Feb. 22, 1966 M. M. YURKO 3,236,295

HEAT EXCHANGER MOUNTING SYSTEM

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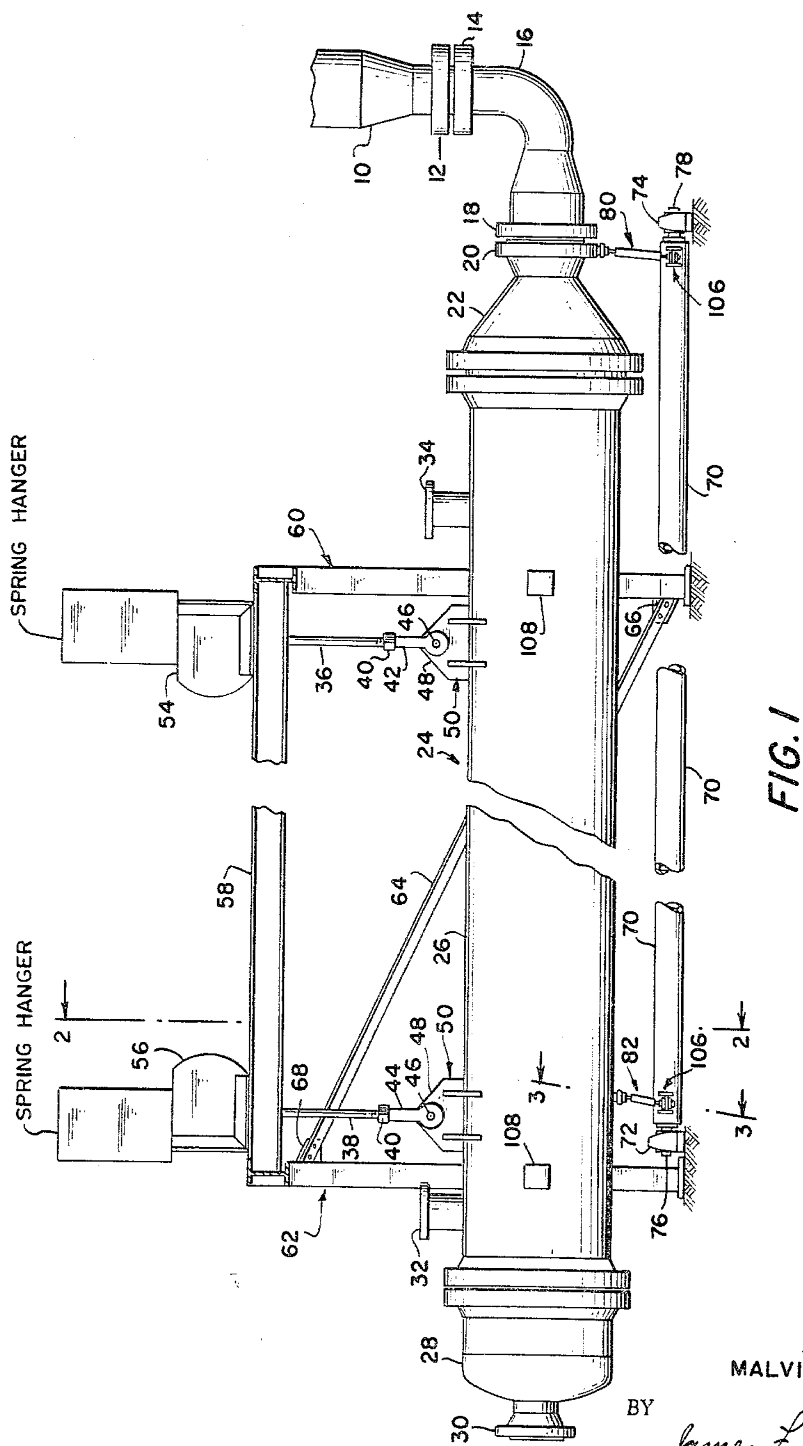

