Sept. 22, 1942. L. ALBRECHT 2,296,414

STORAGE TANK CONSTRUCTION

Filed May 26, 1938 4 Sheets-Sheet 1

Fig. 1

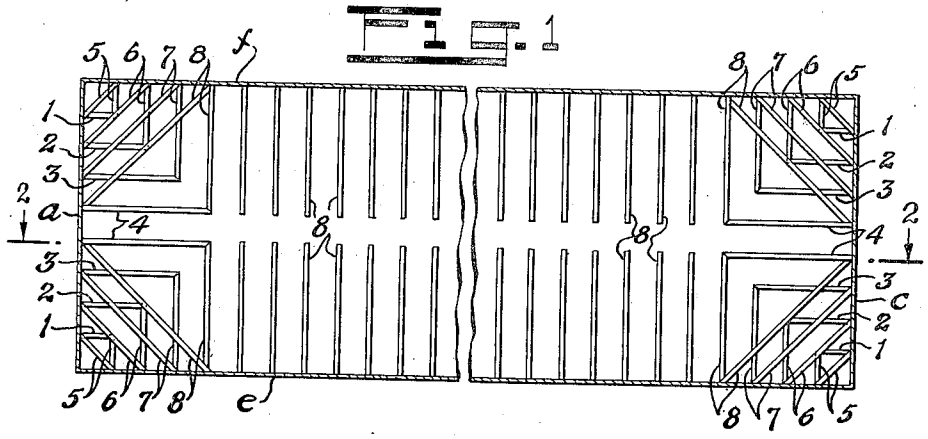

Fig. 2

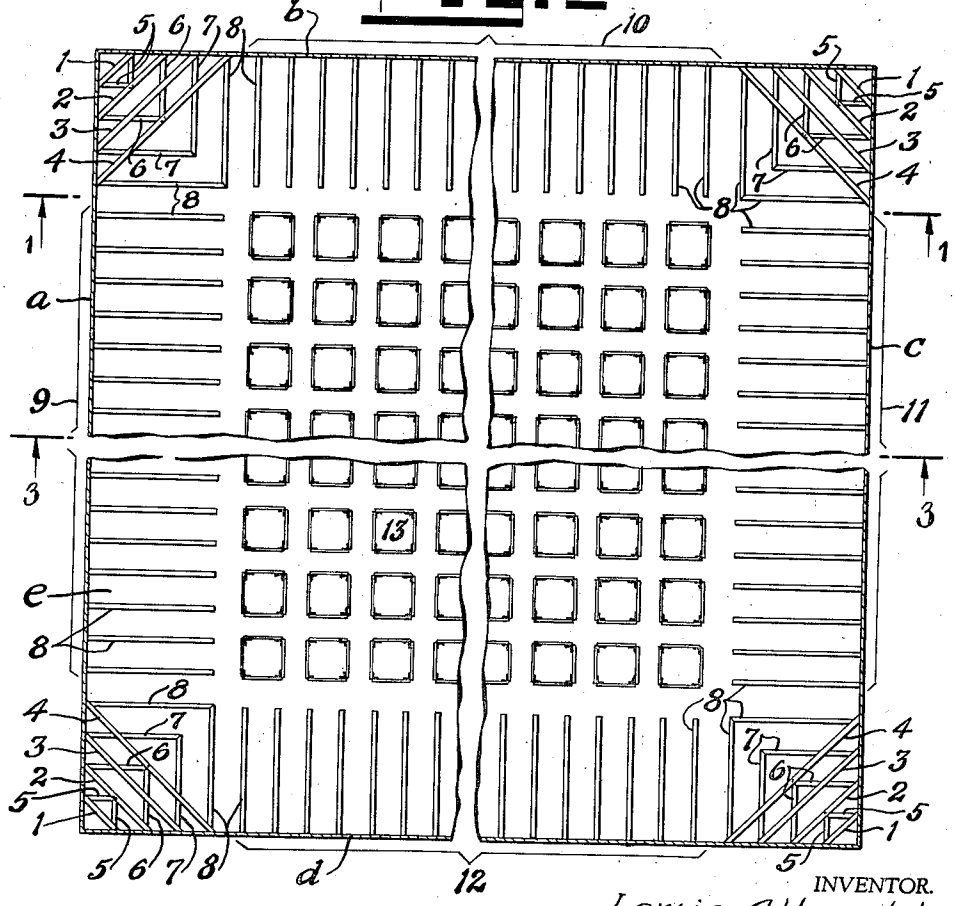

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Fig. 3

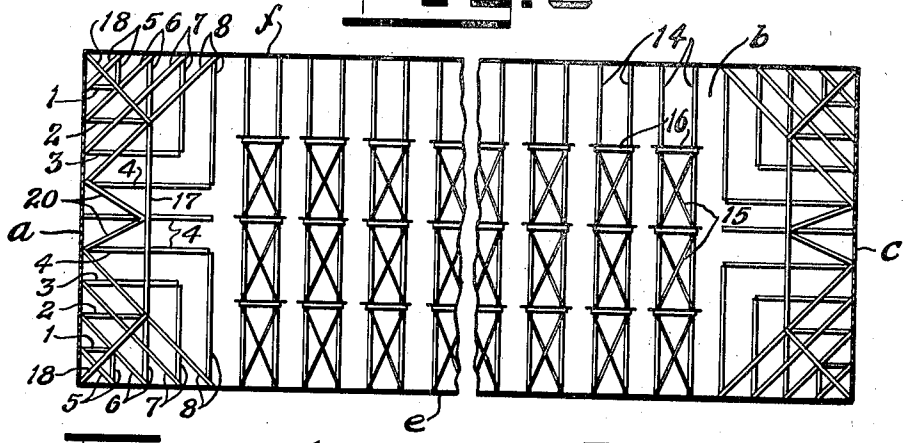

Fig. 4

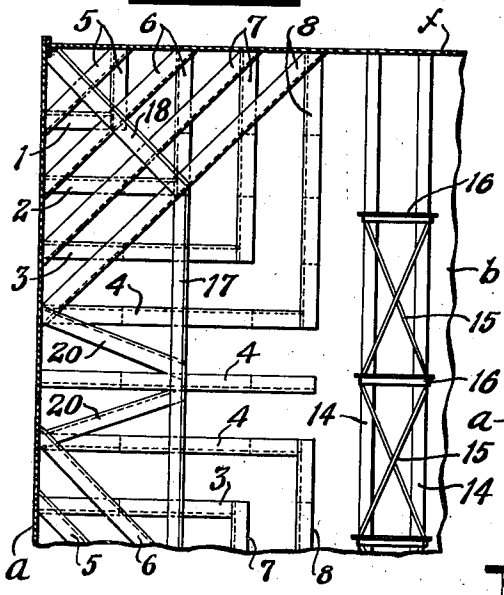

