Sept. 26, 1961 J. H. WIGGINS 3,001,273

APPARATUS AND METHODS FOR ERECTING SUSPENSION ROOFS

Filed June 13, 1958 3 Sheets-Sheet 1

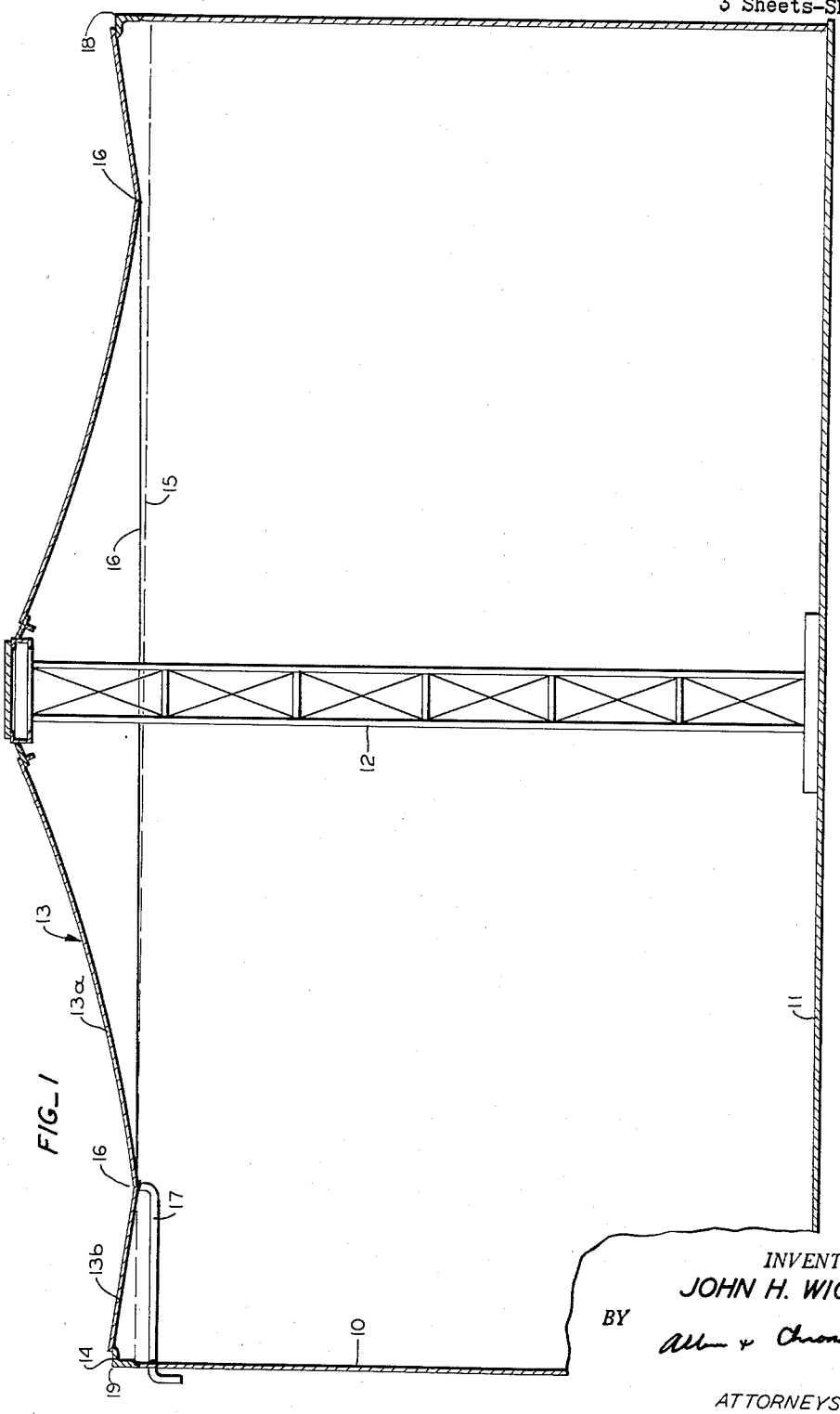


FIG. 1

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Filed June 13, 1958 3 Sheets-Sheet 2

