DESCRIPTION

System and method for welding by transparency a sealing plate to an anchoring plate

The present invention relates to the field of tanks for gas in a liquid state, for example liquefied natural gas (LNG), particularly for maritime or river transport or for an onshore reservoir. More specifically, the invention concerns a welding system for welding a sealing membrane adapted for such a tank, and an associated welding method.

The liquid gas tanks have a capacity of several thousand cubic meters of liquid gas each, or even several tens of thousands of cubic meters of liquid gas. The vessels transporting liquefied gas have holds fitted out specifically to contain these tanks, and their holds are often divided into several tanks. A tank of this type may also be built outside a vessel for onshore storage of natural gas in a liquid state.

The gas is kept inside the tank in a liquid state, for example at -163°C (degrees Celsius) for LNG, at atmospheric pressure. The tank must therefore be watertight and thermally insulated. As a result, the internal surface of such a tank is covered by a sealing membrane, generally made from an assembly of metal sealing plates (typically stainless steel plates) welded together, each sealing plate being a part of the sealing membrane of the tank.

The walls of the tank also comprise, successively underneath the sealing membrane configured to be in contact with the liquefied gas, this sealing membrane being referred to as the primary sealing membrane:

- a layer of primary insulation, for example using wooden shells filled with reinforced polyurethane foam,
- another sealing membrane, referred to as the secondary sealing membrane, for example made of thin sheet metal,
- a secondary layer of insulation, for example also made from wooden shells filled with reinforced polyurethane foam.

The primary sealing membrane is attached to the primary insulation layer by welding the sealing plates to anchoring plates, which are secured to the primary insulation layer and may be riveted to the wooden shells of the primary insulation layer. These anchoring plates form a grid around all the shells, but do not cover them completely.

As this is a welding performed by transparency, the distance between the sealing plate and the anchoring plate must be less than 0.3 mm to ensure a good weld. In the welding by transparency, the two plates are pressed together at a point and welded to one side of these two plates, in the vicinity of the pressing point. Given the differences in height of the various shells in the primary insulation layer, due to the permitted assembly and manufacturing tolerances, it is not possible to be certain of a good fit between the sealing plate and the anchoring plate without exerting a default pressing force of 60kg force, necessary to ensure a contact between the sealing plate and the anchoring plate when the difference in height between these two plates corresponds to a maximum permitted height difference.

However, this welding process is very time-consuming and may result in poor quality welds when the force applied by default causes a leverage effect that lifts the sealing plate at the level of the welding area.

The aim of the present invention is to remedy at least some of the above-mentioned disadvantages by providing a welding system and a welding method that allow to guarantee a good weld quality and allow the welding process to be automated.

To this end, the invention proposes a system for welding a sealing plate of a tank configured to contain liquefied gas, to an anchoring plate, the sealing plate and the anchoring plate being metallic, the welding system comprising a welding device comprising:

- a transparency welding tool configured to perform at least one weld in a welding area,
- pressing means for pressing the sealing plate onto the anchoring plate, and
- control means for controlling a force exerted by the pressing means onto the sealing plate, able to detect a contact between the anchoring plate and the sealing plate, and to act on the pressing means as soon as contact between the anchoring plate and the sealing plate is detected.

The welding tool is, for example, a plasma welding torch or a laser welding device. When the welding system is used to weld the sealing plate to the anchoring plate, the welding tool is positioned above the anchoring plate, and more specifically above a welding area of the sealing plate to this anchoring plate. Such welding areas are located, for example, along an edge of the sealing plate located above the anchoring plate. For example, the sealing plate comprises between 3 and 21 welding areas along the edge, and preferably 15 welding areas along the edge when the sealing plate is 3 meters long. These welding areas are located on "weld areas" which are flat areas of the sealing plate, spaced apart by, for example, around thirty centimeters when the sealing plate has a grid of corrugations. Each

welding area is not located above rivets that allow the anchoring plate to be attached to shells in an underlying primary insulation layer. It is understood that a welding area, on which a weld is performed, may not be larger than the dimensions of an anchoring plate. For example, a welding area forms a rectangle 10 cm (centimeters) long and 5 cm (centimeters) wide, and the anchoring plate is, for example, 100 mm (millimeters) by 70 mm. The pressing means are pressed on the welding area or adjacent to the welding area so that the distance between the sealing plate and the anchoring plate is less than 0.3 mm over the entire welding area. Of course, these figures are given for guidance only and must be adapted to the different types of tank walls and attachment of the sealing plates of these tank walls.

Thanks to the invention, a contact between the anchoring plate and the sealing plate is detected in order to adapt the force exerted by the pressing means and guarantee a quality weld between the anchoring plate and the sealing plate, independently of the initial distance between the sealing plate and the anchoring plate, which depends on the differences in height between the various shells on which the sealing plate is arranged. It should be noted that the anchoring plate is attached to a shell so that it slightly exceeds the height of the shell. The expected overshoot is 0.2mm, for example. As a result, once the welds have been performed between the sealing plate and the underlying anchoring plate or plates, the sealing plate is in contact with the shells.

The control means act on the pressing means by blocking their movement, or by reducing or modulating it, when a contact between the anchoring plate and the sealing plate is detected.

The invention also allows to automate a welding method using the welding system according to the invention.

In the invention, the pressing means are capable of locally pressing the sealing plate at the level of the surface of the area to be welded, thus locally pressing the sealing plate at the location where the welding tool is to operate, so as to bring the sealing plate and the anchoring plate into contact at the level of this area to be welded. These pressing means are distinct from holding means for holding the sealing plate against the wall of the tank being assembled, which comprises this sealing plate. Holding the sealing plate in position against the primary insulation layer, particularly when the sealing plate extends vertically with respect to a bottom wall of the tank, may require an external device which is not the subject of the invention.

Where the welding system comprises a frame comprising at least one rail and a sliding trolley mounted on the rail, with the welding device attached to the trolley, the frame may comprise attaching means for attachment to the sealing plate and/or to a wall of the tank being assembled, to which the sealing plate belongs. The pressing means of pressing the welding device are separate from the attaching means of the frame to the sealing plate and/or the wall of the tank during assembly.

In other words, the pressing means do not allow to hold the frame in position against the sealing plate or against the wall of the tank, nor do they hold the sealing plate in position against the wall of the tank during assembly. In fact, the pressing means are not configured to hold the sealing plate against the anchoring plates and the underlying shells.

According to an optional characteristic of the invention, the pressing means comprise, for example, a pusher comprising a bearing surface defining a plane configured to extend parallel to the welding area, and a cylinder, a head of which is secured to the pusher. The cylinder is, for example, a hydraulic or electric cylinder. The head of the cylinder is, for example, an attachment area located at the end of an extension rod of the cylinder. The extension rod of the cylinder is preferably arranged orthogonally to the plane defined by the bearing surface. However, it may also be inclined relative to this plane.

As previously explained, the welding area is a portion of an area to be welded (surrounded by corrugations when the sealing plate comprise them), with the bearing surface coming against a surface of the area to be welded or bearing on the surface of the area to be welded. The support surface defines a plane that is parallel to the area to be welded, or the plane coincides with the surface of the area to be welded.

According to an optional characteristic of the invention, the welding tool is secured to the pressing means. This allows to set a first distance between a head of the welding tool and the pusher, parallel to the plane, and a second distance between the head of the welding tool and the plane, orthogonal to it. The first distance is, for example, between 2 mm and 20 mm, and is, for example, 5 mm. The second distance is, for example, between 1 mm and 5 mm and is, for example, 2 mm.

The first distance is measured between the edge-to-edge projections of the head of the welding tool on the one hand and between the pusher on the other, these projections lying in a plane parallel to the plane of the bearing surface.