Fig. 5

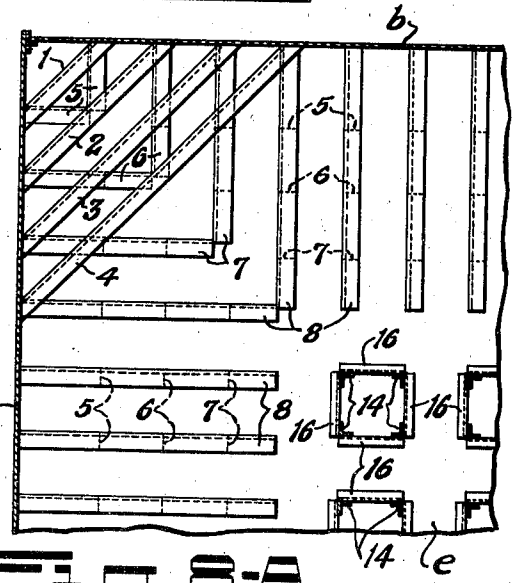

Fig. 8

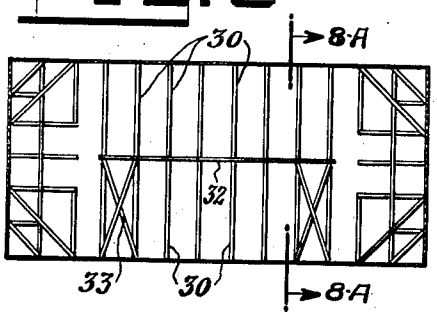

Fig. 8-A

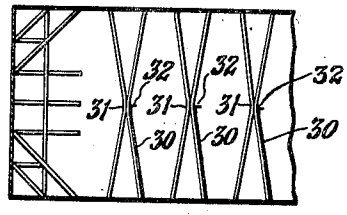

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FIG. 6

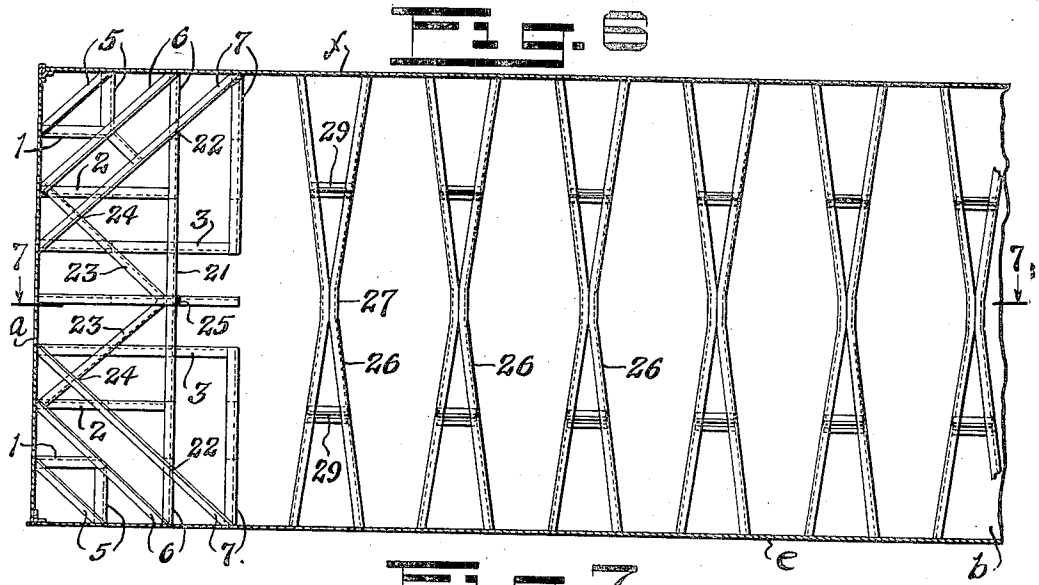


FIG. 7

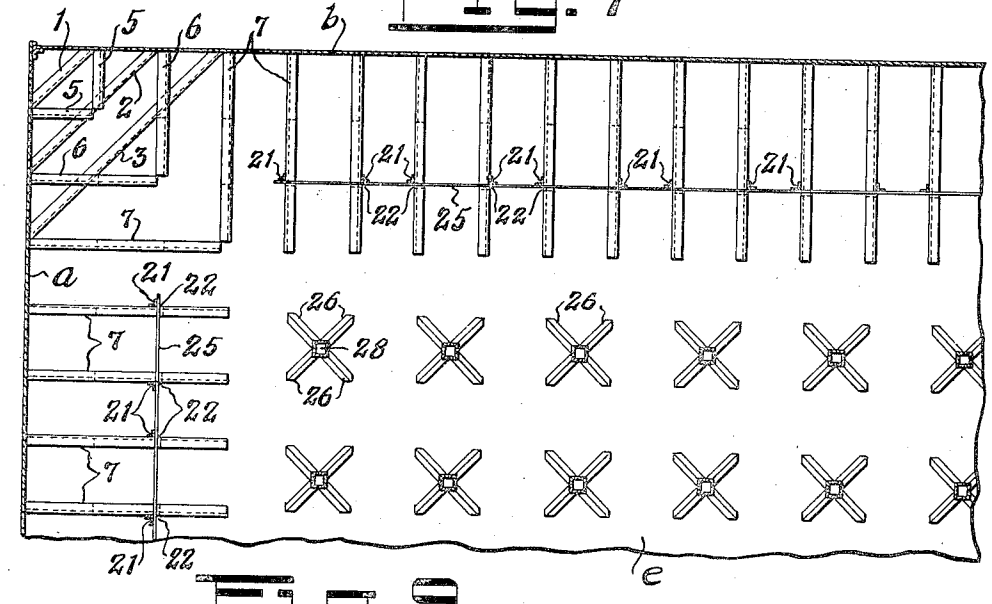
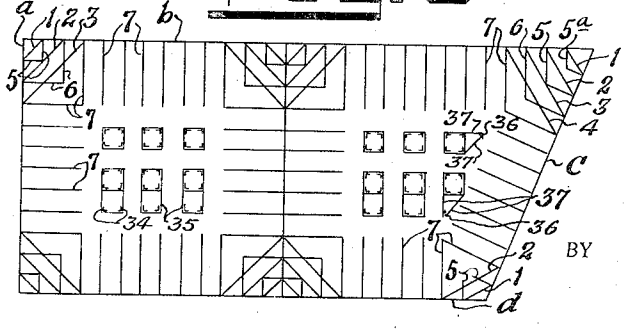