FIG. 1

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FIG. 2

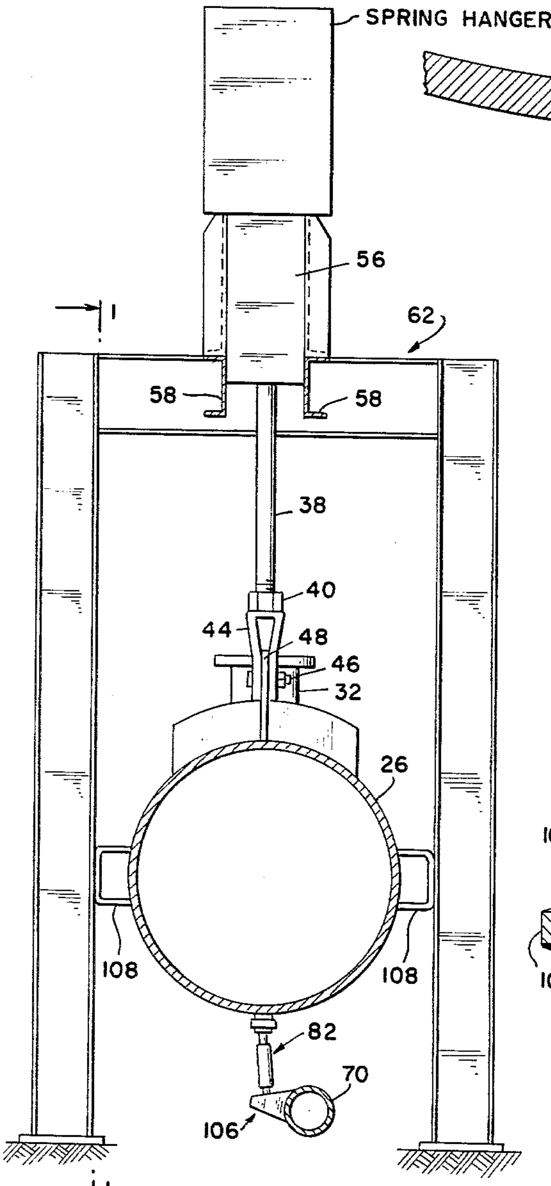
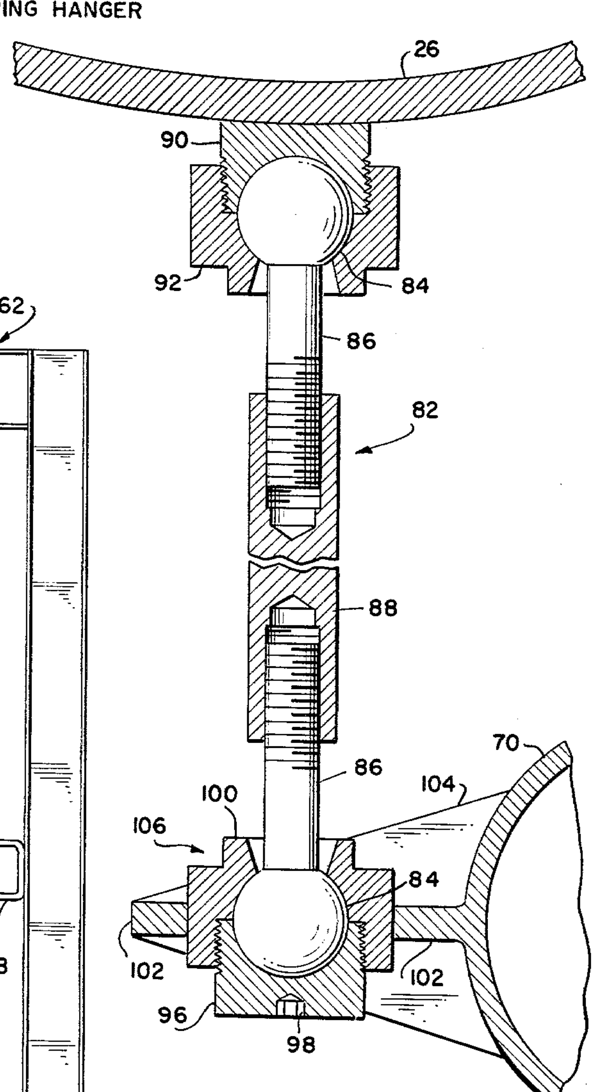


