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Zondag

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[54] **METHODS AND DEVICE FOR WELDING A METAL PIPE TO A METAL BODY BY MEANS OF AN EXPLOSIVE CHARGE**

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[52] **U.S. Cl.** ..... **285/286,** 29/470.1, 228/3, 29/157.3 C, 29/157.4

[51] **Int. Cl.** **F16l 13/02**

[58] **Field of Search** .... 29/421 E, 470.1, 486, 497.5, 29/157.3 C, 157.4; 228/3; 285/286

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[57] **ABSTRACT**

A method for welding a metal pipe in a throughgoing boring of a metal body or the wall of a tube by means of the detonation of an explosive charge provided in said pipe and the use of a shielding plate positioned against said body or tube wall and having a hole which is rounded off towards said body or tube wall and forms an exact fit for said pipe which extends with clearance through the boring of the body or tube wall and

means for carrying out said method and comprising a shielding plate, an explosive charge and an igniter for firing said charge from the end thereof nearest to said shielding plate.

13 Claims, 8 Drawing Figures

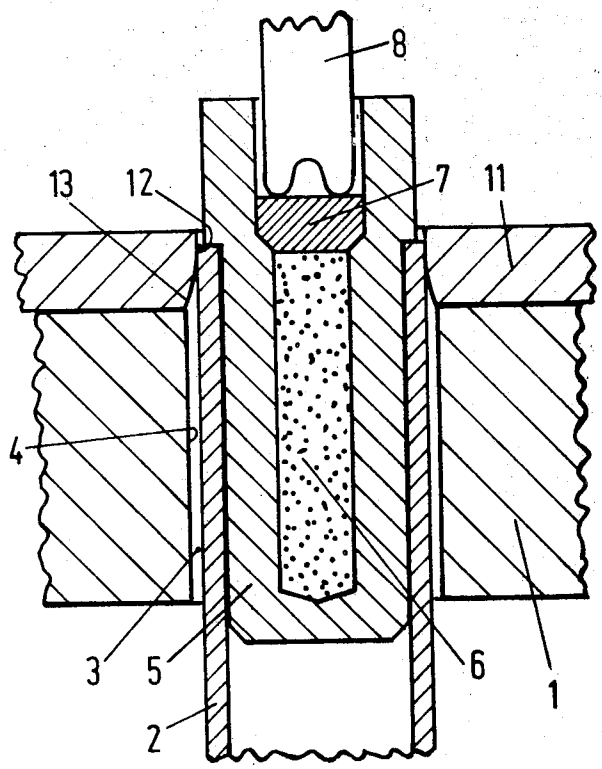


FIG.1

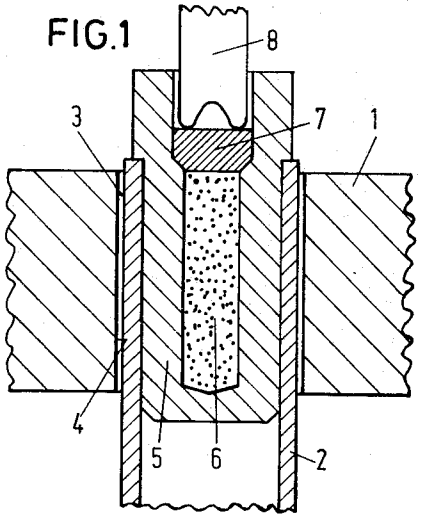


FIG.2

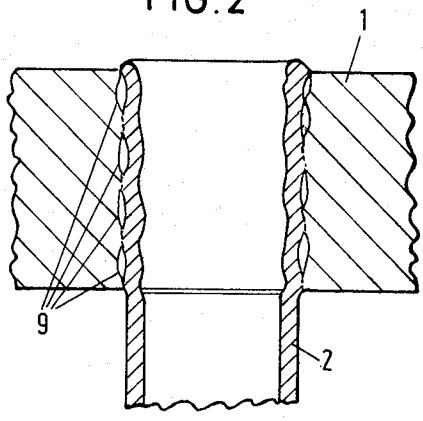


FIG.3

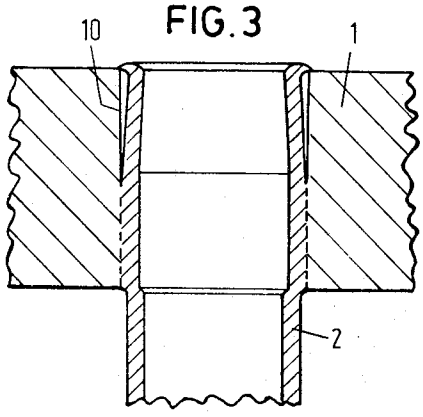


FIG.4