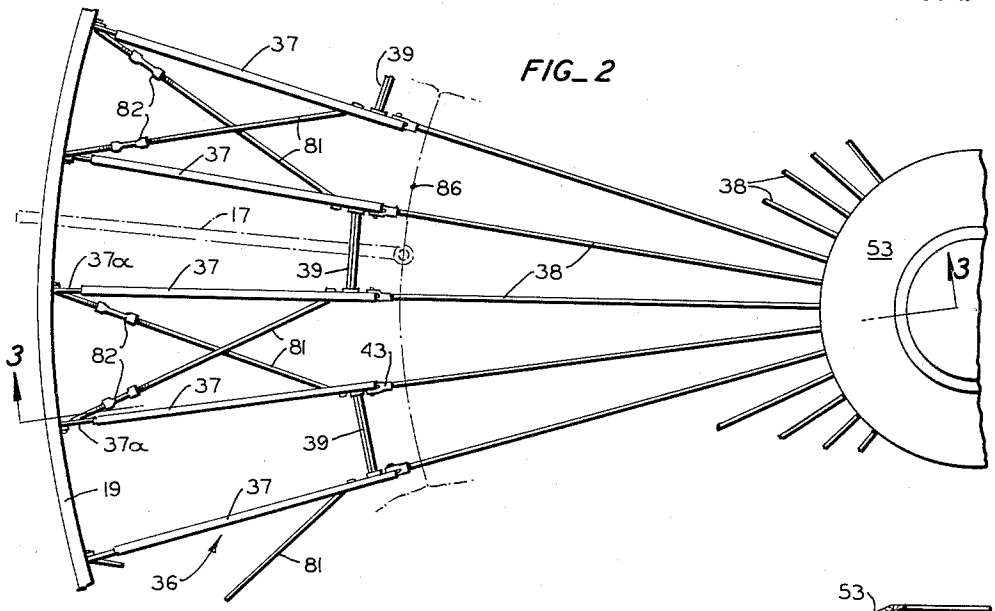


FIG_2

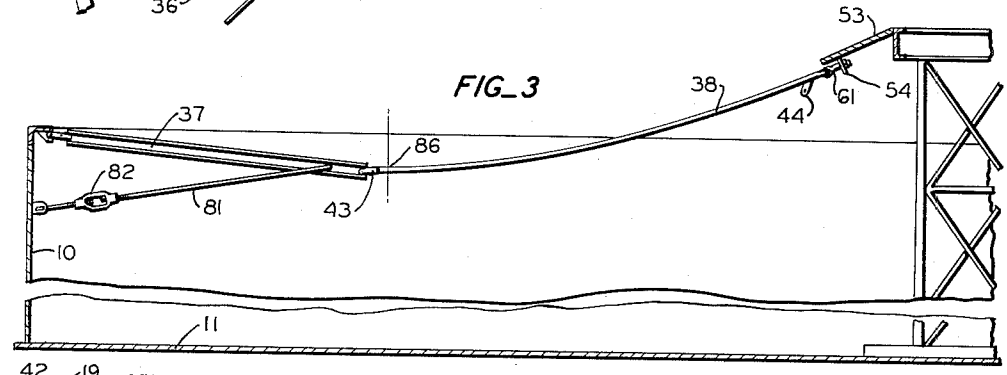


FIG_3

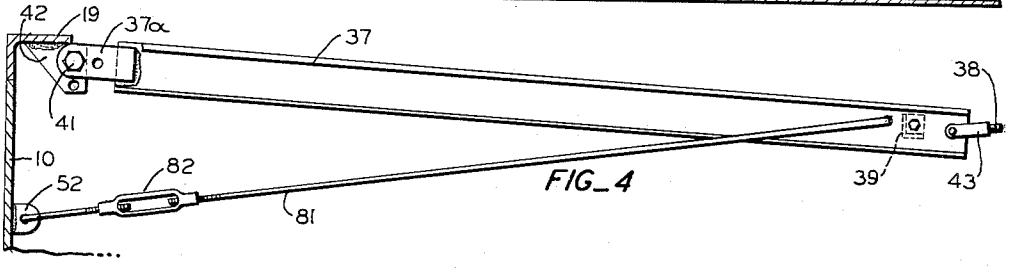


FIG_4

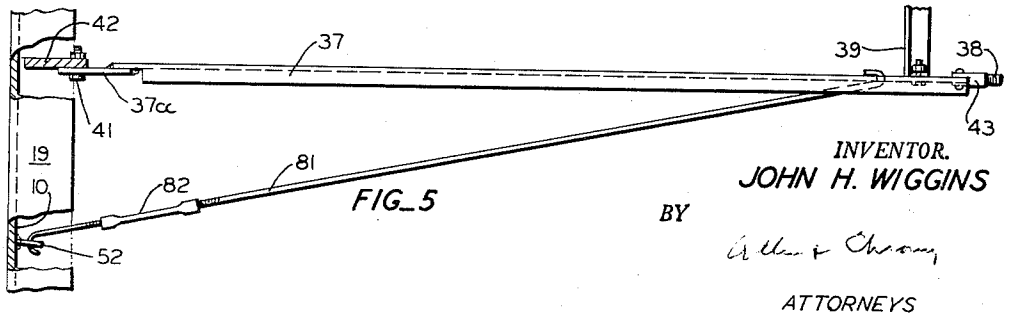


FIG_5

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APPARATUS AND METHODS FOR ERECTING SUSPENSION ROOFS

