June 22, 1971 W. E. STARY 3,585,701

APPARATUS FOR EXPANDING TUBES

Filed Jan. 27, 1969 4 Sheets-Sheet 1

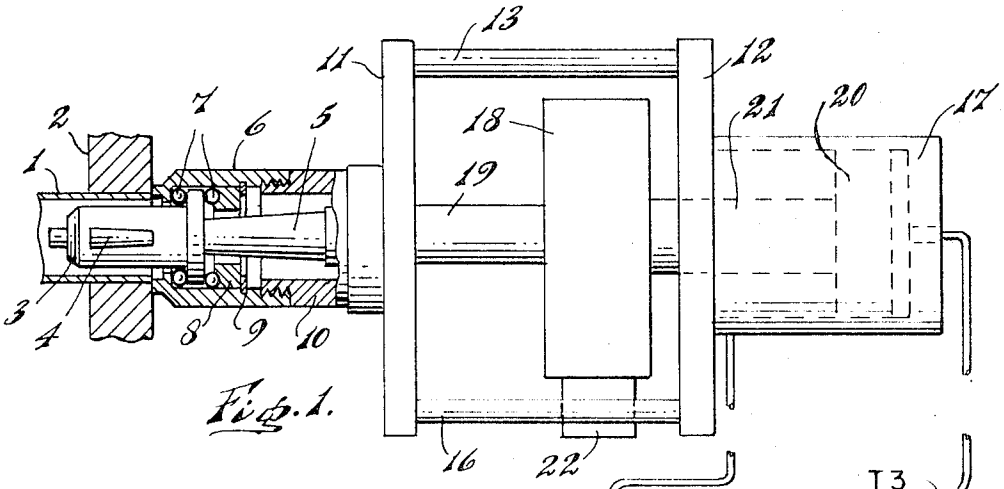


Fig. 1.

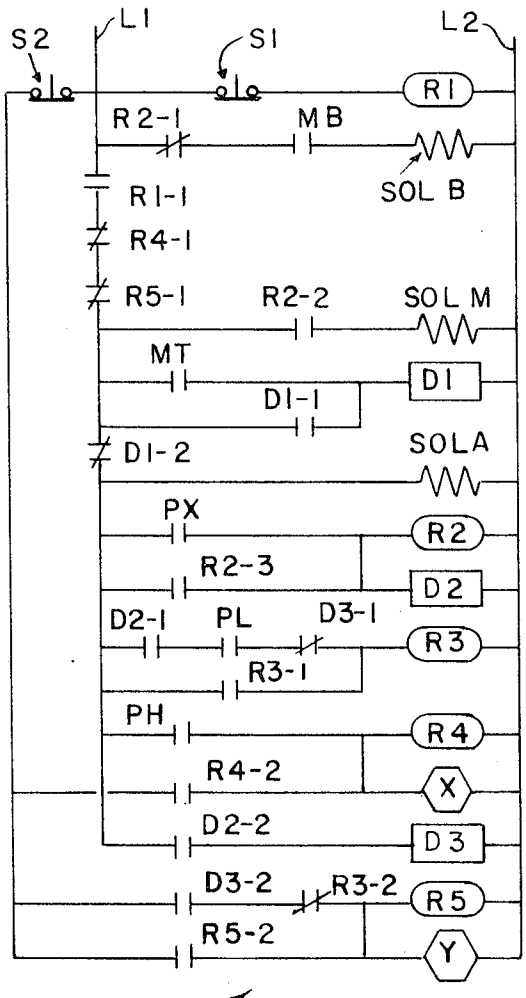


Fig. 3.

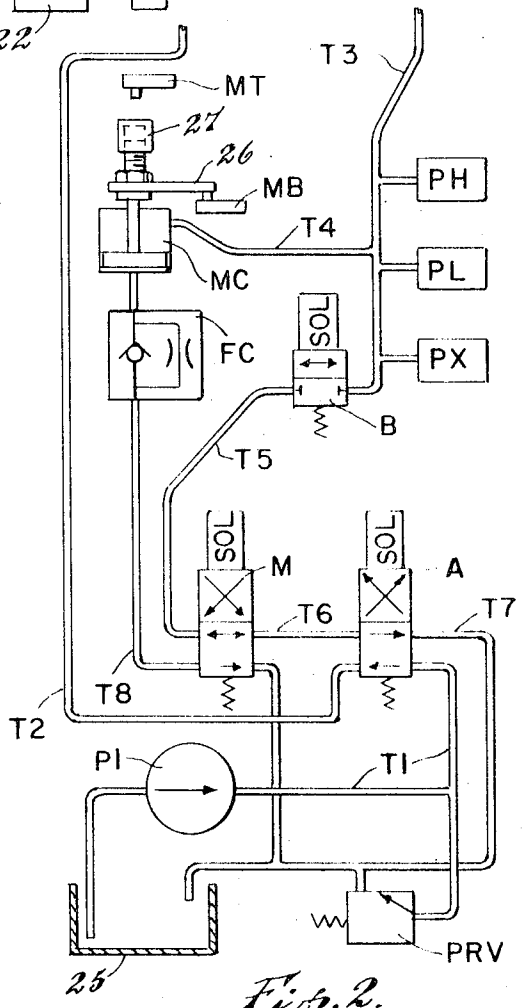


Fig. 2.

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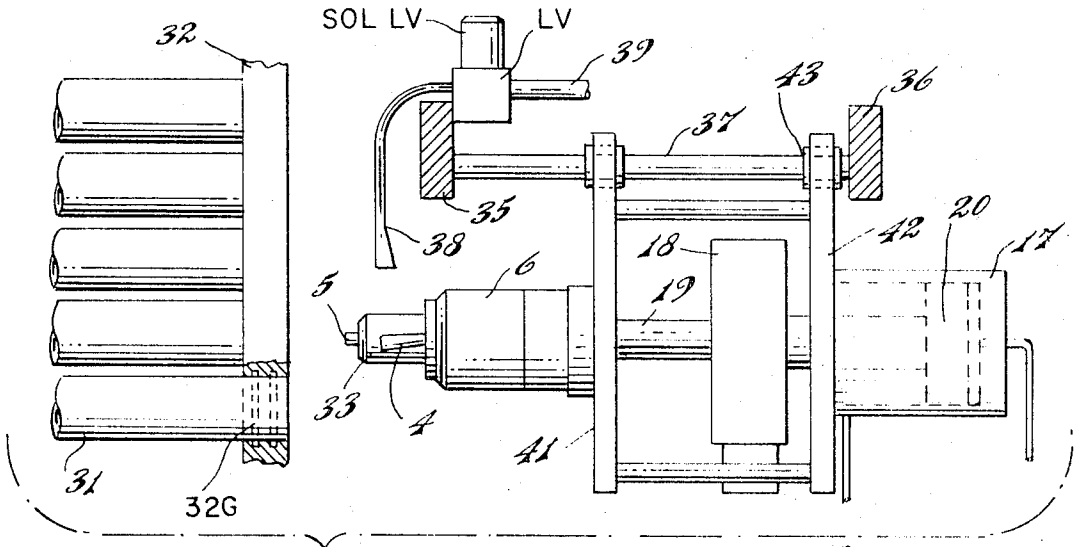


Fig. 4.

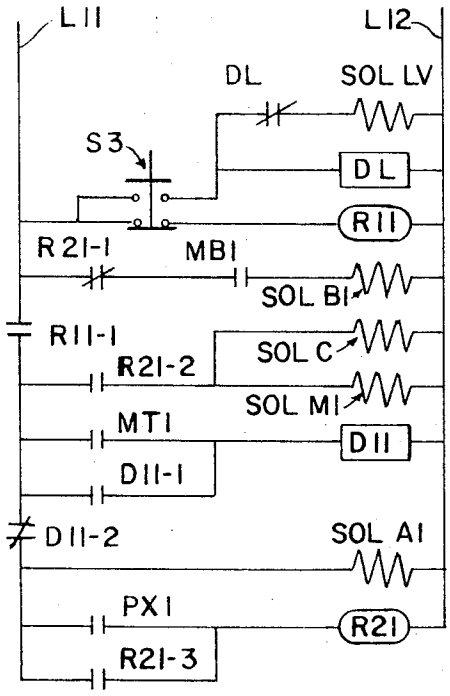


Fig. 6.

