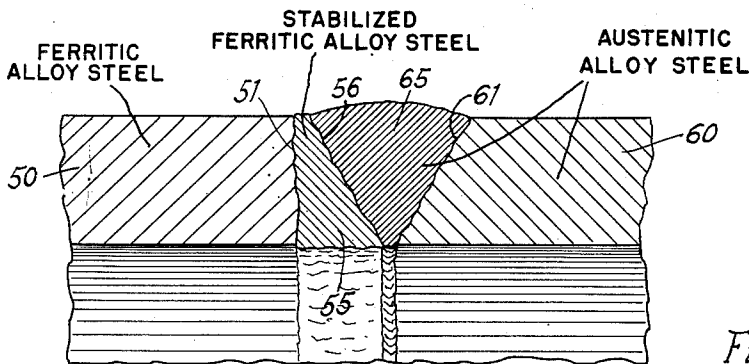
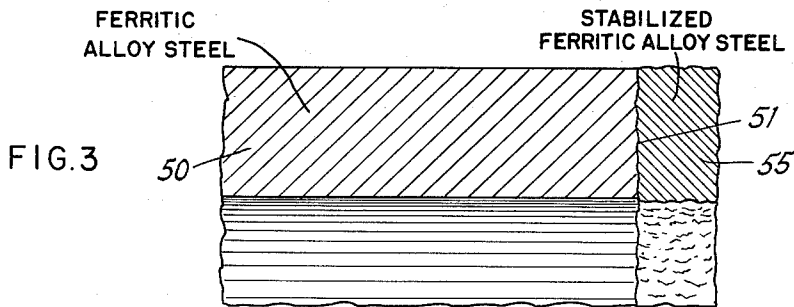
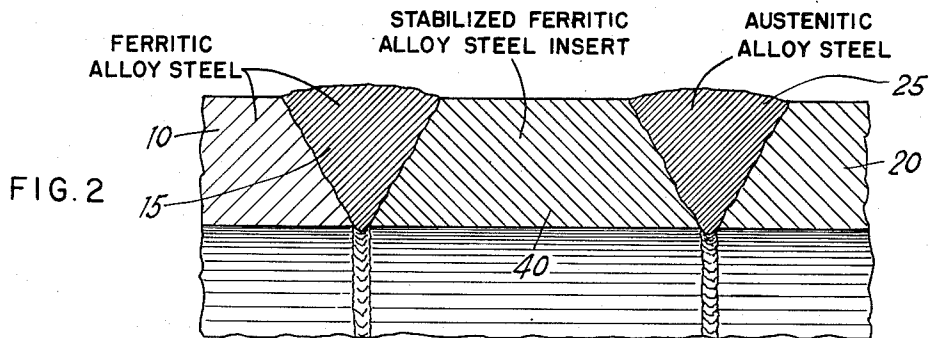
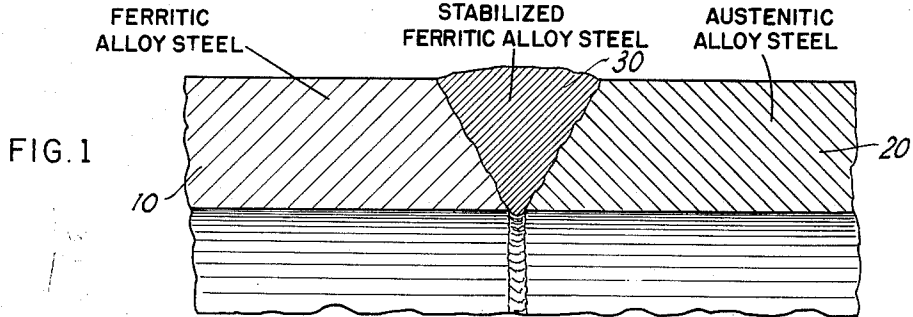


Aug. 21, 1956

F. T. EBERLE
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WELDED JOINT INCLUDING STABILIZED
FERRITIC METAL ZONE
Filed June 20, 1950

2,759,249



INVENTOR
Fritz T. Eberle
BY *J. P. Moran*
ATTORNEY

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2,759,249

WELDING DISSIMILAR METAL MEMBERS WITH WELDED JOINT, INCLUDING STABILIZED FERRITIC METAL ZONE

Fritz T. Eberle, Barberton, Ohio, assignor to The Babcock & Wilcox Company, Rockleigh, N. J., a corporation of New Jersey

Application June 20, 1950, Serial No. 169,187

6 Claims. (Cl. 29—196.1)

This invention relates to the production of a welded joint between austenitic and ferritic materials suitable for high temperature, high pressure service under conditions involving thermal shock and cyclic temperature and load applications.