FIG. 3



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HEAT EXCHANGER MOUNTING SYSTEM
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8 Claims. (Cl. 165—67)

The present invention relates to resiliently supported elongated articles that are subject to deflection by transverse forces and are provided with means to convert such deflection into translatory movement. More particularly, it is concerned with heat exchangers intended for use under extreme temperature conditions.

Multitubular heat exchangers for high temperature service have been constructed and mounted in various ways to withstand heavy stresses. Their shells have been suspended from springs in some instances and placed directly on supporting rollers in other situations to allow for the unavoidable elongation and contraction. The practice of disposing the exchanger vertically with a support at only one end, that is, by mounting the bottom end on a fixed base or hanging the top end from a support is also known. This technique leaves the other end free to move and adapt itself to the particular temperature conditions. However, such mountings are of limited utility since they are restricted to vertical orientation of the device and horizontal disposition is often desirable or necessary. In order that the necessary movement of the heat exchanger housings is not hindered by connections for the piping carrying the fluids used in the indirect exchange of heat, it is common to provide expansion loops, swinging pipe joints or other known flexible piping arrangements that permit considerable movement without leakage.

All of the problems created by high temperatures are greatly aggravated in operations involving high pressures and also when corrosive fluids are present. At low pressures, the structural elements of the heat exchange device can often absorb the strains set up by expansion or contraction. This however is not usually the case with high pressures as much more massive equipment with heavy walls is required and such construction considerably increases the magnitude of the stresses developed by temperature changes. Preventing leakage is also a considerably more difficult matter at elevated pressures. With corrosive fluids at high temperatures, the design may be restricted by the necessity or desirability for cooling a corrosive material quickly and thus avoiding lengthy pipe runs which might be required for a flexible piping arrangement.

An object of the invention is to at least reduce the stresses imparted to an elongated article by external forces.

Another object of the invention is to reduce or eliminate bending moments in an elongated article which is subject to deflection by a transverse force.

A further object of the invention is to provide improved heat exchangers with supports especially suited for high temperature service.

Still another object of the invention is to provide supporting apparatus for elongated heat exchangers in which a transverse deflection is converted into a translatory movement.

A still further object of the invention is to provide a mounting system which orients in parallel and also equalizes displacements in an article due to external forces of expansion and contraction.

Yet, another object of the invention is to provide a supporting system for a high temperature heat exchanger so constructed and arranged as to minimize the stresses set up therein by forces of expansion and contraction in an inlet connection to the exchanger.

Other objects and advantages of the invention will be

apparent to those skilled in the art upon consideration of the detailed disclosure set forth hereinafter.

Broadly, the present invention is concerned with a resiliently supported, elongated, fluid-to-fluid type heat exchanger subject to transverse deflection by a force and means for converting such deflection into a translatory movement. In a narrower embodiment, it comprises an elongated heat exchanger resiliently supported at one or more locations and subject to transverse displacement at a first site by external forces of expansion and contraction having at least substantial components perpendicular to the length of said exchanger that tend to produce a bending moment therein, a rigid torsion member and a pluraliy of linkages each engaging both said exchanger and said bar to transversely displace at least one other site on said exchanger in substantially parallel direction and to substantially the same extent as said first site, said other site being substantially distant from the point of application of said forces, whereby translatory movement substantially reduces said bending movement. Other aspects of the invention include linkages of a self-aligning type (especially ball-and-socket joint links) capable of transmitting forces only in directions lengthwise of said linkages, a rigid torsion tube substantially parallel to the axis of a cylindrical heat exchanger and rotatably mounted in fixed bearings, and constant support spring hangers providing resilient supporting forces which remain substantially constant during substantial travel of said hangers.

