# United States Patent [19]

**Travis**

[11] **3,836,015**

[45] **Sept. 17, 1974**


[54] **TUBE BUNDLE EXTRACTOR**


[76] Inventor: **Bobby J. Travis,** 345 Mayhaw St., Vidor, Tex. 77662



[22] Filed: **Mar. 29, 1973**

[21] Appl. No.: **345,854**

[52] **U.S. Cl.** ..... **214/1 P,** 29/202, 214/16.4 R, 254/105

[58] **Field of Search**..... B66f/1/00; 214/1 P, 1 PA, 214/16.4, 730; 29/202; 254/29, 30, 105; 294/86 TS, 78 A



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 1,204,821 | 11/1916 | Rosner | 214/1 P X |
| 3,075,664 | 1/1963 | Collings | 294/86 LS X |
| 3,180,498 | 4/1965 | Postlewaite | 214/1 P |
| 3,510,012 | 5/1970 | Van Meteren | 214/1 P |
| 3,567,044 | 3/1971 | Travis | 214/1 P |
| 3,695,460 | 10/1972 | Borriello | 294/86 LS X |



*Primary Examiner*—Frank E. Werner
*Attorney, Agent, or Firm*—Roy H. Smith, Jr.



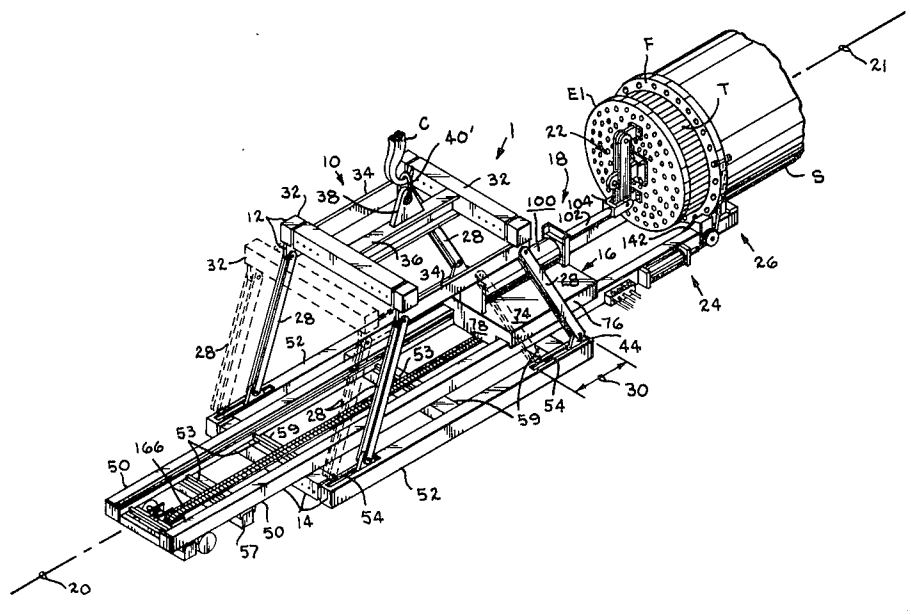
[57] **ABSTRACT**

A tube bundle pulling or pushing mechanism consisting of an elongated framework adapted to be suspended from a crane hook and including a pair of rails which support the tube bundle and a car movable along the rails to pull or push the bundle. The framework consists of two parts shiftable with respect to one another, one part being a base frame including the rails, crossbeams supporting the rails and extending to either side of them, and a pair of longitudinally extending outrigger beams joining the ends of the crossbeams. The outrigger beams are holow, and slidable within each is a link beam having ears at both ends projecting upwardly through longitudinal slots in the outrigger beam.

The sliding beam belongs to the second part of the framework, the cradle, which further includes vertical tension bars joining the four ears at their lower ends and connected to a rectangular superstructure at their upper ends. The superstructure also includes a brace supporting an eye member which receives a crane hook. A pair of linear actuators disposed on the outrigger beams and having their pistons connected to the sliding beams permits the cradle to be moved relative to the base frame.

Also disclosed are novel means for connecting a pulling member which is offset from the center of a bundle of U-tubes to the end sheet of such bundle through a cluster of holes at the center of the end sheet; novel and remotely controlled means for both aligning the extractor with the heat exchanger shell and securing abutting ends of the two structures together against vertical loads; novel means for clamping such two ends together to prevent relative longitudinal movement; improved means for adjusting the width of the extractor to accommodate tube bundles of various diameters; new and improved means for remotely and safely controlling a set of dogs which depend from a movable car and selectively interlock the car with the base frame; and a plurality of auxiliary power means for moving the car along the rails relatively rapidly, after the prime mover on the car has done the major job of breaking loose from a heat exchanger a tightly fitting bundle of tubes.


