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(54) **Title**: APPARATUS AND METHOD OF THERMITE WELDING OF RAILWAY LINES

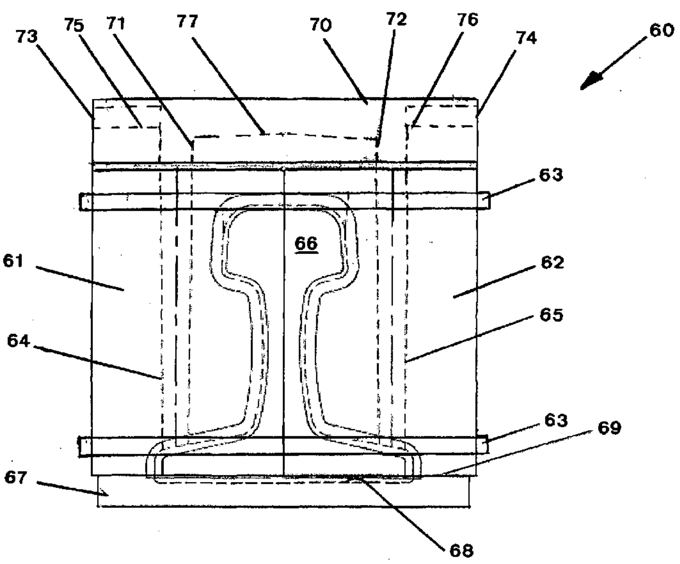

FIGURE 5

(57) **Abstract**: This invention relates to a thermite welding process involving vibration and a casting mould for use in the thermite welding of a railway line, the mould including at least two sections to form a rail cavity profile about the area of the end of sections of railway line to be welded or joined, the cavity being of a profile and size of the railway line being welded, and a means to retain the mould together, the mould having at least one riser vent hole on either side of the rail cavity profile, with each said riser vent hole rising from the foot of the profile cavity to an entry trough for receiving casting mix, and wherein a crucible core is adapted to be fitted to the top of the mould above the entry trough so as to allow, in use, casting mix to drop into the mould when the desired temperature has been reached.

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APPARATUS AND METHOD OF THERMITE WELDING OF RAILWAY LINES

TECHNICAL FIELD

This invention relates to welding railway lines using controlled vibration in association with a thermite welding process for joining the ends of sections of railway lines, and moulds used therewith. More particularly, but not exclusively, the present invention relates to an improved thermite welding vibration method and system applied with an improved thermite mould for aluminothermic or thermite welding, and methods of use of such moulds, to join axially the ends of railway lines.

BACKGROUND ART

Railway lines are generally made of high carbon steel as it is considered a durable and hard wearing material. In recent years, the carbon content of railway lines has increased for added durability and other reasons. However, this increased carbon content has made it more difficult to successfully weld joins between sections of railway line in applications where the newly welded joints must endure a heavy axle loading. Furthermore, the consequences of track failure can lead to catastrophic derailments leading to loss of life and damage to property. Therefore, the integrity of railway lines is considered to be essential for the safe carriage of persons and property.

The techniques for joining and rejoining sections of railway line have come under intense pressure in recent years as a result of rail failures sustained by heavy axle loadings and problems with welding techniques and moulds used therewith, and concerns over the reliability of track repairs is being further compounded by such heavier loadings trains are exerting on railway lines.

One method of welding a railway line is by aluminothermic or thermite welding (hereinafter referred to broadly as "thermite welding"). Thermite welds can result in a lower strength weld compared with other welding methods, and therefore such welds can be perceived to have a higher risk of weld failure. These failures can be caused by sub-standard welding and due to the fact the such welds can be difficult to check for integrity and thus it is not uncommon for such welds to be defective due to porosity and hole problems, and slag inclusions in the weld joint. However, this form of welding a railway line does have its desirable properties, and the present invention seeks to improve the integrity of thermic welds, or at least provide the public with a useful choice.

It is a non-limiting object of the invention to provide an improved termite weld for joining ends of a railway line which overcomes at least some of the abovementioned problems, or at least to provide the public with a useful choice.

It is a non-limiting object of the invention to provide an improved thermite mould for use in welding sections end on end of a railway line which overcomes at least some of the abovementioned problems, or at least to provide the public with a useful choice.

It is also a non-limiting object of the invention to provide vibration apparatus for carrying out the improved thermite weld using an improved thermite mould which overcomes at least some of the abovementioned problems, or at least to provide the public with a useful choice.

SUMMARY OF THE INVENTION

According to a first aspect of the invention there is provided a casting mould for use in aluminothermic welding of a railway line, the mould including at least two sections and forming a cavity about the area of the end of sections of railway line to be welded or joined, the cavity being of a profile and size of the railway line being welded, and a means to retain the mould together, the mould having at least one riser vent hole on either side of the cavity profile, with each said riser vent hole rising from the foot of the profile cavity to an entry trough for receiving casting mix, and wherein a crucible core is adapted to be fitted to the top of the mould above the entry trough so as to allow, in use, casting mix to drop into the mould when the desired temperature has been reached.

Preferably the mould includes a top plate matching the mould and locating to each riser vent hole, and being adapted to centrally receive the casting mix from the crucible core into a trough adapted to feed casting mix into each said riser vent hole.

Desirably the crucible core holds a casting mix of under 6kg volume by weight. Advantageously the crucible core can be adapted to hold a casting mix of between about 4kg to 4.7 kg volume by weight.

Preferably the mould includes two identical halves being clampable together and being provided with a top plate above the head of the ends of the railway lines being welded, and a bottom plate supporting the foot of the ends of the railway lines being welded , and wherein the mould includes at least one riser vent hole venting the cavity to the external air, in use, subjected to hot molten casting mix requiring ventilation during the welding process.

Preferably the casting mould further comprising a top plate adapted for placement on the mould, and having main channels, in use, for directing casting mix received from the crucible and into the riser vent holes.

Desirably the casting mould is adapted wherein each said riser vent hole is between 5 to 40 millimetres in diameter. Alternatively the riser vent hole is between about 15 to 17 millimetres in diameter.

Optionally the crucible core for holding the casting mix further includes a tap hole at the base of the crucible core into the central trough of the mould, and including a tap plug for retaining the casting mix in the crucible core until ignition of the casting mix. Advantageously the tap hole is tapered.

According to a second aspect of the invention there is provided an aluminothermic welding process for joining end sections of a railway line having a gap therebetween, the process including the preliminary step of mounting a mould according to the first broad aspect of the invention about the sections of railway line to be welded and leaving a gap between the ends of the sections of railway line, the steps of the process including:

a. configuring and attaching vibration apparatus on the railway line such that a vibration means is mounted on a section of railway line at a suitable distance from the mould, and vibrating the line at a suitable frequency of vibration and amplitude of vibration, such vibration being induced on the railway line being preset and/or adjustable during the welding process by a vibration control means configured and adapted to measure the frequency of vibration and the amplitude of vibration being applied to the line, the control means being adapted to allow adjustments to the frequency of vibration and the amplitude of vibration;

b. welding the sections of railway line together using an aluminothermic welding process including preheating the weld area to a suitable temperature, igniting the ignitor means to cause a reaction in the mould and allowing a molten casting mix to fill a weld area within the mould; and

c. continuing to apply vibration to the sections of railway line and the weld area for a period of time sufficient to allow the weld area to solidify and stabilise and until stress relieving of the weld area has occurred.