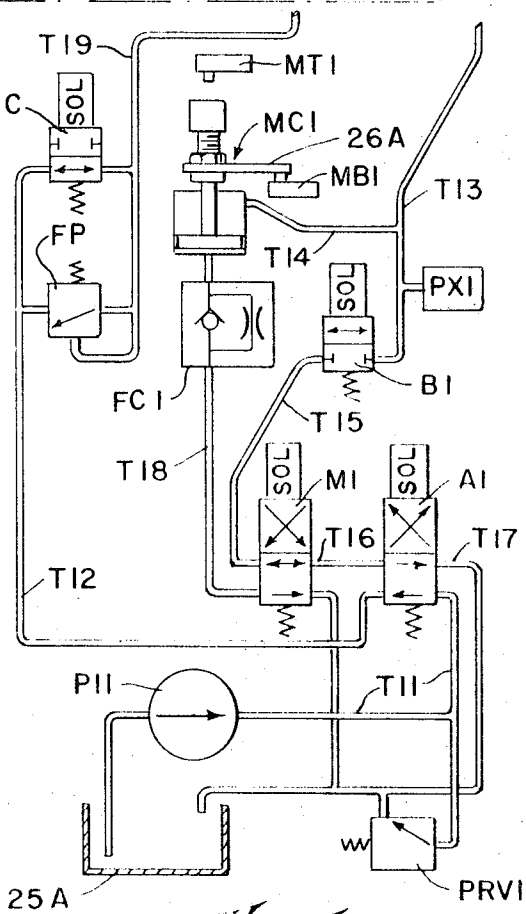


Fig. 5.

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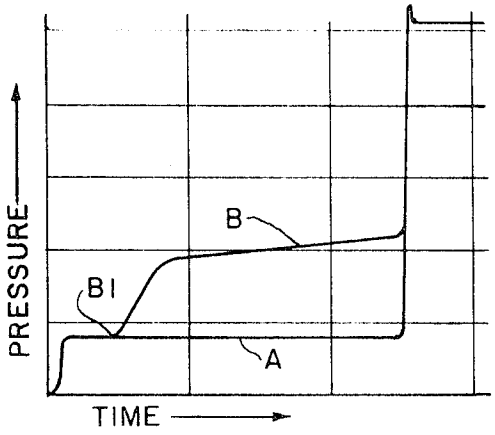


Fig. 7.

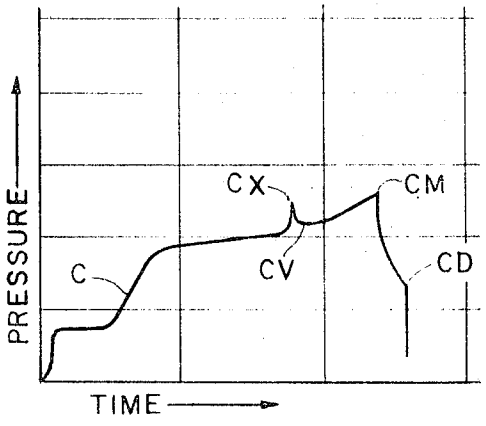


Fig. 8.

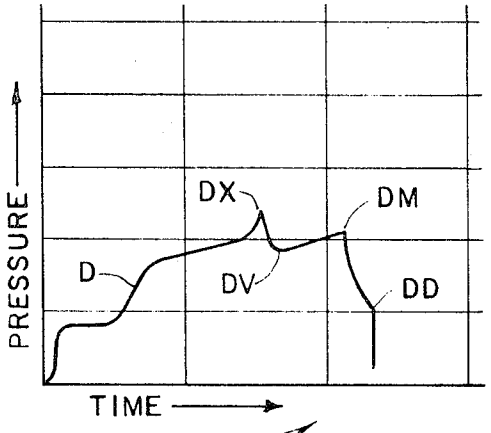


Fig. 9.

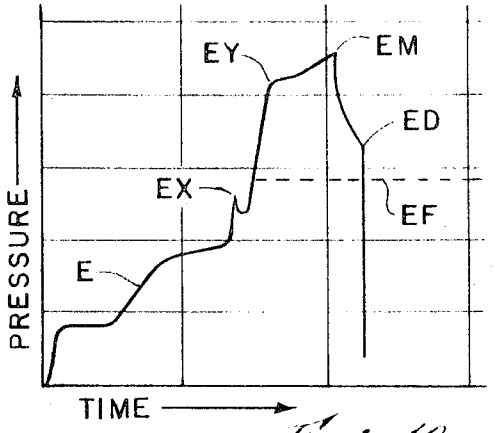


Fig. 10.

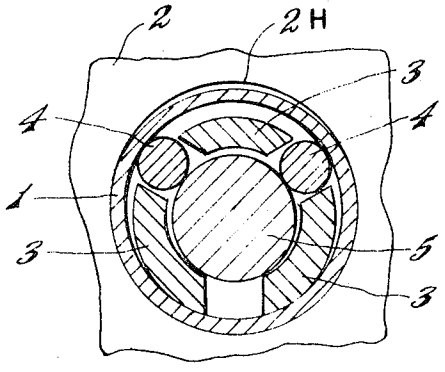


Fig. 12.

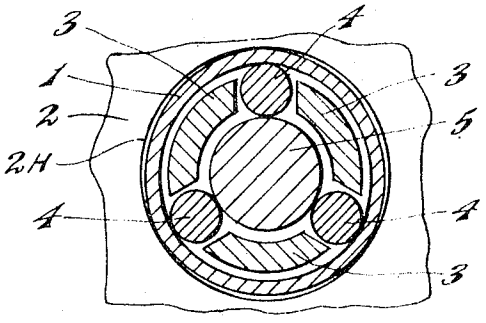


Fig. 11.

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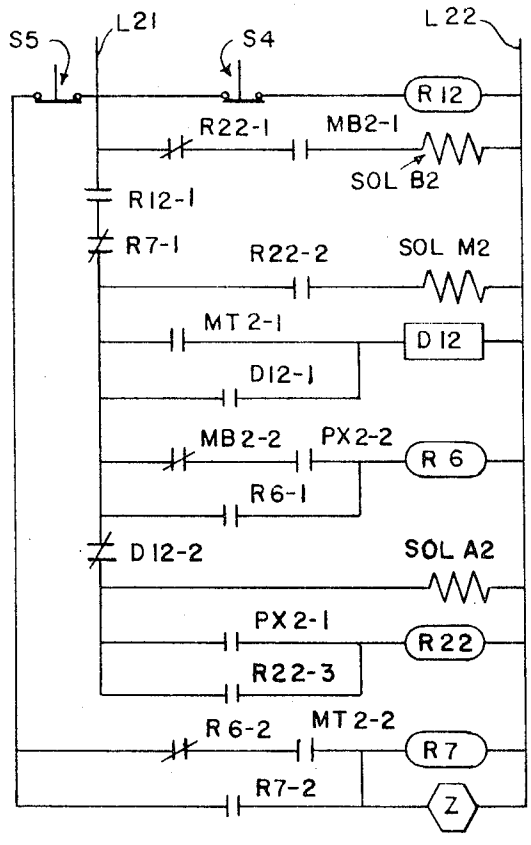


Fig. 14.

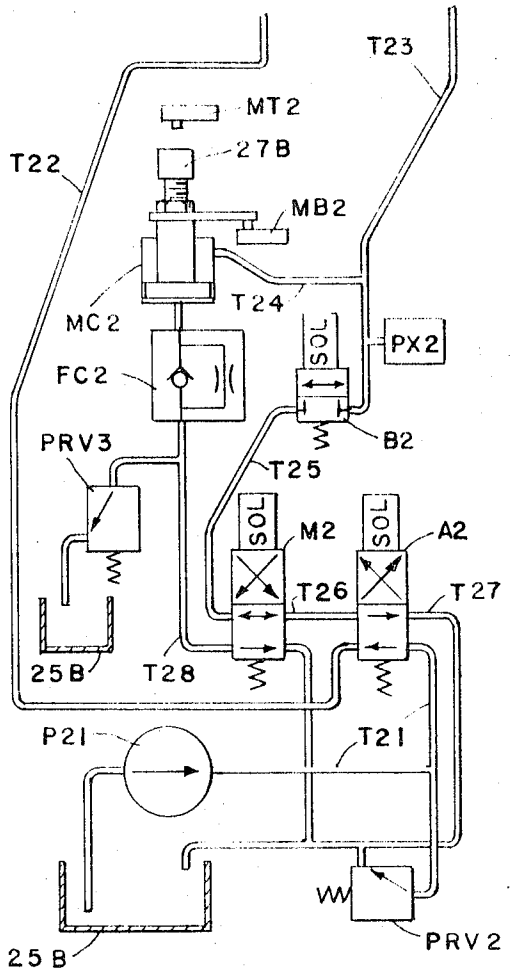


Fig. 13.

