

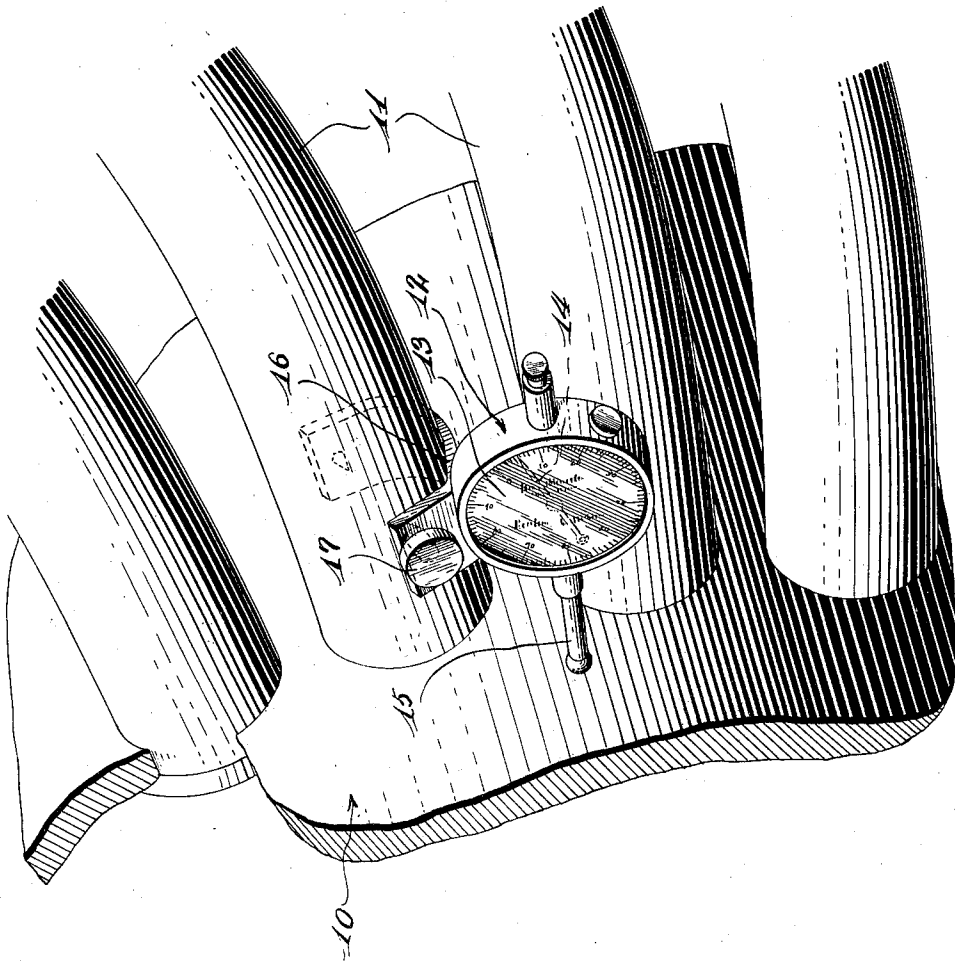
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METHOD OF JOINING TUBES TO HEADERS

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METHOD OF JOINING TUBES TO HEADERS

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This invention relates to a method for securing tubes in tube holes.

One of the primary objects of this invention is to provide a method of the above mentioned character by which the proper amount of rolling or expanding of a tube in a tube hole may be ascertained and by which uniform results in the rolling of a number of tubes may be obtained.

A further object of this invention is to provide a method of the above mentioned character which will prevent the over-rolling or overexpansion of tubes with the result that the number of leaky tubes will be reduced to a minimum as will also the liability of tube failure from caustic embrittlement.

Still further the invention has as an object to provide a method of the above mentioned character by which operators generally may be instructed as to the proper amount of rolling to be imparted to the tubes, with the result that the method may be practiced by relatively unskilled labor.