**14 Claims, 23 Drawing Figures**



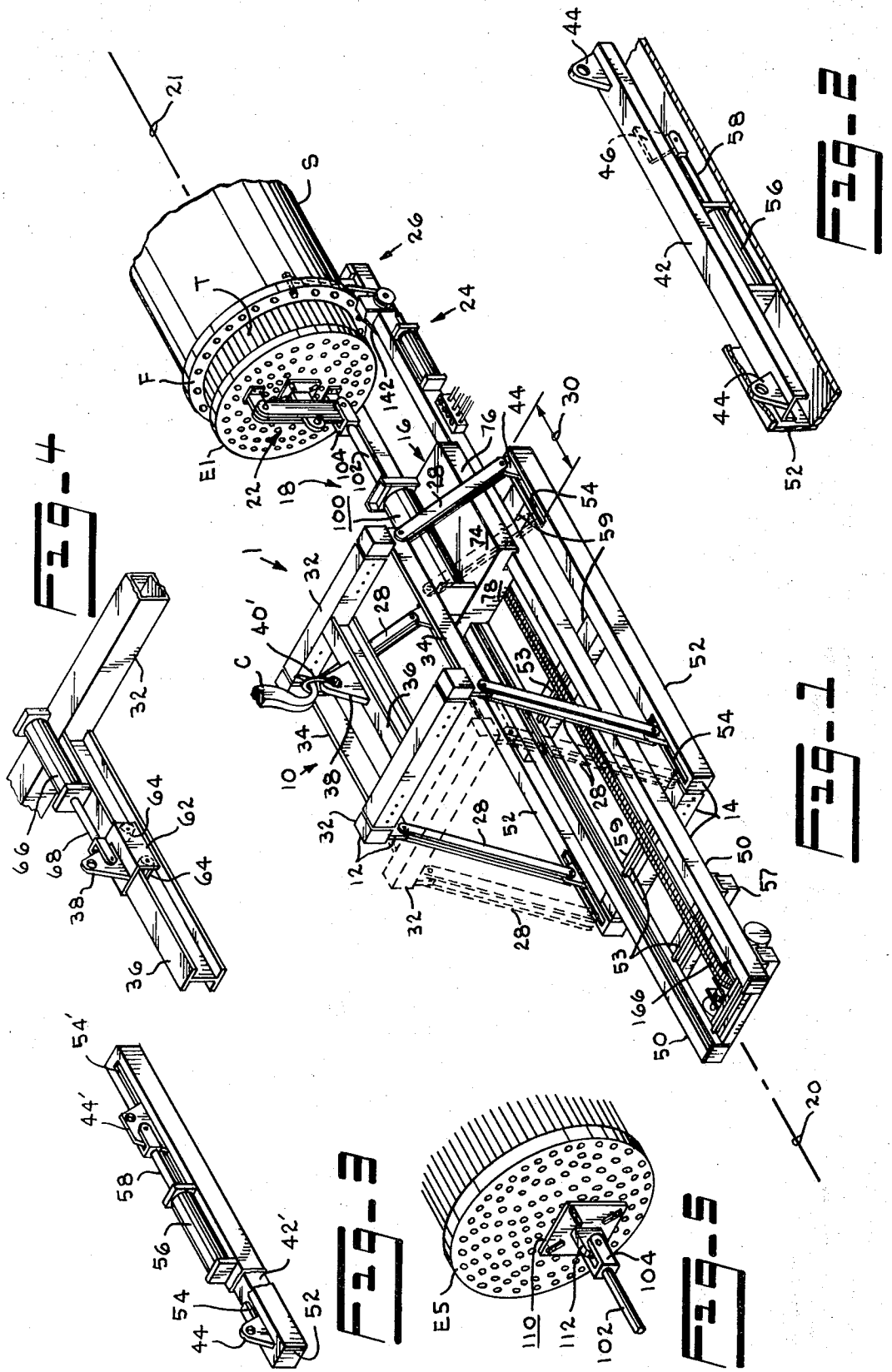



FIG-1

FIG-2

FIG-3

FIG-4

FIG-5

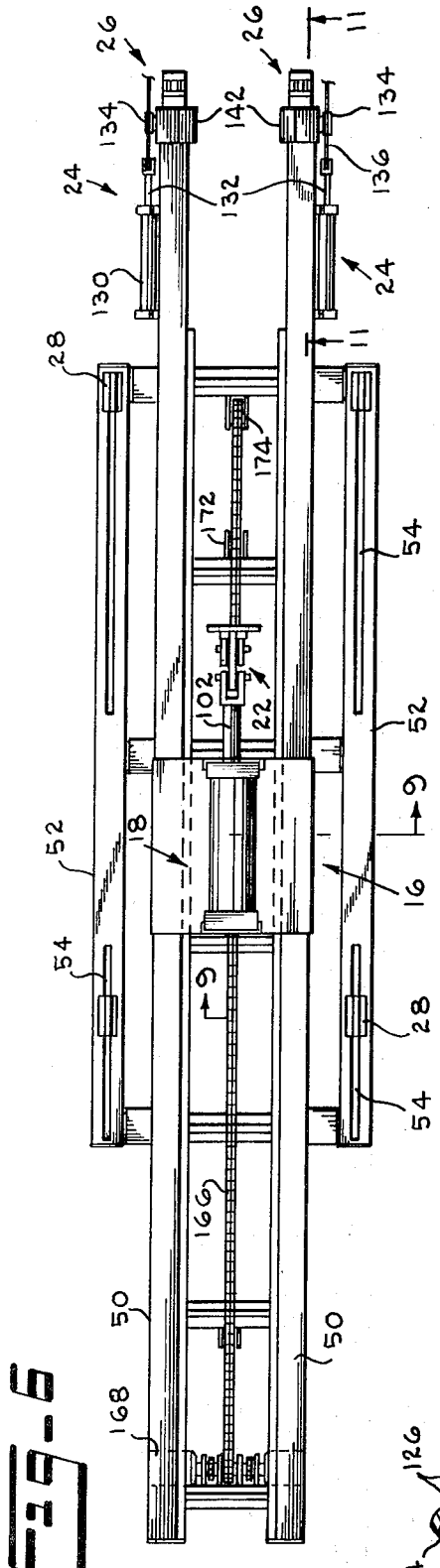


FIG. 6

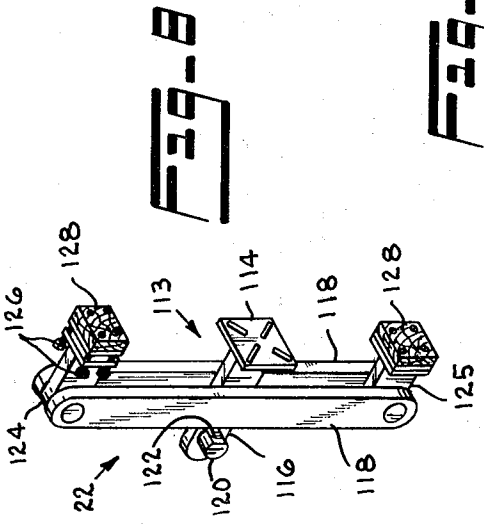


FIG. 8

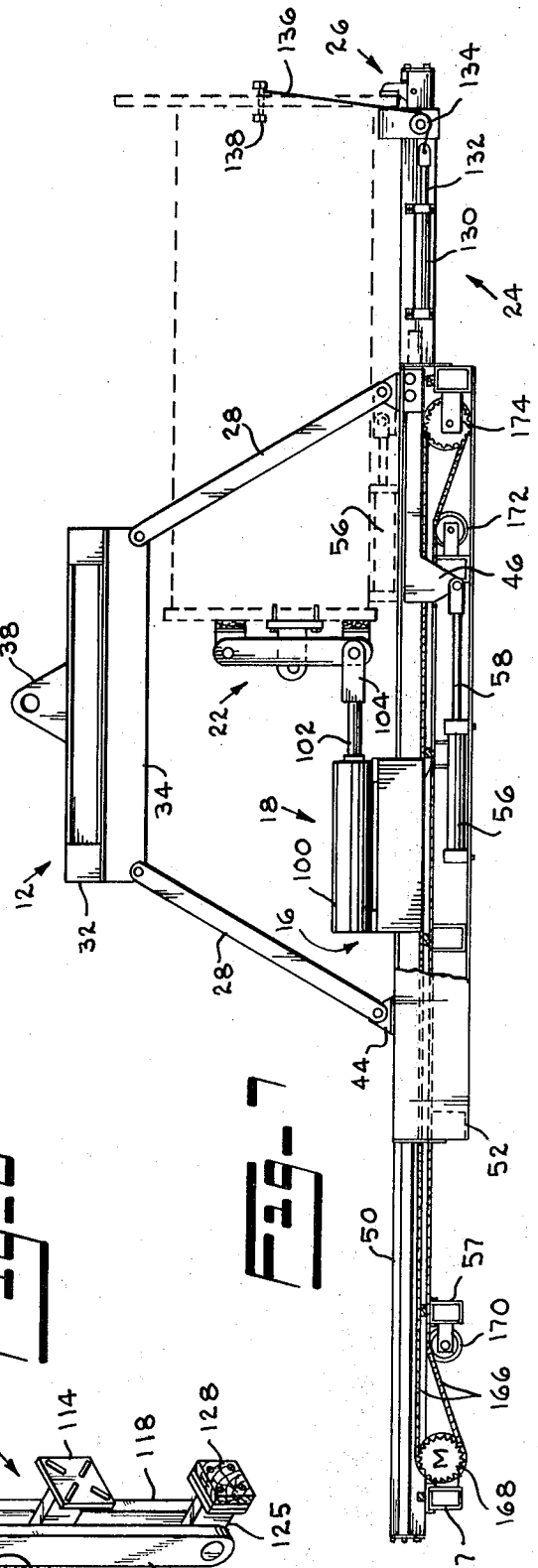


FIG. 7

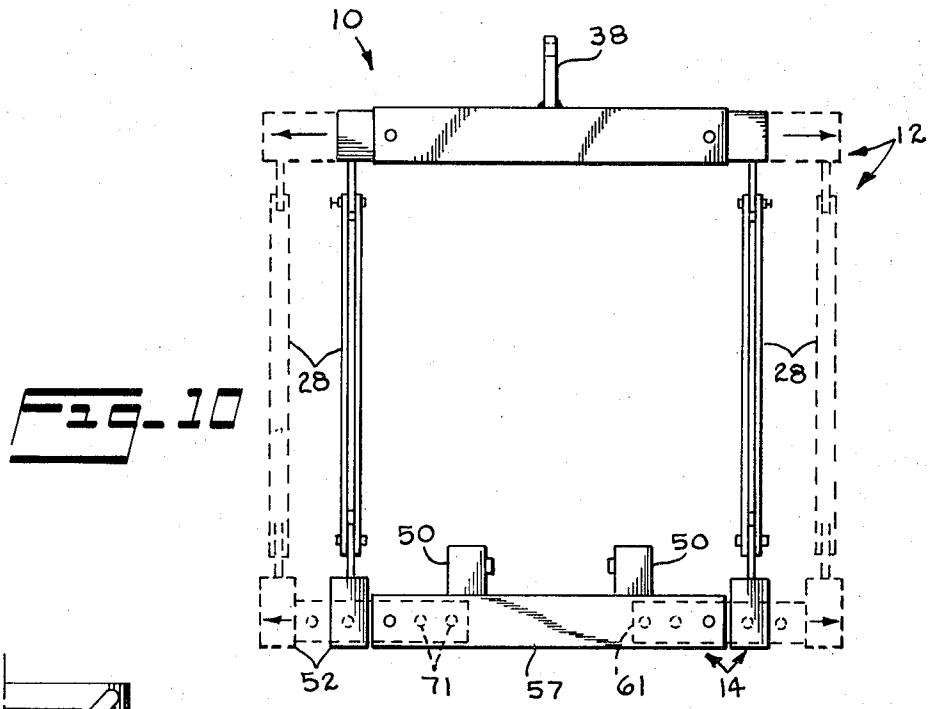

10
38
12
28
28
50
50
52
71
57
61
14

Fig. 10

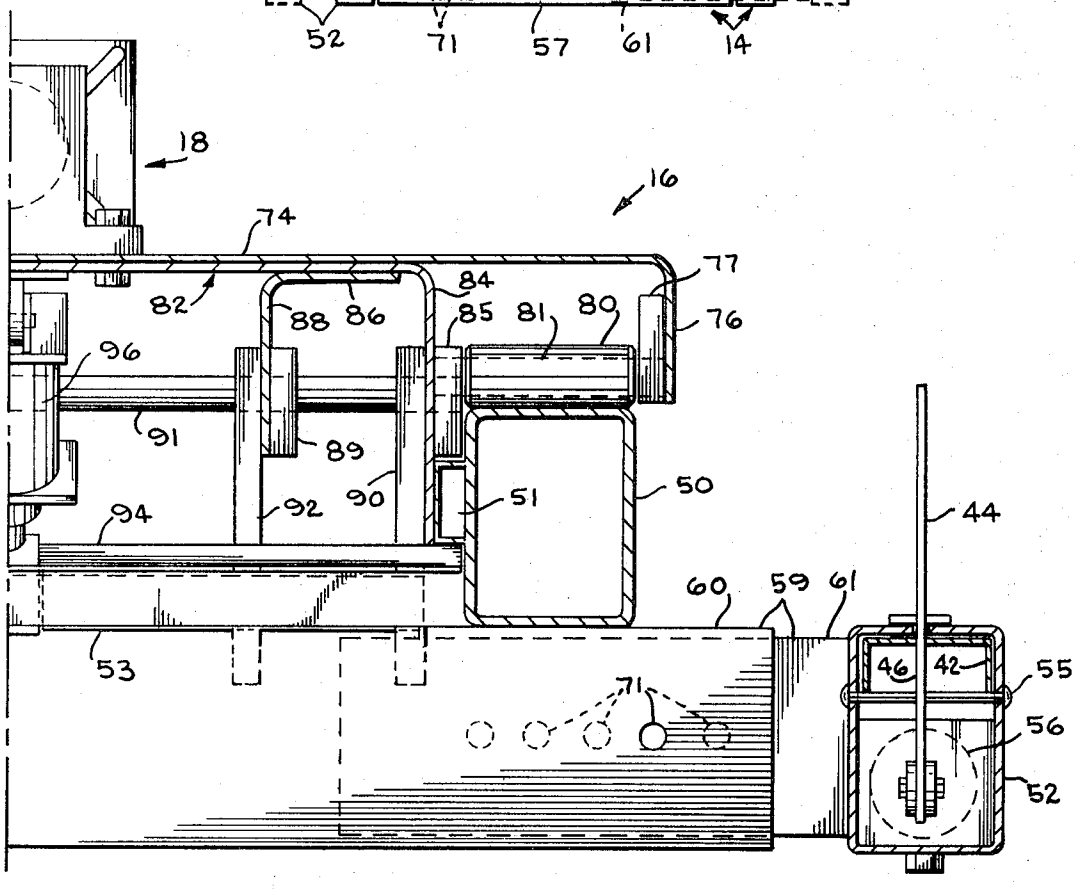

18
16
74
77
82
84
88
86
85
81
80
76
96
91
89
90
92
94
51
50
44
60
59
61
53
71
46
42
55
56
52

