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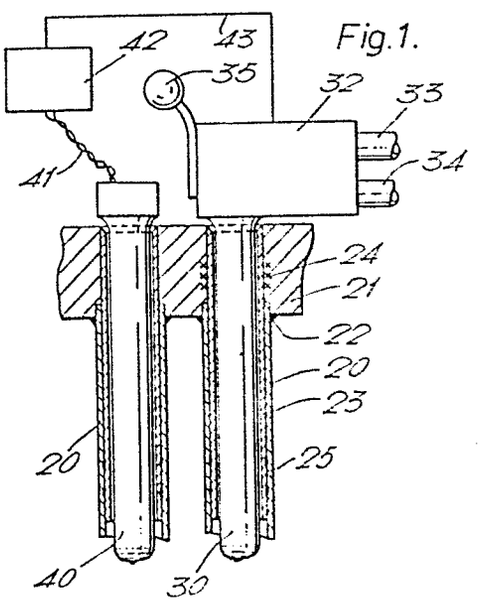
(54) Temperature control during annealing.

(57) Temperature control at a weld (52) between a tube (51) and tube plate (53) having heat input from an inductive heating probe (50) to effect annealing of the weld is performed with the aid of a signal generating receptor coil (54) coupled with the probe (50). The signal from the coil (54) experiences a characteristic change when the temperature of the weld reaches the required annealing temperature and this signal is used to control the heat input to the weld. The receptor coil can be inside the tube (51), outside the tube (51), embracing a number of similar tubes (51) or may be inside an adjacent tube (51). At the anneal, the materials of the tube and weld reach their Curie point which brings about a permeability change. The invention also has application to annealing a braze between a ferritic repair tube and a ferritic tube in a tube plate as can arise during the repair of shell and tube heat exchangers used in nuclear systems.

Fig.1.



EP 0 136 810 A2

Temperature Control During Annealing

This invention relates to temperature control during annealing of ferromagnetic members.

The invention has arisen in response to problems arising in the course of annealing welds where ferritic tubes are welded to tube plates of shell and tube heat exchangers and especially heat exchangers as used in the nuclear field for steam generation such as in fast and pressurised water reactors. In these heat exchangers the tubes are closely spaced and access to their welds for annealing and temperature measurement is difficult. Thus annealing tends to be carried out by an inductive probe internally of the tube in the region of the weld. The probe may be in the form of an RF energised and water-cooled coil or may be as described in our copending British Application Published as GB 2130860A. Anneal temperature control is performed by control of power into the probe which has been predetermined by trials on a model to obtain the required anneal. This form of control leaves uncertainties and a real time control would be preferred. The present invention provides such a control.

In accordance with the invention a method of effecting temperature control during annealing at a joint between a ferritic tube and a tube plate or between a ferritic repair tube and a ferritic tube in a tube plate, comprising inserting an inductive heating probe inside

the tube, is characterised in that there is provided a signal generating receptor having coupling with the probe and in that the signal generated at the receptor, when the Curie Point in said joint is reached, is used to control the power input to said probe.

The invention relies on the fact that the temperature of anneal is close to the Curie point of the material of the tube which is having its weld annealed. Thus, at above annealing temperature, there is a significant change in the permeability of the tube and hence also in the voltage induced in the receptor and this can be used to reduce power input to the probe and vice-versa. The change is so significant that the receptor can be located inside an adjacent unheated tube and, despite the fact that the unheated tube acts as a shield round the receptor, a detectable signal arises.

The use of Curie Point detection as a control element is itself well known. For example GB 360,552 shows the automatic movement of steel through a furnace when a Curie Point is reached. For the detection of the Curie Point a source of magnetic flux and means for measuring the flux are provided so that a control signal can be generated. The furnace is heated conventionally. GB 1,468,852 is concerned with the true detection of Curie Point in a vibrational system. EP 011862A has a Curie Point monitor inserted into a heated roller to give a control signal to control resistance heat input to the

roller.

The present invention shows a very economical use of components. In order to effect control the only basic supplementary component to that required to effect the anneal heating is the receptor, which may be a simple coil. The act of annealing already requires an inductive heating probe and a control system for power into the probe. The magnetic field which is affected by Curie change is that already provided for heating. The item which has a Curie response it that being processed so that no supplementary Curie item has to be provided. The invention is of particular value in the specific context of anneal in the joint repair of congested tube and plate heat exchangers.

The invention, in various forms, will now be described further with reference to the accompanying diagrammatic drawings in which:

Figure 1 is a sectional elevation of a part of a heat exchanger being repaired and involving annealing of a braze used in the repair, the signal generating receptor of the invention being located in an adjacent tube.

