Oct. 24, 1944. J. A. GIBB 2,361,020

CATALYTIC APPARATUS

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Fig. 1.

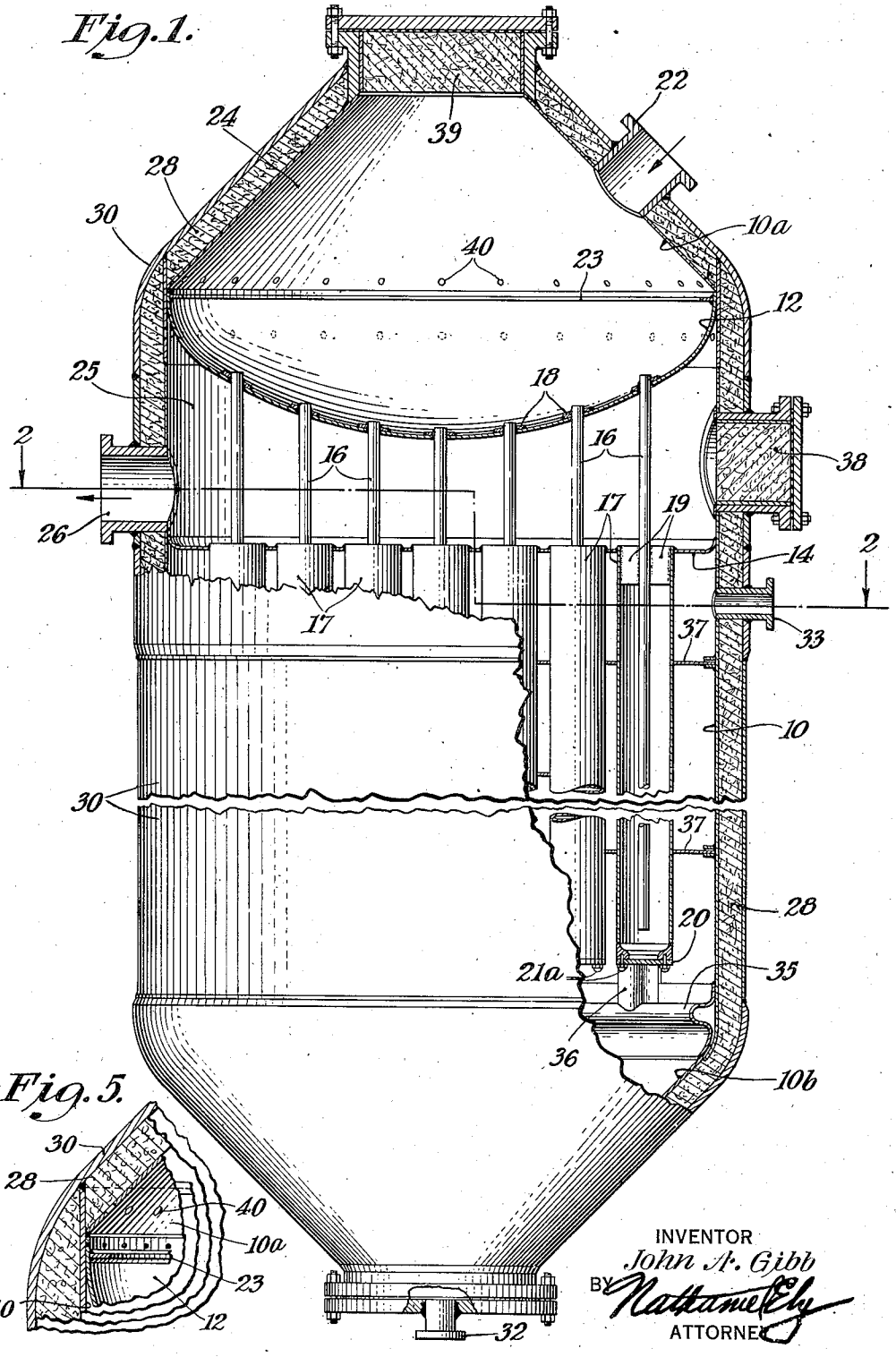


Fig. 5.

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Fig. 2.

