United States Patent

[11] **3,578,233**

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[73] Assignee **Shell Oil Company New York, N.Y.**

[54] **APPARATUS FOR REMOTELY JOINING UNDERWATER PIPELINES**
24 Claims, 16 Drawing Figs.

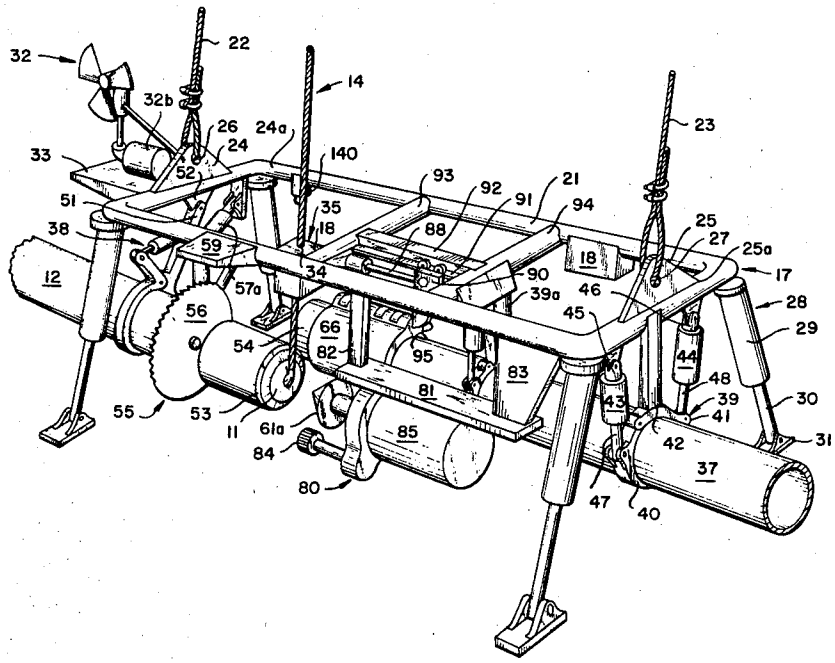
[52] **U.S. Cl.** **228/5,** 29/493, 61/72.5, 228/4, 228/44, 228/49, 269/58
[51] **Int. Cl.** **B23k 1/20**
[50] **Field of Search** 228/4, 5, 6, 44, 49; 219/72, 101, 160; 61/72.1, 72.5, 72.7; 269/58, 287; 29/234

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ABSTRACT: A technique for joining pipelines underwater comprising joint preparation and completion apparatus that is either remotely operated or automatically sequenced. The apparatus is adapted to be used with three alternate embodiments of joining means: (1) a mechanical connection, (2) thermit welding, or (3) a combination of explosive-forming and mechanical joining.



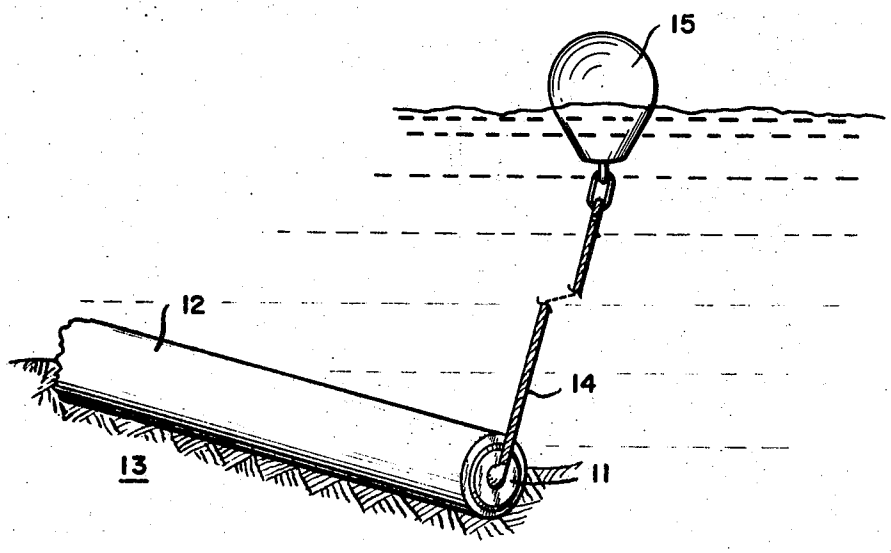


FIG. 1

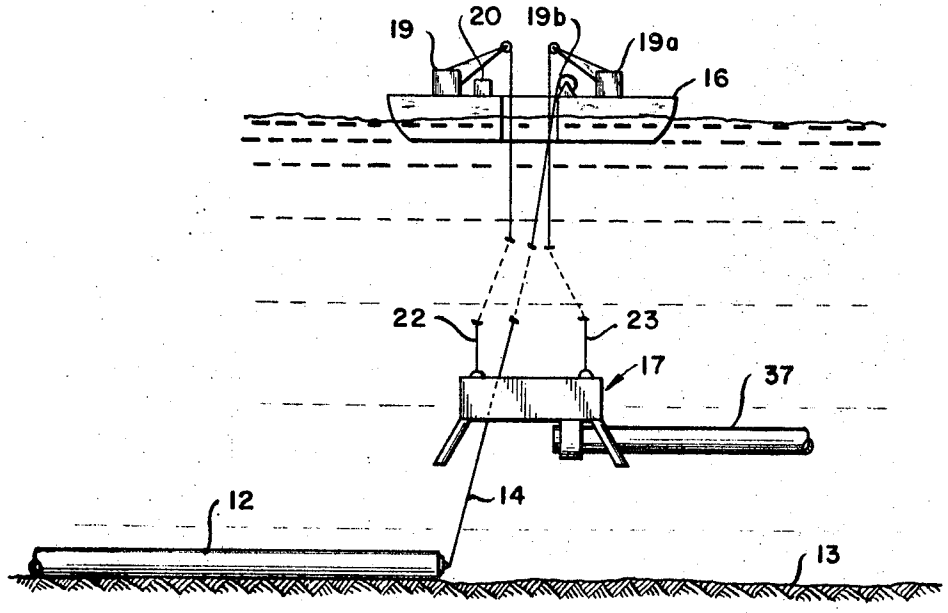


FIG. 1A

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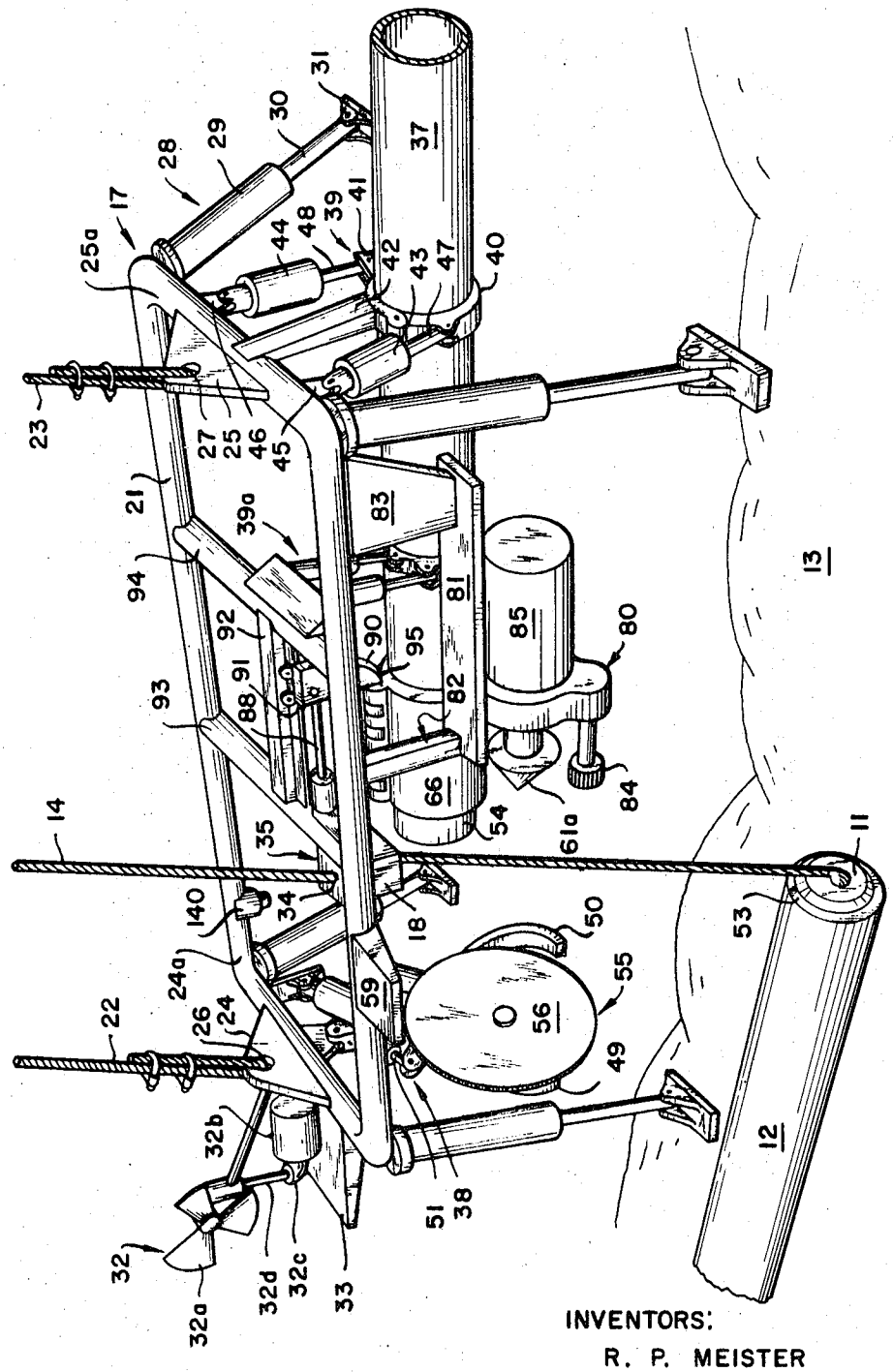


