Nov. 28, 1950 R. C. ULM 2,531,897

METHOD OF MAKING FLOATING ROOFS

Filed Oct. 21, 1949 5 Sheets-Sheet 1

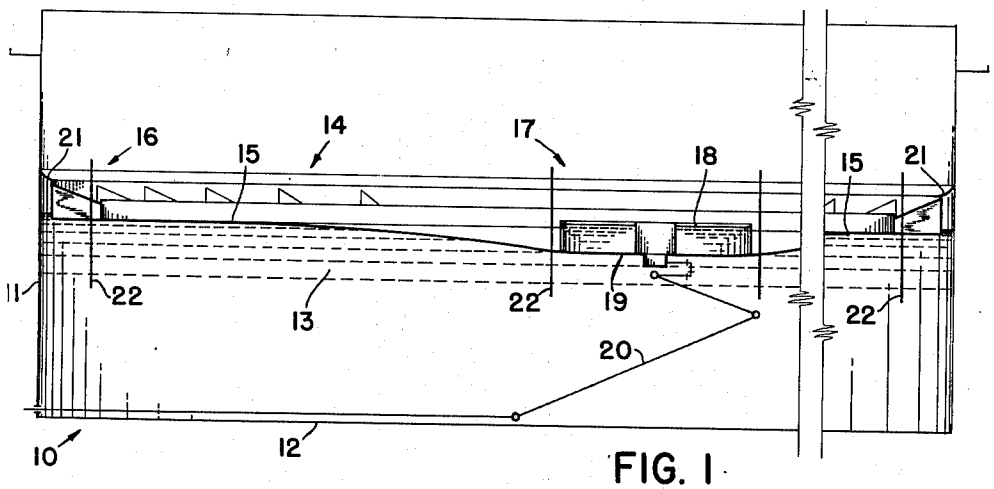
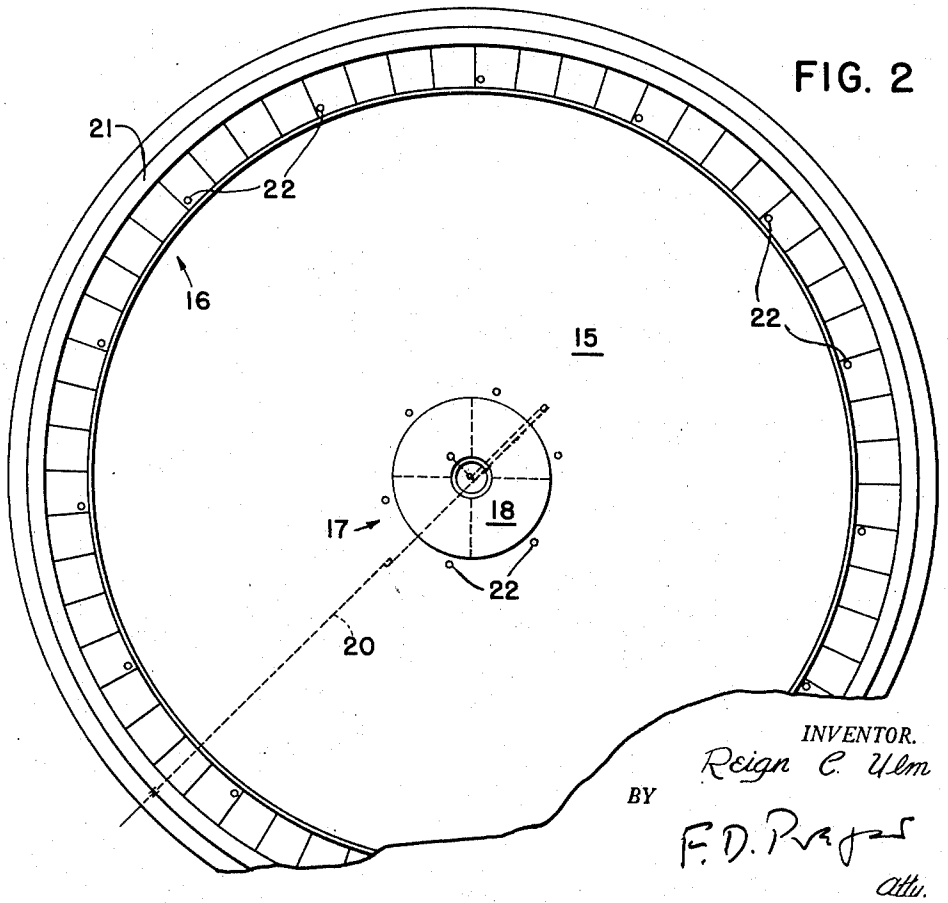


