Aug. 13, 1957 N. A. WEIL 2,802,596

SKIRT SUPPORTED VESSELS

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FIG. 1

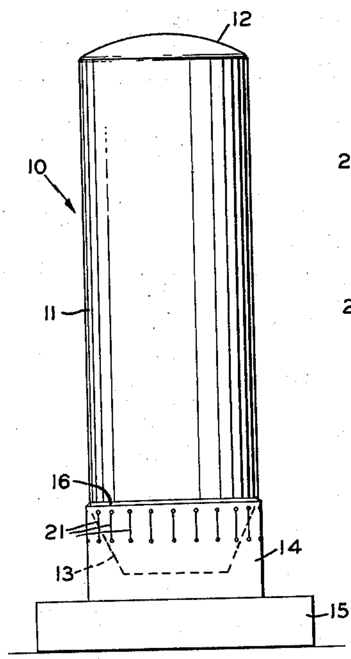


FIG. 2

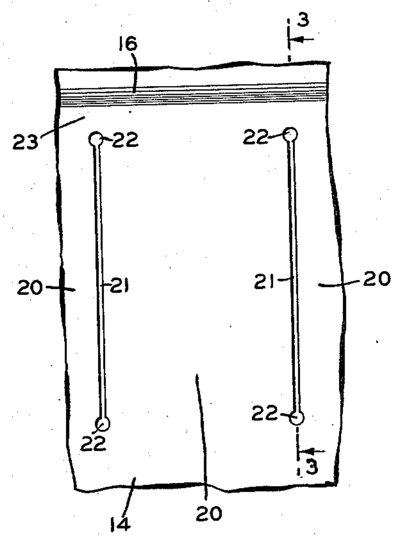


FIG. 3

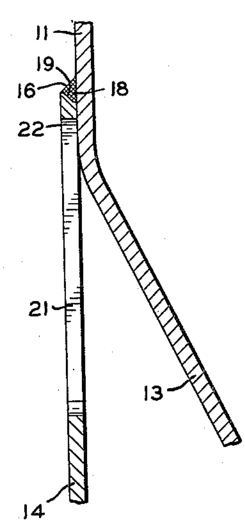


FIG. 4

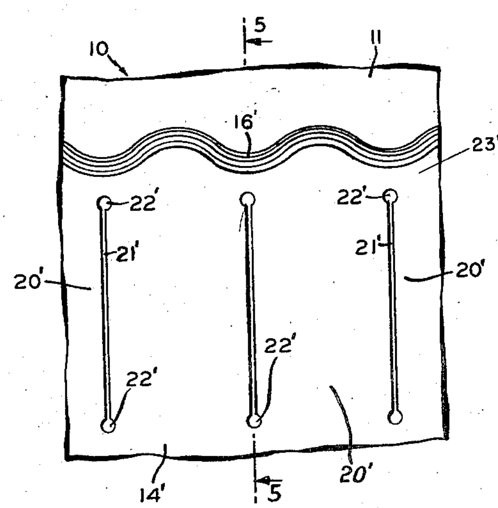
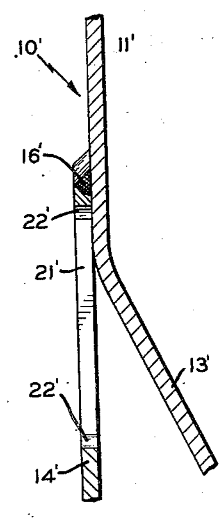


FIG. 5



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SKIRT SUPPORTED VESSELS

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12 Claims. (Cl. 220—69)

This invention relates in general to vessels which in use are subjected to cyclic temperature swings, and in particular to such vessels as are carried on metal support members and connected thereto by fusion welded joints.

It is usual to support large heavy vessel shells on skirts that are attached to, and carried on, foundations suitable to support the vessels in the intended uses. It is also usual to unite the vessel shells to the supporting skirts by fusion welds that are deposited circumferentially as fillet welds around the vessel shells. These fillet welds are deposited on the shoulder defined by the horizontal end surface of the skirt and the contiguous surface of the vessel. When these vessels are used in operations which involve elevated temperatures, it is common practice to insulate the vessels and their supporting skirts in order to conserve heat and thereby maintain the efficiency of the operation. These conventional vessels are satisfactory if in use they remain at substantially constant elevated temperatures for long periods of time and are not subjected to rapid cyclic temperature changes. If, however, comparatively rapid cyclic swings from one to another of widely separated temperatures are involved, considerable trouble is experienced and periodic expensive weld repair is required, as such cyclic operations not infrequently result in cracking of the connecting skirt welds.