Figure 2 is a sectional elevation of a tube to tube plate weld involving an anneal at the weld, the signal generating receptor being located inside the tube having its weld annealed.

Figure 3 is a circuit diagram of a control circuit

for use with the arrangement of figure 2, and

Figure 4 shows an alternative arrangement.

In Figure 1 a tube 20 in a nest of closely spaced similar parallel tubes in a tube plate 21 is assumed leaking at the weld 22. To close off this leak a repair tube 23 is inserted into the leaking tube 20 through the tube plate. The upper end of tube 23 is explosively welded to the tube plate at a region 24 (indicated by crosses) and the lower end of tube 23 is brazed to the tube 20 at a region 25.

To effect the braze at region 25 an induction heating probe 30 (see for example GB 2 130 860A) is inserted inside the tube 23. This probe has a service box 32, water conducting cables 33, 34 and a handle 35.

Inside the probe 30 there is a magnetic flux generating unit and when the probe is powered the braze at region 25 is effected. After making the braze an annealing process is required. To perform this anneal the probe is retained on power but the anneal operation requires control.

In order to provide control of the anneal a signal generating flux receptor coil probe 40 is inserted into a tube 20 adjacent to the tube 20 being annealed. The tube 20 having the probe 40 can itself be a repaired tube (as shown) or an unrepaired tube.

Connections 41 are provided to the flux receptor probe 40 and these connect with a control unit 42 which

controls the power input to the induction heating probe 30 along a control line 43 according to the signal generated at probe 40.

As the annealing temperature is reached at the braze region 25 the Curie point of the repair tube is also reached. This causes a measurable rise in the flux (1 microvolt per turn of the coil of probe 40) received from probe 30 at probe 40 despite the shielding effect of the unheated tube 20. The link from the coil of probe 40 (ie connectors 41) is preferably by optical fibre so that induced error signals do not occur in the link as may arise from the intense magnetic field which is created by the probe 30.

In Figure 2 an induction heating probe 50 is shown inside a tube 51, welded at 52 to a tube plate 53. The probe is located so that the weld can be annealed. Around the probe 50 there is a single turn 54 of a 1mm diameter mineral insulated conductor. This acts as a signal generating receptor and typically it provides a signal of 1.0 - 1.5 mV when the weld 52 is above the Curie temperature and a signal of about 0.5 - 0.7mV when the weld is below the Curie temperature.

Figure 3 shows a circuit for use with the arrangement shown in Figure 2.

A 20 KHz generator 60 is used to power the heating probe 50. The signal in the receptor turn 54 is backed off against an EMF derived from a current transformer 61

via a potentiometer 62. In this way the output signal from receptor 54 can be made zero prior to the Curie temperature being reached and of a magnitude to effect control at the Curie temperature. The backed-off signal passes to an amplifier 63 and thence to a control unit 64 which controls output from the generator 60 to the heating probe.

In Figure 4 a nest of tubes 51 is shown in sectional plan. In one of these tubes a probe 50 is located. A single turn receptor coil 54A is provided enclosing a number of the tubes 51. As the probe is moved from one tube 51 to the next the same receptor coil 54A can be used for control purpose.

In another alternative arrangement the receptor coil 54A encloses only a single tube 51 and is moved from tube to tube as annealing takes place. In yet another alternative arrangement each tube 51 has its own individual mineral insulated receptor coil tack welded to it as the heat exchanger is constructed and the coil terminates at a point of access remote from the tubes. In this way, later annealing can be performed without the need for access to the outside of the tubes (which may be impossible either due to the close packing of the tubes or because the tubes are radioactive).

In arrangements having a coil 54 enclosing one, or more, tubes a substantial signal is generated at the Curie temperature. This may typically be 1.5 volts for a

single turn.

The invention, particularly as exemplified by the arrangement of Figure 2, can be used to control an anneal at the explosive weld 24 indicated in Figure 1.

Claims

1. A method of effecting temperature control during annealing at a joint between a ferritic tube and a tube plate or between a ferritic repair tube and a ferritic tube in a tube plate, comprising inserting an inductive heating probe inside said ferritic tube or repair tube, characterised in that there is provided a signal generating receptor having coupling with the probe, and in that the signal generated at the receptor, when the Curie Point in said joint is reached, is used to control the power input to said probe.

2. A method as claimed in claim 1 in which the receptor is located in an adjacent ferritic tube, which does not enter the Curie Point region.

3. A method as claimed in claim 1 in which the receptor is a coil (one or more turns) located inside the tube at which the joint is being effected.