FIG. 2

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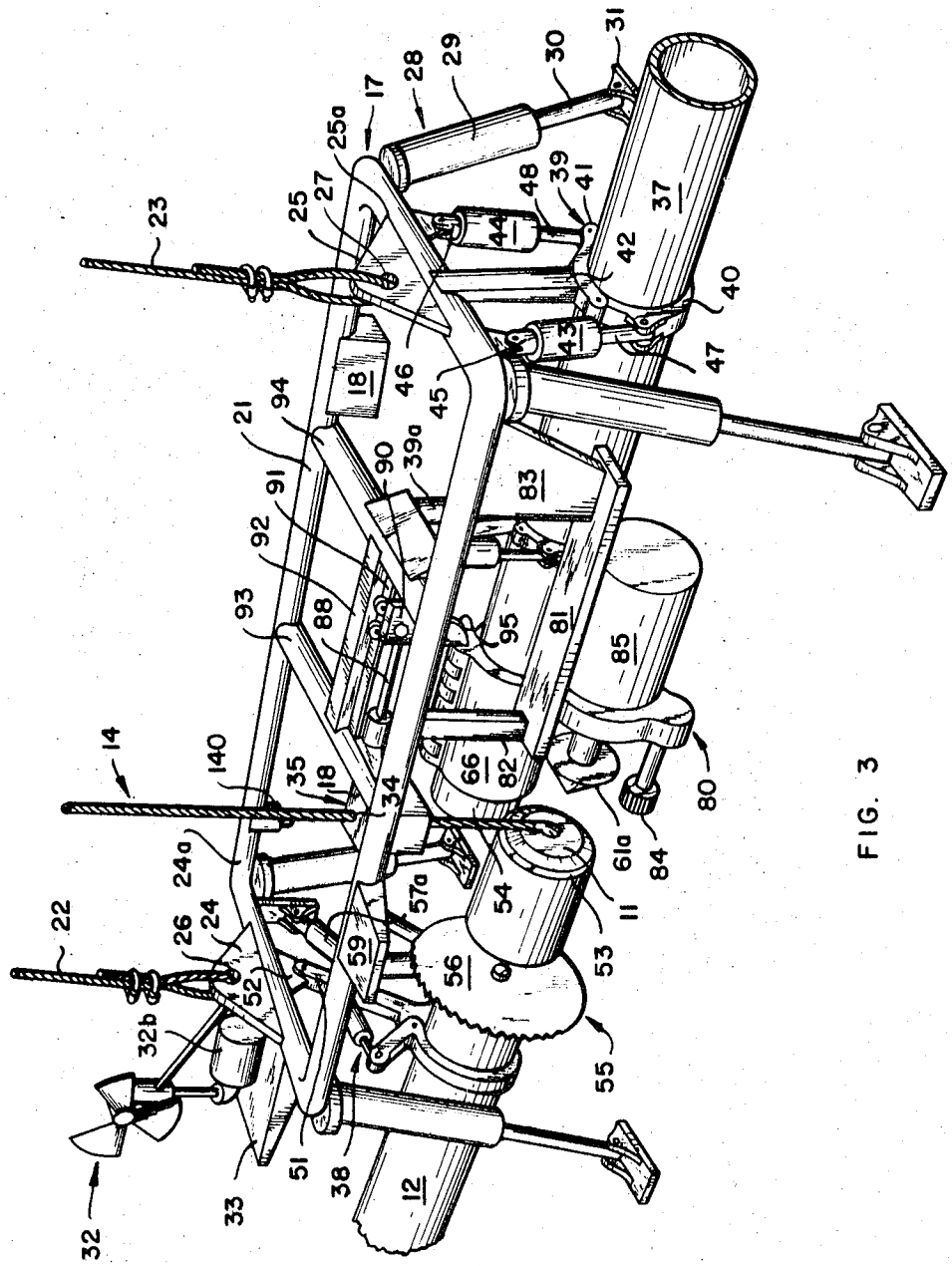


FIG. 3

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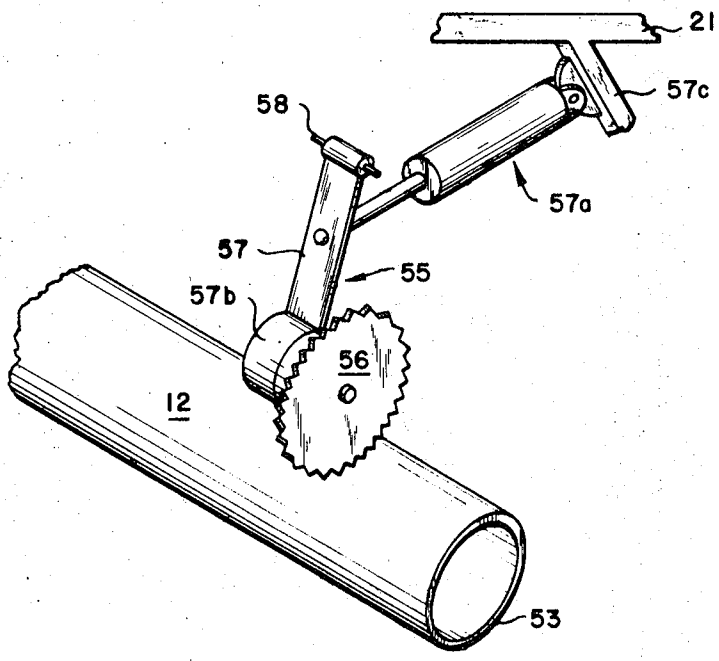


FIG. 4

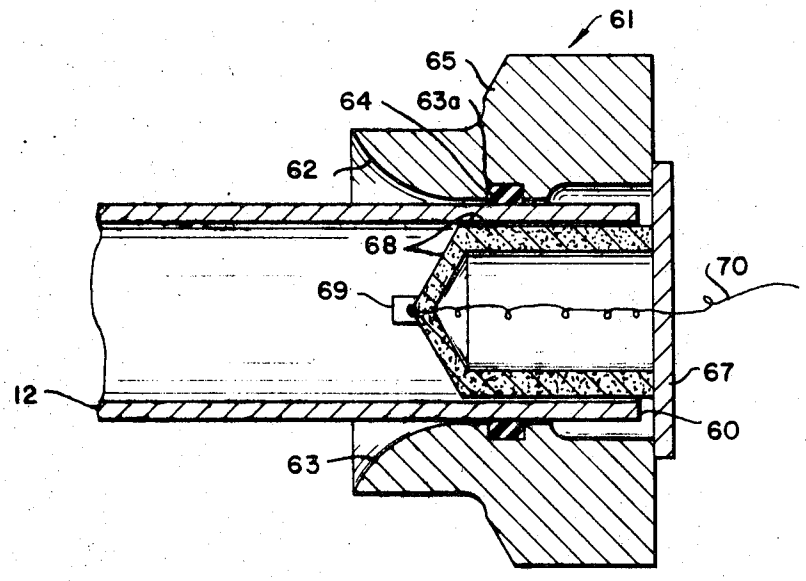


FIG. 5

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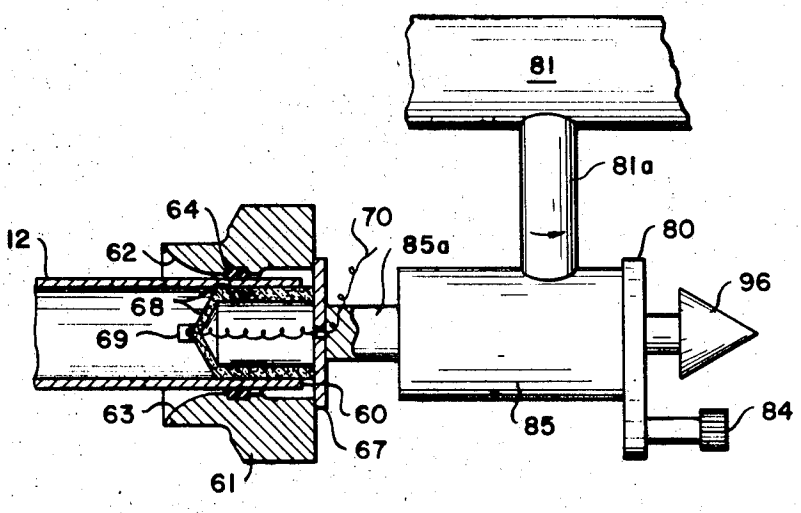


FIG. 5A

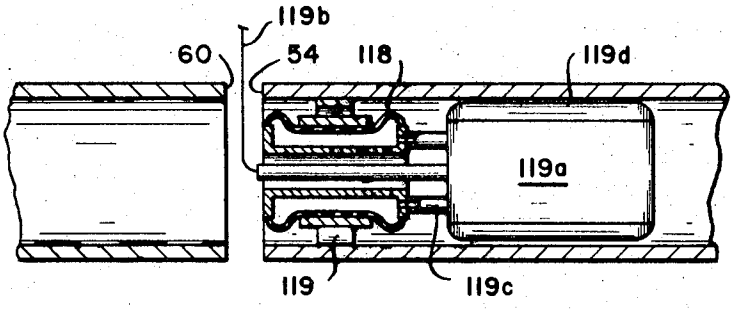


FIG. 9A

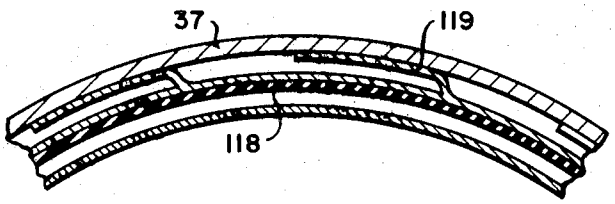


FIG. 9B

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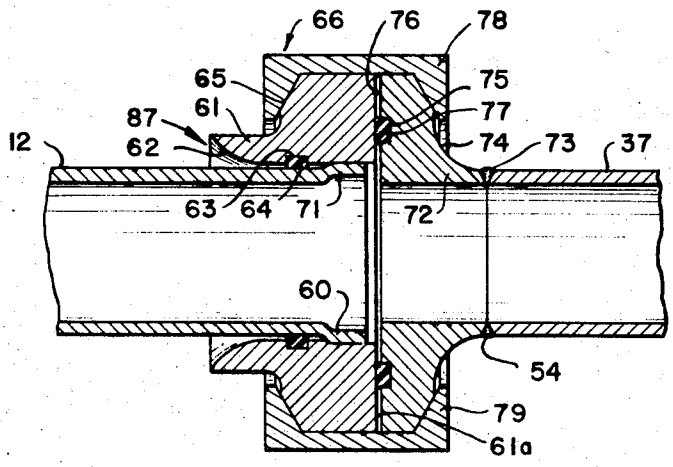