Desirably the process in step c. further includes the vibration apparatus continuing to apply vibration to the weld area for a period of between 5 to 25 minutes after welding is completed, or other desirable time period as sufficient to allow for the weld area to be stress relieved. Preferably the process in step a. further includes the vibration apparatus having a vibration means being a motor having eccentric weights applied to the shaft of the motor, the motor being clamped to a section of railway line adjacent the weld area. Advantageously the process in step a. further includes the frequency of vibration being measured by a tachometer means being releasably attachable to the railway line, and the amplitude of vibration is preferably measured by a velocity meter or an accelerometer means being releasably attachable to the railway line, the tachometer means and the velocity meter or the accelerometer means, optionally, being adapted to provide feedback signals to the vibration control means.

Desirably the process in step a. includes the frequency of vibration being applied by the vibration apparatus is between about 50 Hertz and 800 Hertz. Preferably the process in step a. includes a frequency of vibration is between about 75 and 85 Hertz and the amplitude of vibration is substantially about 1 millimetre per second. Desirably in step a. the amplitude of vibration applied can be substantially at least about 0.5 millimetres per second.

BRIEF DESCRIPTION

Preferred and alternative embodiments of the invention will now be illustrated, by way of non-limiting example only, with reference to the accompanying drawing in which:

Figure 1:	Shows a cross sectional view through two halves of a mould, and including a base plate;
Figure 2:	Shows a plan view of the mould and a crucible;
Figure 3:	Shows a cross sectional view through the mould and crucible; and
Figure 4:	Shows an arrangement of the mould and vibration apparatus for use in an aluminothermic welding process applied to sections of a railway line;
Figure 5:	Shows a cross sectional view through a mould 60 and top plate 70 according to an alternative embodiment of the invention;
Figure 6:	Shows a plan view of the top plate 70; and
Figure 7:	Shows an exploded side view of the mould 60, crucible 80, and lid 90 according to an alternative embodiment of the invention.

DETAILED DESCRIPTION

Referring to figures 1 to 4, a mould 3 for use in an aluminothermic welding process applied to sections of a railway line 1,2 and an arrangement of main components of a vibrating apparatus for use in forming an improved weld on sections of railway line 1, 2 being welded together according to a preferred and non-limiting embodiment of the invention, is illustrated.

The mould 3 is advantageously designed for use in an aluminothermic welding process and for a method of welding involving vibration equipment. The welding process of the invention involves a method and associated vibration apparatus for the application of vibration to sections of a railway line 1, 2 undergoing an aluminothermic welding process.

It is seen in this process that vibration may serve to control the movement of carbon in the steel structure of the sections of railway lines 1,2 during the welding process. Advantageously, it is considered that the mould 3 of the present invention, when used with the vibration apparatus and process of the invention, can desirably improve the mechanical strength, and may increase the working life, of the weld.

Referring now more particularly to figure 1, the mould 3 includes two similar halves referred to as a left mould 4 and a right mould 5. The moulds 4, 5 are desirably formed by sand casting by other such known methods and material. As the moulds 4, 5 can be symmetrically opposite and optionally identical in form, references made herein will refer to a substantially identical left mould 4 and right mould 5, although it will be appreciated that the opposing mould halves do not need to be identical to carry out the present invention, although they can conveniently do so. Alternative embodiments of the invention are envisaged using non-identical mould halves that, when set together, can form a weld area about the butt end of two sections of railway line aligned end on end for welding together, and given that the profile of the railway line will be desirably replicated within the mould accordingly. A gap between the butt ends of the sections of railway line 1,2 is required, and such a gap can vary between welding tasks, and the gap distance can be between preferably only a few millimetres of separation, to a large gap of even about 80 millimetres, more or less. However, it is desirable to weld railway lines 1, 2 using a small gap between the ends so as to advantageously minimise the amount of casting mix required, and more importantly form a reliable and safe weld. Conversely, it could be seen that a very large gap between the railway ends can increase the risk of an unreliable weld being formed.

The mould 3 is made of any suitable and resilient materials, and is advantageously a material suitable for withstanding high temperatures as required to produce a molten casting mix to form the weld.

The parts of the mould 4,5 are held in place over the railway line to be welded by a means to retainer the mould 4,5 together. The retaining means 6 can include any suitable form of fastening device, and in this non limiting embodiment is a clamp 6. It is envisaged that other forms of retaining or fastening means could be employed, as available and desired.

Advantageously the mould includes two identical halves of the mould 4, 5, with each half of the mould including at least one riser vent conduit or hole 7 venting the inner cavity area 8 that is subjected to hot molten casting mix requiring ventilation of hot gas during the welding process. The vent holes 7 can allow for better use of the molten casting mix during the welding process.

The mould 3 includes a base plate 9 of any suitable size and material relative to the outer dimensions of the moulds 4,5 and preferably slightly larger in footprint thereof to enable a suitable seal of the base of the cavity 8 to be prepared. The thickness of the base plate 9 is such that the base plate will not deform substantially and fail during the welding process.

It will be appreciated that the top surface 10 of the base plate 9 can be formed with reliefs, slots, recesses or depressions as desired or required for welding the areas about the butt ends of a railway line. It is seen in one non limiting embodiment that the base plate is of an elongate size and adapted to be mounted under the railway line to be welded, and done so in such a way as to form a guide for setting the mould 3 in place about the end sections of railway line 1,2.

Referring now more particularly also to figure 2, it is seen that the top view of the mould 3 shows a riser vent hole 7 in each half of the moulds 4,5 extending from the cavity 8 to the top surface of each half of the mould 4, 5. The riser vent holes 7 can be between 5 to 40 millimetres (mm) in diameter, and more preferably can be as small as between 10 and 17mm in diameter. More preferably still, in one non limiting embodiment, the riser diameter may be between 15 to 17mm in diameter.

It is usual for known thermite moulds to have a diameter of a riser at about 40mm. However, a problem with such a large riser diameter is that it can result in a poor weld outcome, and in particular affects the HAZ (heat affected zone) of the weld. It is an advantage in the present invention to present a riser vent hole with a smaller diameter of desirably between about 10 to 17 mm in diameter in one embodiment so as to improve the quality of the thermite weld, or at least provide the public with a useful choice. It can be seen that reducing the latent energy in the heat affected zone area or area about the weld can increase the quality of the weld.

An optional yet desirable feature of the invention and the mould 3 is the provision of slots or pockets 12 locatable in the top surface of the moulds 4,5 through which the riser vent hole 7 is located. The pockets 12 are advantageous in allowing excess material to rise and be collected and flushed from the weld area. Further, the pockets reduce the distance of the vent holes 7 to the weld area and thus can be seen to effectively lower the vent distance and force more excess molten metal and gas to escape from the weld area 8 and be ejected through the pocket 12. It is seen that the depth and size of the pockets 12 can vary between the split moulds 4,5 depending on the application of the mould 3 of the invention, and this distance can be reduced along with the diameter of the riser vent holes 7, as required or desired.