Fig. 9

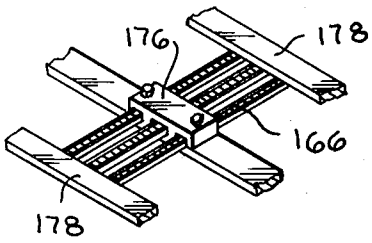



Fig_15

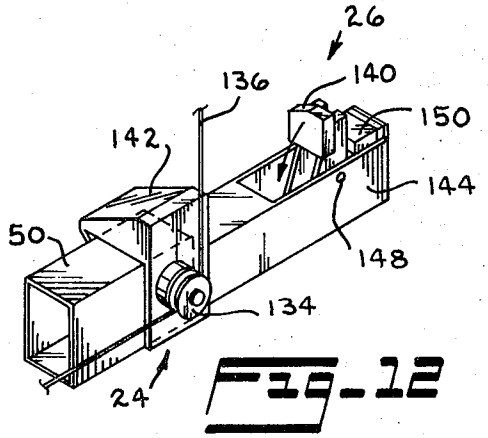



Fig_12

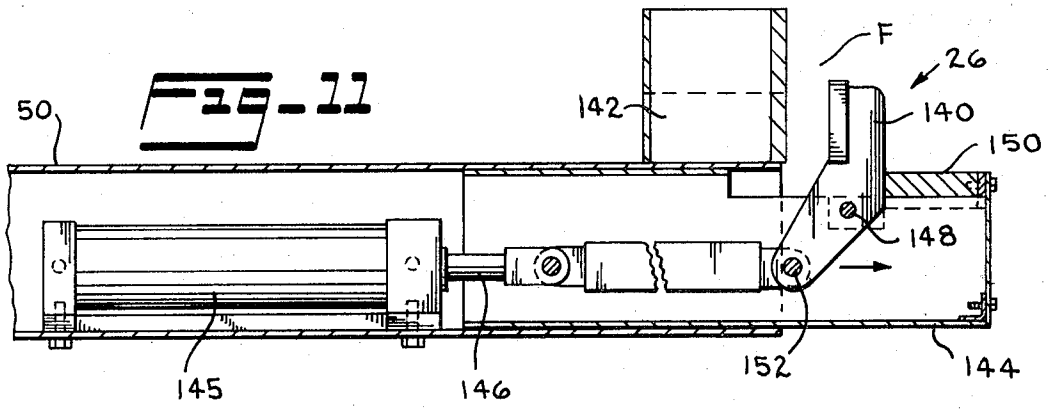



Fig_11

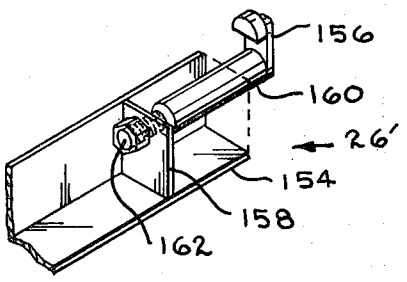



Fig_13

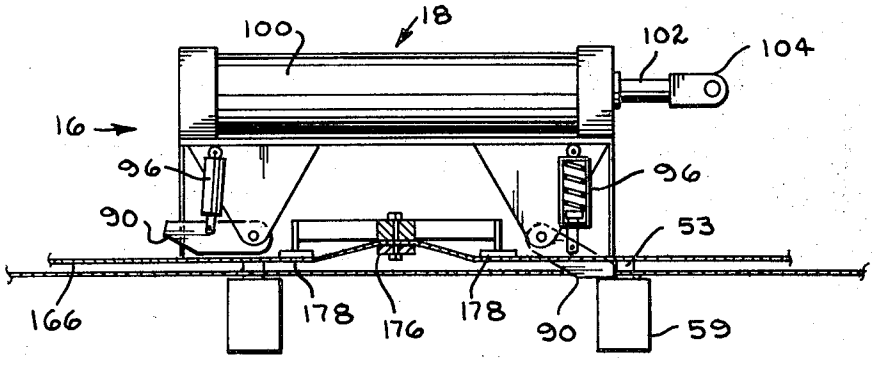



Fig_14

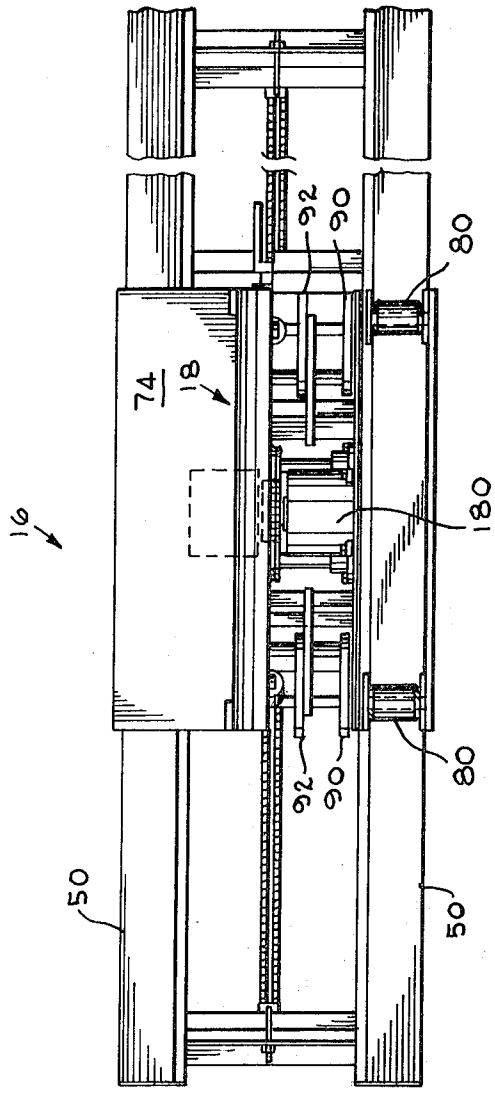



FIG. 17

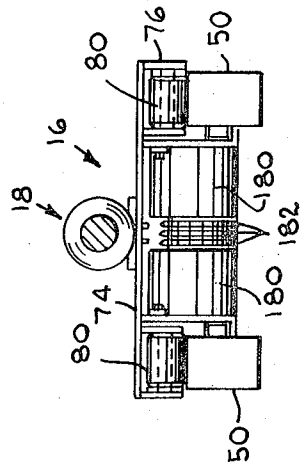



FIG. 18

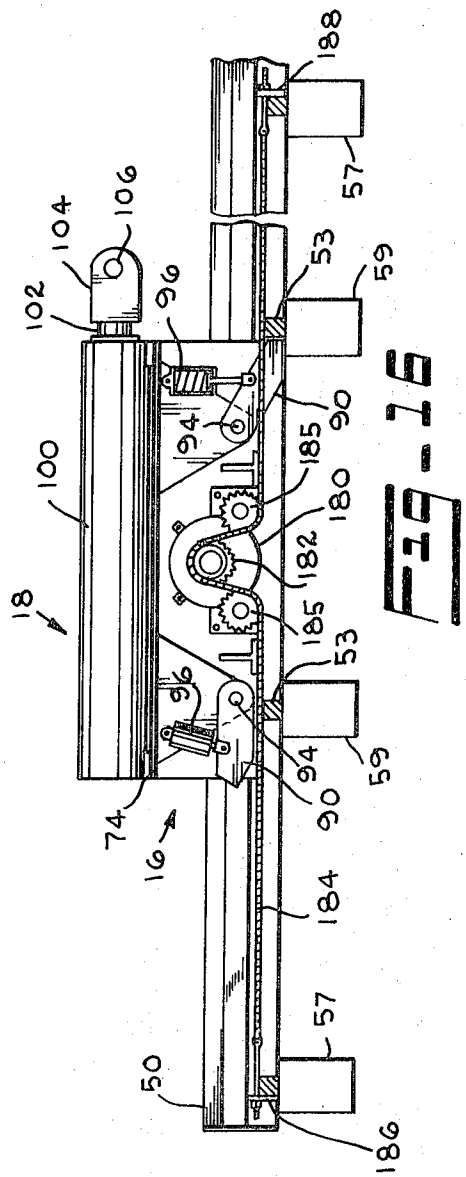



FIG. 19

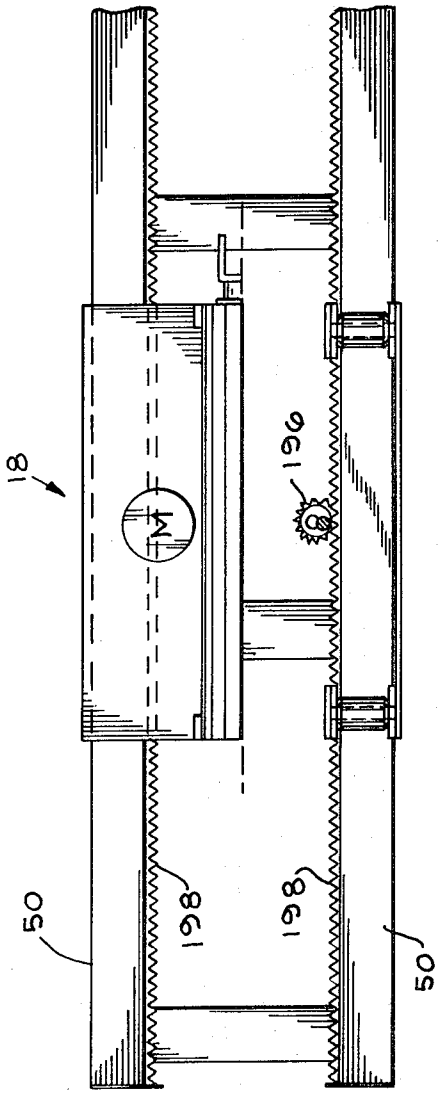



FIG-19

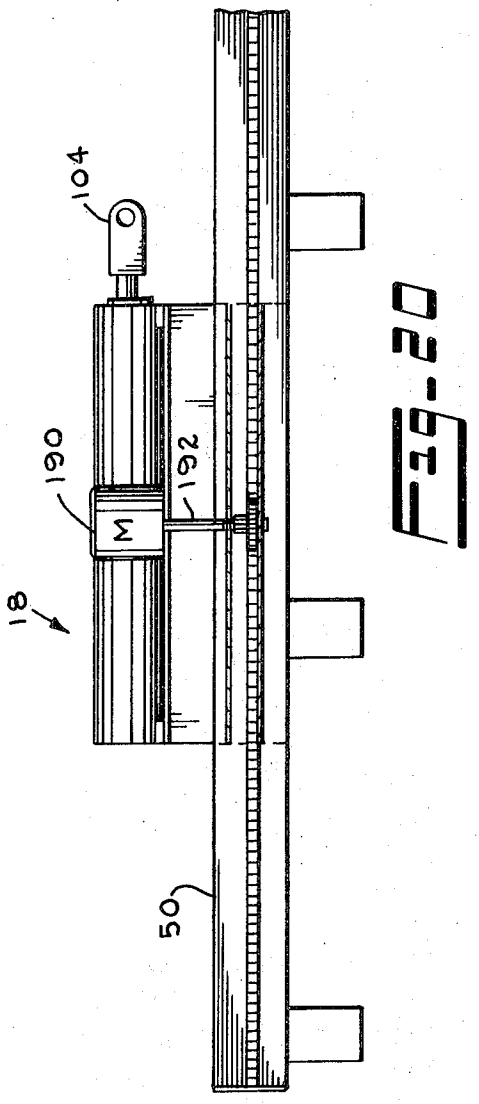



FIG-20

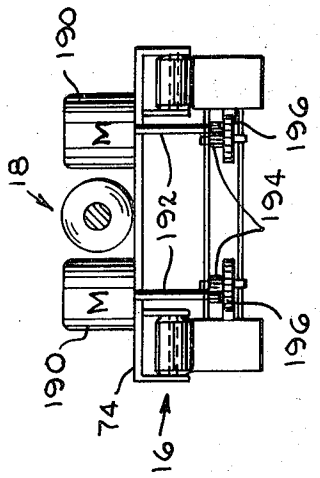



FIG-21

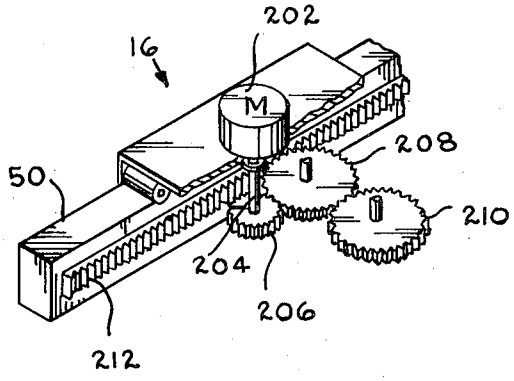



Fig. 22

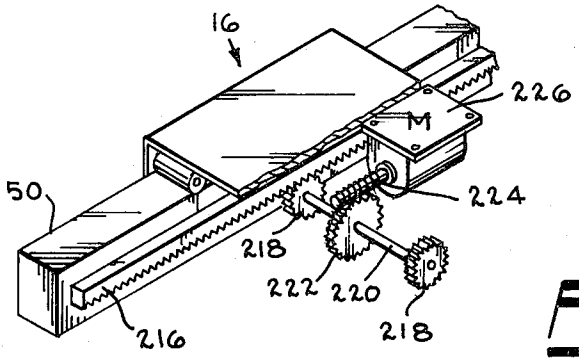



Fig. 23

# TUBE BUNDLE EXTRACTOR

## FIELD OF THE INVENTION

The present invention lies broadly within the field of linear force application devices, i.e., devices to apply a force to one linearly elongated object to move it with respect to another, while at the same time retaining the second linearly elongated object in a static position. More specifically, the present invention constitues an improved tube bundle extractor, one designed and adapted to pull an array of tubing from a horizontally elongated heat exchanger shell.

## PRIOR ART

In the tube bundle extractor field, the closest prior art known to the undersigned inventor is his own U.S. Pat. No. 3,567,044, issued Mar. 2, 1971. This patent discloses a tube bundle extractor including a superstructure adapted to be hung from a cable hook, an elongated base frame including a pair of rails supported by the superstructure and disposed in line with a horizontally mounted heat exchanger, a connector used for clamping one end of the base frame to the shell of the heat exchanger, a car or skid disposed on the rails and movable along the rails in the longitudinal direction of the base frame, a large hydraulic cylinder secured to the movable car and having its piston extensible in the same longitudinal direction, means for connecting the free end of the piston to the end sheet of the tube bundle within the heat exchanger, and dog means depending from the car to contact cross beams of the base frame during a power stroke of the piston, to transmit reaction force to the frame. While such tube bundle extractor has worked admirably, the patent does not disclose any remotely controllable means for adjusting the center of gravity of the extractor and any tube bundle that may be mounted on it during a disassembly or assembly operation, nor does it provide means for making such adjustments other than manually. Such adjustments are very important for the protection of both personnel and equipment, as all of the weight is suspended from a single point and only a small moment would be required to tip the device, when it is disconnected from the heat exchanger, to create a hazard of letting the tube bundle slip off the extractor and crash down to the earth. During the time when the tube bundle extractor and heat exchanger are connected together, the same type of moment may produce undesired stresses on the equipment, stresses which if allowed to increase in magnitude may result in breakage.

