Dec. 21, 1954 R. G. LLOYD 2,697,420

EXPANSION LINKAGE FOR TUBULAR MEMBERS

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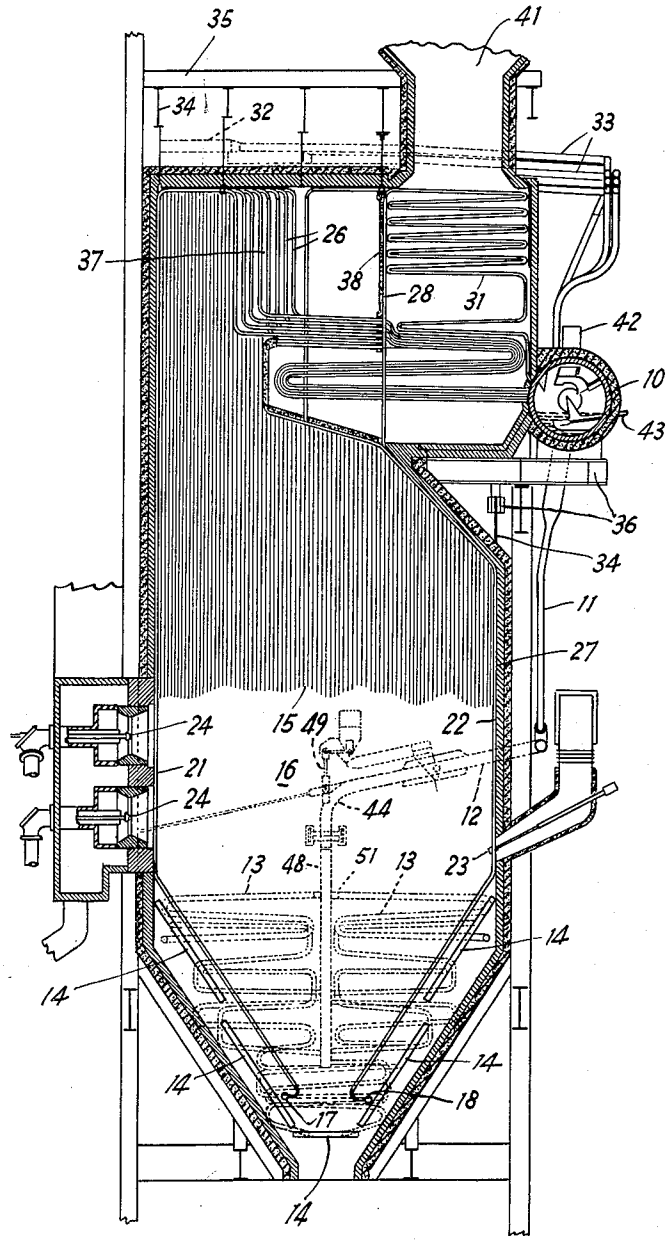


