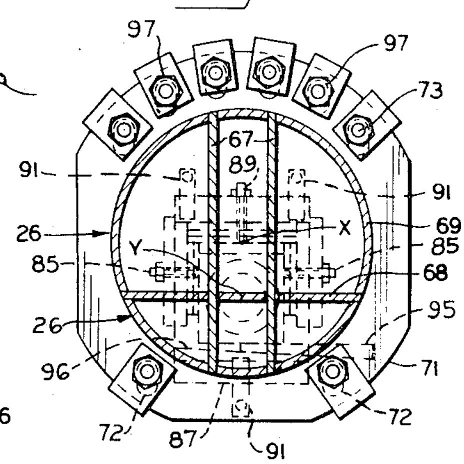


Fig. 12.



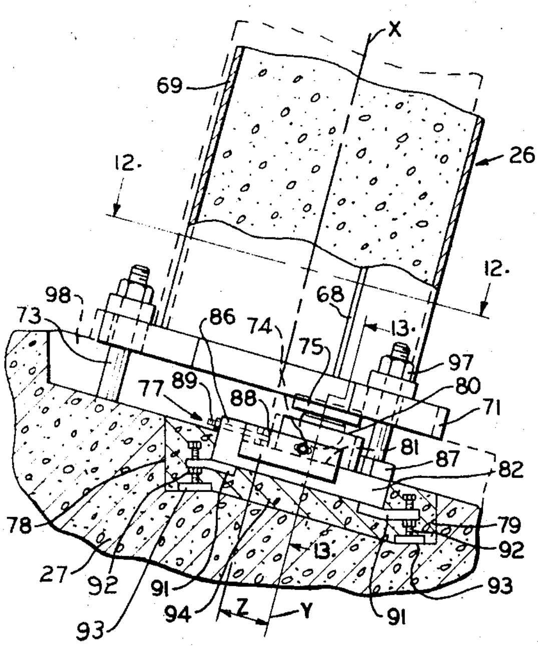
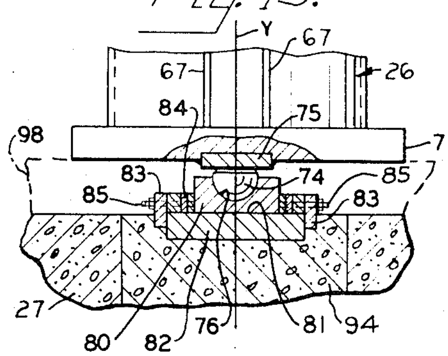


Fig. 11.

Fig. 13.



FURNACE APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a division of application Ser. No. 811,527, filed Mar. 28, 1969, now U.S. Pat. No. 3,630,507, which is a continuation-in-part of copending application Ser. No. 778,883 filed Aug. 29, 1968, now U.S. Pat. No. 3,559,972 which is a division of application Ser. No. 520,945, filed Jan. 17, 1966 now U.S. Pat. No. 3,431,691.

BACKGROUND OF THE INVENTION

The present invention relates to improved supporting structures for upright or upstanding vessels, and more particularly to supporting structures for vessels capable of appreciable expansion and contraction during its operation, such as 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 has, itself, 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 load 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 makes it difficult to maintain a satisfactory tight joint between the furnace top and the portion of the furnace below the top. Since such portion 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 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, consequently, jamming of distributor parts or gas leakage at the distributor may occur.

As a result of dimensional changes in furnace parts during operation, as due to expansion and contraction of the furnace shell from changing temperatures or pressures, the supporting members in conventional blast furnaces can be subjected to diverse and varying forces. Such forces can cause frequent stress reversals in furnace supporting members. For example, a member may be in tension at one stage of the operation of a blast furnace but put into compression as an adjacent furnace part changes dimension due to a change in heat and/or pressure. Such repeating reversals from tension stress through zero stress to compression stress followed by succeeding reversals through zero stress back to tension stress can promote fatigue failure in the support member. As is well known, a member can fail due to fatigue long before it might otherwise fail due to stress-induced causes.

