March 4, 1958 A. H. VAUGHAN 2,825,547

MUFFLE TYPE FURNACE WITH MOVABLE SUPPORT STRUTS

Filed May 24, 1955 6 Sheets-Sheet 1

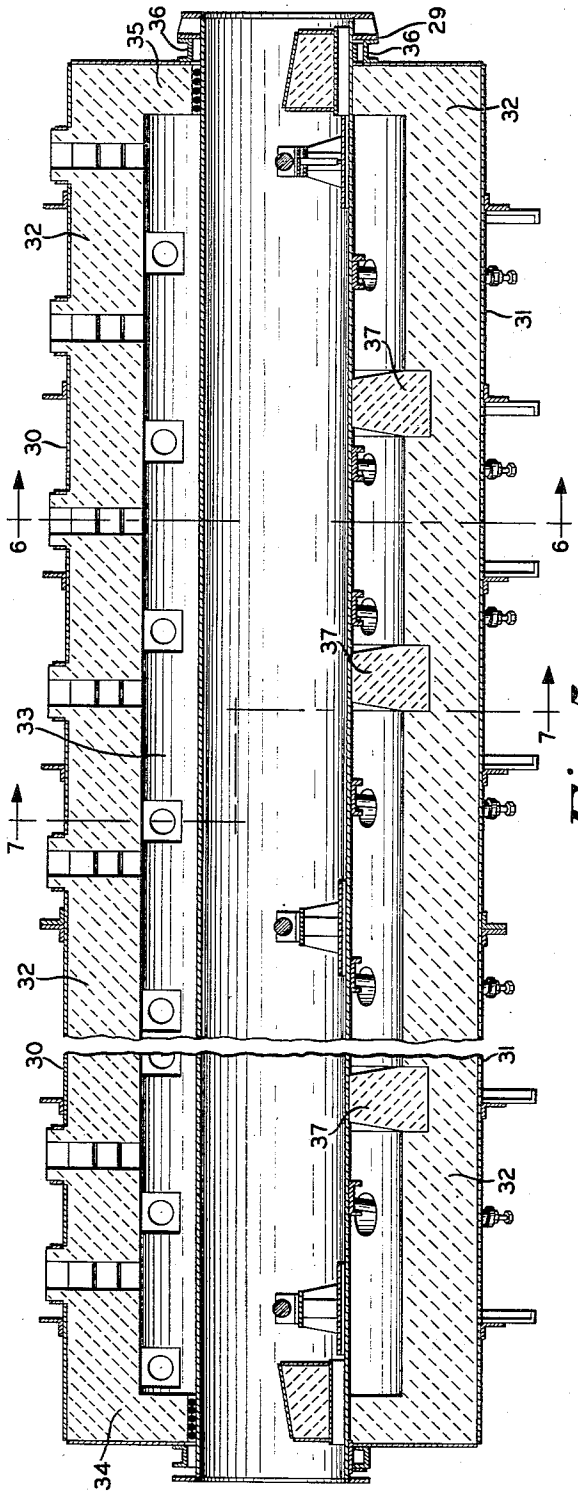


Fig. 5

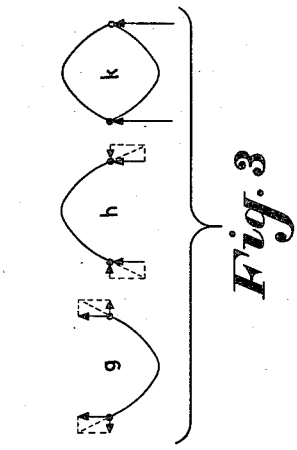


Fig. 3

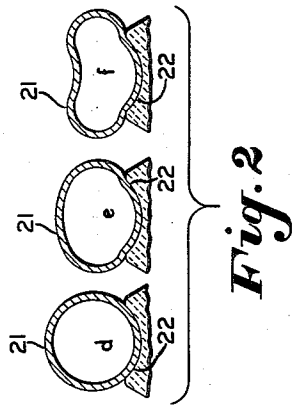


Fig. 2

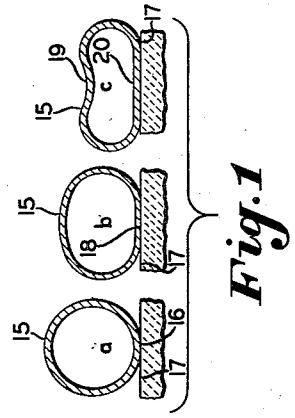


Fig. 1

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March 4, 1958 A. H. VAUGHAN 2,825,547