FIG. 8



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STORAGE TANK CONSTRUCTION

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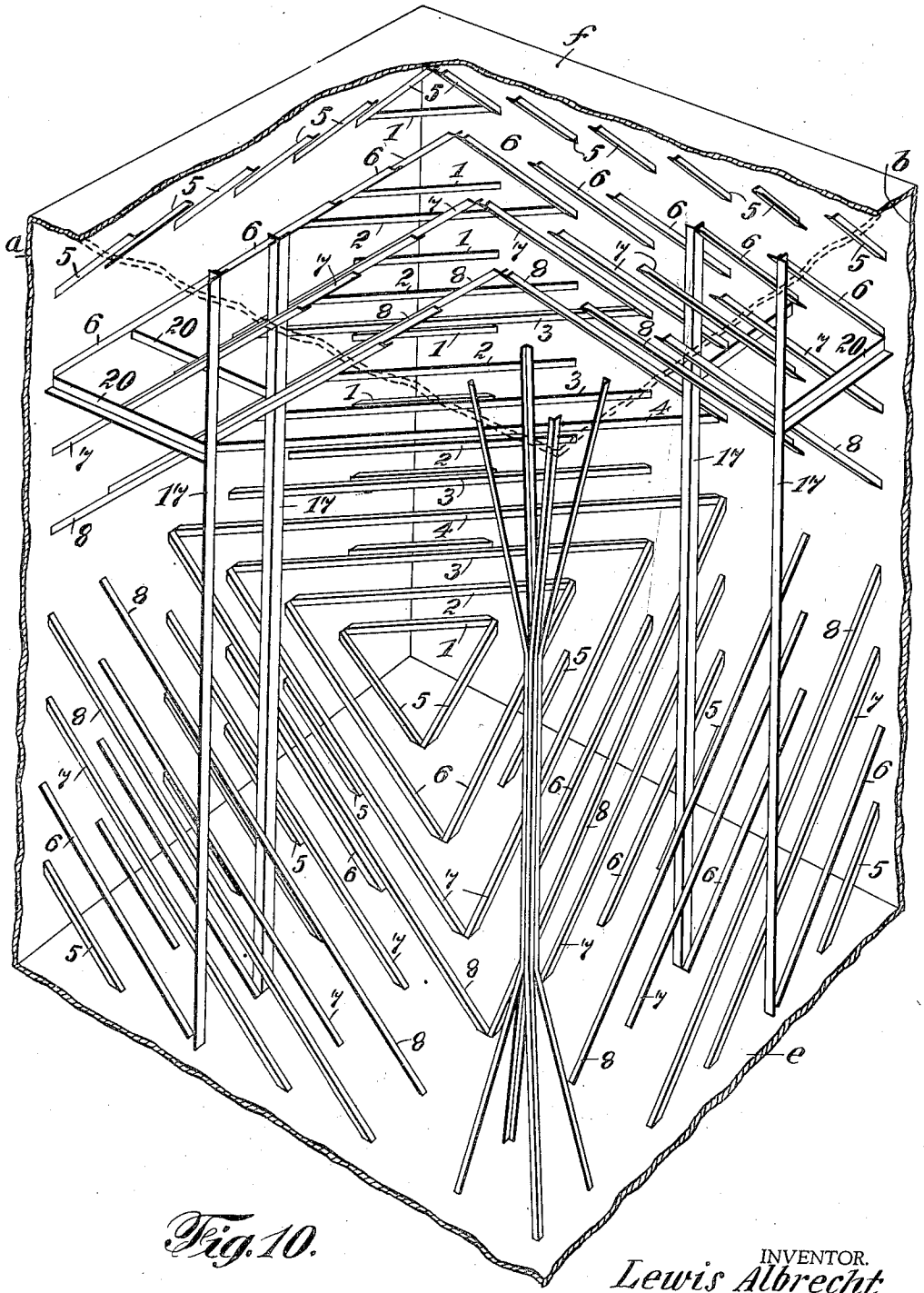

Fig. 10.

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UNITED STATES PATENT OFFICE

2,296,414

STORAGE TANK CONSTRUCTION

Lewis Albrecht, Mahwah, N. J.

Application May 26, 1938, Serial No. 210,176

12 Claims. (Cl. 220—71)

This invention relates to tanks employed for the storage of liquids or gases in large volume and having angular sides made of flat or curved plates as distinguished from circular or globular tanks. In the erection of such tanks it is the practice to locate them entirely above the ground level or to partly or wholly locate them underground in which case the tank walls may be subjected to both internal and external pressures.

In the construction of these tanks it is common practice to provide for the bracing of the side walls tie-rods which extend between opposite vertical walls and vertical struts between the top and bottom walls. These tie-rods and struts constitute point bracing and are usually spaced approximately two to two and one-half feet between centers horizontally and vertically resulting in a close net-work of rods, the open spaces between rod intersections being approximately two to two and one-half feet square throughout the tank. The reason for this close net-work or honeycomb of tie-rods and struts is to reduce the bending moment of the wall plates between points of bracing to safely withstand the internal and external pressures. It is necessary in order to obtain the proper bracing effect to secure these rods and struts to the tank walls and to each other at all points of intersection, and it is the general practice to weld these rods and struts at both ends to the wall plates and to each other at all points of intersection. There are variations of this bracing method, but all are based on the principle of tying opposite walls to each other to resist lateral pressure. This system requires not only a very large number of tie-rods and struts running into very large weight and footage, but requires that all of these rods and struts must be cut to correct length at the time of placing same in position for welding owing to variations in the plane surface of the wall plates. Thus it will readily be seen that owing to the large number of tie-rods and struts and consequent large linear footage and weight, the very large number of welds, and the confined space in which the operations of cutting, fitting and welding are performed and consequent slow progress, the cost becomes exceedingly high.

Heretofore, in designing these large tanks and calculating the stresses, the shell and its bracing members have been treated as two separate units in which the bracing members were calculated to counteract the pressure on the shell plates, and the shell plates were calculated to resist the bending action between the points of bracing.

I have discovered that in order to obtain the greatest safety in the construction of such tanks and reduce the bending moment of the shell plates, the stresses in the bracing members and shell plates should equalize or balance each other or become compensating stresses, and that to obtain this condition the shell and bracing must be treated as a single unit in calculating the distribution of stresses, and therefore the shell plates must be made to serve as braces for the lateral pressures thereby utilizing all the component parts of the tank to the fullest extent in resisting the pressure on the shell plates. I have found by calculating the stresses in this manner that a very considerable reduction in the amount and weight of bracing required for tanks of the type under consideration is obtainable. In this connection it will be understood of course that in tanks of greater height than width, vertical pressure is substituted for lateral pressure in calculating the stresses.

