June 21, 1960 M. HOLT ET AL 2,941,569

FINNED TUBE EXPANSION CONTROL APPARATUS

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Fig. 1.

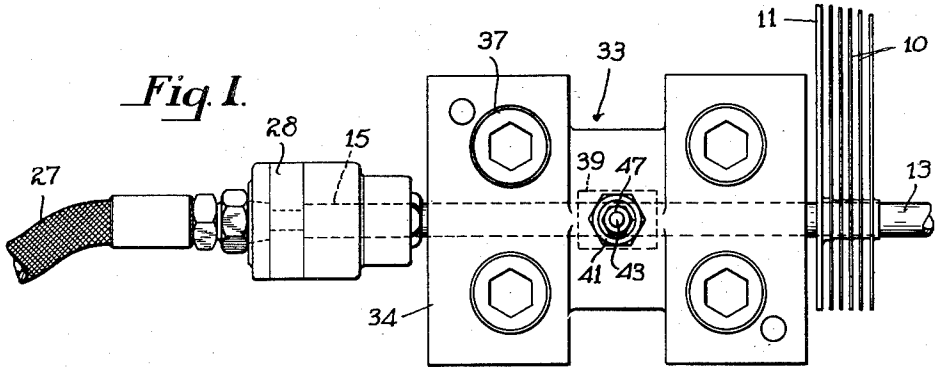


Fig. 2.

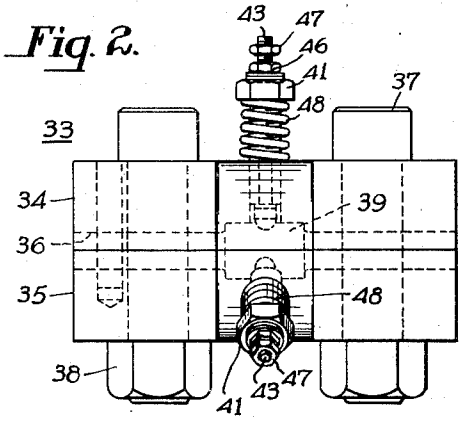
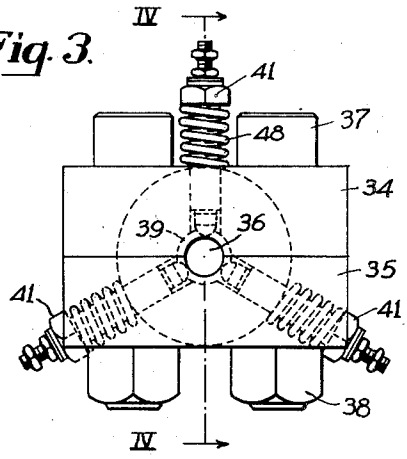


Fig. 3.



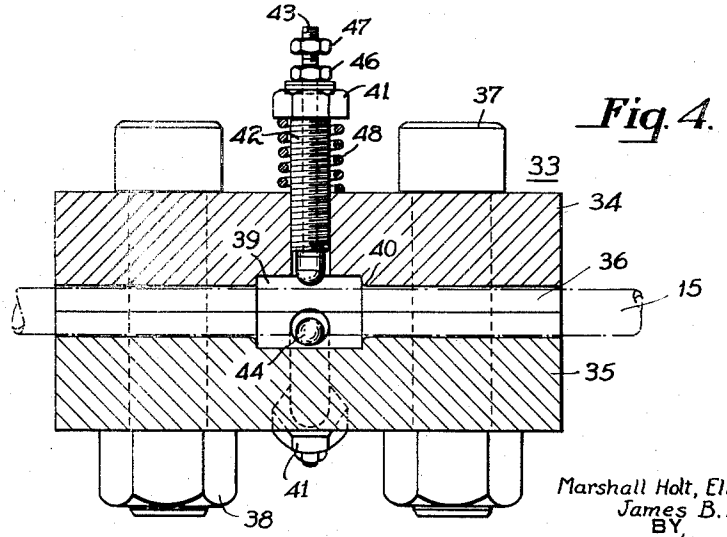


Fig. 4.

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Fig. 7.