As a consequence of being able to provide a mould 3 with a lower riser vent hole diameter is with the advantage of providing a smaller mould and casting mix in a compact crucible 20.

Optionally the mould 3 can be provide with a slot, drain or channel adjacent or in the top surface of the moulds 4,5 referred to herein as slag channels 13. The slag channels can be made in any desirable and suitable part of the top surface of either or both mould 4 and/or mould 5. In this non-limiting embodiment it is conveniently provided at the join between the moulds 4, 5, and thus advantageously allows slag, excess casting mix and contaminants to flow off from the weld area or the mould during the welding process.

Referring now to figure 3, it is seen that a crucible 20 is adapted to be fittable upon the mould 3 for use in a thermite weld of sections of railway line 1, 2 aligned end on end.

The crucible 20 includes a main crucible core 21 seen in this non limiting example as a bowl shaped core 21 being annular with a diameter sufficient to retain the volume of the casting mix within during use. The core 21 is made of any suitable durable and resilient material such as, for example only, steel, so as to withstand high temperatures generated in the core 21. The crucible 20 is adapted to locate in and/or on the top surface of the mould in any known form of the lid to container option so as to allow the crucible 20 in use, to fit and locate well on the moulds 4, 5 for use with the invention.

The crucible core 21 is seen to be advantageously compact in size given that the mould 3 of the invention, with crucible 20, can be adapted to make a thermite weld on a railway line using a more smaller amount of casting mix. In known crucibles, the amount of casting mix required for railway joins or welds can be about 12kg. For the present invention, it is advantageously seen that the welding process for welding end sections of a standard size of railway line may only require about 4 to 4.7kg of casting mix, or alternatively up to 6kg casting mix in volume by weight when the mould 3 and crucible 20 is used in conjunction with vibration equipment 29 as seen with reference to figure 4, and seen to be set up about the railway lines 1,2 in the weld area 30. It will be appreciated that a larger casting mix may well be required for heavier duty railway lines capable of supporting larger axle loadings, and such lines may require about 5.5kg of casting mix.

The crucible has a discharge drain outlet 22 through which the casting mix is drained when the mix is melted and ready to drop into the mould 3. The discharge outlet 22 can be temporarily blocked so as to hold the casting mix by use of a tap button plug 23 configured and positionable within the outlet 22 during the set up process for the weld in accordance with the method of welding of the present invention. The tap plug 23 can comprise one or more layers of combustible material of a thickness of about 4mm or more, the material and thickness being such as to allow the casting mix to burn through when the mix is hot enough to drop into the mould 3. This can usually take about 20 to 25 seconds from when the casting mix is ignited with, for example, a magnesium tablet or other ignitor means, and this takes place after pre-heating of the crucible 20 for a time period of up to around 5 to 10 minutes. The casting mix is expected to melt at a very high temperature of a thousand degrees, more or less, and such temperature applied can be as high as 2100 degrees Celsius.

In one non limiting embodiment by example only, desirably the drain outlet is tapered such that the inner diameter adjacent the inner surface 24 of the crucible core 21 can be about 16 mm diameter, and the outer diameter adjacent the bottom face 25 of the crucible 20 can narrow to about 11 mm. The use of a tapered outlet aperture as shown can assist with controlling the time period before the molten casting mix is ready to drop through to the mould to form the new weld joint about the ends of the railway lines 1, 2.

The crucible desirably includes a lid 26 of a sufficient size and weight to be mountable on the crucible core 21 for desirably a snug and certain fit on the crucible core 21, and be suitable for retaining the casting mix within the crucible 20. A vent aperture or slot 27, advantageously in the form of a rectangular slot or the like, is desirably provided in any suitable position in the lid 26 to allow for venting of gases, and for allowing a user to ignite the casting mix during welding by inserting an ignitor or flame within the casting mix through the slot 27.

Referring now more particularly to figure 4, two sections of railway line 1,2 to be welded together are suitably prepared and aligned axially end to end as shown, and with a gap of between 1mm to about 80mm more or less depending on the particular application. The weld area 30 is indicated between the ends of the sections of railway line 1,2. The ends of the railway line 1, 2 may be cut to shape, and/or be brushed and burned with a gas torch or otherwise as required to form desirable opposing faces and surface areas for welding purposes.

It is usual to prepare faces of the ends of the sections of line 1,2 to be joined are generally square and the gap between the lines 1, 2 is typically about 14 to 17mm in many applications, but may be between about 5 to 80 mm. It will be appreciated by one skilled in the art that the gap can vary depending on the application, and that the larger the gap, the larger the amount of casting mix required to complete the weld across the area of the gap between sections of railway line 1, 2 to be welded together. However, an advantage with the present invention is that a lot less casting mix is needed for completing the same welding job, when compared with conventional thermite moulds in the marketplace.

The mould 3 and crucible 20 of the present invention is set up about the sections of railway line 1, 2, about the weld area 30.

It is accepted that different moulds can be employed depending on the welding task and the required gap or distance between the end faces of sections of line 1,2 and the rail profiles or otherwise as proffered or preferred. The moulds may be two or three piece, stepped, and may be composite moulds such as in applications involving mismatched rail profiles. For current disclosure purposes only the joining of identical profiles of sections of railway lines 1,2 will be described and illustrated.

The thermite moulds 3 as applied are generally pre-fabricated and one shot moulds, and a suitable mould 3 is advantageous for use in the method of the invention to form a reliable weld joint.

Suitable vibration apparatus 29 is set up to supply a constant and suitable vibration before and during the welding process and the ends of the railway line 1,2 are optionally retained in a secured and aligned position as required. This set up may be with the sections of line 1,2 in a clipped and fixed and aligned position on railway sleepers in situ, or undertaken at a remote location. In this respect it will be appreciated that the method of the invention is not limited to location but may be adapted and configured to be completed on a railway line in situ if required.

The vibration apparatus 29 desirably includes a controlled source of vibration including a control means 31 in the form of a computer means including a microprocessor suitably programmed to control the operation of the vibration equipment. A suitable display means 32 associated with the control means 31 is desirably used to allow an operator to read measurements, and the display means 32 can assist in ensuring a suitable frequency, amplitude of vibration and duration of vibration is applied during the welding process to carry out the operation of the invention.

The control means 31 can function to control each step of the vibration process. The control means 31 can desirably be powered by any power supply means 33 and when used remotely can be powered by any suitable and durable portable battery means or power generator means (not shown) for remote testing on railway lines away from an available electrical power source and to allow the vibration apparatus to be used for portable applications. Desirably a rechargeable power supply means can be configured and arranged with components of the vibration apparatus.

The vibration apparatus 29 desirably includes a vibration means 34 that can be mounted by any known and suitable securing means, such as for example releasably attachable clamp, to an appropriate position of the railway line, such as, for example in one non-limiting application, between 50 centimeters to 1.2 metres, and more desirably about 50 centimetres from the weld area 30. The vibration means 34 is desirably in the form of a motor adapted with a vibration inducement means optionally in the form of eccentric weights mounted to the motor shaft and configured to apply a vibration to the line. It is considered that the force as applied is adjustable such that the amplitude of vibration and the frequency of vibration can be increased or decreased as required. The vibration means 34 may include an exciter or shaker unit, as it is known in the art, that is desirably controlled by a user controlling and adjusting the speed of the motor. The motor can be controlled by being adapted to be controllable by the control means 31.