Filed June 13, 1958 3 Sheets-Sheet 3

FIG_6

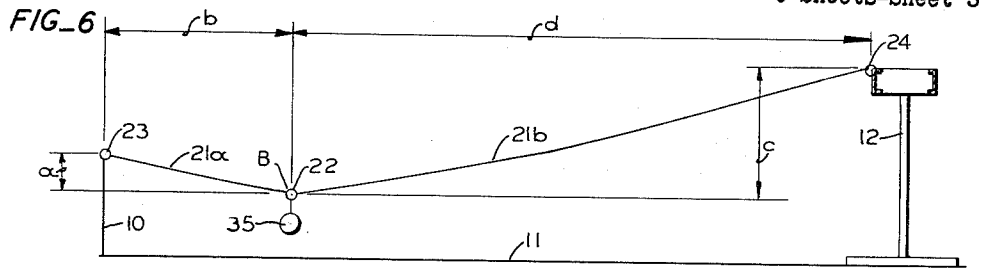


FIG_7

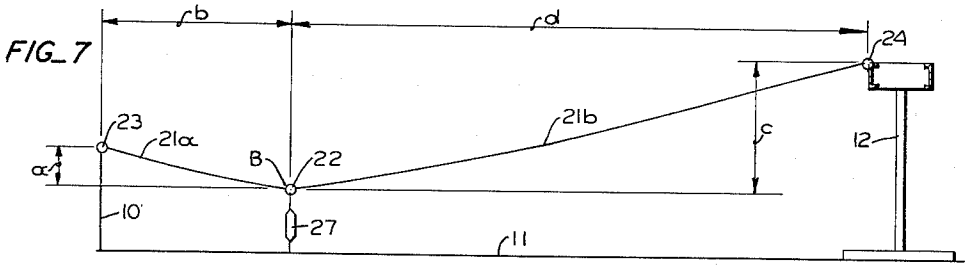


FIG_8

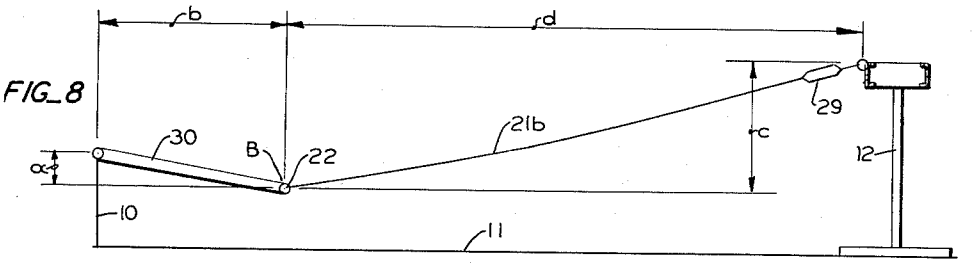
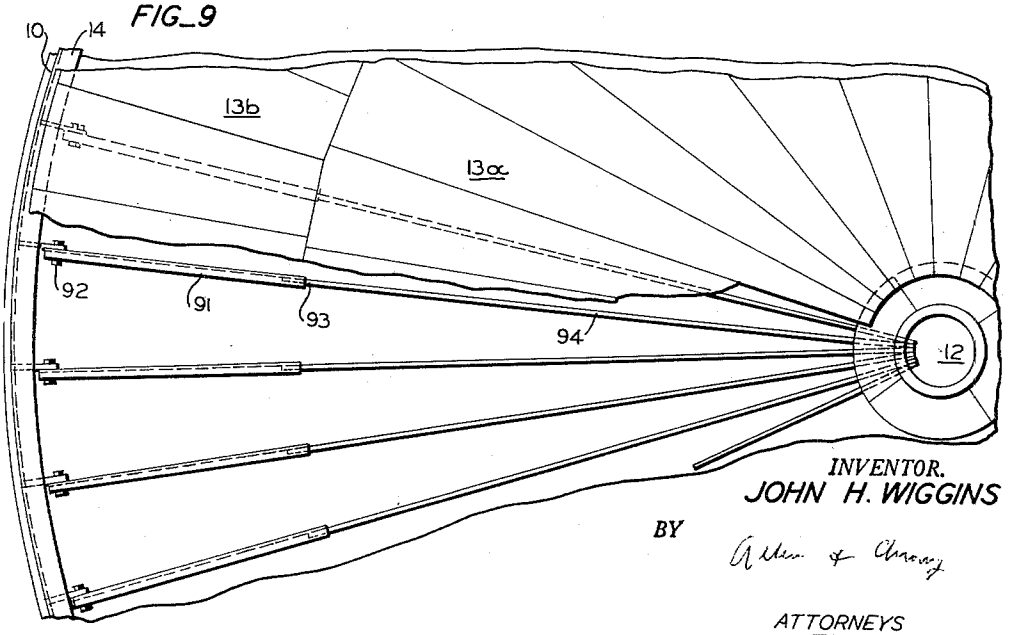