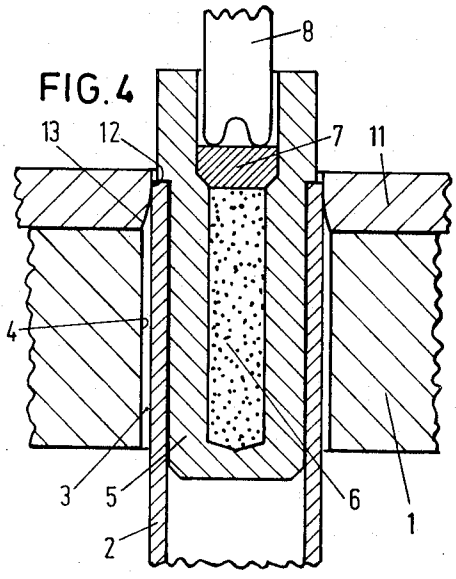


FIG. 5

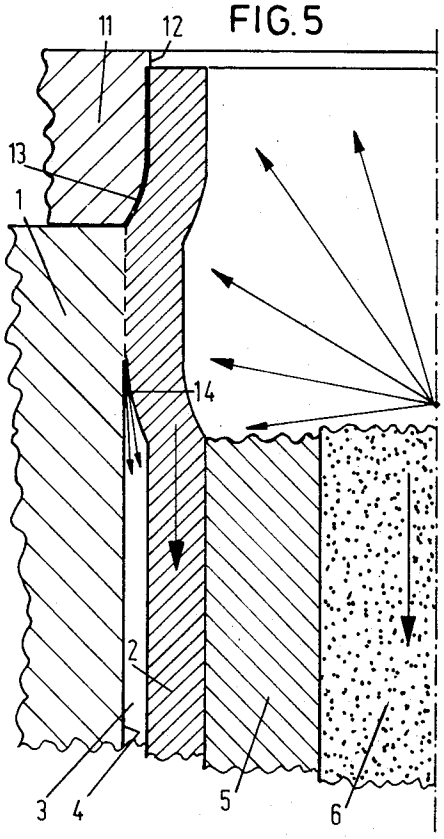


FIG. 6

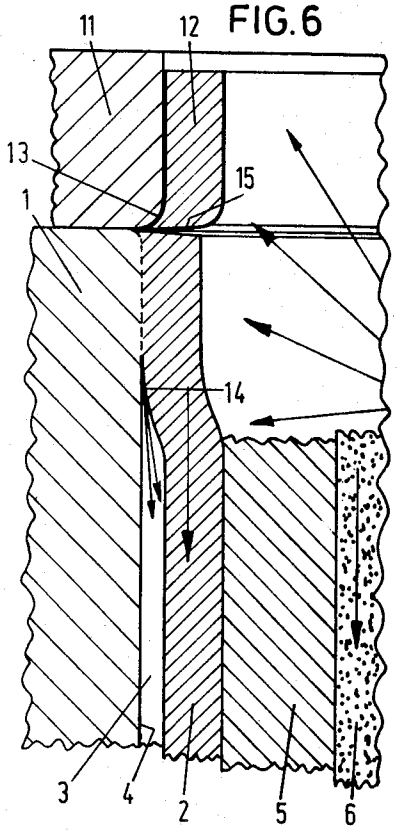


FIG. 7

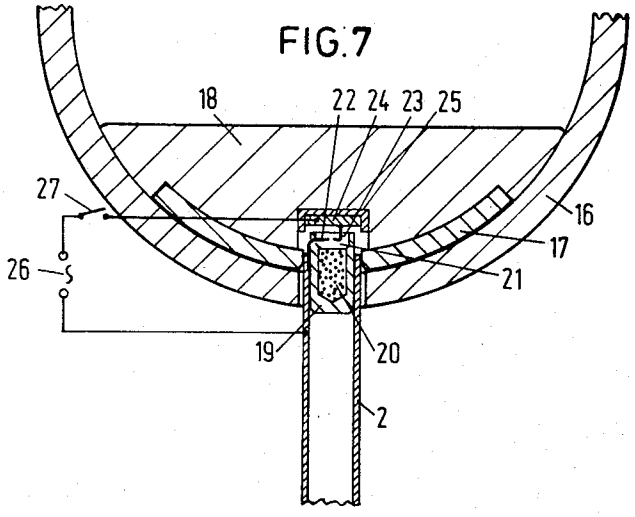
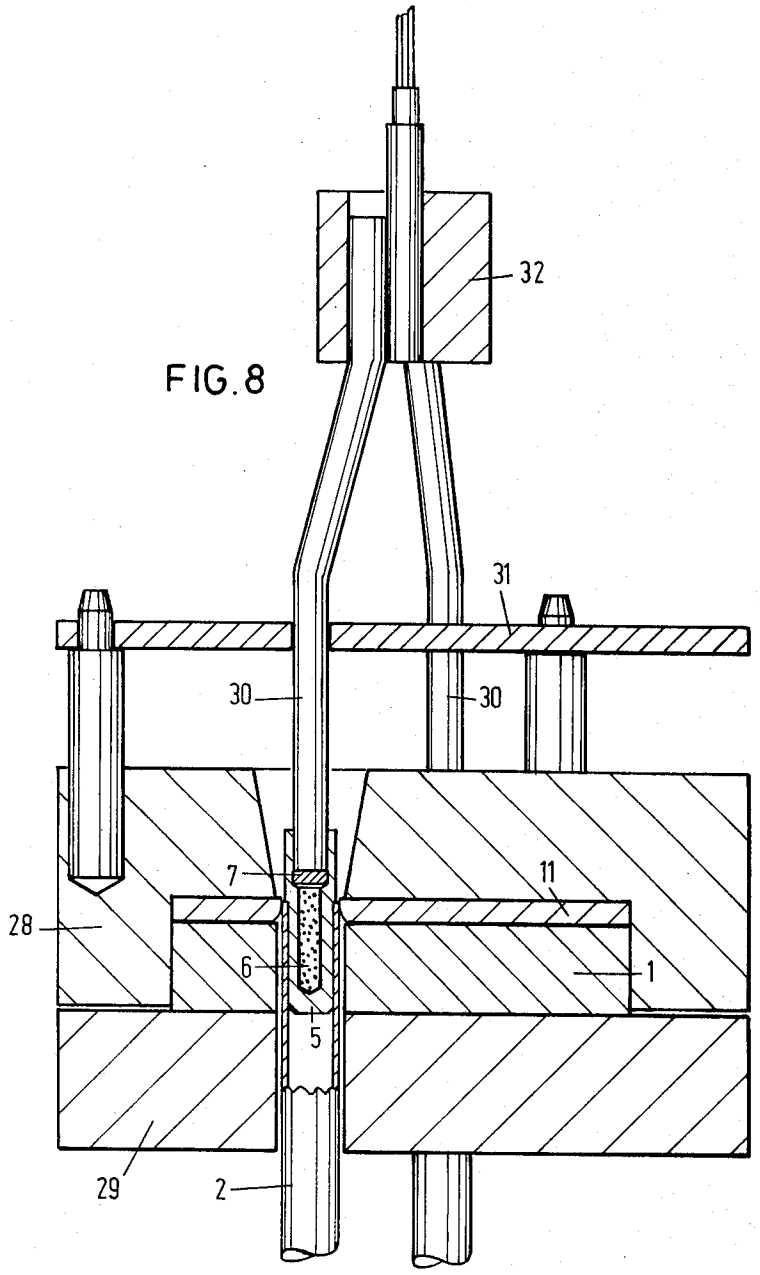


FIG. 8



METHODS AND DEVICE FOR WELDING A METAL PIPE TO A METAL BODY BY MEANS OF AN EXPLOSIVE CHARGE

The invention relates to a method and a device for welding a metal pipe to a metal body by means of an explosive charge, said pipe being inserted into a throughgoing boring of said body and having an outer diameter which is smaller than that of said boring and said charge extending within the pipe in the region of said boring and being adapted to be fired from the outside.