The motor speed of the vibration means can be sensed using any known form of motor speed measuring means and in this embodiment is in the form of a tachometer 35 that can be mounted to the shaft of the motor. The tachometer 35 measures the shaft speed and the measured signal outputs are fed to the control means 31 via a cable 36.

The amplitude of vibration induced on a section of railway line 1,2 is typically about 1mm/second although more or less measure of amplitude may be employed. The amplitude of vibration can be sensed and measured using a signal measuring means in the form of a transducer means, desirably an accelerometer 37. It will be appreciated that any suitable and known vibration measuring instrument may be applied.

The accelerometer 37 generates an electrical signal in response to the vibration acceleration of the railway line as induced by the vibration means 34, and provides a signal that is fed to the control means 31. The control means 31 is configured and arranged desirably to convert the signals into a measurement of frequency of vibration for display on the display means 32.

A temperature measurement means 38 is optionally and desirably used to measure the temperature of the sections of line 1,2 during operation. The temperature measurement means 38 is desirably in the form of a pyrometer and provides measurement signals to the control means 31 that allows the temperature of the line to be advantageously tagged against other recorded data at the time of operation of the vibration apparatus.

The display means 32 can be provided to display the plotted measurements of velocity amplitude (for example, in mm/second) against the frequency of vibration and any other desirable characteristics of the data obtained during operation of the vibration apparatus during and/or after the welding operation. The control means 31 can desirably include a suitable microprocessor means with a storage means to store recorded data.

It is seen, and will be appreciated by one skilled in the art, that the main components of the vibration apparatus are desirably interconnected by the cables 36. However, some of the cables can be replaced by wireless communication devices or means for components adapted with a suitable transmitter and/or receiver means, and such wireless communication means may be particularly useful for measurement and sensing devices as the accelerometer 37 and/or the pyrometer 38 and/or the tachometer 35 that are configured and arranged to provide measured data for processing by the control means 31.

The vibration equipment or apparatus 29 is configured and arranged to allow a user to apply a constant vibration to sections of the railway line 1 and/or 2 at any suitable frequency of vibration that may be substantially between about 50 to 800 hertz (Hz). More preferably the frequency is suitably set at between about 75 to 85 Hz. In this respect it is considered that the lower end of the frequency should desirably be set at least about 55 Hz, but more preferably a least about 70Hz or more.

The application of controlled vibration is based on an arrangement of components on a railway line on which an aluminothermic welding process using the mould 3 and associated crucible 20 as disclosed with reference to figures 1 to 3 of the present invention.

It will be appreciated by one skilled in the art that the criteria for achieving a high quality aluminothermic weld can vary depending on rail conditions, and in that respect the pre-heating process can vary as required.

It is seen then in a summary of the method of thermite welding in accordance with the invention involves the preliminary step of mounting a suitable thermite welding mould 3 about the aligned and prepared sections of railway line 1, 2 to be welded together and sealing the mould 3 and mounting the crucible 20, the steps of the process including step a.) of configuring and attaching a vibration apparatus on the railway line such that a vibration means in the form of a vibration means 35 is mounted on a section of railway line at a suitable distance from the weld area, and vibrating the line at a suitable frequency of vibration and amplitude of vibration, such vibration being induced on the railway line being preset and/or adjustable during the welding process by a vibration control means 31 configured and adapted to measure the frequency of vibration and the amplitude of vibration being applied to the line, the control means 31 being adapted to allow adjustments to the frequency of vibration and the amplitude of vibration; and in step b.) then welding the sections of railway line together using a thermite welding process including preheating the weld area to a suitable temperature, igniting the ignitor means to cause a reaction in the mould 3 and allow molten steel to fill a weld area about and between the sections of railway line 1, 2 retained within the mould 3; and then in step c.) continuing to apply a controlled vibration to the sections of railway line and the weld area for a period of time sufficient to allow the weld area to solidify and stabilise, and until stress relieving of the weld area has occurred.

Example A

One non-limiting example of the aluminothermic or thermite type welding process utilising the vibration apparatus 29 and process of the invention is as follows:

Firstly the preliminary step is taken of a suitable welding gas torch or cutter or grinder being applied to the weld area to make or form a square cut or other suitable formation at the end faces and on surfaces about the end of the sections of railway line 1,2 to be joined. The railway lines 1, 2 are then properly and suitably aligned end to end, and leave a gap between the sections of line 1,2 of about generally between about 5mm to 17mm, more or less, as desired and required.

Then a suitable thermite welding mould 3 is mounted about the aligned end sections of railway line 1,2 to be welded together, and the mould is secured by a means to retain the mould in place, and the mould is desirably sealed to prevent molten metal from escaping from the mould 3 during the welding process.

In accordance with step a. of the process, the vibration apparatus 29 as described above with reference to figure 1 is configured and arranged on the sections of railway line 1,2 ready for use. The vibration means 34 located on the railway line at a suitable distance, in this non-limiting example, of about 1 metre to about 1.2 metres, from the mould 3 and is set to operate at a suitable frequency between 50 and 500 Hz, and more preferably is set to vibrate at a frequency of between 70 to 80 Hz. It may be suitably operated at an amplitude of vibration of substantially about 1mm/second. The vibration apparatus is operated at a predetermined frequency and controlled vibration is induced on the lines 1,2.

Then in accordance with step b., the mould 3 is fitted with known pre-heating equipment suitable for the purpose, and pre-heating occurs to a desirable temperature and then the ignitor means is ignited allowing it to drop into the crucible 20 to react with a predetermined quantity of molten steel placed in the crucible on the mould 3. When a reaction occurs the molten steel will drop and fill the targeted weld area 30. This usually takes about 20 to 25 seconds.

The molten steel then solidifies, and the railway line, according to step c., continues to be vibrated continuously for a further period of time until stress relieving of the weld area has occurred. This period of time may be for about 25 to 30 minutes or for such further time as required to allow for solidification and stabilisation of the weld.

After the process is complete, the mould can be removed, and the weld joint cleaned and grinding takes place to form the final desired rail profile about the weld area 30. It is also considered to be desirable to induce a suitable vibration on the railway line while final grinding is applied to form the final profile in the and about the head rail portion of the railway line.

It is anticipated that the cast thermite weld will be improved by being strengthened as a result of the method of the invention, and further, it can be seen that the porosity of the weld can be advantageously lowered, thus reducing the likelihood of cracking or failure of the weld and joint.

It is considered that the mould 3 when used with vibration equipment 29 may well change the thermodynamic properties of the weld area 30 on the sections of line 1, 2. The application of vibration may also be increasing the conductivity of the sections of line 1,2 and be improving the effective heat dissipation during the welding process. It will be appreciated that in circumstances where the sections of line 1,2 being joined are of different grades of steel, the welding procedures and consumables employed are those specified for the particular type or grade of railway line being welded.