The conventional delayed coking process is an example of a process having a temperature swing cycle of such severity as to render the conventional skirt and skirt attachment unsatisfactory for the vessels used therein. The conventional delayed coking process is batch operation running on a cycle which varies from 24 to 48 hours. During the operating portion of the cycle, the temperature of the equipment rises to about 800° F. and then falls rapidly by reason of water quenching to atmospheric. The severely cyclic nature of this operation subjects the skirt attachment weld to destructive stresses. It has been found that stresses which exceed the yield point of the steel out of which the vessels and their skirts are usually made can be developed if the axial thermal gradient exceeds 10° F. per inch. Examination of actual operating delayed coking installations employing conventional skirted vessels indicated axial gradient values at the skirt welds in excess of 20° F. per inch as not unusual.

Cracking of the skirt welds commonly begins as small incipient cracks on the end surface of the weld, generally at the roots between the weld beads, and as time goes on penetrates both circumferentially and radially inwardly. Often the cracking penetrates the entire weld and vessel shell thickness so that its presence is detected by oil seepage. Cracks have been found to run entirely around the girth of the vessel and in instances, the cracks actually separated the vessel from the skirt support with the vessel sitting loosely on the skirt. The reasons for the cracking of the conventional skirt welds are generally known. During the coking portion of the operating cycle, a heavy heat flow exists conducting heat from the vessel wall through the skirt weld to the skirt and down the skirt to the foundation. The resulting gradients in the order of 10° F. and more, induce high bending moments at the skirt attachment weld. The nature of this bending is such that a tensile stress is present at the outer surface of the weld. With the simple, conventional fillet welds and conventional insulation, the level of this calculated tensile stress is in excess of 100,000 p. s. i. The bending moments at the weld are due primarily to the varying thermal expansion along the length of the cylindrical skirt because of the thermal gradient therealong and the fact that the cylindrical form is stiff and offers great resistance to radial movement of incremental bands thereof.

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Stresses in the order of 100,000 p. s. i. cannot be carried by the material out of which the coke drums, or vessels, are ordinarily fabricated. Instead the weld metal yields a small amount to accommodate the rotation tendency of the skirt. When the vessels are brought down to ambient temperature during quenching, a heavy heat flow also exists. At this time the heat flow is from the foundation up the skirt and through the skirt weld to the vessel wall, so that the reverse plastic flow and rotation takes place mitigated to a certain degree by the previously established locked-up stresses. With every operating cycle, this high amplitude stress reversal continues. The result is fatigue cracking after a sufficient number of cycles, the cracks originating on the tensile outer face of the weld. The fatigue origin of the skirt weld cracking is further indicated by the fact that in cases where the damaged weld was repaired in the conventional manner, cracking of the new repair weld proceeded with almost clockwise predictability after a period of time.

It is a principal object of this invention to provide a skirted vessel whose skirt is so constructed and arranged that the vessel and the portion of the skirt attached thereto may expand and contract without excessive stress inducing restraint due to said skirt.

It is also a principal object of this invention to provide a skirted vessel for use in operations involving cyclic swings between widely separated temperatures whose skirt is so constructed and arranged that the end thereof attached to the vessel may expand and contract with the vessel without undue restraint thereof by reason of the cylindrical formation of said skirt so that fatigue producing stresses in the weld uniting the skirt to the vessel are materially reduced and the tendency to develop fatigue cracks along the weld practically eliminated.

It is a further principal object of this invention to provide a skirted vessel for use in operations involving cyclic swings between widely separated temperatures whose skirt has its upper section so formed that it is comparatively flexible and does not impose excessive stress inducing restraint on the upper end thereof and the weld uniting said upper end to the vessel as said weld and said upper end expand and contract during said cyclic swings whereby the tendency to produce fatigue cracks in the weld metal is practically eliminated.

