

Method of Treating or Repairing
Pressure Vessels.

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5. The present invention relates to a method of treating or repairing pressure vessels of the type adapted to contain high temperature and high pressure hydrogen as are used in petroleum refineries, coal gasification plants and the like.

10. In petroleum refineries, coal gasification plants and the like, hydrogen cracking or hydrogen reactions are carried out in a high temperature and high pressure hydrogen atmosphere within a pressure vessel. Figure 1 is a longitudinal section view of such a pressure vessel 1 which comprises a shell 2 of carbon steel or low alloy steel and a weld cladding 3 of material such as austenitic stainless steel or Inconel^(C.I.M.), which exhibits excellent resistance to corrosion and extends
15. over the inner surface of the pressure vessel 1 and is secured thereto by welding thereby rendering the inner surface of the vessel resistant to corrosion.

20. When fabricating such a vessel, in order to prevent the welded joints from cracking, to relieve residual stresses and to improve the quality of the welded joints, a post-weld heat treatment is carried out in accordance with ASME Sec VIII. In a vessel fabricated in the manner described above, the boundaries between the base metal 2 and the weld-cladding material 3 have a structure which is readily susceptible to
25. hydrogen induced disbonding. As a result, when the vessel 1 containing hydrogen at high temperature and high pressure is used for a long period of time, disbonding due to the hydrogen tends to occur at
30. shut-down in service at the boundary 4 between the base metal and the cladding as shown in Figure 2

which is a scrap perspective view of the wall of the pressure vessel. Such disbonding of the cladding is propagated gradually and those portions of the cladding which are not separated from the base metal are also found to be subject to hydrogen corrosion. Thus, when disbonding of the cladding is found to be occurring, suitable corrective measures must be taken as soon as possible.

In the known method of repairing such damage the portions having cracks in them are removed, and an overlay welding process is carried out to compensate for the removed portions and the repair-welded portions are subjected to a post-weld heat treatment. The repair of such vessels is thus complex and time consuming and therefore extremely expensive.

According to a first aspect of the present invention there is provided a method of treating a vessel adapted to contain hydrogen at high temperature and high pressure comprising a steel shell to the inner surface of which a layer of corrosion resistant material is secured by welding, which method comprises heat treating the boundary between the shell and the corrosion resistant material at a temperature between 700°C and 1100°C by means of an induction heating unit.

According to a further aspect of the present invention, there is provided a method of repairing a vessel adapted to contain hydrogen at high temperature and high pressure comprising a steel shell to the inner surface of which a layer of corrosion resistant material is secured by welding, which

method comprises replacing an area of the corrosion resistant material, e.g. an area at which the corrosion resistant material and/or the welded connection thereof has cracks therein , with

5. fresh corrosion resistant material and securing it to the shell by welding and subsequently heat treating the boundary between the shell and the fresh corrosion resistant material at a temperature between 700°C and 1100°C by means of an induction heating

10. unit.

Subsequent to the treatment by means of the induction heating unit, the vessel may be subjected to a further heat treatment at substantially 700°C for two hours or less,

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Further features and details of the present invention will be apparent from the following description of one specific embodiment which is given by way of example, with reference to the accompanying drawings, in which:-

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FIGURE 1 is a longitudinal sectional view of a vessel containing high temperature high pressure hydrogen;

FIGURE 2 is a scrap view of the wall of the vessel;

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FIGURE 3 is a view similar to FIGURE 2 illustrating the present invention;

FIGURE 4 is a diagrammatic view of a high frequency induction heating unit for use in the method of the present invention;

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FIGURE 5 is a graph of the temperature distribution across the vessel wall when it is heated; and

FIGURE 6 is a schematic illustration of the method of the present invention.

5. The presence or otherwise of cracks at the weld boundary of the pressure vessel 1 is detected periodically or at suitable time by an ultrasonic detector or the like.

10. When relatively large cracks 5, regions of which are indicated by chain lines in Figure 2, are found, the crack regions and the regions adjacent them are removed as indicated by a in Figure 3, and new weld-cladding materials 3 are made and placed in position to compensate for the removed portions and are then welded e.g. arc welded to the shell.

15. Thereafter, the boundary 4 between the base metal 2 and the replacement weld-cladding materials 3 is heated to between 700°C and 1100°C by a high-frequency induction heating unit 6 (seen in Figure 4).