It has appeared that, when a metal pipe is placed in the centre of a somewhat wider boring of a metal body and an explosive charge accommodated in said pipe is fired, it is not possible to obtain, between the pipe and the body, a joint which is reliable in all places. The causes thereof appear to be mainly the presence of oxides and impurities on the surfaces of the pipe and the boring of the body and the difference between the velocity of the shock wave caused by the explosion and the speed of detonation of the explosive substance. If these velocities do not correspond, cavities are formed locally between the pipe and the body and, if the surfaces in question are not free from oxides and impurities, said oxides and impurities accumulate in said cavities. Thereby it is prevented that the material of the pipe is locally firmly welded to the material of the body. The joint is then unrealiable as far as the mechanical strength and the gastightness are concerned. It has also been found that, if an explosive substance is used, of which the detonation velocity differs only little from the velocity of the shock wave, that means from the velocity of sound in the metal of the pipe, and further measures are omitted, the joint will still have, in a portion of its length extending from the starting place of the detonation, a gap which may contain oxides and impurities. Should, in that case, the body in the place adjacent to the tube be relatively thin, e.g.., be the wall of a supply or a collecting tube, the risk is great that there remains no or insufficient length for a reliable joint.

The invention has the object to provide a method and a device for obtaining in a simple, quick and cheap manner a gastight gapless joint between the pipe and the body for the entire length of the boring of the body, so that not only in a thick body, into which the pipe has been inserted for a relatively great length but also in a thin body, e.g., a plate or the wall of a tube, a reliable weld can be formed between the body and the pipe. According to the invention this is achieved by the steps of placing a shielding plate having a boring with said boring in coaxial register with the boring of the body against a surface of the body, the boring of the shielding plate having a minimum diameter which is equal to the outer diameter of the pipe and being so rounded off at its edge adjacent to the body as to have in the surface facing the body a diameter which is at least equal to that of the boring of the body, said pipe with an end through the boring of the body and at least inserting it, with the said end into the fitting portion of the boring of the shielding plate, using an explosive charge which is provided in the pipe before or after the insertion of the latter into the body and the shielding plate extends throughout the entire or nearly the entire length of the boring of the body and to a place beyond the rounded off edge of the boring of the shielding plate, said charge being of such a composition that its velocity of detonation is substantially equal to the velocity of sound in the material of the pipe, and firing said charge from its end lying nearest to the shielding plate.

If one proceeds in this way, it appears first that after the start of the explosion the wall of the pipe is forced gradually, that means with a velocity equal to the velocity of detonation of the charge and, consequently, also equal to the velocity of sound in the material of the pipe, from the end of the charge contained in the shielding plate to the other end of the charge lying about in the surface of the body remote from the shielding plate against the wall of the boring of the shielding plate and thereafter against the wall of the boring of the body, and secondly, that the oxides and impurities found on the surfaces of the pipe and the borings of the shielding plate and the body remain in the region of the sheilding plate in the gap between said plate and the pipe due to the tight fitting of the pipe in the boring of the shielding plate and owing to the progressive angle, through which the pipe in the region opposite the rounded off edge of said boring is expanded, but are driven in the region of the body ahead of th detonation in the longitudinal direction of the pipe out of the boring of the body, so that between the pipe and the body a gapless gastight joint is formed which extends through the entire length of the boring of the body and is clear of oxides and impurities.

This manner of welding has various advantages. A method of cold welding is used in respect of thermal welding operations has the advantage that the crystal structure of the material of the pipe and that of the body are not changed. The weld extends without any gap throughout the entire length of the boring of the body, so that it is possible to weld pipes in borings of relatively thin plates or of the wall of a main tube. Such thin plates or such a tube wall may have a thickness of about half the outer pipe diameter. The pipes, the body and the shielding plate need not be made clear of oxides and impurities in the areas in question. The shielding plate is also used to centralize the pipe in the boring of the body. The welding method according to the invention is particularly adapted for welding thin pipes, that means pipes having a diameter which is smaller than 12 mm, in pipe-plates of heat exchangers or in the wall of main supply and collecting tubes. The pipes can be placed very close to one another. The pipes may project from both sides of the body and they can come to lie with their ends in a surface of the body without any finishing. Finally, the method is so simple that it can be carried out by unskilled people. As the pipe does not become attached to the shielding plate this plate can be easily removed.

If the pipe portion inserted into extending through the shielding plate must be retained a shielding plate may be used which has a boring, of which the rounded off edge has a radius of curvature which is equal to at least four times the thickness of the clearance between the pipe and the wall of the boring of the body and said rounded off edge blends tangentially with the rest of the wall of the boring of the shielding plate. The portion of the pipe projecting from the body towards the shielding plate is then bent over said rounded off edge without cracking.