Applying the theorem of combined tension and bending, the direct tensile stress in the shell plates due to the reaction of the balanced transverse pressure load reduces the bending moments of the shell plates in the area between the braced points since the direct tensile stresses become compensating stresses. The combined direct tensile stress and stresses due to bending of the plates in the areas between the braced points correspond closely with the bending stresses in this area in the absence of applied tensile stress, and, therefore, the shell plates can carry the additional load due to lateral pressure, and consequently the need for separate members to counteract this pressure, as in the conventional bracing methods now in use, is avoided.

One object of my invention is to produce a tank in which all component parts are utilized to their fullest stress-bearing capacity by so arranging the tank bracing that internal and external pressures on the tank walls are transmitted to bracing members which react on adjacent shell plates creating stresses normal to the bending moment thereof, and thereby obtain a balancing or equalizing of the stresses in all directions, and which results in a very considerable reduction in the bending stresses of the plates between the braced points and thereby enabling the shell plates to act as braces to the lateral pressure load.

A further object of my invention is to reduce the weight and amount of steel required per gallon capacity of the tank without reducing its strength. A further object in addition to reducing the cost of steel is to reduce the cost of

erection by simplifying the method of construction. A further object is to so arrange the internal bracing of the walls that lateral pressure at one section is balanced by similar pressure on adjacent sections thereby permitting a very large reduction in the linear feet of bracing members within the tank and incidentally increasing the storage capacity of the tank. And a further object is to arrange the bracing in such manner as will afford far greater facility for the performance of the work in erecting the tank, and greater freedom of movement within the tank during its erection, thereby reducing the cost of operations, and finally affording greater freedom of movement within the tank for removing sludge and cleaning of the interior of the tank after it has been in use.

In carrying my invention into effect, I dispense with the usual net-work or honeycomb arrangement of cross-bracing involving horizontal tie-rods and vertical struts equally spaced throughout the entire tank, and employ instead oblique braces or struts at all angles of the tank which with the shell plates form the sides of triangular trusses, the effect of which is to balance the pressures on adjacent plates against each other and cause the plates to serve as braces, and whereby the pressures normal to the plates produce tensile stresses in the oblique braces and adjacent shell plates, resulting in equalizing or compensating stresses in all directions, and thereby reducing the bending moments of the shell plates between braced points and enabling the tank walls to resist the combined stresses without increase in thickness. For supporting the central part of the tank roof other than the area supported and braced by the oblique struts, vertical skeleton columns formed of angle bars are employed.

By this means the total length of bracing members and roof sustaining supports is greatly reduced; the cost and time consumed in preparing the bracing members for welding, which at present is done entirely at the time and place of erection of the tank, is practically eliminated; and the number of welds is also greatly reduced. The employment of oblique braces at the tank angles permits cutting the braces at the mill, instead of at the time and place of erection, to the required length and with the necessary miter to fit into the angles of the tank, and requires no separate or exact fitting to the tank angles since any slight variations in length or alignment does not substantially affect the stress values, and no alterations in length is required to compensate for variations in the plane surfaces of the shell plates. By employing the oblique braces at the tank angles and the columns for supporting the roof, instead of individual bars, lateral cross-bracing and ties for the roof supports is dispensed with. The roof supporting columns may be fabricated at a mill, thereby reducing the time and cost of erection of the roof supports. By my improved method of construction and erection the amount of steel required is greatly reduced and the large number of welds at the intersections of tie-rods as in the honeycomb arrangement is eliminated.

My invention is illustrated in the accompanying drawings in which,

Figure 1 is a vertical cross-section of a closed rectangular tank taken on the line 1—1 of Figure 2.

Figure 2 a plan view and horizontal cross-section on the line 2—2 of Figure 1.

Figure 3 a central vertical cross-section showing additional bracing members.

Figure 4 an enlarged vertical sectional view looking into a corner of the tank illustrated in Figure 3.

Figure 5 an enlarged sectional and plan view of a corner of the tank.

Figure 6 a vertical section of one end of a tank showing additional bracing members and a preferred form of supporting skeleton column for the mid-section of the roof.

Figure 7 a central cross-section on the line 7—7 of Figure 6.

Figure 8 a diagrammatic view illustrating a longitudinal vertical section of a tank having a modification of the roof supporting column shown in Figures 6 and 7.

Figure 8—A a vertical cross-section on the line 8A—8A of Figure 8;

Figure 9 is a diagrammatic view illustrating the application of the triangular truss bracing to a flat sided tank having acute and obtuse angled corners and an interior partition; and

Figure 10 is a perspective view of a corner of the tank, with parts broken away to reveal the interior construction and the relations of various bracing members to tank walls and to each other.

Referring to the drawings, and more particularly to Figures 1 and 2, the tank is illustrated in the plan view Figure 2 as approximately ninety feet square, the vertical walls being designated by the letters *a*, *b*, *c* and *d*; the bottom by the letter *e*; the top or roof by the letter *f*; and the side walls as illustrated in Figure 1 representing approximately a height of eighteen feet.

In the vertical angles or corners of the tank as seen in Figure 2, are provided a series of horizontally disposed angle braces. These braces start with a row of short braces 1 in each corner beginning two feet above and parallel to the bottom *e* and contacting the adjacent side walls two feet from the corner, and each brace forming the hypothenuse of a right triangle formed with the respective adjacent sides *a*—*b*, *b*—*c*, *c*—*d* and *d*—*a*. As these braces are spaced two feet apart, there will be in the illustration given, a row of eight such braces in each corner, and each brace will be approximately 2.8 feet in length. Beginning at the second brace 1 from the bottom, a second row of six diagonal braces 2, each approximately 5.6 feet in length, are placed in each corner, each brace being in the same horizontal plane with and parallel to and two feet distant from an adjacent brace 1, and each likewise forming the hypothenuse of a right triangle whose sides *a*—*b*, *b*—*c*, *c*—*d* and *d*—*a* are four feet in length, and the uppermost brace of this row being on the same plane as the second brace 1 from the top. Beginning on a level with the third brace 1 from the bottom and ending with the third from the top is a third row of four similar braces 3 approximately 8.4 feet in length each in the same horizontal plane with and parallel to and two feet distant from and adjacent brace 2, and similarly forming the hypothenuses of the right triangles whose sides *a*—*b*, *b*—*c*, *c*—*d* and *d*—*a* are six feet in length. On a level with the fourth and fifth braces 1, that is midway of the height of the tank as illustrated, are two similar braces 4 approximately 11.2 feet in length, each in the same horizontal plane with and parallel to and two feet distant from an adjacent brace 3, and forming the hypothenuses of the right triangles whose sides *a*—*b*, *b*—*c*, *c*—*d* and *d*—*a* are eight

feet in length. Thus in each vertical corner of the tank there is a series of braces starting two feet from the bottom comprising one short horizontal brace 1, then two braces 1 and 2 in the horizontal plane on the four foot level, then three braces 1, 2 and 3 in the horizontal plane on the six foot level, then four braces 1, 2, 3 and 4 each in the horizontal planes on the eight and ten foot levels, and then stepping back toward the top to three, two and one at the twelve, fourteen and sixteen foot levels, respectively. It will be understood that these braces are all welded in position as the plates for walls *a*, *b*, *c* and *d* are erected from the bottom *e*.