Referring to figures 5 to 7, a mould 60 for use in an aluminothermic welding process applied to weld sections of a railway line 1,2, and for use with an arrangement of main components of a vibrating apparatus as described with reference to figure 4, being welded together according to an alternative embodiment of the invention, is illustrated.

The mould 60 is advantageously designed for use in an aluminothermic welding process and for a method of welding involving vibration equipment similar to the invention as described with reference to figures 1 to 4 as already described. Most features and methods of the invention have already been described, and will not necessarily be repeated, and differences are now described and illustrated.

The mould 60 preferably includes two symmetrically opposing halves referred to as a central left mould 61 and a central right mould 62. The moulds 60, 61 are desirably formed by sand casting by other such known methods and materials. As the sections of mould 61, 62 can be optionally identical in form, references made herein will refer to a substantially identical left mould 61 and right mould 62, although it will be appreciated that the central mould halves do not need to be identical to carry out the present invention, although they can conveniently do so, is desired or required. Alternative embodiments of the invention are envisaged using non-identical mould halves that, when set together, can form a weld area about the end sections of railway line 1,2 aligned end on end for welding together, and given that the profile of the railway line will be desirably replicated within the mould.

The central moulds 61, 62 are held in place over the railway line to be welded by a mould retaining means 63 for retaining the mould 61, 62 doing welding. The retaining means 63 can include any suitable form of fastening device, and in this non limiting embodiment include clamp 63 that envelop and clamp the central mounds 61, 62 together. It is envisaged that other forms of retaining or fastening means could be employed, as available and desired or required.

Advantageously either mould 61, 62 includes at least one riser vent conduit or hole 64, or preferably at least also a second riser vent 65, for venting the inner cavity area 66 being subjected, in use, to a hot molten casting mix requiring ventilation of hot gas during the welding process. The vent risers 64, 65 can allow for better use of the molten casting mix during the welding process.

The mould 60 desirably includes a base plate 67 (similar to the base plate 9 with reference to figure 1) of any suitable size and material relative to the outer dimensions of the moulds 61, 62 and preferably slightly larger in footprint thereof as seen in base 68. The thickness of the base plate 68 is such that the base plate will not likely deform substantially or fail during the welding process.

It will be appreciated that the top surface 69 of the base plate 67 can be formed with reliefs, slots, recesses or depressions as desired or required for welding the areas about the butt ends of a railway line. It is seen in this embodiment that the base plate 67 can be of a rectangular size and shape, and is adapted to be mountable in position under the railway line to be welded, and done so in such a way as to function as a guide for setting the moulds 61, 62 in place about the end sections of railway line 1,2.

Furthermore, the mould 60 advantageously includes a top plate 70 configured and arranged to be mountable in and/or on the mould 60 and being composed of suitable materials for the thermite welding process. The top plate 70 preferably is provided with main channels 77 directing, in use, the molten mix or flowable material toward and into the riser apertures 71, 72 oriented in a position to align with the vertically disposed position of the riser vents 64, 65 respectively. The top plate 70 is also configured to allow placement of a crucible thereupon as seen in figure 7, or alternatively with the crucible 20 as described with reference to figures 1 to 3 to be adapted to be aligned on the top plate 70 during the welding process.

The top plate 70 advantageously includes outer vents 73, 74 through which excess slag, excess casting mix and contaminants to escape or flow off from the weld area or the mould during the welding process, as required. The outer vents 73, 74 include respective slag channels 75, 76 linking the riser vent holes 64, 65 respectively with the outer vents 73, 74. It is seen that it is an advantage with allowing excess molten material and gas to rise and be collected and flushed from the weld area via the channels 75, 76 and outer vents 73, 74.

It will be appreciated that the depth and size of the slag channels 75, 56 and vent holes 73, 74 can vary depending on the application of the mould 60 of the invention, and this distance can be reduced or increased along with the diameter of the riser vent holes 64, 65, as required or desired.

Referring now more particularly to figure 7, a side view of the top plate 70 is illustrated for purposes of showing the alignment of the crucible 80, and lid 90 mountable thereupon during the welding process.

Many aspects of the crucible 80 will be similar to the crucible 20 as described with reference to figure 3 and details will not necessarily be repeated. The crucible 80 is desirably of a shape with flared feet 81 and a centrally oriented core 82. The core 82 being bowl shaped and annular with a diameter sufficient to retain the volume of the casting mix during use. The core 82 is made of any suitable durable and resilient material such as, for example only, steel, so as to withstand high temperatures during the thermite welding process. The crucible 80 is adapted to locate into and/or on the top plate 70 of the mould 60. The crucible 80 is optionally attached or secured to the top plate 70 using an adhesive or glue or the like to ensure that crucible 80 and top plate 70 are retained or held together during the welding process.

The crucible 80 is seen to be advantageously compact in size given that the mould 60 of the invention can be adapted to form a thermite based weld on a railway line using a more smaller amount of casting mix. For the present invention, it is advantageously seen that the welding process for welding end sections of a standard size of railway line may only require under 6kg of casting mix, and optionally about 4 to 4.7kg of casting mix, when the mould 60 and crucible 80 is used in conjunction with vibration equipment 29 as seen with reference to figure 4, and seen to be set up about the railway lines 1,2 in the weld area 30. It will be appreciated that a larger casting mix may well be required for heavier duty railway lines capable of supporting larger axle loadings, and such lines may require about 5.5kg of casting mix.

The crucible has a discharge drain outlet 83 through which the casting mix is drained when the mix is melted and ready to drop into the main channels 77 in the central area of the top plate 70. The discharge outlet 83 can be plugged to hold the casting mix by use of a tap button plug 84 configured within the outlet 83 during the set up process. The tap plug 84 can comprise one or more layers of combustible material of any desirable thickness and fittable within the outlet 83, the material and thickness being such as to allow the casting mix to burn through when the mix is hot enough to drop into the mould 60, after pre-heating of the crucible 80 for a time period of up to around 5 to 10 minutes. The casting mix is expected to melt at a very high temperature of a thousand degrees Celsius, more or less, and such temperature applied can desirably be about 2100 degrees Celsius, more or less.

The crucible 80 desirably includes a lid 90 of a sufficient size and weight to be mountable on the crucible 80 for a firm fit on the crucible 80, and be suitable for retaining the casting mix within the crucible 80 during the welding process. At least one heat expansion vent in the form of a side vent, channel or slot 91, is preferably provided in any suitable position in the lid 90 to allow for venting of hot gases during the welding process, and for allowing a user to ignite the casting mix during welding by inserting an ignitor or flame within the casting mix through the side vent slot 91.

It is considered that the thermite weld can be improved and strengthened as a result of the apparatus and process of the present invention, and further, it may be that the increased durability of the weld will reduce the likelihood of cracking, or failure of the weld joint by fatigue cracks, especially in applications whereby the railway line is under constant heavy axle loadings.

According to an aspect of the invention the method of the present invention can have the advantage of reducing residual stress in the thermic weld, decrease poor weld procedures, and control the re-solidification of the weld meld. A strengthened weld could have the advantage of desirably increasing the axle loadings on a railway line to about 37 tonnes, and even maybe up to about 45 to 50 tonnes as line infrastructure allows, and with considering sleeper and base design, rail bridge constructions, or otherwise.