FIG. 1

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FIG. 4

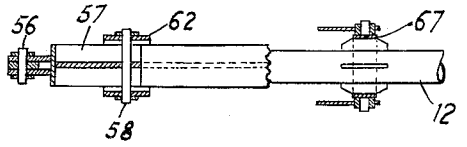


FIG. 2

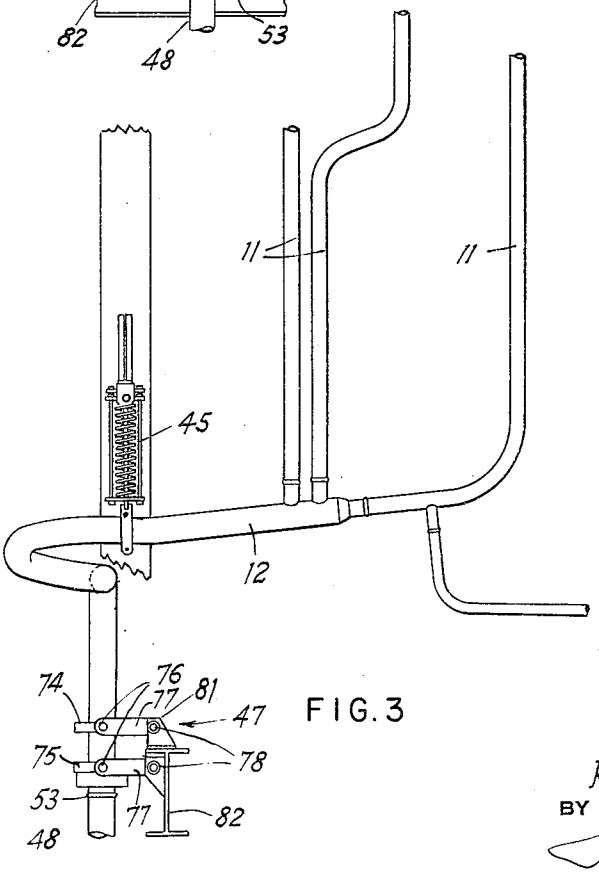


FIG. 3

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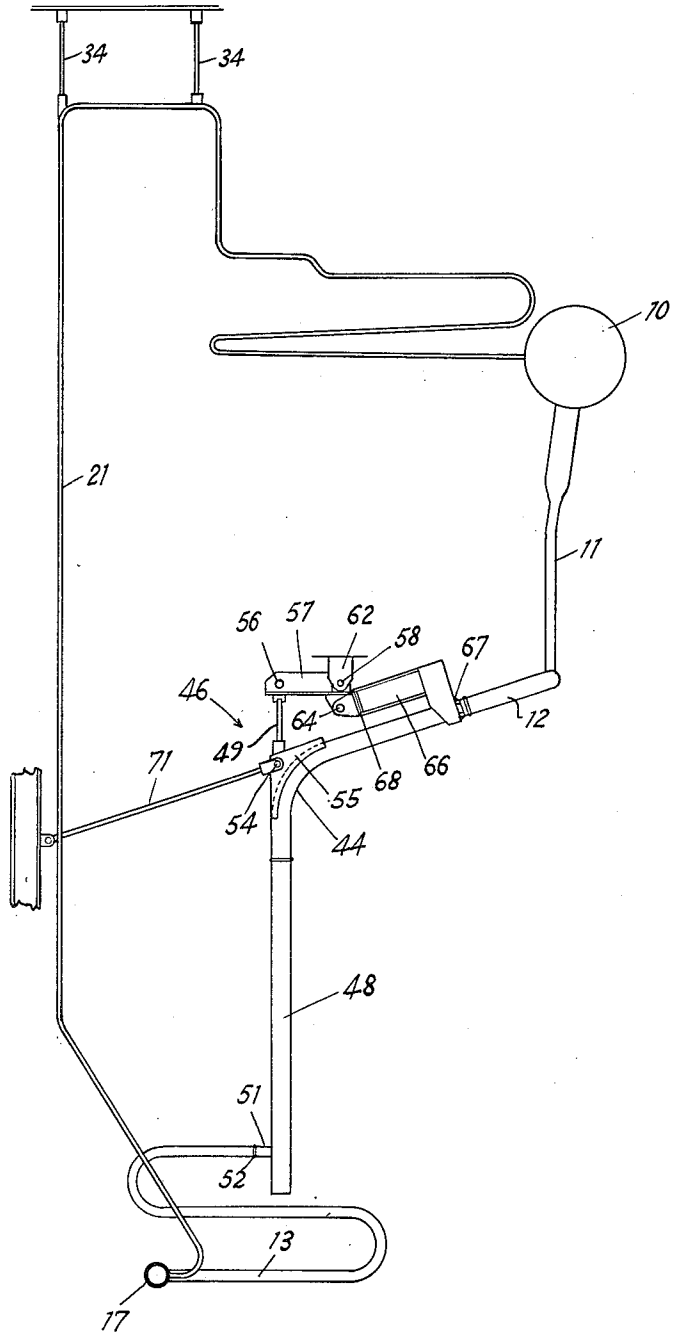


FIG. 5

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EXPANSION LINKAGE FOR TUBULAR MEMBERS

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Application July 12, 1950, Serial No. 173,416

8 Claims. (Cl. 122—4)

The present invention relates to vapor generators, and more particularly to a thermally motivated actuator for driving a tubular element in a predetermined direction and amount in response to temperature changes.

