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Howell et al.

[11] **3,910,478**

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[54] **DUAL HIGH EXPLOSIVE SHAPE DETONATION**

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[73] Assignee: **Exxon Research and Engineering Company,** Linden, N.J.

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[21] Appl. No.: **398,941**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 340,132, March 12, 1973, abandoned.

[52] **U.S. Cl.** **228/2.5;** 228/107

[51] **Int. Cl.**[2] **B23P 3/09**

[58] **Field of Search**.... 29/421 E, 470.1, 486, 497.5; 228/3; 72/56

[56] **References Cited**

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2,367,206	1/1945	Davis	29/148
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3,455,017	7/1969	Zondog	29/482
3,535,767	10/1970	Doherty, Jr. et al.	29/470.1
3,542,276	11/1970	James	228/3
3,563,713	2/1971	Rudd	29/488
3,780,927	12/1973	Kudinov et al.	228/3

Primary Examiner—Ronald J. Shore
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[57] **ABSTRACT**

A high welding explosive mass in placed circumferentially on a metal sleeve having a substantially cylindrical outer surface and is formed of a circumferential body having a greater thickness at the center of the mass than at its ends such that on initiation maximum explosive impact is exerted inwardly toward said sleeve to weld it to the abutting ends of two encircled pipes, the welding explosive body being provided with a sufficient amount of initiating explosive means at its center and extending around said body, the initiating explosive means having a detonation velocity substantially greater than the detonation velocity of the body, both the detonation velocities being above about 15,000 feet per second.

11 Claims, 7 Drawing Figures

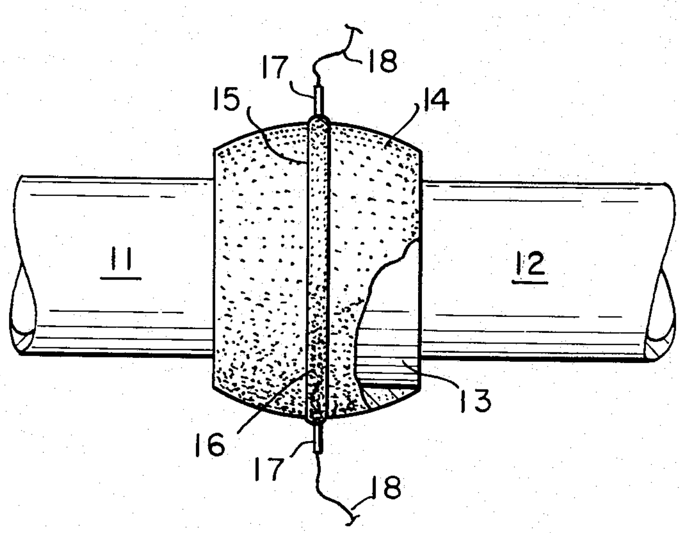


FIG. 3

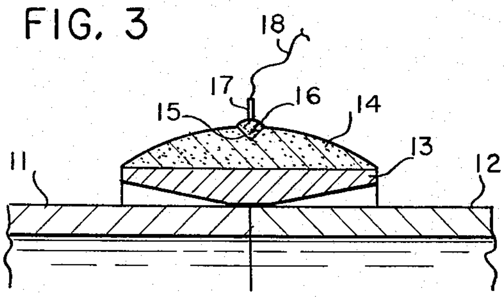


FIG. 1.

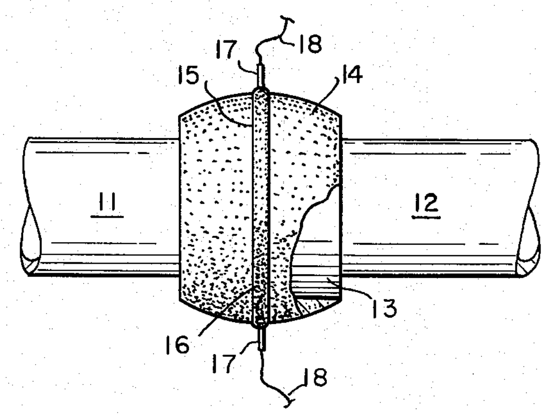


FIG. 4.