Other prior art disclosures teach assemblies somewhat similar to that of the Travis Patent, but differ therefrom primarily in the means for supporting and propelling the movable car or carriage. In one such prior art disclosure, the carriage supports pendent from its lower portion a large nut which threadedly engages a worm gear or feed screw extending longitudinally between the rails on which the carriage travels. In other prior art extractors the carriage is supported on and suspended from a monorail, and slings are used to support the tube bundle from the monorail as it is pulled from the heat exchanger. Yet other extractors make extensive use of chain drive systems, both for pulling the tube bundle loose from the heat exchanger and in moving the car and attached tube bundle to disengage the tube bundle from the heat exchanger.



None of these prior art devices discloses a reliable and efficient means for shifting the center of gravity of the suspended apparatus, a means in which one part of the supporting framework may be moved relative to another part. None of them discloses a means for attaching the pushing or pulling apparatus to a bundle of U-tubes, one in which each tube is open at the available front header, but is bent at the rear and joined to a second such tube so that there is no way of extending a rod all the way through any one tube. All of them are also deficient in failing to disclose various of the other improvements of the present invention, including means for adjusting the suspension framework to accommodate tube bundles of various diameters, improved means for clamping one end of the framework to the shell of a heat exchanger, improved and remotely controllable means for lowering and raising one end of the tube bundle extractor to align the same with the tube bundle, and improved means mounted on the movable car to make it self propelling with respect to the base framework on which it travels.

## OBJECTS OF THE INVENTION

It is the principal object of the present invention to provide a tube bundle extractor overcoming the aforementioned disadvantages of the prior art.

A more specific object is to provide a tube bundle extractor having a suspended and load supporting framework in which one part of the framework is longitudinally movable with respect to another part of such framework in order to shift the center of gravity of the suspended assembly to a position below the point of suspension.

A further object is to provide such a tube bundle extractor which includes novel means for pulling or pushing a tube bundle.

Another object is to provide improved means for clamping one end of the framework of such a tube bundle extractor to a shell of a heat exchanger, some of said improved means being manually adjustable and others being remotely adjustable.

Another object is to provide an improved means of aligning such a tube bundle extractor with a heat exchanger, so that one end of the base frame of the tube bundle extractor will contact the end flange of a heat exchanger shell and the longitudinal axis of the two members will be parallel.

Another object is to provide a tube bundle extractor having a novel means for connecting a car or other power-application structure to a bundle of U-tubes.

A further object is to provide a supporting framework which is adjustable in width to accommodate tube bundles of various diameters.

Another object is to provide such a tube bundle extractor including a movable car supporting a linear actuator to push or pull the tube bundle and equipped with depending dogs operable by remotely controlled and interlocked dog means to alternately brace the car against the base framework to prevent movement of the car in one direction or the other.