The device is particularly adapted for use in high temperature service in which a substantial part of said expansion and contraction occurs in a substantially unyielding conduit carrying a heat exchanging medium which conduit is rigidly attached at one end to said exchanger with all other conduits being attached to the exchanger in a manner permitting limited movement of said exchanger.

In a preferred embodiment, the new apparatus is used to cool the extremely hot gaseous effluent or reaction products of the thermal hydrodealkylation of alkyl aromatic hydrocarbons. Such reactions take place at 1200 to 1400° F. the effluent contains substantial quantities of hydrogen and light hydrocarbons, such as methane or ethane together with benzene or naphthalene as the desired product. This reaction effluent is preferably quenched by the injection of a relatively cool liquid aromatic hydrocarbon, such as benzene, which quickly vaporizes and thus cools the gaseous material. However, the heat exchanger mounting of the present invention is suitable for occasions when the quench system is not operating so that the products enter the heat exchanger at 1200 to 1350° F. instead of a customary inlet temperature of about 950° F. for a quenched effluent. These reactions are customarily conducted under a high hydrogen partial pressure which results in total pressures of the order of 500 to 800 pounds per square inch gage (hereinafter abbreviated as p.s.i.g.). While such conditions render it difficult, it is imperative that the equipment be kept pressure tight. Further difficulties are introduced by the fact that hydrogen at high temperatures and pressure is known to embrittle metals and also lower hydrocarbons, such as methane, have a rapid carburizing effect on metals including many types of stainless steels at temperatures of 1350° F. and higher. The heavy walled equipment required is particularly subject to the building up of unacceptably high stresses, especially at joints, from the expansion and contraction of metal components as the system heats up or cools down. Also, some ferrous alloys of high heat resistance have substantially higher coefficients of thermal expansion than carbon steel.

For a better understanding of the noted objects of this invention, reference should be had to the accompanying drawings in which:

FIG. 1 is fragmentary elevation, partly in section, of one embodiment of the present invention taken on the plane 1—1 of FIG. 2;

FIG. 2 is a fragmentary sectional elevation taken on the plane 2—2 in FIG. 1 with the internal components inside the shell of the heat exchanger omitted for simplicity; and

FIG. 3 is a fragmentary sectional view of a connecting linkage taken on the plane 3—3 of FIG. 1.

For greater clarity a number of conventional features have been omitted from the drawing including heat transfer tubes, piping connected to the heat exchanger and a variety of fastenings, such as weldments, studs, rivets, bolts and nuts.

Turning now to FIG. 1, the outlet fitting **10** of a thermal hydrodealkylation reactor terminates in a flange **12** which mates with and is securely bolted to the inlet flange **14** of an elbow fitting **16** by bolts. The other end of the elbow is of expanded diameter in order to provide space for a lining of refractory cement without constricting the passageway therethrough. The exterior of this outlet flange **18** is at a considerably lower temperature than the inlet flange **14** by reason of that insulation. Flange **18** is securely fastened by bolts to a matching flange **20** of the inlet header **22** of the horizontally disposed indirect heat exchanger **24** of the well known tube and shell type. For this severe service, the inlet header **22** is also insulated on the inside with a layer of refractory cement. The interior of the header **22** is in open communication with the interior of the bundle of tubes within the cylindrical shell **26** which for the purposes of this particular illustration may have a length of about 20 feet and a wall thickness of about 1.2 inches. The outlet end of the tube bundle communicates with the outlet header **28** which is provided with an outlet flange **30** which is bolted to the flange of an outlet line of a flexibilized piping arrangement designed to permit either horizontal or vertical movement, including longitudinal movement of the flange **30** without creating excessive reaction forces. For convenience in maintenance including the cleaning and replacement of tubes in the bundle, the headers **22** and **28** are each provided with a flange which may be detachably bolted to a corresponding flange at each end of the shell **26**.