It is an additional principal object of this invention to provide a skirted vessel for use in operations involving cyclic swings between widely separated temperatures whose skirt has its upper end subdivided into a plurality of parallel longitudinal members that undergo substantially simple flexure as the vessel, the weld joining the vessel to the skirt and the upper end of said skirt expand and contract during said cyclic swings whereby the tendency to develop fatigue cracks in the weld metal is eliminated.

The further objects, advantages, and features of my invention will become apparent from a consideration of the following detailed description thereof taken with the accompanying drawings in which:

Fig. 1 is a front view showing a vessel supported on a skirt which connects the vessel to its foundation;

Fig. 2 is a fragmentary front view of the vessel of Fig. 1 on an enlarged scale showing skirt details;

Fig. 3 is a section taken on line 3—3 of Fig. 2;

Fig. 4 is a fragmentary view similar to Fig. 2 but showing an alternate construction; and

Fig. 5 is a sectional view taken on line 5—5 of Fig. 4.

The skirted vessel of this invention is of general application and is suited for use in operations wherein because of temperature conditions, pressure loadings, or other causes, the top end of the supporting skirt and the wall connecting it to the vessel experience radial movement. The novel vessel of this invention is particularly useful in operations which involve conditions severe enough to generate fatigue producing stresses in the skirt weld of the conventional skirted vessel. The novel vessel of the invention finds its most important use in the materials processing and treating industries wherein elevated temperatures are employed and especially to those operations in said industries which involve cyclic swings from one to another, and vice versa, of widely separated temperatures. The conventional delayed coking processes are typical of the processes in which the vessels of the present invention are especially useful. Thus, by way of illustration rather than by way of limitation, the novel skirted vessel of this invention will be disclosed in detail as a coke drum, or similar vessel of the character used in conventional delayed coking processes.

Conventional delayed coking processes are batch operations which run on a 24 to 48 hour cycle. During the coke forming portion of the operating cycle, the coke drum attains a temperature of 800° F. and more. During the water quenching portion of the cycle the drum is brought down to ambient temperature. The quenching portion of the cycle is of comparatively short duration and takes some eight hours and less to complete. Barring shutdowns due to failure or repair, the cycle is repeated continuously.

Referring now to the drawings and particularly to Figs. 1–3 thereof:

A coke drum **10** suitable for carrying out the conventional delayed coking process is shown in Fig. 1. The coke drum **10** includes a cylindrical body section **11** whose upper end is closed by a dished head **12** and whose lower end is closed by a cone **13**. The drum **10** as is usual, includes various manholes, nozzles, lines, etc., for introducing the heated coke producing materials, for removing vaporous products and the formed coke and for supplying the quenching water. These manholes, nozzles, lines, etc., have not been shown as they are conventional and are not necessary for the proper disclosure and understanding of the present invention. The drum **10** in use is vertically disposed and is mounted on the supporting skirt **14**. The skirt **14** is cylindrical in form and closely encircles the lower end of the cylindrical body section **11**. The bottom of the skirt **14** is connected in any suitable conventional manner, to the foundation **15** which as is usual may be of masonry, concrete, or similar material. The skirt **14** is joined to the cylindrical body section **11** by the circumferential fusion weld **16**. In operaitve condition, the whole external surface of the drum **10** and the whole external and internal surface of the skirt **14** are covered with a thick layer of insulation. The insulation has been omitted from the drawings as it is not necessary to the explanation of the invention. Typically, a coke drum **10** in the erected condition is some 70 feet high and 19 feet in diameter and will yield about 450 tons of coke per coking cycle. Such a coke drum **10** and its skirt **14** are approximately 1 inch thick with the skirt **14** some 4 or 5 feet long; both the drum **10** and the skirt **14** are commonly made of carbon steel.

The skirt **14** may be attached to the drum **10** prior to the erection of the drum **10** at the site or it may be applied to the drum **10** during the erection of the drum **10** at the site. The circumferential weld employed to unite the skirt **14** to the drum may be in the form of a conventional fillet weld, that is, a weld deposited by arc welding or gas welding on the shoulder formed by the horizontal top surface of the skirt **14** and the contiguous vertical, or inclined, surface of the drum **10** and extending along said contiguous surface. However, in accordance with the teachings of the present invention and in order to better secure the results flowing from the use of the invention, said circumferential weld is preferably of the form of the weld **16** shown.