FIG. 6

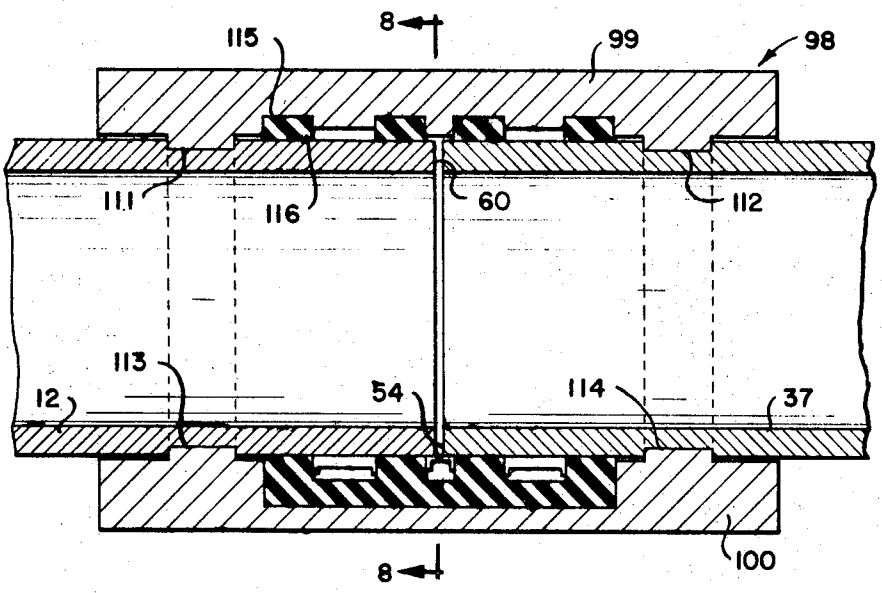


FIG. 7

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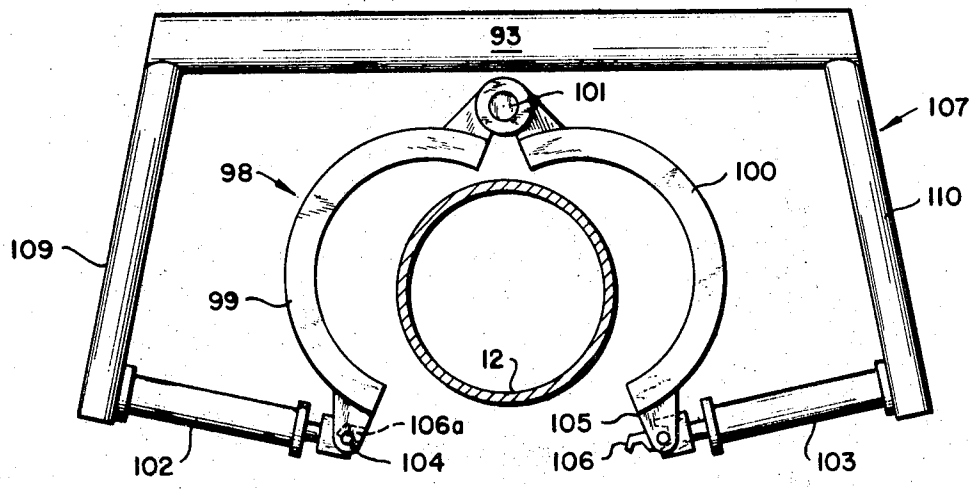


FIG. 8

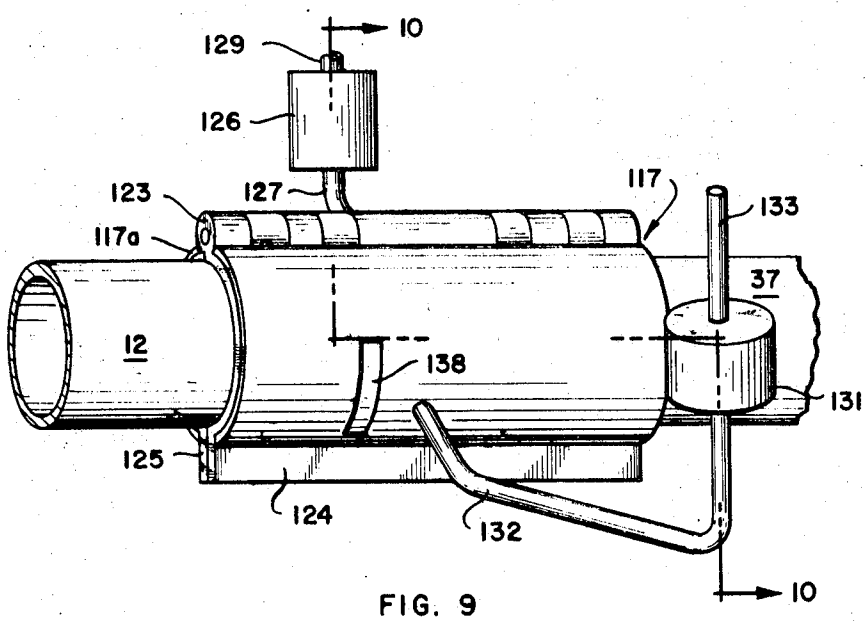


FIG. 9

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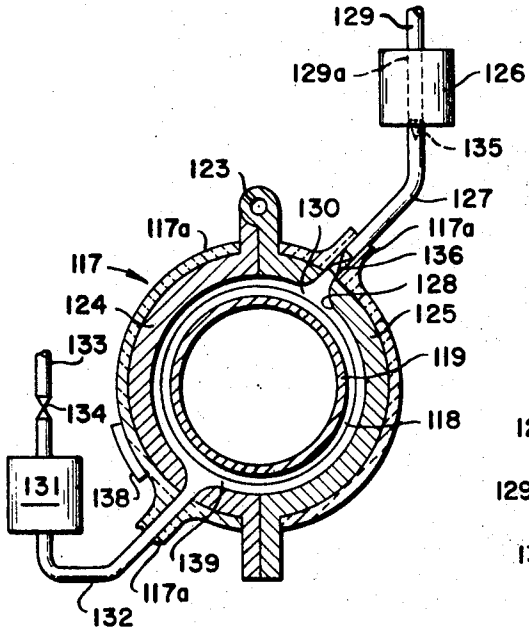


FIG. 10

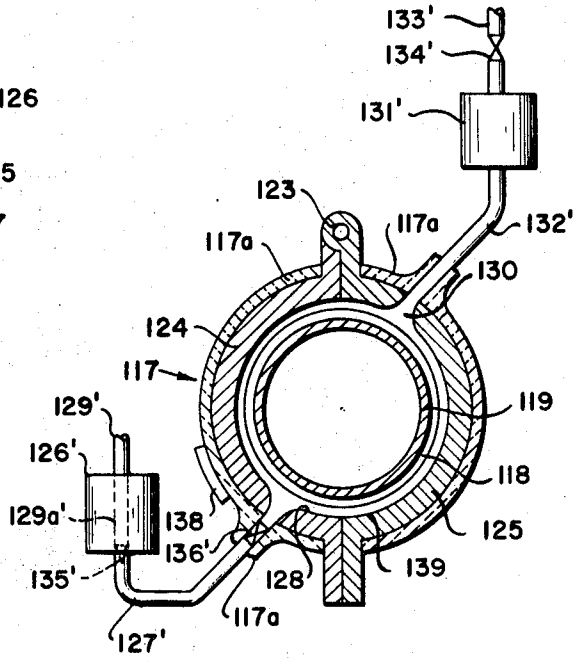


FIG. 12

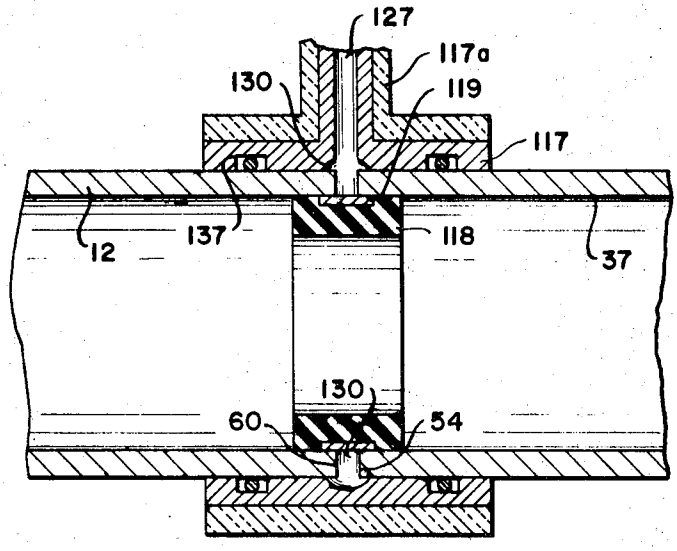


FIG. 11

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APPARATUS FOR REMOTELY JOINING UNDERWATER PIPELINES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to underwater pipe laying and more specifically to a technique for joining pipelines underwater.