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United States Patent Office 3,585,701
Patented June 22, 1971

3,585,701

APPARATUS FOR EXPANDING TUBES

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Filed Jan. 27, 1969, Ser. No. 804,041
Int. Cl. B23p 15/26
U.S. Cl. 29—202 12 Claims

ABSTRACT OF THE DISCLOSURE

This invention provides apparatus to ascertain that the selected degree of interference fit is being produced as each end portion of each tube is expanded into its tube-hole in its mating tube-sheet. The apparatus senses and checks the work-producing force at selected moments during each work cycle, and if any force checked is not the proper magnitude said apparatus indicates a defective work-cycle has been produced.

This invention relates to improvements in apparatus for expanding the end portions of tubes. The apparatus powers and controls a roller-type tube-expanding tool as the tool enlarges a linear portion of a metal tube to bring the tube portion into tight engagement with a tube-hole in which it is being assembled.

A principal use for this apparatus is to make pressure-tight tube-joints between tubes and tube-sheets in heat-exchange apparatus. Heat-exchange apparatus manufacturers make many such tube-joints each work day. Most of this work involves expanding small tubes, 1-inch O.D., or less. The tube-sheets range from very large units, containing thousands of tube-holes, to small tube-sheets, containing about 30 tube-holes for ¼-inch O.D. tubes. The small units are usually quantity-production runs of many units, each with the same number and arrangement of tube-holes.

Automatic drilling equipment which locates the positions for holes and then drills the tube-holes has become a competitive necessity. There is an identical need for similar automatic equipment to make the pressure-tight joints between tubes and tube-sheets. Parts made by the automatic drilling machines can be visually and mechanically inspected to make certain the holes being drilled are satisfactory and within the allowed tolerances. No such inspections can determine the quality, the tightness, of the tube-joints.

A principal objective of this invention is to provide improvements for the apparatus for expanding tubes covered in my Patent No. 2,690,205, issued Sept. 28, 1954, which make said tube-expanding apparatus self-inspecting so that if and when said apparatus produces a defective tube-joint, indicators are activated, the controls are made inoperative, and the action is stopped. The indicators tell which type of fault occurred thus indicating the corrective actions needed. The controls must be manually reset to again make the apparatus operative. Thus the tube-expanding apparatus, as improved by this invention, can work unattended and not do more than one cycle of defective work.

The subject tube-expanding apparatus is thus made usable in an automatic machine which carries the apparatus and moves it over the face of a tube-sheet, positioning the apparatus to get the axis of its tube-expanding tool

coincident with the axis of the selected tube-hole, so that the tube-expanding apparatus can be axially advanced to get its tube-expanding tool into the selected tube-end so that said tube-end can be expanded. After the tube-expanding cycle is completed, the apparatus is retracted, withdrawing the tool from the expanded tube-end, so that a movement to the next programmed location can be made. Thus the automatic machine can continue to do work and expand tube-ends until the programmed work is completed, or until one defective work-cycle is made.

Other objects and advantages of the improvements which are parts of this invention will become apparent from the following description. The accompanying drawings illustrate these improvements.

Referring to the drawings:

FIG. 1 is a side elevation of a tool-driving apparatus with a tube-expanding tool connected thereto. This figure is identical to FIG. 10 in my above described Patent No. 2,690,205, except for the addition of a second annular row of balls in the thrust bearing of the tool.

FIG. 2 is a schematic diagram of a system of hydraulic elements which may be used to produce and control the axial movements of the mandrel of the FIG. 1 tool, and to monitor some of the tool actions to make certain they are proper.

FIG. 3 is a schematic diagram of a system of electrical parts which may be used to actuate and control the hydraulic elements in FIG. 2, and to produce the indicating and work-stopping actions when any hydraulic element in FIG. 2, which is monitoring said tool actions, indicates an improper tool action has occurred.

FIG. 4 is a side elevation of the FIG. 1 tool-driving apparatus, with its tube-expanding tool having angled roll-slots. The FIG. 4 assembly includes different frame plates which provide means for slidably connecting said apparatus to the carriage of an automatic positioning device so that said tool driver may become a part of an automatic machine. An automatic tool lubricating device is also included.

FIG. 5 is a schematic diagram of a system of hydraulic elements which may be used to power and control the FIG. 4 tool-driving apparatus.

FIG. 6 is a schematic diagram of a system of electrical parts which may be used to actuate and control the hydraulic elements in FIG. 5, and to operate the tool-lubricating device shown in FIG. 4.

FIGS. 7, 8, 9, and 10, are graphs showing the relationship of the hydraulic fluid pressure relative to time, as various advance strokes of the tool-driving apparatus are made. They are included to illustrate some of the proper and improper hydraulic reactions which occur, or may occur. They are used for references in the descriptions of some of the improvements brought forth in this invention.

FIG. 11 is the FIG. 9 in said Patent No. 2,690,205, hereinbefore described. It is included for convenience in the references pertaining to it in the discussions of some of the parts of this invention.

FIG. 12 illustrates one of the potential improper conditions which may be encountered in automatically expanding the subject tube-ends which would cause defective work cycles.

FIG. 13 is a schematic diagram of a system of hydraulic elements which may be used to power and control the FIG. 1 tool-driving apparatus, including some

alternate hydraulic elements which may be used to get improved tool action and additional means for monitoring the tool action so as to check the quality of each tube-joint as it is made.

FIG. 14 is a schematic diagram of a system of electrical parts which may be used to actuate and control the hydraulic elements in FIG. 13, with additional means to monitor the tool action and to produce additional indicating and work-stopping actions if said tool actions are not proper.

In the diagrams of hydraulic systems, all solenoid operated valves are schematically shown in their normal condition with solenoids not energized. In the electrical diagrams, all switch contacts are shown in their normal, not actuated, position.

The following notations and abbreviations will be used in the description and discussion of the apparatus.

R+ number prefix will identify contacts on a specific relay.

D+ number prefix will identify contacts on a specific time-delay unit. Each time-delay unit has its contacts shift position the delay interval after coil is energized.

NO signifies normally open, and NC signifies normally closed, for all manual, mechanical, and relay-operated switch contacts, and for switch contacts in pressure sensitive devices.

SOL+ symbol indicates the solenoid on solenoid-operated valve having the same symbol designation.

Referring to the drawings, particularly FIGS. 1, 2, and 3, as hereinbefore mentioned, FIG. 1 shows the FIG. 10 apparatus of said Patent No. 2,690,205. The FIG. 1 apparatus has its tube-expanding tool in position to expand the end of tube **1**, into a tube-hole in tube-sheet **2**. Roll-cage **3**, containing several tapered rolls **4**, has tapered mandrel **5** centrally located in the cage and rolls assembly, with mandrel **5** in its retracted position.

The combination depth-control gage and thrust-bearing housing **6** contains two annular rows of balls **7**, one row on each side of the thrust-flange portion of roll-cage **3**, backup ring **8**, and retaining ring **9**, thus forming an assembly which keeps roll-cage **3** supported, axially positionable, and free to rotate. Connector **10** connects the roll-cage portion of the tool assembly in a fixed axial position relative to the frame of the tool driver. The frame consists of front plate **11**, rear plate **12**, and four tie-rods, tie-rods **13** and **16** being shown, and tie-rods **14** and **15** being positioned at the rear corners of the trapezoid-shaped frame plates **11** and **12**, directly behind rods **13** and **16** in the subject view.

The axial forces which produce the tool actions are provided by hydraulic cylinder **17** attached to rear frame plate **12**. Advancing and retracting movements of mandrel **5** are produced by hydraulic fluid entering the proper end of cylinder **17** and moving piston **20**. Piston rod **21** connects to mandrel power-rotating unit **18**, thus causing power-rotating unit **18** to move axially as piston **20** moves. Shaft **19**, of power-rotating unit **18**, passes thru front frame plate **11** and connects to mandrel **5** so mandrel **5** must rotate with shaft **19**, of power-rotating unit **18**, and reciprocate with piston **20**.