Numerous other objects and advantages of the invention will become more apparent as the following description proceeds, particularly when reference is had to the single figure of the drawing wherein there is diagrammatically illustrated a device or apparatus which may be used in practicing the method.

It has been found upon investigation that the cost of boiler testing and re-expanding of leaky tubes averaged approximately ten percent of the total erection cost. Since this amount seemed to be disproportionately large, a study was made of the methods used in the expanding of tubes in tube holes. This study disclosed the fact that tube expanding, as generally practiced, was based entirely on guess work, the object apparently being to endeavor to get the joint tight in some way. No attention was apparently given to the holding strength of the rolled joint between the tube and the tube hole.

To aid in the further description of the present invention, the phrase "holding strength of the joint" may be defined as follows. In an assembly made up of: (1) a tube having a closed end, and (2) the tube being rolled into the wall of a closed vessel, "holding strength" may be defined as the hydrostatic pressure necessary to be applied to start the tube uncoring in the tube hole. It has been determined that if this uncoring could be controlled, leaks through rolled joints would be negligible in number.

It might be stated further that to aid in the description of the present invention the terms

"front end" and "back end" of the tube will be utilized. The term "front end" is to be construed as meaning the belled or beaded mouth of the tube, while the term "back end" is to be construed as meaning the portion of the tube on the side opposite the tube sheet or boiler drum from the belled or beaded end of the tube.

Tube rolling or tube expanding is a process which consists in cold working the end of a tube by means of a rotating expander or the like until the tube is larger than the hole into which it has been previously inserted. This makes the rolled joint water-tight and sets up opposing forces or stresses between the tube and the metal surrounding the tube hole. The forces in the tube act outwardly while the forces in the metal surrounding the tube hole act inwardly. The sum of these two opposing forces determines the friction pressure on the rolled joint and thus determines the holding power or strength of the joint.

From the above brief statement of the problem of tube rolling, it would appear that the heavier or greater the tube expansion the better the resulting joint formed. This, however, is true up to a certain point only for the reason that the elasticity of the two metals is a deciding factor governing the friction pressure obtained. The maximum friction pressure will be obtained just before the metal defining the tube hole takes a permanent set for the reason that any further rolling will gradually destroy the elasticity of the metals of the tube and tube sheet and will finally reduce the friction pressure to such a point that the tube is held practically by the beaded or belled end alone. Thus where the tube has been rolled or expanded beyond the desired degree, a joint is formed which, after a period of time or if subjected to a jar, will leak. It becomes important, therefore, to provide a method by which the proper amount of rolling may be ascertained and to provide a method whereby each tube of a number of tubes may be rolled or expanded to the same degree.

The operation of expanding a tube into a tube sheet or boiler drum may be described as consisting of two stages. The first step consists in cold expanding the end of the tube until the outside surface of the tube is in contact completely with the inside surface of the tube hole. The next step consists in further cold working of the tube and until the metal comprising the tube hole is given a slight elastic deformation. Since the holding strength of a rolled joint has not started to be developed until the metal of the tube wall has contacted completely with the

metal surrounding the tube hole, it becomes apparent that any method which does not definitely indicate how much the tube is expanded after the tube surface contacts completely with the inside of the tube hole, cannot produce uniform and efficient results.

Heretofore several methods of securing tubes in tube holes have been practiced, one of these methods being known as the bulge method of tube expanding. This has consisted in expanding the tube in the tube hole until the tube has bulged on its back end to a diameter of $\frac{1}{2}$ of an inch greater than the nominal tube hole diameter. In this method an outside gauge with a fixed opening has been used as a testing tool. It has been found, however, that it is absolutely impossible to secure consistently tight joints when using this method for the reason that there is considerable variation in the diameter of the tube holes even when these holes are reamed with the same reamer.