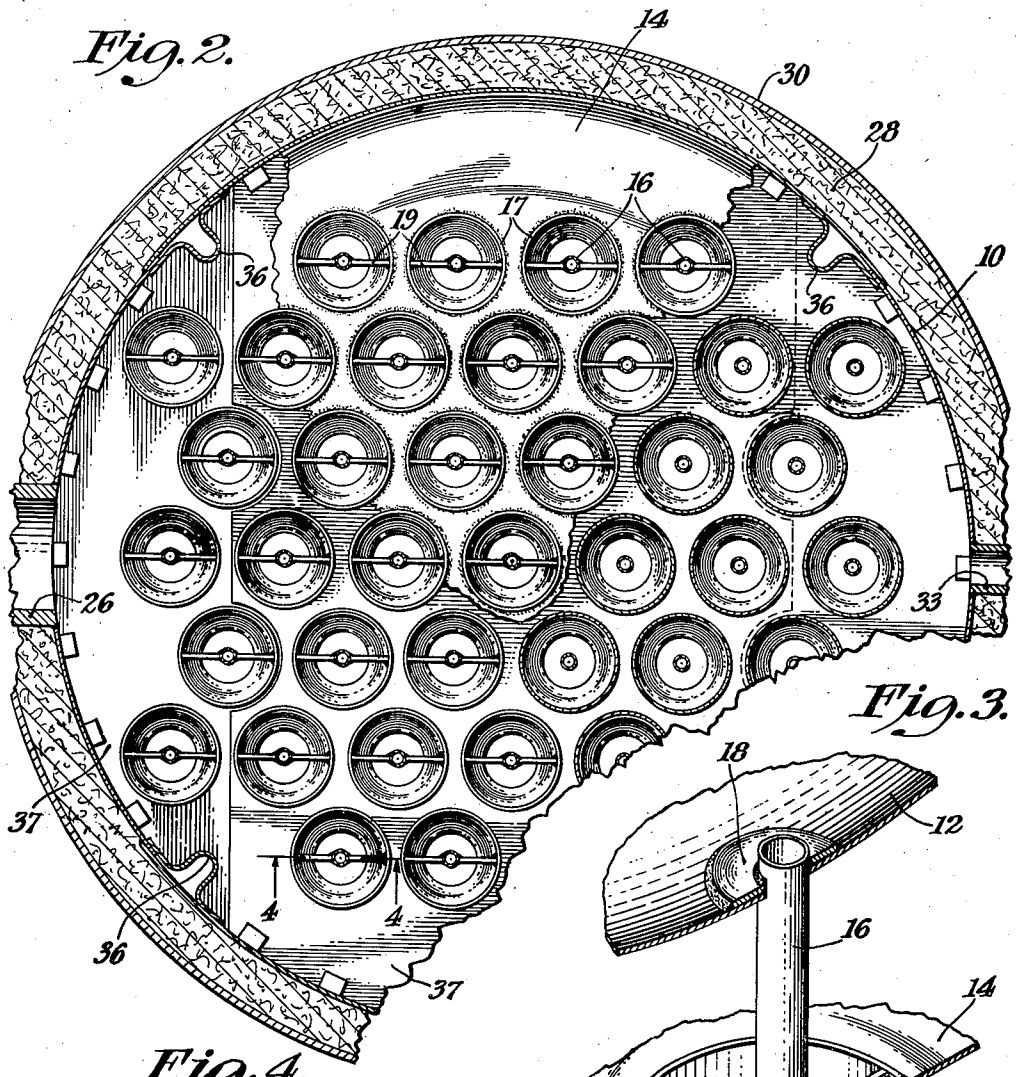
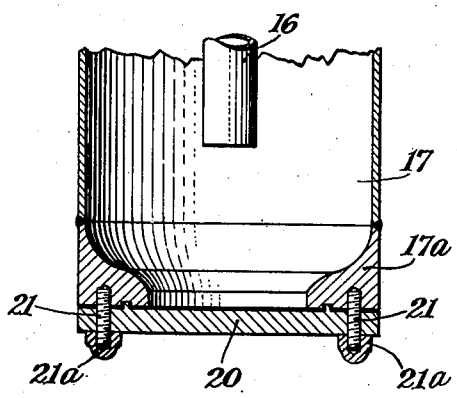


Fig. 3.