## SHORT DESCRIPTION OF THE INVENTION

The present invention includes as its principal improvement a means for remotely adjusting the center of gravity of an entire heat bundle extractor, together with

any tube bundle or other load it may be carrying. The framework may be thought of as comprising two distinct portions which are made slidable with respect to one another to any one of a number of positions, the selected position thereafter being maintained until a second shift is called for. One portion of the framework resembles a railroad track in that it consists primarily of two elongated and parallel rails or hollow beams supported by a number of crossbeams which extend to either side of the rails; these protruding parts are rigidly fixed to a pair of outrigger beams, also extending longitudinally, but not for the full length of the car-supporting rails. The other portion of the framework consists of a beam slidable within the hollow enclosure of the outrigger beams and having at each end an ear which projects upwardly through a longitudinal slot in the outrigger beam. Each of the four ears is connected to a tension bar which projects upwardly, and at the top the four tension bars are connected by a rigid rectangular framework or superstructure which includes a member supporting an ear adapted for connection to the hook of a crane. This second framework portion may be thought of as a supporting cradle, and all parts of the cradle are secured to one another so that the entire cradle is rigid and moves as a unit. To make the cradle shiftable in a longitudinal direction with respect to the base frame, a linear hydraulic actuator has its cylinder fixed to the base framework so that its piston extends in the longitudinal direction, and the free end of the piston is rigidly secured to the slidable inner beam of the cradle assembly. The actuator may be controlled by remotely positioned valves to extend or retract the piston into its companion cylinder, thus shifting the cradle with respect to the base framework.

The U-tube connection of the present invention involves a bundle of U-tubes joined at one end by a header having at or near its center a number of tapped holes especially provided to receive threaded members when pushing or pulling the bundle. These threaded holes may easily be galled or otherwise damaged if the force applied in pushing or pulling varies appreciably in direction from one parallel to the tubes and axes of the threaded holes. The present invention provides a means for applying a force parallel to the tube bundle, but appreciably offset therefrom in such manner that the force applied is first transmitted through a pair of vertical link bars disposed to confront the end sheet of such a tube bundle in close proximity thereto, then through a transverse pin having a flattened portion in contact with the back edges of the link bars, the balance of the surface of the pin being cylindrical in configuration and being seated in an opening through the longitudinally extending leg of a T-shaped member passing between the link bars, and then through the transverse portion of such T-shaped bar and through screws passing through such transverse portion and into the end sheet of the tube bundle. At either end of the link bars another T-shaped member is pivotally attached to the link bars and presses against the surface of the end sheet through the medium of a second plate which is adjustably positioned with respect to the first by means of jackscrews. The jackscrews are adjusted to tighten the pin at the center of the assembly and to assure that the center T-shaped member is pressed flat against the end sheet.

Width adjustability of the framework is provided by having the crossbars fabricated in two parts, one telescoping within the other and adjustable to various positions where they may be secured by appropriate pins. Two types of shell clamps are provided, one being manually adjustable and the other remotely adjustable through a hydraulic cylinder and piston, together with an inner, telescoping portion of the rails, movement of the piston accomplishing both rotation of a clamping jaw from an inoperative, out-of-way position to an upright, operative position and moving both the telescoping portion of the rail and jaw to engage the back side of the heat exchanger shell. Hydraulic control is also provided for the alignment means, such means including a pair of hydraulic cylinders and longitudinally extensible pistons mounted on the rails, a sheave mounted on the end of each rail and a cable passing from the end of the piston around the sheave and upwardly to a bolt hole in the flange of the heat exchanger. The use of this alignment mechanism allows the front end of the extractor to be raised into contact with the heat exchanger, and even permits some rotation of the tube bundle extractor with respect to the fixed heat exchanger. It should also be noted that the alignment mechanism serves an important securing function, as it ties the forward end of the framework to the heat exchanger in such manner that vertical loads can not break the connection.

The invention will be more readily comprehended by referring to the enclosed drawing, in which:

FIG. **1** is a perspective view of a preferred embodiment of the present invention, this view showing the tube bundle extractor suspended from a crank hook and engaged with a bundle of U-tubes shown partly protruding from the shell of a heat exchanger.

FIG. **2** is perspective view of a portion of the same tube bundle extractor, this view showing the inner, sliding beam which forms a part of the cradle subassembly, together with a portion of the outrigger beam containing the sliding member.

FIG. **3** shows the same type of center of gravity adjusting mechanism as FIG. **2**, differing thereform in the position of the hydraulic cylinder and its connection to the sliding member.

FIG. **4** shows an alternative means for adjusting the center or gravity, this view showing a hook-connecting member which is slidable with respect to the upper framework.

FIG. **5** is a partial isometric view showing an alternate, prior art connection between the main power piston and the tube bundle.

FIG. **6** is a plan view of the tube bundle extractor shown in FIG. **1**, with the tube bundle and heat exchanger omitted in order to show other details.

FIG. **7** is a side view of the tube bundle extractor of FIG. **1**. In this view the tube bundle secured to the end of the power piston is shown more completely withdrawn from its heat exchanger, in phantom outline.

FIG. **8** is a perspective detail view of the means shown in the prior figures for connecting the power piston to the tube bundle.

FIG. **9** is a partial cross section shwoing details of the framework, as indicated by the lines and the arrows marked "**9-9**" in FIG. **6.**

FIG. **10** is a front view of the tube bundle extractor of FIG. **1** with the tube bundle and car omitted.

FIG. **11** is a partial longitudinal section of the forward part of one of the rails of the base frame, showing

the preferred form of the shell clamp, as indicated by lines and arrows **11—11** of FIG. **6.**

FIG. **12** is a partial isometric view, also of the forward part of one of the rails of the base frame, showing the pivoted jaw of the shell clamp and part of the alignment mechanism of the invention.

FIG. **13** is an isometric view of an alternate form of shell clamp, this veiw showing the telescopic, slidable frame member and the rotatable jaw of the modified shell clamp.

FIG. **14** is a partial longitudinal section showing parts of the auxiliary chain drive.

FIG. **15** is a detail showing how the auxiliary chain is secured to the underside of the movable car.

FIG. **16** is an elevation showing a modified form of auxiliary chain drive, one in which the driving motor is mounted on the movable car. This view also shows the dog means which cooperates with fixed transverse blocks on the base frame to hold the car in position during a power stroke.

FIG. **17** is a plan view of the apparatus of FIG. **16.**

FIG. **18** is an end view of the apparatus of the two prior figures.

FIG. **19** is a partial plan view, with portions broken away for the sake of clarity, showing another form of auxiliary drive, this form having elongated racks secured to the rails of the base frame meshing with a pinion mounted on a shaft driven by a motor mounted on the upper side of the movable car.

FIG. **20** is an elevation of the structure of FIG. **19.**

FIG. **21** is an end view of the structure shown in the two prior figures.

FIG. **22** is an isometric view showing a slightly different form of rack and pinion drive, this one having only a single driving motor mounted on the car and powering a gear train meshing with a pair of racks on the rails of the base frame.

FIG. **23** is yet another modified form of rack and pinion drive, again with a single driving motor mounted on the undercarriage of the movable car.

## DETAILED DESCRIPTION OF THE DRAWING FIGURES

In FIG. **1,** the numeral **1** has been used to designate the tube bundle extractor as a whole. Shown also are the elements on which the extractor **1** operates, specifically the heat exchanger shell S, the end flange F of the heat exchanger shell, tube bundle T shown partially protruding from shell S, and the end sheet E1 of the tube bundle, to which all of the tubes T are attached. It should be understood that the heat exchanger itself is secured to fixed framework inside a chemical plant or oil refinery by means having nothing to do with the present invention. Such securing means hold the shell of the heat exchanger in place against all types of movements, but do not prevent the tube bundle T from being pulled out of the heat exchanger.

The principal parts of tube bundle extractor **1** are the framework **10,** itself divided into a suspension framework or cradle **12** and a base framework **14,** movable car or sled **16,** the prime mover **18** mounted on the upper surface of car **16,** the connector **22** which ties the prime mover **18** to the tube bundle T, the alignment mechanism **24** which adjustably connects the forward end of base frame **14** to the shell S, and the clamping mechanism **26** which clamps the base frame **14** to shell flange F.

The reason for distinguishing between parts of framework **10** is because the cradle portion **12** is longitudinally movable with respect to base frame **14.** This is made apparent in FIG. **1** by the two positions shown for the vertical or tension bars **28** and the cross bars **32;** the solid outlines of these members indicate one extreme position while the dashed or phantom outlines indicate the other extreme position of these members. The distance traveled by the cradle between its two extreme position is also indicated by the dimension labelled **30.** The cradle framework includes a superstructure consisting of the pair of cross bars **32** and a pair of lengthwise bars **34,** solidly secured together at their corners to form a rigid rectangle and the center brace **36** in the form of an I-beam to which is secured a crane ear **38.** The balance of cradle **12** is made up of the four tension bars **28** secured to and extending downwardly from the corners of the superstructure rectangle, and a pair of beams **42** secured to the lower ends of the pair of tension bars **28** on either side of center line **20.**

As particularly brought out in FIG. **2,** the slide beams **42** are elongated and disposed in a direction parallel to the longitudinal axis or center line **20** of the tube bundle extractor, and are disposed within the pair of hollow rectangular outrigger beams **52** of base framework **14,** outrigger beams **52** likewise extending parallel to longitudinal axis **20** between the lower ends of tension bars **28.** At its opposed upper corners, each beam **52** is provided with a longitudinally extending slot **54,** and on opposed ends each sliding beam **42** had secured an upwardly projecting ear **44** which extends through a slot **54** and is connected by appropriate pinning to the lower end of a tension bar **28.**

To provide for relative movement, a linear actuator in the form of a hydraulic cylinder **56** is fixed to the outrigger beam **52** with its extensible piston **58** projecting longitudinally parallel to axis **20.** At its free end piston **58** is connected to an ear **46** rigidly secured to sliding beam **42.** Thus, when the tube bundle extractor **1** is hanging free from crane hook C and ring **40,** actuation of hydraulic cylinder **56** to move piston **58** causes beams **42** to slide within outrigger beam **52,** moving the four tension bars **28** and the entire upper framework or superstructure including the crane ear **38** in the same direction. Since the crane ear and the hook itself will be static at such moment, the actual movement relative to the ground is a movement of the base frame **12,** together with any load it may then be supporting. By thus shifting the load supported by the cradle, the center of gravity of the entire suspended assembly, both tube bundle extractor and any tube bundle it is then supporting, may be shifted to lie directly below crane hook C, averting any possibility of tipping the assembly and permitting the load to slide along the rails of the base frame. Similar adjustments may be made when the base frame is tightly connected to a heat exchanger, as by first moving the crank hook chain (not shown) to a new location and then actuating cylinder **56** to cause movement of the cradle and hook to a position directly below the chain.