A second method of expanding tubes which has heretofore been practiced to some extent has consisted in expanding the tubes until the expander has entered all of the tubes the same distance. Since the holding strength of a rolled joint depends on the amount of expansion imparted to the tube after the tube wall has contacted completely with the metal surrounding the tube hole, and since there is a marked variation in the clearance between the tubes and the tube holes at the beginning of the expanding operation, it is obvious that there is no relationship whatever between the holding strength of the joint and the distance which the expander has entered the tubes expanded.

The present invention contemplates eliminating the objections to the methods discussed above by providing a method of tube rolling which takes into consideration the extent of expansion of the tube after the tube has contacted completely with the inside of the tube hole. At the beginning of the operation of rolling a tube in a tube hole, the tube is loose in the hole and the expander merely enlarges the tube end. The metal of the tube is thus free to adjust itself during the first stage of the rolling operation. As soon, however, as the tube contacts completely with the inside of the tube hole, the metal of the tube may not then freely adjust itself to the action of the expander. Any further enlargement of the tube after its outer surface has contacted with the inside of the tube hole will be opposed by the resistance of the metal surrounding the tube hole, and in overcoming this resistance, the expanding action will produce a reduction of the tube wall thickness. The tube metal thus displaced will flow to the points of least resistance, that is, from about the metal of the tube hole out toward the outside and inside of the sheet or the like in which the hole is formed. This axial flowing of the metal of the tube may be termed "elongation", and it will be found that this elongation of the tube moves the tube axially as soon as the outside surface of the tube is in tight contact with the inside surface of the tube hole.

It will be apparent that the elongation of the tube will represent the work done to enlarge the tube against the resistance of the metal surrounding the tube hole. As this work produces the friction pressure, it will be apparent that the elongation of the tube may be utilized as an indication of the friction pressure of the rolled joint and thus of the holding strength of the joint.

From the above it will be apparent that if all

of the tubes to be secured in a tube sheet or the like are rolled to the same elongation, the same friction pressure or holding strength should be obtained at all joints. Since the elongation of the tube is used as a measure for determining the amount of rolling to be imparted to the tube and since the elongation takes place only after the tube wall contacts with the metal defining the tube hole, it will be apparent that variations in tube hole diameter, tube wall thickness, tube diameter or hardness does not affect the results obtained.

The present invention contemplates utilizing the elongation of the tube as a measure to indicate the amount of rolling to be imparted to the tube by providing the following method for securing tubes in tube holes. The outside surface of the end of the tube is first cleaned of scale and rust. The tube to be secured in the tube hole is selected at random, that is, there is no effort to match the tubes to the holes, with the result that the clearance between the tubes and tube holes may vary.

The tube is inserted into the tube hole to the correct position and is held in this position by a helper. A dial indicator is then clamped to the back end of the tube, and the point of the spindle of the indicator is placed in contact with the metal surrounding the tube hole. The tube is then expanded, and during the first stage of the expanding process, since the tube is loose in the tube hole, the operation of the tube expander causes a vibration of the tube with a corresponding vibration of the needle of the dial indicator.

The instant, however, that the outside surface of the tube contacts firmly with the inside of the tube hole, the needle of the dial indicator becomes quiet. At this instant the helper reads the indicator and the second stage of the expanding process commences. As the tube is further expanded, the metal in the tube wall is caused to flow axially, and that portion of the tube which constitutes the back end thereof carries with it the indicator. The amount of the movement of the back end of the tube is indicated by the movement of the needle on the dial indicator.

Since, as brought out before, it has been found that a definite relation exists between the holding strength of the joint and the elongation of the tube, the final step of the method consists in stopping the expanding operation when the elongation of the tube reaches a predetermined desired amount. While it is not desired to be limited to any definite elongation, it has been found that excellent results are obtained when the elongation is about .015 inch.

It will be apparent that different devices might be utilized for measuring the elongation of the tube during the expanding operation. One device capable of accomplishing this result is disclosed in the single figure of the drawing wherein the numeral 10 designates a tube sheet or the wall of a boiler drum, in which wall tubes 11 are to be secured. The numeral 12 designates generally a dial indicator or micrometer having an indicating face 13 and a needle 14. The numeral 15 designates the actuating pin of the indicator which is engaged with the wall or tube sheet 10.