FIG. 1

FIG. 2



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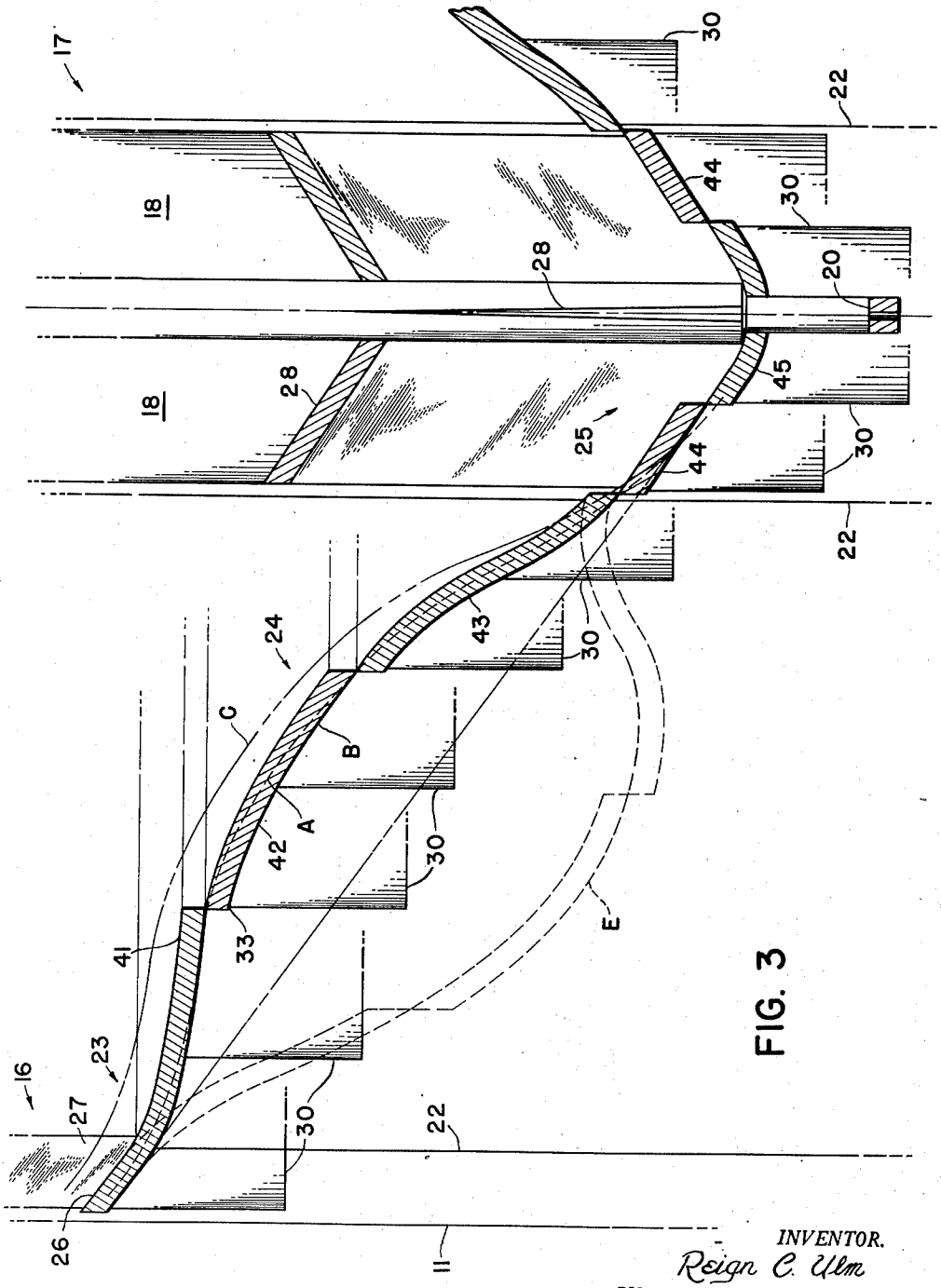


FIG. 3

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METHOD OF MAKING FLOATING ROOFS

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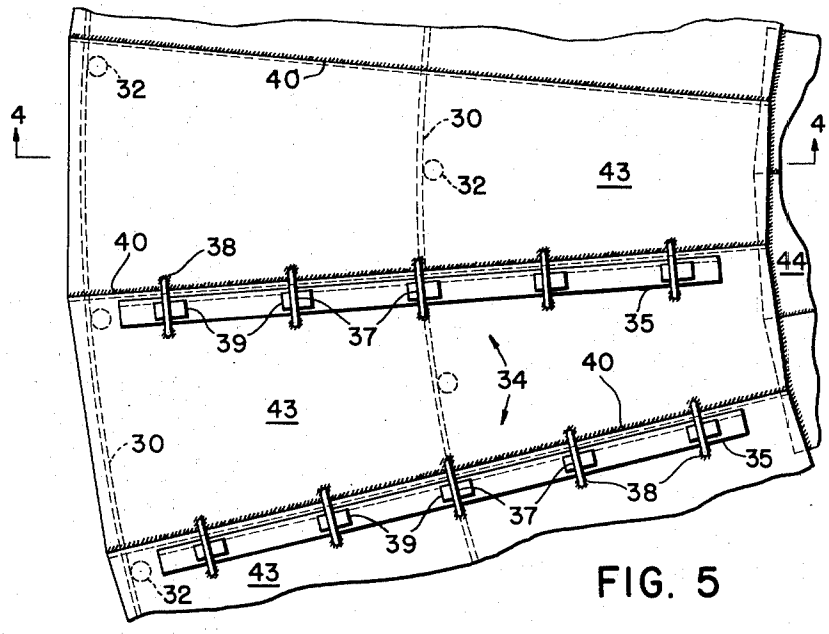


FIG. 5

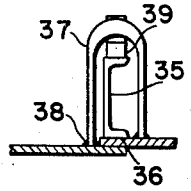


FIG. 7

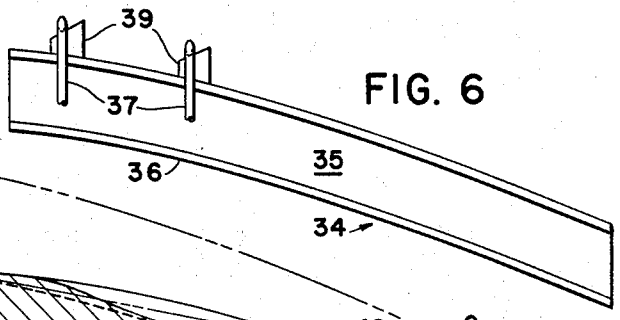


FIG. 6

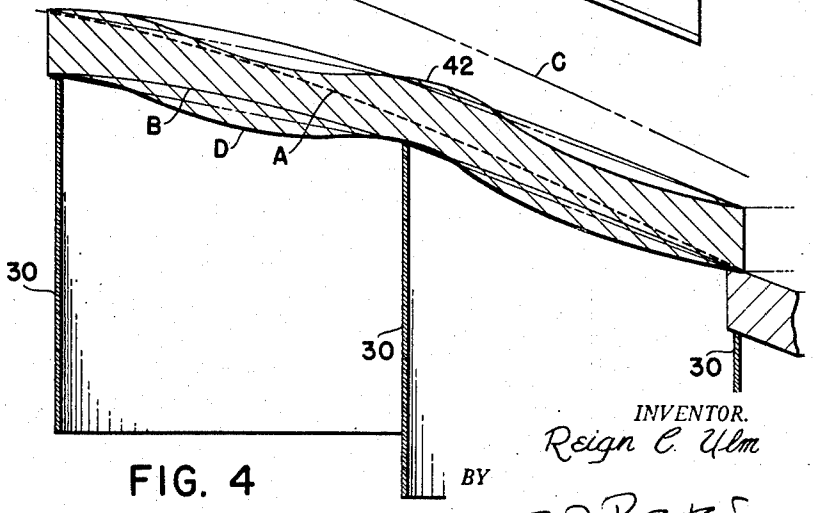


FIG. 4

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METHOD OF MAKING FLOATING ROOFS