In the majority of vapor generating units, thermal-siphonic fluid circulation through the unit is attained by a difference in the densities in the vapor-liquid mixture in the heated leg of the thermal-siphon, as compared with the density of the liquid in the relatively cold leg of the thermal-siphon system. The cold leg of the system comprises the downcomers from the vapor-liquid drum to the receiving ends of the heated vapor generating riser tube portion, with the riser tube portion providing the heated leg of the system. In order to attain maximum differentials in temperature within the riser and downcomer portions of a thermal circulating system, the downcomer system is customarily formed by downcomer conduits positioned out of direct contact with the heating gas stream.

With a difference in temperature between the vapor generating portion of the circulating system and the downcomer portion, differential expansions in the connected portions result. This differential expansion is accommodated, where it is of an appreciable extent, through the use of tubular expansion bends or loops which are differentially moved under operating conditions interposed between the portions. Such movements involve the development of stresses in the metal of the tubular expansion bends or loops. When the amount of expansion to be provided for is unusually great and the expansion loop is heated to a relatively high temperature under operating conditions, the stresses involved may be higher than is considered acceptable for the high operating metal temperatures.

This problem is accentuated in vapor generators using mercury as the fluid heat transfer medium. Mercury not only has a higher specific gravity than water but also has a boiling or saturation temperature considerably higher than water at the corresponding pressure. For example, mercury at 140 p. s. i. has a boiling or saturation temperature of approximately 975° F., while water at the same pressure has a boiling temperature of approximately 350° F. The stressed expansion loops used in a mercury vapor generator must be arranged so that the stresses in the metal of the loop tubes is within satisfactory stress limitations when operating at the relatively high temperatures.

While it is recognized that adequate provision for temperature expansion may be provided by expansion tube loops having large offsets, such an installation would involve a considerable volume of expensive mercury as well as additional costs from the length of tubing and the necessary provisions for supports and guides.

The present invention is directed to an arrangement of expansion loop tubes coordinated with drive means to cause a predetermined displacement of the tubes at a position intermediate their length, whereby the stresses in the metal of the loop tubes are maintained within desired limits under all operating conditions while keeping the size and character of the loop tubes within reasonable cost limits. The invention is particularly directed to an expansion loop tube system in which the expansion loops are displaced by forces exerted by movements resulting from the heat expansion of a part of the vapor generator with which the expansion loops are associated. The invention is also particularly directed to an expansion loop system component interposed in the downcomer portion of the circulatory system of a vapor generator, whereby controlled displacement of the expansion loops is accomplished by the heat expansion of a portion of the downcomer system before the expansion loops attain the temperature of the expanded downcomer portion.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, its operating advantages and specific objects attained by its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of my invention.

Of the drawings:

Fig. 1 is a side elevation view, in section, of a vapor generating unit incorporating the present invention;

Fig. 2 is an enlarged side elevation view of a portion of the apparatus shown in Fig. 1;

Fig. 3 is an enlarged end elevation view of the apparatus shown in Fig. 2;

Fig. 4 is a section view taken on the line 4—4 of Fig. 2; and

Fig. 5 is a somewhat diagrammatic view of a portion of the apparatus shown in Fig. 1.

The drawings illustrate the application of the invention to a vapor generator in which liquid mercury is vaporized to provide a high temperature vapor fluid for use in a prime mover driving an electric generator or for use in other heat using processes. The invention is not limited to such installations inasmuch as it can be used to advantage in other installations where a controlled movement of one component of a unit by a change in temperature of a related component is accomplished in accordance with a change in temperature of the related component.

As shown in Fig. 1, the mercury vapor generator comprises a vapor and liquid drum **10**, with associated mercury heating and vaporizing tubes which receive liquid mercury from the drum and deliver a mixture of mercury vapor and liquid mercury to the drum. In the vapor generator circuit liquid mercury flows from the drum into six downcomer conduits **11** connected at longitudinally spaced positions along the bottom of the drum. A group of three conduits is connected to a downcomer conduit **12** which extends to one side of the unit and a second group is connected to a second similar downcomer conduit to the other side. Downcomer **12** and its complementary one on the opposite side of the unit delivers liquid mercury through groups of expansion loops, such as **13**, to bottom supply headers **14** for the vapor generating tubes **15** of the side walls of the furnace **16**. Expansion loops corresponding to **13**, but not shown, also extend from downcomers **12** to the supply headers **17** and **18** from which the front wall tubes **21** and rear wall tubes **22** of the furnace **16**, respectively, receive liquid mercury.