Fixed to the indicator is a bracket 16 carrying a set screw 17, the arrangement being such that the indicator may be clamped to one of the tubes, as will be readily apparent.

As brought out before, during practicing of the method, the tube 11 is inserted in the tube hole in the sheet 10 and is held in a correct position by an assistant or helper. The dial indicator is then clamped to the tube, and the point of its spindle or pin 15 is placed in contact with the outer surface of the sheet 10.

During the initial expanding operation, the tube being loose in the tube hole, will vibrate and will thus cause a vibration of the needle 14. When, however, the outside surface of the tube contacts firmly with the inside surface of the tube hole, the needle 14 will become quiet.

At this point the assistant will read the indicator, and at this instant the second stage of the expanding operation commences. As the tube is further expanded, the metal of the tube wall will flow axially, and the resulting movement of the back end of the tube to which the dial indicator is secured will cause the dial indicator to move away from the sheet 10. This movement will be indicated by the needle 14, and as brought out before, the expanding operation will be discontinued when the elongation has reached a predetermined desired amount.

It constitutes a feature of this invention that it will be unnecessary to attach an indicator of the above described character to each particular tube being rolled into a tube sheet. It will be apparent that since the elongation of the tube does not commence until the tube walls have contacted with the metal defining the tube hole, the elongation imparted to the tube will bear a predetermined relation to the power utilized in expanding or rolling the tube after the outer surface of the tube has contacted the inner surface of the tube hole. Thus, after it has been determined what amount of rolling or what degree of power is required to roll a test tube to that elongation which provides a joint having the desired holding strength, then all of the tubes in a given group may be rolled to this same elongation by applying the same amount of rolling or the same degree of power to each rolling operation. Thus it will be apparent that operators may be instructed to impart a predetermined amount of rolling or to utilize a predetermined degree of power in the rolling operations and that when they are so instructed, uniform results will be obtained.

It might be noted that the holding strength of the joint depends also somewhat upon the coefficient of friction which varies with the finish of the tube and tube hole. The coefficient of friction is lowest on the smoothest finish and increases with the roughness of the finish. As the finish is fairly uniform in a new boiler, there will be obtained a minimum holding strength in the joint with the smoothest finish, the other joints coming within a range of, say, 20% of this minimum.

It will be found that in the commercial practice of the method it will not generally be possible to obtain all of the tubes and tube holes with the same finish. To close the voids formed by the imperfections found in the tubes in the tube holes and thus make the joints water-tight, it is desirable to increase the elongation somewhat over that found by experiment to be absolutely correct for the tube and tube holes provided.

From the above it will be apparent that the invention provides a method by which tubes may be secured in tube holes in a uniform manner with the result that the number of leaky tubes will be reduced to a minimum. Further, the

method may be practiced by relatively unskilled labor while still maintaining the desired degree of accuracy.

It might be noted that elongation of the tubes during the expanding process does not introduce any serious spreading of the drums to which the tubes are secured in the case of bent tubes. There is sufficient flexibility in the bent tubes to absorb the stresses set up. With straight tubes, however, allowance must be made for the spreading of the drums produced by the elongation, and this may be accomplished by fastening the tack tubes only lightly and locating them at the ends and at the middle of the length of the drum. The tube expanding is then carried out by starting to expand the tubes at either end and proceeding toward the middle to about one quarter of the length of the drum, next starting from the middle of the drum and proceeding to expand toward the end of the drum. This divides the spreading effect of elongation which would otherwise be cumulative to a serious degree if the tubes were expanded successively, starting at one end or even starting in the middle of the drum.