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FIG. 9

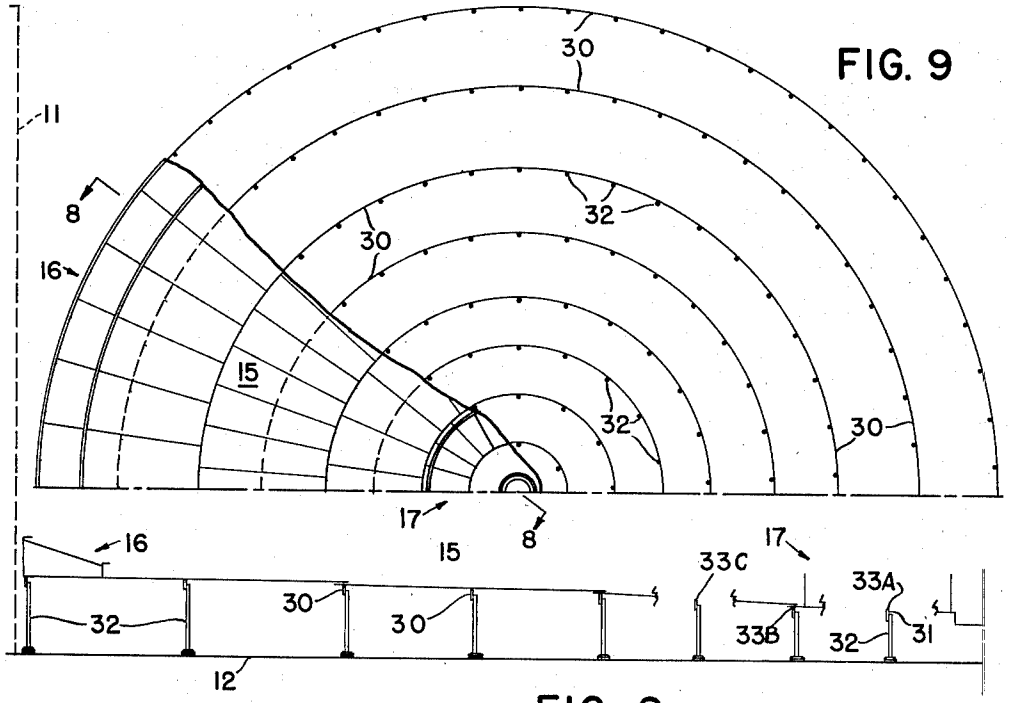
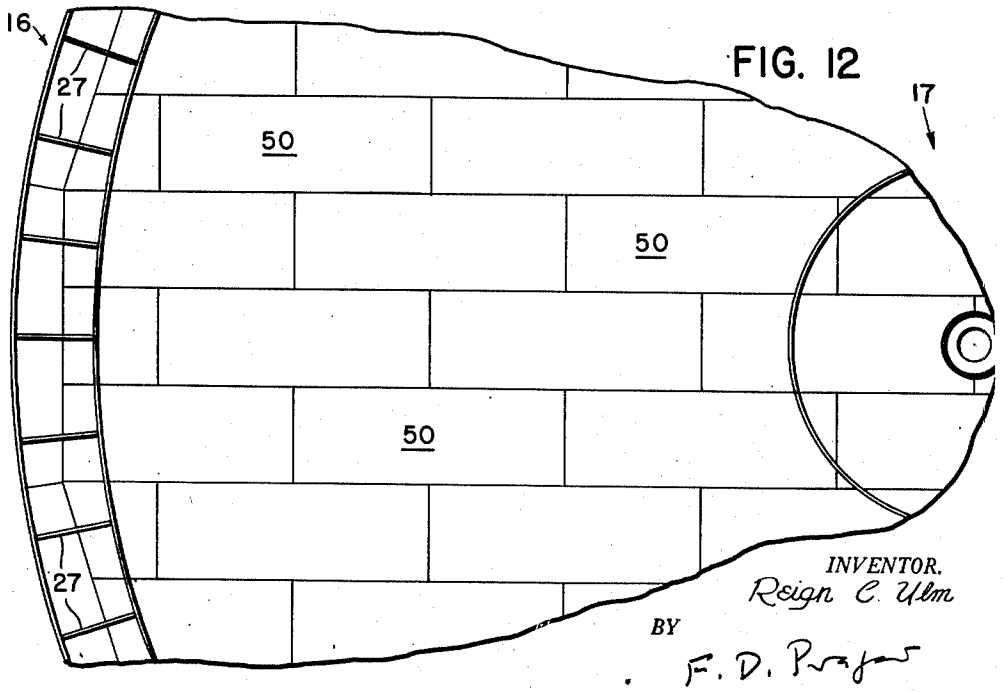