The furnace **16** is heated by products of combustion resulting from operation of the low load liquid fuel burner **23** arranged in the rear wall of the furnace or by burners **24**, of the pulverulent fuel type, positioned in the front wall **25**.

The front wall tubes **21** extend upwardly from headers **17** forming the front hopper wall and then vertically along the front wall to the top of the furnace **16** where rearward extensions thereof line the roof. From the roof level the tubes have vertical extensions **26** which are in relatively wide horizontally spaced relationship. The lower ends of the vertical extensions **26** are individually connected to U-loop tubes which are arranged as part of a horizontally extending bank, with the lowermost outlet ends of the individual tubes connected into the vapor space of drum **10**.

The rear wall tubes **22** extend from headers **18** along the rear hopper wall and then vertically along the rear wall **27**. The majority of tubes **22** extend upwardly to a position adjacent the lower end of the vertical extensions **26** where they connect into tube lengths which are associated as U-loop tube banks and open at their outlet ends connected into the vapor space of the drum. A portion of the tubes **22** have extensions **28** to the uppermost level of the unit and then extend downward in a plurality of

serially connected loops 31 to connections into the vapor space of the drum.

The side walls of the furnace are lined with closely spaced tubes 15, the tubes of each wall being divided into five groups, each of which receives liquid mercury from a header 14. Each group of side wall tubes is connected at its upper end to an outlet header 32 from which individual discharge connections 33 extend to the drum space.

In the vapor generating installation disclosed, the upwardly extending heat absorbing elements, comprising the front and rear furnace wall tubes 21 and 22 and their extensions in the convection pass, are top supported by hanger elements 34 from external structural steel members such as 35 and 36. The outlet headers 32 serving the furnace side wall tubes 15 are correspondingly supported by hangers from superadjacent structural steel members. With this arrangement, the expansion of the heat absorbing elements, upon change of temperature, will be in a downward direction, and in the case of a mercury vapor generator will be of a substantial amount inasmuch as the temperature range will be from atmospheric temperature up to a temperature in excess of the saturation temperature of the mercury, as related to the pressure and the temperature differential between the metal wall of the tube and the confined mercury.

The drum 10 is supported by the steel work 36 at an intermediate position in the height of the unit.

Products of combustion generated in the lower part of the furnace 16 from fuel and air introduced by the burners heat the exposed tubular walls of the furnace in their upward travel to the furnace outlet 37 from which they pass over the spaced vertical tube extensions 26, and in a U-shaped path, because of baffle 38 associated with tube extension 28 over the horizontally extending banks and the multiple loops 31, to a gas outlet 41.

The mercury in the front, rear and side walls is heated and caused to circulate due to the thermosyphonic action, delivering a vapor-liquid mixture of high quality to the drum 10. Unvaporized liquid is separated within the drum and flows by gravity into the conduits 11, while the separated vapor is delivered through outlet 42 to a mercury turbine or other user. A feed of liquid mercury to replace that passing from the drum 10 is provided by conduit 43 which receives its supply from the condenser or some similar source of liquid mercury.

The invention, as applied to the above described mercury vapor generator, is utilized in providing a thermally actuated device in conjunction with the expansion loops interposed in the downcomer portion of the circulatory system, so that adequate provision will be made for the differential expansion incurred without subjecting the metal of the loops to unacceptable stress conditions when hot, yet retaining an economical design as regards the utilization of expansion loops and a relatively small volume of mercury charge.

The downcomer system between the drum and the lower supply headers of the furnace wall tubes is shown in detail in Figs. 2, 3 and 4, and comprises a pair of downcomers 12, of which one only is shown in the drawings, and the description will be limited to one. The downcomer 12 extends horizontally with a slight downward inclination alongside the outside of the unit from the rear to a central position relative to the side of the unit, and between that position and a vertically depending portion is provided with a bend 44. The downcomer 12 is provided with three points of support and guidance by a resilient spring hanger 45 adjacent the rear corner of the unit, a vertical loading attachment by a drive member 46 and a parallelogram guide 47 to the vertical depending portion.