MUFFLE TYPE FURNACE WITH MOVABLE SUPPORT STRUTS

Filed May 24, 1955 6 Sheets-Sheet 2

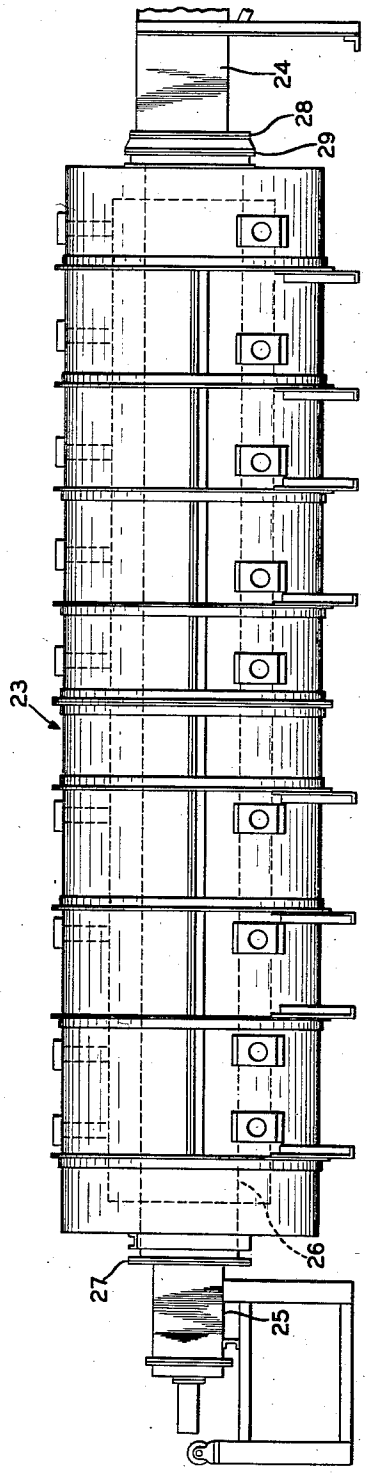


Fig. 4a

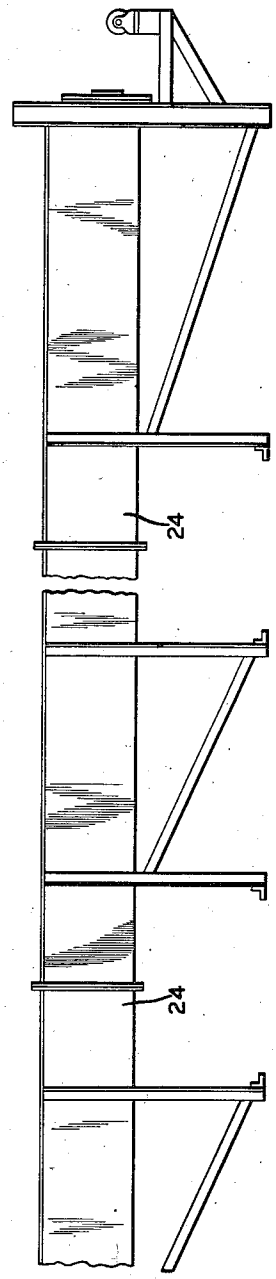


Fig. 4b

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MUFFLE TYPE FURNACE WITH MOVABLE SUPPORT STRUTS

Filed May 24, 1955 6 Sheets-Sheet 3

Fig. 6

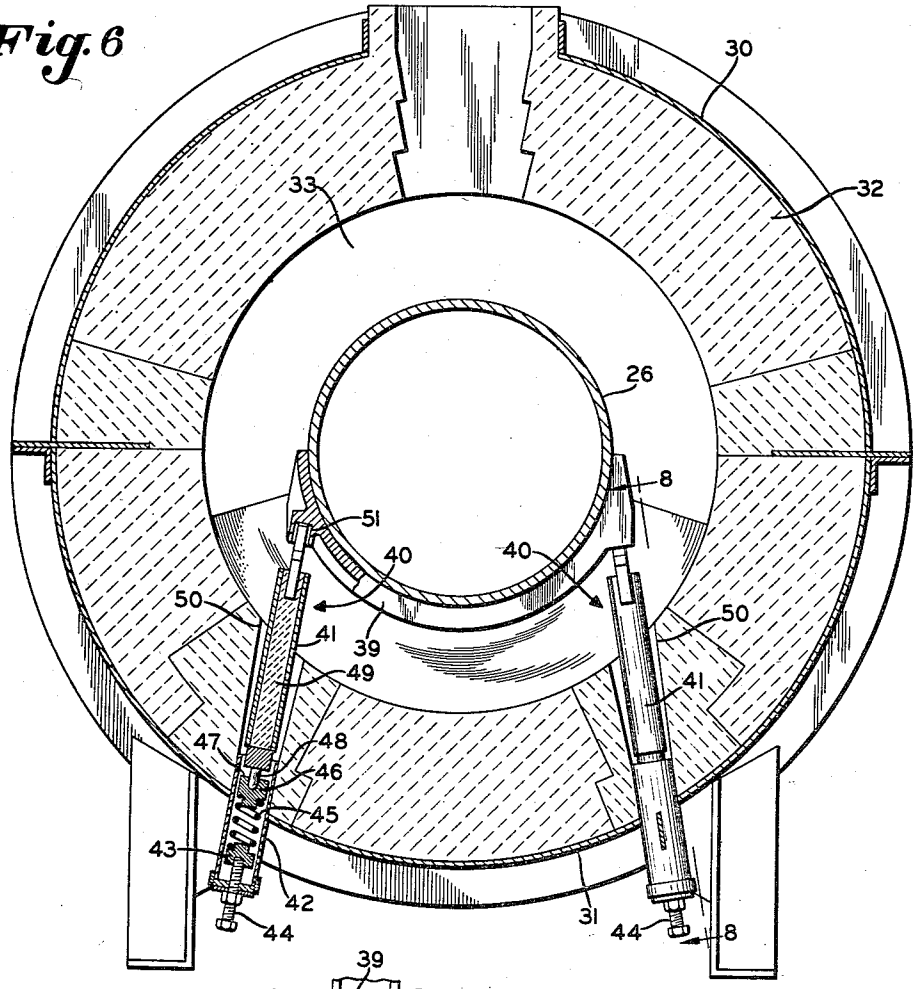
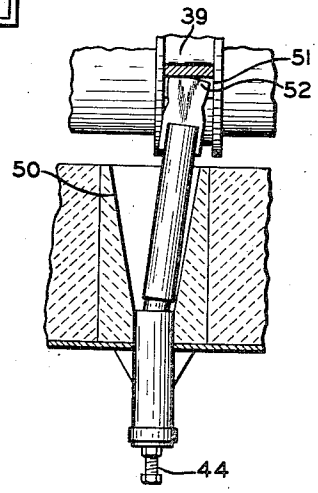


Fig. 8



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MUFFLE TYPE FURNACE WITH MOVABLE SUPPORT STRUTS

Filed May 24, 1955 6 Sheets-Sheet 4

Fig. 7

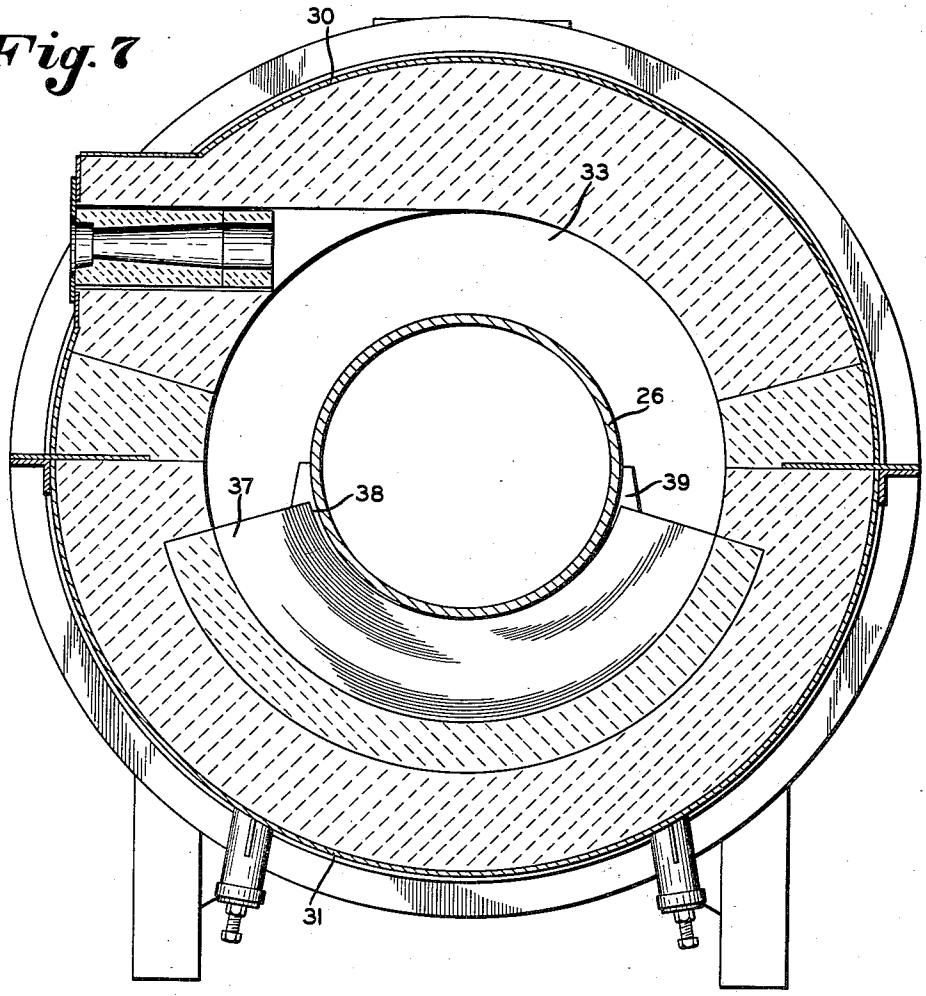
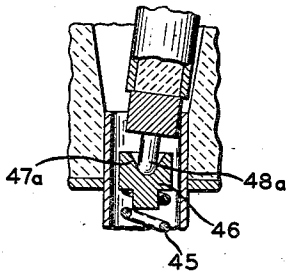