Flanged inlet and outlet connections **32** and **34** for the other cooler fluid heat exchange medium are provided on shell **26**. These fittings communicate with the interior of the shell and the exterior of the heat exchange tubes therein. In the instant embodiment, this cooler medium is the preheated charge for the dealkylation reactor and comprises toluene vapor and hydrogen. As in the case of the piping connected to flange **30**, the temperature of the gaseous stream passing through inlet and outlet fittings **32** and **34** is far below that of the reaction effluent in elbow **16**, accordingly expansion loops or other flexible piping arrangements are employed in the lines connected to the fittings **32** and **34** to provide for a longitudinal or vertical movement of these fittings without undue resistance, that is without creating high reaction forces.

The heat exchanger is suspended from two hanger rods **36** and **38** which are threaded at their lower ends and equipped with lock nuts **40** to permit adjustment to proper lengths in their engagement with the clevis fittings **42** and **44** respectively. The clevises in turn are pivotally connected by the pivot pins **46** which engage the pad eyes **48** of the suspension brackets **50** which are spaced a substantial distance apart on the shell **26** and welded thereto securely in such manner as to distribute the load over a considerable area of the shell in each location. The upper ends of the rods **36** and **38** are pivotally connected by pivots (not shown) in parallel alignment with the pins **46** of the constant support spring hanger assemblies **54** and **56** respectively.

Constant support spring hangers, as exemplified by the Fig. 80–V, type E, model R hangers manufactured by the Grinnel Company, are well known suspension mechanisms that allow substantial travel or deflection of the hanger rods without the substantial increase in the force exerted by those hangers in contrast with a simple spring. With the constant support type of spring hangers properly adjusted for a given load, it is only necessary to apply a force to the hanger rod which is sufficient to overcome the frictional resistance of these hangers in order to move the hanger rod a substantial distance up or down. Such frictional resistance typically is of the order of only about 3 to 6% of the supporting force being exerted by the constant support spring hanger.

These spring hanger assemblies are securely fastened to the longitudinal beams **58** which extend between the supporting frames **60** and **62** which are desirably located adjacent each of the constant support spring hangers **54** and **56** and securely fastened to concrete foundations. To enhance the rigidity of the overall structure a tie member **64** of angle iron or a channel is fastened by rivets or bolts to the brackets **66** and **68** which are attached to the frame members **60** and **62** respectively.

In most instances, it is desirable to support the heat exchanger at two widely spaced points using a constant support spring hanger for each point. However, it is possible to support the heat exchanger illustrated with a single such spring hanger of adequately larger size. This could be accomplished by placing the hanger about midway between hangers **54** and **56** along the girder **58** and pivotally attaching thereto rods threaded into clevises **42** and **44**, which rods would replace rods **36** and **38** and would be sufficiently longer to permit the desired connection.

The exchanger may also be supported from a single bracket **50** and hanger rod attached to a single constant support hanger. In this case, the supporting bracket should desirably be in line with or closely adjacent to the point of balance or center of gravity of the entire heat exchanger. In the case of larger and heavier heat exchangers, it would often be desirable to support these from three or more locations therealong from hangers of the nature described in order to minimize the bending stresses resulting from the dead weight of the heat exchanger itself.

Beneath the heat exchanger is located the rigid torsion or torque tube **70** rotatably supported parallel to the excess of the heat exchanger in ball bearing pillow block **72** of the thrust resisting type and one or more other bearing blocks **74** of a type that permits axial movement of the tube **70**. Additional bearing blocks **74** may be provided as deemed necessary to avoid significant deflection of the torsion tube **70**, especially in the vicinity of the links. All of the bearings are secured to foundations in such manner as to eliminate appreciable deflection under heavy loads.