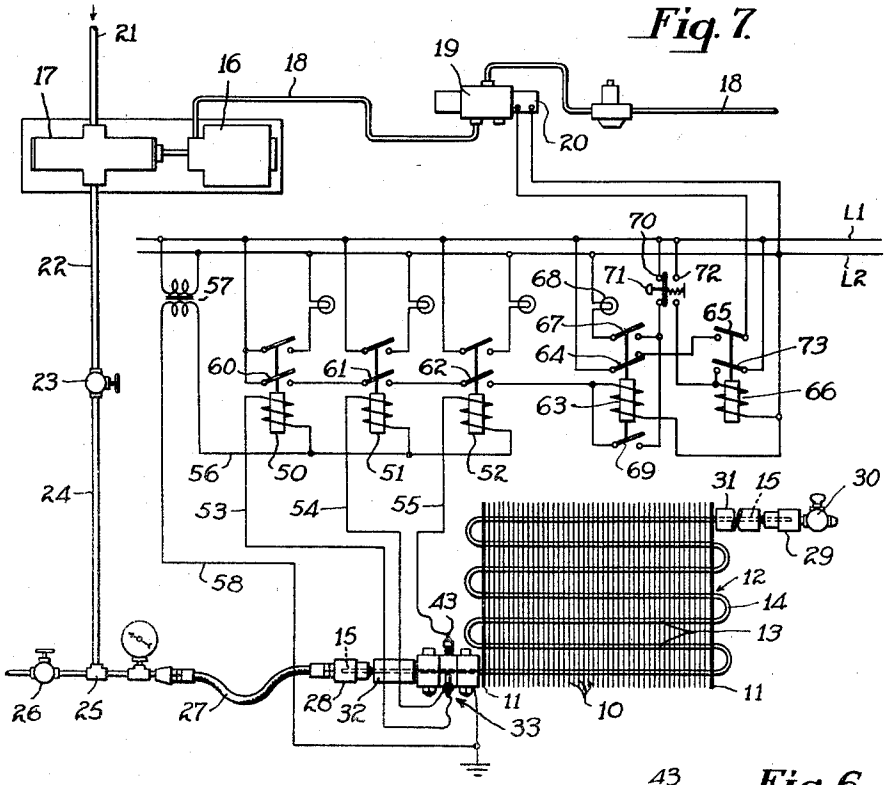


Fig. 5.

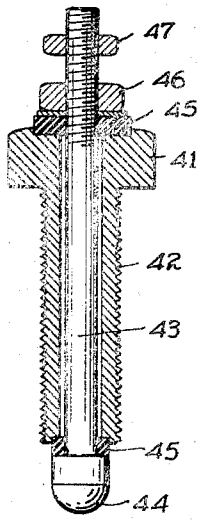
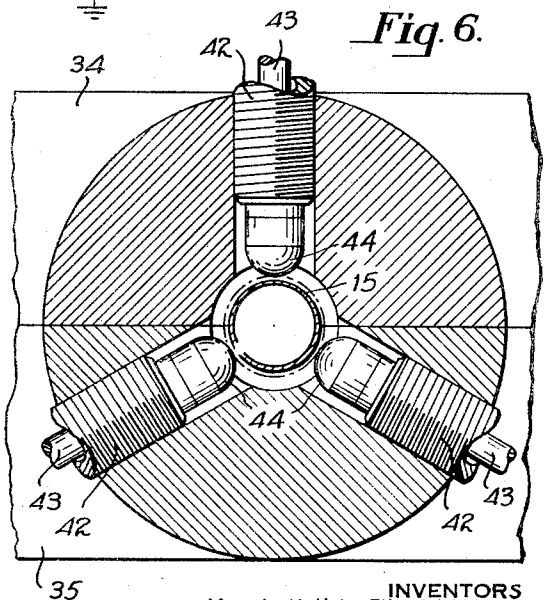


Fig. 6.



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FINNED TUBE EXPANSION CONTROL APPARATUS

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8 Claims. (Cl. 153—79)

The present invention is designated a finned tube expansion control apparatus in that it has been especially designed to control the expansion of thin wall tube or tubing being expanded by hydraulic pressure to obtain tight tube-to-fin fits in making finned tube heat exchanger units such as are employed in refrigerating and air-conditioning equipment and the like.