If, however, it is required that the portion of the pipe extending in the shielding plate is torn off by the explosion from the pipe section extending in the body, it is

necessary to use a shielding plate, of which the boring has a rounded off edge, of which the radius of curvature is at least equal to one time and at the most equal to two and a half times the thickness of the clearance between the pipe and the wall of the boring of the body and which blends tangentially with the rest of the wall of the boring of the shielding plate.

If many pipes must be mounted close together in a pipe plate, it is possible to weld several of said pipes to said plate simultaneously. This is achieved by the steps of providing the explosive charge contained in each pipe with a fuse cord, passing the used fuse cords through fitting borings of a second shielding plate which is mountd at a short distance from the body and the first shielding plate, connecting said fuse cords to a common igniter provided outside the second shielding plate and firing all charges simultaneously with the aid of said igniter. The second sheilding plate prevents that the explosion of the fuse cords damages the first shielding plate and the body with the pipe ends projecting therefrom.

The method according to the invention may also be carried out by providing in the pipe end in question an explosive charge having its own electrical igniter, of which one connecting conductor is in contact with the pipe and the second connecting conductor is insulated from the pipe and projects from the end thereof, mounting a third electrical conductor on the side of the shielding plate remote from the body just behind the boring of said plate, said third conductor being insulated from the shielding plate, inserting the pipe with its end portion containing the charge and the igniter into the boring of the body and so far into the boring of the shielding plate as to bring the second connecting conductor of the igniter into contact with said third conductor and connecting the shielding plate and the third conductor, either before or after the insertion of the pipe, with a voltage supply. Should the voltage difference required for firing the charge already exist between the third conductor and the shielding plate, it would only be necessary to insert the pipe into the boring of the body and that of the shielding plate to fire the charge contained in the pipe.

Devices for carrying out the methods according to the invention will be described with the aid of the drawing. In the drawing:

FIG. 1 is, on an enlarged scale, an axial sectional view of a pipe inserted into a plate or a flange and containing an explosive charge,

FIG. 2 is, on an enlarged scale, an axial sectional view of the pipe inserted in the plate or the flange as shown in FIG. 1 after the detonation of the explosive charge thereof, when an explosive substance is used, of which the velocity of detonation is considerably greater than the velocity of sound in the material of the pipe,

FIG. 3 is, on an enlarged scale, an axial sectional view of the pipe inserted in the plate or the flange as shown in FIG. 1 after the detonation of the explosive charge, when an explsosive substance is used, of which the velocity of detonation is about equal to the velocity of sound in the material of the pipe,

FIG. 4 is, on an enlarged scale, an axial sectional view of a pipe, containing an explosive charge, said pipe being inserted through a plate or flange into a shielding plate placed thereon in the manner according to the invention,

FIG. 5 is, on a still larger scale, a part of an axial sectional view of the pipe shown in FIG. 4 and inserted through the plate or flange into the shielding plate during the detonation of the explosive charge, when a predetermined shielding plate is used and the explosive substance has a velocity of detonation which is about equal to the velocity of sound in the material of the pipe,

FIG. 6 is an axial sectional view as shown in FIG. 5, but therein a differently formed shielding plate is used,

FIG. 7 is, on a true scale, a sectional view of a device for explosively welding a pipe in the wall of a supply or collecting tube and

FIG. 8 is, on a true scale, a sectional view of a device for explosively welding several pipes in a pipe-flange of a heat exchanger simultaneously.

In FIGS. 1, 2 and 3 a pipe-flange of a heat exchanger is designated by 1. The pipes 2 must be welded to said flange in a gastight manner. In the present case this is achieved by means of an explosive charge. In FIG. 1 the pipe 2 is inserted with clearance 3 into a cylindrical boring 4 of the flange 1. In the end portion of the pipe 2 extending in said boring a snugly fitting plug 5 of synthetic subtance containing a explosive charge 6 and a firing chare 7 is inserted. A device for firing the firing charge is designated by 8.

It has appeared that, when for cold welding a pipe to a flange an explosive charge is used which has the usual composition necessary for the explosive deformation of the metal, the velocity of detonation of said charge is so much greater than the velocity of the shock wave produced in the metal of the pipe, that means than the velocity of sound in that metal, that an erratic shock field is produced in the wall of the pipe and cavities are formed beteen the pipe and the flange, into which the oxides and impurities which may be present on the surfaces of the pipe and the boring of the flange accumulate. In that case the joint between the pipe and the flange is often not gastight and it has small mechanical strength. The result of the joint obtained by such an explosion has been shown in FIG. 1, in which the cavities filled with oxides and impurities are indicated by 9. Should the surfaces to be welded to each other be cleaned well, which for instance is almost impossible when one deals with aluminium pipes and flanges, the result will not be better, since also in that case it cannot be prevented that cavities are formed between the pipe and the flange.