While it is contemplated that the bearing blocks may fit around the circumference of the torque tube **70**, in the embodiment illustrated the journals **76** and **78** are depicted as coaxially mounted in the ends of tube **70** by welding two annular discs onto the journal at the end and the middle of the journal's length, inserting the end disc inside the tube and welding the center disc to the end of the tube **70**.

Near the ends of tube **70** are also located the links **80** and **82** of somewhat different lengths and of the construction shown in FIG. 3. These links are ball-and-socket joint connectors in which the balls **84** integrally mounted on the threaded rods **86** have a spacing adjustment therebetween in the form of an internally threaded barrel **88** that engages both upper and lower rods **86**. While a barrel of the turnbuckle type with opposing threads is preferred for simplicity of adjustment, the threads may run in the same direction as the balls may be rotated in the sockets to permit individually adjusting the exposed length of each rod **86**.

The upper socket is made up of the fixed externally threaded base **90** engaging the rotatable internally threaded collar **92** which is rotatable to adjust the fit of the ball and socket and joint. The base member **90** of link **80** is welded to the lowest part of the inlet flange **20**. This flange is the point of application of the heaviest external forces applied to the heat exchanger as a result of expansion and contraction. The same element of link **82** is welded to a substantially distant point on the bottom of the heat exchanger shell **26**. This point of adjustment is desirably near the other end of the shell and also adjacent to a resilient supporting member such as the pivoted rod **38**.

The lower socket is composed of two similar numbers, but the adjustment is reversed here as internally threaded base component **96** is rotatable to adjust the socket to a proper fit on ball **84** and a hexagonal socket **98** is provided therein to permit a hexagonal bar to engage and rotate the base number **96**. The collar socket member **100** is fixedly attached by welding or other suitable means to the web **102** of a crank arm assembly comprising the web **102** projecting from the torsion tube **70** to which it is welded. At each side, the substantially horizontal web web **102** is welded to the two vertically disposed tapering side flanges **104** which also project from the circumference of torsion tube **70** and these flanges are also securely welded to the tube in making up the crank arm assembly **106**.

Referring again to FIG. 2, the lugs **108** are welded onto the exterior of shell **26** adjacent each set of columns in the framing structures **60** and **62**. The cooperation of these lugs with the interior faces of the columns limits the permissible side play or transverse horizontal displacement of the heat exchanger.

The present invention is directed chiefly to alleviating the stresses set up by the vertical displacement of one end of heat exchanger **24**, particularly in the joints at flanges **20** and **14**. With a dealkylation charge stream entering inlet connection **32** at 400° F., the longitudinal thermal expansion from the center of flange **12** to the support rod **38** is 1.0 inch when operating with a quenched hot medium and 1.9 inches for an unquenched medium Although these movements are greater than the vertical displacements, they do not impose as severe stresses on the heat exchanger per se. The pivotal mounting of rods **36** and **38** and flexible piping connections readily permit this longitudinal displacement without setting up undue reaction forces and thus overstressing the joints at flanges **20** and **14**.

The smaller vertical displacement of flange **20** amounting to 0.53" for quenched effluent products and 0.89" for an unquenched dealkylation effluent produces unacceptable bending moments in the heat exchanger unless there is an equivalent downward movement of support rod **38**. Such moments generate excessive stresses which are concentrated in the joints at flanges **14** and **20**. To avoid overstressing these joints it is essential that the entire heat exchanger be moved downward as the system is heating up or upward as it is cooling down in substantially translatory movements—that is the displacement of the entire heat exchanger without any rotational movement. The transverse deflection of one end of the exchanger downward or upward creates this overstressing. In the movement of the resiliently suported heat exchanger, the right constant support spring hanger rod **36** moves downward or upward under the influence of this deflection, but there is no substantial movement in the left hanger rod **38** unless a device such as that of the present invention is employed.