At the base of the tank in the horizontal angles formed by the bottom *e* and the side walls are erected a series of oblique braces 5, 6, 7 and 8, disposed in parallel vertical lines that are two feet apart, see Figure 1. These braces are similar to the tiers of corner braces 1, 2, 3 and 4, and begin with a row of parallel short braces 5 starting at the lower short horizontal corner brace 1 at one end of a side wall and continuing to the corresponding short brace 1 at the other end of the same wall. Similarly the second row of parallel oblique braces 6 begins at the first horizontal corner brace 2 at one end of same side wall, and continues to the corresponding horizontal corner brace 2 at the other end of that wall. The third row of parallel oblique braces 7 begins at the first horizontal corner brace 3 at one end of the same side wall, and continues to the corresponding horizontal corner brace 3 at the other end of the same wall. The fourth row of parallel oblique braces 8 begins at the first horizontal corner brace 4 at one end of the same side wall and continues to the corresponding horizontal corner brace 4 at the other end of that wall. Braces 5, 6, 7 and 8 of each tier of such are all spaced two feet apart, and are of the same respective lengths, the first row of short braces 5 being approximately 2.8 feet, the second row of braces 6 being 5.6 feet, the third row of braces 7 being 8.4 feet, and the fourth row of braces 8 being 11.2 feet in length. Thus, when the walls *a*, *b*, *c* and *d* reach a height of eight feet or more, there will be at each of the walls a complete line or row of tiers of oblique braces 5, 6, 7 and 8, the four bracketed sections 9, 10, 11 and 12 in the plan view of Figure 2 having the row of tiers of parallel braces throughout and extending to a height of eight feet from the bottom *e*, or as indicated in Figure 1, to the point on the section line 2—2; and the four vertical corners of the tank will have respectively a row of tiers of diagonal corner braces stepped up from 1 to 4 to the same level as the points of contact of braces 8 as seen in Figure 2 and in Figure 1 at the section line 2—2. In the aisles between the tiers of braces connecting adjacent vertical and horizontal walls, workmen may move freely.

It may here be noted that when the braces in the vertical corners of the tank and the braces at the horizontal angles of the tank above described are welded in place up to the eight foot level, the first three short braces 1—5—5 form a small triangular truss in a corner of the tank in an oblique plane, and that braces 1 between the adjacent side walls and braces 5 between an adjacent side wall and bottom each form triangular trusses but in three different planes. Similarly the three next longer braces 2—6—6 form larger triangular trusses in the corner, and the next longer braces 3—7—7 form still larger triangular trusses, and the longest braces 4—8—8 form still larger triangular trusses. These four triangular trusses all lie in a plane oblique to the side walls and bottom of the tank, and each of the individual braces 1 to 8 form with the plates of the side walls or the side wall and bottom similar triangular trusses in horizontal and vertical planes of which the wall plates form two sides of the triangle and the individual brace the third side; and in the horizontal and vertical planes at the tank angles in which two or more braces are arranged in the same plane there will be formed two or more triangular trusses, one within the other, two sides of which are formed by the plates and the third sides by the braces. It will be observed that with the arrangement of four tiers and rows of diagonal and oblique braces as above described the tank walls and bottom are trussed to each other at points spaced two feet between centers, each brace with the side walls at the corners, and each brace with the side walls and bottom forming a series of triangular trusses which resist or absorb the pressures and stresses in all directions, and that the stresses of the wall plates due to the bending moment of the plates between braced points caused by pressure normal to the plates react on adjacent plates whereby the plates are caused to act as braces, resulting in compensating or balancing stresses in all directions in the wall plates and braces.

When the side walls and bracing have been erected to the mid-section of the tank as above described, the roof supporting columns 13, Figure 2, may be placed in position. As illustrated more in detail in Figures 3, 4 and 5, the roof supports 13 comprise skeleton columns made of four vertical L-bars 14, spaced to form square columns approximately two feet wide, and trussed with oblique bars 15 and horizontal bars 16 in three panels from the base upward, and the upper section as seen in Figures 3 and 4 being without bracing. The columns are set on the base or floor plates so that the columns will be spaced throughout approximately two feet apart in parallel rows, thus providing roof supports spaced approximately on two foot centers throughout the mid-section, and the area between this section and the side walls will be supported by oblique braces 5, 6, 7 and 8 on two foot centers, so that the entire roof will be supported at equidistant points approximately two feet apart when the upper rows of oblique braces are in position. With this method of supporting the roof no lateral bracing or tie-rods are required for the vertical roof supports.

At this point it may be noted that all welding of the oblique braces is performed as the work proceeds upward from the base *e*, and that the work is done under conditions which permit the greatest freedom of movement of the welders, since there is always ample space and full height of head-room to move about between the braces and columns, and that therefore the work of erecting plates, braces and columns and welding may be done without loss of time and without the undue tiring of the operatives which occurs when operating in the cramped positions in erecting tanks with the honeycomb type of bracing. When the columns 13 are in position the cross-bars 16 and the oblique braces serve as supports for scaffolding from which further operations in erecting the upper half of the tank are conducted with the same degree of freedom of movement and head-room as in bringing the work up from the base to the eight or ten foot level as above described.

From this point on the erection of wall plates and corner braces 1, 2, 3 and 4 is continued as above described, except that the corner braces taper off from four braces to the single short brace 1 at a point two feet below the roof line. When the erection of wall plates reaches the roof line, the laying and welding of roof plates is started from the side walls and corners inward toward the center, temporary supports being provided until a series of supporting oblique braces similar to the series of vertically disposed oblique braces 5, 6, 7 and 8 at the bottom of the tank are in place.

The placement of the upper oblique roof supporting braces is started with the short braces 5 beginning at the uppermost short horizontal corner brace 1, and is continued along the side walls in the same manner as the placement of the lower series of braces 5. When the row of roof braces 5 are in position, the second row of braces 6 are placed in position beginning at the uppermost horizontal corner brace 2; then the third row of braces 7 are placed in position beginning at the uppermost horizontal corner brace 3, and finally the last row of braces 8 are placed in position beginning at the uppermost horizontal corner brace 4. This procedure is followed on all sides of the tank thereby providing a roofing section supported by rows of tiers of oblique braces on the four sides of the tank eight or more feet in width, according to the size of plates employed.