4. A method as claimed in claim 1 in which the receptor is a coil enclosing one or more tubes joined with the tube plate.

5. A method as claimed in any one of claims 1 to 4 in which the annealing is at an explosive weld made between a repair tube and a tube in a tube plate.

6. A method as claimed in any preceding claim in which the control signal is transmitted by optical fibre connections in regions where those connections are subjected to an intense field from the heating probe.

7. A method as claimed in any preceding claim in which the receptor is a coil of one or more turns of mineral insulated cable which is permanently or removably associated with the joint.

8. A shell and tube heat exchanger in a nuclear reactor system having a repair tube brazed inside one of the tube of the heat exchanger and annealed by any one of the methods of Claims 1 to 7.

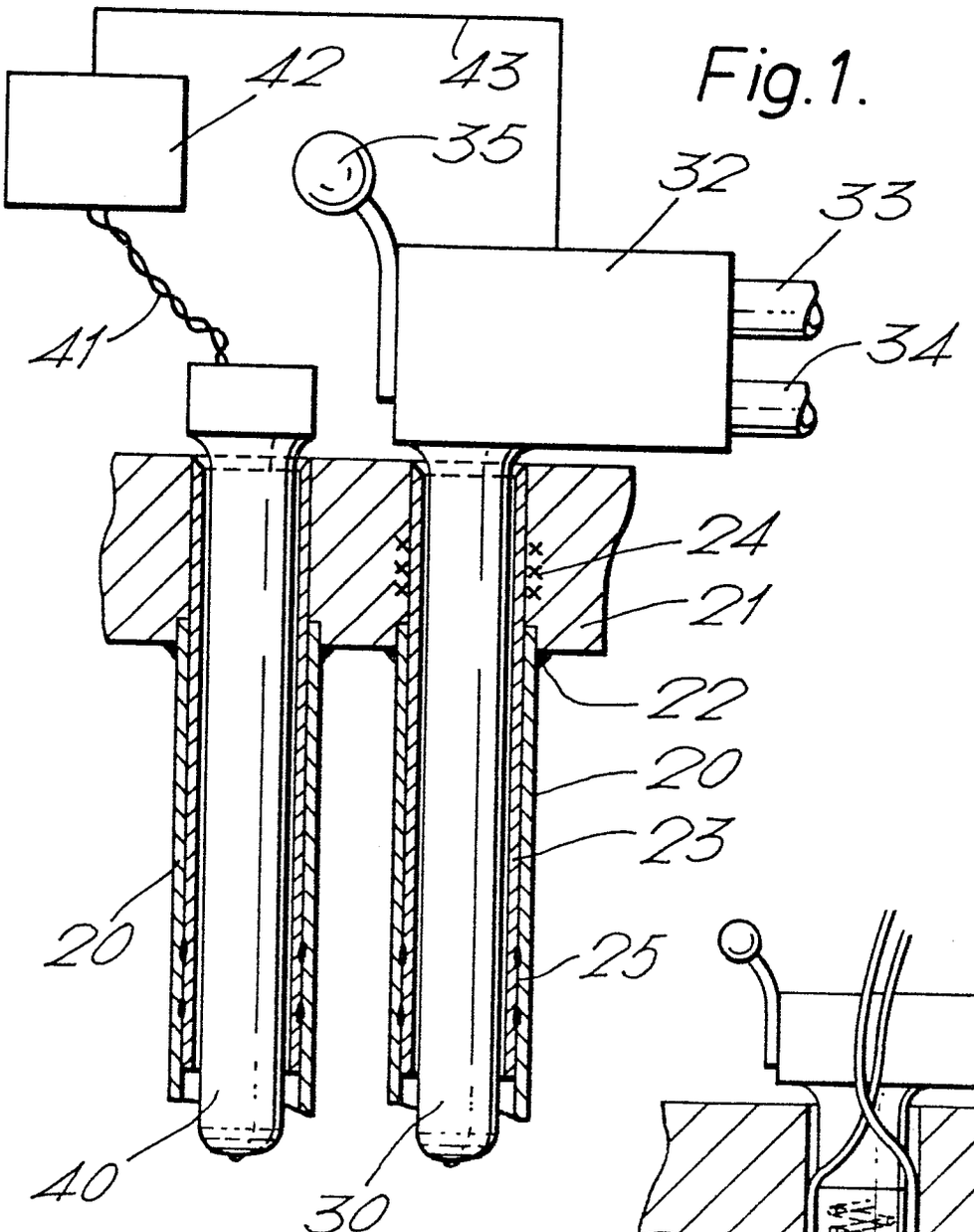


Fig.1.