FIG_9



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3,001,273
APPARATUS AND METHODS FOR ERECTING SUSPENSION ROOFS

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Filed June 13, 1958, Ser. No. 741,946
5 Claims. (Cl. 29—428)

This application is a continuation-in-part of my co-pending applications, Serial No. 525,478, filed August 1, 1955, Serial No. 596,619, filed July 9, 1956, and Serial No. 618,248, filed October 25, 1956, all of which are now abandoned.

The present invention relates to metal storage tanks for liquids, grain and the like and is concerned more particularly with such a metal tank having a suspension roof providing an annular drain area intermediate an outer deck or roof portion of built-in shape sloping downwardly and inwardly from the outer side wall and an inner deck or roof portion of built-in shape of double curvature, said inner deck sloping downwardly and outwardly from the center support, to meet the outer deck at the drain area or gutter in which the lowest circle is included. In particular, the invention pertains to an advantageous method and apparatus for erecting the roof in a tank of the above type and which enables a desirable shaping and sloping or slanting of the entire roof area so as to provide one or more low points at which drain outlets can be provided for draining water from the roof.

It is an object of the invention to provide improved apparatus and methods for erecting a suspension roof of a metal storage tank.

Another object of the invention is to provide erection methods and apparatus of the above character which enable predetermining of the built-in shape of both the outer and inner decks.

Another object of the invention is to provide erection methods and apparatus of the above character which minimize the amount of labor required in roof erection.

A further object of the invention is to provide erection apparatus and methods which provide a positive control of the desired shape of the roof, particularly the lowest circle of the drainage area, both horizontally and vertically.

Still another object of the invention is to provide erection apparatus and methods which provide for preloading of the erection frame so as to provide stabilized conditions of both the curb and the center support of the tank which will not be disturbed materially during the laying of plates on the erection frame.

A still further object of the invention is to provide an erection frame of the suspension type which can be put in place economically and enable efficient, economical assembly of the erection frame and of the roof on the erection frame.

Still another object of the invention is to provide an erection frame in which an annular series of beam members of the frame projecting inwardly from the side wall of the tank have their inner ends positively fixed in position and held against overturning.

Other objects and advantages of the invention will be apparent from the following description of a preferred embodiment of the erection apparatus and improved methods of erecting a suspension roof having a circular drainage area intermediate its center and its outer periphery, as described in the accompanying specification and as illustrated in the attached drawings, in which:

FIGURE 1 is a vertical sectional view through a storage tank of the type with which the present invention is particularly useful;

FIGURE 2 is a fragmentary plan view of a part of the erection frame in place in a tank;

FIGURE 3 is a sectional view taken as indicated by the line 3—3 in FIGURE 2;

FIGURE 4 is an enlarged view of a portion of FIGURE 5;

FIGURE 5 is an enlarged view of a portion of FIGURE 2;

FIGURE 6 is a schematic sectional view of a tank illustrating one form of apparatus and method for applying a downwardly directed vertical force to control the height of the lowest circle with respect to the tank and also to fix its position radially in the desired location;

FIGURE 7 is a schematic view similar to FIGURE 6 illustrating another form of the invention for obtaining the desired position of the lowest circle of the tank;

FIGURE 8 is a view similar to FIGURES 6 and 7 and illustrating a third way of predetermining the built-in shape of the roof and for fixing the position of the lowest circle thereof;

FIGURE 9 is a fragmentary plan view of one form of the erection frame.