Lug **22**, a part of the housing of power-rotating unit **18**, is slidably fitted between tie-rods **16** and **15**, rod **15** being on the other side of lug **22**, in back of rod **16**. Thus the torque reaction produced when the tool does work is transmitted to the tool-driver frame.

The following description of the expanding of a tube-joint to a preselected tightness refers to FIG. 1 apparatus axially powered by the FIG. 2 hydraulic system as controlled by the FIG. 3 electrical system. The apparatus is in its regular operating condition, as it is at the end of a normal work cycle of tube-expanding. Power-rotating unit **18** is running, and mandrel **5** is axially retracted and rotating. The output of hydraulic pump P1 is flowing thru tube **T1**, thru pressure-relief valve PRV, and back to tank **25**. The hydraulic system maximum pressure, as established by valve PRV, exists in tubes **T1** and **T2**, and in cylinder **17** where it acts to hold piston **20** in its retracted position.

The electrical system is operable with cycle-control switch **S1** in its normal, NC, position. The coil of relay **R1** is energized and NO contact **R1–1** is closed. The coil of time-delay unit **D1** is being maintained energized by closed NO contact **D1–1**, and NC contact **D1–2** is held open. The coil of relay **R2** is not energized and NC contact **R2–1** is closed. Measuring cylinder MC is retracted and NO contact MB, in switch MB, is closed. Thus SOL B, on normally-closed hydraulic valve B, is energized and valve B is open.

A work cycle is started by operating switch **S1**, in the following manner. Switch **S1** is operated to open NC contact **S1** and coil of relay **R1** is deenergized, thus opening NO contact **R1–1** and stopping flow of electrical current in line **L1** beyond said contact **R1–1**. Coil of time-delay unit **D1** is deenergized and its switch contacts return to their not-energized condition with contact **D1–2** closed. As switch **S1** is released, relay **R1** is energized and contact **R1–1** is closed. SOL A is energized shifting valve A so it directs hydraulc flow from tube **T1** thru tubes **T6** and **T5**, thru valve B which is being held open, thru tube **T3** and to hydraulic cylinder **17** to put pressure behind piston **20**, forcing piston **20**, and mandrel **5**, to advance.

Rolls **4** move radially outward as mandrel **5** advances, and when the rolls come into contact with the inner surface of tube **1**, said rolls start their planetary rotating about said rotating mandrel **5**. Said mandrel continues advancing, moving rolls **4** outward radially, expanding and distorting the tube portion until the FIG. 11 condition is developed. The tube-sheet metal surrounding the tube-hole provides resistance to the further radially outward movement of said rolls and the hydraulic pressure increases and operates pressure-sensitive switch PX.

As NO contact P5 closes, the coil of relay **R2** is energized, opening NC contact **R2–1** to deenergize SOL B allowing valve B to close. NO contact **R2–2** closes and SOL M is energized shifting valve M so it directs the hydraulic flow thru tube **T8**, thru the orifice of flow-control unit FC, and into measuring cylinder MC, to thus advance the piston of said cylinder MC. NO contact **R2–3** closes to hold relay **R2** energized.

As soon as piston of cylinder MC starts to rise, arm **26**, attached to the piston rod of cylinder MC, allows the NO contact MB, in switch MB, to open. Cap **27**, threadably attached to said piston rod of cylinder MC, also rises as said piston rises. The fluid being discharged from cylinder MC, as its piston rises, is forced into tube **T4**, Since valve B is closed, said fluid is forced to flow thru tube **T3** and into cylinder **17**, to advance piston **20** and mandrel **5**. The piston of cylinder MC continues to rise, carrying cap **27** toward switch MT, until it operates switch MT, closing the NO contact MT. The support for switch MT, not shown, physically stops the further advance of said piston of cylinder MC, thus stopping the flow of fluid into cylinder **17**, and thus stopping the axial advancing of mandrel **5**.

As the NO contact MT, in switch MT, closes, the coil of time-delay unit **D1** is energized. After the selected time-delay, NO contact **D1–1** closes, and NC contact **D1–2** opens. Closed contact **D1–1** maintains time-delay **D1** in its energized condition. As contact **D1–2** opens, SOL A, of valve A, and coil of relay **R2**, are deenergized. Valve A shifts to direct hydraulic flow to tube **T2**. At this same moment relay **R2** is being deenergized and its contact **R2–2** opens and deenergizes SOL M, thus permitting valve M to shift to connect tube **T8** to tank **25**, and to connect tube **T5** to tube **T6**, and NC contact **R2–1** closes. The hydraulic flow thru tube **T2** goes to cylinder **17** forcing piston **20** to retract, thus retracting mandrel **5**. The fluid, in cylinder **17**, on the other side of piston **20**, is forced into tube **T3**. Since valve B is closed, the fluid being discharged from

cylinder 17 must flow through tube T4, into cylinder MC, to force the MC piston to retract. The exhaust flow from cylinder MC flows thru the check valve in flow-control FC, thru tube T8, and into tank 25.

As the piston of cylinder MC is being retracted, arm 26, connected to said piston, is moving toward switch MB. Said arm 26 operates switch MB just before cylinder MC becomes fully retracted, and the NO contact MB, in switch MB, is closed. Since NC contact R2–1 is already closed, SOL B is immediately energized and valve B is forced to open. The remainder of the fluid to be discharged from cylinder 17 can then flow thru tubes T5 and T6, and on to tank 25. When piston 20, in cylinder 17, is fully retracted, the work cycle is completed and the apparatus is ready for another cycle of tube-expanding.

The preceding description of the operation and actions of FIGS. 1, 2, and 3, ignores pressure-sensitive units PL and PH, of FIG. 2, and time-delay units D2 and D3, relays R3, R4, and R5, and recording and indicating units X and Y, of FIG. 3. These additional parts of the apparatus are elements added by this invention. The following description of the actions of these additional elements of hydraulic and electrical apparatus will refer to FIGS. 7, 8, 9, 11, and 12, as well as the basic references FIGS. 1, 2, and 3.

FIG. 11 exaggerates the distortion of tube 1 in its tube-hole 2H, for purposes of illustration. The usual practice is to have a minimum practical clearance between tubes and tube-holes so that the pressure-tight joints can be produced, in minimum time, and with minimum thinning of the tube wall to thus develop the maximum tube-joint strength.

FIGS. 7, 8, and 9, chart the hydraulic pressure in tube T3 relative to time during an advance stroke of piston 20 and its associated mandrel 5.

Curve A, FIG. 7, charts the pressure for an advance stroke with no tube portion restricting the radially-outward movement of rolls 4. All pressure recordings are taken in tube T3, near where pressure-sensitive units PX, PL, and PH, connect to tube T3. Thus the pressure recorded in curve A, FIG. 7, is the pressure required to produce the axial advance of the apparatus plus the pressure required to produce the flow thru the system, beyond the recorder connection point in tube T3, as mandrel freely advances at the velocity produced by the output-volume of pump P1. In curve A, the pressure quickly rises as advance movement starts, then it remains substantially constant until piston 20 reaches its forward-travel limit, then the pressure immediately rises to the maximum pressure available in the system, as controlled by relief valve PRV.

Curve B, FIG. 7, charts the pressure required to get the same full-length advance stroke with a tube portion 1, on the tool, but with no tube-hole 2H surrounding said tube portion, thus indicating the force required to get the maximum expansion and distortion of the tube portion producible by the tool being used. Obviously, the tube-hole must be smaller than this maximum diameter. Curve B starts, and continues, exactly the same as Curve A, until point B1 is reached. At point B1, mandrel 5 has advanced and rolls 4 have moved radially outward to contact tube 1, and the planetary rotation of rolls 4 and cage 3 starts. The pressure rises relatively rapidly for the initial portion of the tube-expansion and distortion, and then the pressure-rise changes to a more gradual rate of increase until the end of the advance stroke. As piston 20 reaches its forward-travel limit, the pressure increases to the system maximum as it did in Curve A. Thus Curve B starts and ends exactly the same as Curve A. The portion of Curve B which differs from Curve A is the portion of the advance stroke in which work is being done on tube portion 1.