2. Description of the Prior Art

In laying pipelines underwater, it is difficult to place and join pipelines accurately. With the pipe sections slung from cranes or the like, the operation must either be carried out by divers, or remotely controlled from the surface, or the pipe sections can be preassembled on the surface and lowered into place. Numerous divers would be required to handle large pipes and would be working under difficult conditions, while remote control would be practical only in shallow water, all of these systems being adversely affected by rough water or currents. Preassembling pipe sections on the surface would simplify the proper sealing of the joints, but lowering the assembled pipes onto a possible uneven surface below water would, in most cases, break the joints and damage the pipes.

The discovery and recovery of offshore oil and gas deposits continues to be of increasing and vital interest. These activities have been in progress for many years, but primarily at relatively shallow depths. Deeper water operations have increased the need for reliable techniques for joining pipelines at depths of 1,000 feet and deeper.

Since many of the underwater locations are at depths at which divers cannot operate or at which it is uneconomical to utilize divers, relatively complicated remote control and surveillance systems would have to be designed in order to produce satisfactory results with the conventionally used welding techniques. Such complicated remote control and surveillance equipment is both expensive to build and to maintain. At this time, there is no present capability for making pipe joints at 1,000 feet or more depths.

SUMMARY OF THE INVENTION

It is an object of this invention to join pipelines underwater at depths in excess of those prohibitive to divers.

It is a further object to remotely join pipelines underwater without any direct manual operation which would require divers operating either in the sea environment or in a chamber.

The invention is carried out by attaching a joining manipulator to the end of one pipeline and lowering that end to the sea floor at a point adjacent a pipeline already on the sea floor. The manipulator then lines up the pipelines ends, cuts the pipeline to which the manipulator is attached to the proper length, and joins the pipeline ends. The joint is formed by any one of three or more methods; thermit welding, mechanical joint using a split-sleeve, tang-groove coupling, or an explosive-mechanical joint. In all embodiments, these operations are carried out on the sea floor by either remote control from the surface or automatic sequential operation.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is an isometric perspective view of a preferred method of marking the end of an ocean-floor pipeline;

FIG. **1***a* is a diagrammatic view illustrating the pipe-engaging apparatus of the present invention being lowered through a body of water together with an end of a pipeline;

FIG. **2** is an isometric perspective view of apparatus of the present invention positioned in the water for carrying out the preferred embodiment of the invention;

FIG. **3** is an isometric perspective view of the apparatus of FIG. **2** in operative position;

FIG. **4** is an isometric perspective view of a detail of the apparatus of FIGS. **2** and **3** in operation with parts broken away;

FIG. **5** is a vertical sectional view of a method of preparing one of the pipelines adapted to be joined for engagement with another pipeline;

FIG. **5***a* is a partial vertical sectional view of a detail of the embodiment of FIG. **5**;

FIG. **6** is a vertical sectional view showing the pipeline of FIG. **5** after preparation joined to another pipeline;

FIG. **7** is a vertical sectional view of an alternate joint for joining the pipelines of FIGS. **1** through **6**;

FIG. **8** is a view taken along line VIII–VIII of FIG. **7**;

FIG. **9** is an isometric view of further joint embodiment for joining the pipelines of FIGS. **1** through **6**;

FIG. **9***a* is a vertical sectional view of the joint of FIG. **9**;

FIG. **9***b* is a detailed view of a portion of FIG. **9***a* after the joint of FIG. **9** has been formed;

FIG. **10** is a view taken along line X–X of FIG. **9**;

FIG. **11** is a vertical sectional view of the joint embodiment of FIGS. **9** and **10**; and

FIG. **12** is an end view of a further modification of the joint embodiment of FIGS. **9** through **11**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing, FIG. **1** shows the method of buoying off one pipeline for subsequent joining to a second pipeline. A variety of methods can be used to bring the pipelines into adjacent relationship. One such method is disclosed in a copending application Ser. No. 738,531, filed June 20, 1968, to Hammett. In this application, the underwater position of a first pipeline is marked visible from the surface. A second pipeline is drawn into position close to the marker for the first pipeline. The free end of the second pipeline is prepared for joining to the first pipeline, if required, and manipulating and joining apparatus is attached to the free end of the second pipeline. Using a guideline from the first pipeline, the second pipeline, together with the manipulating and joining apparatus, is lowered into overlapping position with respect to the first pipeline. Accordingly, the present invention is concerned with the actual joining of the pipelines and not how to arrange the pipelines in juxtaposed relation to one another.

Although various homing or ranging systems may be utilized to guide the manipulating apparatus and the attached prepared pipe end from a point on the sea surface to a point 1,000 feet or more below on the sea floor, FIGS. **1** and **1***a* illustrate the preferred method for carrying out the concepts of the invention.

As shown in FIG. **1**, a pig **11** is pumped along a submerged pipeline **12** which may, for example, extend from shore. The pipeline **12** rests on the sea bottom **13** and pig **11**, adapted to stop at the end of pipeline **12** by means well known in the art, releases a line **14** having a buoy **15** attached thereto. The line **14** is then picked up by a pipe lay large **16** (FIG. **1***a*) and tensioned, as, for example, by a block and counterweight or submerged buoy, to provide a straight-line guide to the submerged pipeline end; or, the line is used as a messenger to attach a cable of greater strength. Using the method suggested in application Ser. No. 738,531 to lay the pipelines would eliminate the necessity for further marking the pipeline **12** extending from the wellhead.

A suggested method for stopping pig **11** at the end of pipeline **12** is to provide pig **11** with one or more fingers spring-loaded against the inside of pipeline **12**. These fingers would be placed on the forward end of pig **11**. When the pig **11** reaches the end of pipeline **12**, the finger or fingers expand outward releasing a catch which in turn actuates spring or hydraulically loaded shoes which extend outward to bear on the inside wall of pipeline **12** and act as a brake or brakes to stop pig **11**. This same mechanism releases the buoy **15** which rises to the surface carrying line **14**. Buoy **15** may be inflated prior to release, if desired. This feature is discussed in detail in a copending application Ser. No. 783,923, filed Dec. 16, 1968 to McCarron. Of course, in the absence of such apparatus, divers may be used to guide the apparatus **17** into position with pipeline **12**.

The manipulating apparatus **17** (FIG. **2**) comprises a conventional cooperating guide mechanism **18** for engaging the

guide wire **14** during the lowering of the manipulating apparatus **17** to the ocean floor. For example, winches **19** and **19***a*, on lay barge **16**, are adapted to carry the new pipe end into contact with the submerged end in the manner suggested in application Ser. No. 738,531. Winches **19** and **19***a* are remotely actuated by suitable control equipment **20** on barge **16** as is well known in the art.

Turning more particularly to FIG. 2, the manipulating apparatus **17** comprises a rectangular frame **21** having a pair of triangular plates **24** and **25** integrally formed or otherwise attached to the short ends **24***a* and **25***a*, respectively, of frame **21**. Guide cables **22** and **23** pass through holes **26** and **27** formed in plates **24** and **25**, respectively, and are suitably fastened to plates **24** and **25**, as can best be seen in FIG. **2**. Guide cables **22** and **23** operatively engage winches **19** and **19***a* (FIG. 1*a*), respectively, on barge **16** for raising and lowering apparatus **17**. Cables **22** and **23**, or at least one of the guide cables **22** and **23**, may be a weight-supporting and power-transmitting cable for supplying power to the various components of apparatus **17**; or it may contain flexible hoses carrying compressed gas and/or liquid for supplying power to the components of apparatus **17**.

As can best be seen in FIG. 1*a*, the line wire **14** coupled to submerged pipeline **12** is released from buoy **15** and the free end thereof is passed through a guide hole **34** in the guide element **18** of the manipulating apparatus **17** at the barge **16**.

The line wire **14** is then tensioned, as, for example, by winch **19***b*, and the manipulating apparatus **17**, having new pipeline **37** attached thereto, is lowered by winches **19** and **19***a* on barge **16** into contact with pipeline **12**.

Manipulating apparatus **17** is adapted to rest on the sea bottom **13** by means of four legs **28** extending outwardly at an angle at each corner of rectangular frame **21**. Each leg **28** may comprise a hydraulic cylinder **29** having an extensible piston arm **30** slidably and adjustably mounted therein. Arm **30** is pivotally attached to a baseplate **31** adapted to rest on the sea bottom **13**. In this manner, legs **28** automatically compensate for the terrain of the sea bottom **13** and permit the apparatus **17** to rest in a substantially horizontal upright position on sea bottom **13**. Thus, when released by remote operation from the surface, arm **30** extends until it contacts the sea bottom **13**. If it is desirable to assume a more nearly horizontal attitude, an attitude sensor (not shown) on apparatus **17** may be used to regulate extension of the arms **30** to assure horizontal position.

A propulsion unit **32** is preferably mounted on a plate **33** integral with frame **21** for selectively driving apparatus **17**. Propulsion unit **32** preferably comprises a propeller **32***a* driven by a reversible motor **32***b* operatively engaging control equipment **20** by means not shown. Propeller **32***a* is pivotally mounted in socket **32***c* and turnable therein, as, for example, through control rod **32***d*, so as to vary the position of the propeller **32***a* and thus the direction of motion of apparatus **17**. A sensor head (not shown) on apparatus **17** may be used to sense the position of line wire **14** in the guide hole **34** of guide element **18**. This sends guidance information to lowering and propulsion unit operators on the surface. Based on this guidance information, the movement of rod **32***d* may be remotely activated through mechanical, electrical or hydraulic means to adjust the position of the propulsion unit **32**. Alternatively, a closed-loop fully automatic system in control equipment **20** may be operated off of the signals from guide element **18**, if desired. Thus, the movement of rod **32***d* can be remotely actuated through means (not shown) operatively engaging surface control equipment **20**.