FIG. 8

FIG. 12



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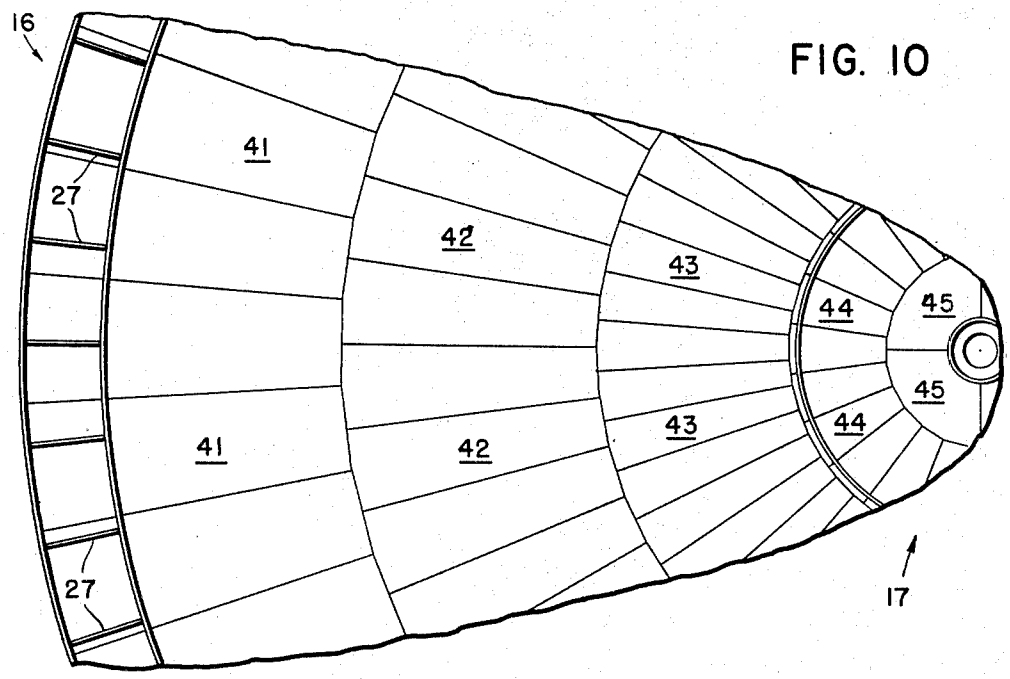


FIG. 10

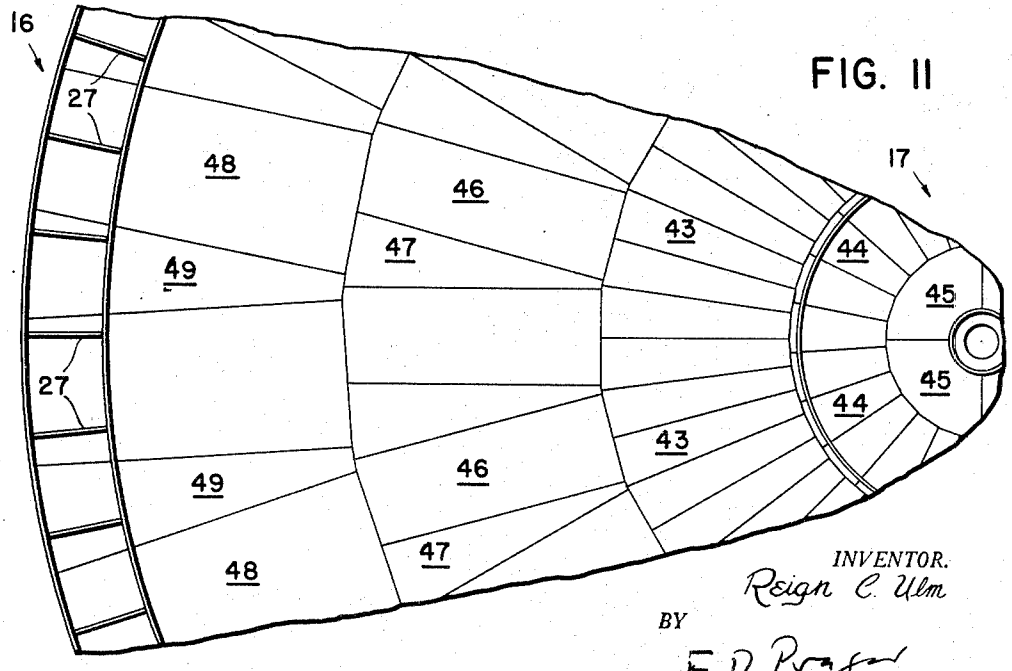


FIG. 11

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Patented Nov. 28, 1950

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UNITED STATES PATENT OFFICE

2,531,897

METHOD OF MAKING FLOATING ROOFS

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Application October 21, 1949, Serial No. 122,639

3 Claims. (Cl. 29—148.2)

1

This invention relates to floating roofs as used mainly for vapor conservation in the storage of gasoline and other volatile liquids. It provides greater efficiency in floating roofs, particularly of the single-deck type, and greater economy in methods of constructing such floating roofs.

Basically, a floating roof according to this invention is an improvement over the floating roof disclosed and claimed in the copending application Serial No. 67,187, filed by Frank D. Prager and myself on December 24, 1948, hereinafter called the Prager-Ulm roof, now patented under No. 2,497,047. The corrosion-resisting, self-draining shape of the Prager-Ulm roof is maintained more safely and more completely by means of the present invention.

This improvement is also applicable to other floating roof designs, for instance of the type disclosed and claimed in Patents 2,425,771 or 2,430,592 by John H. Wiggins, which may be called the Wiggins roofs with flexible deck between inner and outer pontoons. A corrosion resisting shape can be maintained in the flexible deck of such a Wiggins roof, by proper use of my improvement. This will not avoid the necessity of relatively frequent inspections and other maintenance operations, with such a Wiggins roof, due to problems connected mainly with the pontoon structures, but it will add to the useful service life of the flexible deck between the pontoons.

The preferred application of this improvement involves a Prager-Ulm roof of the so-called pan type, and the new invention will be described and explained as applied to this type of roof. The main part of such a roof, a substantially unreenforced, flexible, centrally weighted and centrally drained deck the underside of which contacts the liquid, is improved hereby, as to the safety, completeness and accuracy with which it maintains a certain corrosion-resisting, self-draining shape, in its various operating—that is, floating—conditions. This is achieved by the feature that the roof, as constructed and when not floating, has a deck with a particular contour in vertical cross-section, or a deck with a particular pattern of the joints and weld seams between the plates forming the deck surface, or a deck having a contour and also a pattern as mentioned.