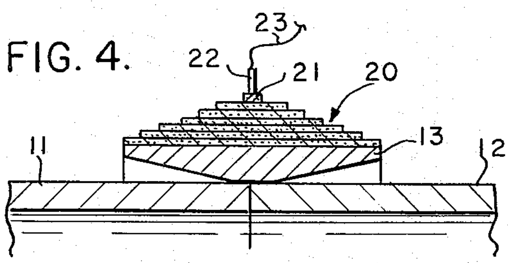


FIG. 5.

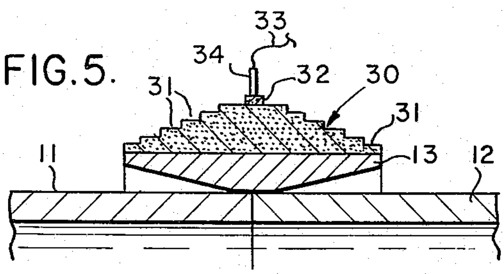


FIG. 2.

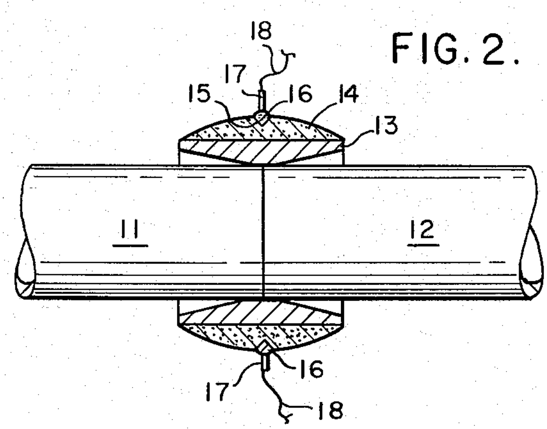
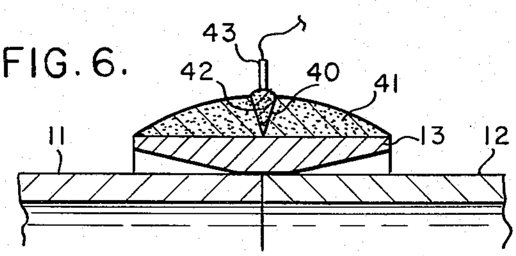


FIG. 6.