In the manufacture of finned tube heat exchanger units, an exemplary type of which comprises a fin pack of loose and closely spaced thin metal fins and a sinuous, multiple bank, tube coil threading the fin pack, it is desired to expand the tube by internally applied hydraulic pressure for the purposes of securing a tight or firm fit between the tube and the fins in order to provide a rigid structural assembly and an efficient heat transfer relation between the two and to avoid the higher costs entailed in making the units with brazed or soldered tube-to-fin joints. End plates are usually included in the fin pack for mounting the finished units, as desired, since the fins are too thin and soft to serve this purpose. The fins are usually formed with collars or flanges about the punched out tube-receiving apertures therein, which collars serve to provide greater fin contact area with the tube and to space the fins from each other.

Where this tube expansion method is employed, the problem is faced of controlling the tube expanding pressure so that the desired tight fit of the tube with the fins may be had throughout the entire fin pack without ballooning or rupturing of the tube anywhere along its length. Heretofore, control of the pressure shut-off to stop the expansion operation has been manually effected by a skilled workman watching a pressure gauge and feeling the fin pack to judge when the fins are tight enough under tube pressure to be firm when the pressure in the tube is released and the tube is relaxed. Such manual fin sensing control has been necessary in order that the operator may take care of variable tube characteristics, as produced within commercial tolerances, by varying the expanding pressure conformably. Such method of control, obviously, has serious drawbacks and deficiencies, is dangerous to the operator and experience has shown that even with exercise of care and judgment on the part of a highly skilled operator, a condition known as ballooning of the tube and even rupture thereof sometimes occurs and results in a total scrap loss. It is desirable that these losses be minimized.

This problem of expansion control becomes more critical, the flatter the curve of the stress-strain relationship above the yield strength of the metal tubing that may be employed in the heat exchanger units. Thus, while copper tube ordinarily has been used, it is highly desired to use a lower cost tube, particularly some aluminum alloy tubes, in order to reduce materially the cost of the finished units. While it has been proposed to use aluminum tube made, for example, from 1100 and 3003 aluminum alloys in the annealed temper, their relatively flatter stress-strain relationships above the yield strength compared to that of the copper tube usually used increase

the need for greater expansion control sensitivity than the available hand control can provide.

It has been found that aluminum cross-overs and return bends used in the construction of a sinuous, multirun tube coil appear capable of sustaining the tube expanding pressure, due to their work hardened condition, but the outwardly extending end portions of the coil, or pigtails as they are known in the art, may swell and burst before the tube becomes tight in the fin pack. This has led to the use of complicated internal fittings extending through the end portions to points inside the fin pack for isolating the end portions from the expanding pressure, but it has failed to abate the problem of controlling tube expansion inside the fin pack.

A principal object of our invention, therefore, is to provide an automatic expansion control apparatus or system by which the tube in loose tube-and-fin pack assemblies can be hydraulically expanded into the required tight tube-to-fin fit and obtain the desired results consistently and repeatedly.

Another object of our invention is the provision of a simple and effective control apparatus for the above stated purpose which is highly sensitive in operation, which employs variable pressure related to expansion resistance and which assures production of tight expanded-tube heat exchanger units without the use of skilled workers, despite the presence of tolerance variations in the tubing employed.

A further object of the invention is the provision of a control muff mountable on one tube end or pigtail and provided with an internal tube wall expansion control chamber and cooperating electrodes which function to set up a control circuit which operates to cut off the hydraulic tube expanding pressure responsively to bulging or swelling of the tube wall in such control chamber by an amount that assures the required expansion of the tube coil inside the fin pack.

The invention further consists in providing an electrical safety switch means in the control circuit which operates in the event of failure of electrical power to lock-out the pressure supply pump and require resetting by the operator in case such failure should occur either during a setting-up operation or during an expansion operation.

The invention still further consists in providing a pressure cut-off switch means for terminating an expansion cycle and which is interlocked with a cycle start switch to prevent operation of the high pressure pump during intervals between tube expanding operations.

One form which our invention may take is shown in the accompanying drawings wherein:

Fig. 1 illustrates a fragmentary part of a fin pack-and-tube coil unit and shows in plan an expansion control muff in operative position on one end portion or pigtail of the tube coil and the coupling of a hydraulic pressure supply line to the end of the tube pigtail, as the parts appear in readiness for the expansion operation;

Fig. 2 is a front elevational view of the muff; shown in Fig. 1;

Fig. 3 is an end elevational view of the muff;

Fig. 4 is a sectional view on a slightly enlarged scale, taken on the line IV—IV of Fig. 3;

Fig. 5 is a vertical cross-sectional view to an enlarged scale of one of the control electrodes;

Fig. 6 is a fragmentary enlarged cross-sectional view of the central portion of the muff and the control electrodes therein, and illustrates on a greatly exaggerated scale a tube characteristic (wall eccentricity) which is sometimes present in the tube employed, and

Fig. 7 is a diagrammatic view illustrating a finned tube heat exchanger unit, the hydraulic mechanism and the electrical control circuits for effecting a controlled tube expansion operation.