As stated generally above, the present invention is concerned with the erection of a suspension type roof on a metal storage tank, which roof has a circular drain area intermediate its center and its periphery, the invention being particularly adaptable to roofs which have a slope or shape to provide one or more low points in the circular drainage area, tanks with roofs of these types being disclosed in my co-pending application, Serial No. 507,887, filed May 12, 1955, and my Patent No. 2,805,631, dated September 10, 1957.

In general, tanks of this character include an outer side wall **10** (FIGURE 1), a bottom wall **11**, a center support or tower **12**, and a suspension roof **13** comprised of an inner portion or deck **13***a* of the form of a catenary of revolution to provide a built-in shape of double curvature for said inner deck which slopes outwardly and downwardly from the center support **12**, and an outer deck **13***b* of substantially frusto-conical form and of built-in shape which slopes inwardly and downwardly from the curb ring **14** at the upper edge of the side wall **10** to the gutter area **16** where it meets the inner deck **13***a*. The two sloping roof decks **13***a* and **13***b* merge or are joined at a circular drainage area **16**, whose lowest points lie on a circle, at the lowest point of which a suitable drain **17** is provided. As illustrated in FIGURE 1, the entire roof is slanted from a high point **18** at the right of FIGURE 1, to a low point **19** at the left of FIGURE 1, the annular drainage area **16** having a corresponding slope and its lowest point as previously stated leading to the drain **17**. The level of liquid of a full tank is illustrated at **15**. If desired, the roof may have an undulating or serpentine form, as illustrated in said Patent No. 2,805,631, with a plurality of low points and a plurality of drain pipes **17** at the low points. Roofs of the above character place severe requirements on the erection apparatus and methods in order to enable a low-cost roof and a low-cost erection method therefor, as well as to provide for the desired built-in shapes of both the inner deck and the outer deck.

In accordance with the instant invention I have provided for an erection frame and method which includes means for applying a downwardly directed vertical force to each of a series of circumferential radial tension members which have a hinge-like action adjacent or at the lowest circle of the roof to provide for definite location of the circle both radially and vertically.

Referring to FIGURE 6, there is illustrated schematically one form of radial tension member employed in connection with the present invention which comprises a radial tension member having an outer portion **21***a* and an inner portion **21***b* which are connected by a hinge or hinge-like connection **22**, the portion **21***a* being attached

by a hinge-like connection 23 to the side wall 10 of the tank and the inner portion 21*b* being connected by a hinge-like connection 24 to the center support 12. Suspended from the lowest point on the radial tension member 22 is a weight 35 which applies a concentrated downward force and pulls the two parts 21*a* and 21*b* into two different curves with the lowest point at 22 on the lowest circle. It will be noted that a limber cable which has a weight connected thereto will act as a hinge-like connection at the point of attachment of the weight. Part 21*a*, while truly a catenary, is approximately a straight line and provides for a frusto-conical shape as far as the surface defined by the series of outer sections 21*a* of the radial members and therefore provides a substantially frusto-conical built-in shape. The longer inner section 21*b* is suspended as a true catenary, and therefore the series of inner sections 21*b* defines a built-in shape of double curvature.

Referring to FIGURE 7, the sections 21*a* and 21*b* are connected to the bottom wall 11 by a connection including a turnbuckle 27 by means of which the height of the point 22 with respect to the curb or side wall, i.e., the dimension *a* can be controlled and an appropriate downwardly directed concentrated force applied to each of the radial tension members.

FIGURE 8 illustrates a preferred way of constructing the radial tension member. In this case the outer section 30 is in the form of a stiff straight beam, and the inner section 21*b* is again a limber tension member, being connected at the hinge point 22, the weight on the rigid member 30 providing a downwardly concentrated force at the hinge point 22, and the height of this hinge point being controlled by the turnbuckle connection 29 connecting the portion 21*b* to the center support.