The advantage of attaching the first distance is to ensure a good pressing between the sealing plate and the anchoring plate just below the welding tool, and to thermally protect

the pusher from the thermal radiation of the welding tool. The "flexibility" of the sealing plate means that this first distance will not be the same depending on the pressing method chosen. It will be smaller when the pressing means use a roller than when the pressing means use a wedge. This first distance is also linked to the presence or absence of thermal protection for the pressing means.

The advantage of setting the second distance is that it ensures good arc voltage for performing the weld, without using a distance sensor on the welding tool.

According to an optional characteristic of the invention, the pusher comprises at least one roller. For example, the pusher consists of a single roller attached to the head of the cylinder, or the pusher comprises a casing carrying several rollers, i.e. several wheels, the casing being attached to the head of the cylinder. This type of pusher allows the welding tool to be moved so that a weld may be performed by transparency over several centimeters of the welding area. In addition, this type of pusher allows a pressure to be exerted on the sealing plate without damaging it. In order not to damage the roller or the weld, the welding tool is moved downstream of the movement of said at least one roller when welding over several centimeters. When the pusher comprises a casing supporting several wheels, said at least one roller forms a front wheel of the casing, the other wheels associated with the casing being rear wheels capable of passing on either side of the weld during movement of the head of the welding tool, secured to the pusher.

According to an optional characteristic of the invention, the welding system comprises protection means for thermally protecting the pusher. These protection means are, for example, a ceramic shield or a cooling liner. They are particularly useful when the pusher comprises a roller. They allow to protect the roller from the thermal radiation of the welding tool and therefore prevent the deformation of the roller, prolonging its service life. The thermal shield is at least partly interposed between the pusher and the welding tool.

According to an optional characteristic of the invention, the pusher comprises at least one wedge on which the welding tool is able to slide parallel to the plane. In this alternative, the cylinder is secured to a socket mounted on a guide such as a rail or a track attached to the wedge. In this way, the pressing force exerted by the cylinder presses the wedge on the sealing plate by means of the pressing force exerted by the cylinder on the socket, while the welding tool, secured to the pressing means and therefore to the cylinder, is able to slide along the guide, allowing to perform a weld by transparency over several centimeters, while controlling the trajectory of the welding tool. As the first distance between the head of the welding tool and the wedge is fixed, the welding tool sliding along the guide will follow

the shape of an edge of the wedge, parallel to the guide. Note that the wedge may comprise several guides. For example, it may form a U shape between the branches of which the welding tool may move. The pusher may also comprise several wedges between which the welding tool may move. More than controlling the trajectory of the welding tool, which may be performed in a different way (for example using a rail on which the welding device is mounted), the advantage of using a wedge rather than a roller is to have a better pressing quality, as the wedge deforms the sealing plate less than a roller, thanks to its contact surface with the sealing plate, which is larger than that of a roller.

According to an optional characteristic of the invention, the control means for controlling the welding system according to the invention comprise means for stopping the pressing means coupled to means for detecting that a speed of the cylinder is less than a low speed threshold, or to means for detecting that a variation in a force exerted on the pusher is greater than a high force variation threshold, or to means for detecting a variation in a metal thickness measurement.

The force exerted on the pusher corresponds to the reaction force exerted by the support against which the pusher is pressed, also referred to as the "normal reaction". The speed of the cylinder is measured, for example, orthogonally to the plane defined by the support surface of the pusher, or along the axis of the extension rod of the cylinder.

The control means comprise, for example:

- a position detection means such as a linear potentiometer coupled to the cylinder and allowing the extension of the latter to be measured accurately, which allows to detect that the speed of the cylinder is below the low speed threshold,
- or a force sensor, such as a strain gauge force sensor, which allows to detect that the variation in a force exerted on the pusher is at the high force variation threshold,
- or a thickness measurement means using, for example, an ultrasonic sensor, which allows to detect the variation in a metal thickness measurement. The variation in the metal thickness measurement here corresponds to the contact between the sealing plate and the anchoring plate. The thickness measurement means measures a metal thickness in contact with the pusher. For example, a first variation in thickness measurement is detected by the thickness measurement means when the pusher comes into contact with the sealing plate, and then a second variation in thickness measurement is detected by the thickness measurement means when the sealing plate comes into contact with the anchoring plate. The detection of the contact between the

anchoring plate and the sealing plate therefore corresponds to this second variation in thickness measurement, when the thickness measurement means is activated before the pusher is in contact with the sealing plate.

The position detection means, the force sensor or the thickness measurement means are mechanically coupled to the pressing means and electrically coupled to a member for processing at least one electrical output signal from the means in question, this processing member may be remote from the welding system. The control means preferably comprise a man-machine interface coupled to a device comprising at least one processor, for example a computer, itself coupled to the processing member. The man-machine interface and the device may also be remote from the welding system.

In the event that the welding system comprises a position detection means, the computer determines the speed of movement of the cylinder using the positions provided by the position detection means, allowing it to detect a contact between the sealing plate and the anchoring plate by reaching a speed of movement of the cylinder that is close to zero, for example a speed of less than 1mm per second.

If the welding system comprises a force sensor, the computer determines the variations in the force measurements supplied by the force sensor, for example every second, which allows it to detect a contact between the sealing plate and the anchoring plate, when a variation thus determined is greater than a high threshold set, for example, at 500 N (Newton). When this contact is achieved, the normal reaction applied by the anchoring plate to the sealing plate suddenly increases the force measured by the force sensor.

If the welding system comprises a thickness measuring means, the computer detects a contact between the sealing plate and the anchoring plate as soon as the output signal from the thickness measuring means varies, the metal thickness in contact with the pusher then being increased by the thickness of the anchoring plate.

According to an optional characteristic of the welding system according to the invention, it comprises a frame comprising at least one rail and a trolley mounted so as to slide on the rail, the welding device being attached to the trolley. Such a frame makes it easier to position the pressing means and the welding tool along the welding areas of a sealing plate. Thanks to the trolley sliding on the rail, several welding areas may be processed consecutively and automatically. The trolley is motorized, for example, and comprises a sliding member such as a rib capable of sliding in a track of the rail, or a slide capable of sliding on the rail, depending on the configuration of the latter. For example, the trolley may be programmed to activate the welding tool and the pressing means only in the welding areas, as it

progresses along the rail. The control means for controlling the force exerted by the pressing means on the sealing plate are preferably also mounted on the trolley.

According to an optional characteristic of the invention, the sealing plate comprising corrugations, the frame comprises means for removable attachment to corrugations delimiting welding areas between them, the frame forming a framework on which the rail is arranged and an internal periphery of which is able to allow the welding tool access to the welding areas. The corrugations on the sealing plate correspond to ribs forming a grid pattern on the sealing plate, allowing to absorb the deformation of the tank due to its thermal variations. In this embodiment of the invention, the removable attachment means are, for example, corrugation node clamps. Such a clamp slides on a first corrugation on either side of a second corrugation intersecting the first corrugation, to clamp the second corrugation.

According to another optional characteristic of the invention, first welding areas being aligned along a first axis, between a first end of the sealing plate and a second end of the sealing plate, and second welding areas being aligned along a second axis, between a third end of the sealing plate and a fourth end of the sealing plate, the rail is configured to allow the welding tool to process all of the first welding areas when it is aligned along the first axis, the frame comprising removable attachment means capable of attaching at least one portion of the frame to a support external to the sealing plate. The first axis and the second axis are distinct, for example they are orthogonal to each other.