Fig. 9



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March 4, 1958 A. H. VAUGHAN 2,825,547

MUFFLE TYPE FURNACE WITH MOVABLE SUPPORT STRUTS

Filed May 24, 1955 6 Sheets-Sheet 5

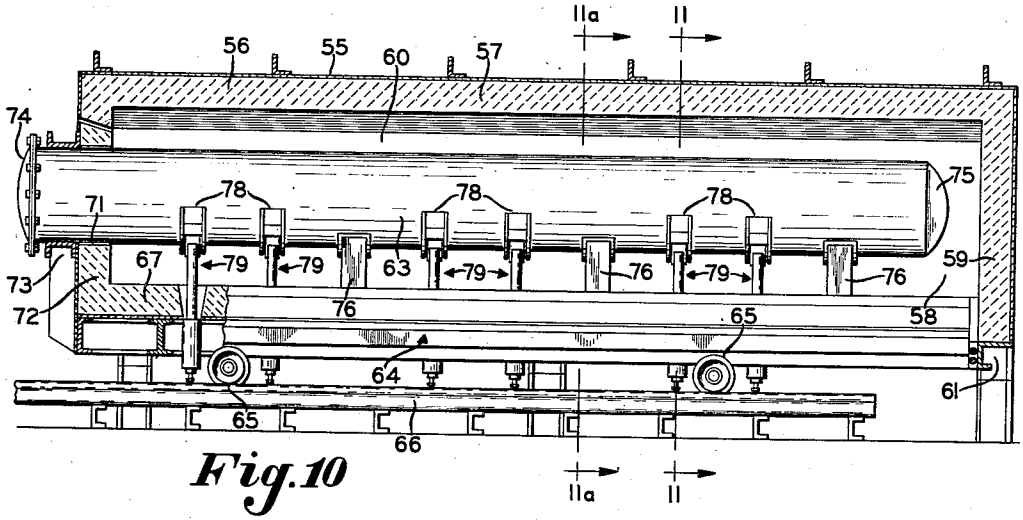


Fig. 10

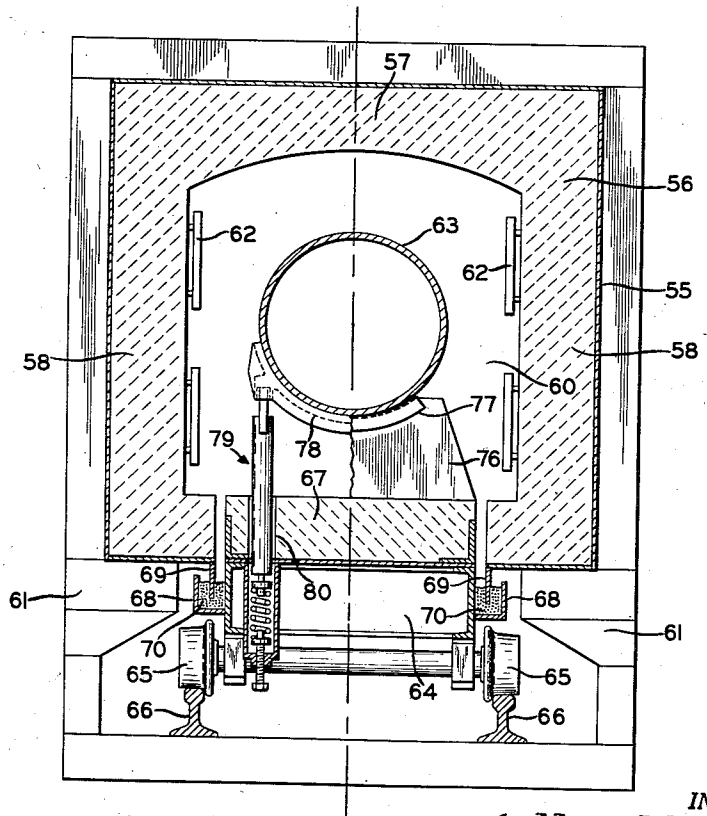


Fig. 11

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March 4, 1958 A. H. VAUGHAN 2,825,547

MUFFLE TYPE FURNACE WITH MOVABLE SUPPORT STRUTS

Filed May 24, 1955 6 Sheets-Sheet 6

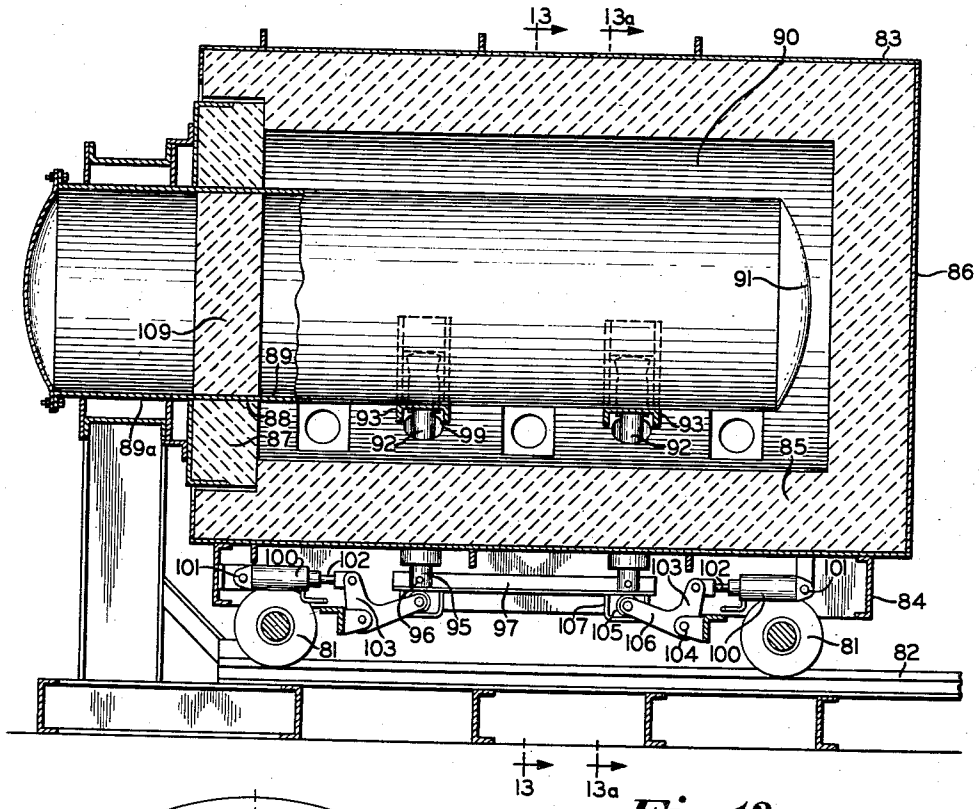


Fig. 12

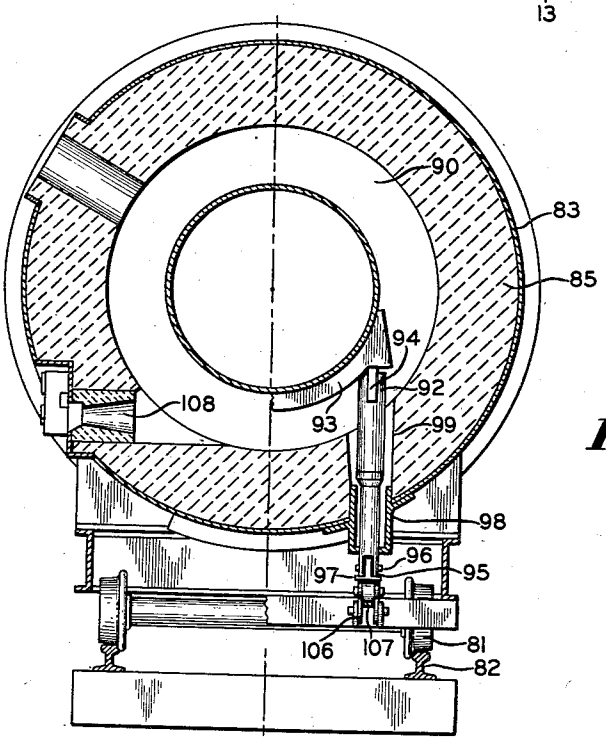


Fig. 13

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2,825,547

MUFFLE TYPE FURNACE WITH MOVABLE SUPPORT STRUTS

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Application May 24, 1955, Serial No. 510,711

