April 19, 1960 W. W. EDENS ET AL 2,933,593

WELDING METHOD

Filed July 24, 1957

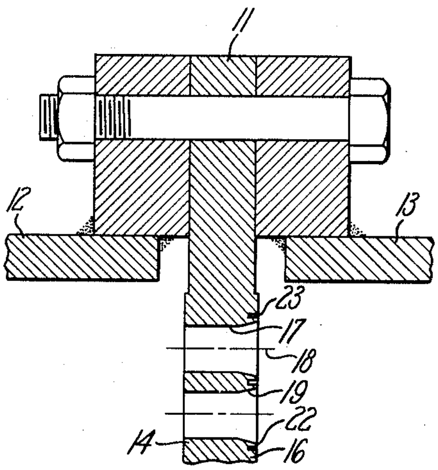

Fig. 1

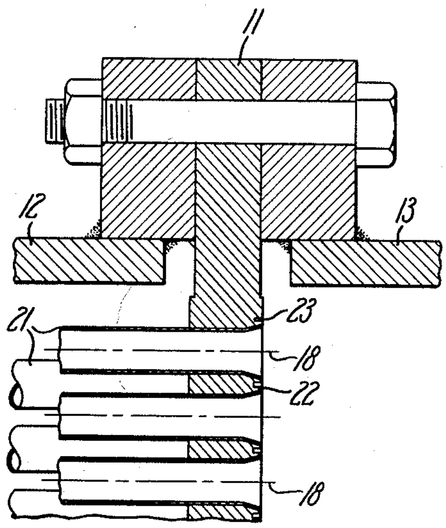

Fig. 2

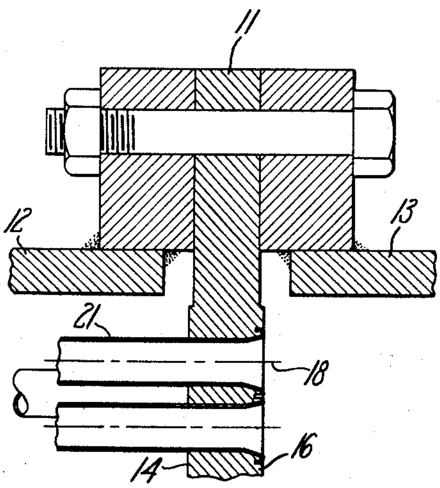

Fig. 3

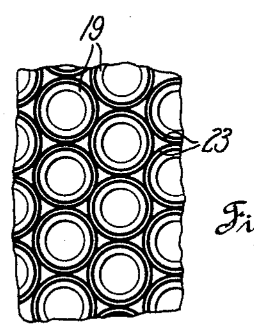

Fig. 4

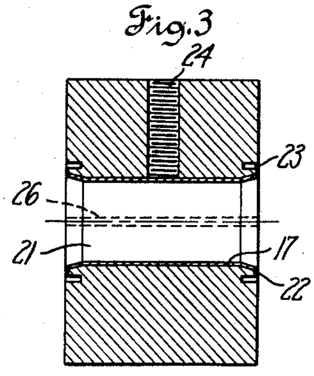

Fig. 5

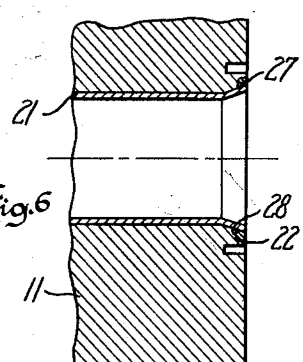

Fig. 6

Inventors
Walter W. Edens
Willard A. Schumacher
R. A. Wilson
By Henry J. Marciniak
Attorney

United States Patent Office 2,933,593
Patented Apr. 19, 1960

1

2,933,593

WELDING METHOD

Walter W. Edens, Wauwatosa, Willerd A. Schumbacker, West Allis, and Rushen A. Wilson, Wauwatosa, Wis., assignors to Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

Application July 24, 1957, Serial No. 673,868

1 Claim. (Cl. 219—137)

The present invention relates generally to a method of joining tubes to a tube sheet and more particularly to a method of joining nonferrous tubes and tube sheets in a surface condenser by electric arc welding, which affords unique advantages of substantial importance.

With the advent in recent years of higher boiler pressures and nuclear power cycles, there has arisen an unsatisfied demand for surface condensers of increased tightness and strength. A frequent source of contamination of the condensate in a surface condenser has been leakage in the joint between the tube and tube sheet. The problem of contamination of condensate has persisted down to the present time, but it is only in recent years that the problem has become one of increasing importance.