Referring to Fig. 7, the illustrated heat exchanger unit comprises a fin pack consisting of a multiplicity of loose and closely spaced thin metal fins 10 (approximately ⅛" spacing of the fins being customary) and thicker end plates 11, provided for mounting the finished unit, and a thin-wall metal tube serpentine 12 of the desired material, such as copper or aluminum, having straight runs 13 traversing the fin pack with return bends 14 outside the end plates. A number of such tube serpentines may be spaced one behind the other and connected by cross-over connectors (not shown) to form a multiple-row continuous tube coil whose end portions or pigtails 15 project outwardly from the fin pack. Such heat exchanger units and the construction and assembly of the parts thereof are well known in the art and form no part of the present invention, and hence, only a typical unit has been diagrammatically illustrated in readiness for the hydraulic expansion operation. It may be mentioned that it is customary to provide the fins with collars or flanges about the tube-receiving apertures therein, as indicated in Fig. 1, to serve as fin spacers, if desired, and to provide greater tube-to-fin heat exchange contact area.

For effecting hydraulic expansion of the straight tube runs 13 inside the fin pack, we provide (Fig. 7) a conventional pressure intensifier in the form of a motor-driven pump unit which may comprise an air actuated, reciprocating piston motor 16 and a reciprocating piston pump 17 capable of developing a pressure in excess of that required to expand the tube and, in fact, sufficient to rupture the tube if not shut off at the proper time. Compressed air for operating the air motor 16 is supplied thereto through a pipe line 18 and a normally spring closed, solenoid operated three-way valve 19 from a suitable source (not shown). Compressed air flow to the motor is effected upon energizing solenoid 20 of the valve, while in its normally closed position, the valve shuts off such flow and also permits residual air pressure in the motor to exhaust to atmosphere. A similar four-way valve may be used with one of its pressure outlets plugged, if desired. Electrical operation of the valve to control operation of the hydraulic pump is effected as hereinafter described.

The pump 17 receives fluid medium, usually tap water under city water main pressure, through inlet pipe 21 and discharges it into delivery pipe 22 containing a shut-off valve 23. The pump is preferably of a known type which, as constructed for this service, has provision for straight through flow of fluid under the supply main pressure to permit prefilling the tube coil without operating the pump and valve 23 enables shut-off of this prefill flow, as needed. Past valve 23, the fluid is conducted through pipe 24, to a T 25, one side of which is connected to a normally closed drain valve 26. The other side of the T is connected with the fitting on one end of a flexible, high pressure hose 27. The opposite end of the hose is provided with a disconnect type of high pressure coupling 28, of well known screw thread or internal piston type, by means of which the hose may be connected to the outer end of one end extension 15 of the tube coil 12. The other end extension of the coil has a similar high pressure coupling 29 connected thereto and it connects with a stop cock 30 by means of which air in the tube coil 12 may be expelled past the cock 30 by the entering liquid as the tube coil is being prefilled. The cock is manually closed after the prefilling operation.

The coil end portions or pigtails 15 vary considerably in length in differently manufactured heat exchanger units and it is desirable to support them against the tube expanding pressure. Hence, when needed by reason of their length, we provide restraining sleeves 31 and 32 on the respective tube end portions 15. Sleeve 31 extends full length between the coupling 29 and the adjacent end plate 11 of the fin pack, while sleeve 32 is short enough to permit a control muff, indicated generally at 33, to be fitted between the sleeve and the adjacent end plate 11.

In Fig. 1, a short end section 15 is illustrated and a sleeve beyond the muff is not needed, as the coupling 28 supports the tube protruding from the muff.