A slightly modified form of the frame balancing structure is shown in FIG. **3.** Here the hydraulic cylinder is disposed on and secured to the top surface of outrigger beam **52,** and one of the ears of sliding beam **42** is elongated at **44'** to provide means for securing the sliding beam to the piston **58** of the linear actuator. The only modification required in the outrigger beam **52** is

to somewhat lengthen the slot **54'** which accommodates the ear **44'**. The alternate construction is somewhat simpler to manufacture, and makes cylinder **56** more readily available for servicing.

A more completely different embodiment of the frame balancing structure is shown in FIG. **4.** In this embodiment the ear **38** which is used as the point of suspension from a crank hook is welded or otherwise firmly secured to a member **62** which is slidable along the top flange of the I-beam brace **36** of the framework superstructure. The sliding member **62** is shaped generally like a hollow rectangle having its bottom wall slotted to receive the vertical web of the I-beam **36.** This same bottom member is bent up, on both sides of the slot adjacent to the web of the I-beam, to provide an inner support or journal for the rollers **64** which are also journalled to the outer legs of the rectangle. Such rollers **64** serve the usual purpose of reducing the frictional force between the sliding member **62** and the I-beam **36.** Sliding of the member **62** and ear **38** is accomplished through a hydraulic cylinder **66** fixed to the frame members **32** and **36** and a piston **68** extending out of the cylinder and actuated by it.

As seen particularly in FIGS. **1,6,7,9** and **10,** the base frame **14** includes the pair of outrigger beams **52,** a plurality of cross beams **59** extending between and secured to the outrigger beams, a pair of parallel rails **50** which are elongated parallel to the axis **20** and project beyond outrigger rails **52** at both ends, and a number of shorter crossbeams **57** tying the projecting portions of rails **50** to each other. The rails **50** rest on crossbeams **59** and are rigidly secured to it, as by welding. As indicated in FIG. **9,** each crossbeam **59** consists of two parts which are telescopic with respect to one another. The larger crossbeam **60** is a hollow rectangular member receiving a slightly smaller rectangular member **61** in sliding relationship. A series of aligned, pin-receiving holes **71** in the two members permit stepwise movement of telescopic sections **61** and thus of the outrigger beams **52** to adjust the width between the outrigger beams. Since the tension members **28** extend directly up from the outrigger beams and these members **28** determine the width of tube bundle that can be accommodated on the tube bundle extractor, it will be apparent that the flexibility afforded by the telescopic arrangement of the crossbeams makes it possible to accommodate tube bundles of various diameters without any radical reorganization of the supporting structure.

The construction and operation of the movable car **16** are seen to best advantage FIGS. **1,9,16,17** and **18.** From these figures will been seen that the framework of the car consists of a top plate **74** bent over at the sides to form side plates **76,** a pair of end plates **78,** an interior U-shaped plate **82** secured to the under side of top plate **74** and having the pair of bent over and depending side plates **84** and an L-shaped plate **86** secured to a portion of the U-plate **82** and having a depending vertical arm **88.** The car is supported on the main rails **50** through the medium of four rollers **80** rotatably supported on idler shafts **81** journaled in journal blocks **77** and **85,** block **77** being secured to the inner surface of side member **76** and block **85** being secured to the vertical plate member **84.** Also journaled in block **85** is the long idler shaft or pivot pin **91,** which extends through vertical plates **84** and **88** at either side of the car, and is also supported in journal blocks **89.** Pivotally mounted on pin **91** are the depending dogs **90** and **92** which, as shown FIG. **16,** have their free ends squared off to be received in the angle formed by the upper surfaces of crossbeams **57** and **59** and the transverse block **53** secured to the same upper surfaces.

The dog members are raised and lowered by spring-biased air cylinders **96,** one at each end of the car **16,** each being pivotally mounted to the under side of plate **82** and pivotally linked to one of the transverse links **94** which also extends through the dogs **90** and **92.** Each air cylinder **96** is open at the top, air being admitted between the closed lower end of the cylinder and the sliding head of the piston within the cylinder bore. The bias is to the downward position as shown for the right hand dog **90** in FIG. **16,** i.e., this is the position the dog is forced into by the action of the spring when there is no air pressure within the cylinder **96.** The two cylinders are hydraulic interlinked at the control valve (not shown) so that when air is supplied to one cylinder to raise the dog clear of block **53,** the air is bled from the cylinder at the opposed end to cause the spring of the cylinder to push the dog into its lower, engaged position. The safety features require that one or both dogs be lowered at all times, thus preventing the car from experiencing an uncontrolled movement greater than the distance between a pair of blocks **53.**

The prime mover **18** is a linear actuator disposed parallel to the longitudinal axis **20** of the framework and axis **21** of the heat exchanger shell S. Its cylinder portion **100** is rigidly secured in the top plate **74** of car **16,** with its piston **102** extendable in the longitudinal direction toward or away from tube bundle T. Mounted on the free end of piston **102** is a clevis **104** for connection to the connector of assembly **22** of FIG. **1** or the connector plate **110** of FIG. **5.** In either event horizontally aligned transverse openings through the arms of clevis **106** receive a pin also extending through an element of the connector means, which in the case of the FIG. **5** connector is an ear **112** rigidly secured to connector plate **110** and extending away from the tube sheet E**5.** It will also be noted that the linear actuator **18** is disposed well below the center line of the tube bundle T: this has been done deliberately because the center of gravity of the tube bundle does not lie on its geometric center line, as might be supposed. Because of the products of corrosion that accumulate within a heat exchanger, the center of gravity is actually well below the center of the tubes themselves.

The tube bundle connector **22** of the present invention is shown in FIG. **1,6,7** and **8,** the latter being an enlarged isometric view of the connector apart from its setting. These figures show a connector **22** especially adapted for use with bundles of U-tubes, those in which a pair of tubes are open at the forward end, as seen in the figures, but are paired together by a connector neck at the rear, making it impossible to push a tie rod all the way through any one tube, as in the FIG. **5** embodiment. When U-tubes are employed in the heat exchanger, the forward end sheet E**1** is provided with a number of tapped and threaded holes clustered about the geometric center of the end sheet, and the connector must be tied to the end sheet through these holes. In the connector **22** this is accomplished by screwing into such holes a structural element herein dubbed "T member" **113,** consisting of a transverse plate **114** integrally secured at its center to a longitudinally extending leg **116** which meets plate **114** at right angles and bisects it at its center line. The leg **116** extends between

a pair of parallel vertical links or tie rods **118,** and has a projection rearwardly of the same provided with a transverse opening receiving a pin **120** having thereon a flat surface **122** designed to press against the rear edges of link bars **118.** At their upper and lower extremities, the pair of link rods **118** are pivotally connected to two additional T-members **124** and **125,** each of which is connected by four jackscrews **126** to a spacer block **128** preferably made of a hard, dense wood such as rosewood. The pivot pin used to connect the lower T-member **125** to the link bars **118** is also used to connect the clevis **104** to the connector **22,** as indicated in FIG. **1.**

In assembling connector **22,** the T-member **113** is first connected to the end sheet E1 of the tube bundle, and the pair of link bars **118** are connected to the clevis **104,** with lowermost T-member **125** in place. The bars **118** are swung to the illustrated vertical position, spanning leg **116** of T-member **113.** The upper T-member is then assembled to the link bars **118,** after which pin **120** is inserted in the opening of leg **116** of center T-member **112** with its flat **122** facing toward the rear edges of link bars **118.** Both sets of jackscrews **126** are then adjusted so that both of the spacer blocks **128** press against end sheet, E1 of the tube bundle. As the jackscrews are tightened, they push link bars **118** away from the tube sheet and cause them to press tightly against pin **120** until the pin is tightly jammed between the link bars and leg **116.** With this arrangement, a pulling force exerted through the power piston and its clevis **104** in the direction away from the end sheet is transmitted to the tube bundle through lowermost pivot pin **127,** link bars **118,** pin **120,** leg **116** and its attached plate **114,** and through the screws holding the plate **114** to the end sheet. It should be noted that in so doing the pulling force must pass through the flat surface **122** of the pin and then through the curved surface of the pin to the similarily curved surface of the opening in leg **116** which accommodates it. In this manner the pulling force is first concentrated in a very small central area and then destributed equaly to the four or more screws holding plate **114** to the end sheet.