In the conventional surface condenser, exhaust steam is condensed by passing it over a large number of relatively small metal tubes through which cooler water is circulated. In some applications more than fifteen thousand one inch tubes are joined to tube sheets by more than thirty thousand joints. The water circulated through these tubes absorbs the heat of vaporization of the steam and condenses it into water. The condensing operation is attended by a continuous temperature fluctuation causing the tubes to expand and contract and by a reduction in volume resulting from the condensation of the exhaust steam. The pressure in the condenser is below atmospheric, and leakage into the condensate side of the condenser can therefore readily take place.

In the earlier condensers of the prior art, provision for the expansion and contraction of the tubes was made by allowing one end of the tubes to slide freely in the holes in the outlet tube sheet. The tightness was maintained by means of packing and ferrules. In more recent years, the provision of an expansion joint in the condenser shell makes it possible to expand the tubes at both ends into the tube sheets of the condenser. The adoption of increased boiler pressures and operating temperatures has highlighted the importance of improving the tightness and strength of the tube and tube sheet joints in order to provide more positive safeguards against the possibility of contamination.

The present invention provides a solution to the problem of improving the tightness and strength of the conventional expanded metal to metal joint that involves a method of making a plurality of relatively small circumferential welds fusing the tips of the tubes to concentric annular projections on the tube sheet by electric arc welding. The tubes can then be rolled by conventional methods if desired. In accordance with this invention, a surface condenser, in which a plurality of tubes are supported by tube sheets in a heat exchanger shell, can be fabricated of proven nonferrous alloys, can be readily erected at the site and maintained during the service life of the condenser. The joint between the tube and tube sheet is further characterized in that increased strength and a more effective seal result from the intimate fusion of the tube sheet projection and the tip of the tube.

Joining a nonferrous tube to a dissimilar nonferrous tube sheet of a surface condenser poses many unique problems that are not normally encountered in ordinary welding operations. First of all, the welding operation must be performed on the tube sheet in the vertical position since most commercial condensers are erected at the site and the tubes are disposed horizontally and in a normal relationship to the tube sheets. In a single condenser as many as thirty thousand relatively small circumferential welds closely spaced in the vertical plane of the tube sheet must be executed. The individual welds may have a radius ranging from ⅜ to ⅝ of an inch depending upon the tube used. The weld puddle should not sag or flow back into the tube opening so as to interfere with the flow of circulating water. It is desirable that each individual weld cause an intimate fusion between the tube and tube sheet materials that is impervious to the passage of fluids so that the joint is effectively sealed. Increased strength is also desirable since added strength will contribute to the permanence of the seal.

The method should produce a high percentage of sound welds in order to prevent the cost of testing and effecting repairs from becoming excessive. In the event that tubes require replacement in service, it should be possible to readily remove and replace the welded tubes. Likewise, if leaks occur in the service, it should be possible to readily repair leaking welds. It is also an important requirement that any tube sheet distortion or stressing resulting from the heat of welding be kept at a minimum to prevent the possibility of tube sheet or joint failure in service from these causes.

It is therefore an object of this invention to provide an improved method of joining nonferrous tubes and tube sheets of a surface condenser by electric arc welding which incorporates the aforementioned requirements.

Another object of this invention is to provide a method of joining nonferrous tubes and tube sheets of a surface condenser by intimately fusing an annular projection formed on the tube sheet with the end of the tube by electric arc welding to make a joint of increased tightness and strength.

Still another object of this invention is to provide an improved method of joining nonferrous tubes and tube sheets of a surface condenser whereby the welded tubes can be readily removed and replaced when necessary.

A further object of this invention is to provide an improved method of welding nonferrous tubes and tube sheets of a surface condenser that will not cause any appreciable tube sheet distortion or objectionable welding stresses in the joints.

It is still a further object of this invention to provide an improved method of joining a non-ferrous tube and tube sheet by producing a plurality of vertically positioned and relatively small circular welds joining tube ends to concentric projections formed on the tube sheets and presenting a minimum amount of interference to fluid flow.

A still further object of this invention is to provide an improved method of joining nonferrous tubes and tube sheets of a surface condenser by electric arc welding using inert gas shielding that is commercial feasible in that welders can readily be trained to make dependable welds on the erection site.