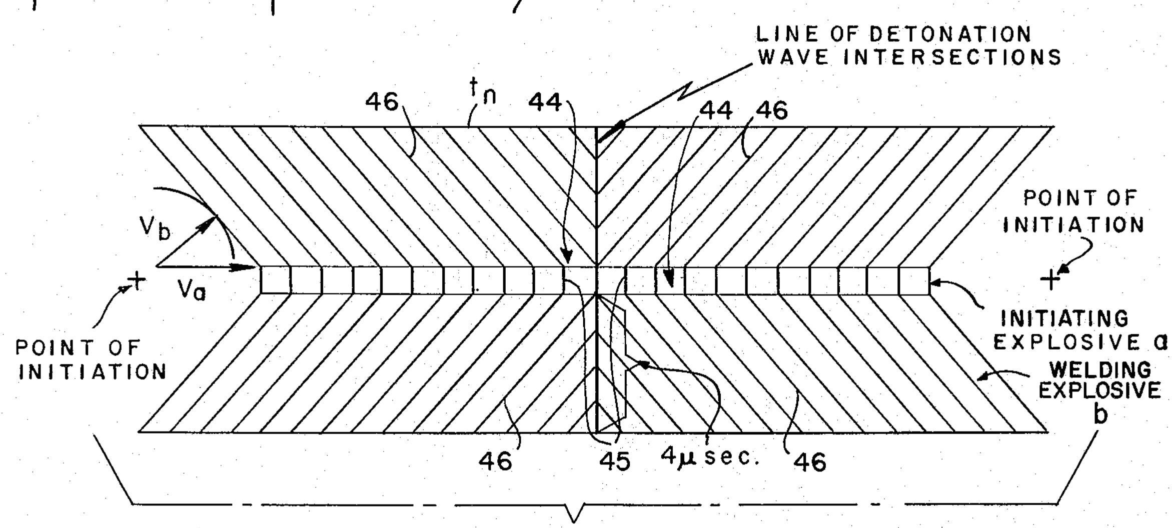


FIG. 7.

DUAL HIGH EXPLOSIVE SHAPE DETONATION

CROSS REFERENCES TO RELATED APPLICATIONS

This application is a continuation-in-part of our now abandoned earlier filed commonly assigned copending U.S. application Ser. No. **340,132,** filed Mar. **12, 1973** which is incorporated herein by reference.

This application is related to and an improvement over the following commonly assigned copending applications;

1. Ser. No. **252,641,** filed May **12, 1972,** and now abandoned in the name of Robert H. Wittman and William G. Howell and entitled "Welding of Hollow Cylinders Such as Pipe," now abandoned in favor of continuation-in-part application U.S. Ser. No. **489,523,** filed July **18, 1974** the subject matter of which is incorporated herein by reference.

2. Ser. No. **252,821,** filed May **12, 1972,** in the names of William G. Howell, Theodore A. Espinoza, and Robert H. Wittman, and entitled "Welding of Pipe by Use of Explosives," now U.S. Pat. No. **3,806,020.**

3. Ser. No. **252,678,** filed May **12, 1972,** in the names of William G. Howell, Steve H. Carpenter and Henry E. Otto, and entitled "Explosive Welding of Pipe with Explosive Means" now U.S. Pat. No. **3,819,103.**

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to explosive welding of pipe. More particularly, the invention is concerned with a formed explosive for explosive welding of hollow cylinders such as pipe. In its more specific aspects, the invention is directed to an explosive mass or body for explosive pipe welding in which a formed welding explosive mass of a particular shape is employed in explosive welding with an initiating explosive means arranged at the center of the mass or body.

2. Description of the Prior Art

Welding of sections of pipe together by the action of explosives is well known. It has also been taught to use interiorly arranged mandrels in welding of pipe to prevent collapse thereof. The prior art also teaches the use of pipe collars for welding pipe by explosive action. Such collars have been formed to provide an angle with the exterior of the pipe but the collars are usually of the same thickness throughout and so is the explosive employed. Likewise, high explosives have been arranged on the exterior of the collar as a cord which is detonated.

Heretofore when single point detonation has been used in connection with the prior art collar and high explosives, there is straight line impact between the wave fronts emanating from the point of detonation and travelling circumferentially in opposite directions around the collar. When the radius of the two circular fronts impacting is small the collision is progressive from the central plane to the edge of the collar. However, where the radius is large the detonation wave front approaches a straight line and the collision occurs essentially simultaneously across the full width of the collar. A strong compressive shock wave having both radial and tangential components progresses in the steel immediately underneath those detonation fronts. At the

collision line of the tangential shock waves the stress doubles and thus creates a plastic shear zone which can result in a tensile failure of the collar. At this line of impact there is created a weak line which can result in producing a flaw in the weld and thus, a possible path of leakage which obviously is undesirable. In order to overcome this problem, multiple point initiation, that is detonators equally spaced about the collar, has been used. While multi-point initiation is satisfactory, it becomes rather cumbersome and very expensive when many initiation points are required for large pipe, e.g., **30** inch. None of the prior art, however teaches or makes obvious the present invention wherein an arrangement of explosive or use of a particular form of explosive with a particular detonation explosive means are employed.