The weld **16** includes a portion **18** which extends below the top edge of the skirt **14** by a distance which approximates the thickness of the skirt **14**, and a fillet portion **19** which is integral with the top of the portion **18** and extends upwardly along the cylindrical section **11** a distance also approximately equal to the thickness of the skirt **14**. The preferred vertical leg of the weld **16** is in the order of twice the thickness of the skirt **14**. With a coke drum **10** dimensioned as above, a weld **16** with a vertical leg 1.8 times the thickness of the skirt **14** is fully satisfactory. The weld **16** is also characterized by the fact that the portion **18** penetrates into the skirt **14** at an angle approximating 45° and changes its angle so that it flattens in the region of the weld root, and the weld metal in said region completely fuses and penetrates into the metal of the skirt **14** and the cylindrical section **11**. The weld deposit **16** is further characterized by the fact that the length of its throat is equal to the thickness of the skirt **14**.

The weld nugget **16** is preferably deposited from the end of a fusing metal electrode under the influence of an electric arc discharge in a conventional manner. After the welding, the exposed surface of the weld nugget **16** is ground to eliminate all projections, undercuttings, pits, and other stress raisers. Likewise, the toe areas of the weld **16** are ground to secure smooth blending of the metal of the weld nugget **16** into the contiguous metal of the skirt **14** and the cylindrical section **11**. The weld **16** provides an improved heat distribution at the juncture of the skirt **14** and the cylindrical section **11** with a consequent better stress distribution.

In order to reduce the stress inducing restraint imposed by the stiff, cylindrical skirt **14** on the expansion and/or contraction movements of the weld **16** and the portion of the skirt **14** attached thereto, the upper end of the skirt **14** is subdivided into a plurality of elongated longitudinal sections **20**. The sections **20** are made of such width that while they have an arcuate transverse section, the curvature thereof will be comparatively flat, i. e., their arcs and chords will approach each other in length. Thus in the movements of the sections **20** in following the expansion and contraction movements of the weld **16** and the end of the skirt **14** attached thereto, the sections **20** will go through approximately a simple flexure with a minimum resistance thereto by the reason of their curvature. The number of sections into which the upper portion of the skirt **14** is subdivided will depend upon the desired reduction in the stress reducing tendency and is related to the skirt diameter and thickness. It has been found that as a general case at least 30 sections **20** are required for a reduction in stress inducing tendency of practical significance. The best practical results are obtained when the number of sections **20** is between 50 and 80. Only large diametered skirts can stand more than 80 sections **20** without substantial diminution in strength and rigidity. The length of the sections **20** is also important as it has a direct bearing on the flexibility of the sections **20**. It has been found that the sections **20** should at least be of a length 10 times the thickness of the skirt **14** and preferably should be around 16 times said thickness. If the length of the sections **20** is increased to 30 times said thickness and beyond, the strength and stability of the skirt are significantly affected. With a coke drug 10 and skirt 14 dimensioned as indicated, excellent results were obtained with the upper end of the skirt 14 subdivided into 60 sections of a length about 16 times the thickness of the skirt 14.

The sections 20 are formed by flame cutting longitudinal slots 21 of appropriate length. The slots 21, cut with the usual torch and with the skirt 14 having a thickness in the order of 1 inch, are approximately between ¼ and ⅜ of an inch in width. To eliminate stress concentrators and other crack starters at the ends of the slots 21, each end of the slots 21 terminates in a drilled hole 22 which with the slots and skirt of the size above mentioned are preferably about ½ inch in diameter. The slots 21 do not extend to the upper periphery of the skirt 14 but terminate at a distance approximately equal to about 1½ the thickness of the skirt 14 away from said end to provide a solid band 23 above the sections 20 which connects the upper ends of said sections 20. With the skirt 14 dimensioned as above, a band 23 about 1½ inches wide is fully satisfactory.

When the heat flows through the weld 16 in either direction, the solid band of metal 23 of the skirt 14 between the weld 16 and the drilled holes 22 will expand substantially uniformly with the weld 16 as the thermal gradient along the band 23 is quite small and for practical purposes negligible. Thus, the band of metal 23 does not impose any substantial stress inducing restraint on the expansion and contraction movements of the weld 16. When the portion of the skirt 14 formed by the sections 20 is affected by said heat flow and the expansion of the weld 16 and the metal band 23, the sections 20 will flex in a manner approximating that of a flat plate and thus impose a minor restraint on the movements of the band 23 and the weld 16. In this manner the stresses are reduced to such a point that fatigue cracking is effectively eliminated.