Such conditions are encountered in high temperature process plants such as, for example, oil refineries, in vapor or steam generators, and in heat exchangers of various types. The particular problems in any one type of installation may differ in one or more aspects from those in another type. Thus, refineries involve high temperatures but only moderate pressures, in conjunction with corrosive environments, alternating oxidation and reducing conditions, and the like. In steam generators, a more complex stress condition exists due to the combined actions of high operating pressures and high operating temperatures, which are further aggravated by cyclic variations in these factors. While the invention is of general application under high temperature, high stress conditions in any type of installation, particular reference will be made, by way of example only, to the high temperature and high stress conditions encountered in steam generating units.

In order to obtain higher efficiencies, the outlet steam temperatures and the operating pressures of central station steam generating plants have been constantly increasing, and presently some central station steam generating units have outlet temperatures of 1050° F. and operating pressures up to and over 2000 p. s. i. The increasing use of such high temperatures and pressures has brought with it problems of providing materials and joints between such materials which will successfully withstand the stresses encountered thereat.

The long-time load-carrying characteristics of metals at high temperatures, together with the economics involved, have led steam generator designers to use both austenitic and ferritic materials for the components of or associated with steam generators. For example, both types of material may be used in the superheater and its supports, and in the main steam line from the generator to the turbine. Use of both types of materials in the same component requires that particular attention be given to the junctions between these materials, which junctions must operate under the particular temperature and stress conditions encountered in producing steam at relatively high temperatures. In a superheater, for example, the external surface and the superheater support lugs are at a higher temperature than the internal surface of the superheater tubes due to the higher temperatures of the heating gases as compared to the temperature of the steam flowing through the superheater. While no external heating is involved in connection with a steam conduit from the superheater outlet of a steam generator to a steam turbine supplied thereby, welded joints between austenitic and ferritic sections are involved in high temperature installations.

Operation under stress at such high temperatures in-

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troduces many problems due to the differential expansion and contraction of the dissimilar materials on either side of the joint, their relative surface and structural stability, etc. Aside from mechanical stresses, such as, for example, those due to differential thermal expansion and contraction, the factors influencing the service life of welded joints between ferritic and austenitic materials have been basically of a metallurgical nature, such as carbon depletion in the heat affected zone of the ferritic material, notching due to oxide penetration occurring therein, micro-fissuring in the weld junction, and accelerated creep due to these conditions. Examples of joints between ferritic and austenitic materials, with which these problems are encountered, are the joining of a ferritic alloy having substantially 2¼% chromium to an austenitic alloy of the "18-8" or "25-20" type.

When an austenitic element, such as a pressure pipe or tube, is welded to a ferritic element, which may likewise be a pressure pipe or tube, and the composite welded structure operated at high temperatures, carbon tends to migrate from the ferritic alloy toward the austenitic alloy, piling up at the fusion line, to form a carbon enriched zone, and leaving a carbon depleted zone in the ferritic metal workpiece. This phenomenon may occur even when the weld metal is an austenitic metal stabilized with columbium, for example. When an austenitic member is joined to a ferritic member by a ferritic weld metal deposit, having, for example, substantially the composition of the ferritic member, the carbon again tends to migrate, forming a carbon enriched zone at the line of fusion and leaving a carbon depleted zone in the ferritic member. In both cases, the carbon enriched zone may become unduly hard and brittle, lessening the resistance of the welded joint to induced stresses, such as due to the differential thermal expansion of the austenitic and ferritic members. The decarburized zone is weakened, due to its loss of carbon, and is a potential point of failure of the composite weld assembly.

In accordance with the present invention, it has been found that such carbide migration can be effectively inhibited, and thus the disadvantageous results thereof substantially eliminated, by including, in the welded joint between a ferritic alloy member and an austenitic alloy member, a stabilized ferritic metal zone intermediate the members. The ferritic alloy metal weld is stabilized with a strong carbide former such as columbium. Titanium may be used as the stabilizer, as well as other carbide stabilizers such as zirconium, cerium, tungsten, boron, tantalum or vanadium.