23 Claims. (Cl. 263—42)

The invention relates to muffle type furnaces such as are used for continuous bright annealing of stainless steel strip and the like. Furnaces for this purpose ordinarily include an elongated refractory lined furnace chamber, a heat resisting alloy muffle extending longitudinally through the furnace chamber, a water-jacketed cooling chamber, and entrance and exit vestibules with suitable air-excluding means such as curtains.

The muffle, cooling chamber and vestibules are connected by gas-tight joints. The interior of the muffle and cooling chamber is filled, when in operation, with a protective atmosphere, preferably hydrogen or dissociated ammonia, maintained at a dew point of minus 40° C. or lower by careful exclusion of oxygen.

In a representative furnace of this type, the muffle, cooling chamber and entrance and exit passages may have an inside width of about 24 inches, the furnace heating chamber may have a length of about 25 feet and the cooling chamber may have a length of about 75 to 100 feet.

Under present practice, a common muffle construction involves a centrifugally cast, circular cylinder of suitable length to extend through the end walls of the furnace heating chamber. This muffle is anchored at or near the point of connection to the cooling chamber so as to expand, under heat, toward the entrance end of the furnace.

At temperatures approaching 2000° F., the metal of the muffle has extremely low strength, and, with ordinary methods of support, flattening caused by the action of gravity is a serious problem. Experiment indicates that for a circular cylinder of alloy containing 30% Cr and 20% Ni, operated at 2000° F. and supported between points 30 degrees each side of the vertical, longitudinal, central plane, the thickness of the muffle wall must be at least 3½%, and preferably approaching 5%, of the mean diameter of the cylinder, in order to obtain a rate of flattening low enough to be tolerable.

For a cylinder of 25 inches mean diameter, this corresponds to between ⅞ and 1¼ inches wall thickness. Such a muffle is obviously very heavy and therefore expensive, and in addition, the support loads are high enough to cause great resistance to the longitudinal movement of the muffle required by expansion of the same under high temperatures.

One common method of support is to provide a series of transverse refractory piers in the bottom of the furnace chamber. These piers may be shaped to fit the contour of the bottom of the muffle and may be provided with metal caps.

A continuous support for the muffle is objectionable, because of the large amount of surface area to be rendered inactive, and because of the thermal stresses which would result. Even spaced piers which carry the entire load of the muffle produce these effects to an appreciable degree. The space around the muffle, both above and below the same, should be largely open for satisfactory results.

If such piers are fitted around the underside of the

muffle for a sufficient distance to resist flattening, the muffle first settles into a snug fit upon the piers when heated, and the metal of the muffle then further subsides adjacent to the piers, producing appreciable indentations.

When the muffle shrinks upon cooling, the piers are often destroyed because the intended sliding of the muffle upon the piers, due to contraction, has thus become impossible.

It is therefore an object of the present invention to provide a muffle support which overcomes the above described difficulties and disadvantages.

Another object is to provide improved muffle support means having certain distinct advantages over common practice.

A further object is to provide muffle support means, whereby gravity produces a spreading effect in the upper portion, and a narrowing effect in the lower portion of the muffle, these effects largely neutralizing each other.

A still further object is to provide a muffle support producing minimum interference with heat absorption by the muffle, and therefore good heating capacity and small temperature stresses.

Another object of the invention is to provide resilient muffle supports which do not become inactive in the event of muffle warpage.

A further object is to provide for low unit pressure at the supports.

A still further object is to provide muffle support means including support struts tiltably engaging the muffle adjacent each marginal edge thereof.

Another object of the invention is to provide spaced, fixed piers shaped to substantially conform to the contour of the under portion of the muffle, and spaced pairs of movable struts carrying the larger portion of the load, but less than the full load, of the muffle.

A further object is to provide muffle support means including a spaced pair of struts tiltably engaging the muffle adjacent each marginal edge thereof, the line of action of said struts intersecting the plane of greatest muffle width at points near the marginal edges of the muffle.

A still further object is to provide such a muffle support means including means for applying a predetermined lifting force to the lower end of each strut.

It is also an object of the invention to provide lifting means of the character referred to in which the total of lifting forces applied to the struts is less than the weight of the muffle.

And finally, it is an object of the invention to provide a muffle of such cross-sectional shape that the lower half of the muffle is in the form of a catenary curve and the upper half thereof in the form of an inverted catenary curve with upright supports at the junction points between the two portions.

These and other objects, apparent from the drawings and following description, may be attained, the above described difficulties overcome and the advantages and results obtained, by the apparatus, construction, arrangement and combinations, subcombinations and parts which comprise the present invention, a preferred embodiment of which, illustrative of the best mode in which applicant has contemplated applying the principle, being set forth in detail in the following description and illustrated in the accompanying drawings.

Briefly stated, the invention may be described as comprising a muffle type furnace including an elongated refractory lined furnace chamber, a heat resisting alloy muffle extending longitudinally through the chamber, spaced fixed piers supporting the muffle at intervals, spaced pairs of movable struts tiltably engaging the muffle adjacent each marginal edge thereof, means for applying a predetermined lifting force to each strut, and means an-

choring the muffle against longitudinal movement at a convenient point, for example near the exit end of the furnace.

The muffle may extend through one or both end walls of the heating chamber, and a cooling chamber of considerable length may be attached to the discharge end of the muffle by means of an air-tight joint.

Entrance and exit vestibules may be provided having suitable air excluding means such as curtains, the vestibules being connected by gas-tight joints, so that the interior of the muffle and cooling chamber may be filled with a protective atmosphere.

In the application of the invention to a batch-type furnace, at least one end of the muffle may terminate within the heating chamber of the furnace, the cooling chamber and exit vestibule being omitted in the batch-type furnace.