In connection with all of the different modifications shown in FIGURES 6–8 it will be noted that as the plates are laid on the radial tension members the dimension *a* of the hinge point 22 at the lowest circle tends to change very little, and dimension *b* does not change at all. This is because as the load is applied through the outer members 21*a* or 30 to the curb, it tends to shorten the curb and move it inwardly a very slight amount, and this tends to lower the hinge point 22. As the plate load is applied to the inner portion 21*b* of the radial tension member it tends to assume a smaller radius which shortens it and tends to raise the point B. Thirdly, as the plates are laid on the inner portion 21*b* its tension increases and hence its length increases which tends to lower the point B. These three effects tend to balance and have a very small effect on the dimension *a*. Any such change in dimension *a* can readily be compensated for either by increasing the weight 35, by increasing the tension through the turnbuckle 27, or by adjusting the height of the hinge point 22 in FIGURE 8 by adjustment of the turnbuckle 29. It will be seen that it is desirable in constructing the above type of double suspension roof that the vertical dimension *a* be kept as small as consistent with appropriate drainage down to the gutter area, and as small as consistent with maintaining an angular relation of less than 180° between the outer deck and the inner deck. This correspondingly enables maintaining the vertical dimension *c* as small as possible to obtain the same results, thereby enabling a minimum height of the center support and a corresponding saving in material. The fixing of the dimensions *a* and *c* will correspondingly determine, together with the location of the downwardly directed force, the horizontal dimensions *b* and *d*.

Referring to a specific embodiment of the form of the invention illustrated in FIGURE 8, reference is made to FIGURES 2–5, an erection frame is provided which comprises a circumferential series of identical units 36, each unit in the present embodiment being composed of a plurality of radial frame elements including a pair of outer rigid beams 37 (FIGURE 2) and a pair of inner limber or flexible bars 38, the outer rigid beams 37 corresponding to the outer deck 13*b*, and the inner flexible bars 38 corresponding to the inner deck 13*a* (FIGURE 1).

As seen in FIGURE 2, each frame unit 36 includes a pair of beams 37 which are joined rigidly by a cross-brace 39 in the form of an angle suitably secured therebetween and spacing their inner ends in the desired relation and preventing the inner ends of the beams from turning over as plates are laid thereon. The outer end of each beam 37 is provided with an apertured lug 37*a* (FIGURES 2 and 3) for pivotal attachment by a bolt 41 to an installation lug 42 on the curb 19, and at its inner end with a suitable aperture to receive a fastening yoke 43 at the end of the bar 38 to provide a pivotal connection therebetween. At the inner end of the flexible bar 38 there is provided a lug 44 by means of which it is connected to the center support as later described.

On the side wall of the tank there are also provided certain permanently installed elements for use in the erection of the frame during installation of the roof, which may be used later, for example, during repair of the roof. These elements include a series of apertured lugs 52 (FIGURES 4 and 5) secured about the periphery of the tank side wall 10 in evenly spaced relation directly below the lugs 42. These lugs 52 are used in securing certain bracing elements for the erection frame units as will be later described in detail.

At the center of the tank and forming a part of the center support is a frustum plate 53 (FIGURES 2 and 3) having a downwardly extending circular bracing rib 54. The rib 54 is provided with a series of apertures to receive eye bolts 61 for attachment of the inner ends of the limber bars 38, as seen in FIGURE 3.

The erection frame includes means for bracing of the frame in a generally horizontal plane to resist horizontal forces which would be set up or caused, for example, by sliding of a plate circumferentially along the frame during laying of the plates, or other similar horizontal forces. The erection frame also includes means for pre-loading the frame by applying tension in a vertical direction, so that the inner end of beam 37 is pre-loaded in accordance with the approximate vertical stress to be carried thereby; also, the pre-loading places a circumferentially balanced load on the center support. For these purposes the erection frame units 36 are provided with bracing connections extending both laterally and downwardly to exert a downward pre-loading or pull on the beams 37, which is partially resisted by the extra tension imposed upon limber members 38, this tension being adjustable by adjustment of the eye bolts 61 and the rods 81. Each bracing connection (FIGURES 2 through 5) comprises a rod 81 which has its inner end hooked into a suitable aperture in the rigid frame member or beam 37 and has its outer end hooked into a lug 52. Each rod 81 includes a conventional turnbuckle 82. It will be noted that there are two of the bracing rods or tension rods 81 for each frame unit 36, these respective pairs of rods 81 diverging outwardly and downwardly from their points of connection to the unit 36 so as to place balance forces on the frame unit, this being resisted by the tension in the members 38 and 39. In this manner and by suitable adjustment, the erection frame can be pre-stressed to any desired extent, and the position of the lowest circle 86 (FIGURE 2) or gutter can be definitely fixed. The optimum pre-load upon the erection frame is theoretically at least as great, or greater than the load that would be imposed by the weight of the plates of the outer deck 13*b* of the roof and constitute a balanced load with respect to the center support, thus loading will not vary materially when the roof plates are placed on the erection frame, because the effect of the weight of the roof plates is to reduce correspondingly the tensions in the bracing rods 81. As stated above, the effect of pre-loading of the frame units 36 minimizes the application of unbalancing forces or tensions on the center support, and insures that as the plates of the outer deck are laid, the tension on

the respective limber bars or cables 38 will not be materially changed. This is true because the effect of the laying of the plates is merely to reduce the tension on the bracing connections 81, and to replace the reduction in force and stresses applied thereby by the addition of the weight of the plates. This pre-loading in effect prestresses the rods 38 so that the vertical position of the gutter or lowest circle of the roof will remain substantially unchanged during laying of the outer deck plates.