Furthermore it has appeared that, when the method shown in FIG. 1 is carried out and an explosive charge is used, of which the velocity of detonation is about equal to the mentioned velocity of sound, the result shown in FIG. 3 is obtained. In that case a gap 10 extending from the end of the pipe for a predetermined part of the weld length is produced, into which oxides and impurites, if present, accumulate. However, in the remaining part of the weld the joint becomes gapless and gastight. In said part of the joint the material is homogeneous, when the pipe and the flange are of the same metal, or a transition layer is produced, of which material behaves as an alloy, when the metals of the pipe and the flange differ. Such a joint could be used when the flange is thick in respect of the diameter ofthe pipe. However, such a joint is not reliable, since one cannot know for which length the gap 10 will extend. This length depends highly on the volume of the explosive charge, the ratio between the diameter and the

length thereof and on the diameter, the thickness of the wall and the material of the pipe

An ideal gapless weld which extends throughout the entire length of the boring of the flange is obtained, when one proceeds in the way shown in FIGS. **4, 5** and **6.** Therein a shielding plate **11** having a boring **12** is placed upon the flanage **1** with its boring in coaxial register with the boring **4** of the flange **1.** The diameter of the boring **12** is equal to the outer diameter of the pipe **2,** so that the latter exactly fits said boring. Thus, the shielding plate **11** is also used to centralize the pipe in the too wide boring **4** of the flange **1.** The edge of the boring **12** of the shielding plate **11** facing the flange is rounded off at **13,** in such a manner, that the rounded off edge **13** blends tangentially with the rest of the boring **12** and the latter has, in the surface of the shielding plate facing the flange a diameter which is at least equal to the diameter of the boring **4** of the flange **1.** In FIG. **4** it is not shown, how the shielding plate **11** is held on the flange **1.** This may be done by means of bolts, clamps or a holder. Provided in the plug **5** is an explosive charge **6,** of which the velocity of detonation is about equal to the velocity of sound in the wall of the pipe.

If the rounded off edge **13** has a radius of curvature, which is at least equal to four times the thickness of the clearance **3,** then what is shown in FIG. **5** will happen during the detonation. The detonation starts at the end of the pipe **2.** This end fits exactly in the boring **12** of the shielding plate **11,** so that it cannot expand. This makes that the layer of oxides and impurities cannot be blasted away so that it remains between the end portion of the pipe and the shielding plate. The same happens at the rounded off edge **13** as a result of the progressive blending of the pipe **2** caused by said edge. Owing thereto the shielding plate **11** and the pipe **2** will not become attached to each other, so that the removal of the shielding plate **11,** after the pipe has been welded to the flange, is easy. Below the rounded off edge **13** the pipe is forced with so much force and speed against the wall of the boring **4** of the flange that a firm joint is formed between the pipe and the flange. This joint spreads in the longitudinal direction of the boring **4** with the velocity of sound, that means with the velocity of the detonation which is equal thereto. It has furthermore appeared that all oxides and impurities are flung away with great force at **14,** that means ahead of the expanding weld, in the direction of the boring **4** of the flange **1** through the clearance space **3,** so that throughout the entire length of the boring **4,** that means throughout the entire thickness of the flange **1,** a clean joint is obtained. This joint is completely gapless and, if the pipe and the flange are of the same metal, it cannot be found back, since the material in the region of the joint has the same composition and substantially the same density as the material in the wall of the pipe and the flange. Then, the pipe and the flange form an integral metal body.

If the radius of curvature of the rounded off edge **13** is, as is shown in FIG. **6,** made at least equal to the thickness and at the most equal to 2½ times the thickness of the clearance **3** the pipe **2** will crack in the surface of the shielding plate **11** facing the flange **1** and will be torn off from its end portion inserted into the shielding plate, that means at **15.** After that the same happens during the detonation as when the method and the device shown in FIG. **5** are used.

If the radius of curvature of the rounded off portion **13** is smaller than the thickness of the clearance **3** the pipe will also crack, but the first of the joint between the pipe and flange will not become gapless, that means something as shown in FIG. **3** will occur.