The control muff, as best seen in Figs. 1 through 4, comprises two mating elongated block members 34 and 35 having between them an axial bore 36 sized for a clearance fit with the tube, and muffs with a range of bore sizes are to be provided to accommodate a range of tube sizes. The two block members are adapted to be clamped together by any suitable means; as shown, simple bolts 37 being provided whose nuts 38 need merely be drawn up hand tight. Intermediate and preferably centrally of the ends of the block members a cavity or chamber 39 concentric to the bore 36 is provided and its end walls where they meet the wall of the bore are radiused or rounded off, as indicated at 40, so as to eliminate danger of cutting the tube during the expansion operation. The chamber provides an expansion space for the length of tube extending thereacross. Its axial length has been found to be rather critical in that if it is too short, the tube will be supported against swelling to such an extent that the tube may balloon or even rupture inside the fin pack without adequate swelling in the chamber for control purposes. If made too long, the reverse may occur in that the tube may swell and rupture in the chamber before it becomes tight in the fin pack. Desirably, the tube expansion occurring in chamber 39 will be of sufficient magnitude for control purposes and be accompanied by expansion in the fin pack to an extent which assures or produces a tight fit between the fins and the straight runs of the tube coil; the control hereinafter described operating to disconnect the fluid pressure supply from the tube when the desired expansion has been effected. We have found that a chamber length of between about 1.5 and 3 times the O.D. of the tube is effective in attaining this result, since it correlates the swelling in the chamber to that occurring in the fin pack.

The control muff 33 carries a plurality of switch operating control members for automatically terminating an expansion operation. These may take various forms, but preferably comprise electrodes for making electrical contact with the tube, at least three such electrodes being found necessary, substantially equally spaced about the tube in the expansion chamber 39 and in fixed radially spaced relation thereto for contact by the tube wall when it expands. Each comprises a head 41 and an elongated, outside threaded body member 42 provided with fine pitch screw threads and screwed into a threaded radial bore in the muff to extend radially from chamber 39. While each member 42 may be made from any suitable electrical insulation material and a central conductor member provided therethrough, it may conveniently be made from a hex-head cap screw or bolt and bored lengthwise to accommodate in insulated relation thereto a conductor member 43 which is provided with a head 44 on its inner end preferably of hemispherical shape to provide point contact with the tube initially and of progressively increasing area of contact thereafter. Top and bottom insulating washers 45, seated in counterbores in the opposite ends of the body 42, center the conductor member and hold it out of contact with body 42. The outer end of the conductor member 43 is threaded and receives a washer and a clamp nut 46 to clamp the conductor member in rigid assembly with the body 42, a second nut 47 being provided for convenient attachment of a conductor wire to the electrode. Between the head 41 of each electrode and the body of the muff, a stiff spring 48 is provided to take back-lash out of the screw thread connection and permit precise radial adjustment of the electrode with respect to the tube in the muff and to maintain the adjustment.

Adjustment of the electrodes may be effected in various ways. One way that has been found suitable is to use a gauge block suitably sized in diameter on the basis of the desired tube expansion in chamber 39 and held

concentric to the axis of chamber 39 by ends fitted to the bore 36 and then screwing in each electrode until its head 44 makes electrical contact with the gauge block, as indicated by a conventional test lamp probe. Another way is to have a skilled operator effect a coil expansion operation under the manual feel or sensing control of tightness hereinabove described, with the control muff in position on a tube end but with the electrodes backed-off to a position that they will not be contacted by the bulged tube wall in the muff chamber 39. Then, with the desired tight fin-to-tube fit obtained, the operator locks the hydraulic pressure in the expanded tube coil, whereupon each electrode is adjusted inwardly until it makes contact with the bulged tube wall in the muff chamber 39, as indicated by a test lamp probe.

After being set for a given alloy and wall thickness of tube, the control muff is ready for use with the control circuit for automatically reproducing tube-to-fin joints of the same tightness in subsequently expanded tube coils fabricated from the same alloy and wall thickness of tube regardless of nominal variations in yield strength or temper. One of the problems in the tube producing industry is that of maintaining a specified temper in successive production lots. An advantage of using the control muff 33 in contact with an extension of the tube being expanded is that it will assure the same amount of expansion regardless of temper variations in tubes from different lots.