Furthermore, 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 furnace by automatic machinery for performing these functions. Moreover, since the legs are closely disposed relative 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 construction of the bosh and hearth portions which must act as supports for the upper furnace portions.

SUMMARY OF THE INVENTION

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 support means for an upright vessel, such as a blast furnace, in which stress in a support member can fluctuate but never pass through zero stress. Such a member is always maintained either in tension or compression in accordance with the present invention. Failure due to fatigue in such member may be eliminated.

A further object is to provide an improved system of stabilizing members which, in one form, embrace an upstanding vessel at substantially the same elevation to steady it.

A further object is the provision of gussets to support and reinforce a furnace shell or the like having a refractory lining, by having the gussets extend on the interior of the shell into the refractory.

A further object is to provide a process and structure for prestressing support legs or columns for carrying an upright vessel and its attendant parts, so that the legs are deflected during construction when not supporting the vessel and essentially undeflected while supporting the vessel.

DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a side elevation, partly in section, of a blast furnace embodying the present support means, parts not necessary for the disclosure being omitted for clearness;

FIG. 2 is a transverse section of FIG. 1 on the line 2—2 to an enlarged scale;

FIGS. 3 and 4 are partial sections generally along lines 3—3 and 4—4, respectively of FIG. 2, to a still larger scale;

FIG. 5 is a section on line 5—5 of FIG. 1 and to the same scale as FIG. 2;

FIGS. 6, 7, 8 and 9 are detail sections on lines 6—6, 7—7, 8—8 and 9—9 respectively of FIG. 5;

FIG. 10 is a somewhat diagrammatic side elevation of the supporting leg structure, illustrating prestressing of such structure before a load is applied, the deflections of the legs being greatly exaggerated for the sake of clearness;

FIG. 11 is an enlarged, fragmentary vertical section of the bottom end of one of the legs of FIGS. 1 and 10;

FIG. 12 is a section along line 12—12 of FIG. 11 and to the same scale; and

FIG. 13 is a fragmentary view, partly in section along line 13—13 of FIG. 1 and to the same scale.

General Arrangement

In the illustrated apparatus, a supporting structure **9** supports a furnace **10**.

The furnace **10** comprises a shaft **11**, bosh **12**, and hearth portion **13**, all enclosed in a continuous steel shell **14** free of sharp bends and lined with suitable refractory material. The hearth portion may be supported by an underlying foundation **16** indicated in FIG. **1**, set into the earth, or it may be wholly or substantially unsupported by being suspended, as disclosed by the above-identified related applications. A conventional bustle pipe **22** surrounds the bosh **12** and communicates with conventional tuyeres **23** leading into the furnace. Conventional uptakes **24** are connected to the top of the furnace, which may also house or connect to other conventional equipment, not shown, such as a burden distributor, bell hopper, bells, downcomer, etc.

The structure **9** comprises a generally horizontal main frame, generally indicated at **25**, and widely spaced legs **26** that are rigidly secured to frame **25** and supported by base **27** set into the earth. There may also be a working or case house floor, not shown, at the lower end of the furnace. Frame **25** also rigidly carries an upper auxiliary structure comprising upstanding posts **28** connected to frame **25** and supporting several horizontal-disposed working platforms **29** as well as superstructure **30** and other equipment usually associated with the top of a blast furnace.