The rail extends, for example, from the first end of the sealing plate to the second end of the sealing plate when positioned along the first axis. The attachment means are, for example, hydraulic suction cups attached on either side of the rail to another sealing plate already anchored to the primary insulation layer, or to shells in the primary insulation layer. By way of example, the sealing plate forms a rectangle of sheet metal measuring three meters by one meter. The rail allows all the welding areas to be processed over the three-meter length or one-meter width of the sealing plate. The welding system, which mainly comprises the rail, the trolley, the means for attaching the rail, the pressing means, the welding tool and the control means, is easy to handle and therefore easy to move along the welding areas as the sealing plates of the primary sealing membrane of the tank are welded to the anchoring plates of the primary insulation layer.

According to an optional characteristic of the invention, the welding system comprises two welding devices attached to the trolley on either side of the rail. This means that the welding system allow to process two welding areas simultaneously, on either side of the rail.

According to an optional characteristic of the invention, the welding system comprises two arc-shaped guide members, on each of which a separate end of the rail is mounted so as to slide, the guide members being capable of causing the rail to pass from a first configuration wherein the welding system is capable of processing all the first welding areas, to a second configuration wherein the welding system is capable of processing second welding areas. In this case, the rail may allow the welding tool to process the first areas and then the second areas without moving the attachment means of the frame.

In addition, the welding system may comprise a station external to the frame, the station being connected by electrical and possibly hydraulic connections to the attachment means of the frame, to the trolley, to the welding tool and to the cylinder, the external station comprising an electrical generator and possibly an air compressor as well as liquid for the cylinder, if the latter is hydraulic, or for cooling a roller of the welding system, if this roller is thermally protected by a cooling liner.

The invention also relates to a method for welding a sealing plate of a tank configured to contain liquefied gas, to an anchoring plate, using the welding system according to the invention, and comprising the steps of:

- positioning the pressing means above the sealing plate and the anchoring plate,
- actuating the pressing means,
- controlling a force exerted by the pressing means on the sealing plate,
- locking the pressing means as soon as a contact between the anchoring plate and the sealing plate is detected, to maintain a contact between the anchoring plate and the sealing plate, and
- welding by transparency the sealing plate to the anchoring plate.

The invention also relates to a method for welding a sealing plate of a tank configured to contain liquefied gas, to an anchoring plate, using the welding system according to the invention, wherein the pressing means comprise a pusher comprising a bearing surface defining a plane configured to come parallel against a welding area, and a cylinder, a head of which is secured to the pusher, and wherein the control means comprise means for stopping the pressing means coupled to means for detecting that a speed of the cylinder is below a low speed threshold, the welding method comprising the steps of:

- positioning the bearing surface above the sealing plate and the anchoring plate,
- actuating the cylinder,

- controlling the displacement speed of the cylinder,
- locking the cylinder as soon as the displacement speed falls below the low speed threshold, to maintain a contact between the anchoring plate and the sealing plate, and
- welding by transparency the sealing plate to the anchoring plate.

When the cylinder is locked, its extension rod stops extending and remains stationary in relation to the hollow tube wherein it has slid.

The invention also relates to a method for welding a sealing plate of a tank configured to contain liquefied gas, to an anchoring plate, using the welding system according to the invention, wherein the pressing means comprise a pusher comprising a bearing surface defining a plane configured to come parallel against a welding area, and a cylinder, a head of which is secured to the pusher, and wherein the control means comprise means for stopping the pressing means coupled to means for detecting that a variation in a force exerted on the pusher is greater than a high force variation threshold, the welding system comprising a force sensor, the welding method comprising the steps of:

- positioning the bearing surface above the sealing plate and the anchoring plate,
- actuating the cylinder,
- controlling an output signal of the force sensor,
- locking the cylinder as soon as a variation in the output signal is greater than the high force variation threshold, in order to maintain a contact between the anchoring plate and the sealing plate, and
- welding by transparency the sealing plate to the anchoring plate.

The invention also relates to a method for welding a sealing plate of a tank configured to contain liquefied gas, to an anchoring plate, using the welding system according to the invention, wherein the pressing means comprise a pusher comprising a bearing surface defining a plane configured to come parallel against a welding area, and a cylinder, one head of which is secured to the pusher, and wherein the control means comprise means for stopping the pressing means coupled to means for detecting a variation in a metal thickness measurement, the welding system comprising a measuring means for measuring a metal thickness in contact with the pusher, the welding method comprising the steps of:

- positioning the bearing surface above the sealing plate and the anchoring plate,
- actuating the cylinder,

- controlling an output signal from the measuring means,
- locking the cylinder as soon as a variation in the output signal is detected, to maintain a contact between the anchoring plate and the sealing plate, and
- welding by transparency the sealing plate to the anchoring plate.

A variation in the output signal is detected when this variation is clearly distinct from variations due to measurement noise.

When the pusher comprises at least one roller, or a wedge on which the welding tool is able to slide parallel to the plane, the welding step of the methods according to the invention preferably comprises a step of moving the roller on the sealing plate, or a step of sliding the welding tool on the wedge.

Furthermore, in each of the welding methods according to the invention, when the welding system comprises a frame comprising at least one rail and a sliding trolley mounted on the rail, the welding device being attached to the trolley, the positioning step is preceded, for example, by a step of attaching the frame relative to the sealing plate and then by a step of programming the trolley so as to cause it to move successively over several welding areas, and to activate the subsequent steps of the welding method as soon as one of the welding areas is reached. Of course, between each repetition of the steps of one of the welding methods according to the invention, these comprise a step of deactivating the pressing means, i.e. the cylinder, for example, which allows the welding device to be moved to the next welding area without deforming the sealing plate.

The program resulting from the programming step comprises instructions which, when executed on a processor, activate actuators of the welding system according to the invention, in particular the cylinder, a motor allowing the trolley to be moved, and/or commands for these actuators such as a command to lock or deactivate the cylinder.

The welding methods according to the invention comprise advantages similar to those of the welding system according to the invention.

Other characteristics and advantages of the invention will become apparent from the following description, on the one hand, and from a number of examples of embodiment given by way of indication and without limitation with reference to the attached schematic drawings, on the other hand, wherein:

[Fig. 1] shows, in plan view, a portion of a wall of a tank configured to contain liquefied gas, this portion being in the process of being assembled and comprising a sealing plate on

which welds are visible allowing it to be attached to anchoring plates underlying the sealing plate,

[Fig. 2] represents, according to a first embodiment of the invention, a welding system according to the invention, comprising in particular pressing means equipped with a roller, and a welding tool,

[Fig. 3] shows a perspective view of the welding system of Figure 2 operating on a sealing plate shown transparent above the shells of a primary insulation layer of the tank wall mentioned in relation to Figure 1,

[Fig. 4] shows a perspective view of a pusher in an alternative mode to the roller in Figure 2, suitable for use by the welding system in Figure 2,

[Fig. 5] shows a perspective view, according to a second embodiment of the invention, of a welding system according to the invention, wherein the pressing means comprise a wedge, along which a welding tool of the welding system is able to slide,

[Fig. 6] shows a perspective view, according to a third embodiment of the invention, of a welding system according to the invention, wherein the pressing means comprise a U-shaped wedge, between the arms of which a welding tool of the welding system is able to slide,

[Fig. 7] shows a top view of the wedge of the pressing means in Figure 6,

[Fig. 8] shows different states of the welding system shown in Figure 5 or Figure 6, as a function of time, when welding a sealing plate to an anchoring plate, in one embodiment of a welding method according to the invention,

[Fig. 9] shows a perspective view, according to a fourth embodiment of the invention, of a welding system according to the invention, comprising a frame shaped like a framework equipped with a rail on which the welding system of Figure 2 may travel, the frame being shown attached to a corrugation rectangle of the sealing plate of Figure 1,

[Fig. 10] shows a top view, according to a fifth embodiment of the invention, of a welding system according to the invention, comprising a rail on which a trolley is able to travel, two welding systems conforming to the first embodiment of the invention being attached to the trolley on either side of the rail,

[Fig. 11] shows two views of a hydraulic suction cup that could be used as a means of attaching the rail in Figure 10,

[Fig. 12] represents, seen from above, according to a sixth embodiment of the invention, a welding system according to the invention, comprising a frame equipped with a removable rail on which the welding system of Figure 2 may travel, and

[Fig 13] shows welding methods steps according to the invention, in several embodiments of the invention.