Fig. 4.



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CATALYTIC APPARATUS

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Application November 9, 1940, Serial No. 364,971

9 Claims. (Cl. 23—288)

This invention relates to improvements in pressure vessels particularly of the shell and tube type such as heat exchangers, catalyst chambers, and the like.

Catalytic reactions carried out in pressure vessels have introduced new problems of corrosion and erosion not only because of the effect of the high temperature of operation and of the substantial weight of the catalyst but also because the necessary heat exchange has often required that a molten material, usually a salt, be circulated in indirect contact with the catalyst to maintain it at a uniform temperature; such materials are frequently highly corrosive. This is particularly true in the forms of heat controlling media used in the control of the catalytic reactions of hydrocarbons as in the production of superior qualities of gasoline.

The principal object of my invention is to provide an improved form of tubular heat exchanger especially adapted for the carrying out of catalytic reactions, in which the weight and cost of the equipment can be greatly reduced without impairing the effective life of the vessel or increasing its maintenance.

It is a more particular object of my invention to provide a high temperature, relatively high pressure vessel having a substantial weight of supported tubular elements carried by a corrosion resistant and high tensile strength steel tube sheet, which in cross section has a form that is initially a catenary so that there is substantially no bending moment placed in the tube sheet by the supported load and no resistance against flexure is required.

A still further object of my invention is to provide a catalyst chamber of corrosion resistant, high tensile strength alloy steel having the catalyst mass suspended substantially uniformly across a tube sheet of the same material, such tube sheet having marginal portions closely fitting and coaxial with the chamber and welded thereto, the tube sheet between its edges being a surface of revolution of a curve of initially catenary or modified parabolic shape so that all suspended loads are resolved to tension loads in the tube sheet.

Another and more particular object of the invention is to provide a catalyst chamber, the principal parts of which may be of welded stainless steel and with concentric tubes holding the catalyst and distributing the vapors therethrough.

Further objects and advantages of my invention will appear from the following disclosure of a preferred form of embodiment thereof taken in connection with the attached drawings illustrative thereof, and in which

Fig. 1 is an elevation, with parts broken away, of an improved type of catalyst chamber in accordance with my invention;

Fig. 2 is a horizontal section taken substantially along the line 2—2 of Fig. 1 showing the arrangement of the tubes and the expansion elements;

Fig. 3 is an enlarged perspective view showing the manner of attaching the tubes to each other and to the tube sheet;

Fig. 4 is a detailed vertical section taken on the line 4—4 of Fig. 2 showing the manner of securing the bottom to the catalyst-containing tubes;

Fig. 5 is an enlarged detail showing the manner of attaching the tube sheet to the shell.

In accordance with the preferred form of my invention, I have shown a form of heat exchanger more particularly adapted for the catalytic reaction of hydrocarbons; such vessel is conveniently of the double wall type having an interior shell or liner 10 which is preferably of a corrosion resistant material such as stainless steel of the 18–8 variety and is particularly adapted to resist erosion and corrosion at the relatively high temperatures which exist in hydrocarbon reactions which are frequently carried out in the temperature range of 1100° F. Preferably this shell 10 is cylindrical and it may be surmounted by truncated conical top and bottom portions 10*a* and 10*b* respectively.

Within such shell and in the main body portion there is a tubular structure which is conveniently mounted in a vertical manner due to the normal size of such apparatus, such structure consisting of a top or supporting tube sheet 12 and a lower or secondary tube sheet 14 and a plurality of tubes 16 and 17 supported thereby.

The manner of securing the tubes 16 to the tube sheet 12 is more particularly shown in Fig. 3, in which it will be noted that the tube 16 extends through the tube sheet 12 and is provided with a collar or a reinforcing flange 18, which is welded to the tube sheet and to the tube. Each of these tubes 16 supports a larger tube 17, which is concentric therewith and slightly longer. The tube 17 is provided with a web 19 which spaces the tube 17 from the tube 16 and is welded to the exterior of tube 16 and serves as the principal vertical support of the external tube. The tube 17, as shown in Fig. 4, is provided with a bottom which is detachable, such bottom consisting of a plate 20 which is conveniently bolted to the bottom extension 17*a* of the tube by studs 21 having

nuts 21*a*, which may be of the acorn type to prevent destruction of the threaded portions. It will be noted in Fig. 4 that the tube 16 extends substantially throughout the tube 17 and it may be longitudinally perforated.