Having thus described the invention in general terms, reference is now made to the accompanying drawings, in which;

Fig. 1 is a diagrammatic view of a round or cylindrical muffle supported upon a flat surface, showing successive deformed or flattened shapes which the muffle assumes when submitted to high temperatures;

Fig. 2 a similar diagrammatic view of a round or cylindrical muffle supported by a curved surface showing successive distorted or flattened shapes which the muffle assumes under high temperatures;

Fig. 3 a diagrammatic view illustrating the use of catenary curves as applied to muffle construction;

Fig. 4*a* is a side elevation of a complete furnace showing an embodiment of the invention;

Fig. 4*b* is a side elevation of water-jacketed cooling chamber;

Fig. 5 an enlarged, longitudinal, sectional view of the furnace proper;

Fig. 6 a transverse, sectional view through the furnace, taken as on the line **6—6**, Fig. 5, and showing the movable strut support means forming an important part of the invention;

Fig. 7 a transverse, sectional view, taken on the line **7—7**, Fig. 5, showing one of the fixed support piers;

Fig. 8 an enlarged view of one of the movable support struts, viewed at right angles to the furnace length;

Fig. 9 an enlarged fragmentary sectional view of the upper spring disc and the lower end of the tubular center portion of one of the struts;

Fig. 10 a longitudinal sectional view through a batch furnace of the vacuum type with removable muffle or retort, embodying the invention;

Fig. 11 a transverse, sectional view through the furnace shown in Fig. 10, taken partially as on the line **11—11** and partially on the line **11*a*—11*a***, Fig. 10;

Fig. 12 a longitudinal sectional view through another type of batch furnace; and,

Fig. 13 a transverse sectional view through the furnace shown in Fig. 12, taken partially on the line **13—13** and partially on the line **13*a*—13*a***, Fig. 12.

Referring now more particularly to the embodiment of the invention illustrated in the drawings, in which similar numerals refer to similar parts throughout, reference is first made to the diagrams shown in Figs. 1 to 3.

In Fig. 1 is a diagrammatic showing of a circular, cylindrical muffle, indicated at **15**, supported along a single line contact, indicated at **16**, upon a flat supporting member **17**. At *a* the cylindrical muffle **15** is shown in the original form before it has been subjected to high temperature.

When this muffle is subjected to considerable temperature and time it will flatten to substantially elliptical shape as shown at *b*, and the lower side of the muffle, in contact with the support **17**, will be flattened as indicated at **18**.

With additional time at high temperature, it will become increasingly flattened as shown at *c*, the top side of the muffle becoming slightly concaved as at **19** and the bottom side of the muffle becoming increasingly flattened as at **20**.

The diagram in Fig. 2 shows a cylindrical muffle **21** supported upon a curved or concaved support member **22**. If this support member fits the cylinder through an angle of about 90 degrees, the original circular cross-sectional shape *d* distorts successively to the shapes indicated at *e* and *f*.

Assuming that the curved support **22** is in the form of spaced piers, the muffle first moves into a snug fit upon the piers under the effect of temperature and time, and the metal of the muffle then further subsides adjacent the piers, producing appreciable indentations, so that when the muffle shrinks on cooling the piers are often destroyed as it has become impossible for the muffle to slide thereon.

In Fig. 3 is diagrammatically shown the use of catenary curves in the formation of a muffle. At *g* is shown a view with the shape of a catenary curve, and at *h* is a similar view representing an inverted catenary curve of the same shape and size. With such sections, if supported by vertical and horizontal forces, there is no bending stress.

Since the horizontal forces are equal and opposite, a completed band as shown at *k*, formed of like upper and lower catenary shaped portions, will have no tendency to flatten, if vertical supports are provided at the junction points between the two portions.

A catenary profile or cross section, such as this could be adopted for a tubular muffle, and in the case of construction by welding of formed plates, or use of still-cast metal, it would be entirely practical.

However, much of the advantage is still retained if a circular or even an elliptical cylindrical muffle, is supported in the neighborhood of the intersection of its horizontal diameter and the opposite walls.

It is not practical to provide continuous support throughout the length of the muffle, but, if local supports are spaced at reasonably frequent intervals, the stresses due to beam action will not be great.

Referring now more particularly to the embodiment of the invention illustrated in Figs. 4 to 9, in which a continuous annealing furnace is shown, the furnace proper is indicated generally at **23**, a water-jacketed cooling chamber is shown at **24**, an entrance vestibule at **25** and a muffle at **26**.

The muffle is joined to the entrance vestibule by a gas-tight joint, indicated at **27**, and to the cooling chamber by a similar gas-tight joint **28**. The muffle is anchored to the furnace structure, preferably outside of the furnace chamber as by a flange **29**, to prevent longitudinal movement of the muffle at this point, so that upon heating, the end of the muffle to which the entrance vestibule **25** is attached, expands to the left, as viewed in Fig. 4.

As shown in Figs. 5, 6 and 7, the furnace proper includes the steel shell upper and lower halves **30** and **31** respectively, a refractory lining **32** enclosing a cylindrical heating chamber **33**, and refractory end walls **34** and **35**. The furnace chamber may be heated in any conventional manner by fuel or electric heating elements.

Anchor members **36** are integrally attached to the steel shells **30** and **31**, for the purpose of attaching the flange **29** of the muffle at the working exit end of the furnace, or the right hand end, as viewed in the drawings.

A spaced plurality of refractory piers **37** are located in the bottom of the furnace chamber, and the upper surfaces thereof are curved, preferably to a radius slightly greater than that of the muffle, as indicated at **38** in Fig. 7. These piers **37**, together with the end walls **34** and **35**, contribute to the support of the muffle **26**, and also resist any tendency to lateral curvature of the muffle, which might result from temperature differences.

As a further support for the muffle, and preferably for supporting the major portion of the muffle load, a series of strut assemblies are provided, as best shown in Figs. 6, 8 and 9. Each of these strut assemblies comprises an arcu-

ate band 39, curved to conform to the lower half of the muffle 26, and a pair of struts indicated generally at 40, tiltably engaged with said band.

The bands 39 are preferably so attached to the muffle 26 as to permit them to "wrap" into conformity with the muffle. One method of obtaining this result is to weld or otherwise attach the bands to the muffle near the bottom center point, leaving the ends of the band free, thus permitting the desired "wrapping" action, while preventing displacement of the bands lengthwise or circumferentially of the muffle.

Slots 50 are formed in the refractory lining 32, of such size as to permit the necessary rocking motion of the struts. For a heated length of 25 feet, the distance from the anchoring point to the most remote pair of struts is about 23 feet.

The expansion of the muffle at the rate of .30 inch per foot, allowing for only partial heating of the portion of the muffle located through the end wall 35, is about 7 inches, assuming that the muffle is formed of an alloy of 35% Ni and 15% Cr, heated to 2000° F. It is practical to allow for this much movement. The movement is preferably divided so that the fixed parts, such as the sockets 42, are about midway in the range of movement of the corresponding bands 39.

The struts are shown in the drawings tilted inward toward the muffle at a slight angle to the vertical. The desirable angle of the struts will generally be between vertical and about 30 degrees inward tilt. In practice, this inward tilt is found to exert some sidewise flattening action to counteract the vertical flattening tendency produced at the piers. If there are no piers, as in a short furnace, the struts may be vertical or nearly so.

The lower end of each center portion 41 of each strut is mounted within a spring socket 42, attached to the lower half of shell 31 and extending downwardly and below the shell. A spring seat 43 is adjustably mounted in the lower end portion of each socket 42, as by the adjusting screw 44, and fits the lower end of a coil spring 45, upon the upper end of which is mounted the upper spring disc 46, having a socket 47 in its upper surface within which is mounted the axial pin 48 fixed upon the lower end of the tubular center portion 41 of the strut.

This tubular center portion is filled with insulation 49, to prevent the flow of excessive amounts of heat outward from the heated chamber 33 of the furnace. Thus the spring 45 is not subjected to a high enough temperature to destroy its elasticity.

Recesses 51 are formed in the bands 39, near opposite ends thereof, and the upper portion 52 of each strut 40 is of rocker shape, as best shown in Fig. 8, so as to permit tilting of the strut caused by longitudinal expansion or contraction of the muffle.