The operation of the present invention eliminates, or at least substantially reduces, the bending moments which overstress the joints at flanges **14** and **20**. This is accomplished by transmitting said deflection forces to one or more sites on said exchanger substantially distant from the point of application of said deflecting forces to the exchanger and said forces are transmitted through the links, crank arms and the torsion tube which is rotatable about a fixed axis.

In the drawings, the equipment is depicted at atmospheric temperature and it is to be noted that both links **80** and **82** are out of plumb, that is not vertically oriented, in either a transverse plane or a longitudinal plane. This is due in part to the position of the crank arms attached to the torsion tube, which is about 5° above the horizontal. As the system heats up during operation, the heat exchanger expands longitudinally and also is displaced in a direction away from inlet elbow **16**. Simultaneously, the inlet flange **20** of the heat exchanger is moved downward by combination of forces resulting from the downward expansion of the lower section (not shown) of the reactor below its supporting skirt and the downward expansion occurring in inlet elbow **16**. This downward movement of the inlet flange **20** pushes down on the link **80** rotating the torsion tube **70** about 5° and thereby moves the crank arm web **102** into a horizontal position. Such rotation pulls downward on the other linkage member **82** attached ot the bottom of the exchanger near the other end a distance equal to the movement of ball-and-socket link **80** and in a direction that is parallel and substantially equal to that movement for practical purpose.

It will be appreciated that the ball-and-socket construction of these connecting members not only renders them self-aligning under all circumstances but also enables them to transmit only those components of forces which are parallel to the links, without any side thrust. This is particularly desirable in view of the eccentricity of the loadings in the embodiment illustrated.

At normal operating temperature with a quench in use, both linkage members are plumb and the same effects can be attained for operations in which an unquenched reactor effluent is cooled by simply increasing the deviation or deflection from the vertical of these linkages at atmospheric temperature to a proportionately greater extent based on the expansion displacements stated hereinbefore.

The force transmitted to the torque system is directly proportional to the downward thrust force at flange **20** and is far greater than necessary to move the hanger rod **38** down the same distance as said flange.

In the present invention, one of the linkages is pushed or subjected to a compressing force while the other one, in fact all others if more than two linkages are used, is pulled or subjected to tension. It is of no importance whether the deflecting force is applied in compression or tension, and the same is true for the other linkage or linkages which exert the force which produces the necessary translatory movement. For example, the torsion tube may be located above the heat exchanger and a tension link connecting said tube with the top of inlet flange **20** may be used in combination with a compression link that applies the correcting forces to the opposite end of the heat exchanger.

Despite the relatively large size of the equipment involved, it is important to reduce play or lost motion to the practical minimum in the support system described. For example, it is desirable that the flange **20** should not move more than a few thousandths of an inch before the link **82** commences to move that end of the heat exchanger downwardly. Several features may be utilized in accomplishing this. It is desirable that a tube be employed as the torsion member in place of a solid bar, because for a given weight of metal, the tubular construction is of much larger diameter than a bar and, therefore, offers distinctly greater resistance to transverse deflection and also to the absorption of twist by the torsion member. As an example of a suitable size of torsion tube for a heat exchanger with a shell about 20 feet long, a pipe with an external diameter of 6.63 inches is distinctly superior to a 2.66 inches diameter solid torsion bar of equal weight from a standpoint of rigidity. To minimize transverse displacement of the tube, it is highly desirable to have a bearing for the tube located relatively close to each linkage between the tube and heat exchanger. Also, it is recommended that the ball-and-socket joints be machined to essentially zero clearance and "worked in" with a fine lapping compound to obtain a non-binding fit with very little play. These joints are desirably lubricated with a suitable high temperature, dry lubricant.

For minimum play in this system, it is desirable to preload or impose a slight torque on the system of the present invention in order to take up any play in the linkages as well as any twist absorbed by the torsion tube. This preloading torque should, of course, be directed in the same direction as the expected movement under the external force.