Prior art considered with respect to this invention includes the following patents:

U.S. Patents

2,367,206
3,137,937
3,261,088
3,263,323
3,409,975
3,455,017

Belgian Patent

655,943

SUMMARY OF THE INVENTION

The present invention may be briefly described and summarized as involving an explosive with a detonation explosive adapted to be arranged on a collar circumferentially embracing abutting ends of pipe at least adjacent to the center of the collar. A mandrel is useful in explosive welding of pipe sections together. In the present invention, a mandrel may be placed within abutting pipe sections under a metal collar. The ends of the pipe may be buffed to clean metal. The collar is preferably interiorally formed to have a tapered shape such that the ends thereof are of a lesser thickness than the center. The outer surface of the collar is substantially cylindrical and on it is placed a formed mass or body of high explosive used for welding which is adapted to cover the collar and which is layered, stepped, molded, or mounded, cast, or formed in any shape such that the thickness of the high welding explosive mass is greater at the center thereof than at its outer periphery. Arranged in explosive contact with the high welding explosive is a high explosive detonation means at the center of the body of high welding explosive. The high welding explosive mass or body on the collar is contacted on its periphery by this high explosive detonation or initiating explosive means connected to at least two equidistant spaced apart detonators which in turn are connected to a source of electrical energy or source of energy such that on initiation of the welding explosive, the collar is substantially instantaneously driven at a sufficient force against the abutting ends of the pipe sections to weld the inner surface of the collar thereto and weld the sections together; the mandrel may then be moved in the pipe to the next section to be welded onto the ever-increasing length of pipe line being formed.

By providing an arrangement according to the present invention, there is obtained on detonation at least a pair of wave fronts having a wedge-shape or arrow configuration which travel circumferentially in opposite directions about the collar. These waves impact at their apex which is the leading point or portion of the wave and is created by the high velocity of the initiating explosive. The remainder of the wave which flank the apex is formed by the welding explosive being actuated by the initiating explosive in explosive contact therewith. According to the preferred embodiment of this invention the apex of each wave collides with a corresponding apex on a line about halfway between detonators and the pressure doubles when such collision takes place. Initially, there is substantially only apex contact between the opposing waves followed by progressive impaction of the wave flanks. By this invention, the foregoing problems of the prior art are overcome by using a dual explosive charge. The main charge or welding explosive and the initiating charge or explosive wrapped about the welding explosive in the central plane. The initiating explosive is in explosive contact with the welding explosive, so that upon detonation of the initiating charge the welding explosive also explodes. The detonation velocity of the initiating explosive is substantially greater than that of the welding explosive in order that, as explained before, the detonation wave front created upon initiation has a wedge or arrow shape and collision of the two fronts resembles that of two closely spaced initiation points of a homogeneous explosive. By placing the detonators, at least two of which are required, directly opposite each other on the collar to assure a symmetrical blast load being applied to the pipe, this avoids any unbalancing force which could be created if the points were located otherwise. An unbalancing force could result in moving the pipe or collar.

VARIABLES OF THE INVENTION

The high welding explosive used in the mass or body on the collar and in the initiating explosive means may be any one of a number of high explosives such as, but not limited to, Detasheet C which is 63% by weight PETN, 7% by weight nitrocellulose and 30% polymeric materials and has a specific gravity of 1.48, a detonation velocity of about 23,000 feet per second, and is currently supplied on the market in rubbery sheet form, pentaerythritol tetranitate (PETN) with red lead and a binder composed of a mixture of butyl rubber and polymers of β=pinene, TNT, cyclomethylene (RDX), Pentolite which is a 50:50 mixture of TNT and PETN, amatol, a 50:50 mixture of ammonium nitrate and TNT, and other well-known high explosives and mixtures thereof which may be shaped, formed or case on the collar as will be described more fully hereinafter.