It is still a further object of this invention to provide an improved method of joining nonferrous tubes and tube sheets by electric arc welding which also permits the tubes to be rolled into the tube sheet in accordance with conventional practice if so desired.

The invention, accordingly, consists of the various methods or processes of joining nonferrous tubes and tube sheets in a surface condenser, as more particularly set forth in the appended claim and in the detailed description, in which:

Fig. 1 is a fragmentary longitudinal sectional view of a surface condenser illustrating a tube sheet with tube bores reamed and the tube sheets trepanned to form an annular projection in preparation for the insertion of tubes in accordance with the present invention;

Fig. 2 is a view similar to the one shown in Fig. 1 with the tube positioned in a tube sheet bore and flared to conform to the taper in the bore;

Fig. 3 is a view similar to the one shown in Fig. 1 illustrating the joint which has been welded in accordance with this invention;

Fig. 4 is a partial side view of the joints illustrated in Fig. 3;

Fig. 5 is a cross sectional view of the test blocks used to test the welded joints for tightness; and

Fig. 6 is a fragmentary sectional view of a tube and tube sheet joint illustrating how a ring insert is placed prior to welding.

Referring to Fig. 1, a portion of a surface condenser is shown to illustrate the relative disposition of the various parts involved in the present invention. A vertically upstanding tube sheet **11** is interposed between a shell **12** and a water box **13**. The tube sheet **11**, the shell **12** and water box **13** are bolted together to form a rigid structure.

As indicated in Fig. 1, the vertical faces of the tube sheet **11** are further identified as a steam side **14** and water side **16**. A tube bore **17** has a center line **18**. A taper **19** is formed at the water side **16** by reaming. In the preferred method of the present invention a ten degree taper is used. As the angularity of the taper increases, the number of tubes that can be installed per square foot of the tube sheet **11** decreases. It is found that the ten degree taper is sufficient to eliminate any restriction to flow that may be caused by any slight lip formed on the inside surface of the tube by the weld bead. A taper ranging from ten to fifteen degrees is satisfactory for most weld beads. The use of the larger taper necessarily restricts the number of tubes that can be inserted in a tube sheet of a given size.

At the water side **16** of the tube sheet **11** an annular projection **22** concentric with the center line **18** is provided. To illustrate the physical dimensions involved in the preferred method of practicing the present invention, the diameter of the projection **22** is such as to allow an approximately 1/16 inch thickness at the surface of the projection **22**. To form the projection **22**, a groove **23** was trepanned to a depth approximately 3/16 of an inch. Thus, by way of summary, the preparation of the tube sheet **11** involves the steps of drilling, reaming and trepanning to form the tube sheet projection **22**.

Referring now to Fig. 2, cooling tubes **21** are shown inserted in the tube sheet **11** and flared at the end to fit the reamed end of the tube bore **17**. The tubes **21** are flared by the use of a conventional flaring tool. At the water side **16** of the tube sheet **11** circulating water either leaves or enters the tube depending upon the direction of water flow through the condenser. At the steam side **14** a heat transfer takes place between the steam and circulating water flowing through the tubes **21**. The tubes **21** are flared to fit the taper **19** in the bore **17** to minimize the possibility of any restriction of flow of circulating water by irregularities in the weld bead.

In Fig. 4 the completed welded joints are illustrated. A continuous circumferential weld bead fuses the end of the tube and the upper portion of the annular projection **22**. The thickness of the tube sheets to be joined by the present method of welding may vary from 1¼ inches to 1½ inches. The outside diameter of the tube to be joined may vary from ¾ inch to 1¼ inches. The approximate wall thickness of such tubes is 1/16 inch. It should be understood that the physical dimensions given herein are not intended to limit the scope of the present invention but are presented herein for the purpose of enabling one skilled in the art to more fully understand the significant results obtained by the practice of the present method.

In general, the method of the present invention comprises a procedure of joining nonferrous tubes and tube sheets comprising the steps of drilling and reaming the tube sheet, inserting and flaring the tube to fit the configuration of the tube sheet bore, and providing an annular projection on the tube sheet having a thickness substantially equal to the thickness of the tube wall, and fusing the end portion of the projection on the tube sheet and the tube by a tungsten inert gas electric arc. The steps involved in drilling and reaming a hole in a tube sheet, inserting the tube and flaring the tube end to fit to the tube sheet bore are well known to practitioners of the art. These steps may be satisfactorily performed in accordance with the past practice.