Figure 1 shows a portion of a tank wall configured to contain liquefied gas, i.e. a cryogenic liquid such as liquid natural gas or liquid dihydrogen, at a very low temperature, for example -163°C (degrees Celsius) for liquid natural gas. Such a tank is configured to contain at least several thousand cubic meters of liquefied gas. Its walls are watertight and insulated.

The portion of the tank wall shown in Figure 1 comprises:

- a secondary insulation layer, for example made up of wooden shells filled with insulating foam,
- a secondary sealing membrane made of corrugated sheet metal plates,
- a primary insulation layer, formed by wooden shells 72 filled, for example, with reinforced polyurethane foam, and
- a primary sealing membrane, made up of sealing plates 1 welded together to line the inside of the tank.

Anchoring plates 21, 22 grid the surface of the primary insulation layer, and are attached to the shells 72 by rivets. These anchoring plates 21, 22 allow the sealing plates 1 to be attached to the anchoring plates 21, 22 by transparency welding. Other anchoring plates (for example anchoring plate 24 in Figure 3) are smaller and may be arranged diagonally on certain shells.

The tank portion shown in Figure 1 extends mainly along a first axis A1 and a second axis A2 orthogonal to the first axis A1, and in thickness along a third axis A3 orthogonal to the first and second axes A1, A2. The tank portion may be horizontal and form part of a lower or upper wall of the tank, or vertical and form part of a lateral wall of the tank.

The sealing plates 1 are, for example, each around three meters long and one meter wide, and are clinch-welded together at their edges. They also comprise corrugations forming a grid on the primary sealing membrane.

In particular, they comprise large corrugations 12 extending in the direction of the first axis A1, and small corrugations 14 extending in the direction of the second axis A2. The large corrugations 12 are wider than the small corrugations 14 which connect the large

corrugations 12 together. These corrugations 12, 14 form corrugation rectangles, two adjacent sides of which comprise a small corrugation 14 and a portion of a large corrugation 12.

One of the sealing plates 1, shown in full in Figure 1, extends in the direction of the first axis A1 from a first of its ends 17 to a second of its ends 19, these ends 17, 19 being edges of the sealing plate 1 parallel to the second axis A2. This sealing plate 1 also extends in the direction of the second axis A2 from a third of its ends 16 to a fourth of its ends 18, these ends 16, 18 being edges of the sealing plate 1 parallel to the first axis A1.

The sealing plate 1 is welded along the direction of the first axis A1 by first welding lines 31 formed in corrugations rectangles on a peripheral portion of the sealing plate 1, these corrugation rectangles covering first anchoring plates 21 oriented along the first axis A1, of length 100mm and width 70mm, in this example of use of the invention.

The sealing plate 1 is welded along the direction of the second axis A2 by second welding lines 32 formed in corrugation rectangles of the sealing plate 1 covering second anchoring plates 22 oriented along the second axis A2, 100mm long and 70mm wide, in this example of use of the invention. These second anchoring plates 22 are positioned under the sealing plate 1 every three corrugation rectangles. The sealing plate 1 is thus welded along the second axis A2 to second anchoring plates 22 evenly spaced along the first axis A1.

The second anchoring plates 22 partially overlap the first anchoring plates 21 under three corrugation rectangles wherein the sealing plate 1 comprises four third welding lines 34 oblique relative to the directions of the first and second axes A1, A2. It should be noted that these oblique welding lines 34 may be made with a welding system shown later in relation to Figure 9, but that when the welding lines 31, 32 are made with other welding systems shown later in relation to Figures 10 and 12, the welding lines made at the level of the intersections of the anchoring plates 21 and 22 are L-shaped corresponding to a half welding line 31 adjacent to a half welding line 32 (as seen in Figures 10 and 12).

The first, second and third welding lines 31, 32, 34 correspond to welds of the sealing plate 1 performed by transparency on a first or second anchoring plate 21, 22. These welding lines 31, 32, 34 are performed on predetermined welding areas, corresponding in particular to rivet-free portions of the anchoring plates 21, 22.

Of course, the invention is not limited to this particular tank wall composition, as the invention may also be applied to different shapes and sizes of sealing plates, which may not contain corrugations. In addition, the invention is applicable to the attachment of the

sealing plates by welding points and not only by welding lines. The locations of the welding areas are of course not limited to those shown in Figure 1.

Figure 2 shows a welding system S1 in a first embodiment of the invention, allowing the welding lines 31, 32, 34 of the sealing plate 1 to be performed on the anchoring plates 21, 22 by transparency.

The welding system S1 comprises a welding tool 5 for welding by transparency, in this case a plasma welding torch. Positioned on the sealing plate 1, it may be welded to one of the anchoring plates 21, 22. For example, the sealing plate is approximately 1.2 mm thick, and the anchoring plates are approximately 2 mm thick.

The welding tool 5 is attached by an attachment flange 47 to an extension rod of a cylinder 45 arranged parallel to the welding tool 5. The cylinder 45 comprises an electric motor 44 connected to an outer tube 46 of the cylinder wherein the extension rod of the cylinder is mounted. A linear potentiometer 6 integrated into the cylinder measures the displacement of the extension rod relative to the outer tube 46.

The end of the extension rod is connected to a pusher. More specifically, the end of the extension rod is connected to a roller, being equipped with a U-shaped attachment wherein the axle of the steel roller 48 is mounted in a rotating manner. Finally, a cooling device 42 is formed in the vicinity of the pusher, here by surrounding the extension rod just above the attachment area, so as to cool the roller 48 when the welding tool 5 is in operation. As the extension rod and the attachment are themselves made of steel, they are likely to conduct the cold produced by the cooling device 42 to the roller 48. Of course, materials other than steel may be used for the roller and/or the cylinder elements mentioned if they have sufficient mechanical and thermal strength to achieve the invention. In addition, the cooling device may take a form other than a cooling liner cylindrically surrounding the extension rod of the cylinder and, for example, comprise a tab forming a thermal barrier and configured to be interposed between the roller 48 and the welding tool 5.

The attachment flange 47 for attaching the welding tool 5 to the cylinder 45 allows to set a first distance d1 between the head 52 of the welding tool 5 and the roller 48, measured parallel to a plane P coplanar with the surface of a welding area on the sealing plate P, the roller 48 being positioned on this surface which defines a bearing surface for the roller 48, and the axis X of the extension rod of the cylinder 45 being orthogonal to the plane P.

Similarly, the attachment flange 47 for attaching the welding tool 5 to the cylinder 45 allows a second distance d2 to be set between the end of the head 52 of the welding tool and the plane P, for example 2 mm, which ensures a good quality of welding by transparency. Of

course, this value must be adapted according to the welding tool used and the plates to be welded.

When the pusher, in this case the roller 48, is positioned on the welding area just before welding the sealing plate 1, the cylinder 45 being orthogonal to the weld surface, the cylinder 45 is able to exert a force F on the welding area which increases until the sealing plate 1 comes into contact with the underlying anchoring plate 21 or 22, detected by the potentiometer 6 which measures a sudden reduction in the extension of the extension rod of the cylinder 45. Once the contact has been detected, the welding tool 5 is activated and the welding system S1 moved over the sealing plate 1 by means of the roller 48 so as to form a welding line 31, 32 or 34.