Explosives should be selected having detonation velocities within the range from about 15,000 to about 30,000 feet per second. Generally, explosives having detonation velocities within the range from about 22,000 to about 30,000 feet per second may be used in the initiating explosive means and explosives having detonation velocities within the range from about 15,000 to 23,000 feet per second in the body or mass of welding explosive. The initiating explosive means should have a detonation velocity substantially greater than the detonation velocity of the welding explosive body or mass. Suitably a detonation velocity of the initiating explosive should be about 25% to about 35% greater than the detonation velocity of the welding explosive body or mass, preferably about 30% greater within the broad range of about 15,000 to about 30,000 feet per second.

The high welding explosive shaped or formed or otherwise placed on the collar such as by casting or molding may have a thickness at least adjacent its center about 200% to about 100% of the thickness of the sleeve or collar on which it is adapted to be placed at least adjacent its center and a thickness adjacent its ends about 200% to about 100% of the collar at least adjacent the ends of the collar. This high explosive may be shaped, formed, cast, molded, or layered and may be stepped, triangular, conical, truncated conical, or mounded in cross-section.

The size of the pipe which may be welded may vary from about 2 to about 48 inches in diameter with collars corresponding in size to weld the ends of the pipe together, but larger diameters of pipe may be used.

The amount of high welding explosive to be employed will vary, of course, with the size of the pipe collar and the detonation velocity of the explosive. However, the high explosive mass or body in the form of a ring on the collar may have thickness at the center of the collar sufficient to have a from about 8 to about 16 grams per square inch down to a thickness of from about 4 to about 8 grams per square inch at the ends or edges of the collar. For example, in welding 12 inch pipe and employing Detasheet C explosive, the explosive would have a thickness at the center of the collar of about 12 grams per square inch and at the ends or edges of the collar from about 4 to about 6 grams per square inch.

The initiating explosive means may be in the form of a strip of high explosive at the center of the welding explosive mass or body and may comprise from about 1 to about 10% by weight of the body and may be arranged in an indentation in the mass or body which may extend inwardly to the outer surface of the collar or sleeve. The indentation may be in the form of a notch and may have a V-shape.

The collar may have a thickness at the center substantially the same as or slightly larger than the wall thickness of the pipe sections tapering on its inner surface to about one-half the pipe sections wall thickness. The center inner surface of the collar or sleeve may be from about 1/16 inch to about 1 inch in width, while the inner tapered surfaces may each be from about 45% to about 48% of the length of the collar. For example, a 12-inch pipe may require a collar about 4 inches in length while a 48-inch pipe may require a collar of about 4 to about 6 inches length. A nominal 2-inch pipe may require a collar of about 2 inches length, whereas pipe of nominal 20 inches diameter may require a nominal 4 inches length collar.

BRIEF DESCRIPTION OF THE DRAWING

The present invention will be further described and illustrated by reference to the drawing in which:

FIG. 1 is a view of the high explosive body or mass on a pipe collar on two sections of pipe;

FIG. 2 is a sectional view of FIG. 1;

FIG. 3 is a partial sectional view of a notched high welding explosive with an initiating explosive means and a detonator;

FIG. 4 is a partial sectional view of a cylindrically layered high welding explosive with initiating explosive means and a detonator;

FIG. 5 is a partial sectional view of stepped, molded or cast high welding explosive similar to FIG. 4;

FIG. 6 is a partial sectional view similar to FIGS. 1–3 except that the notch or indentation extends inwardly to the outer surface of the collar; and

FIG. 7 is a view showing the pattern of detonation wave fronts disclosed by the present invention.