The tube sheet 12, which forms the principal feature of my invention, is a surface of revolution and has a cross section which is initially a catenary, which ultimately becomes a parabola. As shown in Fig. 5, the edges of the tube sheet 12 are coaxial with and closely fit the inner liner 10 near the top and are welded thereto. The tube sheet is thus suspended in shear but with the tube sheet in tension. A bar member 23 preferably supplements the joint and adds to the rigidity of the tube sheet at its edge.

The tube sheet 12, when loaded, becomes parabolic in cross section, which is the shape of a flexible member supported on its ends and having uniform loads suspended therefrom. The vertical loads imposed by the respective tubes 16 and 17, which are suspended therefrom in a uniform spacing, cause on reaction in the tube sheet except in tension.

This construction is especially effective inasmuch as the use of stainless steel of the 18–8 variety or other high tensile strength, non-corrosive materials can be used in relatively thin gauge with the minimum of weight for both the tube sheet as well as the inner liner 10 of the vessel. It will be understood that the tensile strength of stainless steel is especially high, and, as it is adequate in thin gauge to resist both corrosion and erosion, the thin gauge material meets all structural requirements and very substantially reduces the gross load of the vessel.

Catalytic reactions of hydrocarbons require substantial surfaces of catalyst, through which the vapors are conducted. In the present instance this is accomplished by introducing the vapors through the nozzle 22 into the principal manifold or top channel 24 with the vapors passing into the respective tubes 16 and passing downwardly to the bottom of the tubes 17. Each of these tubes 17 is normally filled with the desired catalyst with the result that the catalytic reaction takes place during the emanation of the vapors from the tubes 16 until the reacted products are released from the top of the tubes 17 into the intermediate chamber 25. This is conveniently formed by the supporting tube sheet 12 and the secondary tube sheet 14. The secondary tube sheet 14 also serves to space the tops of tubes 17. The discharge of reacted products is through the nozzle 26.

The high temperature of reaction requires not only the most careful and complete insulation, which is accomplished by providing insulating material 28 around the shell 10, which may be held in place by an external wall or cover 30, but means are provided for filling the chamber surrounding the catalyst reaction zone with a heat exchanging medium such as molten salt of the desired temperature. The entire zone below the lower tube sheet 14 is thus maintained full of a hot and usually corrosive material which is introduced through the nozzle 32 at the bottom of the chamber and may be removed through the nozzle 33 at the side of the chamber. The means for continuously maintaining this heat transfer medium at the desired temperature is not shown as it forms no part of this invention. It is to be understood, however, that during endothermic reactions, which are characteristic of hydrocarbon reactions, it is necessary to supply heat by the fluid heating medium, and during the reactivation of the catalyst by oxidation, which is an exothermic reaction, it is necessary to remove the heat by aid of the heat transfer medium without, in either case, exceeding limiting temperatures which are required for maximum efficiency.

The normal high temperature conditions of operation are such that suitable expansion joints 35 and 36 are provided for changes in size during expansion and contraction. It may also be desirable to provide baffles such as 37 at suitable places transverse of the heat transfer medium zone for indirect flow and appropriate transfer of the fluid medium between the inlet 32 and the outlet 33. Hand-holes or cleanout plugs 38 and 39 are also usually provided for maintenance of the apparatus. The equalization of pressure between the outer end inner walls at the top of the vessel may be accomplished by using a series of apertures 40 in the inner liner 10*a*. They may also be provided in the liner 10 in the region of chamber 25.

A practical and characteristic size apparatus of this type has an inside diameter of the liner of ten feet and an overall height of twenty-five feet. With such a construction the insulation is approximately 6'' thick, and the top and bottom cones of the outer shell, which were of low carbon steel, were 1'' and ¾'' in thickness respectively. The shell liner of 18–8 stainless steel, having a tensile strength of 95,000 pounds per square inch, was only $\frac{3}{16}$'' in thickness with the top tube sheet 12 of ½'' and the lower tube sheet 14 of ¼'' thickness. The tube sheet 12 is deeply dished. A satisfactory depth for the sheet, prior to loading thereof, and measured along the vertical center line of the sheet from the bar 23 to the sheet is one-fourth the diameter of the projected area of the sheet.