The primary difficulty encountered in welding conventional type of joints is that the heat of the welding arc rapidly dissipates into the tube sheet making it necessary to use relatively high welding currents. Welding currents in the order of 190 amperes are generally required to make satisfactory fusion welds of this type. Whenever the hot arc approaches too closely to the tube portion of the joint, the tube melts away from the tube sheet face. This frequently necessitates the removal or repairing of the tube. Also, the use of the high welding current frequently causes the fused metal to sag and flow.

The present method overcomes these difficulties by the provision of a projection on the face of the tube sheet having a radial thickness on its vertical annular surface substantially equal to the thickness of the tube wall. Inasmuch as the fusion of the metal takes place between the outer portion of the projection and the tip of the tube by forming a projection having an annular surface of the approximate thickness of the tube, it was found that the time at which fusion occurred and the fluidity of the two nonferrous metals could be readily controlled in the vertical plane in which the weld is being executed. It is desirable that the two fusing metal portions have substantially similar heat capacities so that melting and fusion of the metals can occur simultaneously and the heat of welding reduced to prevent flow or excessive sag of the puddle due to the vertically extending nature of the weld and gravity action. It should be apparent to one skilled in the art that where the melting point and thermal conductivity of the tube sheet material are widely divergent the thickness of the projection may accordingly be varied to obtain instantaneous melting and fusion of the portions to be joined.

It is noted that the formation of the projection on the tube sheet in accordance with the practice of this invention makes it possible to use 40 to 50 amperes less welding current. Thus, the annular projections on the tube sheet prevent the tubes from melting prematurely by properly distributing the heat of the weld between the two fusing portions and insure that a tight seal is formed by the fused portions of the tube and tube sheet. The heat input to the tube sheet is appreciably reduced because the heat is transmitted only through the thin cross sectional area of the annular projection and because of the lesser welding currents required to obtain satisfactory fusion. Consequently, any possible distortion of the tube sheet and stressing caused by an increased heat input is minimized. The formation of the thin walled projection also provides immediate relief for a large portion of the welding stresses because of the flexibility of the projection and the circumscribing air space.

Another advantage resulting from the improved method and specifically from the step of forming the projection on the tube sheet is that tubes can be readily removed in service. The relative flexibility and stress free condition of the welded joint make it possible to readily remove a tube by machining off the weld nugget on the annular groove without damaging the remaining portion of the tube wall. The tube can then be pulled out from one end of the tube sheet and a new tube is inserted. The tip of the new tube is again fusion welded as described herein to the existing projection on the tube sheet. It is found that as many as three successive tubes can be inserted in the same tube sheet bore and rewelded.

After the aforementioned physical modifications have been accomplished to the tube and tube sheet, the operation of welding the tube sheet projection to the tip of the tube is the next step of the present method. The welding technique selected to illustrate the preferred method for most combinations of tube and tube sheet materials is the tungsten inert gas method with direct current. In some cases it is found, depending upon the specific material joined by the weld, that sound and tight welds are obtained only by using alternating current and an overriding high frequency. Where aluminum brass tubes are being joined in Naval brass tube sheet consistently, tight and sound welds are obtainable in accordance with this invention only when the alternating current and an overriding high frequency is continuously used during the welding operation. In all cases, high frequency excitation is used to initiate the arc.

Both helium and argon are used for shielding. However, it is found that argon consistently gives a tighter weld. The tungsten electrodes to be used are 3/32 inch and 1/8 inch in diameter of the one percent thoriated type. In most cases where direct current was used, a range of between 130 to 150 amperes was found to give good results for an automatic welding operation. Likewise, for this current range, it was found that six seconds is an optimum period of time to complete a welding cycle along the circumferential path defined by the tip of the tube and the tube sheet projection where the tube has an outside diameter of one inch. Accordingly, if the welding is accomplished about the periphery of the tube end and tube sheet projection at a faster rate, a higher current is required to provide the same total heat input to the fusible portions of the tube and tube sheet.