A pair of hydraulic clamps **38** and **39** serve to retain pipes **12** and **37**, respectively, in position on the apparatus **17**. Clamp **39**, similar to clamp **38**, comprises a pair of semicircular sections **40**, **41**, hinged to the short portion of a substantially inverted T-shaped mounting bar **42** integral with frame **21**. A pair of hydraulic cylinders **43** and **44** are pivotally attached, respectively, to mounting brackets **45** and **46** integral with frame **21**. Extensible piston arms **47** and **48** are slidably mounted in cylinders **43**, **44**, and **41**, respectively, and pivotally attached at their free ends to sections **40** and **41**, respectively. In this manner, the pipeline **37**, adapted to be joined to pipeline **12**, can be loaded on manipulating apparatus **17** prior to being lowered to the sea bottom **13** by means of winches **19** and **19***a* and guide cables **22** and **23**. At the same time, wire **14**, attached to pig **11** within pipeline **12**, is drawn through the hole **34** in housing **35** so as to substantially align the free ends **53** and **54**, respectively, of pipelines **12** and **37**. If desired, a second clamp **39***a*, similar to clamp **39**, may be used to hold pipeline **37** in place.

The tension necessary for proper laying of the pipeline **37** may be as much as 200,000 pounds or more, thus making automatically guided self-propulsion through propulsion unit **32** of the manipulating apparatus **17** highly impractical. Accordingly, tugs, anchors, winches, and heavy hoists may be additionally necessary for manipulating apparatus **17**.

Thus, as can be seen in FIG. **2**, apparatus **17** is lowered to the sea bottom **13** along wire **14** until pipeline **12** abuts against hinged arms or sections **49**, **50**, normally in open position, of hydraulic clamp **38**. As can be best seen in FIG. **3**, the hydraulic cylinders of clamp **38** (only one of which is visible in FIGS. **2** and **3**) are then actuated to close sections **49**, **50** and thereby grip pipeline **12**. Clamp **38** is similar to previously described clamp **39** excepting that the L-shaped mounting bar **51** of clamp **38** is hinged at **52** so as to permit swinging of pipeline **12** into alignment with pipeline **37** after end **53** is sawed off. The positioning of apparatus **17** on pipeline **12** is accomplished by guidance of the apparatus **17** through line wire **14** and the sensing system as discussed hereinabove. Final positioning of apparatus **17** is accomplished by the gripping action of clamp **38**.

Once manipulating apparatus **17** is guided into contact with the submerged pipeline **12** on the sea bottom **13**, a known orientation must be established between the end **53** of pipeline **12** and the apparatus **17**, the relationship between the apparatus **17** and the end **54** of pipeline **37** having been preestablished on the surface. This is accomplished by either moving the apparatus **17**, the submerged end **53**, or both.

Preferably, the apparatus **17** is lowered down the tensioned guide wire **14** to the pipeline end **53** but with an attitude only approximately known with respect to the submerged pipeline end **53**. The azimuth alignment of the parts is governed by compass headings and buoy sightings maintained during laying of the lines. The fore-and-aft (i.e. pitch) attitude is influenced by the contour of the sea bottom **13** and other factors, but, for submarine topographies selected for pipelines laying, will be reasonably close to horizontal. Thus, given reasonable limits of relative angular attitude, the powerful hydraulic clamp **38** on the manipulating apparatus **17** contacts the submerged pipe end **53** and forces parallel offset alignment of pipe ends **53** and **54**.

This orientation function results in motion of both the submerged end **53** and the apparatus **17**, the final attitude of which has no affect on subsequent operations, although the widely spaced legs **28** aid in keeping the apparatus **17** nearly level.

Suitable connecting means couples all the hydraulic clamps and other mechanisms herein disclosed to the surface control equipment **20**. For example, hydraulic conduits may extend from the various hydraulically actuated clamps passing into a hydraulic multiconduit cable which, as discussed above, may form one or both of the hoisting guide cables **22** and **23**. Like electrical connection may also be provided between the various motors on frame **17** and control equipment **20**. Suitable connection is also provided between the cables and the control equipment **20** on barge **16**. The connections between the clamps, motors and cables may, for example, pass through various portions of frame **17** which may be hollow for this purpose. In this regard, additional cables may be provided for supplying power to the apparatus **17** in addition to cables **22** and **23**.

A cutting unit 55 is pivotally mounted on frame 21. Unit 55 is shown in detail in FIG. 4. Cutting unit 55 preferably comprises a cutting blade 56 fixed to an operating arm 57. Arm 57 is pivotally attached at pivot 58 to the underside of a bracket 59 (actual connection not shown) integral with frame 21. The cutting blade 56 is prealigned with the free end 54 of pipe 37. In other words, pipe 37 is prearranged in clamps 39 and 39*a* so that end 54 is parallel to cutting blade 56. Operating arm 57 is preferably actuated by means of a hydraulic cylinder 57*a* remotely actuated by the surface control equipment 20. A hydraulic motor 57*b* coupled to blade 56 and arm 57 preferably rotates cutting blade 56. Cylinder 57*a* is pivotally attached to a bracket 57*c* integral with frame 21.

In operation, the cutting unit 55 is remotely actuated from the barge at the surface and operating arm 57 is pivoted into engagement with the overlapped portion of pipe 12 thereby cutting off end 53 (FIG. 3). Since the cutting unit 55 is an integral part of the manipulating apparatus 17 which is fixed to the pipe end 54, the submerged end 53 is precisely established with respect to all other joint components by the blade cut as discussed previously. The cutoff portion of pipeline 12 together with pig 11 is cleared from the pipeline 12 by means of guide wire 14 which is attached to end 53 by pig 11.

This parallel offset alignment of the pipeline 12 with respect to apparatus 17 results in accurate orientation of the various components by requiring only a short lateral motion of clamp 38 for final alignment. The submerged pipeline 12, however, must be first cleared for preparation for subsequent joining to pipeline 37. Although remote actuation of all operations has been discussed, it is to be understood that these operations can be prearranged to be sequentially actuated after engagement of the apparatus 17 with the submerged pipeline 12 by means of appropriate electrical switching circuits, hydraulic sequencing valves, fluidics or various types of programmers as is well known in the art.

FIGS. 5 and 6 illustrate one method of joining the pipelines 12 and 37 after end 53 of pipeline 12 has been cut off. Referring more particularly to FIG. 5, an internal explosive charge is used to expand the cutoff end 60 into an enlarged internal portion of a flange. A die flange 61 surrounds pipeline end 60 and serves the dual function of a backup die for the explosive-forming operation and a flange for the final mechanical coupling as will be explained further hereinbelow. Die flange 61 preferably consists of a heavy cylindrical section having an internal contour 63 adapted to receive pipeline end 60 and a groove 63*a* for retaining therein a preferably soft metal or elastomer seal 64. The inside diameter of die flange 61 is accurately machined to a configuration that will accept rather loose tolerances on the diameter, roundness, and fit of the submerged pipeline end 60.

The outside contour 65 of die flange 61 is machined to a taper which fits the locking collar 66 (FIG. 6) and interacts with collar 66 to form a powerful axial cam adapted to pull the pipeline joint together as will be explained further hereinbelow. Die flange 61 also carries a frangible charge support or holder 67 having an explosive charge ring 68 attached thereto. Ring 68 is adapted to extend into the end 60 of pipeline 12 when die flange 61 is in position about the circumference of pipeline 12. Ring 68 serves to retain detonator 69 in position centrally of pipeline 12 and substantially on the longitudinal axis of pipeline 12 as can be seen in FIG. 5. An electrical lead 70 extends from detonator 69 to actuating means (not shown) for exploding the explosive charge ring 68.

In operation, detonator 69 is detonated thereby exploding ring 68. The explosion expels the frangible charge holder 67 to the sea and an explosive upset flange 71 is formed on the end 60 of pipeline 12 as can best be seen in FIG. 6.

Prior to lowering pipeline 37 to the sea bottom 13, a flange 72 is welded at weld 73 to the end 54 of pipeline 37. The welded flange 72 is identical in its external contour 74 to the contour 65 of die flange 61; preferably, however, it is of somewhat lighter hub section and is simply butt-welded to the available or surfaced pipeline end 54. The inside diameter of flange 72 is cylindrical and of the same diameter as pipelines 12 and 37. Thus, the two flanges 61 and 72, when mated, offer little restriction to the flow of product fluids or equipment through the joint of FIGS. 5 and 6.

As can be seen in FIG. 6, flange 72 has a circular groove 75 on its face portion 76 which abuts against face portion 61*a* of die flange 61. Groove 75 is adapted to contain therein a preferably ring-shaped soft metal or elastomer face seal 77. Seal 77 and previously mentioned seal 64 are completely retained in their respective grooves which are proportioned to give optimum final compression and configuration to the elastic seal component, regardless of the residual preload in the metal parts. The seals 64 and 77 are wide and pliant enough to engulf reasonably large particles of grit or other matter which is flushed out as the face seal 77 is seated. Alternatively, a soft metal or elastomeric sheet (not shown) may be used in place of seal 64 to seal the die flange 61 to pipeline 12.

Locking collar 66 preferably consists of two semicircular halves, 78 and 79, hinged together as seen in FIGS. 2 and 3 (a collar 66), thus forming a ring when locked. Collar 66 is internally machined to match the external contours 65 and 74 of flanges 61 and 72 and to achieve an axial flange preload greater than any expected service forces. In this manner, the flange faces of flanges 61 and 72 will not separate under load or pressure, and the joint strength and seal configuration will be maintained. Collar 66 is actuated hydraulically or explosively, and locked in the preloaded condition.