The vertically depending conduit portion below the guide 47 includes a manifold section 48 with a plurality of longitudinally spaced integral tube stubs 51 for field attachment by welding to the supply ends of the expansion loops 13 as indicated at 52. The upper end of the manifold section 48 has a field weld attachment as indicated at 53 connecting it to the vertical conduit portion depending from drive member 46. With completion of the aforementioned welds a liquid mercury flow path is provided from the drum 10 to the lower supply headers 14, 17 and 18 of the furnace wall tubes.

As illustrated by Figs. 1, 2, 3 and 4, a linkage arm 49 of the drive member 46 is attached to the bend 44 of downcomer 12 by a pin 54 extending between a pair of plate lugs 55 attached by welding to the arc of the bend 44. The upper end of the linkage arm 49 has an attachment by pin 56 to a horizontally extending arm 57 of a bell crank which is provided with a pin type fulcrum at 58 and has a depending arm 61.

The thermally motivated actuator or drive member 46, for modifying the position of bell crank mounted pin 54 is made up of the hereafter related elements.

The pin type fulcrum 58 is carried by a fixed bracket 62 attached to the structural steel member 63. The depending arm 61 is attached by pin 64 and bolted bracket 65 to a tie member 66 which is built up of steel members and extends substantially parallel to the horizontally inclined section of downcomer 12. The member 66 is attached at a position spaced from pin connection 64 to opposite sides of a collar 67 encircling the downcomer conduit 12 and rigidly fixed thereon. A shim plate 68 of selected thickness is interposed between the bracket 65 and the tie member 66 as a means of adjusting the dimension A between pin 54 and the collar 67.

A guide link 71 extends between the pin connections 54 in the lugs 55 to a pin connection 72 in a fixed structural steel member 73, permitting the pin 54 to move through a relatively flat vertical arc. This serves as a relatively simple guide for movement of the bend 44 of the downcomer 12.

In the assembly of the downcomer conduit parts with the associated expansion loops 13 attached to the lower headers 14, 17 and 18, the length of the depending manifold section 48 of the downcomer below the weld 53 is made of a dimension that it must be moved downward in order to bring the related conduit ends in juxtaposition to complete the weld 53. With the previous connection of expansion loops 13 to the manifold section by welds 52, such a downward movement distorts the expansion loops, tending to close them. This places the metal of the expansion loops under a prestressed condition upon initial assembly.

The parallelogram guide 47 as shown in the drawings has two collars 74 and 75 at longitudinally spaced positions on the depending manifold section 48 of the downcomer conduit. These collars each have pin attachments 76 to corresponding ends of a pair of guide links 77, which are attached by pins 78 to brackets 81 fixed to a stationary structural member 82. The links are of the same lengths between pins, and the pins 76 are the same distance apart as pins 78, so that with any up or down movement of the collar embraced section, it is kept in parallelism as regards its previous positions. The combination of guide link 71 and the parallelogram guide 47 insure a controlled positioning of the depending section of the downcomer 12 irrespective of any vertical movement caused by the drive member 46.

In the normal operation of the mercury vapor generator described, the mercury level is maintained between the bottom of the drum 10 and the elevation at which the conduits 11 are attached to the inlet end portion of the downcomer conduit 12. Even though the mercury level may, under abnormal conditions, attain an elevation within the drum 10, the level of the mercury is always considerably below the top or discharge end of the furnace wall tubes 15, 21 and 22. With such a level relationship, circulation does not take place within the vapor generator until a sufficient proportion of the mercury in the tubes is vaporized so that the vapor-liquid mixture discharges through the convection heated tube extensions 26 or 28 or the side wall discharge connections 33 to the drum 10.

During the period of time when the change of density is being accomplished by the initial burning of fuel, the wall tubes are heated up and expand downwardly from their top supports. This expansion moves headers 14, 17 and 18 downward, and this movement tends to open the expansion loops 13, inasmuch as the manifold section 48 does not move. This opening of the loops modifies the stresses in the loop tubes as previously imposed in the initial prestressing during assembly, as before described, by imposing opposite stresses due to the great extent of the downward movement of the lower headers. The opposite stress inducing movement is of such magnitude as to have this reversed stress minimized upon subsequent downward thermal expansion of the header 12, manifold 48 and loops 13 by rising temperature of the mercury flowing therein.