The necessity for executing the weld with the tube sheet in a vertical position makes the point at which the weld is started of a particular importance. In the preferred procedure, a metal fusing arc is established at either the three or nine o'clock position depending upon whether the electrodes are rotated in a clockwise or counterclockwise direction. A better weld is effected if the initial puddle formed is caused by gravity action to follow the electrode as the electrode begins to rotate downwardly. In the present welding operation, the speed at which the electrode is moved in a vertical plane along the tube tip and tube sheet projection and the amount of current which is supplied to the electrode are adjusted so that as the metals fuse at a given point of travel, solidification of the metal commences without excessive sag or flow by virtue of the reduced heat due to rotation of the arc to adjacent unfused points. As previously indicated, it is found that for a current ranging from 130 to 150 amperes a continuous weld could be completed about a one inch tube in approximately six seconds. For manual operations with slower speeds of rotation, it is found that currents of between 90 to 130 amperes are required to produce sound and tight welds. It should be noted that for the manual operation, the electrode setting will cause the current requirements to vary. The actual amperage used for a given combination of materials will, of course, depend to some extent upon the nature of the tube and tube sheet materials.

To illustrate the preferred practice with a specific example, a current of 130 amperes was used to weld an Admiralty metal tube in a Naval brass tube sheet with a 3/32 inch thoriated tungsten electrode shielded by argon gas. The arc was initiated in three o'clock position with an overriding high frequency alternating current and the electrode was rotated in a clockwise direction at a uniform rate of speed to form a continuous circumferential weld extending beyond 360 degrees of the circular path for a period of approximately six seconds. The arc was feathered off when the electrode was slightly beyond the three o'clock position from which it was started so as to minimize crater cracking. A weld of superior tightness was produced by this procedure.

A power unit which is satisfactory for practicing the herein described procedures must be capable of supplying either direct or alternating current for welding plus a high frequency source for starting the arc. Such power units are commercially available. The commercially available welding unit used to practice the present method incorporated a feature which permitted the control of the welding current at any time during the welding cycle and also permitted a "feathering out" of the arc in order to control the crater fill at the end of the weld.

It should be apparent to one skilled in the art that the welding step of the concerned method of the present invention can be accomplished manually or with hand operated gun type of welder which automatically accomplishes the welding when the gun is triggered. In the herein described exemplifications of the present invention both manual and automatic welding means were employed to accomplish the welding operation. Thus, the present method of joining nonferrous tubes and tube sheets in a surface condenser is adaptable to both manual and automatic welding techniques.

It is well known that the compatibility of different combinations of nonferrous materials varies to a considerable extent. The alloys more commonly used in the fabrication of condenser tube sheets and tubes are of the yellow brass type. Muntz metal and Naval brass are frequently used as tube sheets. Also tubes of Admirality metal and Naval brass are frequently used as tube sheets. Generally, these alloys contain small amounts of corrosion inhibiting elements such as tin, antimony, arsenic or phosphorous. The particular materials selected for the tube and tube sheet depends to a certain extent upon the corrosive effect of the cooling water used in the surface condenser. In applications where a highly corrosive cooling water is used, the 70–30 and 90–10 copper nickel alloys, silicon bronze and aluminum bronze are often used. A nominal analysis of the alloys used in steam surface condensers, the melting point, and thermal conductivities of the alloys are tabulated in Table I below:

TABLE I

Nominal analysis

[PERCENT OF ALLOYS USED IN SURFACE CONDENSERS.]

Alloy	Copper	Zinc	Tin	Lead	Others	Melting Point, ° F.	Thermal Conductivity, B.t.u./Sq.ft./ft./hr./° F.
Naval Brass	60	39	1	.2 Max.		1,635	68
Admiralty	71	28	1	.07 Max.	.07 As, Sb or P	1,715	64
Aluminum Brass	77	21		.07 Max.	2 Al .07 As, Sb, or P.	1,770	58
Muntz Metal	60	40		.6 Max.		1,660	73
Arsenical Copper	99				.3 As .02 P	1,978	45
Silicon Bronze	95				3 Si 1.5 Mn, Zn or Fe.	1,860	27
Aluminum Bronze	91				2 Fe 7 Al	1,905	36
Copper Nickel:							
70–30	70			.05 Max.	30 Ni	2,250	17
90–10	88			1.5 Fe	10 Ni	2,130	27

Among the preferred materials to be used in the practice of the present invention are Admiralty metal tubes joined with a Naval brass tube sheet and aluminum brass tubes joined with Naval brass tube sheets. It is noted that joints of varying degrees of dependability and tightness can be made with 90–10 copper nickel tubes, 70–30 copper nickel tubes and arsenical copper tubes with Naval brass tube sheets and also by combining Admiralty metal tubes with silicon bronze tube sheets. With one exception, all of the above combinations of materials were joined by the tungsten inert gas method of electric welding using direct current. However, to obtain dependable welds by the use of the present method for the combination of aluminum brass and Naval brass tube sheets, the tungsten inert gas method is used with alternating current and an overriding high frequency. The continuous use of the high frequency excitation is necessary in this combination in order to break up the oxide film that tends to form on the surface of the weld puddle. A joint of improved tightness and soundness is thereby obtained by use of the alternating current with a continuous high frequency excitation.