The general scheme for obtaining proper vertical and transverse orientation of the tube bundle extractor **1** with respect to the heat exchanger is first to adjust the position of the extractor by means of the crane until rails **50** are approximately tangent to flange F of the heat exchanger shell, then fix the vertical location of the forward ends of the rails in contact with flange F, by means of the alignment mechanism **24,** and finally adjust the vertical position of crane hook C until the axis **20** of the tube bundle extractor is parallel to the axis **21** of the heat exchanger. At the same time that this is being done, of course, the longitudinal position of the extractor is determined by causing the forward annular surface of the flange F to contact the vertical surfaces of the pair of blocks **142** which are fixed on the forward ends of rails **50** and serve as the fixed jaws of the shell clamps **26.**

The vertical alignment and securing mechanism **24** is shown in FIGS. **1,6,7** and **12.** It consists primarily of a hydraulic cylinder **130** secured on the outside wall of rail **50** adjacent its forward end, the cylinder and its extensible piston **132** being disposed longitudinally so that the piston may be extended toward end sheet E5 or retracted from it. The other components are the sheave **134** mounted on the outer wall of block **142** on a horizontally disposed idler shaft, the cable **136** having one end secured to the free end of the piston, bent around sheave **134** and extending upwardly to join a connecting bolt **138** through one of the bolt openings in flange F of the shell. The cable is shown attached to the portion of the connector **138** petruding from the back face of the flange F simply because there is more room available in the back than on the front side of the flange. It will be apparent that retraction of the piston **132** from the position shown in FIGS. **1** and **7** will cause the cable to tighten, tending to lift the forward end of the framework upwardly with respect to the heat exchanger. Since there is an alignment mechanism **24** on each of the rails **50,** adjustment of both of them can be used to correct any roll of the extractor framework, i.e., the alignment mechanism may be used to insure that the rails **50** lie in a common horizontal plane. What is not so apparent is that these mechanisms may also be used to rotate the tube bundle within its shell, alternately pulling down on one side and then on the other when the tube bundle has become so tightly corroded to its shell that some twisting is in order in an attempt to loosen the tube bundle for more ready extraction.

The shell clamping mechanism **26** serves two functions, one being to orient the tube bundle extractor in the longitudinal relationship to the heat exchanger and the other to serve as a means for transmitting the unavoidably produced thrust; there must be something tied to the earth to push against before the pulling mechanism of the extractor can effectively pull the tube bundle out of its shell. A remotely controlled form of shell clamp is pictured in FIGS. **1,6,7,11** and **12,** the last two figures showing particular details. As illustrated, the clamp includes fixed jaw **142** rigidly secured to rail **50,** movable jaw **140,** a telescopic inner beam **144** slidably within rail **50,** a hydraulic cylinder **145** disposed inside of rail **50** and secured thereto with a longitudinal disposition, and the piston **146** extensible from and retractable into cylinder **145.** The movable jaw **140** is pivotally mounted on an idler pin **148** journaled to the side walls of extensible rail **144,** and has an angular portion pivotally attached to the end of piston **146** at the pinned connection **152.** A stop block **150** is secured to the top of the otherwise open telescopic member **144** to prevent further clockwise rotation of pivoted jaw **140** than indicated in FIGS. **11** and **12.**

Operation of the clamp **26** can best be understood by looking at FIGS. **11** and **12** together, and then starting from the position shown in FIG. **12,** where the movable jaw **140** is spaced from fixed jaw **142** a considerably greater distance than the thickness of a shell flange F. Since the movable jaw **140** is shown in FIG. **12** is already in its upright, operative position, it will be apparent that retraction of piston **146** into its cylinder **144** will merely pull the slidable telescopic member **144** within rail **50** until jaw **140** meets with resistance, as by contacting the rear surface of flange F as shown in FIG. **11.** As long as the retraction pressure is maintained on the piston, the flange F will be tightly gripped between the jaws **142** and **140.** On the other hand, if the pressure in the cylinder **144** is reversed to cause the piston **146** to be extended further from its cylinder, it will be apparent that two things will happen: first, telescopic section **144** will be moved out of rail **50,** in the direction indicated by the arrows in FIGS. **11** and **12,** and secondly, the movable jaw will be rotated about its pivot **148** until it is wholly contained within the hollow

enclosure defined by member **144.** In this non-operative position, the tube bundle extractor can be assembled to or disassembled from the heat exchanger without interference from the jaws **140.**

An alternate form of shell clamp **26'** is illustrated in FIG. **13,** one requiring some manual adjustment in tightening or loosening the movable jaw **156.** It is similar to the previously described embodiment in that it includes a telescopic member **154** slidable within the rail **50** and actuated by a hydraulic cylinder and piston like those indicated in the FIG. **11,** but differs therefrom in that in the manual embodiment of FIG. **13** the piston is linked directly to sliding member **154.** A bearing plate **158** is welded or otherwise secured within the enclosure defined by beam **154,** at a spacing from the end thereof. The movable jaw **156** is rigidly secured to one end of a shaft **160** rotatably mounted in the end plate (not shown) of telescopic beam **154** and extends longitudinally to a reduced diameter shoulder which butts against plate **158.** The small diameter portion of shaft **160** extends through an opening in bearing plate **158,** and is threaded to receive a nut **162** welded to plate **158** concentric with the opening therethrough. Thus the assembly may be completed by tightening the threaded engagement between shaft **160** and nut **162,** then loosening the same during an inoperative period just enough to let shaft **160** rotate until the jaw **156** hangs downwardly, out of the way. When the clamp is to be engaged, it is not essential that the threaded engagement be made up tightly, as the clamping pressure is obtained through the hydraulic cylinder rather than the mechanical interlock of the threads. All that is necessary is to have some of the threads engaged and the jaw in its upright position, as illustrated, when the sliding member **154** is pulled in the direction to cause jaw **156** to contact the back surface of the shell flange.

The highest levels of pull strength are required when first pulling a tube bundle loose from the heat exchanger, and perhaps for a few feet thereafter, because usually at this time the tube bundle is tightly corroded to the shell. During the initials movements the prime mover **18** on car **16** is used to apply the necessary force, and at such times the dogs **90** are set in the positions indicated in FIGS. **14** and **16** in order that the necessary reaction force can be applied to the framework and the heat exchanger shell. If the tube bundle is still tight within the heat exchanger shell after a complete retraction stroke of the piston **102,** the car **16** is moved away from the tube sheet by reversing the flow of hydraulic fluid through cylinder **100** to extend the piston rod **102** toward the tube sheet (after first reversing the dogs **90** from the position illustrated). Since the car is much lighter than the tube bundle, and is mounted on rollers **80** to reduce friction, the car is moved away from the tube sheet for the length of a piston stroke, after which the dogs can be restored to the FIG. **14** position and the pulling stroke repeated.

Once a tube bundle is broken loose, the remaining part of the extraction requires a relatively small pull, and this can be accomplished by the auxiliary prime mover illustrated in the drawing figures. One such a auxiliary prime mover is shown in drawing FIGS. **1,6,7,14** and **15,** and consist primarily of chain **166** centered between rails **50** and below the path of car **16,** driving motor end sprockets **168** located at the rear of base frame **14,** and the idler and guide sprockets **170,172** and **174.** The chain **166** is preferably secured to the undercarriage of car **16** by a clamp **176** having teeth not shown which enter between links of the chain to prevent all relative movement. This is depicted in FIGS. **14** and **15,** which also show a pair of guide members **178** for the chain. This structure on car **16** is rigidly linked to chain **166,** but power need never be applied through the motor **168** during the periods when it is necessary to use the prime mover **18** on the upper side of car **16.**

A somewhat different type of auxiliary prime mover is illustracted in FIGS. **16,17** and **18.** In **17** half of the upper plate **74** of car **16** has been cut away to show the arrangements of power components. In this form a pair of rotary motors **180** secured to the nether side of car **16** have a common shaft on which is mounted the necessary sprockets **182** to engage the chain **184.** The idlers sprockets **185** simply fix the position of the chain, which is secured against rotation by an anchor **186** at the rear end of the base frame and a similar anchor **188** which secures it to the framework at the forward end of the base frame. Thus, the mode of travel when using this form of auxiliary prime mover is to rotate the motor **180** and let the motor pull the car through the chains: the car walks on the chain.

FIGS. **19,20** and **21** illustrate another form of auxiliary prime mover, one in which a pair of motors **190** mounted on the upper plate **74** of car **16** have vertical depending shafts **192** with appropriate reduction gearing **194** and pinions **196** at their lower ends. The pinions **196** and mesh with and rotate over the longitudinally extending racks **198** on the inside walls of the main rails **50.** It will be noted that in this form the rack and pinion teeth extend vertically. As the motor **190** is acutated to rotate shaft **192** and pinion **196,** pinion walks along the rack **198,** carring the car **16** with it.

The alternate form of auxiliary prime mover shown in FIG. **22** is virtually the same as that shown in FIGS. **19-21,** with the exception of using a single drive motor **202** which has on the lower end of its vertical shaft **204** a gear **206** which meshes directly with the first of a pair of intermeshing pinions **208** and **210.** The pinions **208** and **210** mesh directly with racks **212** on the inner walls of main rails **50.**

FIG. **23** illustrates yet another form of rack and pinion drive, this one employing racks in which the teeth edges of the rack **216** are horizontally oriented and the matching pinions **218** rotate on a horizontal shaft **220.** At the center of shaft **220** is a large gear **222** meshing with a small worm gear **224** driven by the motor and gear reducer **226.** With this structure a large gear reduction will be accomplished, and a large amount of power may be applied to move the car along the direction parallel to the racks **216.**

What is claimed is:

**1.** A tube bundle extractor comprising a framework elongated along its longitudinal direction and including both means for suspending the extractor from a support and a base portion adapted to support a tube bundle, said framework comprising a pair of portions selectively slidable with respect to each other along the longitudinal direction but otherwise secured together, a car supported on and movable along the longitudinal direction of the base of the framework, means for detachably securing one end of the framework to the shell of a heat exchanger so that the two members (framework and heat exchanger) are vertically and longitudinally aligned and the base of the extractor is in position

to receive and support a tube bundle being pulled from or inserted into the shell, power means on said car to pull said tube bundle from the shell or insert it therein, and hydraulic means on said framework to shift one portion thereof in the longitudinal direction relative to the other, whereby the center of gravity of said extractor and any tube bundle supported thereon may be disposed approximately directly below said support, said hydraulic means comprising a linear actuator having its cylinder secured to one of the portions of the framework and its extensible piston secured to the other said portion, said linear hydraulic actuator being disposed parallel to the longitudinal direction of the framework.