20. The suitable heating temperature of the surface of the cladding and the temperature distribution across the vessel wall are shown in Figure 5.

25. When the high-frequency induction heat treatment is carried out, the boundary 4 can be heated to a predetermined temperature without subjecting the base metal to extensive thermal effects, as shown in Figure 5. Thus the temperature at the surface of the cladding is such that the temperature at the weld boundary is within the desired range, but falls off rapidly in the shell 2. In addition, the heating range can be easily determined and the temperature
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can be readily controlled.

5. When the heat treatment of the boundary is carried out, the carbon migration and chromium carbide precipitation which occurred during the annealing step in the fabrication of the vessel are dispersed and the micro-structure at the boundary is refined.

As a result, further cracking of this type can be prevented..

10 Figure 6 shows the heating cycle during the repair operation. Thus, the initial repair welding is effected at a relatively high temperature following which the high frequency induction heat treatment is effected at a somewhat lower temperature. Thereafter,
15. a post-repair-weld heat treatment may also be carried out at an even lower temperature. This latter treatment may not be necessary and the temperature curve thereof is indicated by a chain line.

20 When the cracks are relatively small, the cracked portions are directly subjected to the high frequency induction heat treatment without the removal and repair welding steps. The structure of the boundary is improved by the direct high frequency induction heat treatment so that the
25. progagation of the cracking can be prevented.

The table below shows the results of four experiments on a mock-up testing plate which was repaired in accordance with the method of the present invention. The test plate was maintained
30. at a temperature of 450°C within a hydrogen atmosphere in which the partial pressure of hydrogen was maintained

at 150 kg/cm² for 48 hours. In two of the experiments after heating the weld boundary to 700 to 1100°C, with the high frequency induction heating unit, the test plate was also heat treated at 700°C.

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Experiment No.	Base metal	Cladding metal	Heat treatment	Result
1	ASME SA387 Gr.22	ASME SA240 Type 304	none	no crack
2			none	no crack
3			700°C x 2Hr	no crack
4			700°C x 2Hr	no crack

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A high frequency induction heating unit suitable for use in the present invention will be described with reference to Figure 4. A carriage 8 with wheels 7 is attached by springs 9, to a carrier member 10. An inductor 12 is mounted on the carriage 8 and connected to a high frequency power supply 11.

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When the inductor 12 is energised all the desired portions of the vessel wall may be heated by moving the carrier member 10.

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In this case, the carriage 8 is pressed against the inner surface of the vessel wall under the action of the springs 9 and moves over the surface. As a result, the distance between the inductor 12 and the inner wall surface of the vessel 1 is maintained constant so that this surface is uniformly heated.

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The method of the present invention is applicable not only to repairing a pressure vessel and treating a pressure vessel with small cracks therein to prevent

the further propagation thereof but also to treating a pressure vessel which is as yet undamaged thereby preventing the formation of cracks.

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CLAIMS

1. A method of treating a vessel adapted to contain hydrogen at high temperature and high pressure comprising a steel shell to the inner surface of which a layer of corrosion resistant material is secured by welding, which method comprises heat treating the boundary between the shell and the corrosion resistant material at a temperature of between 700°C and 1100°C by means of an induction heating unit.
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2. A method of repairing a vessel adapted to contain hydrogen at high temperature and high pressure comprising a steel shell to the inner surface of which a layer of corrosion resistant material is secured by welding, which method comprises replacing an area of the corrosion resistant material with fresh corrosion resistant material and connecting it to the shell by welding and subsequently heat treating the boundary between the shell and the fresh corrosion resistant material at a temperature of between 700°C and 1100°C by means of an induction heating unit.
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3. A method as claimed in Claim 1 or Claim 2 in which after the heat treatment step, the vessel is subjected to a further heat treatment at substantially 700°C for two hours or less.
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4. A method of treating a vessel adapted to contain hydrogen at high temperature and high pressure, substantially specifically as herein described with
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reference to the accompanying drawings.

5. A method for repairing a high temperature high pressure hydrogen containing vessel whose base metal is carbon steel or low alloy steel overlaid with a corrosion resistive material by welding, including a step for heat treating a boundary between the base metal and the material at 700 to 1100°C by means of a high frequency induction heating unit.
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6. A method as claimed in Claim 5 wherein after the heat treatment step, the vessel is subjected to post-weld heat treatment at substantially 700°C for a short time within two hours.

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