The sensor associated with the cylinder, in this case the potentiometer 6, is different and measures other data which also allows the increase in force pick-up exerted on the rod of the cylinder 45 to be noted. Alternatively, the sensor is a force sensor, such as a strain gauge force sensor, or a thickness measurement means using ultrasound, for example, the position of the sensor on the cylinder or more generally in the welding system obviously depending on the type of sensor used. In particular, the ultrasonic thickness measurement means does not have to be physically linked to the cylinder; it is sufficient for it to be arranged close to the pusher.

The potentiometer 6 therefore forms part of the control means for controlling the welding system S1, these means comprising a member for processing the output signal from the potentiometer, which may be located on the cylinder or at a distance from it.

It is understood that thanks to the attachment of the welding tool 5 to the extension rod of the cylinder 45, and thanks to the implementation of the control means which ensure that an adequate pressure is exerted to press the sealing plate on the associated anchoring plate, the welding tool 5 is positioned at the correct distance from the sealing plate 1 to perform a welding by transparency, when the cylinder presses the sealing plate 1 to a welding area.

The roller 48 and the cylinder 45 form pressing means 4 for pressing the sealing plate onto the anchoring plate 21 or 22.

Figure 3 illustrates the welding by transparency of the sealing plate 1 to an anchoring plate 23 attached to a corner of a shell 72, using the welding system S1. In order to visualize the differences in height between the shells 72 under the sealing plate 1, the latter is made transparent in Figure 3, although it is represented by a few raised lines 15. The roller 48

allows to provide easy access to this corner of the sealing plate 1 and allows a welding line 33 to be performed by transparency to the anchoring plate 23, between the rivets attaching it to the shell 72. It should be noted that by using a welding tool which is a laser welding device, the optics may be offset, allowing the roller 48 to be pressed as close as possible to the weld 33 to be performed.

It is clear from Figure 3 that the sealing plate 1 has to be deformed more to press it onto the anchoring plate 23, to perform the welding line 33, than if it had to be performed on an anchoring plate 24 of a shell 72 located higher up than the one to which the anchoring plate 23 is attached. This means that the force F exerted by the cylinder 45 must be greater. As an indication, the tank manufacturing standards are set so that this force F must not exceed 60kg, i.e. a maximum threshold of height difference between the shells 72 is established.

Figure 4 shows an alternative pusher 48b to the roller 48 for the welding system S1, which may be attached to the attachment of the extension rod of the cylinder 45. This reciprocating pusher 48b comprises a roller attached, for example by its axle, to the attachment of the extension rod of the cylinder. This roller forms a front wheel 482 of the reciprocating pusher 48b, its axle also passing through the ends of flanks 480 which are parallel to each other and extend orthogonally to the axis X of the extension rod of the cylinder. The opposite ends of the flanks 480 each comprise a rear wheel 484 on the opposite side to the front wheel 482 with respect to the corresponding flank 480.

The front wheels 482 and rear wheels 484 are configured to roll over a welding area without rolling over the welding line being formed, when using the welding system S1. To do this, the head 52 of the welding tool 5 is positioned, for example, on the upper walls of the flanks 480, in a median area 488 located between the rear wheels 484 and the front wheel 482.

According to a second embodiment of the invention shown in Figure 5, a welding system S2 according to the invention comprises elements similar to those of the welding system S1 of the first embodiment and referenced in the same way, in particular the welding tool 5, the elements of the cylinder 45 and the potentiometer 6.

Unlike the welding system S1 of the first embodiment, the pusher of the pressing means of the welding system S2 of the second embodiment is formed by a wedge 43, comprising:

- a long plate configured to come into contact with the sealing plate 1,
- a guide 432 in the form of a circular section rail attached to two supports projecting from the elongated plate on either side of the welding tool 5 attached to the cylinder 45,
- a bead socket mounted in a sliding manner on the guide 432,

- an attachment tab 430, a first part of which is secured to the bead socket and a second part of which, orthogonal to the first part, is attached to the end of the extension rod of the cylinder, in this case by a through screw, and
- a return spring 434, capable of being compressed between the attachment tab 430 and a wall of one of the supports, as shown in an initial state S2(t0) of the welding system S2, shown in Figure 8.

According to a third embodiment of the invention shown in Figure 6, a welding system S3 according to the invention is also similar to the welding system S1 of the first embodiment with the exception that the pusher attached to the cylinder 45 is a wedge 43b, as in the second embodiment of the invention, but comprising two guides 432b of circular cross-section.

More specifically, the wedge 43b of the welding system S3, also shown in Figure 7, comprises:

- a U-shaped plate configured to come into contact with the sealing plate 1,
- the two guides 432b in the form of rails of circular cross-section, each attached to two supports projecting from each branch of the U-shaped plate, on either side of the welding tool 5 attached to the cylinder 45, the welding tool 5 being arranged between the two branches of the U-shaped plate,
- two bead socket, each mounted in a sliding manner on one of the guides 432b,
- an attachment tab 430b, a first part of which is secured to the bead socket and a second part of which, orthogonal to the first part, is attached to the end of the extension rod of the cylinder, in this case by a through screw, and
- two return springs 434b, capable of being compressed between the attachment tab 430b and the supports, in an initial state of the welding system S2.

As may be seen in Figures 5, 6 and 8, the welding systems S2 and S3 with wedge allow a radiation area 54 created by the head 52 of the welding tool 5 to run along the long or U-shaped plate of the welding system S2 or S3 respectively, when a welding line 31, 32, 33 or 34 is made on the sealing plate 1. The pusher remains stationary while the welding head is moving, which ensures that the sealing plate is uniformly pressed onto the anchoring plate throughout the entire duration of the performance of the welding line.

Figure 8 illustrates the performance of a welding line using the welding system S2 in the second embodiment, which may be transposed to the production of a welding line using the welding system S3 in the third embodiment.

During the initial state S2(t0) of the welding system S2, at a time t0, the control means for controlling the welding system S2 detect a contact between the sealing plate 1 and an anchoring plate 22, and stop the extension rod of the cylinder 45 from deploying, thus attaching the value of the pressing force F between the sealing plate 1 and an anchoring plate 22. In this initial state S2(t0), the return spring 434 is compressed between a first of the supports of the guide 432 and the socket which allows the cylinder 45 and the welding tool 5 to slide along the wedge 43.

A welding line is then performed by activating the welding tool 5 and sliding the cylinder 45 and the welding tool 5 along the wedge 43 by means of the bead slide, in a direction D, parallel to the guide 432, the pressing force F being kept constant. The movement of the cylinder 45 and the welding tool 5 is ensured, for example, by a trolley on which the cylinder 45 and the welding tool 5 are mounted. The bead socket ends its travel along the guide 432 at a time t1, the return spring 434 being stretched in the direction of a second of the supports, and the welding system S2 being in a state S2(t1).

Finally, at a time t2 following time t1, at the end of the welding operation, the cylinder 45 is unlocked and its extension rod retracted, so as to cancel the pressing force F. In the corresponding state S2(t2) of the welding system S2, the wedge 43 is lifted from the sealing plate 1, and the welding system S2 is ready to be reused on another welding area.

As mentioned previously, the use of a wedge 43, 43b rather than a roller ensures even pressing along the welding line, and less damage to the surface of the sealing plate 1.

In a fourth embodiment of the invention, a welding system S4 incorporating the elements of the welding system S1 of the first embodiment of the invention is now described in relation to Figure 9.