The control circuit, as shown in Fig. 7, comprises electromagnetic relays 50, 51 and 52 individual to each electrode, conductors 53, 54 and 55 connecting the control conductor members 43 of the electrodes to one end of the operating coil of the respective relays. The other ends of the operating coils are connected to a conductor 56 leading to one terminal of the secondary winding of a transformer 57, the other end of the winding being connected by conductor 58 and a suitable spring terminal clip (not shown) to the muff 33 and ground, so as to put the finned tube coil assembly at ground potential. The transformer primary is connected to a suitable supply source, such as 110 volts, as indicated by conductors L1 and L2. The transformer steps down the line voltage to a relatively low voltage, say 24 volts, for safety to operating personnel. Switch contacts 60, 61 and 62 of relays 50, 51 and 52 are connected in series to provide a series circuit controlling energization of a series relay 63 that controls the pump control valve 19, the operating coil of relay 63 being connected directly across lines L1 and L2 when its series control circuit is completed. This requires each of the switch contacts 60, 61 and 62 to be closed which can be effected only by expansion of the tube in the expansion chamber 39 to make contact with each of the control electrodes.

We have found that at least three electrodes are required in order to take care of variable tube characteristics inherently present as produced within commercial tolerances, in order to assure expansion of the tube runs 13 in the fin pack adequately to produce the desired tight tube-to-fin fits. For example, as illustrated in Fig. 6, the tube may be of non-uniform wall thickness and the thin portion may expand into contact with an electrode before the thicker portion receives adequate expansion. In such case, the head of the engaged electrode serves to give support over a progressively increasing area to the thin portion to prevent it bulging excessively as the thicker portion expands to contact the other electrodes. Under the pressure required to expand the tube in the muff into contact with the three control electrodes, the tube in the fin pack expands into firm or tight contact with the fins. On the other hand, the tolerance variation of the tube with respect to either straightness or roundness may cause the tube end portion to contact one of the electrodes during the expansion operation before the tube is properly expanded; but, since at least three points of contact must be made before the expanding pressure is cut-off, proper expansion of the tube into the fins to create the requisite firm or tight tube-to-fin fit is assured. By way of example of the extent of expansion involved, the industry commonly expands a tube of .375 in. O.D. x .035 in. wall thickness by between about .008 in. and .015 in. to produce the firm or tight tube-to-fin fit.

Reverting to Fig. 7, relay 63, at its break contacts 64, controls the action of valve 19 through a circuit which extends from L1 through contacts 64, contacts 65 of a normally energized reset relay 66 and solenoid 20 of valve 19 to line L2. When relay 63 energizes by contact of the expanded tube with each of the three electrodes, it opens this circuit at contacts 64 and air valve 19 closes to stop the pump 17, thereby terminating the tube expansion operation. Make-contacts 67 of relay 63 close the circuit of a single device, such as a lamp 68, to indicate completion of the expansion operation. At contacts 69, the relay completes a locking circuit for itself which extends through normally closed contacts 70 of a cycle start push switch 71. Thereby, relay 63 remains energized until the operator is ready to expand the next coil, at which time he depresses push switch 71 to cause de-energization of relay 63 and, as a result, energization of solenoid 20 to open valve 19 and thereby cause operation of motor 16 and pump 17. By locking-in relay 63 at the termination of the expansion operation, the control circuit is prevented from chattering in attempting to maintain pressure when the tube in the muff contracts elastically as the operator reduces the pressure in the tube preliminary to disconnecting it from the pressure line.

In the above description, it is said that relay 66 is normally energized. It serves as a start switch when the apparatus is started up for a production run and thereafter as a pump lock-out control in case of electrical power failure.

In operation, when the operator is ready to expand the first coil after opening valve 23 and prefilling the coil, he depresses push switch 71 to close its contacts 72, thereby initially energizing relay 66 which locks-in across the line through its contacts 73 and holds its contacts 65 closed. Since relay 63 is de-energized and its contacts 64 are closed at this time, closure of contacts 65 completes the circuit of solenoid 20 and it energizes to open valve 19 and the pump 17 operates to build up pressure in the tube coil to effect expansion thereof. Responsively to energization of relays 50, 51, and 52 when the tube in the muff expands sufficiently to make electrical contact with each electrode, in any order, the series circuit through contacts 60, 61 and 62 closes and relay 63 energizes to stop the pump and this terminates the expansion operation, as hereinbefore described.