It is considered that the vibration may well effect the thermodynamic properties of the sections of railway line 1, 2. It may be seen that the grain structure of the rail becomes more refined, and a greater mechanical strength with the weld joint could be achieved.

It will be appreciated that in circumstances where the sections of line 1,2 being joined are of different grades of steel, the welding procedures and consumables employed are those specified for the harder grade of railway line being welded.

It will also be appreciated that the process of the invention can be applied to sections of railway line in situ or to sections railway lines in an engineering workshop or at any location, and an advantage of such vibration apparatus and equipment according to the invention is that it can be constructed as a portable kit, and such vibrating equipment can be easily transported on location where the railway line requires thermite welding to take place.

Wherein the aforegoing reference has been made to integers or components having known equivalents, then such equivalents are herein incorporated as if individually set forth. Accordingly, it will be appreciated that changes may be made to the above described embodiments, variants, and alternatives of the process and other aspect so the present invention without departing from the principles taught herein.

It is to be understood that the above description is intended to be illustrative, and not restrictive. Additional advantages of the present invention will become apparent for those skilled in the art after considering the principles in particular form as discussed and illustrated. Thus, it will be understood that the invention is not limited to the particular embodiments described or illustrated, but is intended to cover all alterations or modifications which are within the scope of the appended claims.

CLAIMS:

1. A casting mould for use in aluminothermic welding of a railway line, the mould including at least two sections and forming a cavity about the area of the end of sections of railway line to be welded or joined, the cavity being of a profile and size of the railway line being welded, and a means to retain the mould together, the mould having at least one riser vent hole on either side of the cavity profile, with each said riser vent hole rising from the foot of the profile cavity to an entry trough for receiving casting mix, and wherein a crucible core is adapted to be fitted to the top of the mould above the entry trough so as to allow, in use, casting mix to drop into the mould when the desired temperature has been reached.

2. A casting mould in accordance with claim 1, wherein the mould includes a top plate matching the mould and locating to each riser vent hole, and being adapted to centrally receive the casting mix from the crucible core into a trough adapted to feed casting mix into each said riser vent hole.

3. A casting mould in accordance with claim 1, wherein the crucible core holds a casting mix of under 6kg volume by weight.

4. A casting mould in accordance with claim 1, wherein the crucible core holds a casting mix of between about 4kg to 4.7 kg volume by weight.

5. A casting mould in accordance with claim 1, wherein the mould includes two identical halves being clampable together and being provided with a top plate above the head of the ends of the railway lines being welded, and a bottom plate supporting the foot of the ends of the railway lines being welded , and wherein the mould includes at least one riser vent hole venting the cavity to the external air, in use, subjected to hot molten casting mix requiring ventilation during the welding process.

6. A casting mould in accordance with claim 1, further comprising a top plate adapted for placement on the mould, and having main channels, in use, for directing casting mix received from the crucible and into the riser vent holes.

7. A casting mould in accordance with claim 1 wherein each said riser vent hole is between 5 to 40 millimetres in diameter.

8. A casting mould in accordance with claim 1, wherein the riser vent hole is between about 15 to 17 millimetres in diameter.

9. A casting mould in accordance with claim 1, wherein the crucible core for holding the casting mix further includes a tap hole at the base of the crucible core into the central trough of the mould, and including a tap plug for retaining the casting mix in the crucible core until ignition of the casting mix.

10. A casting mould in accordance with claim 9, wherein the tap hole is tapered.

11. An aluminothermic welding process for joining end sections of a railway line having a gap therebetween, the process including the preliminary step of mounting a mould according to the first broad aspect of the invention about the sections of railway line to be welded and leaving a gap between the ends of the sections of railway line, the steps of the process including:

(a.) configuring and attaching vibration apparatus on the railway line such that a vibration means is mounted on a section of railway line at a suitable distance from the mould, and vibrating the line at a suitable frequency of vibration and amplitude of vibration, such vibration being induced on the railway line being preset and/or adjustable during the welding process by a vibration control means configured and adapted to measure the frequency of vibration and the amplitude of vibration being applied to the line, the control means being adapted to allow adjustments to the frequency of vibration and the amplitude of vibration;

(b.) welding the sections of railway line together using an aluminothermic welding process including preheating the weld area to a suitable temperature, igniting the ignitor means to cause a reaction in the mould and allowing a molten casting mix to fill a weld area within the mould; and (c.) continuing to apply vibration to the sections of railway line and the weld area for a period of time sufficient to allow the weld area to solidify and stabilise and until stress relieving of the weld area has occurred.

12. An aluminothermic welding process according to claim 11 wherein in step c. the vibration apparatus continues to apply vibration to the weld area for a period of between 5 to 25 minutes after welding is completed, or other desirable time period as sufficient to allow for the weld area to be stress relieved.

13. An aluminothermic welding process according to claim 11 wherein in step a. the vibration apparatus includes a vibration means being a motor having eccentric weights applied to the shaft of the motor, the motor being clamped to a section of railway line adjacent the weld area.

14. An aluminothermic welding process according to claim 11 wherein in step a. the frequency of vibration is measured by a tachometer means being releasably attachable to the railway line, and the amplitude of vibration is preferably measured by a velocity meter or an accelerometer means being releasably attachable to the railway line, the tachometer means and the velocity meter or the accelerometer means, optionally, being adapted to provide feedback signals to the vibration control means.

15. An aluminothermic welding process according to claim 11 wherein in step a. the frequency of vibration applied by the vibration apparatus is between about 50 Hertz and 800 Hertz.

16. An aluminothermic welding process according to claim 11 wherein in step a. the frequency of vibration is between about 75 and 85 Hertz and the amplitude of vibration is substantially about 1 millimetre per second.

17. An aluminothermic welding process according to claim 11 wherein in step a. the amplitude of vibration applied can be substantially at least about 0.5 millimetres per second.

18. A weld joint prepared and made by the thermite welding process as claimed in claim 1.

19. A thermite butt welding process for joining sections of a railway line according to claim 1 substantially as herein described.