The welded joint of the present invention may take any one of several forms. In one form, a ferritic alloy member is joined to an austenitic alloy member by a weld formed of a fusion deposited, stabilized ferritic alloy metal. In another form, an insert of stabilized ferritic alloy metal is joined to the ferritic alloy workpiece member by a non-stabilized ferritic alloy weld, and is joined to the austenitic alloy workpiece member by a fusion deposited austenitic metal weld. In still another form, a layer of a stabilized ferritic alloy metal is "battered" on an edge of the ferritic alloy workpiece, and the "battered" layer is joined to the austenitic alloy workpiece member by a fusion deposited austenitic alloy metal.

For a more complete understanding of the invention principles, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawings.

In the drawings:

Fig. 1 is a partial transverse section through a composite welded assembly including a ferritic alloys workpiece, such as a pressure pipe or tube, united to an aus-

tenitic alloy workpiece, such as a pressure pipe or tube by a stabilized ferritic alloy weld;

Fig. 2 is a partial transverse section through a composite welded assembly including a tubular stabilized ferritic alloy insert joined to a tubular ferritic alloy workpiece by a non-stabilized ferritic alloy weld, and to a tubular austenitic alloy workpiece by an austenitic alloy weld deposit;

Fig. 3 is a partial transverse sectional view illustrating a tubular ferritic alloy workpiece having a layer of a stabilized ferritic alloy metal "buttered" on one edge thereof; and

Fig. 4 is a partial transverse sectional view illustrating the composite workpiece of Fig. 3 with the "buttered" layer united to a tubular austenitic alloy workpiece by an austenitic alloy weld deposit.

In the following description of the invention, the term "ferritic alloy" is used to designate alloys having compositions such as carbon-0.5% molybdenum 2% Cr-0.5% Mo, 2¼% Cr-1% Mo, 5% Cr-0.5% Mo, or similar predominantly ferritic alloy steels. Similarly, the term "austenitic alloy" refers to alloys known to those skilled in the art as "18-8" (18Cr-8 Ni), "18-8 Cb," "18-8 Ti," "25-12," "25-20," or any other alloy steel which is predominantly austenitic in structure.

Referring to Fig. 1 of the drawing, a predominantly ferritic alloy steel workpiece 10, such as a pressure tube or pipe, is illustrated as weld united to a predominantly austenitic alloy steel workpiece 20, such as a pressure tube or pipe, by a fusion deposited, suitably stabilized ferritic alloy weld 30. The metal of weld 30 may have substantially the same composition as workpiece 10, but is stabilized by a suitable carbide former, such as columbium, for example, or any other known stabilizer. For example, if workpiece 10 has a composition of 2¼% Cr and 1% Mo, weld metal 30 may have 2¼% Cr, 1% Mo, and be stabilized with columbium. It is not essential that the percentage constitution of weld metal 30 be identical to that of workpiece 10. Thus, in the foregoing example, wherein workpiece 10 has 2¼% Cr, weld metal 30 may have 5% Cr. It is essential, however, that weld metal 30 be predominantly ferritic in structure and be stabilized against carbon migration by the addition of columbium or other stabilizing elements.

In the arrangement of Fig. 1, there is essentially no carbon migration between workpiece 10 and weld metal 30 as these are ferritic alloys of substantially the same or closely related composition. Similarly, the stabilization or "fixing" of the carbon in weld metal 30, sets an effective barrier against carbon migration between the stabilized ferritic alloy weld 30 and the austenitic alloy workpiece 20. As the compositions of workpiece 10 and weld 30 are essentially the same, there is substantially no differential thermal expansion between member 10 and weld 30. In the absence of significant carbon migration between member 20 and weld 30, formation of carbon-rich zones conducive to embrittlement at the line of fusion, or carbon depletion adjacent the line, is minimized thus enhancing the ability of the welded joint to withstand stresses due to differential thermal expansion between members 10 and 20.

Fig. 2 illustrates an alternative embodiment of the invention in which carbon migration between ferritic alloy workpiece 10 and austenitic alloy workpiece 20, which may be pressure members, is inhibited by a novel welded joint including an insert 40 of a stabilized ferritic alloy. Insert 40, in the same manner as weld 30 of Fig. 1, may have substantially the same composition as ferritic workpiece 10, or a composition similar thereto. The insert, while predominantly ferritic in structure, the same as workpiece 10, is stabilized against carbon migration by the addition of a stabilizing element such as columbium. While columbium is preferred, any of the other mentioned stabilizing additions may be used.