Curve C, FIG. 8, charts the pressure when the advance stroke expands tube portion 1 into pressure tight engagement in its tube-hole 2H, in tube-sheet 2. The tube portion is the same (size, metal, and length) as the tube portion charted in curve B, FIG. 7. The pressure-peak CX is the pressure developed at the moment the hydraulic apparatus responds to the closing of NO switch contact PX, in pressure-sensitive unit PX. Said action occurs as the FIG. 11 condition is developed, as described hereinbefore, in connection with the description of FIGS. 1, 2, and 3.

As valves M and B are shifting, and as cylinder MC is starting and accelerating to its selected piston-advance velocity, there is a short time interval during which no fluid is added to cylinder 17, and a short time interval while the fluid flow-rate is accelerating to its full velocity. The mandrel continues to rotate, during these short time intervals, but mandrel does not advance, and the rolls continue to roll and thin the tube-wall. The resultant reaction is a decrease in the pressure in tube T3. Then the mandrel resumes its advancing, and as the tube portion becomes in its tube-hole, the resistance to further advancing of the mandrel is increasing, and the pressure is increasing. The second pressure peak CM, in curve C, occurs at the momen the piston in cylinder MC stops advancing. During the dwell period which follows, while time-delay unit D1 is timing out, the mandrel continues to rotate but not advance, the tube-wall is additionally thinned and the pressure is decreasing. The pressure at the moment the apparatus responds to the opening of NC contact D1–2 is indicated by point CD, FIG. 8.

Various faulty conditions can exist which permit the making of an automatic work cycle with the tube-joint not properly expanded. One such faulty condition is illustrated in FIG. 12, where one roll 4 has fallen out of its roll-slot. Rolls are normally contained in their roll-slots by one of two methods, a retaining device such as spring 42, illustrated in FIG. 4, of my Patent No. 3,016,944, or by caging lips L, illustrated in FIG. 6, of my Patent No. 2,772,716. The retaining device can break, the caging lips wear out, and in either case the roll may then fall out of its slot when tool is withdrawn from a tube end.

Curve D, FIG. 9, charts the pressure as it might be when the advance stroke expands a tube-end with the faulty tool of FIG. 12. The tube portion, and the tube-hole, for curve D, are identical to those used in making curve C, FIG. 8. The pressure peak DX will be substantially the same magnitude as peak CX, but the pressure reaction thereafter will be different. Note valley DV is considerably lower than valley CV, and peak DM is much lower than peak CM. It is obvious the FIG. 12 tube can not be properly expanded. An unattended automatic machine could continue to make such faulty work cycles.

This invention provides means to stop the apparatus as soon as it has made one, above described, faulty work cycle, in the following manner.

As hereinbefore described, the pressure peak CX, FIG. 8, occurs as the tube portion is being expanded, just after pressure-sensitive unit PX and relay R2 are operated. Time-delay unit D2, FIG. 3, operates to start its time-delay interval at the same moment relay R2 is energized. The NO contacts D2–1 and D2–2, close at the end of the D2 time-delay interval. Said D2 time-delay interval is selected to close said D2 contacts at about the bottom of the valley CV, FIG. 8. Contact D2–2 closes and energizes the coil of time-delay unit D3. Time-delay unit D3 is set to operate its contacts after a short delay. Thus NC contact D3–1 opens soon after contact D2–1 is closed. Pressure-sensitive unit PL is set to operate at the pressure developed at the bottom of valley CV, FIG. 3. Thus, if a pressure equal to, or greater than, the selected minimum CV pressure exists in the system, so that NO contact PL, on pressure-sensitive unit PL, is closed, at any time after contact D2–1 is closed and before D3–1 opens, relay R3 will be energized. As relay R3 is energized, its NO contact R3–1 closes and holds relay R3 energized, and NC contact R3–2 opens and is held open. Then, when time-delay unit D3 times out and closes its NO contact D3–2, relay R5 cannot be energized because said contact R3–2 is open. Thus the work cycle is an approved work cycle

in that the minimum pressure after the CX, FIG. 8, pressure-peak was adequate.

If the pressure is too low so that NO contact PL, on pressure-sensitive unit PL, is not closed during said time interval after contact D2–1 closes and before D3–1 opens, relay R3 will not be energized and its NC contact R3–2 will remain closed. Then, when time-delay unit D3 times out and closes its NO contact D3–2, relay R5 will be energized, thus closing its NO contact R5–2 to hold relay R5 energized, and its NC contact R5–1 will be held open, thus making the electrical system inoperable until switch S2 is operated. The elements associated with relay R5 act to stop the automatic action of the apparatus when a too-low pressure exists, during the selected short time interval, after pressure-sensitive unit PX is operated.

As relay R5 operates to close contact R5–2, indicator Y is energized to give the selected indications that machine has stopped because relay R5 is energized, thus indicating that the pressure was too low after the CX peak, during the previous work cycle.

Some faulty actions can produce a pressure which is higher than the normal pressure developed at peak CX, or peak CM, FIG. 8, whichever is the highest for the correct actions for a particular set of working conditions.

If a too-high pressure is developed at any time during a work cycle, pressure sensitive unit PH, FIG. 2, which is set to operate at a pressure slightly higher than the normal maximum pressure, is actuated, thus closing NO contact PH, FIG. 3, and coil of relay R4 is energized. As relay R4 operates, NO contact R4–2 closes to hold relay R4 energized, and NC contact R4–1 opens and stops the tube-expanding action. Contact R4–2 remains closed, holding relay R4 energized, until reset switch S2 is operated. The X indicator is operated and held operated by closed contact R4–2. Difference in pitch of bells, or color of lights, gives a quick indication telling why the apparatus stopped, that is, whether it was a too-high pressure, or a too-low pressure, which stopped the apparatus from making automatic work cycles. Proper corrective actions should be taken before switch S2 is operated to reset the control system.

FIGS. 4, 5, and 6, disclose some other features of this invention which provide means for incorporating the tube-expanding apparatus into an automatic machine which traverses a tube-field, advances and retracts the tube-expanding apparatus to get its tool into each tube-end, and expands said tube-ends, as detailed in the following description.

In FIG. 4, frame members **41** and **42** contain guide bearings **43** and two or more rod-ways **37**, with said parts arranged to permit the tube-expanding apparatus to slide on rods **37** so it may axially reciprocate within the limits provided by the spacing of frame members **35** and **36**. Frame members **35** and **36** are elements of a carriage, not shown, of the positioning device, not shown, which provides means for moving said carriage in two normal directions so as to position the tube-expanding tool, attached to said apparatus, with its axis coincident with the axis of the tube to be expanded, so that said positioning device can then axially advance the tool driving apparatus to get its tool positioned in said tube to be expanded.

Roll-cage **33** has its roll-slots angled as shown so that when a tube portion is being expanded and the tool planetary action starts, rolls **4** tend to follow a spiral path forcing roll-cage **33** to follow said spiral path in such a manner that said roll-cage tends to advance into the tube. Since tool depth-gage **6** is in contact with the outer face of tube-sheet **32**, preventing said tool from traveling inward into the tube-hole, and since said tube is loose in said tube-hole, said tube is pulled toward the face of depth-gage **6**, until it comes into firm contact with said depth gage. Thus, if a tube is not in its proper axial position, it will be pulled into said desired axial position as the tube-expanding operation starts. Obviously, if the tube is projecting outward beyond the face of the tube-sheet, it will be pushed into position as the tool enters said tube and its tube-hole, when the face of depth-gage **6** contacts the end of said tube during its travel movement as it enters said tube. Thus the tubes are properly positioned relative to the face of the tube-sheet.

Solenoid-operated valve LV, nozzle **38**, and hose **39**, are parts of the tool lubricating device. Hose **39** can conduct a compressed gas containing atomized particles of a lubricant, and nozzle **38** can be positioned and shaped so that, when valve LV is opened, said lubricant is sprayed onto the roll-containing portion of roll-cage **33**. A principal reason for lubricating the tool is to keep it clean and prevent a buildup of particles of scale on the rolls and mandrel of said tool. Said particles of scale are worked loose from the inner surface of the tube, by the rolling action of the tool, and they tend to become bonded to the surface of rolls and mandrel, by the extremely high pressure existing between contacting portions of the surface of said rolls and mandrel, when the rolling action carries the particles into said areas of high-pressure contact. The coating, thus bonded to surface of rolls and mandrel, provides additional resistance to the axial sliding of the mandrel, relative to the rolls, thus reducing the effective force advancing the mandrel.