The embodiment of the invention illustrated in Figs. 4 and 5 is identical with that of Figs. 1–3 except as to the conformation of the top end of the skirt and the skirt weld. The apparatus elements of Figs. 4 and 5 are identified by the same numerals as the corresponding apparatus elements of Figs. 1–3 but with a prime designation added. The skirt 14' has the portion of its end below the band 23' subdivided into a plurality of sections 20' by a plurality of slots 21' which terminate at each end in the drilled holes 22'. The number of sections 20', the width of the band 23', the length and width of the slots 21', and the size of the drilled holes 22' are determined by the same criteria as set forth in connection with the embodiment of the invention illustrated in Figs. 1–3. The end of the skirt 14' above the band 23' is formed by flame shaping, or otherwise, into a sinuous or scallop-like conformation. The scalloped end extends at its maximum approximately 2½ times the thickness of the skirt 14' above the band 23'. The scalloped skirt end accentuates the action of the sections 20' and results in a more flexible arrangement. The weld 16' is a continuous girth weld and takes the sinuous path defined by the scalloped skirt end. The weld 16' is otherwise exactly like the weld 16.

Although many changes can be made by those skilled in the art without departing from the scope of the invention, it is intended that all matter contained in the above description and appended claims and shown in the accompanying drawings shall be interpreted as illustrative and not limitative.

I claim:

1. In combination, a vessel of substantially circular cross section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, weld metal deposit uniting said upper end of said skirt to the portion of said vessel in contact therewith, a plurality of spaced longitudinal slots formed in said skirt and extending to the region thereof adjacent said weld metal, said slots subdividing the upper portion of said skirt into a plurality of elongated sections, said elongated sections of a width in the order of $\frac{1}{60}$ the circumference of said skirt and of a length at least 10 times the thickness of said skirt.

2. In combination, a vessel of substantially circular cross section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, weld metal deposit uniting said upper end of said skirt to the portion of said vessel in contact therewith, a plurality of spaced longitudinal slots formed in said skirt and extending to the region thereof adjacent said weld metal, each terminus of said slots in said skirt formed by a substantially circular drilled hole, said slots subdividing the upper portion of said skirt into a plurality of elongated sections, said elongated sections of a width in the order of $\frac{1}{60}$ the circumference of said skirt and of a length at least 10 times the thickness of said skirt.

3. In combination, a vessel of substantially circular cross section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, weld metal deposit uniting said upper end of said skirt to the portion of said vessel in contact therewith, said weld metal extending longitudinally along said vessel a distance approximately twice the thickness of said skirt, said weld metal deposit having a throat length approximating said thickness, a plurality of spaced longitudinal slots formed in said skirt and extending to the region thereof adjacent said weld metal, each terminus of said slots in said skirt formed by a substantially circular drilled hole, said slots subdividing the upper portion of said skirt into a plurality of elongated sections of comparatively flat curvature whereby the radial movements of said weld metal deposit and the metal of said skirt and said vessel united thereto are relatively unrestrained by the portion of said skirt therebelow.

4. The combination defined in claim 3, in which said elongated sections are of a width less than $\frac{1}{30}$ the circumference of said skirt and of a length at least 10 times the thickness of said skirt.

5. The combination defined in claim 3, in which said elongated sections are of a width in the order of $\frac{1}{60}$ the circumference of said skirt and of a length at least 10 times the thickness of said skirt.

6. In combination, a vessel of substantially circular cross section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, weld metal deposit circumferentially around said vessel uniting said upper end of said skirt to said vessel, a plurality of spaced substantially parallel longitudinal slots formed in said skirt subdividing the upper portion of said skirt into a plurality of elongated sections of comparatively flat curvature, each of said slots beginning in a drilled hole in said skirt spaced from the upper end of said skirt a substantial distance and terminating in a second drilled hole spaced downwardly from said first hole by a distance at least approximately equal to 10 times the thickness of said skirt.