Frame Structure

Main frame **25** surrounds and is spaced from the shaft **11** above and adjacent a ring member **31** adjacent the lower portion of the shaft between the shaft and bosh in essentially the same vertical relationship on the furnace as a mantle in a conventional blast furnace. The frame **25** is polygonal in plan and, as illustrated, preferably comprises (FIGS. **1**, **2**, **3** and **5**) four deep horizontal steel beams **32** that are rigidly welded or bolted together at their ends to form a square in plan. Each beam **32**, which may be about 10 feet deep on a large furnace, is an I-section girder having (FIG. **3**) a wide vertical web **33**, generally horizontal top and bottom flanges **34** and **35**, and generally vertical reinforcing stiffeners **36**. The top flange **34** of each beam carries two internally laterally projecting portions **37** (FIG. **5**) substantially equally spaced along the length of each beam **32** essentially at its third points. Beams **32** may be conventionally fabricated, as by welding from steel plates.

At each of several locations of essentially equal deflection on frame **25**, which are essentially at the third points of beams **32** in the illustrative embodiment to provide eight symmetrically spaced locations, there is a relatively large inwardly projecting plate connector member **38** (FIGS. **1**, **2**, **3**, **5**) essentially vertically and radially disposed with respect to the axis A of shaft **11**, about which frame **25** is essentially symmetrical. Each member **38** is welded at its upper edge to a projection **37**, and at its outer edge to web **33**, of a beam **32**. The inner edge of each member **38** slants downwardly and outwardly from shaft **11**.

At the juncture of the shaft **11** and the bosh **12**, supporting gussets **39** in the form of upstanding thick steel plates extend between and are welded to the top of ring member **31** and the outside of the shell **14** at the lower portion of the shaft. Preferably the ring member **31** is fixed to the shell of the furnace 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 frame **25**. Stiffening gussets **40** and **41**, essentially radial with respect to the shaft **11**, also are welded to and extend from the outside of the shaft shell and the top of ring member **31**. Lateral stiffeners **42** and **43** (FIGS. **2**, **3**, **4**) are fixed to gussets at their upper and outer edges. Thus, lateral stiffeners **42** are welded to the outside of the furnace shell and to the upper ends of each gusset **39** and its adjacent gusset **40,** while lateral stiffener **43** takes the form of a strip welded to the outer edges of all gussets and the ring member **31.**

The outer edge of the ring member is polygonal in plan having straight edges that extend between the gussets **39** (FIG. **2**). Gussets **39** therefore extend radially from the furnace shell a greater distance than gussets **40** and **41.** These shapes and relationships of ring member **31** and the gussets provide desirable maximum strengths at the locations of gussets **39** by which the shell is supported.

Connecting means, generally indicated at **44** (FIGS. **1, 2, 3, 5**) connect the members **38** on frame **25** with the gussets **39** on the furnace shell **14.** In the embodiment illustrated, means **44** comprises duplicate pairs of elongated connecting members **45.** Members **45** of each pair are shown as relatively thick steel struts fixed to the opposite sides of members **38** by bolts **46** extending through both members **45** and member **38,** and to the opposite sides of gussets **39** on the furnace shell by bolts **47** extending through the lower portions of the members **45** and the gussets. Members **45** extend diagonally downwardly and inwardly from frame **25** toward the furnace shell and are located at the points of maximum deflection of the frame in essentially vertical planes that extend substantially radially to the furnace shaft **11,** and essentially pass through and are essentially equiangularly spaced about vertical axis A of the furnace.

In such supporting structure, during changes in dimensions of the shell **14** occuring during normal operations, such as expansion or contraction of the shell due to increases or decreases in temperature or internal pressure, the magnitude of the longitudinal stresses on the members **45** fluctuate, but without reaching zero stress or undergoing reversal of such longitudinal stress. By "longitudinal stress" is meant the stress in the members **45** between the locations where such members are attached to the members **38** and **39.** Preferably the members **45** are always in tension; they may be substantially rigid members as shown that are capable of withstanding substantial compressive stresses such as might occur in unusual circumstances such as explosions. As illustrated by FIG. **3,** connector members **45** provide substantially the only direct connection between frame **25** and ring member **31** on the furnace shell. Because of their inclination, they cause vertical and horizontal components of tension forces acting on member **31.** The parts are so designed, moreover, that the forces to which ring member **31** is subjected by members **45** during normal changes in dimensions of the shell may vary substantially, but they are always in one direction and do not reverse direction.