The operator then closes valve 23 and opens drain valve 26 to reduce the pressure in the expanded coil, and valve 30 may be opened after the pressure drops to facilitate liquid drainage from the coil. The disconnect couplings 28 and 29 and the sleeves 31 and 32 are then removed from the ends of the coil. The muff bolts are then loosened to permit parting of the axially split muff sufficiently to clear the tube enlargement formed in the muff chamber 39 so that the muff can be removed. Of course, the use of other forms of muff clamps is contemplated, such as pivoted muff halves with a latch to hold them closed, or one half may be fixed and the other movable with respect thereto, as by an operating cylinder, the requirement being muff opening to permit passage of the tube enlargement therefrom. With the muff open the operator removes the expanded tube coil and proceeds to set-up to expand the next coil. After prefilling the coil, he merely depresses push switch 71 and relay 63 de-energizes to start the pump and the coil is expanded to the point of automatic termination by re-energization of relay 63, as heretofore described.

If there is any power interruption during an expan-

sion operation, valve 19 will close and stop the pump, thus preventing any accidental over-expansion of a coil in process. Reset relay 66 will also drop-out and open a point in the circuit of solenoid 20 of the valve at contacts 65, so that the valve cannot be reopened to continue the expansion operation until the circuit is reset. The operator resets the circuit, when the power returns, by depressing switch 71 and the tube expansion operation proceeds to completion and series relay 63 locks-in, as before decsribed. Should a power interruption occur after the series relay 63 has been energized and locked-in in termination of an expansion operation and while valve 23 is closed, the relay 63 would drop-out and, except for the safety provided by reset relay 66, the pump would accidently operate when the power returns with consequent danger of damage to the pump and the closed hydraulic piping. Drop-out of the reset relay 66 due to any power interruption eliminates this danger. Moreover, the circuit is so arranged that when the operator completes the set-up operation, including prefilling the coil next to be expanded, he merely depresses push switch 71 to start the expansion operation, the reset relay thereby being re-energized and locked-in across the line, as for an initial start.

It will be seen from the foregoing description that we have provided a simple and effective mechanism for obtaining the objectives of our invention and which results in converting a precarious duty heretofore required of a highly skilled workman to a routine operation for an unskilled workman, to obtain rigid expanded tube heat exchanger assemblies. It should be clear that various changes and modifications in the apparatus may be made without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. In a system of expansion control for a finned tube heat exchanger unit wherein a thin-wall tube initially extends loosely through a pack of closely spaced thin metal fins and has end portions exterior to the fin pack and is expanded by internal fluid pressure into tight or firm fit with the fins to produce a rigid structural unit with efficient heat transfer relation between the tube and the fins, the combination with fluid pressure supply means for expanding the tube, of means comprising a control muff encircling one of said end portions and detachably clamped thereto, an axial chamber in said muff to permit swelling of the tube length extending thereacross and of a length correlating the tube swelling therein to that occurring in the fin pack, at least three circumferentially spaced electrodes carried by said muff in substantially equal angular relationship to each other and extending radially from said chamber in fixed radially spaced relation to said tube length for contact thereby upon swelling thereof, valve means operative to disconnect the fluid pressure supply from the tube, and electrically actuated switch means responsive only to contact of each of said electrodes by said tube length for actuating said valve means in termination of the tube expanding operation, said muff being axially split for removal from the expanded tube length embraced thereby.

2. The combination as defined in claim 1 wherein said switch means comprises an electromagnetic relay individual to each electrode, a set of contacts for each said relay connected in series circuit relation with each other, a second electromagnetic relay connected in said series circuit and energized upon closure of each of said sets of contacts to actuate said valve means, and a push switch controlled self-locking circuit for said second relay to maintain it energized during intervals between successive tube expansion operations.

3. In a system of expansion control for a finned tube heat exchanger unit wherein a thin-wall tube initially extends loosely through a pack of closely spaced thin metal fins and has end portions exterior to the fin pack and is expanded by internal fluid pressure into tight or firm fit with the fins to produce a rigid structural unit with efficient heat transfer relation between the tube and the fins, the combination with fluid pressure supply means for expanding the tube, of restraining means including a muff encircling said end portions for supporting the same against the tube expanding pressure, said muff having an axial chamber therein of a length exceeding the outside diameter of the tube to permit swelling of the tube length extending thereacross correlated to that occurring in said fin pack, at least three electrodes screw threadedly carried by said muff in substantially equally spaced relation about the axis of said chamber and extending radially therefrom in prefixed radially spaced relation to said tube length for contact thereby upon swelling thereof, valve means operative to disconnect the fluid pressure supply from the tube, and electrically actuated switch means responsive only to contact of each of said electrodes by said tube length for actuating said valve means in termination of the tube expansion operation, said muff being split along the axis of said chamber for removal from the expanded tube length embraced thereby.