When the upper oblique roof braces and the first section of roof plates are in position there will be formed in each roof corner a series of four triangular trusses 1—5—5, 2—6—6, 3—7—7 and 4—8—8 in oblique planes similar to those at the bottom corners, and each brace forming with the plates triangular trusses in the horizontal and vertical planes as above described, and the roof section extending along the sides of the tank will be supported by the oblique braces 5, 6, 7 and 8 at points spaced two feet apart.

It will be noted that the roof braces 5, 6, 7 and 8 form with the side walls and roof plates, a series of triangular trusses, which with the triangular trusses at the four corners, not only serve to support the roof plates, but also serve to compensate or balance the stresses in all directions at the upper half of the tank in the same manner as above described in connection with the bracing of the lower half of the tank, and that the mid-section of the roof plates will be sustained by the series of columns 13.

After the first section of roof plates supported by the braces 5, 6, 7 and 8 are laid and welded, the rest of the roof plates are laid on the columns 13 and welded thereto. This work as above noted will be performed from the scaffolding laid on the cross-bar 16 of the columns and the oblique braces, and it will be seen that the welding of the roof plates to the columns may be done with complete freedom of movement between the two foot spacing of column bars 14 and full head-room since there are no horizontal tie-bars or struts to impede the work. In the old honeycomb arrangement of tie-rods this final stage of the work becomes quite difficult, and since these rods must all be spaced, both vertically and horizontally, approximately two feet apart, the final operation of welding vertical struts to the roof plates becomes extremely difficult and slow.

As the roof plates are laid inward toward the center, one or more open spaces or manholes are provided between the columns for entrance into the tank, and at those points a ladder or rungs may be provided between the columns for descent to the tank bottom.

In Figures 3 and 4 are shown additional struts or bracing members for increasing the load carrying capacity of the oblique braces 5, 6, 7 and 8; also for tanks of greater height; also to prevent buckling of the oblique braces, and for dividing the stresses due to lateral pressure and the roof load between the upper and lower triangular trusses to cause a greater compensating or balancing effect.

For this purpose a series of vertical struts 17 are welded between the centers of aligned upper and lower oblique braces 8 along all sides of the tank, and these struts are tied to each of the four aligned braces of a tier 5, 6, 7 and 8 by struts 18 which extend into and are welded to the horizontal upper and lower angles of the tank. In other words, each set of upper and lower aligned braces 5, 6, 7 and 8 at all sides of the tank are tied together and to the angle of the tank by struts 18 and the aligned upper and lower sets are tied together by vertical struts 17. At the mid-section the vertical struts 17 may be tied to the side walls by oblique struts 20 for balancing the pressure at a wall having a section which is not balanced by the oblique braces 5 to 8. This would occur where the dimensions of the tank are such that the oblique braces of the upper and lower halves of the tank do not reach the mid-section of the side walls. In such cases the mid-sections of the side walls are braced by the oblique struts 20. These struts also serve to prevent buckling of the vertical struts 17 and serve to transmit stresses to the wall plates.

In Figures 6 and 7 is illustrated a modification of the system of bracing and roof support shown in Figures 3 and 4. In this arrangement the bracing at the angles of the tank walls is similar to the plan of Figures 1 to 5 except, to illustrate a variation for a tank of different dimensions, three diagonal braces 1—2—3 and oblique braces 5—6—7 are shown to form the triangular trusses. A series of vertical L-bar struts 21 similar to struts 17 in Figure 3 are provided, but in this arrangement, instead of the struts being joined between the mid-sections of the last row of oblique braces, they extend the full height of the tank and are positioned at the intermediate oblique braces 6 and welded at the ends of such braces where those braces are welded to the top plates *f* and bottom plates *e*, Figure 6, and the struts 21 are also welded to the oblique braces 7 at the points of intersection 22. Also in the arrangement of Figure 6, instead of employing the oblique struts 20 as in Figure 3, two longer oblique struts 23 are connected between the middle of strut 21 and the bearing points of upper and lower braces 6 at the side walls, and which struts 23 are welded to upper and lower braces 7 at the intersecting points 24. Thus with this arrangement in addition to the triangular truss system for the walls an additional system of bracing for the side walls and for supporting the roof is provided. To prevent lateral bowing of the vertical struts 21 they are tied together at the mid-section by flat bar ties 25 which are welded to the outer flanges of L-bars 21.

Instead of the form of skeleton column for supporting the roof plates as shown in Figures 3–5, I prefer the novel design of skeleton column formed of L-bars as shown in Figures 6 and 7, which for the usual height of tanks, is the most economical. In this arrangement four L-bars 26 are bent at the mid-section as seen at 27 in Fig-

ure 6 to make the same self-bracing against lateral deflection. These bars are welded together at the flanges, edge to edge at the bend **27**, forming a hollow square section at the joint as seen at **28** in Figure 7. At one or more points according to the height of the column between the joint **27—28** and the upper and lower ends of the bars **26**, a pair of L-bar ties **29** are welded diagonally between and to the inside of the legs of the column to prevent deflection in the direction of least radius of gyration. The bars **26** forming the legs of the column will have approximately a two foot spread at the base and top, and the spacing between columns when placed in position will be approximately two feet so that the roof will be supported at points approximately two feet apart in each direction. It will be observed that with this form of column still greater room for movement between columns will be afforded, the space between columns at the mid-section **27** being approximately twice the space at the base and top.

For the roof supports instead of the arrangement of skeleton columns having four legs **26** as shown in Figures 6 and 7 supports consisting of a pair of legs **30** may be provided as shown in Figures 8 and 8A. This arrangement is suitable for tanks of less height and for use in combination with skeleton columns shown in Figures 6 and 7 where the dimensions of the tank will not admit four-leg columns throughout. In such case the two-leg columns would be employed to support the roof sections at such points where the space will not permit the use of the four-leg column. In Figures 8 and 8A the two L-bars forming the supporting column are bent at the mid-section to bring two flat sections together for welding as indicated at **31** in Figure 8A, or the bend may be such as to bring the apex of the angles together to form an X in cross-section, or the bend may be such as to form a hollow square as in Figure 7. Each row of such supports will be tied together by longitudinal L-bars **32** welded to the supports at the joint **31**. In addition to the longitudinal tie-bars **32** in some cases each row of two-leg columns **30** may have additional bracing by means of oblique crossed struts **33** between two columns at each end of a row of such columns as seen in Figure 8. These struts **33** may be of any given length but preferably extend from the ends of the legs to the point at which the longitudinal tie-rod extends across the row of legs and are welded at the ends to the legs **30** and to each other where they cross. This bracing consisting of the longitudinal tie **32** and the two crossed struts **33** secures the legs **30** of each row together and prevents lateral deflection.