Additional means for resisting varying forces exerted on the furnace shell at the juncture of the shaft and bosh, and on the ring member **31,** due to variations in temperatures of pressures and weights of the furnace due to changing loads include companion portions ***39a,*** ***40a*** and ***41a*** to gussets **39, 40** and **41,** fixed to and radially extending from the inside of the furnace shell and fixed to the portion of ring member **31** inside the shell. These inwardly projecting portions are embedded within the refractory lining **14** (FIGS. **2** and **3**) which may also have conventional coolers **48.** Preferably portions ***39a***, ***40a*** and ***41a*** have openings **49** that remove sufficient area of metal to weaken these projections sufficiently so that during expansion and contraction of the shell these internally projecting portions can upset or change dimension due to compressive stresses without overstressing the outer gussets. Moreover, any upsetting of these internal projecting portions does not appreciably reduce their reinforcing effects.

Compression Ring Member

A compression ring member generally indicated by **51** and shown in the illustrated embodiment as octagonal with sides of equal length and equal angles between the sides, is fixed as by welding to the top flanges **34** of the beams **32** of the main frame **25.** Member **51** resists tilting of the beams **32** about their longitudinal generally horizontal axes, from forces arising from the weight of the furnace or from expansion of the furnace shell on heating or from increased pressure. As the furnace shell increases in diameter for these reasons the lower ends of the connecting members **45** tend to move outwardly with the lower portion of the shell of shaft portion **11.** This can tend to cause the upper ends of the connectors **45** to move inwardly so that they tend to cause the beams **32** to twist about their longitudinal axes so their upper flanges **34** tend to move closer to the furnace than their lower flanges **35.** However, any tendency of the beams **32** thus to twist or tilt is resisted by the ring member **51** which is thus subjected to compressive forces. Since the ring member **51** is a symmetrical polygon with straight sides at the junctures of which connectors **45** are located, member **51** is exceptionally efficient in resisting the forces to which it is subjected. A polygonal member is less expensive to make than a circular one, and is less subject to distortions due to heat or other factors to which it is subjected. Member **51** may be fabricated from relatively thick steel plate welded to the underlying beams **32** of frame **25.** The internal corners of the polygon defined by member **51** are enlarged at **52** to provide increased material and strength for connection to stabilizing ties to be described. As shown in FIG. **5,** these enlarged interior portions **52** overlie the interior projecting portions **37** of the top flanges **34** of beams **32,** which thereby provide further support for member **51** and the stabilizing tie means **53** and **54.** Ring member **51** thus acts as an auxiliary frame.

Stabilizing tie means **53** and **54,** connected to shell **14** of the furnace and compression ring member **51** around the shell, add lateral stability to the furnace in frame **25.** Tie means **53** comprises a generally horizontally extending elongated fastening member **55** welded to the furnace shell **14** and two tie bars **56,** each connected at one end to an end of member **55** and the other end through a turnbuckle **57** to a connector member **58** pivotally connected by pin **59** passing through adjacent portion **52** of member **51** and portion **37** of beam **32.** Each tie bar **56** is formed of two spaced members ***56a*** and ***56b***, (FIG. **6**). Tie means **54** is similar, comprising an elongated fastening member **61** welded in an essentially horizontal position o the to shell; this member has its end portions forked at **62** to receive and be pivotally connected to one end of each of two tie bars **63.** Each bar **63** passes between the members ***56a*** and ***56b*** of a crossing tie bar **56** of the adjacent tie means **53,** and are connected through a turnbuckle **64** to a connector member **65** that is pivotally connected by a pin **66** to adjacent portion **52** of member **51** and portions **37** of a beam **32.** Preferably the stabilizing tie means **53** and **54** surround the furnace shaft **11** and are essentially at the same elevation, as is made possible by the crossing of tie bars **56** and **63**, so that the lateral stabilizing forces acting between the frame **25** and the shell fall essentially in the same horizontal plane located above the center of gravity of the furnace and that of frame **25.** Furthermore, each tie means **53** and **54** and their tie bars and associated turnbuckles and connector members extend essentially tangentially of the furnace shell, and the forces acting between the shell and frame **25** through the tie means are essentially tangential forces. The four tie means **53** shown essentially define a first square, while the other tie means **54** define another square intersecting the first square and displaced 45° angularly. Each square thus is a polygon of half the number of sides of the polygons defined by the member **51** and the supporting gussets **38.** The lengths of the tie means can be adjusted as necessary by turnbuckles **57** and **64,** even while the tie means are in place.