While the invention has been described more particularly as being embodied in a method for securing tubes to drums or tube sheets, it will be apparent that the method may be utilized to fasten a tube into a tube hole wherever such an operation is necessary. Further, while the invention has been described with some detail, it is to be understood that the description is for the purposes of illustration only and is not definitive of the limits of the inventive idea.

What I claim as my invention is:

1. The method of securing a tube in a tube hole which consists in expanding the tube in the tube hole until the outer surface of the tube contacts firmly with the inside surface of the tube hole, further expanding the tube in the tube hole after said firm contact has been effected, measuring the elongation of the tube incident to said further expanding thereof, and discontinuing the further expansion of the tube when the elongation thereof measures a predetermined amount.

2. The method of securing a tube in a tube hole which consists in cleaning the outside surface of the end of the tube, inserting the tube into the tube hole to the proper position, expanding the tube while the same is held in its proper position in the tube hole until the outer surface of the tube contacts firmly with the inside surface of the tube hole, indicating the instant of firm contact of the outer surface of the tube with the inside surface of the tube hole, further expanding the tube in the tube hole after said firm contact has been effected, measuring the elongation of the back portion of the tube adjacent the tube hole incident to said further expansion, and discontinuing the further expansion of the tube when the elongation thereof measures a predetermined amount.

3. The method of determining when a tube end is properly rolled in a tube hole which consists in initiating the rolling, measuring the elongation of the back end of the tube, and ceasing rolling when the elongation reaches a value indicative of proper compression of the tube end in the hole.

4. The method of expanding a tube in a tube hole which consists in predetermining the degree of elongation of the tube which indicates a proper compression of the tube end in the hole, predeter-

mining the amount of expanding necessary to obtain said predetermined elongation, and imparting said predetermined amount of expanding to the tube.

5 5. The method of expanding a tube in a tube hole which consists in predetermining the amount of elongation of the tube which indicates a proper expansion of the tube in the tube hole, predetermining the amount of power required to effect
10 said predetermined elongation of the tube, expanding the tube into initial contact with the wall of the tube hole and thereafter utilizing said predetermined amount of power to effect an expansion of the tube end in the tube hole.

15 6. The method of securing a tube in a tube hole which consists in expanding the tube until the outer surface thereof contacts the inside surface of the tube hole, further expanding the tube in the tube hole after said contact has been effected,
20 measuring the change of a selected characteristic of the tube incident to said further expansion, and discontinuing the further expansion of the tube when the said change measures a predetermined amount.

25 7. Those steps in the method of securing a tube in a tube hole which consists in expanding the tube in the hole and determining the degree of expansion required to effect proper compression of the tube in the hole by measuring the elongation of the tube incident to the expansion thereof.
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35 8. The method of expanding a tube member in a tube hole formed in a member which consists in expanding the tube in the hole, predetermining the degree of change of a selected characteristic of one of the members which indicates the proper compression of the end of the tube member in

the hole, measuring the change of the selected characteristic during expansion and discontinuing expansion when said degree of change reaches the predetermined amount.

9. Those steps in the method of securing a tube 5 in a tube hole which consists in effecting a firm contact of the outer surface of the tube end with the inside surface of the tube hole, expanding the tube in the tube hole and determining the degree of expansion required to effect a proper
10 compression of the tube in the hole by measuring the elongation of the tube incident to expansion thereof.

10. The method of expanding a tube in a tube hole which consists in expanding the tube in the 15 hole, predetermining the degree of elongation of the tube required to effect a proper compression of the tube in the hole, measuring the degree of elongation of the tube during expansion, and discontinuing expansion of the tube when the degree
20 of elongation thereof reaches the predetermined amount.

11. The method of expanding a tube member in a tube hole formed in a member which consists in predetermining the degree of change of a selected characteristic of one of said members 25 which indicates a proper compression of the end of the tube member in the hole, predetermining the amount of expanding necessary to obtain said predetermined change, expanding the tube member
30 into contact with the wall of the tube hole and thereafter compressing the tube end in the hole by imparting said predetermined amount of expanding to the tube member.

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