The contour of such a deck, in vertical cross-section, is not the same, under different conditions, although the changes are seemingly small. The contour of the deck as originally constructed, hereinafter called the "construction curve," is influenced by the fact that the deck is shored up or

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supported, against its own weight, at distributed points or lines. The corresponding contour of the deck, when in floating condition, is different, being subject to different factors and forces. This latter contour, hereinafter called the "operating curve," is influenced by the fact that the deck tends to bulge or curve due to the pressure of the displaced liquid; the deck being weighted down locally, by the central ballast weight and the peripheral rim and seal. Strictly speaking, different operating curves exist under different operating conditions. For instance, a snow load on the roof affects this curve. Still another contour exists when the deck is not shored up and not supported by liquid; we can call it the "dry suspension curve." The change of contour of the deck, between these different curves, is allowed by the flexible, substantially unreenforced deck construction. However, I have discovered that it is desirable, and possible, to minimize this change, or the actual amount of flexing. For this purpose I form the construction curve so that it closely approaches the normal operating curve. For the same reason I prefer to eliminate irregularities by a certain seam pattern.

The pattern of weld seams between the plates is important for the safe and accurate maintenance of the corrosion-resisting, self-draining condition, since the forces acting upon the deck in its different operating conditions result in stresses which are largely channelled into and along these seams. The seams are the strongest part of the deck; they relate to the intermediate plate material somewhat like the ribs to the web of the leaf. I have found it most efficient to design the pattern of seams so as to emphasize the radial direction; mainly in the central part of the deck where maximum stresses are encountered. In other words, prefer to minimize the use of seams running at an angle to the radii. I mainly prefer to minimize, or eliminate, the use of seams running at different angles to the various radii. I have also found it desirable to use larger plates in outer parts and smaller plates in inner parts of the deck.

Both basic expedients—the special construction curve and the special seam pattern—aid in eliminating or at least minimizing the danger of local irregularities in the operating curves of the deck. Such a danger exists in certain other forms of flexible decks, as discovered when building and testing some of them. It is most important to minimize this danger. One of the principal advantages of the Prager-Ulm roof, aside from its general economy, resides in the fact that corro-

sion of upper or lower deck surfaces—a factor which has shortened the useful service life of floating roofs previously known—is counteracted. This is achieved by eliminating the depressions and bulges, which were formed in prior floating roof decks by and between the structural reenforcements which kept the center deeply immersed for central drainage. The advantage of the Prager-Ulm design is partly impaired, or in extreme cases entirely lost, if the flexible deck is allowed to develop a new kind of bulges and depressions due to excessive and/or irregular annular stresses and strains. Floating roofs of the prior art were centrally drained of most but not all of the rain water. The Prager-Ulm design eliminates residual pools, formed by the drainage-supporting truss work. The present improvement eliminates the danger of still other residual pools which might be formed by the elimination of said truss work.

This object is served by said special construction curve and seam pattern in the deck. More basically, this object is served by a new process of construction using greater accuracy than has been required or actually provided in the customary routines used for the construction of earlier types of floating roofs. I found that such accuracy can be provided with inexpensive tools, and without significant extra cost for material and labor; sometimes even with actual savings by proper tooling.

I will now describe the preferred construction curve, seam pattern, and construction method; also some modifications thereof. In view of the central importance of the construction curve, and of certain details thereof, it is important to give close attention to certain dimensions and proportions of the deck. The drawing discloses basic features in this respect, although no attempt has been made, of course, to present actual shop details.

Figure 1 is a cross-sectional elevation and Figure 2 a plan view of the preferred embodiment of the present invention. The floating roof tank represented in these figures will be assumed to be about 40 feet high and about 120 feet in diameter.

Figure 3 is a partial, cross-sectional elevation of the floating roof, on a scale larger than that of Figure 1 as to the horizontal dimensions and much larger as to the vertical dimensions; this distortion being necessary in order to disclose important features of the construction and operating curves. The approximate ratio of horizontal to vertical dimensions in this figure is somewhere in the vicinity of 1:50. The thickness of the deck plates is somewhat exaggerated, in order to avoid confusion between different lines.

Figure 4 is a detail from Figure 3, in a similar view but on a still larger scale in order to disclose certain features of the different curves more clearly. The ratio of horizontal and vertical scales is about the same as in Figure 3. Figure 5 is a plan view of the detail shown in Figure 4. The plane of Figure 4 is indicated by lines 4—4 in Figure 5.

Figure 6 is a diagrammatic elevation, in the plane of Figure 4, of special templates and other tools used in the new construction method; and Figure 7 is an end elevation of such tools. The curvature of the template is shown in Figure 6 on a scale similar to that of Figure 4; otherwise, the dimension in Figures 6 and 7 are undistorted.

Figure 8 is a partial, sectional elevation of other special means, preferably used in the present construction method, and Figure 9 is a partial plan view thereof. The scale of Figure 9 is approximately that of Figure 2; that of Figure 8 is about 2 times larger. The plane of Figure 8 is shown by lines 8—8 in Figure 9.

Figure 10 is a partial plan view of the deck, with a preferred pattern of seams. Figures 11 and 12 are similar views with modified patterns of seams.

The storage tank 10, with cylindrical shell 11 and circular bottom 12, contains the volatile liquid or product 13, often a sour crude, which is admitted and withdrawn through suitable openings and conduits (not shown). The top of the tank is open, eliminating the cost of a fixed roof with structural supports.

The floating roof 14, substantially unreenforced and flexible in accordance with the Prager-Ulm disclosure and thereby additionally contributing to the overall economy of the apparatus, floats on the surface of the product 13. It covers all but a minor, annular, peripheral area of this surface and protects the bulk of the volatile liquid from contact with the atmosphere and from the influence of the wind, thereby greatly reducing the tendency towards evaporation and vapor loss. A single-deck floating roof of the so-called pan type is used. In accordance with the Prager-Ulm disclosure it comprises a flexible deck 15, the entire underside of which is in contact with the product 13; a rigid, upstanding rim 16 around the periphery of the deck; and a large and heavy body 17 of ballast weight material 18 permanently installed upon, limited to and substantially distributed over an inner, concentric portion of the deck surface. The body 17 is heavier than the underlying, inner deck portion 19. It is higher than the slightly sloping deck, but it is also much wider than high. It is usually cylindrical, and installed above the underlying and surrounding deck surface.

A suitable drain 20 is connected to the center of the deck 15, to allow removal of rainwater from the roof surface. A seal 21 practically closes the annular space around the deck. When the tank is drained, for instance for the removal of sediment from the bottom, the deck is supported by legs 22 equally spaced along the rim portion 16, and sometimes by similar legs spaced around and adjacent the ballast weight 17.