In operation, manipulating apparatus 17 is lowered into place on the submerged pipe end 53 carrying the prepared end 54 (i.e., with flange 72 welded thereto) down with it as previously discussed. The manipulating apparatus 17 follows wire 14 to submerged pipe end 53 and, on contact, hydraulically clamps and centers itself with sufficient force to attain parallel alignment of the joint members. The apparatus 17 is designed to allow for considerable parallel overlap of the submerged and prepared pipelines which must be provided to ensure that the two ends 60 and 54 will meet.

After attachment, the submerged pipeline 12 is cut off by the orbiting milling cutter or sawing unit 55 (FIG. 4). This establishes a squared-off end 60 on the submerged pipeline 12 located at a known position with respect to the prepared end 54.

Having established the pipeline end 60, another orbiting milling cutter or single point tool 80 removes the concrete or other protective coating from end 60 and prepares the pipe circumference for insertion of the die flange 61. This operation can be seen in FIGS. 2 and 3 where the tool 80 is shown mounted on a housing 85 fixed to plate 81 which is attached to frame 21 through mounting brackets 82 and 83. Housing 85 also includes a centering cone 61*a*. Preferably, tool 80 comprises a machining cutter 84 rotatable by conventional means (not shown) in housing 85. Bracket 83 is slidably mounted on frame 21 and bracket 82 is slidably mounted on rod 88 so that plate 81 and thus tool 80 can be advanced into engagement with end 60. Machining cutter 84 is positioned so as to contact the outer circumference of pipeline 12. Cutter 84 is preferably prepositioned so as to be adapted to machine end 60 to the predetermined die flange 61 outside diameter within a preferred diametral tolerance. For the first embodiment of this invention, after the machining operation is completed, housing 85 is withdrawn and rotated about a vertical axis on its mounting shaft 81*a* leading to plate 81 as shown in FIG. 5*a* so that cutter 84, for example, leads away from pipeline 12. This places die flange 61 which may be attached to the back end of housing 85 by adhesive bonding to frangible charge support 67 which is in turn attached to shaft 85*a* in position for installation on end 60 as seen in FIG. 5*a*. The die flange 61 also carries the seal 64, explosive charge 68, and detonator 69. At this point, die flange 61 is manipulated onto the pipeline end 60 by sliding plate 81 into engagement with end 60. The bell mouth 87 formed on die flange 61 assists in readily sliding flange 61 on end 60.

The explosive process for forming upset flange **71** is not particularly critical with respect to alignment of the component parts, and the die flange **61** need not be positioned concentrically over pipeline end **60**. The die flange **61** is rigidly held during detonation of detonator **69** as discussed previously in order to maintain an accurate relationship to the mating flange **72** welded to the prepared end **54**.

The detonation of detonator **69** is initiated electrically after all components are properly placed. As stated above, the charge ring **68** is attached to die flange **61** through support **67** and thus carried into place with it. Products of the detonation and the frangible charge support **67** are preferably expelled to the sea by the blast, or can be subsequently pumped out, if desired. The detonation expands the pipeline end **60** to conform to the internal configuration of the die flange **61**, thus forming upset flange **71** and preloading the radial seal **64**.

If desired, a shock wave attenuator (not shown) may be provided to prevent damage to the pipeline **12** beyond the die flange **61**. This attenuator, which may be a crushable plastic foam or honeycomb, is inserted when the die flange **61** is installed, and removed as the die flange manipulator is withdrawn.

As can be seen in FIGS. **2** and **3**, clamp **66** surrounds the prepared end **54** of pipeline **37**. Clamp **66**, shown in position on end **54**, must be open so that it can be slid into engagement with end **60** of pipeline **12** by means of a hydraulically-actuated installation arm **90** which is slidably mounted in a runner **91** formed in a bracket **92** integral with cross arms **93** and **94** of frame **21**. Accordingly, conventional hydraulic means, as will be discussed below concerning FIG. **8**, are used to selectively open and close sleeve **66**.

The lower end **95** of arm **90** abuts against the rear end of hinged split clamp **66** as to advance clamp **66** into pipeline end **60**.

It is to be understood that end **54** of pipeline **37** as shown in FIGS. **2** and **3**, in this particular embodiment of the invention would include welded flange **72** shown in detail in FIG. **6**. Thus, the two flanges, **61** and **72**, are now rigidly fixed to their respective pipeline ends and are next actuated to a coaxial position thus aligning the two pipelines **12** and **37**. The flanges **61** and **72** are positioned so as to allow clearance of the edges and seals as they pass. Sufficient force is necessary to permit this purely lateral motion of pipelines **12** and **37** a distance of approximately 2 feet. One preferred method is to hydraulically rotate bar **51** of clamp **38** into a predetermined position with respect to the axial alignment of pipeline **37**.

Finally, locking collar **66** is drawn over flanged **61** and **72** and adapted to engage contoured portions **65** and **74** of flanges **61** and **72**, respectively. This is accomplished by actuating arm **91** which moves collar **66**, in its open unlocked position, over flanges **61** and **72** as seen in detail in FIG. **6**. Collar **66** is then locked as, for example, by hydraulic means as discussed hereinbelow with reference to FIG. **8**, thereby drawing and locking the two halves **78** and **79** together.

The mating flange and ring tapers of flanges **61** and **72** and collar **66** are designed so as to cause terminal centering and longitudinal drawing of the parts. The collar halves **78** and **79** are locked with the residual preload necessary for proper seal performance and joint strength. If desired, the joint may be flushed with sea water during the final collar loading in order to remove silt, grit and organisms.

This embodiment of the invention is advantageous since sea water need not be excluded since the explosive forming is normally done underwater and accuracy requirements are not stringent.

An alternate joint for coupling pipelines **12** and **37** is illustrated in FIGS. **7** and **8**. The joint of this embodiment comprises a seal-carrying split sleeve having a locking groove to provide longitudinal strength. More particularly, a split sleeve **98**, comprising a pair of semicircular sections **99** and **100** hinged at **101** (FIG. **8**), surrounds ends **60** and **54**, respectively, of pipelines **12** and **37**. A pair of hydraulic cylinders **102** and **103** operatively engage the free ends **104** and **105** of sections **99** and **100** for selectively opening and closing the sections **99** and **100**. At least one of the free ends, as, for example, end **105** in FIG. **8**, includes a hook or similar locking device **106**, adapted to engage a mating locking hole or groove **106***a* opposite end **105** in free end **104** so as to lock the sections together. The ends of cylinders **102** and **103** opposite ends **104** and **105** engage a frame **107** which includes a crossbar **93** integral with frame **21** (FIGS. **2** and **3**) having a pair of outwardly extending legs **109** and **110** which engage cylinders **102** and **103**, as can be seen in FIG. **8**.

Thus, the frame **107** of FIG. **8** is actually a portion of the manipulating apparatus **17** of FIGS. **2** and **3**. Sleeve **66** of FIGS. **2** and **3** is similar to sleeve **98** of FIGS. **7** and **8**, the integral contour varying depending on type of joint desired. For convenience of illustration, frame **107** and cylinders **102** and **103** are not visible in FIGS. **2** and **3**; however, it is to be understood that these elements form a part of the frame **21** and are used to either selectively open and close halves **78** and **79** of hinged locking collar **66** or selectively open and close halves **78** and **79** of hinged locking collar **66** or selectively open and close sections **99** and **100** of split sleeve **98**. In both cases, the particular collar or sleeve to be used is placed on end **54** of pipeline **37** prior to lowering apparatus **17** in place.

In the embodiment shown in FIGS. **7** and **8**, the attachment, cutoff and cleanup operations are indentical to the operations performed on the submerged pipeline **12** to prepare for the explosive-mechanical joint as discussed previously. A small difference is that, since the pipeline ends **60** and **54** do not mate with other parts, the cutoff tolerance is not critical, provided the ends do not interfere in passing during alignment.

To provide a good sealing surface, a tight diametral fit and optimum groove strength, a relatively precise contour machining operation is required. The most critical aspect of the mechanical joint method of FIGS. **7** and **8** is the fashioning of a groove **111** in end **60** of pipeline **12**. It is to be understood that a similar groove **112** is to be prepared in end **54** of pipeline **37** prior to lowering apparatus **17** in position; accordingly, the following comments regarding the formation of groove **111** are also deemed pertinent with regard to the formation of groove **112** wherever applicable.

Grooves **111** and **112** (FIG. **7**) are necessary for positive joint strength, independent of friction clamping, but it decreases the actual pipeline strength. The presence of grooves **111** and **112** in pipelines **12** and **37**, respectively, increases the stresses in the pipelines by reducing the cross-sectional area and by aggravating stress concentrations. Therefore, grooves **111** and **112** should be as shallow as possible and carefully shaped. A typical groove for a 12-inch, ½-inch wall pipe, for example, is one that is preferably ⅞-inch wide and 1/16-inch deep with tolerances on these dimensions of about ±0.010 inch.

The locations of grooves **111** and **112** is important since the point of maximum axial stress in the pipelines **12** and **37** will be at the grooves while the bending stress will be highest at the sleeve end. Thus, sleeve **98** is extended beyond the grooves **111** and **112** such that these stresses are not directly additive. Additional axial strength is realized by taking frictional forces into account.

The groove **111** is machined in end **60** of pipeline **12** by means of the cutter **84** of the single point tool **80** as discussed above concerning FIGS. **2** and **3**. Housing **85** is provided with conventional control means, not shown, for regulating the extent to which cutter **84** engages the circumference of end **60**.

Alignment of pipeline ends **60** and **54** is carried out as discussed previously. The sleeve **98** is installed by hydraulically closing it around the two pipe ends **60** and **54**. Since the sleeve **98** is carried by the frame **21** of apparatus **17** as discussed previously, and since the machining of groove **111** is done with respect to the alignment of sleeve **98** on frame **21**, tang and groove engagement is assured.

Thus, sleeve **98** preferably includes a pair of radially extending projections or tangs **113**, **114** adapted to engage grooves **111** and **112**, respectively. Sleeve **98** also includes a plurality

of grooves **115** adapted to contain therein soft metal or elastomer seals **116** as discussed previously. Discontinuities in seals **116** may constitute potential leakage paths; accordingly, a liquid or plastic sealant is preferably pumped into the selected sealant compound as a final step in preparing the joint of FIGS. **7** and **8**.