The tube-expanding actions of the FIG. 4 apparatus may be axially powered by the FIG. 5 hydraulic system as controlled by the FIG. 6 electrical system, in the following manner. The systems are operable and in condition for an automatic-cycle start, with pump P11 running, hydraulic fluid flowing thru pressure-relief valve PRV1, back to tank 25A, the system pressure existing in tubes T12 and T19, passing thru normally-open valve C, and acting to hold piston **20**, of cylinder **17**, and its associated mandrel **5**, retracted. The power-rotating unit **18**, its shaft **19**, and its associated mandrel **5**, are rotating. Tubes T13, T15, and T18, are connected to tank return line T17. Measuring cylinder MC1 is retracted, and arm 26A is holding NO contact MB1, in switch MB1, closed, and normally-closed solenoid-operated valve B1 is open.

Control switch S3, FIG. 6, is operated to open its NC switch contact. The coil of relay R11 deenergized and NO contact R11–1 is open. Relay R21 is deenergized and its NC contact R21–1 is closed. As described above, NO contact MB1, in switch MB1, is being held closed, and SOL B1 is energized and holding valve B1 open.

The positioning device is at a work position and it makes an axial-advance movement to get the tube-expanding tool into the tube-end. Frame members **41** and **42** axially slide on ways **37**, advancing the tool-driver apparatus until depth-gage **6** contacts the face of tube-sheet **32**. As said depth gage contacts the tube-sheet, switch S3 is operated to let its NC contact close, thus energizing the coil of relay R11, closing NO contact R11–1. Time-delay unit D11 is not energized, and its NC contact D11–2 is closed. SOL A1 is energized and valve A shifts to direct the hydraulic flow from tube T11 to tube T16, thru valve M1 and tube T15, thru valve B1 and tube T13, and on to cylinder **17** to advance piston **20** and mandrel **5**.

As mandrel **5** is advancing, the hydraulic fluid being exhausted from cylinder **17** flows thru tube T19, thru normally-open valve C, thru tube T12 and back to tank 25A. The mandrel continues advancing, and when the FIG. 11 condition is developed pressure-sensitive unit PX1 is actuated, closing its NO switch contact PX1, the coil of relay R21 is energized, and the following actions occur. NC contact R21–1 opens and SOL B1 is deenergized, allowing valve B to close. NO contact R21–2 closes and energizes SOL M1 and SOL C of valves M1 and C respectively. NO contact R21–3 closes and holds relay R21 energized. The mandrel starts to make the additional, measured-advance, portion of its axial advance.

As hereinbefore described, rolls **4** are caged in the angled roll-slots in roll-cage **33**, so as to produce the tube-pulling action. Said angled roll-slots also produce a self-

feeding effect, advancing the tool mandrel. This self-feeding effect is referred to in my Patent No. 3,016,944, wherein reference is made to Brackett, Patent No. 2,448,512. A prime objective of this invention is to make a tube-joint in minimum time, thus making a maximum number of tube-joints per minute. It is necessary to complete the tube-pulling action before the FIG. 11 condition is established and the tube outer surface is in firm contact with its tube-hole. It may, therefore, be necessary to angle rolls **4** more than said rolls would be angled to get the normal, mandrel, self-feeding effect. Then, when the FIG. 11 condition is established, the mandrel may be pulled forward too rapidly so as to seriously overload the apparatus or the tool. Or a normal self-feeding angle may cause the rolls to pull the mandrel forward faster than the desired mandrel-advance rate, to produce the proper tube-wall thinning action, during said measured-advance portion of the cycle.

This invention includes means to stop the self-feeding action as the FIG. 11 condition develops and the tube-joint tightening action starts. Said means acts to hold back the mandrel with a holding-back force equal to, or greater than, the mandrel pulling force produced by the self-feeding effect of the angled rolls. As hereinbefore described, when the FIG. 11 condition is developed, pressure sensitive unit **PX1** is actuated, normally-closed valve **B1** is allowed to close, normally-open valve C is closed, and valve **M1** shifts to direct the hydraulic flow thru tube **T18** to get an advance action of cylinder **MC1**. When valve C closes, the exhaust flow from cylinder **17** must flow thru counterbalance valve FP, to get from tube **T19** to tube **T12** and on to tank **25A**. Said counterbalance valve FP is set to open at a pressure which gives a holding-back force acting on piston **20** equal to, or greater than, the force needed to stop the mandrel-advancing action produced by angled rolls **4**.

Curve E, FIG. 10, charts the pressure for a representative mandrel-advance action when a tube portion is being expanded with the FIG. 4 apparatus. Curve E, from the beginning of the mandrel avance until pressure peak EX is developed, is similar to the same part of Curve C, FIG. 8. The pressure needed in tube **T19**, to stop the advance movement of piston **20**, produced by the self-feeding effect developed by angled rolls **4**, may be of the magnitude represented by the dotted horizontal line EF, FIG. 10. Obviously, it is necessary to develop a pressure in tube **T13** of a greater magnitude than said EF pressure to get any additional advancing movement of mandrel **5**. The pressure producing the additional mandrel-advance must rise to the EY magnitude to get the desired rate of additional advance, and said pressure then rises to the EM magnitude at the end of said mandrel advance. Pressure then drops off to the ED magnitude at the end of the dwell interval.

When time-delay unit **D11** times out and opens NC contact **D11–2**, SOL **A1** and coil of relay **R21** are deenergized, valves **A1** and **M1** shift to give the normal measuring-cylinder retract and mandrel retract actions, SOL C is deenergized allowing valve C to return to its normally-open condition, and counterbalance valve FP becomes inactive in the circuit.

As soon as the mandrel retract action commences, the tool is free to be withdrawn from the tube-end it has expanded, and another contact on time-delay unit **D11**, not shown, can initiate the actions of the positioning device so that the tool-driving apparatus retracts, sliding back on ways **37**. As frame member **42** approaches its travel limit, relative to carriage member **36**, switch **S3** can be operated to close its NO contact thus initiating the action of the tool lubricating device. As said NO contact on switch **S3** closes, SOL LV is energized, and normally-closed valve LV, FIG. 4, is opened to allow flow of the atomized lubricant from hose **39** to nozzle **38** so as to spray said lubricant on roll-cage **33** and rolls **4**. At this same moment, the coil of time-delay unit DL is energized, and when time-delay DL times out its NC switch contact DL is opened, thus deenergizing SOL LV, allowing valve LV to close and stop the flow of said lubricant. The NC contact on switch **S3** opens as the above lubricating action starts, but this does not affect the mandrel-retracting action, if mandrel is not completely retracted at the moment switch **S3** is operated.

Means associated with the NO contact of switch **S3** or with time-delay unit DL, not shown, can be used to start actions of the positioning device to move its carriage and said tube-expanding apparatus to the next programmed location so that another cycle of tube-expanding action can be made. As said carriage and tube-expanding apparatus arrive at said next programmed location, the positioning device initiates actions to advance said tube-expanding apparatus to get its tube-expanding tool into the next tube-end to be expanded.

FIGS. 13 and 14 show alternate systems of hydraulic and electrical elements for powering and controlling the FIG. 1 apparatus. FIG. 13 has a large-diameter piston rod in its measuring cylinder **MC2** and pressure-relief valve **PRV3** acting to limit the pressure when cylinder quality of the tube-joint being made. The actions of the FIGS. 13 and 14 systems in powering, controlling, and **MC2** acts. FIG. 14 has means for sensing the actuating of pressure-sensitive unit **PX2** twice during a normal tube-expanding cycle together with means whereby the second acting of said pressure-sensitive unit **PX2** inspects the monitoring, the actions of the FIG. 1 apparatus, as a tube portion is expanded, are as follows:

The action starts as described for the FIGS. 2 and 3 systems and continues until **PX2** is actuated, closing its NO switch contacts **PX2–1** and **PX2–2**, when the FIG. 11 condition is developed. Since measuring cylinder **MC2** is retracted and switch **MB2** is being held operated with its NC contact **MB2–2** open, the coil of relay **R6** is not energized this first time **PX2** acts. **PX2–1**, closing, energizes the coil of relay **R22**, thus starting the **MC2** measuring-cylinder action, as the similar contact on PX does in the FIG. 3 system. As shown in the FIG. 8 graph, after the first pressure peak CX, which occurs in response to the FIG. 11 condition being developed, the pressure drops and then rises again as the measured stroke is made, said pressure rising to the CM peak. The FIG. 14 electrical system uses this pressure increase, after the FIG. 11 condition is developed and the CX pressure peak is established, as a means of determining a satisfactory tube-expanding action in the following manner.