The construction curve

Reference is made to Figure 16 of the Prager-Ulm drawing and particularly to the curve 63 which represents the contour of the deck in normal operating position. As pointed out in the pertinent specification the curve 63 is almost horizontal, but has at least some upward-outward direction everywhere; the inclination being sharper near the center of the deck than in the outer parts thereof.

The normal operating curve of the deck, as defined hereinabove, is presented by said line 63, for the deck of said earlier application. The same line substantially represents the normal operating curve of a deck in accordance herewith when assuming roofs of identical material, diameter and average slope.

It has been explained that said curve 63 represents a certain formula, expressing the interrelationship of certain values. These values can be defined as follows, for purposes hereof:

a—the inside radius of the flexible part 15 of the roof, which flexible part surrounds the inner

part 19 supporting the ballast weight 17 (in inches).

b—the height of the product, above the bottom of the rim 16 (in inches).

h—the overall depth of the roof, being the difference in elevation between the bottom of the rim 16 and the bottom of the weight 17 (in inches).

R—the radial distance from the center of the roof to the centroid of the rim section; that is, for practical purposes, to a point inwardly spaced from the extreme edge of the roof by ⅔ of the radial width of the rim section (in inches).

r—the radial distance from the center of the roof to the point to be analyzed as to deflection Z (in inches).

t—the thickness of the deck 15 (in inches).

T_a—the radial stress existing in normal operating condition at the outer end of *a* (in lbs. per square inch; being

$$\frac{WR}{2\pi tah}\Big)$$

W—the magnitude of the central ballast weight 17 (in pounds).

w—the unit weight of the product displayed by the roof (in lbs. per cubic inch).

w^1—the unit weight of the deck plate (in pounds per cubic inch).

The formula is as follows:

$$(1)\qquad Z=\frac{r^3(2w(h+b)-wh\frac{r}{R}-2w^1}{12taT_a}+C_1r+C_2$$

I have subsequently found that this formula is mathematically simplified by the elimination of the integrating factors C_1 and C_2, the separate calculation of which, according to previously known methods, was complicated and tedious. The formula can be further simplified by the assumption that the value *b* bears a constant relation to the value *h*; preferably

$$b=\frac{h}{10}$$

an assumption which I have found justified and which introduces no error of practical magnitude into the formula. On this basis the simplified formula reads:

(2)

$$Z=\frac{(A_1+B_1)e^{\gamma r}}{2}-\frac{(A_1-B_1)e^{-\gamma r}}{2}-\frac{1}{\gamma^2}\left(A_2r-B_2\left(\frac{2}{\gamma^2}-r^2\right)\right)$$

In this Formula 2 I am using values derived from the basic data *a*, *b*, *h*, R, *r*, *t*, T_a, W, *w* and w_1 as follows:

$$(3)\qquad \gamma=\left[\frac{w(R+a)}{2taT_a\sqrt{1+\left(\frac{h}{R}\right)^2}}\right]^{1/2}$$

$$(4)\qquad A_2=\frac{22w}{5tT_a}\left(\frac{h}{R}\right)-\frac{4w'}{T_aR}$$

$$(5)\qquad B_2=-\frac{4w}{tT_aR}\left(\frac{h}{R}\right)$$

$$(6)\qquad N_a=A_2a+B_2\left(\frac{2}{\gamma^2}+a^2\right)$$

$$(7)\qquad N_R=A_2R+B_2\left(\frac{2}{\gamma^2}+R^2\right)$$

$$(8)\qquad N=\frac{1}{2}(e^{\gamma a}e^{-\gamma R}-e^{-\gamma a}e^{\gamma R})$$

$$(9)\qquad A_1-B_1=\frac{N_ae^{\gamma R}-N_Re^{-\gamma a}}{N\gamma^2}$$

$$(10)\qquad A_1+B_1=\frac{N_ae^{-\gamma R}-N_Re^{-\gamma a}}{N\gamma^2}$$

The letter *e* of course denotes the basis of natural logarithms.

The Formulas 3 to 10 must be solved before the solution of Formula 2 can be undertaken. This will be found considerably simpler than the conventional solution of Formula 1.

By either Formula 1 or 2 the operating shape of a deck in accordance herewith is substantially predetermined. This shape is approximated, as mentioned, by the "construction curve" in accordance herewith, in order to minimize the actual values of deflection Z. By this expedient I also minimize the actual values of radial elongation or strain in the plate material. This again minimizes the peripheral strain, and the peripheral stresses connected therewith. In this manner I minimize peripheral compression forces in the body of the deck, which would otherwise tend to produce radial bulges or wrinkles.

The theoretical shape of this construction curve, for deck 15, is shown by line A in Figure 3 hereof. This line approximately coincides with said line 63 when plotted to the same scale. It is theoretical insofar as it disregards the sudden steps due to the lapwelds between the plates. Of course, as mentioned initially, the figure exaggerates the thickness of the plates and therefore the magnitude of the sudden steps. Nevertheless these steps have actually appreciable magnitude in proportion to the total rise of the line or curves. When reference is made to the construction curve, hereafter, the actual curve B is meant except if the context is different.

Lines A and B share the significant properties of line 63 in the earlier disclosure. They rise outwardly at least to some slight extent throughout the extent of the lines. The rise is such that the outer, annular part 23 of the deck surface is curved downwardly or concave to the top; in some instances, if the rim 16 and seal 21 are relatively light, the outer, annular part 23 may not be actually concave to the top, but it is never bulged upwards to the same degree as is the intermediate ring 24. (The innermost, circular part 19 of the floating roof can be considered as an integral part of the deck surface, in accordance herewith. Similarly the outermost, annular part 26 of the floating roof can be considered as an integral part of the deck surface. The original form of the Prager-Ulm roof was preferably based on the use of special, strong plate means 36, 37, 38, 39 and 41 for these innermost and outermost parts of the deck. I have discovered that this is unnecessary, and I prefer to use steel plates of identical thickness—usually $\frac{3}{16}$ inch—for the entire deck. As in the earlier construction, the rim 16 and the rim portion 26 of the deck 15 are reenforced by structural means including gussets 27. The center portion 19, below the ballast material 18, is reenforced by drain channels 28.)