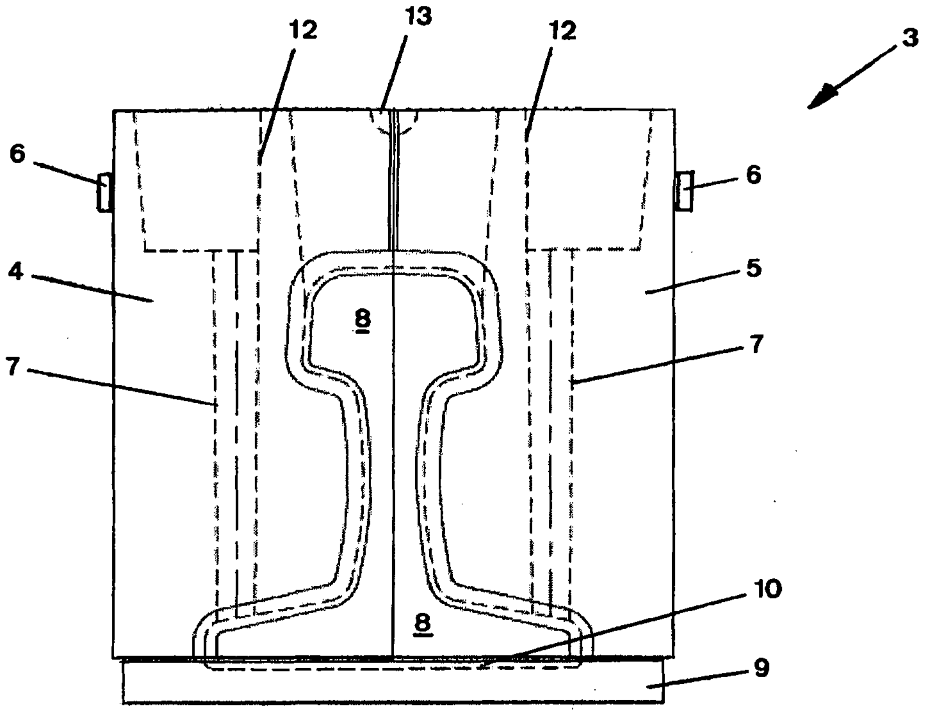

FIGURE 1

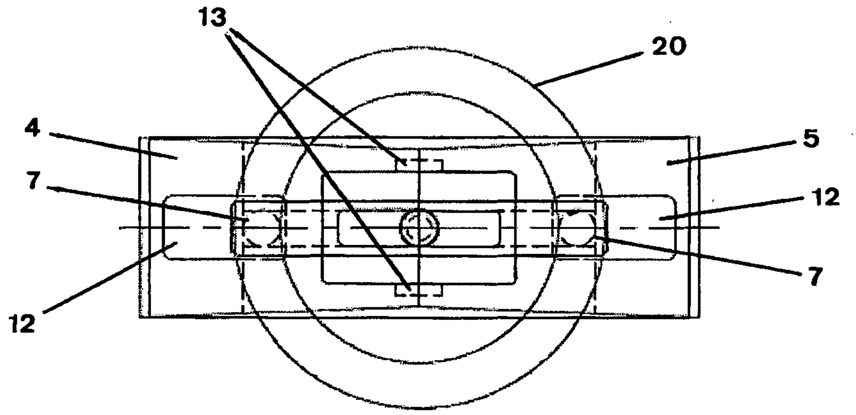

FIGURE 2

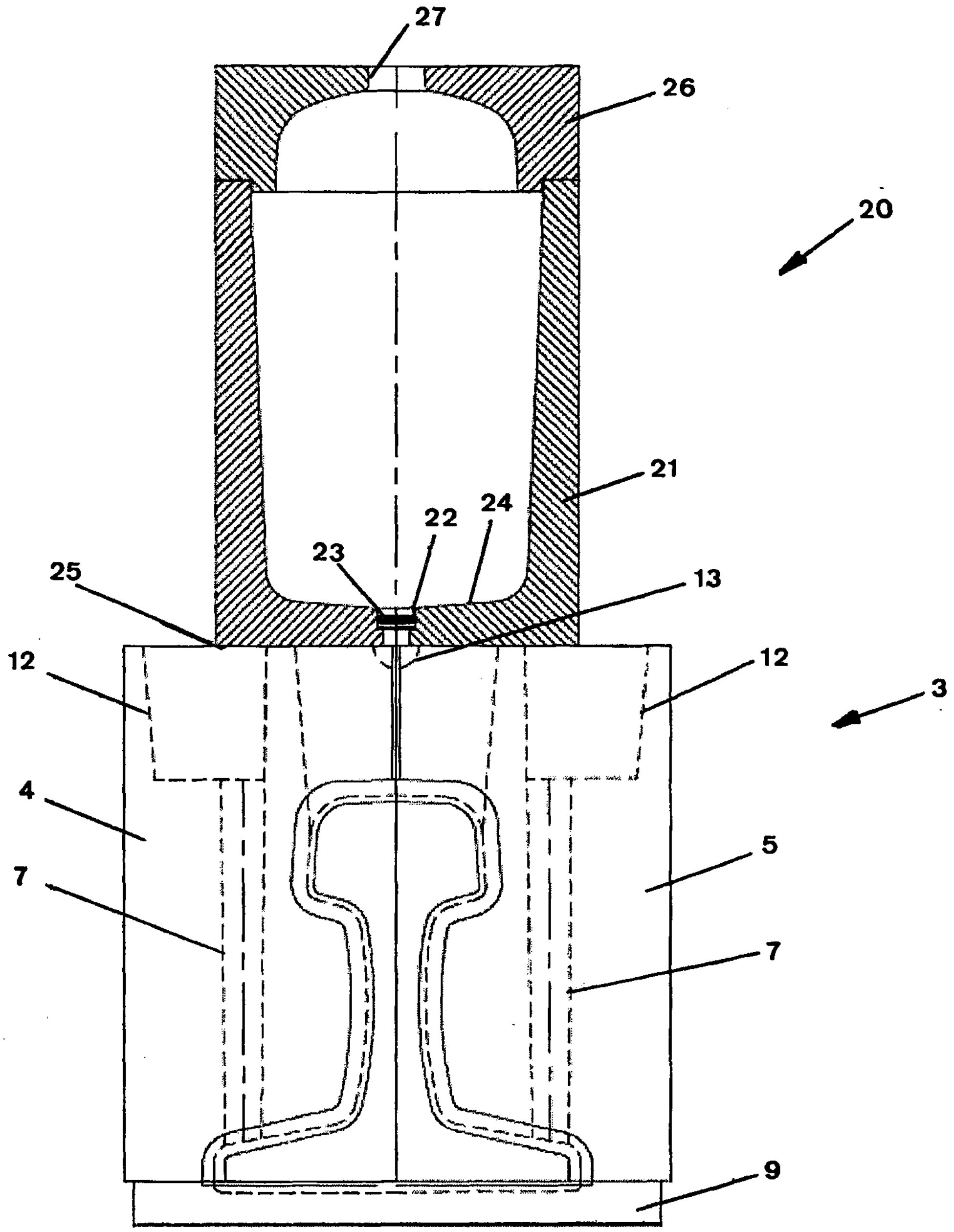

FIGURE 3

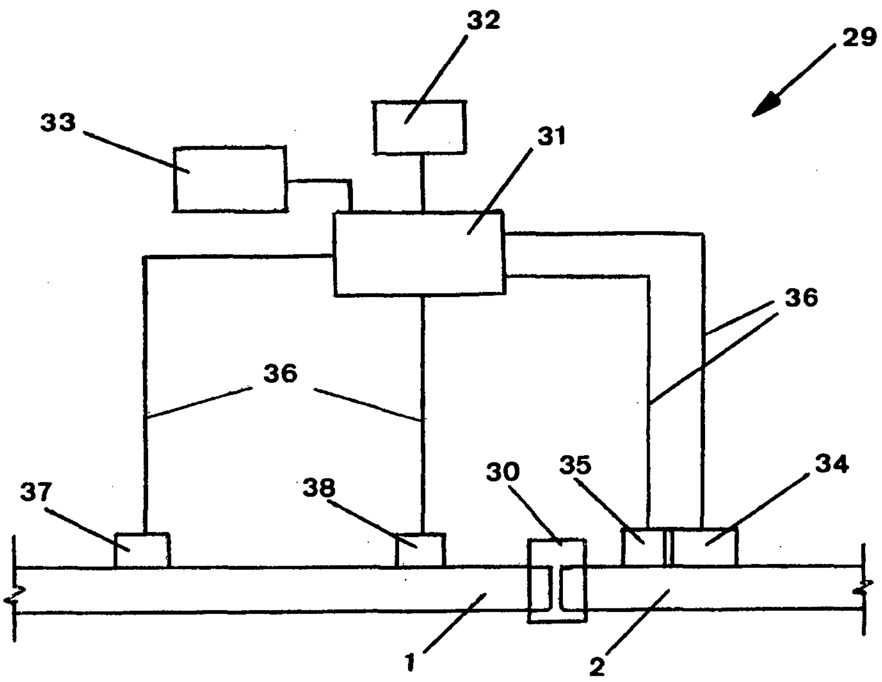