4. A control muff for use in an electrical system of tube expansion control of the character described, comprising two elongated, mating block members for encircling an end portion of the length of a tube which is to be expanded and having between them an axial bore sized to fit the tube extending therethrough, clamp means for releasably holding said block members in closed position about said tube, a chamber formed in said block members coaxially of said bore to permit swelling of the tube length extending thereacross under internally applied tube expanding pressure, a plurality of at least three electrodes substantially equally spaced about the axis of said chamber and screw threadedly carried by said block members for radial adjustment, an electrical conductor extending centrally through each electrode in insulated relation thereto, the inner end of each conductor having a head of hemispherical shape for contact by said tube length upon swelling thereof, thereby to complete an electrical control circuit and give support of progressively increasing area to the expanded tube wall after initial contact has been made, said electrodes being adjusted to position their heads in fixed spaced relation to said tube length, and said chamber having an axial length of between about 1.5 and 3 times the outside diameter of said tube, to correlate the swelling of said tube length in said chamber to that occurring exteriorly of the muff.

5. The muff structure defined in claim 4 further characterized by the provision of a stiff spring cooperating with each electrode to urge it outwardly and take out back-lash in its screw threaded connection with the said block members and to maintain the electrodes in adjusted position.

6. Apparatus for expanding a sinuous tube coil having straight runs threading loosely through a pack of closely spaced thin metal fins and pigtails extending outwardly from the fin pack, and for terminating the tube expansion with a tight tube-to-fin fit to produce a rigid finned tube heat exchanger unit, said apparatus comprising a hydraulic pump, motor means operative to actuate the pump, means including a detachable coupling connected to one pigtail to deliver pressure fluid from said pump to said tube coil to expand the same, a venting valve connected to the other pigtail to shut off flow of pressure liquid therefrom, means for supporting said pigtails against expansion, including a muff detachably surrounding one of them, said muff having an internal chamber permitting expansion of the tube length extending thereacross and being of a length correlating tube swelling therein to that occurring in said fin pack, a plurality of at least three electrodes substantially equally

spaced about the axis of said chamber and extending radially from said chamber in fixed radially spaced relation to said tube length for contact thereby upon expansion, a relay individual to each electrode, means to supply electrical energy at low voltage in a circuit including said muff, said electrodes and said relays for operating said relays, contacts controlled by each relay and connected in series, a second relay energized by closure of said serially connected contacts, electrically actuated means connected in a circuit controlled by said second relay and operatively connected to said motor means for rendering the same inoperative and thereby stopping said pump responsively to expansion of said tube length in said chamber into contact with each of said electrodes, and a push switch controlled holding circuit for said second relay to maintain the latter energized during periods between successive expansion operations.

7. Apparatus as defined in claim 6 including a reset relay normally energized from said electrical energy supply through a self-locking circuit and having contacts interposed in and operable to open said circuit controlled by said second relay upon any electrical power interruption, and a circuit including normally open contacts on said push switch for energizing said reset relay.

8. In a system of expansion control for a finned tube heat exchanger unit wherein a thin-wall tube initially extends loosely through a pack of closely spaced thin metal fins and has end portions exterior to the fin pack and is expanded by internal fluid pressure into tight or firm fit with the fins to produce a rigid structural unit, the combination with a motor driven hydraulic pump unit together with means for connecting the pump there-

of with said tube for delivering liquid under pressure to the tube for expanding the tube and means including an electromagnetically actuated relay for controlling the starting and stopping of said motor, an energizing circuit for said relay, a push-switch controlled locking circuit for said relay, said motor being rendered operative to drive said pump and initiate the tube expansion operation in response to deenergization of said relay by manual depression of said push-switch, a plurality of at least three switches connected in series circuit relation and constituting said energizing circuit for said relay, restraining means encircling said tube end portions for supporting them against the tube expanding pressure, including a muff detachably clamped on one of them, said muff having an axial chamber of a length of between about 1.5 and 3 times the outside diameter of the tube for correlating the swelling of the tube length extending thereacross to that occurring in said fin pack, and at least three control members carried by said muff at substantially equally spaced intervals about the axis of said chamber, each arranged to actuate an individual one of said three switches responsively to a predetermined extent of swelling of said tube length in said chamber, whereby said relay is energized and locked-in to terminate the tube expanding operation, said muff being axially split for removal from the expanded tube length embraced thereby.

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