The construction process

The construction curve for the deck 15 is defined and impressed on the steel plates of the deck by a framework or system of reenforcements 29 temporarily installed above the tank bottom during the process of construction of the floating roof.

The building of apparatus according to this invention starts with the construction of the tank bottom 12, of any suitable material. Erection of the shell 11 is preferably postponed until the floating roof 14 has been built; the floating roof can then be used as a construction platform.

Above the bottom 12 I install, temporarily, supporting rings 30 for the deck 14, concentrically distributed over the bottom or tank area. Each ring 30 preferably consists of a series of elongated steel bars welded together endwise. Each ring 30 has one of its sides 31 secured to steel support posts 32, spaced along the periphery of a circle concentric with the tank, so that the upper edge 33 of the ring is horizontal and circular.

The upper edges 33—A, 33—B etc. of successive inner and outer rings 30 are disposed in horizontal planes vertically spaced above one another; the elevation of each upper edge 33 coinciding with a point in the predetermined construction curve. In order to control these elevations accurately, according to the construction curve, I adjust the installation of support posts 32, or rings 30, or both. For this purpose I may insert shims under the supports, as shown, or use various other methods known from general civil engineering practice. When properly adjusted the supports are rigidly secured to the bottom 12 as well as to the rings 30. These rings then are ready for use as lower members of the temporary framework 29.

The steel plates forming the deck are supported by these rings; each plate being properly supported, directly or through the next adjoining plate edges, by three concentric rings. For assembly purposes the plates may be temporarily spot welded to the rings.

When all, or at least two concentric ring areas have been assembled the weld seams which approximately follow the circular supports can be made.

Next, I install upper members of the temporary framework, formed by rigid templates 34 which span the radial distance between two or more rings 30, as shown in Figures 5 and 6. Such templates are most economically made by forming a structural shape 35 so that a lower surface 36 thereof practically coincides with a predetermined part of the actual construction curve B. Such shaping can be achieved by cold rolling; it is generally possible by this method to produce a flat circular arc 36 which will not differ from the actual curve B more than an insignificant fraction of an inch at any point. In some instances, a modified circular arc may be produced, which has even better agreement with the curve B.

Templates 34 are secured to the upper surface of deck 15. As shown in Figure 5 the individual plates 43 are joined by radial seams, and a template 34 is arranged adjacent and along each seam. It is secured to the deck by a suitable number of U-bars 37 disposed in inverted position so as to straddle the structural member 35 and the seam. Each U-bar 37 has its ends secured to the upper deck surface by welded joints 38. A wedge 39 is driven into the space between each U-bar 37 and the top of the structural member 35, drawing the steel plates tightly against the lower template surface 36 and thereby impressing the proper contour according to the construction curve on the plate. The plate can be lifted and transported from the storage pile to the proper location in the tank area, with templates 34 secured to it, or the templates can be applied when the plate has been deposited, and temporarily fastened, in the proper location. The subassembly of the plate and templates is then supported on the proper rings 30, with the necessary overlap over adjoining plates previously installed. The rings may be recessed to accommodate such overlap. The shape of the plate, existing along the templates, is similarly impressed on the plate areas between the templates, by the rings 30, forming the lower parts of the framework.

When not so shaped by the framework 29, the plates would have a tendency to sag, as illustrated in Figure 4. This figure shows the construction curves A and B and operating curve C. It indicates the aforementioned sagging of the plates by curve D. It is the function of the framework 29 to correct the curve D into the curve B, along each template and between the templates.

When this has been achieved the shape impressed on the plates is secured by depositing of continuous weldseams 40 along all seams between adjoining plates which have not been welded as yet. When a suitable number of seams have been joined templates 34 can be removed from the finished area of welding work and transferred to subsequent working areas. Of course, each set of templates serves only a certain annular set of work areas. Each set of templates will usually consist of about three to six structural shapes formed to the same contour. The number of plates in each annular set of work areas is usually much greater. Thus it will be seen that the cost of the templates, and generally the cost of the temporary framework, can be kept in very moderate limits.

When all annular work areas have been welded as described, the templates are no longer required for the particular floating roof in question. The welded lapjoints running radially of the deck or nearly so have a similar reenforcing effect on the plates, at least to some extent, as did the templates. However, even if the plate, upon removal of the templates but after deposition of the welds, sags back toward curve D, such sagging will now produce internal stresses tending to reestablish curve B.

It is of the utmost importance for the present invention that the proper welding routines and preparatory procedures are used, as indicated. The curling up of plates that would be caused by premature or improper welding could easily reach dimensions sufficient to cause the formation of wide, shallow bulges and depressions in the deck, whereby it would seriously impair or even destroy the basic advantages of the Prager-Ulm roof.

When the deck has been completed the rim 16, center weight 17, drain 20, seal 21 and legs 22 are installed, in the proper sequence, and the roof will usually be tested for tightness of the lapwelds, and locally repaired, if necessary. When the rigid rim 16 and legs 22 have been installed the temporary support posts 32 and rings 30 can be removed, whereupon the deck tends to assume a contour defined by the "dry suspension curve" E in Figure 3. Substantially the same curve is shown at a different scale, in Figure 10 of the Prager-Ulm disclosure.

The tank is then filled and the normal operating curve is gradually established thereby, substantially as shown in Figures 11 to 13 of said earlier disclosure. It must be understood, however, that in accordance with my new invention,

this establishment of the normal operating curve C constitutes very nearly the reestablishment of the theoretical construction curve A. This will be noted mainly upon comparison of the present Figure 3 with the earlier Figure 10.

Irregular operating curves can be established by rain or snow loads or the like, substantially as shown in Figures 14 and 15 of the earlier disclosure.