FIGURE 4

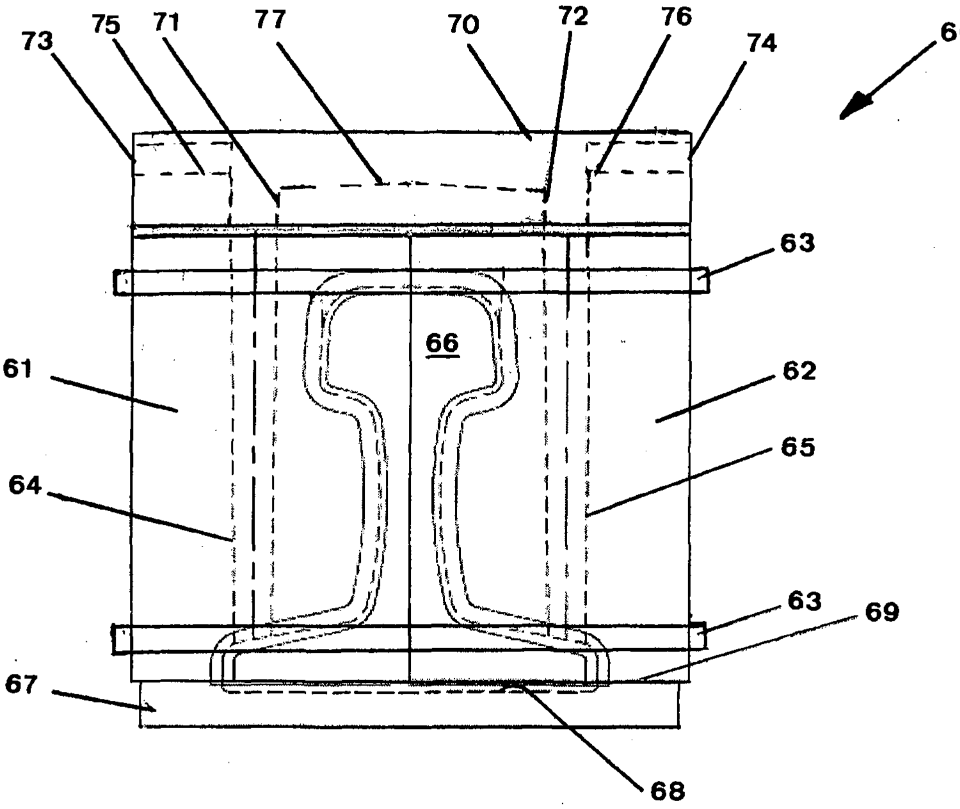

FIGURE 5

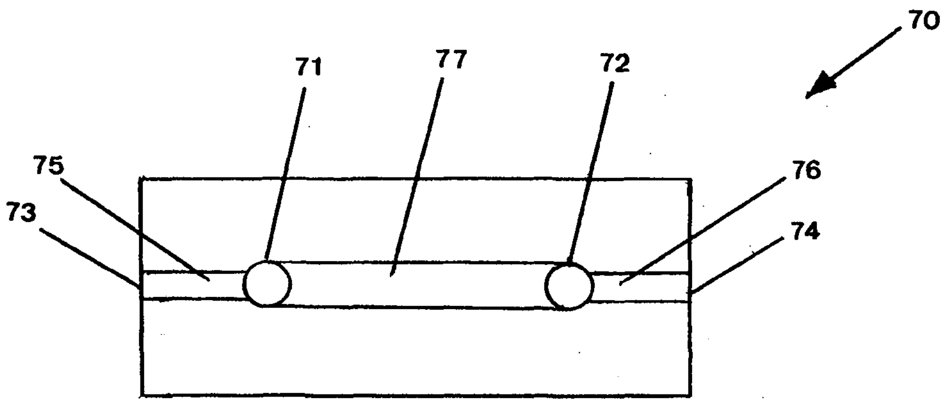

FIGURE 6

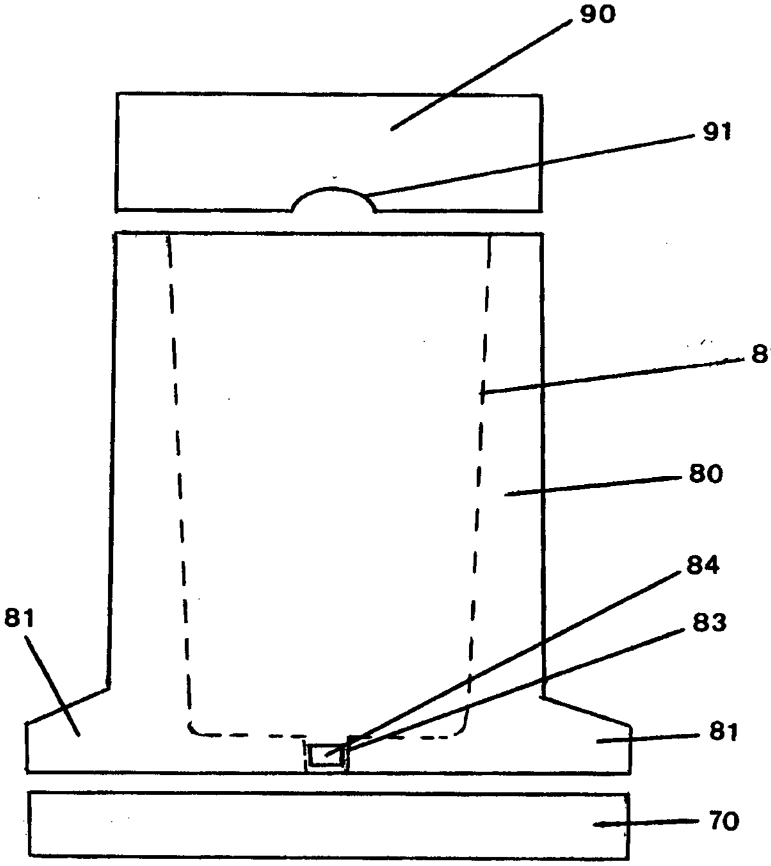

FIGURE 7