7. In combination, a vessel of substantially circular cross section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, weld metal deposit circumferentially around said vessel uniting said upper end on said skirt to said vessel, a plurality of spaced substantially parallel longitudinal slots formed in said skirt subdividing the upper portion of said skirt into a plurality of elongated sections of comparatively flat curvature, each of said slots beginning in a drilled hole in said skirt spaced from the upper end of said skirt by a distance in the order of once to twice the thickness of said skirt and terminating in a second drilled hole spaced downwardly from said first hole by a distance at least approximately equal to 10 times the thickness of said skirt.

8. In combination, a vessel of substantially circular cross section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, weld metal deposit circumferentially around said vessel uniting said upper end of said skirt to said vessel, a plurality of spaced substantially parallel longitudinal slots formed in said skirt subdividing the upper portion of said skirt into a plurality of elongated sections, each of said slots beginning in a drilled hole in said skirt spaced from the upper end of said skirt by a distance in the order of once to twice the thickness of said skirt and terminating in a second drilled hole spaced downwardly from said first drilled hole by a distance at least approximately equal to 10 times the thickness of said skirt, said slots being spaced apart by a distance not exceeding $\frac{1}{30}$ the circumference of said skirt.

9. In combination, a vessel of substantially circular cross section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, weld metal deposit circumferentially around said vessel uniting said upper end of said skirt to said vessel, a plurality of spaced substantially parallel longitudinal slots formed in said skirt subdividing the upper portion of said skirt into a plurality of elongated sections, each of said slots beginning in a drilled hole in said skirt spaced from the upper end of said skirt by a distance in the order of $1\frac{1}{2}$ the thickness of said skirt and terminating in a second drilled hole spaced downwardly from said first drilled hole by a distance at least approximately equal to 10 times the thickness of the skirt, said slots being spaced apart by a distance not exceeding $\frac{1}{30}$ the circumference of said skirt.

10. In combination, a vessel of substantially circular cross section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, weld metal deposit circumferentially around said vessel uniting said upper end of said skirt to said vessel, a plurality of spaced substantially parallel longitudinal slots formed in said skirt subdividing the upper portion of said skirt into a plurality of elongated sections, each of said slots beginning in a drilled hole in said skirt spaced from the upper end of said skirt by a distance approximately $1\frac{1}{2}$ the thickness of said skirt and terminating in a second drilled hole spaced downwardly from said first drilled hole by a distance approximately 16 times the thickness of said skirt, said slots being spaced apart by a distance approximately $\frac{1}{60}$ the circumference of said skirt.

11. In combination, a vessel of substantially circular cross section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, weld metal deposit circumferentially around said vessel uniting said upper end of said skirt to said vessel, said weld metal extending longitudinally along said vessel a distance approximately twice the thickness of said skirt, said weld metal deposit having a throat length approximating said thickness, a plurality of spaced substantially parallel longitudinal slots formed in said skirt subdividing the upper portion of said skirt into a plurality of elongated sections, each of said slots beginning in a drilled hole in said skirt spaced from the upper end of said skirt by a distance approximately $1\frac{1}{2}$ the thickness of said skirt and terminating in a second drilled hole spaced downwardly from said first drilled hole by a distance approximately 16 times the thickness of said skirt, said slots being spaced apart by a distance approximately $\frac{1}{60}$ the circumference of said skirt.

12. In combination, a vessel of substantially circular section, a cylindrical supporting skirt surrounding the lower end of said vessel with the upper end of said skirt in contact with said vessel, said upper end having a scalloped conformation, weld metal deposit circumferentially around said vessel uniting said scalloped upper end of said skirt to said vessel, said weld following the scalloped contour of said upper end to thereby attain a sinuous form, a plurality of spaced substantially parallel longitudinal slots formed in said skirt subdividing the upper portion of said skirt into a plurality of elongated sections, each of said slots beginning in a drilled hole in said skirt at a level spaced from the lowest portion of said scalloped end by a distance in the order of $1\frac{1}{2}$ the thickness of said skirt and terminating in a second drilled hole spaced downwardly from said first drilled hole by a distance at least approximately equal to 10 times the thickness of said skirt, said slots being spaced apart by a distance not exceeding $\frac{1}{30}$ the circumference of said skirt.

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