As the measured stroke starts and **MC2** piston advances, switch **MB2** is released and its NC contact **MB2–2** is allowed to close. Then, as the measured stroke is made, when the pressure rises to a magnitude equal to the CX pressure, said pressure-sensitive device **PX2** is again actuated. Relay **R22** is being held energized by its contact **R22–3** and the signal given by **PX2–1** is ignored. Switch contact **MB2–2** is now closed and as **PX2–2** closes, the coil of relay **R6** is energized. NO contact **R6–1** closes and holds relay **R6** energized. NC contact **R6–2** opens and is held open. As measuring cylinder **MC2** reaches its advance limit and operates switch **MT2**, NO contacts **MT2–1** and **MT2–2** are closed. Contact **MT2–1** initiates the action of time-delay unit **D12**. Contact **MT2–2** closes but there is no action since NC contact **R6–2** is being held open. Thus the tube-joint is inspected and found to be satisfactory.

Obviously, if the pressure does not increase to a magnitude sufficient to operate pressure-sensitive unit **PX2** the second time, before switch **MT2** is operated, relay **R6** will not be energized, NC contact **R6–2** will remain closed, and the coil of relay **R7** will be energized when contact **MT2–2** closes. Then, as NO contact **R7–2** closes to hold relay **R7** energized, NC contact **R7–1** opens and is held open, and the control system is inoperative.

The recording and signaling means Z, similar to means X and Y of FIG. 3, can give the desired signal to tell

that the apparatus is inoperative because said second pressure peak was not produced during the last work cycle. Operating reset-switch S5 deenergizes the coil of relay R7 to permit the system to again be operative.

As described hereinbefore, measuring cylinder MC2, in FIG. 13, has a large-diameter piston rod. This provides means for getting a proportionally longer stroke of said cylinder MC2 relative to the stroke of cylinder 17, FIG. 1, and its associated mandrel 5. Thus it is possible to get a finer-degree of adjustment of the additional-advance movement of mandrel 5, after the CX peak, FIG. 8. Said adjustments are made by rotating the threadably attached cap 27B, on the MC2 piston rod, thus changing the working-stroke of said measuring-cylinder MC2. Said finer-degree of adjustment is especially desirable when the actual axial-advance of the mandrel, after the CX peak condition of FIG. 8, is near the short-stroke end of the adjustment range, when said actual axial advance of the mandrel is on the order of .020-inch.

As the diameter of the MC2 piston rod approaches the inside diameter of the cylinder, the potential magnitude of the pressure on the exhaust side, in proportion to the pressure on the other side of the MC2 piston, increases since this pressure-ratio is substantially the same as the ratio of the net areas on the two sides of said piston. Thus, if pressure-relief valve PRV3 is not acting to limit the pressure entering cylinder MC2, the pressure in tube T24, and in cylinder 17, FIG. 1, could be much greater than the system pressure as controlled by PRV2.

The various applications for heat-exchange apparatus lead to a great range of requirements for the tube-expanding apparatus. Obviously, a tube-joint satisfactorily pressure-tight for a small heat-exchange unit working at a maximum temperature of about 200 degrees, Fahrenheit, with a pressure differential of 5 to 10 p.s.i. from one side of its tube-sheet to the other side, would not be satisfactory in a heat-exchange unit working at a temperature of 1400° F., with a pressure differential in excess of 5,000 p.s.i. cross its tube-sheet. Both of these examples are common production items. The low temperature, low pressure, example would not be economically feasible if made with the same thickness tube-sheets, and same wall-thickness tubes, of the type of metals required in the high temperature, high pressure, example.

Other factors affect the tube-expanding requirements. For example, a thin tube-sheet and plain tube-hole is satisfactory for the low-pressure example, above. Most all higher-pressure units have tube-holes containing annular grooves, similar to grooves 32G, shown in tube-sheet 32, FIG. 4. The grooves provide recesses into which tube metal is forced during the tube-expanding operation. Proper flow of metal into said grooves increases the strength and pressure-tightness of the tube-joint. Obviously, the mandrel advance, after the CX pressure peak, FIG. 8, is the portion of the mandrel advance forcing the metal to flow into said grooves. Thus a considerably longer stroke of measuring cylinder MC is required when expanding tubes into grooved tube-holes than is needed to properly expand a tube portion into a plain, not-grooved, tube-hole.

For all the above examples, the general configuration of the pressure to time curves are similar. The magnitude of the pressure will be different, and, as described above, the time to get from the X to the M peaks, such as time from CX to CM, FIG. 8, will be substantially longer when expanding tubes into the tube-holes in tube-sheet 32, FIG. 4, wherein said holes have grooves 32G. For purposes of illustration, the times between the X and M peaks, in FIGS. 8, 9, and 10, are substantially proportional to the average time when expanding tube-portions into tube-holes containing said grooves 32G. The cycle time, and the pressure-magnitudes, will vary substantially with the work requirements, but the general characteristics always apply, and the monitoring and inspection elements disclosed in this invention always apply.

It is obvious that all the inspection devices shown in the several sets of hydraulic and electrical systems can be combined and used in one application, and it is obvious that economics will frequently dictate the choice of which features should be included in a machine built for a specific type of tube-expanding work.

It will be understood that, while the features of this invention are described in terms of their applications in automatically operated tube-expanding apparatus, the features of this invention apply equally as well in manually-operated apparatus with which the operator moves said apparatus to get its tube-expanding tool into a tube-end to be expanded, and he then starts an automatic cycle of tube-expanding. It is obvious the operator may be any unskilled person, with no knowledge of the requirements for a satisfactory tube-joint. The monitoring and inspecting means added by this invention, make the tube-expanding apparatus inoperable as soon as one faulty work cycle is made. Said unskilled operator can then get skilled help to make the necessary corrections so that he can proceed with the work.

It will also be understood that, while the features of this invention are described in terms of hydraulic apparatus producing the axial movements of the tube-expanding-tool mandrel, the invention applies equally as well with apparatus having mechanical means for producing the mandrel advance movement, wherein a change in the power requirements for the source providing said mechanical force actuates watt-meters, or other devices, sensing the amount of electrical energy demanded to produce the actions, or wherein strain gages, or spring-powered force-sensing devices, sense the changes in, or the minimum or maximum amounts of, said forces, so as to then actuate means giving the reactions and responses which have been herein described.

Thus, while the invention has been described with reference to the particular devices illustrated, it will be appreciated that it is not so limited. It is rather of a scope commensurate with the scope of the subjoined claims.

What I claim as my invention is:

1. An apparatus which powers and controls a roller-type tube-expanding tool as it expands a lineal portion of a tube to a preselected tightness in its tube-hole, said tool having a plurality of angularly-spaced, rotatable, radially movable, expanding rolls caged in an axially-positionable, rotatable, roll-cage mounted about a tapered, axially movable, rotatable, mandrel, with said apparatus supporting said roll-cage assembly and said tapered mandrel so that said mandrel is axially movable relative to said roll-cage, said mandrel, while rotating, being axially advanced by a measurable axial force with cooperating means to sense the increase in said axial force produced the moment several angularly spaced areas on the tube outer surface are brought into firm contact with the defining wall of its tube-hole, whereupon said apparatus is thereafter controlled to produce a preselected, additional, axial advance of said rotating mandrel, whereby said tube portion is expanded to the preselected tightness in its tube-hole; wherein force-sensing means is provided for sensing the magnitude of said axial force producing said mandrel advance, for a preselected, short, time interval after said preselected, additional, axial advance of said mandrel starts, said force-sensing means being actuatable by a force a preselected amount less than the magnitude of said axial force produced the moment several angularly spaced areas on the tube outer surface are brought into firm contact with the defining wall of the tube-hole, said means acting so that if said force-sensing means is not actuated the apparatus control system is made inoperable, and an indicator is actuated to thus indicate said force-sensing means was not actuated during said preselected, short, time-interval.