The preference for the combination of Admiralty metal tubes and Naval brass tube sheets for surface condensers stems from several significant considerations. The maximum weight that a rectangular cast tube sheet can be cast is fifteen thousand pounds as compared to eight thousand pounds for a comparable silicon bronze tube sheet. This weight limitation imposes an important physical limitation on the size of an available tube sheet plate. In other words, a tube sheet fabricated of silicon bronze has to be fabricated of twice as many sections as one made of Naval brass. Furthermore, Naval brass and Admiralty metal are relatively compatible as indicated by their melting point and thermal conductivity as set forth in Table I, which makes the combination preferable from the standpoint of welding. The low cost and machinability of these two materials make the combination particularly adaptable to surface condensers.

The relatively close spacing of the welded joints formed on the water side of the tube sheets is illustrated in the partial side view shown in Fig. 4. The annular grooves **23** formed by the trepanning operation are tangentially contingent to the grooves formed around the adjacent tubes. The necessity for trepanning grooves to form the annular projection **22** around the tube openings makes the machinability of the material used as a tube sheet an important factor in determining the preferred materials to be used to practice the present invention.

To exemplify the tightness of the joints obtained by the practice of the present method test blocks, such as the one shown in Fig. 5, were fabricated so that pressure tests could be performed to check the individual welds. It was found that a test on a tube sheet having a plurality of tubes did not give a satisfactory indication of the tightness of individual welds since a leak in one or more of the joints frequently tended to conceal smaller leaks in the other welds. In Table II the combinations of tube and sheet materials which tested without any leaks in all of the six welds checked by the soap test are tabulated with the amperage required to accomplish the welds.

TABLE II

Tube to tube sheet welds

[3/32 INCH DIAMETER TUNGSTEN ELECTRODE ARGON GAS SHIELDING.]

Test No.	Sheet	Tube	Amp.
1	Admiralty Brass	Admiralty Metal	100
2	do	Aluminum Brass	100
3	Naval Brass	Aluminum Bronze	100
4	do	Aluminum Brass	100
5	do	Arsenical Copper	120
6	do	Everdur	100
7	do	70 Cu—30 Ni	100
8	70 Cu—30 Ni	Aluminum Brass	75
9	70 Cu—30 Ni	Admiralty Metal	75
10	70 Cu—30 Ni	Aluminum Bronze	95
11	90 Cu—10 Ni	Aluminum Brass	100

The testing block is essentially a bar having an approximately two inch square cross section and is twelve inches in length. The bars are drilled, reamed and trepanned to provide a weld preparation as shown in Fig. 1. The annular groove **23** is trepanned concentrically around each tube bore **17** to form a tube sheet projection **22** having a vertical annular surface with a thickness approximately equal to the tube gauge. A hole **24** is drilled and tapped at right angles to the tube bore **17** of the weld preparation to provide an inlet for the pressure fluid used in the test. To insure that the tightness of the weld is being tested and not the mechanical tightness of the tube and tube sheet, four shallow longitudinal grooves **26** extend longitudinally along the tube bore so that the air pressure reaches the weld. The tube samples are cut approximately 1/16 of an inch longer than the thickness of the tube sheet and inserted into the tube sheet and flared against the tapers at the ends of the tube bore **17**. The tubes are made longer than the thickness of the test block in order to provide adequate material for the flaring operation.

To simulate actual conditions of welding in a surface condenser, the welds are made with the tubes in a horizontal position. Three tubes of each type of alloy are welded to a test block. The welds on three tubes provide a total of six welded joints for one combination of tube and tube sheet materials. After the tubes are welded to the tube sheet in accordance with the present invention air pressure at ninety pounds per square inch is supplied to the testing hole and the tightness of the six welds are checked with soap water. The welds are executed manually or by the use of a manually operated gun type of automatic welder.