As originally designed, with the typical dished head construction adapted to support a catalyst load of approximately forty tons, the weight of the apparatus alone was approximately fifteen tons. By using the stainless steel, however, not only in the liner but particularly in the tube sheets, it was possible to reduce the weight of the apparatus to approximately ten tons thereby saving over five tons of material. A large portion of the saving would have been impossible even with stainless steel in the top tube sheet of the ordinary type as the moment of inertia of thin sections is so low that the customary beam would have been inordinately thick to resist flexure.

It will be appreciated that, in addition to static load of tubes and catalyst, the tube sheet has the additional load due to the pressure differential which exists between the inlet channel 24 and the discharge chamber 25. This is inevitable in view of the passage of hydrocarbons through the catalyst and in view of the very large diameters. A pressure differential of as little as fifteen pounds per square inch will exert a tremendous gross load, which also must be carried by the welded construction of the upper tube sheet 12 to the shell 10. With the catenary type of construction, no resistance to flexure had to be provided and the tensile strength could be most effectively used, with the resulting thin gauge of material.

While I have shown and described a preferred form of embodiment of my invention, I am aware that modifications may be made thereto and I, therefore, desire a broad interpretation of my invention within the scope and spirit of the de-

scription herein and of the claims appended hereinafter.

I claim:

1. A pressure vessel, a plurality of vertically arranged catalyst tubes therein, vertically arranged tubes for admission of reactants to the catalyst, means attaching the catalyst tubes to the said reactant admission tubes, a deeply dished substantially horizontal tube sheet having when unloaded a catenary cross-section fixedly attached at its periphery to the walls of said pressure vessel, and means attaching said tube sheet to said walls, said tube sheet being of such thickness and flexibility that the full tube load thereon will deform said catenary cross-section into a parabolic cross-section so that the tube load will resolve into substantially tensile stress alone on said tube sheet.

2. A pressure vessel, a plurality of vertically arranged catalyst tubes therein, vertically arranged tubes for admission of reactants to the catalyst, means attaching the catalyst tubes to the said reactant admission tubes, a deeply dished substantially horizontal tube sheet having when unloaded a catenary cross-section fixedly attached at its periphery to the walls of said pressure vessel, and means attaching said tube sheet to said walls, said tube sheet being of high tensile strength corrosion resistant metal and being of such thickness and flexibility that the full tube load thereon will deform said catenary cross-section into a parabolic cross-section so that the tube load will resolve into substantially tensile stress alone on said tube sheet.

3. A pressure vessel, a plurality of vertically arranged catalyst tubes therein, vertically arranged tubes for admission of reactants to the catalyst, means attaching said catalyst tubes to the said reactant admission tubes, a deeply dished substantially horizontal tube sheet for said reactant admission tubes, said tube sheet having when unloaded a catenary cross-section, and means fixedly attaching said tube sheet at the periphery thereof to the inner walls of said vessel, the said reactant admission tubes being connected to said tube sheet for support of the load of all of said tubing by the tube sheet and said tube sheet being of such thickness and flexibility that the full tube load thereon will deform said catenary cross-section into a parabolic cross-section so that the tube load will resolve into substantially tensile stress alone on said tube sheet.

4. A reaction vessel, a plurality of vertically arranged parallel catalyst tubes therein, vertically arranged tubes extending downwardly into said catalyst tubes for admission of reactants to the catalyst, a deeply dished substantially horizontal tube sheet for said catalyst admission tubes within the vessel and over the catalyst tubes, said tube sheet having when unloaded a catenary cross-section, means fixedly attaching said tube sheet at the periphery thereof to the inner walls of said vessel, and means interconnecting all of said tubing and said tube sheet for support of the load of the tubing by suspension from the tube sheet, the tube sheet being of such thickness and flexibility that the full tube load thereon will deform said catenary cross-section into a parabolic cross-section so that the tube load will resolve into substantially tensile stress alone on said tube sheet.