Leg Structures

According to another aspect of the present invention, the inclined legs **26** that carry the frame **25** of the supporting structure **9** are, prior to loading of the supporting structure, first prestressed by having the lower end of each leg moved outwardly from its initial unstressed position in a direction and by an amount essentially corresponding to the direction and amount at the lower end of the leg would move outwardly from its unstressed position if the supporting structure **9** of which the leg forms a part was subjected to a load corresponding to the furnace, so that the legs are deflected during prestressing as exaggeratedly indicated by the full lines in FIG. **10.** The lower ends of the legs are then secured in such position. Supporting structure **9** is then loaded with the furnace so that the legs **26** assume positions in which they are essentially undeflected, as shown in broken lines in FIG. **10** and in full lines in FIG. **1.** The legs may thereafter be filled with poured concrete which is allowed to solidify; the concrete after it has been hardened and cured stiffens the legs **26** and acts to maintain them in their undeflected conditions under load, in which conditions they have their maximum strength.

According to the present invention, this outward movement of the lower portions of the legs to achieve the desired prestressing is facilitated by initially temporarily supporting each leg during construction, after the legs have been fixed rigidly to the frame **25,** at suitable locations off-center from the center line parallel to the axis of the leg at lower end thereof passing through this vertical center at the bottom of the leg at which the force resulting from the load would be concentrated; with a leg of circular or other symmetrical cross section about a centerline, as shown, such line is the centerline of the lower portion of the leg, and will for convenience by referred to as such below. The leg is so supported off-center by an amount and in a direction calculated to cause the leg to move outwardly the desired distance in the desired direction, to put the desired prestress in the leg. The lower ends of the legs are then locked in such positions, and concrete or other supporting means is inserted under the bottom of the leg to take most or all of the load that is carried by the leg and represented by its proportion of the weight of the supporting structure **9** and the furnace.

A shear and a bending moment is therefore temporarily applied to the lower portion of each leg during such prestressing construction, the shear being caused by the outward movement of the above described lower portion of the leg, and the bending moment being caused by locating the temporary support of the leg off the centerline of the leg. Such shear and bending moment are eliminated when the supporting structure **9** is loaded with the weight of the furnace.

More specifically, in the illustrated apparatus, the four legs **26** are rigidly connected to frame **25** at the four corners thereof as by welding or bolting, the legs diverging equally in a downward radial direction from the vertical axis A of the furnace; the legs in a major portion of their lengths are of generally circular cross section and hollow, and quite limber until loaded and filled with concrete that hardens. FIG. **10** shows diagrammatically in full lines the bowed dispositions of the legs **26** when they are prestressed but not loaded, by having their lower ends displaced outwardly from the axis A of the furnace to the positions they are calculated to assume under full load. Under load, the horizontal beams **32** between the legs deflect and thus cause the rigidly attached upper ends of the legs to have an outwardly directed bending movement which essentially removes the prestress deflection in the legs, so that there is no appreciable deflection remaining in the legs after loading and the legs are straight and can develop their maximum strength, as shown by the broken lines in FIG. **10.**

FIGS. **11** to **13** show preferable means according to the invention for supporting the lower ends of the legs **26** off center and moving them outwardly to prestress them as described. At the lower end of each leg there are internal reinforcing plates **67** and **68** that extend upwardly from the bottom of the leg for a substantial distance. Plates **67** extend across the interior of each leg at each side of axis X of the leg, preferably being welded into slots in the leg wall **69** (FIG. **12**) while cross plate **68** extends at right angles to plates **67,** fitting and being welded in slots in plates **67** and in the leg wall.