In Figure 9 is shown diagrammatically an illustration of a narrow tank having sides *a*, *b*, *c* and *d*, the side *a* being short and presenting with sides *b* and *d* right-angled corners, and side *c* being longer than side *a* presenting with sides *b* and *d*, respectively, acute and obtuse angled corners. The arrangement of vertical corner bracing in the right-angled corners of the tank is similar to the arrangement shown in Figures 1 and 2, except that in this illustration three tiers of horizontally disposed diagonal braces **1**, **2** and **3** and three rows of vertically disposed oblique braces **5**, **6** and **7** are shown. The number of tiers and rows of these braces, however, may be varied to suit specific requirements. At the corner of the tank having the acute angle four horizontally disposed oblique corner braces **1**, **2**, **3** and **4** are arranged in parallel tiers similar to the arrangement of Figures 1 and 2, except that the lengths vary according to the degree of the angle. The vertically disposed oblique braces in this corner, likewise, vary in length with shorter braces **5a** at the corner, but the arrangement of triangular trusses is similar to and effect the same result as the arrangement in Figures 1 and 2. At the corner of the tank having the obtuse angle there will be two tiers of horizontally disposed oblique braces **1** and **2** which will be of a length to extend between pairs of vertically disposed oblique braces **5** and **7** at the horizontal angles and welded to the adjacent side walls to form triangular trusses.

The supports for the mid-section of the roof in the shape of tank illustrated in Figure 9 may be of either form illustrated in Figures 3 and 6, except that, owing to the width of the tank, it may be necessary or desirable to provide a pair of vertical struts **34** which will be cross-braced by bars similar to bars **15** and **16** in Figure 3, or by bars similar to bars **29** in Figure 6 when the columns are formed by a pair of legs bent and welded together at the middle as in Figure 8A, and such pair of struts may be tied to an adjacent column by ties **35**. At the end of the tank having the acute and obtuse angles a single vertical strut **36** is provided to afford the necessary point of roof support in the angle, and such strut will be tied to the adjacent column by ties **37**.

Where tanks are required to be divided into several compartments by partitions, each partition may be braced from either or both sides by horizontally and vertically disposed oblique braces in the same manner as the outer walls, and where applied to both sides of the partition, a plan view of the arrangement would be as indicated at the central part of Figure 9.

It will be understood that by reason of the compensating or balancing stresses effected by the method of bracing shown and described, and consequent reduction of the bending moments of the wall plates, the weight of bracing members may be considerably reduced. Also it will be seen that by this method of bracing, fewer bracing members may be employed for wall plates of given thickness. Also it will be seen that as a result of the use of oblique bracing the miter point of contact with the wall plates increases the contact and welded area of the brace on the plate and decreases the space between the braced points as compared to the honeycomb arrangement of cross-ties, and consequently decreases the bending moment of the plates between the braced points, and hence wider spacing between braces is permissible for given lateral pressures. It will also be understood that the number and arrangement of the oblique braces and extra bracing struts therefor will vary with the size and height of a tank, the essential point being the provision of the triangular trusses whereby the wall plates become part of the bracing system.

While the spacing of the diagonal and oblique braces is illustrated and described as being uniform, it will be understood that the spacing may be reduced progressively downward to the lower part of the tank to maintain uniform stress values owing to progressive downward variation in static pressure. Such variation cannot readily be accomplished with the conventional honeycomb type of bracing because it would be very difficult, if not impossible or impracticable, to

work between the tie-rods to make the welded joints.

Specific vertical supporting columns between roof and floor, not claimed herein, are covered in my copending application Serial Number 455,189, filed August 18, 1942.

What I claim is:

1. A storage tank having flat side, top and bottom walls of metal plates, a plurality of vertically spaced tiers of braces at the angles of adjacent vertical walls, each tier comprising a plurality of substantially parallel horizontal equally spaced braces lying in a common plane, a plurality of substantially horizontally spaced rows of braces at the angles of adjacent vertical and horizontal walls, each row comprising a plurality of spaced inclined and parallel braces lying in a common vertical plane, and each of said braces forming with the adjacent walls a separate triangular truss, thereby causing the stresses in the bracing members and wall plates to become compensating stresses.

2. A storage tank having flat side, top and bottom walls of metal plates, a plurality of vertically spaced tiers of braces at the angles of adjacent vertical walls, each tier comprising a plurality of substantially parallel horizontal equally spaced braces lying in a common plane, a plurality of substantially horizontally spaced rows of braces at the angles of adjacent vertical and horizontal walls, each row comprising a plurality of spaced inclined and parallel braces lying in a common vertical plane, the vertical spacing of all said braces being reduced progressively downward to resist increase in static pressure and thereby maintain uniform stress values.

3. A storage tank having flat side, top and bottom walls of metal plates, a plurality of vertically spaced tiers of braces at the angles of adjacent vertical walls, each tier comprising a plurality of substantially parallel horizontal equally spaced braces lying in a common plane, a plurality of substantially horizontally spaced rows of braces at the angles of adjacent vertical and horizontal walls, each row comprising a plurality of spaced inclined and parallel braces lying in a common vertical plane, each of said braces forming with the adjacent walls a separate triangular truss in a horizontal or vertical plane, as the case may be, thereby causing the stresses in the bracing members and wall plates to become compensating stresses, some of said horizontal braces cooperating with some of said inclined braces to form a plurality of triangular trusses formed in oblique planes in the corners of the tank and connecting the walls forming each of the vertical corners with each other and with one of the horizontal walls.

4. A storage tank having a flat side, top and bottom walls of metal plates, a plurality of vertically spaced tiers of braces at the angles of adjacent vertical walls, each tier comprising a plurality of substantially parallel horizontally equally spaced braces lying in a common plane, a plurality of substantially horizontally spaced rows of braces at the angles of adjacent vertical and horizontal walls, each row comprising a plurality of spaced inclined and parallel braces lying in a common vertical plane, each of said braces forming with the adjacent walls a separate triangular truss, thereby causing the stresses in the bracing members and wall plates to become compensating stresses, and vertical struts between the top and bottom walls, certain of said vertical struts being located adjacent and secured to certain of the braces between adjacent vertical and horizontal walls.

5. A storage tank having flat side, top and bottom walls of metal plates, a plurality of vertically spaced tiers of braces at the angles of adjacent vertical walls, each tier comprising a plurality of substantially parallel horizontally equally spaced braces lying in a common plane, a plurality of substantially horizontally spaced rows of braces at the angles of adjacent vertical and horizontal walls, each row comprising a plurality of spaced inclined and parallel braces lying in a common vertical plane, each of said braces forming with the adjacent walls a separate triangular truss, thereby causing the stresses in the bracing members and wall plates to become compensating stresses, vertical struts between the top and bottom walls, certain of said vertical struts being located adjacent and secured to certain of the braces between adjacent vertical and horizontal walls, and oblique braces between and connecting said vertical struts and a side wall.