The welding system S4 comprises a frame 8 shaped like a framework, which is attached to the nodes of a corrugation rectangle of the sealing plate 1. To do this, it comprises, at each of the corners of its lower face (i.e. facing the sealing plate 1), clamps 84 each comprising two jaws sliding on small corrugations 14 located on either side of a large corrugation 12, and clamping this large corrugation 12. Each clamp 84 also comprises a locking member 840 allowing it to be held clamped on the node of the corrugation rectangle corresponding

to the intersection of the large corrugation 12 and the small corrugations 14 on which it is installed.

Handles 82 installed each on opposite sides of the frame 8 make it easy to transport the welding system S4.

On its upper face (i.e. opposite the sealing plate 1), the frame 8 comprises a rail 86 defining its inner perimeter, and a trolley 9 mounted in a sliding manner on the rail 86. The rail 86 draws a framework parallel to the plane P, coplanar or substantially coplanar with the welding areas in the corrugation rectangle. The rail 86 is arranged as parallel as possible to the welding areas, substantially coplanar with the main plane of elongation of the sealing plate 1, i.e. coplanar to within 10 degrees.

The pressing means 4, equipped with its sensor 6 forming part of the control means, and the welding tool 5, attached to the pressing means 4, are attached to an arm 92 of the trolley 9, extending towards the inside of the frame 8, so that the axis X of the extension rod of the cylinder 45 is orthogonal to the plane P. The position of the arm 92 is adjustable so that the pressing means 4 and the welding tool 5 may be moved more or less towards the center of the corrugation rectangle.

It is understood that thanks to the attachment of the welding tool 5 to the extension rod of the cylinder 45, and thanks to the implementation of the control means which ensure that an adequate pressure is exerted to press the sealing plate on the associated anchoring plate, the welding tool 5 is positioned at the correct distance from the sealing plate 1 to perform a welding by transparency, when the cylinder presses the sealing plate 1 on a welding area. In addition, the welding tool 5 is moved parallel to the plane P to perform a welding line by moving the trolley 9 along the rail 86, this movement being followed by the roller 48 over the distance required to perform the welding line.

Finally, as may be seen in Figure 8, when the trolley 9 runs around the perimeter of the rail 86, it is used to form welding lines 31 or 32 with the welding tool 5 when it is positioned on a median area of one side of the rail 86, or welding lines 34 when it is positioned on oblique corners 862 of the rail 86.

This fourth embodiment of the invention is particularly suitable for targeted repairs to scattered corrugation rectangles in the sealing membrane of the tank.

Of course, as an alternative embodiment to this fourth embodiment, the roller 48 is replaced by the wedge 43 or 43b. In this case, the welding tool 5 is moved parallel to the plane P to perform a welding line by moving the trolley 9 along the rail 86, this movement being

followed by the socket or sockets of the wedge 43, 43b pressed against the sealing plate 1, over the distance required to perform this welding line. Once the welding line has been performed, the upward movement of the extension rod relative to the plane P lifts the wedge 43, 43b, causing the socket or sockets to return to their initial position on the wedge 43, 43b by the effect of the return spring or springs 434, 434b.

According to a fifth embodiment of the invention shown in Figure 10, a welding system S5 according to the invention also comprises a rail 86b on which a trolley 9b is mounted in a sliding manner, this rail 86b being straight and of greater length than the main dimension of the sealing plate 1.

In the example of use of the invention shown in Figure 10, the rail 86b is arranged parallel to the first axis A1 on a line of corrugation rectangles of the sealing plate 1 located above the first anchoring plates 21.

A first end of the rail 86b may be attached to a shell 72, beyond the edge 19 of the sealing plate 1 and outside it, by a foot 83 screwed to the shell 72.

A second end of the rail 86b is adapted to be attached beyond the edge 17 of the sealing plate 1 and outside it, to another sealing plate by an attachment by suction cup 84b, described below in relation to Figure 11.

The assembly formed by the foot 83 and the attachment by suction cup 84b forms a frame 8b on which the rail 86b is mounted.

Two template tabs 80 sliding together on the rail 86b are spaced apart by the length of the sealing plate 1 in the direction of the axis A1. They are therefore adapted to the template of the sealing plate 1. They allow the rail 86b to be positioned optimally above the sealing plate 1 to perform the welding lines 31 parallel to the first axis A1.

To do this, two welding systems S1, in accordance with the first embodiment of the invention, are attached on either side of the trolley 9b, so that the axis X of the extension rod of the cylinder 45 is orthogonal to the plane P of the welding areas on the sealing plate 1.

The welding lines 31 are performed in a similar way to the welding lines 31 using the welding system S4 in the fourth embodiment of the invention. In this fifth embodiment of the invention, however, the trolley 9b is controlled by programming means 90 attached to the trolley 9b and comprising a man-machine interface. These programming means 90 comprise a computer and are able to program the movement of the trolley 9b to perform several welding lines 31 on either side of the rail 86b along the length of the sealing plate

1. The corresponding program instructions therefore comprise means for activating a motorization of the trolley 9b, means for activating and stopping the cylinder 45, coupled to means for detecting a contact between the sealing plate 1 and the underlying first anchoring plate 21, and means for activating and stopping the welding tool 5. The instructions may also comprise means for adapting the speed of the trolley 9b depending on whether the welding tool 5 is switched on or off.

It should be noted that, in an alternative embodiment of the invention, the template tabs 80 are stationary, which means that the programming of the trolley 9b does not need to be modified in order to process the welding areas along the same axis A1 or A2 on different sealing plates 1.

In addition, several frames 8b with their rails 86b may be arranged one after the other so as to allow the trolley 9b to make welds on two adjacent sealing plates without having to move the entire welding system S5.

In another example of use of the invention not shown, the rail 86b is arranged parallel to the second axis A2 on a line of corrugation rectangles of the sealing plate 1 located above second anchoring plates 22. In this other example of use, the welding system S5 is used to perform the welding lines 32 of the sealing plate 1 on these second anchoring plates 22, in a similar way to making the welding lines 31 on the first anchoring plates 21.

It should be noted that in this fifth embodiment of the invention, the oblique welding lines 34 are each replaced by a half welding line 31 extended by a half welding line 32 so as to follow a corner of the rectangle of corrugations covering an intersection of anchoring plates 21 and 22. The welding system S5 is therefore sufficient to process all the welding areas on the sealing plate 1.

Figure 11 shows in more detail how the frame 8b is attached by a suction cup 84b. This attachment comprises a suction cup 846 and a vacuum pump 841 comprising a compressed air inlet 844 for activating and deactivating the suction cup 846. The vacuum pump 841 creates a pressure difference allowing the suction cup 846 to hold a heavy load such as the welding system S5. A ball-and-socket joint 848 allows the rail 86b to rotate around the attachment by suction cup 84b as long as the foot 83 is not screwed down.

The vacuum pump 841 and the ball-and-socket joint 848, attached movable in rotation to the suction cup 846, are elastically connected to the edges of a buttonhole arranged in a bracket 843 and wherein they may slide in a direction substantially parallel to the gripping surface of the suction cup 846. The bracket 843 is attached by a hinge 845 to a support 847

of the rail 86b, the hinge 845 forming a pivot connection with an axis orthogonal to the main extension axis of the buttonhole (along its length) and substantially parallel to the gripping surface of the suction cup 846.

Gas cylinders 842 coupled to compressed air inlets 849 to block the movement of their pistons, allow the support 847 to be rotated relative to the bracket 843 about the hinge 845. For this purpose, each of the gas cylinders 842 comprises, at one of its ends, attached to its body, an eye mounted so as to be able to rotate in a rod attached to one end of the bracket 843, distal to the support 847, and at the other of its ends, attached to the piston of the cylinder 842, an eye mounted so as to be able to rotate in a rod attached to the support 847.