The lower end of each leg **26** has a strong steel transverse flange **71** fixed to the bottoms of the leg wall and the plates. The flange has elongated openings **72** for anchor bolts **73,** two such openings being located on the side of the flange nearest furnace axis A and six being located on the opposite side of the flange toward which the lower end of the leg is moved in prestressing. A ball portion **74** of hardened metal, somewhat greater than a hemisphere, is fixed to a base plate **75** welded on the underside of flange **71** at a location such that axis Y passing through the center of portion **74** is parallel to axis X of the leg **26** and displaced by a predetermined distance Z toward furnace axis A.

During erection, the ball portion of each leg seats in a mating socket **76** of a temporary adjustable base **77** located beneath flange **71** in the lower portion **78** of a recess **79** formed in permanent base **27.** Temporary base **77** comprises a slidable member **80** carrying socket **76.** Member **80** is slidably mounted in a guideway **81** on temporary fixed base member **82,** defined by fixed side ribs **83** and adjustable shims **84** held in place by bolts **85,** that properly laterally locates and guides member **80** for movement in the desired direction of movement of the lower end of the leg. Member **82** also has fixed end shoulders **86** and **87.**

Member **82** is temporarily supported on three welded legs **91** that have threaded into them adjusting bolts **92** bearing against metal bases **93** resting on the bottom of recess **78**, which has a suitably inclined and shaped bottom surface for the purpose. Bolts **92** and their bases **93** permit the member **82**, before it supports its associated leg **26**, to be mounted in recess **78** with considerable accuracy as to a predetermined lateral location, elevation and inclination.

During initial construction, the temporary base **77** for each leg is installed as accurately as possible utilizing the adjustability provided by the legs **91**, bolts **92** and bases **93**. Each base **77** is then grouted firmly in place by concrete **94** (FIGS. **11, 13**). After hardening of this concrete, each member **80** is then installed, being accurately located in its lateral position by insertion of proper shims **84**; shims **88** are then installed adjacent shoulders **86** to limit properly the lateral outward movement of the lower ends of legs **26**. The legs **26** and the remainder of supporting structure **9** are then erected; at this time the ball portion **74** of each leg is seated in socket depression **76** of its member **80**, the flange **71** being installed so the previously fixed anchor bolts extend through its slots **72**. The off-center distance Z, identical for each leg, has been calculated so that the weight of the supporting structure **9** in the off-center position of the ball portion tends to cause the lower end of each leg to move outwardly in guided movement of slidable member **80** in fixed member **82**. Such movement is assisted if necessary by forcing a movable wedge **95** into the space between slidable member **80** and stationary wedge **96** adjacent shoulder **87** of base **82**. The temporary support of the legs on the ball and socket joints permits the lower ends of the legs to tilt or swivel as necessary.

After the lower portions of the legs have all been moved to the desired prestressing position indicated in broken lines in FIG. **13**, nuts **97** are partially tightened on anchor bolts **73** to hold the legs in proper position. The space under the flange **71** is then completely filled in with concrete grouting material **98** shown by broken lines; after this material has hardened, the nuts **97** are fully tightened to lock the lower ends of the legs **26** in desired displaced position. The legs are thus largely and if desired completely supported by the flanges **71**. After the supporting structure **9** is fully loaded, there is no prestress remaining in the legs **26**, and no shear or bending moment at the lower portions of the legs.

If desired, before or after installing the furnace shell, the legs can be filled either fully or for a major portion of their lengths with concrete, preferably of a type that does not shrink, to stiffen the legs. Holes **99** (FIG. **2**) may be used for this purpose.