6. A storage tank having a flat side, top and bottom walls of metal plates, a plurality of vertically spaced tiers of braces at the angles of adjacent vertical walls, each tier comprising a plurality of substantially parallel horizontally equally spaced braces lying in a common plane, a plurality of substantially horizontally spaced rows of braces at the angles of adjacent vertical and horizontal walls, each row comprising a plurality of spaced inclined and parallel braces lying in a common vertical plane, each of said braces forming with the adjacent walls a separate triangular truss, thereby causing the stresses in the bracing members and wall plates to become compensating stresses, vertical struts between the top and bottom walls, certain of said vertical struts being located adjacent and secured to certain of the braces between adjacent vertical and horizontal walls, and struts tying certain of said last named braces together.

7. A closed tank structure comprising horizontally disposed top and bottom walls whose bounding edges define substantially congruent polygons and the corresponding edges of which lie in the same vertical planes, respectively; and a plurality of side walls, all lying in substantially vertical planes, each having top and bottom substantially horizontal edges, edge-joined to corresponding edges of the top and bottom walls, and having substantially vertical edges edge-joined to the corresponding vertical edges of adjacent vertical walls; each and every angle defined between adjacent edge-joined walls being subtended by a row of diagonal angle braces that connect them, individual braces of the row being regularly spaced apart and parallel to each other along substantially the full length of the common line of the two walls, and corresponding to each such row of angle braces a second row of the same, with individual braces spaced from each other as in the case of the first row, and with individual braces of the second row parallel to the corresponding braces of the braces of the first row and to each other, the second row being spaced away from the first row; substantially as for the purposes set forth.

8. A closed tank structure comprising horizontally disposed top and bottom walls whose bounding edges define substantially congruent polygons and the corresponding edges of which lie in the same vertical planes, respectively; and a plurality of side walls, all lying in substan-

tially vertical planes, each having top and bottom substantially horizontal edges, edge-joined to corresponding edges of the top and bottom walls, and having substantially vertical edges edge-joined to the corresponding vertical edges of adjacent vertical walls; each and every angle defined between adjacent edge-joined walls being subtended by a row of diagonal angle braces that connect them, individual braces of the row being regularly spaced apart and parallel to each other along substantially the full length of the common line of the two walls, and corresponding to each such row of angle braces a second row of the same, with individual braces spaced from each other as in the case of the first row, and with individual braces of the second row parallel to the corresponding braces of the braces of the first row and to each other, the second row being spaced away from the first row; and cross-braces tying together the alined braces of certain of the rows of braces that connect adjacent vertical and horizontal walls; substantially as and for the purposes set forth.

9. A closed tank structure comprising horizontally disposed top and bottom walls whose bounding edges define substantially congruent polygons and the corresponding edges of which lie in the same vertical planes, respectively; and a plurality of side walls, all lying in substantially vertical planes, each having top and bottom substantially horizontal edges, edge-joined to corresponding edges of the top and bottom walls, and having substantially vertical edges edge-joined to the corresponding vertical edges of adjacent vertical walls; each and every angle defined between adjacent edge-joined walls being subtended by a row of diagonal angle braces that connect them, individual braces of the row being regularly spaced apart and parallel to each other along substantially the full length of the common line of the two walls, and corresponding to each such row of angle braces a second row of the same, with individual braces spaced from each other as in the case of the first row, and with individual braces of the second row parallel to the corresponding braces of the braces of the first row and to each other, the second row being spaced away from the first row; and cross-braces tying together the alined braces of certain of the rows of braces that connect adjacent vertical and horizontal walls, and that also connect said last-named braces to the adjacent vertical wall; substantially as and for the purposes set forth.

10. A closed tank structure comprising horizontally disposed top and bottom walls whose bounding edges define substantially congruent polygons and the corresponding edges of which lie in the same vertical planes, respectively; and a plurality of side walls, all lying in substantially vertical planes, each having top and bottom substantially horizontal edges, edge-joined to corresponding edges of the top and bottom walls, and having substantially vertical edges edge-joined to the corresponding vertical edges of adjacent vertical walls; each and every angle defined between adjacent edge-joined walls being subtended by a row of diagonal angle braces that connect them, individual braces of the row being regularly spaced apart and parallel to each other along substantially the full length of the common line of the two walls, and corresponding to each such row of angle braces a second row of the same, with individual braces spaced from each other as in the case of the first row, and with individual braces of the second row parallel to the corresponding braces of the braces of the first row and to each other, the second row being spaced away from the first row; and cross-braces tying together the alined braces of certain of the rows of braces that connect adjacent vertical and horizontal walls, and that also connect said last-named braces to the said vertical and horizontal walls; substantially as and for the purposes set forth.

11. A closed tank structure comprising horizontally disposed top and bottom walls whose bounding edges define substantially congruent polygons and the corresponding edges of which lie in the same vertical planes, respectively; and a plurality of side walls, all lying in substantially vertical planes, each having top and bottom substantially horizontal edges, edge-joined to corresponding edges of the top and bottom walls, and having substantially vertical edges edge-joined to the corresponding vertical edges of adjacent vertical walls; each and every angle defined between adjacent edge-joined walls being subtended by a row of diagonal angle braces that connect them, individual braces of the row being regularly spaced apart and parallel to each other along substantially the full length of the common line of the two walls; individual braces between adjacent vertical walls being substantially horizontally disposed, and individual braces between each horizontal wall and each vertical wall to which it is edge-joined being oblique to both walls and lying in parallel vertical planes; at least one of the horizontally disposed braces having its ends connected to the adjacent horizontal wall, by means of oblique braces, running from said ends of the horizontal brace to said horizontal wall and substantially converging as they approach said horizontal wall.

12. A closed tank structure comprising horizontally disposed top and bottom walls whose bounding edges define substantially congruent polygons and the corresponding edges of which lie in the same vertical planes, respectively; and a plurality of side walls, all lying in substantially vertical planes, each having top and bottom substantially horizontal edges, edge-joined to corresponding edges of the top and bottom walls, and having substantially vertical edges edge-joined to the corresponding vertical edges of adjacent vertical walls; each and every angle defined between adjacent edge-joined walls being subtended by a row of diagonal angle braces that connect them, individual braces of the row being regularly spaced apart and parallel to each other along substantially the full length of the common line of the two walls, the spacing of the braces in the rows connecting adjacent vertical walls being progressively closer from top to bottom.

LEWIS ALBRECHT.

CERTIFICATE OF CORRECTION.

Patent No. 2,296,414. September 22, 1942.

LEWIS ALBRECHT.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 18, for "lines" read --planes--; page 6, first column, line 59, claim 4, and second column, line 24, claim 6, strike out "a" before "flat"; line 69, claim 7, after "as" insert --and--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 27th day of October, A. D. 1942.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)