It will be seen therefore, that the pre-loading of the frame units 36 insures that the entire erection frame will remain in its desired shape and location throughout the laying of the plates from no-plate load to full-plate load.

It is to be understood that desirable and satisfactory results can be obtained without necessarily using the full optimum theoretical pre-loading.

Referring to the modification illustrated in FIGURE 9, this is also of the general type shown schematically in FIGURE 8. In FIGURE 9 the series of radial tension members includes a rigid outer beam 91 pivoted at 92 to the side wall 10 and having a hinge-like connection at 93 with an inner part comprising a limber rod 94. The rod 94 is provided with an adjustable connection to the center support 12 similar to the turnbuckle 29 of FIGURE 8. A vertical section through FIGURE 9 would appear as shown in FIGURE 8. Also, if desired, each rigid beam 91 may be provided with braces to resist horizontal and/or vertical forces such as the braces 81 employed in connection with the embodiment of FIGURES 2–5, and will result in providing the outer deck of built-in substantially frusto-conical shape and the inner deck of built-in shape of double curvature.

The operation of the installation of the roof plates is performed in the same manner with any of the above described modified erection frames. This installation usually is begun at the location of the drain 17 in laying of the ring of roof plates of the outer deck. Preferably a complete ring of plates is laid at a time to simplify the maintaining of the roof load balance as successive rings of plates are laid until the plates of the entire roof portions or decks are in place. Usually a preliminary tack welding is used to hold the plates in place and still permit minute relative adjustment between them as the roof changes in shape due to the addition of other plates. If desirable, the radial tension members 81 are adjusted from time to time to maintain the designed shape of the roof as the next ring or rings of plates are being laid.

Thereafter the joints between the plates are welded so that a built-in shape is obtained in both the outer deck and the inner deck. After this is done the erection frame is removed, and, in the case of the outer deck, a slight sagging will occur where rigid frame members are employed due to the weight of the plates so as to reform the frusto-conical shape to an arced configuration.

The entire operation insures that the inner deck will have a built-in shape of double curvature, that the outer deck will have a built-in shape of arced configuration which is substantially frusto-conical, and that the entire load of the roof is distributed in the desired proportions between the center roof support and the side wall.

It is believed apparent that the erection frame structure and the method of assembling it on the tank materially simplifies the problem of providing a sloping of the entire roof of the tank inasmuch as it is merely a matter of placement of the mounting means for the frame units by the same configuration preselected by the shape of the top of the wall of the tank. In other words, the problem of erecting a roof of complex shape becomes the same as erecting a roof of simple or standard shape.

While I have shown and described certain preferred embodiments of the invention, and certain ways of performing the method of my invention, it will be understood that the invention is capable of variation and modification from the form shown so that its scope should be

limited only by the scope of the claims appended hereto.

I claim:

1. In a storage tank of the suspension roof type having an outer side wall, a center support, and a double suspension roof between said outer side wall and said center support and comprising an outer deck or roof portion of built-in shape sloping downwardly and inwardly from the outer side wall and an inner deck or roof portion of built-in shape of double curvature, said inner deck sloping downwardly and outwardly from the center support, said roof decks being joined to form an annular drain trough or gutter area including the lowest circle of the roof; an erection frame for the roof of the tank comprising a circumferential series of radial tension members for supporting roof plates, each member including an outer part connected to said outer side wall and sloping downwardly and inwardly therefrom to the lowest circle of the roof and also including an inner part sloping downwardly and outwardly from said center support to said lowest circle, said outer part forming substantially a straight line, said inner part being limber and of catenary shape, means connecting said inner part and said outer part to provide a hinge-like connection therebetween adjacent said lowest circles, and means for applying a downwardly directed concentrated vertical force to each said radial tension member, adjacent said hinge-like connection to control the height of said hinge-like connection relative to said side wall and thereby also control the position of the lowest circle of the roof both radially and vertically.