Although a pair of hydraulic cylinders **102** and **103** are disclosed, preferably a plurality of cylinders are used so as to increase the number of latching points, reduce forces, and prevent cocking. Preferably, the joint of FIGS. **7** and **8**, upon completion, is purged by conventional means in order to flush away or exclude grit, organisms, and other foreign material since the presence of such objects will affect joint strength and sealing efficiency.

In a final thermit weld joint embodiment illustrated in FIGS. **9** through **12**, a weld is produced by heating the joint faces wit a superheated metal resulting from a chemical reaction. Here, pipelines **12** and **37** are illustrated as in abutting relationship after the manipulating apparatus **17** has performed the operations of cutting and aligning the two pipelines **12** and **37**. Accordingly, mold sleeve **117**, preferably of steel and externally insulated at **117***a*, is similar to collar **66** and sleeve **98** as discussed previously; thus collar **66** of FIGS. **2** and **3** can be considered as illustrative of both sleeve **98** and sleeve **117** in position prior to insertion on end **60** of pipeline **12**. In operation, end **54** of pipeline **37**, prior to being lowered into position with pipeline **12**, is provided with an internal expandable metal backing ring **119** bushed by an inflatable rubber backing seal **118** as can best be seen in FIG. **11**. Several possible methods can be used to place backing ring **117** in position in pipelines **12** and **37**. For example, in addition to the external mold sleeve **117** which is carried down with pipeline **37**, the expandable, internal backing ring **119** is also carried down. This ring and its positioning mechanism is placed on a pig **119***d* (FIG. **9***a*) inserted a fixed, predetermined distance into end **54** of pipeline **37**. After alignment of the pipeline ends **54** and **60** underwater as discussed previously, the ring **119** is moved by the positioning mechanism the fixed distance required to place it under the circumferential joint and is expanded to bear against the inside wall of pipeline ends **54** and **60**.

A mechanical spring mechanism is preferably used to move ring **119** into place and a hydraulic mechanism is preferably used to expand it. The placement mechanisms are preferably triggered by a wire line through the joint. FIGS. **9***a* and **9***b* illustrate the placement of backing ring **119**. A hydraulic system **119***a* may be used to move ring **119** into position and expand it. After alignment of the pipeline ends, the hydraulic system **119***a* is actuated through wire line **119***b* extending up to the surface through the joint. The hydraulic system **119***a* causes ring **119** to be moved under the joint by extension of actuator arms **119***c*. When the arms **119***c* are fully extended, a valve (not shown) in the arms **119***c* is opened and the inside of the inflatable backing seal **118** is pressurized to cause the segmented backing ring **119** to be expanded against the underside of the joint (see FIG. **9***b*). The wire line **119***b* is then severed by the action of the molten weld metal while making the joint.

After welding is completed, the pig **119***d* is pumped out of the pipeline **37**. The movement of pig **119***d* or the application of internal pressure to the pipeline **37** may be used to break a seal in the inflatable backing seal **118** causing it to collapse.

After alignment of ends **60** and **54** with backing ring **119** in place, mold sleeve **117** is movable into position about the juncture of pipeline ends **54** and **60** in the manner discussed previously concerning collar **66** and sleeve **98**. Sleeve **117** is preferably a split mold sleeve with a hinge **123** and locking latch similar to the sleeve **98** discussed previously. Alternatively, sleeve **117** may be solid, if desired.

If a split mold sleeve **117** is used, it can either be removed or left in place after welding. A solid sleeve is preferably left in place after welding. In both cases, the sleeves are temporarily sealed to the pipelines by hydraulically actuated seals **137** (FIG. **11**) to form a watertight mold cavity. This is accomplished by closing sections **124** and **125** of sleeve **117** in the manner suggested above concerning sleeve **98** of FIG. **8**.

Mold sleeve **117** preferably has one or more retorts or reaction chambers and receivers connected thereto by one or more conduits. These conduits are as short as possible and preferably form an integral portion of the sleeve wall.

Thus, as can best be seen in FIG. **10**, a reaction chamber or retort **126** communicates with a conduit or sprue **127** preferably forming a portion of the inner wall **128** of sleeve section **125**. An air inlet **129** communicates with retort **126** for introducing air from a remote surface source (not shown) into the mold cavity **130** formed between the pipeline joint and the inner wall **128** of sleeve **117**. A receiver **131** communicates with a conduit or sprue **132** which also forms a portion of inner wall **128** of section **125**. A vent **133**, controlled by a one-way valve **134**, communicates with receiver **131** for reasons to be discussed hereinbelow.

The particular number and placement of retorts and receivers depends on factors such as the type of feed (i.e., gravity or pressurized), the type of mold sleeve (i.e., split or solid), and the heat balance at various parts of the mold sleeve. For reasons of convenience, only one retort and one receiver are illustrated in FIGS. **9** and **10**.

The outlet from retort **126** into sprue **127** is closed by a tapping plug **135**. This plug is preferably a fusible plug as shown in FIG. **10**; however, it could also be a mechanically controlled pin if desired. An air passage **129***a* in the wall of retort **126** bypasses plug **135** extending from above the plug **135** to below the plug **135**. This air passage **129***a* is used to purge the mold sleeve **117** as will be described hereinbelow.

In addition, a valve **136** is located at the junction of the sprue **127** and the mold sleeve cavity **130** in order to seal the retort **126** and sprue **127** from sea water. The retort **126** is pressurized to the ambient sea water pressure by means of an air line (not shown) from the surface which operatively engages air inlet **129**.

The vent **133**, of receiver **131** which is connected at the bottom of mold sleeve **117** as shown in FIG. **10**, is closed by a one-way valve **134** thereby permitting flow from receiver **131** into the sea but preventing flow in the opposite direction.

The backing ring **119**, as discussed previously, preferably consists of an expandable segmented metal ring backed by rubber as shown in FIG. **11**. A steel ring can be used if it is to be fused into the weld and left in place. A copper or ceramic coated ring may be used if it is to be removed after welding. The function of the rubber backing-up metal ring **119** is to seal against the inside pipe surface. The backing ring **119**, in conjunction with external mold sleeve **117**, thus forms a closed chamber around the joint to permit exclusion of sea water.

In operation, manipulating apparatus **17** performs the functions of cutting and aligning the pipeline ends **54** and **60** as discussed previously concerning the embodiment of FIGS. **2** and **3**. As shown in FIG. **11**, the joint preparation for the thermit weld consists of a square-butt joint with a gap width of about one-half the pipeline wall thickness. The joint gap tolerance and the finish on the pipeline ends is not critical. A flame cut or explosively cut end is preferably used. The surface condition of the pipelines next to the joint is also not critical, excepting that any concrete or heavy bitumastic coating must be removed as discussed previously by means of single point tool **80**. Alignment of the pipeline ends **54** and **60** must be good enough so that mold sleeve **117** can be sealed to the pipeline surfaces without any large spaces in which the filler metal would flow as will be discussed further hereinbelow.

After alignment of the pipelines **12** and **37** as discussed previously, the manipulating apparatus **17** clamps the external mold sleeve **117** over the spacing between pipeline end **54** and **60** in the manner discussed previously concerning collar **66** and sleeve **98**. In other words, in this embodiment, using the apparatus **17** of FIGS. **2** and **3**, collar **66** would have the internal configuration of mold sleeve **117**. Since the external configuration of both sleeve **117**, collar **66** and sleeve **98** is the same and the operation placing them on the pipeline ends **54**

and 60 is similar, further illustration or discussion is deemed unnecessary.

Alternatively, sleeve 117 may be a solid cylinder in which case it is merely slid over the pipeline ends 54 and 60 rather than being clamped in place. In both cases, the hydraulic seals 137 are then actuated by means well known in the art to seal the mold sleeve 117 to pipeline ends 54 and 60. The internal backing ring 119 is then moved under the spacing between the ends 54 and 60 and expanded against the inside pipeline surfaces by remotely controlled mechanism, all in the manner discussed previously.

Once the mold sleeve 117 and the backing ring 119 are in place, the mold cavity 130 is purged of sea water by pressurizing it through the air inlet 129 and air passage 129*a* through the retort 126. The water is expelled through the one-way valve 134 and vent 133 at the receiver 131. A flow of dry air or gas through inlet 129 is continued after purging long enough to dry the joint.

After the joint is dried, a thermit mixture located in retort 126 is ignited. IN order to start the reaction, a conventional thermit igniter such as peroxides and aluminum dust is ignited by an electrical spark discharge actuated from the surface. The ignition powder burns with enough heat to reach the ignition temperature of the main charge.

The charge preferably consists of a metal oxide such as iron oxide and aluminum having an ignition temperature of approximately 2,700° F. The charge is placed in retort 126 prior to lowering it to the sea bottom 13. For example, a 25- to 30-pound charge of three parts iron oxide and one part aluminum is required to weld a 12-inch diameter by ⅝-inch wall pipe with a ½-inch nominal joint width. The exact amount of charge will depend on the mold design. Other ingredients in the charge preferably include alloying elements to control mechanical properties and elements to control fluidity of the slag.

The thermit reaction preferably burns to completion in less than 1 minute. However, sufficient time is necessary to allow the slag to float to the top of the retort 126 after completion of the reaction. Accordingly, the retort 126 is preferably tapped by a fusible plug 135 located in the bottom of retort 126 which is melted by the hot metal. Alternatively, a mechanically actuated pin may be used in place of plug 135.

Using gravity feed, the initial superheated metal within retort 126 flows through the mold cavity 130 of sleeve 117 and into bottom receiver 131, thus serving to preheat the joint. This flowing metal may initially flow into the crevices between the sleeve 117 or the ring 119 and the pipelines 12 and 37. The metal freezes very rapidly forming a "flash." Some charring of the seals 118 and 137 may occur; however, it will not cause failure of the seals.