5. A reaction vessel, a plurality of vertically arranged parallel catalyst tubes therein, vertically arranged tubes extending downwardly into said catalyst tubes for admission of reactants to the catalyst, a deeply dished substantially horizontal tube sheet for said admission tubes within the vessel and over the catalyst tubes, said tube sheet being of relatively thin high tensile strength corrosion resistant metal and having when unloaded a catenary cross-section, means fixedly attaching said tube sheet at the periphery thereof to the inner walls of said vessel, and means interconnecting all of said tubing and said tube sheet for support of the load of the tubing by suspension from the tube sheet, the tube sheet being of such thickness and flexibility that the full tube load thereon will deform said catenary cross-section into a parabolic cross-section so that the tube load will resolve into substantially tensile stress alone on said tube sheet.

6. A reaction vessel, a plurality of vertically arranged parallel catalyst tubes therein, vertically arranged tubes extending downwardly into said catalyst tubes for admission of reactants to the catalyst, a deeply dished substantially horizontal tube sheet for said reactant admission tubes within the vessel and over the catalyst tubes, said tube sheet having when unloaded a catenary cross-section, means fixedly attaching said tube sheet at the periphery thereof to the inner walls of said vessel, means interconnecting all of said tubing and said tube sheet for support of the load of the tubing by suspension from the tube sheet, the tube sheet being of such thickness and flexibility that the full tube load thereon will deform said catenary cross-section into a parabolic cross-section so that the tube load will resolve into substantially tensile stress alone on said tube sheet, and a second tube sheet within the vessel and spaced below the said first tube sheet, the first tube sheet delimiting a reactant receiving space thereabove and in communication with the reactant admission tubes, and the first and second tube sheets defining therebetween a vapor receiving space in communication with the upper ends of the catalyst tubes.

7. A reaction vessel, a plurality of vertically arranged parallel catalyst tubes therein, vertically arranged tubes extending downwardly into said catalyst tubes for admission of reactants to the catalyst, a deeply dished substantially horizontal tube sheet for said reactant admission tubes within the vessel and over the catalyst tubes, said tube sheet having when unloaded a catenary cross-section, means fixedly attaching said tube sheet at the periphery thereof to the inner walls of said vessel, means interconnecting all of said tubing and said tube sheet for support of the load of the tubing by suspension from the tube sheet, the tube sheet being of such thickness and flexibility that the full tube load thereon will deform said catenary cross-section into a parabolic cross-section so that the tube load will resolve into substantially tensile stress alone on said tube sheet, and a second tube sheet within the vessel and spaced below the said first tube sheet, the first tube sheet delimiting a reactant receiving space thereabove and in communication with the reactant admission tubes, the first and second tube sheets defining therebetween a vapor-receiving space in communication with the upper ends of the catalyst tubes, and the second tube sheet delimiting a space therebeneath for a heat exchange medium to surround the catalyst tubes.

8. A reaction vessel, means for effecting contact of reactants and a catalyst within said vessel

and including a plurality of vertical parallel tubes within the vessel, a deeply dished substantially horizontal tube sheet for the upper end portions of said tubes, said tube seet having when unloaded a catenary cross-section, means fixedly attaching said tube sheet at the periphery thereof to the inner walls of said vessel, and means to impose upon said tube sheet, in distribution over the area thereof, the combined weight of said tubes and of a quantity of the catalyst, said tube sheet being of such thickness and flexibility that said weight will deform said catenary cross-section into a parabolic cross-section so that said weight will resolve into substantially tensile stress alone upon the tube sheet.

9. The method of supporting a load of catalyst tubing and associated reactant admission tubing from a tube sheet for said reactant-admission tubing within a reaction vessel, which method comprises forming a flexible plate into a deeply dished form having a catenary cross-section when unloaded and deformable by said load to a parabolic cross-section, fixedly attaching the tube sheet at the periphery thereof to the walls of the vessel, distributing said load horizontally and substantially evenly over the vertically projected area of the tube sheet, and connecting the so-distributed load to the tube sheet at points substantially evenly distributed over said area for support of the load by suspension from the tube sheet and for deformation of the cross-section of the latter into a parabolic cross-section, so that the load will resolve into substantially tensile stress alone on said tube sheet.

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