While the stresses so developed in the metal of the

expansion loops 13 under starting conditions, wherein the wall tubes are expanded and the downcomer is relatively cold due to absence of circulation, may be of an acceptable value while the expansion loop tubes are relatively cold, the stresses would be too high for normal operating conditions when liquid mercury at a relatively high temperature flows through the tubular loops.

A downward flow of relatively cold mercury in the downcomer portion of the system is initiated upon discharge of a mixture of vapor and liquid to the drum from the furnace heat absorbing tubes. The vapor portion of the mixture is separated from the liquid portion and delivered to point of use, while the separated liquid and a feed of liquid mercury from an external source passes into the downcomer system. This mercury liquid is at a relatively high temperature.

As the flow through the downcomer proceeds with the continued generation of vapor, the hot mercury liquid will reach the inclined portion of the conduit 12 at collar 67. As the zone of hot liquid advances from the collar toward the bend 44, the liquid will heat up the metal of the conduit from its initial relatively cold temperature to closely approach the temperature of the liquid, inasmuch as the conduit 12 is suitably covered with heat insulation. The change of temperature causes an expansion and elongation of the heated zone of the conduit so that points on the conduit as measured by dimension "A" under cold conditions are moved further apart, when heated. As the drive member 46 is not subject to a corresponding temperature change, a compensating increase in the dimension "B" between the pin 56 and collar 67 is accomplished by a counter-clockwise rotation of the drive member about its fulcrum pin 58. Counter-clockwise rotation of the drive member moves the pin 54 downward lowering the manifold section 48 and reducing the stresses in the expansion loops 13 as incurred from the previous downward movement of headers 14, 17 and 18. As the hot liquid progressively flows downward from the bend 44 to the lower end of the depending manifold section 48 a further downward stress modifying movement results from the elongation of the section due to its rise in temperature. Thus, the subsequent entrance of hot liquid mercury into the expansion loops 13 has been anticipated by the movement of the manifold section 48 to reduce the stresses in the loops to a value which is acceptable for high temperature operation.

With the described arrangement of a combination of a thermally actuated drive member and a prestressed assembly of the expansion loops when in an unheated condition, the overall range of loop displacement is incurred with tube metal bending stresses changing from a minus value at one extreme to a plus value at the other extreme of movement, with maximum stress values of a character which are but a fraction of the values incurred if such stresses were solely minus or solely plus in character.

While other expedients, as for example by an increase in the tube wall thickness, might be used to obtain a stress condition in the expansion loop tubes which would be satisfactory for the relatively high temperature operating condition, the decrease in flexibility of thicker tubes requires an increase in the offset dimension of the loops and involves higher costs due not only to higher material and fabrication costs, but also because of the increased weight of costly mercury to fill the additional expansion tube volume.

It will be apparent that the movement developed by the thermally actuated drive mechanism of the invention may be directed in an upward direction, if such a direction of the developed thrust is indicated. The drive mechanism of the invention is also applicable to the movement of tubular expansion bends or loops handling high temperature fluids other than heated mercury, and in applications other than in the circulatory system of a vapor generator.

While in accordance with the provisions of the statutes I have illustrated and described herein the best form of the invention now known to me, those skilled in the art will understand that changes may be made in the form of the apparatus disclosed without departing from the spirit of the invention covered by my claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

I claim:

1. In a vapor generator having a top supported vapor generating tube opening to a lower header and to an upper liquid supply drum, the combination comprising a downcomer conduit connected with said drum and having a substantially upright lower end portion ending adjacent said lower header, a flexible tubular expansion loop connecting said downcomer conduit and said header, and thermally motivated means operative to regulate downward movement of the substantially upright lower end portion of said downcomer conduit in response to temperature changes within another portion of said downcomer conduit.