The springs 45 are adjusted by the screws 44, so as to support at least a substantial part of the weight of the muffle, the exact proportion being subject to wide choice. Excellent results were obtained in a furnace in which two pairs of struts were located between each pair of piers, and the load of the muffle was supported about 50% by the struts and 50% by the piers.

A desirable upper limit for strut loading might be of the order of 75% of the total weight of the muffle, in which case the permissible error in spring adjustment is still fairly large without danger of lifting the muffle completely off of the piers.

In the case of a short muffle, such as one with a heated length 5 times its diameter, all piers in the furnace chamber proper may be omitted, the muffle receiving fixed support only by the surrounding brickwork in the end walls of the furnace chamber or by external support members.

In such a case, the struts are preferably adjusted to carry a major portion, say 75% to 100%, of the average load per unit length. Thus, for a 3 foot strut spacing, with a muffle weight of 100 pounds per foot, each pair of struts may be adjusted to carry from 225 to 300 pounds.

In the drawings the struts are shown tilted inward at a slight angle to the vertical. Applicant has used this arrangement in actual practice, in order to exert some sidewise flattening action to counteract the vertical flattening tendency produced at the piers.

However, in any event, the force exerted is predominately upward. The desirable angle of tilt of the struts will generally be between vertical and about 30° inward tilt, a preferred angle being about 10 degrees to the vertical, as best shown in Fig. 6. If there are no supporting piers, as in a short furnace, the struts may be vertical or nearly so.

The strut seats 51, in the support bands 39, are located below the horizontal center line of the muffle 26, so that the line of action of the strut passes through or near, preferably inside, the muffle wall at the widest point. Thus, the lines of action of the struts intersect the plane of greatest muffle width at points near the marginal edges of the muffle, as best shown in Fig. 6.

It will be seen that the marginal edges of the muffle referred to are located in a horizontal plane passing through the axis of the muffle, this horizontal plane being the plane of greatest muffle width.

While the strut seats 51 are shown in the support plate 39, it should be understood that correspondingly located strut seats may be formed integral with the muffle. However, the use of separate support bands 39, with strut seats therein, is convenient, effective and practical.

Although the muffle 26 is shown as circular in cross section, it should be understood that this cross section may be varied. As previously pointed out, a muffle cross section as shown in Fig. 3 is very desirable, in which the shape is that of a catenary curve for the lower half combined with a like inverted catenary curve for the upper half. Such a shape has the least possible bending stresses tending to produce flattening, and this would be a very desirable shape for a muffle made of rolled sheet or plate.

Another cross-sectional shape which is very useful is that of an ellipse with its major axis horizontal, substantially as shown at *b* in Fig. 1 with the omission of the flattened lower portion 18. This cross-sectional shape of muffle is economical for handling wide strip, and while very unsatisfactory when supported only in the bottom region, as shown in Fig. 1, since it resembles a round muffle which already is flattened by heat, and bending stresses are excessive, such stresses may be reduced to a safe value by the support means above described and illustrated.

It should be understood that with this elliptical form of muffle, there will be some tendency for the upper, center portion to buckle inward, and for the upper portion near the axis to be forced upward and outward, while corresponding areas in the lower portion tend to be distorted in opposite directions relative to the major axis of the ellipse.

Although the above description has mentioned only muffles of circular, elliptical and catenary profile, it should be understood that other curves or combinations of curves may be used to develop a suitable profile by the use of the supporting means herein described.

It is not absolutely necessary that the profile be exactly symmetrical about a horizontal diameter, although symmetry is preferred in the absence of some reason for a special shape. The struts, as above described, are positioned so that their lines of action are directed through regions near the muffle wall at the level of greatest width, whereby gravity acts on the upper part of the muffle wall to produce a widening effect, and on the lower part thereof to produce a narrowing effect, these opposing effects counteracting each other at least to a considerable degree.

Although the upper ends of the struts are shown of rocker form at 52, it is not absolutely necessary that they be of this exact form, since various simple shapes are satisfactory which permit the required tilting movement.

For example, a rounded pin and socket engagement, as shown at 47*a* and 48*a* in Fig. 9, may be used with satisfactory results. While it is true that with such an engagement the lifting force exerted on the spring will change slightly as the strut tilts, by using a spring of low rate this effect is not objectionable.

In Figs. 10 and 11 is shown an application of the invention to a batch furnace which may be of the vacuum type with removable muffle or retort. This furnace includes the steel shell 55, with refractory lining 56 forming the top wall 57, longitudinal side walls 58 and rear end wall 59, defining the furnace heating chamber 60 which is open at its forward end and its underside and supported spaced above the floor, as by the base members 61 at each side and at the rear end thereof.

This furnace is shown in the drawings as an electric furnace adapted to be heated with electric heating elements, as indicated at 62, but it should be understood that the furnace may be fuel fired in any conventional manner.

The muffle or retort 63 is carried upon a car, indicated generally at 64, the wheels 65 of which ride upon the rails 66, longitudinally disposed upon the floor below the furnace chamber. The car includes the refractory top or platform 67 adapted to be received within the open bottom of the furnace chamber between the lower ends of the side walls 58 thereof.

Channels 68 are formed upon each side of the car and receive the depending flanges 69, at opposite sides of the open bottom of the furnace chamber, and any suitable sealing material, such as sand or the like as indicated at 70, may be contained in the channels 68 in order to prevent loss of heat from the furnace chamber and to protect the running gear of the car from the extreme temperature of the furnace.

Furnaces of this type are especially adapted for heat treatment of the so-called reactive metals such as titanium, zirconium, vanadium, etc., with which ordinary prepared atmospheres cannot be used. The vacuum is produced within the muffle by means of a pump (not shown) carried by the car so that work within the muffle may be heat treated in a substantial vacuum.

It will be seen that the atmospheric pressure outside of the muffle 63 will tend to increasingly flatten this muffle when the internal pressure thereof has been so greatly decreased. For this reason, the muffle supporting means to which the invention pertains, including the movable struts tiltably engaging the muffle adjacent to each marginal edge thereof, is ideally suited for supporting this muffle and avoiding additional flattening tendency caused by gravity.

The outer end of the muffle is located through an opening 71 in the end bulkhead 72 of the car, which, as shown in Fig. 10, substantially closes the open front end of the furnace chamber, and this front end of the muffle is anchored to the structure 73 at the front end of the car. A removable door or cover 74 is provided for the open front end of the muffle, and the closed rear end 75 thereof terminates at a point spaced from the rear end wall 59 of the furnace chamber.

The muffle is supported at spaced intervals throughout its length upon the spaced refractory piers 76, mounted upon the platform 67 of the car and preferably provided with metal caps 77 of arcuate shape to receive the underside of the muffle.

As a further support for the muffle 63, and preferably supporting the major portion of the muffle load, as above described, a series of movable strut assemblies are provided. These strut assemblies are similar to those above described, each comprising an arcuate band 78, curved to conform to the lower half of the muffle 63, and a pair of struts indicated generally at 79, tiltably engaged with said band in the manner above described in detail.

These struts are located through slots 80 in the refractory platform 67 of the car and are of the construction, arrangement and operation above described in detail with reference to Figs. 5 to 9, with the exception that, as shown in Fig. 11, they are located substantially vertical rather than being tilted inward toward the muffle. However, as above pointed out, these struts may be located at any angle between vertical and above 30 degrees inward tilt.