The seam pattern

I have determined that the most efficient seam pattern for a floating roof of the present kind is that diagrammatically shown in Figure 10, wherein sector-shaped deck plates are arranged in concentric rings. In the floating roof of 120 foot diameter, with the construction curve as shown and described, I prefer using four such rings of plates, numbered 41 to 44 in inward succession as shown, and an innermost plate means 45 forming a circle. The radially reenforced rim section 26 of the deck 15 forms the outermost part of the outer ring of plates 41. The ballast weight supporting portion 19 of the deck covers all of the inner circle 45 and part of the innermost ring 44.

Preferably, the radial width of the rings of plates is relatively small in the inner rings. I further prefer to use plates, in each ring, with sides running radially and ends running along and adjacent the temporary ring supports 30. The templates 34 can then be installed along and practically parallel with the radial weld seams. In the welding procedure it will often be best to start the continuous welding with the annular seams between the rings of plates, and to complete these continuous annular seams before the continuous radial seams are started.

The preferred pattern of seams and plates improves the accuracy of construction and performance in a Prager-Ulm roof, even if the construction curve is not precisely the curve A or B disclosed hereinabove. Best results are obtained when using both this preferred seam pattern and the preferred construction curve.

In some instances it may be more economical to use a slightly modified seam pattern, as shown in Figure 11. Here the innermost plates 43, 44 and 45 may be the same as in Figure 10, but ring 42 is formed by alternating sets of one or more rectangular plates 46 with more or less triangular plates 47, and similar plates 48, 49 are used in the outermost ring 41. A certain economy is achieved by the use of rectangular plates 46 and 48, because less plate preparation and somewhat less welding is required. On the other hand it may be preferable to simplify the loading of the plates, their field manipulation, and the use of the templates. In this respect the pattern of Figure 10 is more economical.

Still another modification is shown in Figure 12 wherein the plate pattern is purely conventional, substantially the entire deck area being formed by rectangular plates 50. This involves a minimum of plate preparation and welding. However, a deck constructed according to such a pattern is likely to be less accurate and smooth than either that of Figure 10 or 11, even when great care is used in impressing the construction curve upon the deck. The preparation for the welding procedure, accordingly, becomes more costly, compensating at least in part for the savings in welding labor and material.

Results

Due to the absence of a frame work permanently installed on the deck, the present deck—like all Prager-Ulm roofs—is free from depressions and bulges formed by and between the rigid structures of such a framework.

Due to the fact that the present deck tends to return from the dry suspension curve to the construction curve, and that the latter resembles the normal operating curve, a minimum of deflection is involved in the full and extreme change between operative (floating) and inoperative (dry) conditions. This minimum of deflection, again, involves a relative minimum of stress differentials between said extreme conditions. Inasmuch as all stresses—whether radial or annular—increase and decrease together, although not at the same rate, I provide a relative minimum of annular tension and compression, and a relative minimum of bending moment, between the extreme conditions. Otherwise, very considerable bending moments could be developed, tending to seriously warp the deck and even the rim. I have determined this point by testing different floating roofs with central weights, and accurately measuring the stresses as well as deflections, along different radii. The relative smallness of stresses and strains in my improved floating roof allows the use of relatively thinner, peripheral and central deck plates, as indicated above; also the use of a relatively weaker, lighter and cheaper rim and reenforcing system for the same.

Moreover the new and improved deck surface is particularly smooth and free from irregularities. This is basically due to the use of a construction method as described, and particularly due to the feature that a construction curve is impressed on the deck which involves a minimum of deflection and stress in the extreme transition to the operating curve.

Again this absence of irregularities in the deck simplifies the maintenance of the floating roof. Corrosive accumulations are practically non existent, above and below the deck. After a rainfall, and after the melting of snow, all of the water drains away; no residual pools are formed, which would be removed only by slow evaporation.

Equally no layers of vapor in gas phase are formed anywhere below the deck; at most, bubbles of vapor are formed, moving through the product in liquid phase. This, again, contributes to the vapor economy. Where extensive layers of vapor are formed under a metal deck, as in prior floating roofs where vapor accumulating spaces were intentionally or inherently formed, such layers act as thermal insulators, postponing both the heating up and the cooling down of the product during the daily temperature cycle. However, such layers of vapor also promote evaporation; in fact the existence of an interface between a body in liquid phase and one in vapor phase is one of the main requirements for evaporation. Inasmuch as my improvement reduces the chance for the formation of such layers or bodies in vapor phase, it also resists the formation of such an interface, the evaporation of liquid, and the ultimate loss of vapor.

It will be obvious to persons skilled in the art that a number of further modifications can be applied, in addition to those described, all within the scope and spirit of my invention.

I claim:

1. A method of constructing a floating roof for volatile liquid, comprising the steps of installing a set of rigid but vertically adjustable support members upon a substantially circular

tank bottom previously prepared, said support members being distributed over the area of the bottom and having well defined upper edges; vertically adjusting said support members so that said edges lie in predetermined, uniform, slightly inclined, substantially flat construction curves running radially of the bottom, outwardly-upwardly throughout, with upward curvature over a part of the radius between the inner and outer parts thereof; supporting metal plates for the roof on said edges; supporting rigid templates, running crosswise of said support members and having undersides formed in accordance with said construction curves, on upper portions of the metal plates overlying such edges; raising other portions of the metal plates, between such edges, to the undersides of the templates, whereby their tendency to sag is counteracted and said construction curves are impressed on the plates; then joining the plates together endwise and thereby completing the deck of the floating roof; providing the deck with the necessary associated parts such as an upstanding rim, central downwardly loading means, permanent support means, sealing means and draining means; and removing said templates and support members.

2. A method as described in claim 1 wherein the support members are rings concentric with the bottom, disposed at different radial distances from the common center thereof and formed of upright plate-like members.

3. A method as described in claim 2 wherein the templates are radially installed and extend approximately from one of said rings to the next.

REIGN C. ULM.

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The following references are of record in the file of this patent:

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Certificate of Correction

Patent No. 2,531,897 November 28, 1950

REIGN C. ULM

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 2, line 39, for "words, prefer" read *words, I prefer*; column 5, line 32, for that portion of formula (1) reading "$-2w^1$" read $-2w^1)$; line 52, for that portion of formula (2), reading "$e\gamma^r$" read $e^{\gamma r}$;

and that the said Letters Patent should be read as corrected above, so that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 10th day of April, A. D. 1951.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.