After the receiver 131 is filled, the additional metal starts filling the mold cavity 130 to complete the joint. The size of the receiver 131, therefore, is such to allow sufficient superheated metal to flow through the joint for preheating. Enough charge is present to assure that none of the slag flows from the retort 126 into the joint.

It may be desirable to provide auxiliary means of preheating critical parts of mold sleeve 117. Accordingly, molded exothermic charges or electrical strip heaters 138, only one of which is shown for convenience of illustration in FIGS. 9 and 10, are preferably placed outside of mold sleeve 117 in order to preheat certain portions of sleeve 117. In this manner, the design of mold sleeve 117 is not as critical as one without preheating means since it is not necessary to control closely the initial metal flow in the point in order to obtain uniform heating.

Alternately, a pressurized feed may be used in place of the preferred gravity feed. Referring to FIG. 12, if the retort 126 and receiver 131 locations are interchanged, a pressurized feed system would result. Here, like numerals refer to like parts of FIG. 10. In this case, a positive pressure is introduced into the top of retort 126′ through the air line 129′. This pressure forces the molten metal out of retort 126′ located now near the bottom of mold sleeve 117, into the bottom of mold cavity 130, up through the mold sleeve 117, and into the receiver 131′ located near the top of the mold sleeve 117. The remaining primed numerals refer to like elements of FIG. 10; thus, further discussion is deemed unnecessary.

This pressurized feed method has one major advantage over the gravity feed method of FIG. 10. With pressurized feed, the mold sleeve 117 is filled from the bottom and the air can be vented out the top of the mold sleeve 117 as it fills. With gravity fed, the metal enters the top of the mold sleeve 117. Air in the mold sleeve 117 must flow counter to the incoming metal in order to reach the top of the mold sleeve 117 and escape. With the small mold cavity 130 required for the pipeline weld, it is possible that air may become entrapped in the weld metal causing a porous weld. In this case, suitable air vents (not shown) may be built into the mold sleeve 117 of FIGS. 9 through 11 as an alternative to the pressurized feed of FIG. 12.

Finally, the split mold sleeve 117 is preferably removed after joining. The internal surfaces of the mold cavity 130 are preferably lined with a ceramic lining 139 so that the sleeve 117 is can be readily parted from the weld. Of course, if a solid sleeve 117 is used, it may be left in place after joining without any harmful effects to the pipelines.

In both cases, the retort and receiver conduits are cut off at the mold sleeve 117, preferably by explosive cutting. The backing ring 119 is then collapsed and removed by means of passing a pig through the pipelines as is well known in the art.

If desired, a remotely actuated viewing device such as a television camera 140 may be included on manipulating apparatus 17 coupled to surface control equipment 20 through power transmitting cable or cables 22 or 23 for viewing the various phases of operation.

It is understood that minor variations from the embodiments of the invention disclosed herein may be made without departure from the spirit and scope of the invention and that the specification and drawings are to be considered as merely illustrative rather than limiting.

We claim:

1. Apparatus for the underwater coupling of a pair of pipelines on the sea bottom remotely actuated from the water surface comprising:

a frame;

frame stabilizing and support means depending from said frame for maintaining said frame in a stabilized upright position on the sea bottom;

first clamping means mounted on said frame for retaining the first of said pair of pipelines in overlapping relationship with the second of said pipelines;

second clamping means mounted on said frame adapted to secure the second of said pipelines in a fixed, predetermined position to said frame and in overlapped relationship with the first of said pair of pipelines;

pipe cutting means mounted on said frame for cutting off the overlapped portion of the first of said pipelines;

coaxial alignment means mounted on said frame for coaxially aligning the cutoff end of the first of said pipelines with respect to the second of said pipelines;

joining means operatively engaging said frame and adapted to securely join the first of said pipelines in fixed, coaxial relationship with the second of said pipelines; and

remote actuating means extending from said frame to said water surface for remotely actuating all of said first and second clamping means, said pipe cutting means, said coaxial alignment means and said joining means.

2. The apparatus of claim 1 including a guideline attached to the first of said pipelines, said frame further including cooperating guide means adapted to coact with said guideline attached to the first of said pipelines for clamping and guiding the frame into engagement with the first of said pipelines.

3. The apparatus of claim 1 including propulsion means mounted on said frame for moving said frame through a body of water.

4. The apparatus of claim 1 wherein both of said clamping means includes hydraulically actuated cylinders for operating said clamping means.

5. The apparatus of claim 1 wherein the cutting means comprises a sawing unit having a cutting blade adapted to engage the overlapped portion of the first of said pipeline.

6. The apparatus of claim 5 wherein the cutting blade is prealigned on the frame so that it is adapted to cut in substantially the same plane as the free end of the second of said pipelines.

7. The apparatus of claim 1 including clearing means mounted on said frame for clearing the cutoff portion of the first of said pipelines free of said frame.

8. The apparatus of claim 1 wherein the coaxial alignment means includes preset prime mover means adapted to pivot the first clamping means retaining the cutoff end of the first of said pipelines a fixed distance, such that said cutoff end is moved in a direction normal to the longitudinal axis of said pipelines thereby coaxially aligning the first of said pipelines with the second of said pipelines.

9. The apparatus of claim 1 wherein said frame includes cutoff end preparing means mounted thereon adapted to prepare the cutoff end of the first of said pipelines for subsequent joining to the second of said pipelines.

10. The apparatus of claim 9 wherein the cutoff end preparing means includes a die flange attached to said cutoff end preparing means and adapted to be inserted onto the cutoff end of the first of said pipelines prior to coaxial alignment of the first of said pipelines with the second of said pipelines; and

flange forming means coupled to said die flange adapted to form a flange on the cutoff end of the first of said pipelines.

11. The apparatus of claim 10 wherein the cutoff end preparing means further includes machining means adapted to machine the cutoff end to the predetermined inner diameter of the die flange.

12. The apparatus of claim 10 wherein the flange forming means includes an explosive charge adapted to cooperate with said die flange to form said flange on the cutoff end of the first of said pipelines.

13. The apparatus of claim 12 wherein said joining means includes a weld flange welded to the free end of the second of said pipelines;

said weld flange being adapted to abut against said die flange in sealing engagement when said pipelines are coaxially aligned; and

third clamping means mounted on said frame and adapted to engage both of said weld and die flanges to form an axial cam and pull said weld and die flanges into sealing engagement with each other and with said pipelines.

14. The apparatus of claim 13 wherein said third clamping mean is a hinge split clamp locked in a preloaded condition on said frame;

said frame further includes split clamp moving means mounted on said frame and adapted to move said split clamp into engagement with said weld and die flanges; and

prime mover closing means for closing said split clamp about said weld and die flanges.

15. The apparatus of claim 9 wherein the cutoff end preparing means includes machining means adapted to form a circumferential groove in the outer wall of said cutoff end;

the free end of the second of said pipelines further including a similar circumferential groove; and

said joining means including a third clamping means having projection means thereto adapted to engage both of said grooves.

16. The apparatus of claim 15 wherein said third clamping means is a hinged split clamp locked in a preloaded condition on said frame;

split clamp moving means mounted on said frame and adapted to move said split clamp into engagement with said grooves; and

prime mover closing means for closing said split clamp so that the projection means engage said grooves thereby sealing said split clamp about both of said pipelines.

17. The apparatus of claim 1 wherein the joining means includes externally insulated mold sleeve means adapted to surround both the cutoff end of the first of said pipelines and the free ends of the second of said pipelines when said pipelines are in coaxial alignment with one another;

said mold sleeve means being adapted to form a mold cavity between the inner wall of said mold sleeve means and the outer walls of said pipelines;

a reaction chamber adapted to contain therein a thermit mixture in communication with said mold sleeve means and having a reaction chamber conduit communicating with said mold cavity;

air inlet means operatively engaging both said reaction chamber and said mold cavity for introducing air through said chamber and into said cavity;

a receiver communicating with said mold sleeve means and having a receiver conduit communicating with said mold cavity;

a vent operatively engaging said receiver;

a one-way valve permitting flow from the receiver to the vent located between said vent and said receiver; and

insulated expandable backing ring means carried by the second of said pipelines and adapted to be moved into sealing abutting engagement with the inner walls of both of said pipelines adjacent to the juncture of said pipelines when they are in coaxial relationship with each other.

18. The apparatus of claim 17 wherein said thermit mixture consists basically of iron oxide and aluminum;

valve means located in the reaction chamber conduit adapted to control the introduction of the molten metal resulting from the ignition of said thermit mixture within said chamber into said cavity; and

a fusible tapping plug located between said reaction chamber and said reaction chamber conduit and bypassed by the air from said air inlet means for allowing the slag resulting from the ignition of the thermit mixture to float to the top of the reaction chamber after completion of the reaction.

19. The apparatus of claim 18 wherein the reaction chamber is located on the upper portion of said mold sleeve means and the receiver is located on the lower portion of said mold sleeve means.

20. The apparatus of claim 18 wherein the reaction chamber is located on the lower portion of said mold sleeve means and the receiver is located on the upper portion of said mold sleeve means.

21. The apparatus of claim 18 wherein said mold sleeve means includes a hinged split sleeve; and split sleeve moving means mounted on said frame and adapted to move said split sleeve into engagement with the juxtaposed ends of said pipelines when they are in coaxial relationship with one another.

22. The apparatus of claim 21 including a ceramic lining located in the mold cavity.

23. The apparatus of claim 18 wherein said mold sleeve means includes a solid cylindrical sleeve; and sleeve moving means mounted on said frame and adapted to move said sleeve into engagement with the juxtaposed ends of said pipelines when they are in coaxial relationship with one another.

24. The apparatus of claim 17 including auxiliary heating means cooperating with said mold sleeve means for selectively heating predetermined portions of said mold sleeve means.