In the example of Fig. 2, insert 40 is weld united to

workpiece 10 by a fusion weld deposit 15 of a non-stabilized, predominantly ferritic alloy whose composition is substantially the same as, or closely similar to, the composition of member 10. The fusion welded joint 25 uniting insert 40 to austenitic alloy member 20 comprises a predominantly austenitic alloy whose composition may be, but not necessarily must be, the same as, or closely similar to, the composition of member 20, and which may be stabilized with columbium or the like. Thus, if member 20 is a "19-9 Cb" alloy, weld deposit 25 may be the same composition, preferably stabilized, or may be 25Cr-20Ni, or 80Ni-20Cr, etc. In this case, there is practically no carbon migration between the ferritic member 10 and the ferritic weld deposit 15, nor between the austenitic member 20 and the austenitic weld deposit 25. Likewise, due to stabilization of insert 40, there is essentially no carbon migration between this insert and the austenitic weld deposit 25.

While the arrangement of Fig. 2 is very effective in inhibiting carbon migration, it will sometimes occur that stabilized inserts of the required dimension are not available, particularly in the weld uniting of a pair of pressure members, such as boiler or superheater tubes or supports, or steam line sections. Under such circumstances, the arrangement of Figs. 3 and 4 may be effectively utilized. Referring to Fig. 3, a ferritic alloy workpiece 50 which may, for example, be a tubular pressure member, has "buttered" on one end 51 thereof a layer of a predominantly ferritic alloy 55 which is stabilized against carbon migration by the addition of columbium, for example, or other suitable carbide stabilizer. Such "buttering" may be effected by any suitable metal deposition process.

As shown in Fig. 4, the "buttered" deposit 55 has its outer edge beveled as at 56 to form, with the similarly beveled edge 61 of a predominantly austenitic alloy workpiece 60, a welding groove. This welding groove is then filled with fusion deposited predominantly austenitic weld metal 65, preferably stabilized with columbium or the like. The "buttered" layer 55 desirably has essentially the same composition as ferritic member 50, whereas the austenitic weld deposit 65 may have the same composition as austenitic alloy member 60 or may be of any other suitable composition of a predominantly austenitic nature.

In the arrangement of Fig. 4, there is essentially no carbon migration between ferritic member 50 and stabilized ferritic layer 55, nor between austenitic alloy member 60 and the preferably stabilized austenitic weld deposit 65. Due to the stabilization of the carbon in layer 55, carbon migration between stabilized ferritic layer 55 and austenitic weld deposit 65 is inhibited.

The weld deposits 15, 25, 30, and 65, and "buttered" layer 55, may be applied by any of the fusion metal deposition processes known to those skilled in the art, such as shielded metal arc welding, atomic hydrogen welding, inert gas arc welding, submerged flue arc welding, or the like, depending upon the particular application involved.

While the drawings illustrate tubular members as the workpieces, it is desired to emphasize that this is only by way of illustrating a particular application of the invention, and that the welded joint of the invention is not limited to composite welded structures involving tubular elements. For example, the principles of the invention are equally applicable to the joining of an austenitic support lug to a ferritic superheater tube, or to the joining of a ferritic tubular element, such as a steam line section to an austenitic turbine valve. Other examples of the application of the invention will readily suggest themselves to those skilled in the art, such as, for instance, the weld uniting of an austenitic plate or bar to a ferritic plate or bar, or any combination of the foregoing illustrative examples.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the invention principles, it should be understood that the invention may be otherwise embodied without departing from such principles.

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What is claimed is:

1. A composite welded assembly for service at cyclically varying elevated temperatures and pressures, said assembly comprising a ferritic alloy member, selected from the class consisting of carbon-0.5% Mo, carbon-2% Cr-0.5% Mo, carbon-2¼% Cr-1% Mo, and carbon-5% Cr-0.5% Mo, an austenitic alloy member, selected from the class consisting of 18% Cr-8% Ni, 18% Cr-8% Ni-Cb, 18% Cr-8% Ni-Ti, 25% Cr-12% Ni, and 25% Cr-20% Ni, and a welded joint uniting said members and including a ferritic alloy steel stabilized with an element selected from the class consisting of titanium, columbium, zirconium, cerium, tungsten, boron, tantalum, vanadium, and an austenitic steel, said ferritic alloy steel being of substantially the same composition as said ferritic alloy member and being fused directly to the latter, said austenitic alloy steel being of substantially the same composition as said austenitic alloy member and being fused directly to the latter and to said stabilized ferritic alloy steel.