**2.** The tube bundle extractor of claim **1** in which said pair of framework portions are a base framework and a cradle, said cradle interlockingly supporting said base framework and including said suspension means, and in which said cylinder of the linear hydraulic actuator is secured on one of said framework portions, either said cradle or said base, and its extensible piston secured to the other framework portion, said hydraulic cylinder and piston being disposed parallel to the longitudinal direction of the framework so that movement of the piston out of or into its cylinder moves the cradle relative to the base framework.

**3.** A tube bundle extractor framework elongated along a longitudinal axis and comprising a cradle, a base frame, and a linear

said cradle comprising (a) a superstructure including means above the longitudinal axis for suspending the extractor from a support such as a crane hook, (b) two pairs of tension bars pendent from the superstructure, one pair on each side of said axis, and (c) a link beam extending longitudinally and connecting the lower ends of each pair of link bars,

said base frame comprising (d) a pair of longitudinally extending outrigger beams disposed in transversely spaced relationship at substantially the same locations as said link bars, said outrigger beams being hollow and receiving said link beams within themselves in slidable relationship, there being longitudinal slots in the upper wall of each outrigger beam receiving the connections between each tension bar and the sliding link bar, (e) a multiplicity of longitudinally spaced crossbeams extending transversely between and secured at their ends to said outrigger beams, and (f) a pair of parallel, longitudinally extending main rails supported by and secured to said crossbeams, said main rails being capable of supporting a tube bundle and means movable along the rails to push or pull such a bundle,

said linear actuator comprising (g) a hydraulic cylinder and (h) mating linearly extensible piston, one of which is secured to the base frame and the other to the slidable link beam, said linear actuator being disposed so that extension or retraction of the piston slides the cradle longitudinally relative to the base frame.

**4.** The tube bundle extractor of claim **1** which further includes an auxiliary prime mover in the form of an endless chain and a motor on same framework, together with a chain clamp secured to the nether side of the car to engage the teeth of said chain, said chain being disposed beneath the path of travel of the car from the rear end of the framework to approximately the forward end thereof and about midway between said rails, said auxiliary chain and motor having the capacity to move said car and attached tube bundle when the tube bundle is not tightly bound to its shell by corrosion or friction.

**5.** The tube bundle extractor of claim **1** which further includes an auxiliary prime mover in the form of chain on said framework and a motor on said car, said motor driving a sprocket having teeth engaging the chain, said chain being disposed longitudinally parallel to the center line of the extractor centered between said rails, the ends of the chain being fixed to the framework so that operation of the motor and sprocket causes the car to walk along the chain.

**6.** The tube bundle extractor of claim **1** which further includes an auxiliary prime mover in the form of a rack and pinion drive, there being racks being mounted on the base framework and corresponding pinions being mounted on shafts depending from the car and driven by one or more motors mounted on the car.

**7.** The tube bundle extractor of claim **1** in which the power means on said car comprise a hydraulic cylinder fixed to the car and an extensible-retractable piston extending longitudinally from said cylinder, said extractor further including means for connecting said piston to a bundle of U-tubes, said connecting means comprising

a. a T-shaped attachment member having for the crossbar a connecting plate with openings therethrough for the passage of threaded connectors to be received in tapped holes in the end sheet of such a tube bundle,

b. a leg or base secured to and projecting rearwardly from the crossbar and having a transverse opening therethrough,

c. a pin having a flat surface extending through said transverse opening,

d. a pair of parallel vertical links spanning the base of the T-member and partially blocking the opening therethrough,

e. a pair of T-members disposed at opposite ends of said pair of levers and each pivotally secured thereto, and

f. a spacer block parallel and adjacent the crossbar of each end T-member, said spacer blocks each presenting a vertical surface facing forwardly of the levers to contact the vertical surface of said tube sheet, and

g. a number of jackscrews connecting each spacer block to the adjacent T-member crossbar for adjusting the position of said block,

whereby when said pin is passed through the leg opening of the center T-member with its flat surface contacting the back edges of the levers said jackscrews may be adjusted to form a rigid connection to the tube bundle, the lower of said jackscrew spacers also being pivotally secured to a clevis secured to the end of said piston.

**8.** The tube bundle extractor of claim **1** in which said detachable securing means includes means for aligning and securing said framework to the heat exchanger from which a tube bundle is to be withdrawn or into which it is to be inserted, said alignment and securing means comprising a matching pair of subassemblies on each side of the base framework to be coupled to points on the front flange of the heat exchanger shell at opposed points thereon, each subassembly including a linear hydraulic actuator having a cylinder secured to the

base frame and a piston extending longitudinally forwardly therefrom, a sheave rotatably mounted on the base frame forwardly of the cylinder on a horizontal axle, and a cable secured to the free end of the piston and passing through the sheave to be secured to an opening in the flange, said actuators being remotely controlled to lift or lower the forward end of the framework relative to the heat exchanger flange.

**9.** The tube bundle extractor of claim **1** in which said means for detachably securing the framework to the shell of a heat exchanger comprises fixed jaws and pivoted jaws, one of each forming a pair on opposite sides of the framework, said fixed jaws being secured to and projecting upwardly from the base framework near the forward end thereof in a common transverse plane, said pivoted jaws each being mounted on pins passing through the base framework on opposite sides thereof and in a common transverse plane spaced forwardly of the fixed jaws, each said jaw being linked to a hydraulic piston which pivots the jaw between an inoperative position in which it is received in a recess in the base and an operative position in which it projects upwardly from the base and is spaced forwardly of the fixed jaw by the thickness of the heat exchanger shell.

**10.** The tube bundle extractor of claim **9** further improved by mounting each of said pivoted jaws on a pin passing through an inner rail of a telescoping pair of rails forming a part of said base framework, and in which said hydraulic piston is linked to said pivoted jaw while the cylinder from which it extends is secured to the outer or fixed rail, whereby said clamp amy be used to accommodate various thicknesses of shells by extending the piston to simultaneously extend the inner rail and pivoted jaw until the latter is positioned behind the shell when the fixed jaw abuts the front of the shell, then retracting the piston to both raise the pivoted jaw to its upwardly projecting position and retract both inner rail and pivoted jaw until the latter engages the back surface of the shell.

**11.** The tube bundle extractor of claim **1** in which said detachable securing means includes a pair of shell clamps on opposed sides of the framework, each clamp comprising a fixed jaw projecting upwardly from the forward end of the framework in a common transverse plane, a linear hydraulic actuator having its cylinder secured longitudinally to the framework abaft of the end thereof and its piston extending forwardly toward the end of the framework, a sliding framework member telescopically disposed within the base frame and secured to said piston for longitudinal movement therewith, and a jaw mounted on said sliding framework member, said jaw and member being adjustably connected so that the jaw has a disengaged position in which it lies below the upper edges of the sliding member and an engaged position it which it projects above said sliding member, in position to engage the back side of the heat exchanger shell.

**12.** The tube bundle extractor of claim **1** in which said framework includes both a cradle and a base framework, the base framework including a pair of longitudinally elongated outrigger beams and a multiplicity of crossbeams joined to said outrigger beams while said cradle comprises a superstructure of crossbeams and longitudinal beams joined at their corners, together with a multiplicity of vertical tension bars extending upwardly from the outrigger beams to the superstructure, both said crossbeams between the outrigger beams and said crossbeams of the superstructure being made of telescoping parts detachably pinned together by pins extending through aligned openings in the telescoping parts, whereby the distance between said tension bars over the rails may be adjusted to accommodate tube bundles of various diameters.

**13.** The tube bundle extractor of claim **1** further comprising improved dog means for securing said car to the base portion of the frame during a power stroke of the car-mounted power means, said dog means comprising a number of dogs pivotally secured to the underside of the car and having both a lowermost operative position in which it engages members of the base frame to prevent longitudinal movement of the car in one direction, and an uppermost non-operative position in which it is free of contact with the base frame, said dog being moved between said positions by a remotely controlled linear hydraulic actuator having its cylinder pivotally secured to the underside of the car and its extensible piston pivotally connected to the dog, said actuator being spring-biased so that the piston will be extended to push the dog to its lowermost position in the absence of hydraulic pressure in the cylinder.

**14.** The improved tube bundle extractor of claim **13** in which there are two said sets of dogs and hydraulic actuators, one said set of dogs being disposed so that in their lowermost position they prevent forward movement of the car while the other set is disposed so that in their lowermost position they prevent rearward movement of the car, the actuators being hydraulically interlinked so that when one set of dogs is in its uppermost position the other set is in its lowermost position.

* * * * *

# UNITED STATES PATENT OFFICE
# CERTIFICATE OF CORRECTION

Patent No. 3,836,015 Dated September 17, 1974

Inventor(s) Bobby J. Travis

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the Abstract, column 2, line 2, "holow" should read -- hollow --;

Column 6, line 57, "crank" should read -- crane --;

Column 10, line 36, "slidably" should read -- slidable --.

In the Claims:

Claim 3, line 3, -- actuator, -- should be inserted after "linear".

Signed and sealed this 31st day of December 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
U.S. GOVERNMENT PRINTING OFFICE: 869-930