It is understood that this attachment by suction cup 84b allows to attach the distance of the rail 86b with respect to the position of the suction cup 846 thanks to the buttonhole arranged in the bracket 843. In addition, the system of cylinders 842 coupled to the bracket 843 and to the support 847, which are attached to each other by the hinge 845, allows the rail 86b to adapt to the angular and height differences between the gripping surface of the suction cup 846 in relation to a welding area, and to maintain the rail 86b parallel to the plane P of the welding area and at the same height therefrom, even when the sealing plate 1 is pressed to an anchoring plate 21, 22 or 23 by the cylinder 45.

According to a sixth embodiment of the invention shown in Figure 12, a welding system S6 according to the invention comprises a frame 8c equipped with a removable rail 86c on which a trolley 9b identical to that of the fifth embodiment of the invention and referenced in the same way is mounted in a sliding manner. As in the fifth embodiment of the invention, two welding systems S1 conforming to the first embodiment of the invention are attached on either side of the trolley 9b, so that the axis X of the extension rod of the cylinder 45 is orthogonal to the plane P of the welding areas on the sealing plate 1. Programming means 90 for the trolley 9b, identical to those used in the fifth embodiment of the invention, are attached to the trolley 9b.

Unlike in the fifth embodiment, however, the frame 8c comprises a framework. Attachments by suction cup 84b are attached to the underside of the framework so that the frame 8c may be attached to either side of the sealing plate 1, to shells 72 or to other sealing plates 1. In addition, handles 82c are attached to two opposite bars of the framework for maneuverability of the frame 8c.

The size of the framework is approximately one meter by one meter, so that it encompasses one third of the welding areas on the sealing plate 1. In the example shown in Figure 12,

the framework of the frame 8c encompasses 8 welding areas aligned along the first axis A1 and 8 welding areas aligned along the second axis A2. These sixteen welding areas may be processed by the welding system S6 without moving the frame 8c, thanks to the removable rail 86c.

To achieve this, a first arc-shaped guide rail 85 is attached to the framework, joining two opposite corners of the framework. One end of the removable rail 86c comprises a track able to slide on this first arc-shaped guide rail 85 and whose center of curvature is close to a corner of the framework near which a second arc-shaped guide rail 87 is attached, less extensive than the first guide rail 85. The second arc-shaped guide rail 87 is attached to the frame 8c on the outside of the framework. The other end of the removable rail 86c comprises a track able to slide on this second arc-shaped guide rail 87. In other words, the arc-shaped guide rails 85, 87 are arranged relative to each other so that the distance between the two ends of the removable rail 86c is constant during the travel of the rail 86c from one end of each guide rail 85, 87 to the other.

The removable rail 86c is thus able to move from a position aligned along the first axis A1, which allows the welding system S6 to perform all the weld lines 31 on the welding areas aligned along this first axis and encompassed by the framework, to a position aligned along the second axis A2, which allows the weld system S6 to perform all the welding lines 32 on the welding areas aligned along this second axis and encompassed by the framework.

It should be noted that, as in the fifth embodiment of the invention, the oblique welding lines 34 are each replaced by a half-welding line 31 extended by a half-welding line 32 so as to follow a corner of the rectangle of corrugations covering an intersection of anchoring plates 21 and 22. The welding system S6 is therefore sufficient to process all the welding areas on the sealing plate 1.

The welding system S6 therefore allows to process all the welding areas of a sealing plate 1 with three steps of positioning the frame 8c on three distinct portions of the sealing plate 1, whereas four steps of positioning the frame 8b are necessary with the welding system S5 of the fifth embodiment of the invention.

Template tabs may be attached to the frame 8c to avoid having to modify the programming of the trolley 9b from one portion of the sealing plate 1 to be processed to another.

Referring now to Figure 13, a method is described for welding 100a the sealing plate 1 to one of the anchoring plates 21, 22 or 23. This welding method 100a uses one of the welding systems S4, S5 or S6.

A first step 102 of the welding method 100a is to attach the frame 8, 8b or 8c so as to position the rail 86, 86b or 86c parallel to at least one welding area to be processed, i.e. parallel to the plane P, and parallel to at least one direction of one of the axes A1, A2 on at least one portion of the rail 86, 86b, 86c. This attachment step 102 uses the clamps 84, or one or more suction cups 84b and/or a foot 83 which is screwed into a shell 72, and possibly template tabs when the frame 8b, 8c is equipped with them, depending on the welding system S4, S5 or S6 used.

A second step 104 of the welding method 100a may be to program the trolley 9b, giving it instructions to move it successively over several welding areas, and to activate the subsequent steps of the welding method 100a as soon as one of the welding areas is reached. This second step 104 may take place before the first positioning step 102 if template tabs are used.

A third step 106 of the welding method 100a is to position the bearing surface of the pusher, and in particular the roller 48, above a welding area. During this step, the welding tool 5 and the cylinder 45 are positioned above the welding area by means of the trolley 9, 9b, so that a welding line may then be formed on the welding area. This positioning step 106 may be performed in conjunction with the step 102 of attaching the frame 8, 8b, 8c.

A fourth step 108 of the welding method 100a, after the positioning step 106, is the actuation of the cylinder 45, so as to press the sealing plate 1 at the level of the welding area progressively against the underlying anchoring plate 21, 22 or 23.

The next step 110a is to control the speed of movement V of the cylinder, using the output signal from the potentiometer 6, processed for example by an analogue-digital conversion circuit, connected to an input of the computer, whether this is on-board the welding system or arranged remotely and connected by a wired or wireless link to the conversion circuit. From the output signal processed by the conversion circuit, the computer deduces the speed of movement V of the cylinder.

The movement of the cylinder, i.e. the movement of the sealing plate towards the anchoring plate, continues as long as the speed of movement remains substantially the same, reflecting the fact that the sealing plate is not pressed against the anchoring plate. As soon as this displacement speed V is less than a low speed threshold Sb, set for example at 1 mm/s, it is considered that the sealing plate is sufficiently pressed against the anchoring plate to be able to carry out the welding operation by transparency, and we move on (branch Y) to the next step 114a of locking the cylinder 45. If this is not the case (branch N), the extension rod of the cylinder 45 continues to extend.

The step 114a of locking the cylinder 45 corresponds to stopping the deployment of the extension rod of the cylinder 45. When the cylinder 45 is locked, it is thus ensured that the sealing plate 1 is in contact with the anchoring plate 21, 22 or 23 at the level of the welding area, since the adjustment of the pressing force to obtain this contact, without it being necessary to apply too great a force, allows to avoid a lever effect which would tend to move the two plates away from each other as the distance from the bearing surface increases.

The next step 116a is then to weld by transparency the sealing plate 1 to the anchoring plate 21, 22 or 23. This step 116a may consist of producing a single welding point, or a welding line 31, 32, 33 or 34, by moving the trolley 9, 9b, causing the roller 48 to move upstream of the welding tool 5.

Referring now to Figure 13, a method is described for welding 100b the sealing plate 1 to one of the anchoring plates 21, 22 or 23. This welding method 100b uses a variant of one of the welding systems S4, S5 or S6, wherein, instead of being equipped with a potentiometer 6, the welding system S4, S5 or S6 is equipped with a force sensor, arranged, for example, at the level of the axle of the roller 48.

As shown in Figure 13, the welding method 100b comprises first steps 102 to 108 which are identical to those of the welding method 100a described above.