In the specific embodiment of the invention in the drawings, it is apparent that the connecting linkages need not be equal length to produce the necessary translatory movement of the entire heat exchanger. However, the torsion tube crank arms are of the same length inasmuch as the displacement or distance traveled must be the same for all linkages.

While the present invention has been illustrated by means of one specific embodiment, it will be apparent to those skilled in the art that the invention is not limited to single structure nor solely in application to supporting heat exchangers. For instance, the same system could obviously be utilized in supporting reactors, condensers, etc. Accordingly, it is not to be inferred that the invention is limited in any other respect than the clear import of the appended claims or as may be required by the prior art.

I claim:

1. A resiliently supported, elongated, fluid-to-fluid type heat exchanger subject to transverse displacement at a first site thereon by an external force having at least a substantial component perpendicular to the length of said exchanger that tends to produce a bending moment therein, a rigid element, and a plurality of members each engaging both said exchanger and said rigid element to transversely displace at least a second site on said exchanger to substantially the same extent as said first site, said second site being substantially distant longitudinally from the point of application of said force whereby translatory motion at least substantially reduces said bending moment.

2. An elongated, fluid-to-fluid type heat exchanger resiliently supported at a plurality of locations and subject to transverse displacement at a first site in response to external forces resulting from expansion and contraction and having at least substantial components perpendicular to the length of said exchanger that tend to produce a bending moment therein, a rigid torsion member and a plurality of linkages each engaging both said exchanger and said torsion member to transversely displace at least one other site on said exchanger in substantially parallel direction and to substantially the same extent as said first site, said other site being substantially distant longitudinally from the point of application of said forces whereby translatory motion at least substantially reduces said bending moment.

3. A device according to claim **2** in which said linkages are of a self-aligning type capable of transmitting forces only in directions lengthwise of said linkages.

4. A resiliently supported, elongated cylindrical, fluid-to-fluid type heat exchanger which is subject to deflection at a first site thereon by external forces resulting from expansion and contraction and having at least substantial components perpendicular to the longitudinal axis of said exchanger that tend to produce bending moments therein, at least one constant support spring hanger connected to said exchanger to provide a resilient supporting force which remains substantially constant during substantial travel of said hanger, a rigid torsion member substantially parallel to said exchanger axis and rotatably mounted in fixed bearings, a plurality of links each engaging both said exchanger and said torsion member to transmit said deflecting forces to at least one other site on said exchanger substantially distant longitudinally from said first site whereby translatory motion at least substantially reduces said bending moments.

5. A resiliently supported, elongated cylindrical, fluid-to-fluid type heat exchanger which is subject to deflection at one end by external forces resulting from expansion and contraction and having at least substantial components perpendicular to the longitudinal axis of said exchanger that tend to produce bending moments therein, a plurality of constant support spring hangers connected to said exchanger at a plurality of locations to provide resilient supporting forces which remain substantially constant during substantial travel of said hangers, a rigid torsion tube substantially parallel to said exchanger axis and rotatably mounted in fixed bearings, at least two substantially separated ball-and-socket joint links each connected both with said exchanger and with said tube whereby said deflecting forces displace a first said link in applying torques to said tube that displace a second said link in substantially parallel direction for substantially the same distance as said first link to provide translatory movements which at least substantially reduce said bending moments.

6. A device according to claim **5** supported for longitudinal movement by pivotal connections between said springs and said exchanger.

7. A device according to claim **5** in which at least a substantial part of said expansion and contraction occurs in a substantially unyielding conduit for a heat exchanging medium, said conduit having one end rigidly attached to said exchanger and all other conduits for heat exchanging media are attached to said exchanger by means so disposed and arranged as to permit limited movement of said exchanger.

8. A device according to claim **5** in which at least one of said links is adjustable in length and said adjustable link is adjusted to apply a longitudinal twist to said tube when the device is at atmospheric temperature, which twist is in the same direction as the twist applied during expansion and is sufficient to eliminate substantially all lost motion from said tube and links.

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