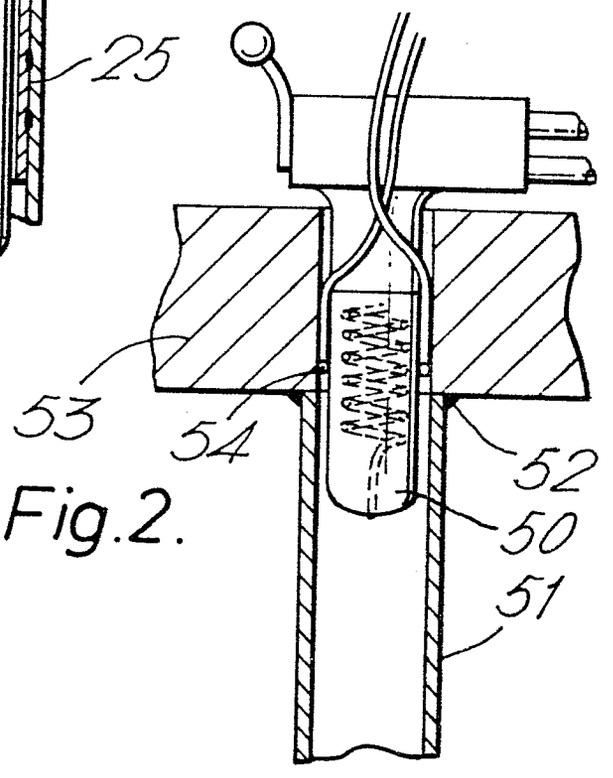


Fig.2.

Fig.3.

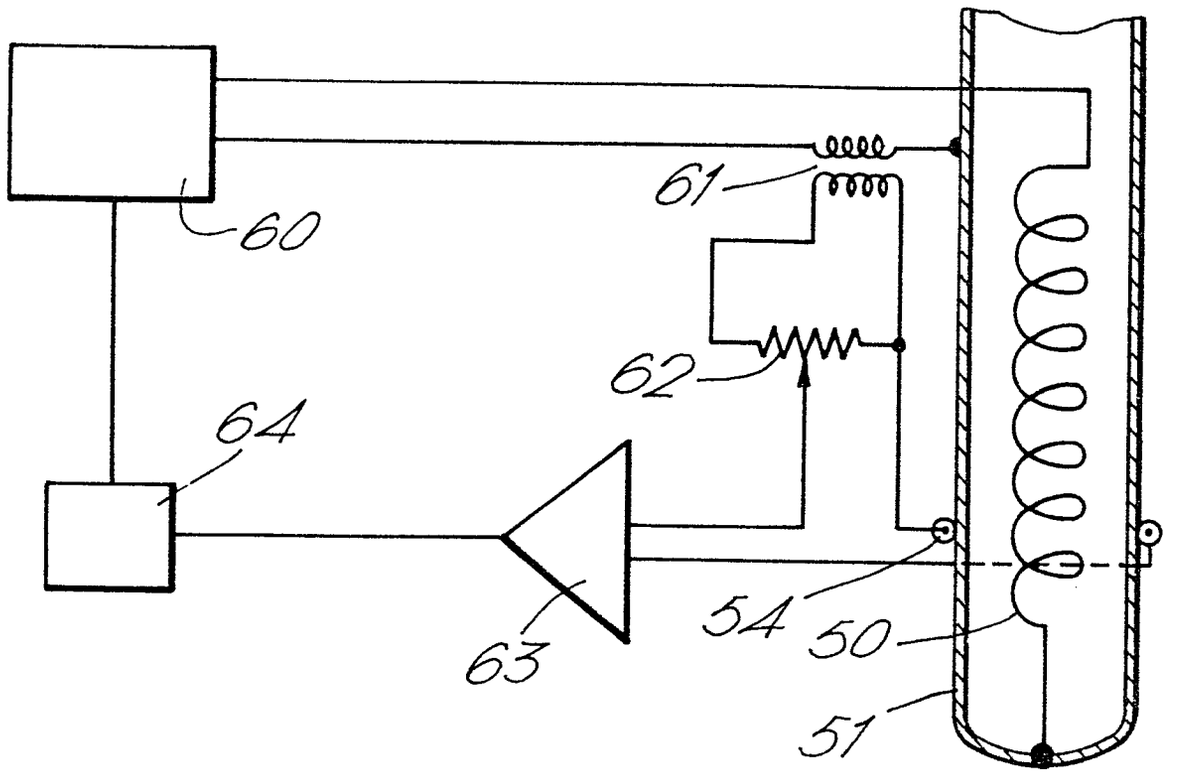


Fig.4.