2. An apparatus which powers and controls a roller-type tube-expanding tool as it expands a lineal portion

of a tube to a preselected tightness in its tube-hole, said tool having a plurality of angularly-spaced, rotatable, radially movable, expanding rolls caged in an axially-positionable, rotatable, roll-cage mounted about a tapered, axially movable, rotatable, mandrel, with said apparatus supporting said roll-cage assembly and said tapered mandrel so that said mandrel is axially movable relative to said roll-cage, said mandrel, while rotating, being axially advanced by a measurable axial force with cooperating means to sense the increase in said axial force produced the moment several angularly spaced areas on the tube outer surface are brought into firm contact with the defining wall of its tube-hole, whereupon said apparatus is thereafter controlled to produce a preselected, additional, axial advance of said rotating mandrel, whereby said tube portion is expanded to the preselected tightness in its tube-hole; wherein force-sensing means is provided for sensing the magnitude of said measurable axial force advancing said mandrel, so that if the magnitude of said axial force increases to a preselected magnitude greater than the maximum magnitude normally produced during the expanding of a tube-portion, said force-sensing means is actuated to initiate actions of the apparatus control system whereby the axial-advancing is immediately stopped, said rotating mandrel is retracted, and means are actuated to make said control system inoperable and to indicate said axial force reached the preselected excessive magnitude.

3. An apparatus which powers and controls a roller-type tube-expanding tool as it expands a lineal portion of a tube to a preselected tightness in its tube-hole, said tool having a plurality of angularly-spaced, rotatable, radially movable, expanding rolls caged in an axially-positionable, rotatable, roll-cage mounted about a tapered, axially movable, rotatable, mandrel, with said apparatus supporting said roll-cage assembly and said tapered mandrel so that said mandrel is axially movable relative to said roll-cage, said mandrel, while rotating, being axially advanced by a measurable axial force with cooperating means to sense the increase in said axial force produced the moment several angularly spaced areas on the tube outer surface are brought into firm contact with the defining wall of its tube-hole, whereupon said apparatus is thereafter controlled to produce a preselected, additional, axial advance of said rotating mandrel, whereby said tube portion is expanded to the preselected tightness in its tube-hole; wherein force-sensitive means is provided for sensing the magnitude of said axial force advancing said mandrel during said preselected, additional, axial advance of said mandrel, so that if the magnitude of said axial force during, and before the end of, said preselected, additional, axial advance does not equal, or exceed, the magnitude of said axial force at the moment the several angularly spaced areas on the tube outer surface are brought into firm contact with the defining wall of the tube-hole, the apparatus control system is made inoperable, and an indicator is actuated to thus indicate said axial force did not increase to the preselected, minimum, magnitude before the end of said preselected, additional, axial advance of said mandrel.

4. An apparatus which powers and controls a roller-type tube-expanding tool as it expands a lineal portion of a tube to a preselected tightness in its tube-hole, said tool having a plurality of angularly-spaced, rotatable, radially movable, expanding rolls caged in an axially-positionable, rotatable, roll cage mounted about a tapered, axially movable, rotatable, mandrel, with at least some of said rolls cocked to effect a self-feeding of the mandrel, with said apparatus supporting said roll-cage assembly and said tapered mandrel so that said mandrel is axially movable relative to said roll-cage, said mandrel, while rotating, being axially advanced by a measurable axial force with cooperating means to sense the increase in said axial force produced the moment several angularly spaced areas on the tube outer surface are brought into firm contact with the defining wall of its tube-hole, whereupon said apparatus is thereafter controlled to produce a preselected, additional, axial advance of said rotating mandrel, whereby said tube portion is expanded to the preselected tightness in its tube-hole; wherein means is provided to stop the self-feeding effect produced by said cocked rolls at the moment the preselected, additional, axial advance of said mandrel starts, so that the only additional axial advance of said mandrel, after the several angularly spaced areas on the tube outer surface are brought into firm contact with the defining wall of the tube-hole, is said additional axial advance produced by said apparatus, said self-feeding action being stopped by an opposing force acting to hold back the mandrel, with said opposing force being equal to, or greater than, the mandrel-advancing force produced by the self-feeding action of the tool.

5. In an automatic machine containing an apparatus which powers and controls a roller-type tube-expanding tool as it expands a lineal portion of a tube to a preselected tightness in its tube-hole, said tool having a plurality of angularly-spaced, rotatable, radially movable, expanding rolls caged in an axially positionable, rotatable, roll-cage mounted about a tapered, axially movable, rotatable, mandrel, with said apparatus supporting said roll-cage assembly and said tapered mandrel so that said mandrel is axially movable relative to said roll-cage, said mandrel, while rotating, being axially advanced by a measurable axial force with cooperating means to sense the increase in said axial force produced the moment several angularly spaced areas on the tube outer surface are brought into firm contact with the defining wall of its tube-hole, whereupon said apparatus is thereafter controlled to produce a preselected, additional, axial advance of said rotating mandrel, whereby said tube portion is expanded to the preselected tightness in its tube-hole; with said automatic machine carrying, at least, the tool driver portion of said apparatus, so as to move said tool driver in two normal directions over an area containing a quantity of said tube-holes, with said moves being programmed and controlled so as to position said tool driver with the axis of its tube-expanding tool coinciding with the axis of the selected tube-hole, so that said tool driver can then be axially advanced to get its tube-expanding tool into the tube portion and to then expand said tube portion, with means whereby, after said tool driver and its tube-expanding tool are retracted, said tool is lubricated with a controlled amount of lubricant, before, or as, said automatic machine moves said tool driver and its tube-expanding tool to the next programmed location.

6. An apparatus as in claim 1; including force-sensing means for sensing the magnitude of said measurable axial force advancing said mandrel, so that if the magnitude of said axial force increases to a preselected magnitude greater than the maximum magnitude normally produced during the expanding of a tube-portion, said force-sensing means is actuated to initiate actions of the apparatus control system whereby the axial-advancing is immediately stopped, said rotating mandrel is retracted, and means are actuated to make said control system inoperable and to indicate said axial force reached the preselected excessive magnitude.

7. An apparatus as in claim 3; including force-sensing means for sensing the magnitude of said measurable axial force advancing said mandrel, so that if the magnitude of said axial force increases to a preselected magnitude greater than the maximum magnitude normally produced during the expanding of a tube-portion, said force-sensing means is actuated to initiate actions of the apparatus control system whereby the axial-advancing is immediately stopped, said rotating mandrel is retracted, and means are actuated to make said control system inoperable and to indicate said axial force reached the preselected excessive magnitude.

8. An apparatus as in claim 1; wherein said axial movements of said mandrel are produced by an hydraulic cylinder-and-piston motor contained in the tool driving portion of said apparatus.

9. An apparatus as in claim 2; wherein said axial movements of said mandrel are produced by an hydraulic cylinder-and-piston motor contained in the tool driving portion of said apparatus.

10. An apparatus as in claim 3; wherein said axial movements of said mandrel are produced by an hydraulic cylinder-and-piston motor contained in the tool driving portion of said apparatus.

11. An apparatus as in claim 4; wherein said axial movements of said mandrel are produced by an hydraulic cylinder-and-piston motor contained in the tool driving portion of said apparatus.

12. An apparatus as in claim 5; wherein said axial movements of said mandrel are produced by an hydraulic cylinder-and-piston motor contained in the tool driving portion of said apparatus.

References Cited

UNITED STATES PATENTS

2,690,205	9/1954	Stary	72—20
2,736,950	3/1956	Mathews	29—157.5

THOMAS H. EAGER, Primary Examiner

U.S. Cl. X.R.

29—157.5, 243.5; 72—20

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,585,701 Dated June 22, 1971

Inventor(s) Walter E. Stary

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

Column 1, line 32, cancel "con- --. Column 3, line 30, "3, as" should read -- 3. As --. Column 4, line 38, "contact P5" should read -- contact PX --; line 51, "T4," should read -- T4. --. Column 6, line 17, after "becomes" insert -- tight --; line 20, "momen" should read -- moment --. Column 8, line 55, "valve A" should read -- valve A1 --. Column 10, lines 24 thru 29 should read -- MC2 acts. FIG. 14 has means for sensing the actuating of pressure-sensitive unit PX2 twice during a normal tube-expanding cycle together with means whereby the second acting of said pressure-sensitive unit PX2 inspects the quality of the tube-joint being made. The actions of the FIGS. 13 and 14 systems in powering, controlling, and --. Column 11, line 39, "cross" should read -- across --.

Signed and sealed this 16th day of May 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

FORM PO-1050 (10-69)

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