The method illustrated in FIG. **6** is important for welding a pipe to the wall of a supply or collecting tube. This case is illustrated in FIG. **7.** Therein **16** is a tube of great diameter and in a boring of the wall thereof a thin pipe **2** is welded. The pipe **2** is inserted with its end portion through the too wide boring of the wall of the tube **16** into a fitting boring formed in a shielding plate **17** and provided with the required rounded off edge. The shielding plate **17** is supported by a block **18** which is fixed in the tube **16** in a manner not indicated. In the end portion of the pipe a plug **19** containing an explosive charge **20** is inserted. The velocity of detonation of said charge is again adapted to the velocity of sound in the wall of the pipe. Said plug also contains a fuse charge **21** which is provided with electrodes **22, 23** for the electric firing. The electrode **22** is connected to the wall of the pipe and the electrode **23** projects axially outwards from the fuse charge.

When the pipe **2** is placed into the borings of the tube **16** and the shielding plate **17** the electrode **23** is brought into contact with a conductor **24** which is mounted in the block **18** and insulated therefrom by an insulating layer **25.** The pipe **2** and the conductor **24** are connected with the terminals of a voltage supply **26.** Inserted in the connection between the voltage supply and the conductor **24** is a switch **27.** If the switch is closed the fuse charge **21** is ignited and owing thereto also the explosive charge **20** is fired, so that the pipe **2** is welded to the wall of the tube.

It is also possible to close the switch **27** previously, so that at the moment, at which during the insertion of the pipe **2** the electrode **23** contacts the conductor **24,** the firing takes place. In this way it is possible to weld quickly a number of pipes to the tube **16.**

The device shown in FIG. **8** is used for welding several pipes **2** to a pipe-flange **1** simultaneously. To that end the flange **1** and the shielding plate **11** are placed in a holder which consists of parts **28** and **29.** The part **29** itself may consist of parts in order to make it possible to remove the part **29** laterally after the welding operation has been carried out. This is necessary, when the part **29** cannot be slid lengthwise from the nest of pipes.

A fuse cord **30** is inserted into the upper end of each plug **5.** The fuse cords of all pipes **2** to be welded simultaneously are passed through fitting borings of a second shielding plate **31** which is positioned at some distance above the part **28** of the holder. These cords come together above said second shielding plate **31** in an igniter **32** which is common to all pipes. The second shielding plate **31** breaks the shock wave caused by the detonation of the fuse cords and prevents that the holder **28, 29** containing the flange **1,** the shielding plate **11** and the pipes **2** is damaged.

It is observed that the methods and the devices according to the invention are particularly suitable for welding thin pipes of aluminium, for instance pipes having an inner diameter smaller than 12 mm, to a body of aluminium or a harder metal. However, the pipes may also be of other metal, but this metal may not be harder than that of the body, to which the pipes must be welded. For pipes of aluminium having a diam-

eter of 12 mm at the most the thickness of the clearance will be about 0.4 mm. This thickness depends on the thickness of the wall, the diameter and the material of the pipes.

Although in the above specification reference has been made to the electric firing of the charge only, it is stated that firing by means of a percussion pin or firing in an other manner is also possible.

What I claim is:

1. A method for welding to a metal body having a throughgoing boring a metal pipe extending through said boring and having an outer diameter which is smaller than that of said boring, said welding being effected with the aid of an explosive charge extending within said pipe in the region of said boring and adapted to be fired from the outside, said method comprising the steps of placing a shielding plate having a boring with its boring in coaxial register with the boring of the body against a surface of the body, the boring of the shielding plate having a diameter which is equal to the outer diameter of the pipe so that the pipe fits the boring and being so rounded off at its edge adjacent to the body as to have in the surface facing the body a diameter which is at least equal to that of the boring of the body, passing said pipe with an end thereof through the boring of the body and at least inserting said pipe with that end into the fitting portion of the boring of the shielding plate, inserting before or after the insertion of the pipe into the body and the shielding plate an explosive charge having a composition, of which the velocity of detonation is substantially equal to the velocity of sound in the material of the pipe, into the pipe end portion extending in the body and the shielding plate and firing said charge from its end lying nearest to the shielding plate.