2. In a vapor generator having a top supported vapor generating tube opening to a lower header and to an upper liquid supply drum, the combination comprising a downcomer conduit connected with said drum and having a horizontally inclined portion and an upright lower end portion ending adjacent said lower header, a flexible fluid supply tube connecting said downcomer conduit and said header, and means motivated by thermal changes in the horizontally inclined portion of said conduit to direct and control downward movement of the upright lower end of said downcomer conduit.

3. In a vapor generator having top supported vapor generating tubes opening to lower headers and to a liquid supply drum supported at a level intermediate the height of said tubes, the combination comprising a downcomer conduit connected with said drum and having a substantially upright lower end portion ending adjacent said lower headers, a plurality of prestressed flexible tubes connecting said downcomer conduit and said headers, the fabricated straight line distance between ends of each of said flexible tubes having a selected vertical dimension greater than the vertical spacing between the header and conduit connections of each tube when cold, and a thermally motivated mechanism including a fixed position fulcrum, and a bell crank pivotably connected with said fulcrum and a linkage connected to said bell crank and at spaced positions on said downcomer conduit to position the lower portion of the downcomer conduit downwardly in response to temperature changes in the portion of said conduit between the spaced positions of said mechanism.

4. Apparatus for controlling the thermal movement of an elongated tubular element in response to changes in the temperature of the element, said apparatus comprising a collar attached to said element, a lug longitudinally spaced from said collar and attached to said element, a tie member attached to said collar at one end of the tie member and having an arm portion of the tie member extending generally parallel to said element toward said lug, a pivot pin rigidly supported at a position spaced from said elongated element, a bell crank having a depending arm pivotably connected with said tie member and pivotably attached to said supported pivot pin, and a linkage arm pivotably mounted at its opposite ends to said bell crank and said lug.

5. Apparatus for controlling the thermal movement of an elongated tubular element having a bend intermediate its length, said apparatus comprising a collar attached to said element, a lug longitudinally spaced from said collar and attached to said element at said bend, a member attached to said collar at one end of the tie member and having an arm portion of the tie member extending generally parallel to said element toward said lug, a fulcrum pin supported at a position spaced from said elongated element, a lever arm pivotably connected with said member and pivotably attached to said fulcrum pin, and a linkage arm pivotably connected at its opposite ends to said lever arm and said lug and substantially in alignment with the longitudinal axis of the portion of said element extending beyond said bend remote from said collar and lug.

6. Apparatus for controlling the thermal movement of an elongated tubular element in response to changes in the temperature of said element, said apparatus comprising a fixed fulcrum spaced from said element, a bell crank attached to said fulcrum, a member pivotably attached to a depending arm of said bell crank and its opposite end attached to said elongated tubular element, and a linkage arm having one end pivotably attached to the other arm of said bell crank and depending therefrom with the lower end of said linkage arm pivotably connected with said tubular element at a position longitudinally spaced from the point of attachment of said member and said tubular element, whereby to urge said tubular element downwardly at said position.

7. In a fluid flow system, the combination comprising

an inlet and an outlet conduit, a plurality of flexible tubular expansion loops arranged in parallel with each other and connecting the end portion of said inlet conduit with the outlet conduits for fluid flow respectively therethrough, heating means causing downward movement of said outlet conduit in response to a temperature change within said conduit, and a driving mechanism including a fixed fulcrum positioned externally of said inlet conduit, a bell crank associated with said fulcrum and attached by connecting linkage to spaced positions along and motivated by temperature change within said inlet conduit causing movement of the expansion loop end portion of said inlet conduit.

8. Apparatus for controlling the thermal movement of an elongated tubular element having a bend intermediate its length comprising a collar attached to said element, a lug longitudinally spaced from said collar and attached to said element at said bend, a member attached to said collar at one end and having an arm portion extending generally parallel to said element toward said lug, a fulcrum pin rigidly supported at a position spaced from said elongated element, a lever arm pivotally connected with said member and pivotally attached to said fulcrum

pin, a linkage arm pivotally connected at its opposite ends to said lever arm and said lug and substantially in alignment with the axis of the portion of said tubular element beyond said bend remote from said collar and lug, a guide link arranged to guide the movement of said bend in a flat arc lying in a plane common with the longitudinal axis of said tubular element, and a parallelogram guide attached to said tubular element at a position spaced from said collar and said lug to restrain the movement of said tubular element within the plane of said flat arc.

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