2. A composite welded assembly for service at cyclically varying elevated temperatures and pressures, said assembly comprising a ferritic alloy member, selected from the class consisting of carbon-0.5% Mo, carbon-2% Cr-0.5% Mo, carbon-2¼% Cr-1% Mo, and carbon-5% Cr-0.5% Mo, an austenitic alloy member, selected from the class consisting of 18% Cr-8% Ni, 18% Cr-8% Ni-Cb, 18% Cr-8% Ni-Ti, 25% Cr-12% Ni, and 25% Cr-20% Ni, and a welded joint uniting said members and including a ferritic alloy steel stabilized with columbium, and an austenitic alloy steel; said ferritic alloy steel being of substantially the same composition as said ferritic alloy member and being fused directly to the latter, said austenitic alloy steel being of substantially the same composition as said austenitic alloy member and being fused directly to the latter and to said stabilized ferritic alloy steel.

3. A composite welded assembly for service at cyclically varying elevated temperatures and pressures, said assembly comprising a ferritic alloy member, selected from the class consisting of carbon-0.5% Mo, carbon-2% Cr-0.5% Mo, carbon-2¼% Cr-1% Mo, and carbon-5% Cr-0.5% Mo, an austenitic alloy member, selected from the class consisting of 18% Cr-8% Ni, 18% Cr-8% Ni-Cb, 18% Cr-8% Ni-Ti, 25% Cr-12% Ni, and 25% Cr-20% Ni, a stabilized ferritic alloy steel insert, of substantially the same composition as said ferritic alloy member, intermediate said members; a ferritic alloy steel weld metal deposit, of substantially the same composition as said ferritic alloy member, uniting said ferritic alloy member to said insert; and an austenitic alloy steel weld metal deposit, of substantially the same composition as said austenitic alloy member, uniting said austenitic alloy member to said insert.

4. A composite welded assembly for service at cyclically varying elevated temperatures and pressures, said assembly comprising a ferritic alloy member, selected from the class consisting of carbon-0.5% Mo, carbon-2% Cr-0.5% Mo, carbon-2¼% Cr-1% Mo, and carbon-5% Cr-0.5% Mo, an austenitic alloy member, selected from the class consisting of 18% Cr-8% Ni, 18% Cr-8% Ni-Cb, 18% Cr-8% Ni-Ti, 25% Cr-12% Ni, and 25% Cr-20% Ni, and a welded joint uniting said members and including a stabilized ferritic alloy steel zone, of substantially the same composition as said ferritic alloy member and fused directly thereto, and fusion de-

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posited austenitic alloy steel, of substantially the same composition as said austenitic alloy member, intermediate and fused to said zone and said austenitic alloy member.

5. A method of joining a ferritic alloy member, selected from the class consisting of carbon-0.5% Mo, carbon-2% Cr-0.5% Mo, carbon-2¼% Cr-1% Mo, and carbon-5% Cr-0.5% Mo, to an austenitic alloy member selected from the class consisting of 18% Cr-8% Ni, 18% Cr-8% Ni-Cb, 18% Cr-8% Ni-Ti, 25% Cr-12% Ni, and 25% Cr-20% Ni, for service at cyclically varying elevated temperatures and pressures, said method comprising weld uniting the members by a welded joint including a stabilized ferritic alloy steel zone and an austenitic alloy steel zone, said ferritic alloy steel being of substantially the same composition as said ferritic alloy member and being fused directly to the latter and said austenitic alloy steel zone being of substantially the same composition as said austenitic alloy member and being directly fused to the latter and to said stabilized ferritic alloy steel zone.

6. A method of joining a ferritic alloy member, selected from the class consisting of carbon-0.5% Mo, carbon-2% Cr-0.5% Mo, carbon-2¼% Cr-1% Mo, and carbon-5% Cr-0.5% Mo, to an austenitic alloy member, selected from the class comprising 18% Cr-8% Ni, 18% Cr-8% Ni-Cb, 18% Cr-8% Ni-Ti, 25% Cr-12% Ni and 25% Cr-20% Ni, for service at cyclically varying elevated temperature and pressures, said method comprising disposing a stabilized ferritic steel alloy insert between the members; joining the insert to the ferritic member by fusion depositing ferritic alloy steel, of substantially the same composition as said ferritic alloy member, therebetween; and joining the insert to the austenitic member by fusion depositing austenitic alloy steel, of substantially the same composition as said austenitic alloy member, therebetween.

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