In the present case it will be seen that it is convenient to locate the struts substantially vertical, as otherwise it would be necessary to increase the width of the car as well as the width of the furnace chamber itself in order to tilt the struts inward at any appreciable angle.

The arrangement and operation is otherwise the same as above described in detail, the struts being adjusted to produce the desired lifting force and preferably supporting the major portion of the muffle load, the remainder of which is supported by the piers and the opening 71 in the end bulkhead of the car. The muffle being anchored at its forward end, under high temperatures it will elongate toward its rear end, whereby the struts will rock backward and forward as the muffle expands and contracts.

In Figs. 12 and 13 is shown another, and comparatively simple form of batch furnace, in which the entire furnace may be provided with wheels 81 mounted to roll upon rails 82. The furnace comprises the steel shell 83 mounted upon the structural frame 84 to which the wheels are attached. This shell may be of cylindrical shape, as best shown in Fig. 13, and is provided with the refractory lining 85 within the vertical side walls and the closed rear end wall 86.

The front end wall is also lined with refractory material, as shown at 87, and provided with the opening 88 through which the front end of the muffle 89 extends, this front end of the muffle being supported within the opening 88 in the front end wall 87 and being anchored as at 89*a* to the structural frame attached to the front end wall of the furnace.

This muffle extends rearwardly through the furnace chamber 90 to a point near the rear end wall thereof, being closed at its rear end as shown at 91. As the muffle is of relatively short length, no pier is provided for assisting and supporting the same, the entire length of the muffle within the furnace chamber being supported only by two spaced piers of movable struts 92, each pair of struts being tiltably connected to an arcuate band 93 for conforming to the underside of the muffle.

As shown in Figs. 12 and 13, the movable struts 92 each has a rocker portion 94 at its upper end, similar to that illustrated and described above, for engagement in a socket in the adjacent end portion of the arcuate band 93. Instead of providing springs for adjusting the lifting force of the struts, as shown in Figs. 4 to 9, fluid cylinder means may be provided.

For this purpose, the lower end of each strut member 92 may be bifurcated, as shown at 95, and pivoted as at 96 upon a horizontal T-bar 97. The lower portions of the struts 92 are located through the sockets 98, which extend downward through the lower side of the steel shell 83 of the furnace. The struts are thus guided through these sockets, when they are lowered, and upon lifting the rocker portions 94 at their upper ends will enter the sockets in the band 93, before this guiding action is lost. Slots 99 are formed in the lower portion of the refractory lining 85 of the furnace, to permit tilting movement of the struts in the manner above described.

As best shown in Fig. 12, the T-bar 97 is adapted to be vertically adjusted by fluid cylinder means. This fluid cylinder means may comprise a pair of cylinders

100, pivotally mounted in the car frame 84, as indicated at 101. The piston rod 102 of each cylinder is pivotally connected to one arm 103 of a bell crank, fulcrumed as at 104 upon the frame of the car. A roller 105 is journalled upon the free end of the other arm 106 of each bell crank, and is movably mounted within a yoke 107 depending from the T-bar 97.

The fluid pressure in the cylinders 100 will urge the pistons inwardly therein, and through the bell cranks 103—106, the T-bar 97 will be raised, increasing the lifting force of the struts. Thus the desired fluid pressure may be maintained in the cylinders 100 to produce any desired or necessary lifting force for the movable struts.

The furnace chamber 90 may be heated to desired temperature by any conventional means such as gas or oil burners located through the burner openings 108, or by electric heating elements, or other conventional means.

In this embodiment of the invention, the muffle being anchored at its forward end as at 89, the elongation thereof under high temperatures will be toward the rear end thereof. It will be seen that as the muffle expands and contracts the movable struts 92 will tilt rearwardly and forwardly, carrying the entire weight of the muffle within the furnace chamber. An insulation plug 109, of any suitable material, is removably mounted in the forward end of the muffle and may be removed for loading and unloading the muffle.

Although springs are illustrated in the drawings and above described in detail, for providing the lifting force, it should be understood that an equivalent means, such as air cylinders, counter-weights or the like, may be provided for producing the lifting force, the only requirement being that a predetermined lifting force within reasonable limits be exerted, regardless of movement of the muffle.

The muffle support means is illustrated and described as applied to a horizontal muffle, but it should be understood that it is also useful for a muffle located in a somewhat inclined position, since the flattening tendency still exists in such a muffle.

Throughout the description and claims, the terms "cylindrical" and "tubular" apply to muffles of generally cylindrical form, not necessarily circular, where both the portions above and below the plane of greatest width are curved so as to be outwardly convex at substantially all points, and further, that the profile or cross section is such that the action of gravity on the upper portion results in outward forces, and the action of gravity on the lower portion results in inward forces, these opposing forces being of at least the same order of magnitude. In other words, the improved support means to which the invention pertains is applicable to muffles of any cylindrical form, whether the profile or cross section thereof be circular or otherwise curved.

In the foregoing description, certain terms have been used for brevity, clearness and understanding, but no unnecessary limitations are to be implied therefrom beyond the requirements of the prior art, because such words are used for descriptive purposes herein and are intended to be broadly construed.

Moreover, the embodiments of the improved construction illustrated and described herein are by way of example, and the scope of the present invention is not limited to the exact details of construction.

Having now described the invention or discovery, the construction, the operation, and use of preferred embodiments thereof, and the advantageous new and useful results obtained thereby; the new and useful construction, and reasonable mechanical equivalents thereof obvious to those skilled in the art, are set forth in the appended claims.

I claim:

1. In a furnace, walls defining a heating chamber, a cylindrical muffle located through one end wall of the furnace chamber and terminating within the chamber at a point spaced from the opposite end wall thereof, means anchoring the muffle adjacent said one end wall, and support means for the muffle within said chamber including a pair of pivoted upwardly acting struts tiltably engaging opposite sides of the muffle near a horizontal plane located through the axis of the muffle.

2. In a furnace, walls defining a heating chamber, a cylindrical muffle extending longitudinally within said chamber, a support band conforming to the underside of said muffle, means connecting said support band to the muffle at only one point an upwardly acting support strut adjacent each side of the muffle, seat means associated with said support band and tiltably engaging the upper end of each of the struts, and means for applying a predetermined lifting force to the lower end of each strut, the lines of action of said struts intersecting points near the marginal edges of the muffle in a horizontal plane located through the axis of the cylindrical muffle.

3. In a furnace, walls defining a heating chamber, a cylindrical muffle extending longitudinally within said chamber, spaced fixed support piers within the chamber, said piers having concave supporting surfaces substantially conforming to the shape of the muffle bottom, spaced pairs of upwardly acting support struts between said piers, the struts of each pair having lines of action intersecting the horizontal plane of greatest muffle width near the intersection of the opposite muffle walls with said horizontal plane, seat means associated with the muffle and tiltably engaging the upper ends of the struts, and means for applying a predetermined lifting force to the lower end of each strut.

4. In a furnace, walls defining a heating chamber, a cylindrical muffle extending longitudinally within said chamber, spaced fixed support piers within the chamber, said piers having concave supporting surfaces substantially conforming to the shape of the muffle bottom, spaced pairs of upwardly acting support struts between said piers, the struts of each pair having lines of action intersecting the horizontal plane of greatest muffle width near the intersection of the opposite muffle walls with said horizontal plane, seat means associated with the muffle and tiltably engaging the upper ends of the struts, and means for applying a predetermined lifting force to the lower end of each strut, the total of said lifting forces being such as to leave an appreciable load upon said piers thus tending to prevent lateral warpage of the muffle.