To further exemplify the minimal effects resulting from any distortion or weld stresses which might occur during the practice of the present method, the joints of small rectangular heat exchangers were made by the present method in order to more closely simulate the actual conditions of assembly. The tube spacing was comparable to that used in the usual commercial installations. As an example, a 110 tube heat exchanger core was fabricated of Admiralty metal tubes welded into a Naval brass tube sheet. The welds were made with a thoriated tungsten electrode 3/32 of an inch in diameter, using an argon gas shield and direct current in the range of 90 to 130 amperes. The core did not leak when it was tested hydrostatically at fifty pounds per square inch gauge. During the welding operation, the tube sheet was closely observed for possible distortion, resulting from the heat of the weld. No measurable distortion of the tube sheet was noted. Several tubes were removed with a special tapered reamer and new tubes were replaced without difficulty. After the replacement tubes were welded, the core was again hydrostatically tested and again no leaks were observed. After completion of the pressure test, the tubes then expanded into the tube sheet in accordance with conventional tube rolling practice. The core was again tested hydrostatically and no leaks were found. The welds were individually inspected for possible damage that might have been caused by the rolling operation. However, a visual inspection indicated the rolling operation did not visibly damage the welded joints. Additional heat exchangers involving combinations of some of the materials listed in Table II were made. None of the welded joints leaked when subjected to a hydrostatic test of fifty pounds per square inch gauge. No measurable distortion was noted.

The increased strength of a welded joint as compared to an expanded joint should be readily apparent to one skilled in the art. Tests were conducted on one inch tubes to determine the pull-out and push-out forces required to break a joint. The pull-out force required averaged over three thousand pounds and the push-in force required to break a joint average four thousand pounds. It was found that the welded joint exhibits a strength appreciably greater than a rolled tube joint.

Although the method of the present invention has been described in connection with a step of fusion welding, it should be readily apparent to one skilled in the art that where it is desirable to join a tube and a tube sheet comprising materials that cannot be fusion welded, a braze type of weld can be utilized. Referring to Fig. 6, a low melting alloy ring **27** is inserted between the tube **21** and the tube sheet projection **22** to allow a braze weld type of joint to be used. In some applications it may be desirable to join such materials because of the superior corrosion resistance, cost or some other factor. The type of ring insert **27** used is governed by the analysis of the weld deposit desired. For example, a high zinc base material that does not lend itself to a fusion type of weld would require a ring insert **27** of silver type alloy or one containing phosphorous to complete a braze type of joint rather than a weld. In the event that cracking difficulties occur, the composition of the ring insert could be selected to change the weld analysis in order to remedy the difficulty. The welding method hereinbefore described would not be changed in any way. A notch **28** at the flared end of the tube bore is required for the insertion of the metal filler ring insert **27** and the tube **21** would be flared over the ring insert **27** to pinch it into position.

The term "stable fusing arc" as it is used herein and in the appended claim is defined as an arc formed by the electrode so positioned with respect to the work that the arc is of sufficient intensity to cause the fusion of the metal and continues to cause the fusion of metal as the electrode moves by virtue of the action of the arc and weld puddle.

It should also be understood that the term "fusing portions" as it is used herein, refers to those parts of the tube and tube sheet projection that fuse together to form the weld.

Although the present invention has been described and illustrated in connection with several specific procedures, it is not intended to limit the invention to the exact procedure herein shown and disclosed, as various modifications within the scope of the appended claim may occur to persons skilled in the art.

What is claimed is:

A method of joining tubes of aluminum brass in tube sheets of Naval brass to form a joint of improved tightness and soundness by an electric arc shielded by an inert gas in which said tubes are horizontally supported in tube bores formed in said tube sheets, said method comprising the steps of: providing an annular projection on said tube sheets concentric with and in a circumscribing relationship to each end of said tubes, said projection presenting a vertical annular surface having a radial width substantially equal to the thickness of said tube and flush with the end of said tube; and intimately fusing said tube ends and said projection by a stable fusing arc energized by alternating current overridden by high frequency excitation, said fused tube ends and projections being free of leaks when subjected to an air pressure of fifty pounds per square inch gauge and requiring a pull out force of three thousand pounds or more applied to said tubes to cause said weld to rupture.

References Cited in the file of this patent

UNITED STATES PATENTS

874,084	Jottrand et al.	Dec. 17, 1907
1,485,120	Lincoln	Feb. 26, 1924
1,782,373	Trageser et al.	Nov. 18, 1930
1,949,251	Gilbert	Feb. 27, 1934
2,228,087	Rose	Jan. 7, 1941
2,817,745	Pilia et al.	Dec. 24, 1957