Unlike the welding method 100a, in the welding method 100b, the step 108 of actuating the cylinder 45 is followed by a step 110b of controlling an output signal from the force sensor. This output signal is again processed, for example by an analogue-to-digital conversion circuit, connected to an input on the computer attached to the trolley 9b, or to a remote computer.

From this output signal processed by the conversion circuit, the computer deduces a variation ΔNin the reaction force exerted by the sealing plate 1 on the roller 48. As soon as this variation ΔNexceeds a high threshold Sh for variation in force, set for example at 70 N/mm, then the cylinder 45 moves on (branch Y) to the next step 114b of locking the cylinder, otherwise (branch N) the extension rod of the cylinder 45 continues to deploy.

The step 114b of locking the cylinder 45 corresponds to stopping the extension rod of the cylinder 45 from extending. When the cylinder 45 is locked, it is ensured that the sealing plate 1 is in contact with the anchoring plate 21, 22 or 23 at the level of the welding area.

The next step 116b is then to weld by transparency the sealing plate 1 to the anchoring plate 21, 22 or 23. This step 116b may consist of producing a single welding point, or a

welding line 31, 32, 33 or 34, by moving the trolley 9, 9b, causing the roller 48 to move upstream of the welding tool 5.

As an alternative to these welding methods 100a, 100b, when the system S4, S5 or S6 uses an ultrasonic thickness measurement means to measure the metal thickness under the roller 48, a method for welding the sealing plate 1 to an underlying anchoring plate 21, 22 or 23 comprises the first steps of attaching the frame 8, 8b or 8c, possibly programming the trolley 9b, positioning the roller 48 above a welding area and actuating the cylinder 45, identical to those of the methods 100a, 100b previously described. These first steps are followed, in this variant of the welding method, by a step of controlling an output signal from the ultrasonic thickness measurement means, processed by an analogue-digital conversion circuit, connected to a computer attached to the trolley 9b or remote from the trolley 9, 9b.

As soon as a variation in metal thickness under the roller 48 is detected, the cylinder 45 is locked, since this means that the contact between the sealing plate 1 and the underlying anchoring plate 21, 22, 23, at the level of the welding area, has been obtained. Then, in this variant of the welding method, the welding by transparency is performed, in a similar way to steps 116a, 116b already described.

Of course, the invention may be used without the frame 8, 8b or 8c. A corresponding welding method according to the invention does not then comprise the steps 102 of attaching the frame and 104 of programming the trolley 9b, but comprises the following steps, identical to those of the welding methods previously described depending on the control means used to detect a contact between the sealing plate 1 and the underlying anchoring plate 21, 22 or 23 at the level of the welding area.

Finally, the welding methods described are adaptable to the use of the welding system S2, using a wedge 43 or 43b rather than a roller 48. Another variant consists of using a trolley 9b that may be programmed with the frame 8 of the fourth embodiment of the invention.

The invention is not, of course, limited to the examples just described and many adjustments may be made to these examples without departing from the scope of the invention. In particular, the characteristics of different variants or different embodiments of the invention may be combined to achieve the invention, insofar as these variants or these embodiments are not mutually incompatible.

CLAIMS

1- A system (S1, S2, S3, S4, S5, S6) for welding a sealing plate (1) of a tank configured to contain liquefied gas to an anchoring plate (21, 22, 23), the sealing plate (1) and the anchoring plate (21, 22, 23) being metallic, the welding system (S1, S2, S3, S4, S5, S6) comprising a welding device comprising:

- a transparency welding tool (5) configured to perform at least one weld in a welding area,
- pressing means (4) for pressing the sealing plate (1) onto the anchoring plate (21, 22, 23), and
- control means (6) for controlling a force (F) exerted by the pressing means (4) on the sealing plate (1), able to detect a contact between the anchoring plate (21, 22, 23) and the sealing plate (1), and to act on the pressing means (4) as soon as a contact between the anchoring plate (21, 22, 23) and the sealing plate (1) is detected.

2- The welding system (S1, S2, S3, S4, S5, S6) according to claim 1, wherein the welding tool (5) is secured to the pressing means (4).

3- The welding system (S1, S2, S3, S4, S5, S6) according to claim 1 or 2, wherein the pressing means (4) comprise a pusher comprising a bearing surface defining a plane (P) configured to extend parallel to the welding area, and a cylinder (45), a head of which is secured to the pusher.

4- The welding system (S1, S2, S3, S4, S5, S6) according to claim 3, comprising protection means for thermally protecting the pusher.

5- The welding system (S1, S4, S5, S6) according to claim 3 or 4, wherein the pusher comprises at least one roller (48, 482).

6- The welding system (S2, S3) according to claim 3 or 4, wherein the pusher comprises at least one wedge (43, 43b) on which the welding tool (5) is able to slide parallel to the plane (P).

7- The welding system (S1, S2, S3, S4, S5, S6) according to any one of claims 3 to 6, wherein the control means (6) comprise means for stopping the pressing means (4) coupled

to means for detecting that a speed (V) of the cylinder (45) is less than a low speed threshold (Sb), or to means for detecting that a variation (ΔN) in a force exerted on the pusher is greater than a high force variation threshold (Sh), or again to means for detecting a variation in a metal thickness measurement.

8- The welding system (S4, S5, S6) according to any one of claims 1 to 7, comprising a frame (8, 8b, 8c) comprising at least one rail (86, 86b, 86c), and a sliding trolley (9, 9b) mounted on the rail (86, 86b, 86c), the welding device being attached to the trolley (9, 9b).

9- The welding system (S4) according to claim 8, wherein the sealing plate (1) comprises corrugations (12, 14), the frame (8) comprises means (84) for removable attachment to corrugations delimiting welding areas between them, the frame (8) forming a framework on which the rail (86) is arranged and an internal periphery of which is able to allow the welding tool (5) access to the welding areas.

10- The welding system (S5, S6) according to claim 8, wherein, first welding areas being aligned along a first axis (A1, A2), between a first end (17, 16) of the sealing plate (1) and a second end (19, 18) of the sealing plate (1), and second welding areas being aligned along a second axis (A2, A1), between a third end (16, 17) of the sealing plate (1) and a fourth end (18, 19) of the sealing plate (1), the rail (86b, 86c) is configured to allow the welding tool to process all the first welding areas when it is aligned along the first axis (A1, A2), the frame (8b, 8c) comprising removable attachment means (84b) capable of attaching at least one portion of the frame (8b, 8c) to a support external to the sealing plate (1).

11- The welding system (S5, S6) according to claim 10, comprising two welding devices attached to the trolley (9b) on either side of the rail (86b, 86c).

12- The welding system (S6) according to claim 10 or 11, comprising two arc-shaped guide members (85, 87), on each of which a separate end of the rail (86c) is mounted so as to slide, the guide members (85, 87) being capable of causing the rail (86c) to pass from a first configuration wherein the welding system (S6) is capable of processing all the first welding areas, to a second configuration wherein the welding system (S6) is capable of processing second welding areas.

13- A method for welding (100a) a sealing plate (1) of a tank configured to contain liquefied gas to an anchoring plate (21, 22, 23), using the welding system (S1, S2, S3, S4, S5, S6) according to one of claims 1 to 12, comprising the steps of:

- positioning (106) the pressing means (4) above the sealing plate (1) and the anchoring plate (21, 22, 23) to be welded,
- actuating (108) the pressing means (4),
- controlling (110a) a force (F) exerted by the pressing means (4) onto the sealing plate (1),
- locking (114a) the pressing means (4) as soon as a contact between the anchoring plate (21, 22, 23) and the sealing plate (1) is detected to maintain a contact between the anchoring plate (21, 22, 23) and the sealing plate (1), and
- welding (116a) by transparency the sealing plate (1) to the anchoring plate (21, 22, 23).