In the illustrated application the parts are so designed that the ball portions **74** and slidable members **80** at the lower ends of the legs move in inclined paths essentially normal to the axes X of the legs during prestressing; this is made possible by the inclined position of the guideways **81**. The flanges **71** are also essentially normal to the axis of the legs. Such inclined movements and inclined relationships of the flanges are preferable, since they provide less bending moments in the legs during prestressing than if the members **80** and ball portions **74** moved in horizontal paths, and since the positions of the flanges **71** normal to the axes X essentially eliminate shear and bending moments in the legs after the legs are largely or fully supported by flanges **71**. Lateral forces could be present if the flanges were not normal to axes X.

The concrete in the legs, after it has hardened and cured, stiffens the legs **26** 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 **32**, while the legs **26**, 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. The addition and curing of 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 large legs. This large added mass and the resistance of the concrete to compressive forces provides added protection against damage from impacts on the legs, thus adding to the safety of the structure. The mass of the concrete also acts to substantially absorb and dissipate the energy of either steady or transient otherwise harmful vibrations to which the legs or the furnace structure as a whole could be subjected. Concrete thus set 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.

While four legs of circular cross section are shown, one at 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 cross sections other than circular, such as polygonal cross sections. 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 standpoints of stability, adequate support, economy and cost. While the illustrated legs are diagonally inclined for increased stability of the furnace structure, they may be vertically disposed, if desired.

According to the present invention, an upright vessel may be adequately and safely supported by a strong, stable supporting structure in which stresses are efficiently distributed. Studies have indicated that even if one of the legs of the illustrated embodiment should be damaged or eliminated, the three remaining legs can safely support the entire structure. Furthermore, studies also indicate that even if one of the illustrated eight sets of connecting members should be damaged or destroyed, the vessel would still remain safely supported in an upright position. These studies indicated that the redistribution of loads can result in stresses greater than normal, but still within safe margins. The use of the desired stabilizing ties was found to be particularly helpful in maintaining steady support of the vessel under such conditions.

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. In apparatus comprising a shell, refractory material lining the shell, and means for reinforcing the shell including a gusset secured to the outside of the shell, the improvement comprising a companion gusset se-

cured to the inside of said shell substantially in alignment with said first-mentioned gusset, said companion gusset being disposed within said refractory material and having openings therethrough that inhibit overstressing of said companion gusset on expansion and contraction of said shell.

2. In apparatus comprising a shell, refractory material lining the shell and means for reinforcing the shell including a gusset secured to the outside of the shell, the improvement comprising a companion gusset secured to the inside of said shell substantially in alignment with said first-mentioned gusset, said companion gusset being disposed within said refractory material and being apertured therethrough to inhibit overstressing of said companion gusset on expansion and contraction of said shell.

3. The apparatus of claim **2** in which said companion gusset is apertured with at least one opening therethrough, which opening has a closed boundary.

4. The apparatus of claim **3** in which said opening is a generally round opening.

5. The apparatus of claim **2** in which said shell has an upright axis and in which said gussets extend axially of said shell.

6. The apparatus of claim **5** in which said shell includes a generally horizontally disposed ring member having a portion that extends outwardly of said shell and a portion that extends inwardly of said shell, and in which said gusset secured to the outside of said shell is secured both to the outer surface of said shell and to the outer portion of said ring member and in which the companion gusset secured to the inside of said shell is secured both to the inside of said shell and to the inner portion of said ring member.

7. The apparatus of claim **6** in which said gussets are secured to a portion of the shell above said ring member and to the upper side of said ring member and in which the portion of the shell below said ring member is of smaller circumference than the portion above said ring member.

8. The apparatus of claim **6** in which said inwardly extending portion of said ring member forms a reentrant shoulder in said shell and in which said companion gusset is fixed to said ring member above said shoulder.

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