2. In a storage tank of the suspension roof type having an outer side wall, a center support, and a double suspension roof between said outer side wall and said center support and comprising an outer deck or roof portion of built-in shape sloping downwardly and inwardly from the outer side wall and an inner deck or roof portion of built-in shape of double curvature, said inner deck sloping downwardly and outwardly from the center support, said roof decks being joined to form an annular drain trough or gutter area including the lowest circle of the roof; an erection frame for the roof of the tank comprising a circumferential series of radial tension members for supporting roof plates, each member including a rigid outer part connected to said outer side wall and sloping downwardly and inwardly therefrom to the lowest circle of the roof and also including a limber inner part sloping downwardly and outwardly from said center support to said lowest circle, said inner part being of catenary shape, means connecting said inner part and said outer part to provide a hinge-like connection therebetween adjacent said lowest circle, and means for applying a downwardly directed vertical force to each said radial tension member adjacent said hinge-like connection to control the height of said hinge-like connection relative to said side wall and thereby also control the position of the lowest circle of the roof both radially and vertically.

3. A method of building a metal storage tank of the type having a double suspension roof wherein two roof portions are suspended to meet at the lowest circle of the tank in which a drain trough is provided and wherein the location of said circle is predetermined, characterized by erecting a circular side wall provided at its top edge with an annular compression member designed to carry a predetermined percentage of the roof load, erecting a vertical roof support at the center of the tank designed to carry a predetermined percentage of the roof load, suspending an erection framework between the top edge portion of the tank side wall and the upper end portion of the center roof support, said framework including a rigid erection support member for said peripheral roof portion, assembling roof plates on said framework and joining said plates together so as to form a central roof portion of arced shape extending downwardly and outwardly from said center support and attached at its upper end to said support, assembling and joining roof plates on

said framework and joining said plates together so as to form a peripheral roof portion of frusto conical shape extending downwardly and inwardly from the compression member on the side wall and attached at its upper end to said member, joining the outer edge of said arced central roof portion to the inner edge of said frusto conical peripheral roof portion on a substantially circular line that constitutes the lowest circle of the roof's area, and at the completion of the operation of fabricating the roof removing the erection framework and utilizing the roof load to impart a downward sag to the lowest portion of the roof to reform the peripheral roof portion from said frusto conical shaped peripheral roof portion to an arced surface that is disposed in a predetermined relationship with the arced central portion of the roof, whereby the load is distributed between the center roof support and the side wall in the desired proportions.

4. In a storage tank of the suspension roof type having an outer side wall, a center support, and a suspension roof between said outer side wall and said center support and comprising an outer deck sloping downwardly and inwardly from the outer side wall and an inner deck sloping downwardly and outwardly from the center support, said decks being of built-in shape and joined to form an annular drain area including a gutter containing the lowest circle of the roof; the method of roof erection which comprises first suspending an erection frame between the side wall and the center support to provide an outer frame section of substantially frusto-conical shape sloping downwardly and inwardly from the outer side wall and an inner frame section of catenary shape sloping downwardly and outwardly from the center support, the shape of the erection frame corresponding to the desired built-in shapes of the decks of the roof, fixing the location of the lowest circle or gutter of the roof in the drain area by applying a concentrated downward force on the erection frame adjacent this lowest circle, then placing roof plates on the erection frame and assembling and joining said roof plates to form said respective inner and outer decks, and securing the decks together and to the center support and the side wall.

5. In a storage tank of the suspension roof type having an outer side wall, a center support, and a suspension roof between said outer side wall and said center support and comprising an outer deck sloping downwardly and inwardly from the outer side wall and an inner deck sloping downwardly and outwardly from the center support, said decks being joined to form an annular drain trough or gutter area at the lowest circle of the roof; an erection frame for the roof of the tank comprising a circumferential series of radially disposed members attached to the outer side wall, each member including an outer part extending inwardly and downwardly from the side wall in substantially a straight line and an inner part attached to the center support and extending outwardly and downwardly therefrom in catenary form and connected to said outer part of a member by hinge-like means, and means for applying a concentrated load adjacent the radial location of the lowest circle of the roof at the connection between said substantially straight line outer part and said catenary inner part whereby the predetermined form of the roof is defined.

References Cited in the file of this patent

UNITED STATES PATENTS

1,846,294	Wiggins	Feb. 23, 1932
2,327,085	Wiggins	Aug. 17, 1943

OTHER REFERENCES

Engineering News-Record, Sept. 2, 1954 (pages 31 and 32 relied on). (Copy in Scientific Library and in Division 33).