2. A method as claimed in claim 1 for welding to a body a pipe which after the welding process projects from both sides of the body, said method comprising the step of using a shielding plate provided with a boring, of which the rounded off edge has a radius of curvature which is at least equal to four times the thickness of the clearance space between the pipe and the surface of the boring of the body and said rounded off edge blends tangentially with the rest of the surface of the boring of the shielding plate.

3. A method as claimed in claim 1 for welding to a body a pipe which after the welding process ends flush with the surface of the body remote from the rest of the pipe, said method comprising the step of using a shielding plate provided with a boring, of which the rounded off edge has a radius of curvature which is at least equal to one time and at the most equal to 2½ times the thickness of the clearance space between the pipe and the surface of the boring of the boring of the body and said rounded off edge blends tangentaially with the rest of the surface of the boring of the shielding plate.

4. A method as claimed in claim 1 for welding several pipes to a body simultaneously said method comprising the steps of inserting in each explosive charge contained in a pipe a fuse cord, mounting a second shielding plate having borings, in each one of which a fuse cord fits, at some distance from the first shielding plate, passing the fuse cords of all pipes in question through the borings of the second shielding plate, inserting the other ends of said fuse cords into a common igniter and firing said igniter.

5. A method as claimed 1, comprising the steps of providing the pipe end portion in question with an explosive charge and an electrical igniter, of which one connecting conductor is connected to the pipe and the second connecting conductor is insulated from the pipe and so directed as to protrude from the end of the pipe, mounting a third electrical conductor on the side of the shielding plate remote from the body just behind the boring of said plate and insulating said third conductor from the shielding plate, inserting the pipe with its end portion containing the explosive charge and the igniter through the boring of the body and so far into the boring of the shielding plate as to bring the second connecting conductor of the igniter into contact with said third conductor and connecting, either before or after the insertion of the pipe, the pipe and the third conductor with the terminals of a voltage supply.

6. A device for carrying out the method as claimed in claim 1, comprising a shielding plate provided with at least one boring having a rounded off edge and a diameter which is equal to the outer diameter of a pipe to be welded to a body in a boring thereof, of which the diameter is slightly greater than said outer pipe diameter, a holder for holding the shielding plate with its boring in coaxial register with the boring of said body and a plug fitting in said pipe and containing an explosive charge and means for firing same.

7. A device for carrying out the method as claimed in claim 4, comprising a shielding plate provided with at least two borings each having a rounded off edge and a diameter which is equal to the outer diameter of a pipe to be welded to a body in a boring thereof, of which the diameter is slightly greater than said outer pipe diameter, a holder for holding the shielding plate with its borings in coaxial register with the borings of the body, plugs fitting in said pipes and each containing an explosive charge, fuse cords adapted to be connected with their one ends to said explosive charges, a second shielding plate having borings for letting said fuse cords pass through said second shielding plate, said second shielding plate being attached to the holder at some distance from the first shielding plate and a common igniter adapted to be connected to the other ends of all fuse cords.

8. A device for carrying out the method as claimed in claim 5, comprising a shielding plate provided with at least one boring having a rounded off edge and a diameter which is equal to the outer diameter of a pipe to be welded to a body in a boring thereof, of which the diameter is slightly greater than said outer diameter, a holder for holding the shielding plate with its boring in coaxial register with the boring of said body, an explosive charge, an electrical igniter, a plug containing said charge and said igniter and fitting in said pipe, one connecting conductor of said igniter projecting from the sides surface and the second connecting conductor projecting from the end surface of said plug, a third conductor which is insulated from the holder and the shielding plate and mounted on the side of the shielding plate remote from the body, said third conductor haaving a bare area, where it crosses the boring of the shielding plate, a voltage supply and means for the electric connection of the pipe inserted into the boring of the shielding plate on one hand and said third conductor on the other hand with said voltage supply.

9. A metal body with at least one pipe which is welded thereto in a boring thereof, the joint between

said body and said pipe being obtained with the method as claimed in claim **1**.

10. A metal body with at least one pipe which is welded thereto in a boring thereof, the joint between said body and said pipe being obtained with the method as claimed in claim **2**.

11. A metal body with at least one pipe which is welded thereto in a boring thereof, the joint between said body and said pipe being obtained with the method as claimed in claim **3**.

12. A metal body with at least one pipe which is welded thereto in a boring thereof, the joint between said body and said pipe obtained with the method as claimed in claim **4**.

13. A metal body with at least one pipe which is welded thereto in a boring therof, the joint between said body and said pipe being obtained with the method as claimed in claim **5**.

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