5. In a furnace, walls defining a heating chamber, a cylindrical muffle extending longitudinally within said chamber, spaced fixed support piers within the chamber, said piers having concave supporting surfaces substantially conforming to the shape of the muffle bottom, spaced pairs of upwardly acting support struts between said piers, the struts of each pair having lines of action intersecting the horizontal plane of greatest muffle width near the intersection of the opposite muffle walls with said horizontal plane, seat means associated with the muffle and tiltably engaging the upper ends of the struts, and means for applying a predetermined lifting force to the lower end of each strut, the total of said lifting forces being more than half the total load of the muffle.

6. In a furnace, walls defining a heating chamber, a cylindrical muffle extending longitudinally within said chamber, spaced fixed support piers within the chamber, said piers having concave supporting surfaces substantially conforming to the shape of the muffle bottom, spaced pairs of upwardly acting support struts between said piers, the struts of each pair having lines of action intersecting the horizontal plane of greatest muffle width near the intersection of the opposite muffle walls with said horizontal plane, seat means associated with the muffle and tiltably engaging the upper ends of the struts, and means for applying a predetermined lifting force to the lower end of each strut, the struts carrying a major portion of the load of the muffle but less than the full load thereof.

7. In a furnace, walls defining a heating chamber, a cylindrical muffle extending longitudinally within said chamber, the cross section of said muffle comprising a catenary curve forming the lower half of the muffle and an inverted catenary curve forming the upper half thereof, said lower and upper halves being joined at a horizontal plane of greatest muffle width support means for the muffle, and means associated with the muffle for engaging the support means, the line of action of said support means intersecting said plane of greatest muffle width at points near the intersection of said curves with said plane.

8. In a furnace, side walls, a rear end wall and a top wall, and a car movable relative to the furnace and having a horizontal platform forming a movable bottom wall and together with said furnace walls defining a heating chamber, a cylindrical muffle carried by said car and terminating within said chamber at a point spaced from said rear end wall, means anchoring the muffle adjacent to the front end of the car, and support means within said chamber including spaced pairs of upwardly acting struts tiltably engaging opposite sides of the muffle adjacent the point of maximum muffle width, the lower ends of said struts being supported upon said car.

9. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a pair of support seats associated with said muffle adjacent its opposite side walls and near its horizontal plane of greatest width, there being tension-resisting connecting means between said seats circumferentially of the lower portion of the muffle, a pair of upwardly-acting support struts engaging said seats, and means for applying a predetermined force to the lower ends of said struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

10. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a pair of support seats associated with said muffle adjacent its opposite side walls and near its horizontal plane of greatest width, there being tension-resisting connecting means between said seats circumferentially of the lower portion of the muffle, a pair of upwardly-acting support struts engaging said seats, and spring means for applying a predetermined force to the lower ends of said struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

11. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a pair of support seats associated with said muffle adjacent its opposite side walls and near its horizontal plane of greatest width, there being tension-resisting connecting means between said seats circumferentially of the lower portion of the muffle, a pair of upwardly-acting support struts engaging said seats, and fluid cylinder means for applying a predetermined force to the lower ends of said struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

12. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a pair of support seats associated with said muffle adjacent its opposite side walls and near its horizontal plane of greatest width, there being tension-resisting connecting means between said seats circumferentially of the lower portion of the muffle, a pair of upwardly-acting tiltable support struts engaging said seats, and means for applying a predetermined force to the lower ends of said struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

13. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a pair of support seats formed upon said muffle adjacent its opposite side walls and near its horizontal plane of greatest width, the lower portion of the muffle forming tension-resisting connecting means between said seats, a pair of upwardly-acting support struts engaging said seats, and means for applying a predetermined force to the lower ends of said struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

14. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a pair of support seats formed upon said muffle adjacent its opposite side walls and near its horizontal plane of greatest width, the lower portion of the muffle forming tension-resisting connecting means between said seats, a pair of upwardly-acting support struts engaging said seats, and spring means for applying a predetermined force to the lower ends of said struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

15. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a pair of support seats formed upon said muffle adjacent its opposite side walls and near its horizontal plane of greatest width, the lower portion of the muffle forming tension-resisting connecting means between said seats, a pair of upwardly-acting support struts engaging said seats, and fluid cylinder means for applying a predetermined force to the lower ends of said struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

16. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a pair of support seats formed upon said muffle adjacent its opposite side walls and near its horizontal plane of greatest width, the lower portion of the muffle forming tension-resisting connecting means between said seats, a pair of upwardly-acting tiltable support struts engaging said seats, and means for applying a predetermined force to the lower ends of said struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

17. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a support band conforming to the underside of the muffle, a pair of support seats formed upon said support band at points adjacent opposite side walls of the muffle near the horizontal plane of greatest width of the muffle, said support band forming tension-resisting connecting means between said seats, a pair of upwardly-acting support struts engaging said seats, and means for applying a predetermined force to the lower ends of the struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

18. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a support band conforming to the underside of the muffle, a pair of support seats formed upon said support band at points adjacent opposite side walls of the muffle near the horizontal plane of greatest width of the muffle, said support band forming tension-resisting connecting means between said seats, a pair of upwardly-acting support struts engaging said seats, and spring means for applying a predetermined force to the lower ends of the struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

19. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a support band conforming to the underside of the muffle, a pair of support seats formed upon said support band at points adjacent opposite side walls of the muffle near the horizontal plane of greatest width of the muffle, said support band forming tension-resisting connecting means between said seats, a pair of upwardly-acting support struts engaging said seats, and fluid cylinder means for applying a predetermined force to the lower ends of the struts, whereby a tension com-

ponent of stress is applied to said tension-resisting connecting means.

20. In a furnace, walls defining a heating chamber, a horizontal cylindrical muffle extending longitudinally within the chamber, a support band conforming to the underside of the muffle, a pair of support seats formed upon said support band at points adjacent opposite side walls of the muffle near the horizontal plane of greatest width of the muffle, said support band forming tension-resisting connecting means between said seats, a pair of upwardly-acting tiltable support struts engaging said seats, and means for applying a predetermined force to the lower ends of the struts, whereby a tension component of stress is applied to said tension-resisting connecting means.

21. In a furnace, walls defining a heating chamber, a cylindrical muffle extending longitudinally within said chamber, seat means adjacent opposite sides of the muffle, upwardly-acting support struts engaging said seat means, each of said struts having a line of action substantially tangential to each side of the muffle near a horizontal plane located through the axis of the muffle, and means for applying a predetermined lifting force to the lower end of each strut.

22. In a furnace, walls defining a heating chamber, a cylindrical muffle extending longitudinally within said chamber, seat means adjacent opposite sides of the muffle, upwardly-acting support struts engaging said seat means, each of said struts having a line of action substantially tangential to each side of the muffle near a horizontal plane located through the axis of the muffle, and spring means for applying a predetermined lifting force to the lower end of each strut.

23. In a furnace, walls defining a heating chamber, a cylindrical muffle extending longitudinally within said chamber seat means adjacent opposite sides of the muffle, upwardly acting support struts engaging said seat means, each of said struts having a line of action substantially tangential to each side of the muffle near a horizontal plane located through the axis of the muffle, and fluid cylinder means for applying a predetermined lifting force to the lower end of each strut.

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