DESCRIPTION OF THE PREFERRED MODES AND EMBODIMENTS WITH REFERENCE TO THE DRAWING

Referring now to the drawing and particularly to FIGS. 1–3, numerals 11 and 12 designate sections of pipe which are to be joined by explosive welding by means of a collar or sleeve 13 on which is arranged circumferentially a mass or body 14 of mounded high welding explosive which is provided with a slit, indentation, or notch 15 which is filled with an explosive detonation or initiating explosive means 16 and which may protrude above the body 14. Arranged on the means 16 spaced apart equidistantly are at least two detonators 17 connected by electrical leads 18 to a source of electrical energy not shown. Sufficient amount of the initiating explosive means 16 is used to set off and explode the welding explosive 14 simultaneously. More than two equally spaced apart detonators may be used when a large pipe is to be welded but in this particular case they are 180° apart since the pipe may be nominally 12 inches in diameter.

Referring to FIG. 4 a collar or sleeve 13 on pipe sections 11 and 12 has layers 20 of high welding explosive circumferentially arranged thereon with a layer or strip of the initiating explosive means 21 also circumferentially arranged provided with at least two detonators 22 (although only one is shown) to which they are connected by electrical leads 3 to a source of electrical energy (not shown).

FIG. 5 is somewhat similar to FIG. 4 but in this case the welding explosive 30 is cast into steps 31 in cross section and has arranged on it at the center thereof an initiating explosive strip 32 with electrical leads 33 connected to detonators 34.

In FIG. 6, which is somewhat like FIGS. 1–3, a V-shaped notch or indentation 40 is formed in welding explosive body 41 and is filled with initiating explosive means 42 on which are arranged detonators 43 connected by electrical leads to a source of electrical energy not shown. In this case, V-shaped notch extends to the outer surface of the collar or sleeve 13.

When the two detonators of the several embodiments are exploded, wedge-shaped detonation wave fronts 44 as shown in FIG. 7 are set up.

These wedge or arrow shaped waves 44 travel in opposite directions from the point of initiation around the collar and impact halfway between initiation points. Initial impact is at their apex or leading portion 45. The leading portion 45 is created by the initiating explosive 16 having a greater detonation velocity than that of the welding explosive 14 and thus, always precedes the wave front created by the welding explosive 14. The rearward sloping flank 46 of the wave 44 symmetrically located on either side of the centerline of the explosive is created by the detonation of the welding explosive 14. These portions 46 of the wave, designated by force vector V_b, impact progressively within about 4 microseconds after the impact of the leading portions designated by force vector V_a. Each of the wave fronts are spaced by a time (t_n).

Currently in the method used for initiation of the main welding explosive in explosive welding of pipe, as shown and described in the copending applications supra, many initiation points around the circumference of the explosive are separated by about 1-½ inches. Thus, for initiating the charge for a 12-inch pipe joint weld, a large even number of points on the circumference of the explosive are initiated simultaneously. When initiation points are much more widely separated a leak may occur near shock wave intersections between initiation points. It has also been shown that with currently used sleeve geometry single point initiation will produce a leak-tight weld all around the pipe joint except in the area where the shock waves collide at the opposite side from the initiation point. An understanding of this problem may be developed if the geometry of intersecting detonation waves is examined for different spacing of the initiation points. For this purpose consider the surface of the explosive charge to be flat. Consider three adjacent points of initiation drawn to scale 1-½ inches apart and centered on a 3-¾ inch wide strip of explosive. These dimensions are typical for pipe with a ⅜ inch wall thickness. The detonation waves radiate outward from their respective initiation points in a circular pattern. Each larger concentric circle (or arc) represents a later micro-unit of time from time zero, time zero being the time of simultaneous initiation where many points are used. As the detonation waves propagate outward toward the edges of the sleeve, the undisturbed surface of the waves approach a high angle intersection condition in which they tend to blend into a single wave front perpendicular to a plane through the axis of the pipe. This causes the jet, which is typical of an explosive weld, to have a direction essentially parallel to the axis of the pipe. Now consider two initiation points spaced a relatively long distance apart. As the detonation waves emanating from these two points approach each other their radii become long and the detonation waves approach straight lines parallel to the axis of the pipe, exactly 90° from the condition described above and generating a low angle collision. In a parallel geometry weld this condition would cause the jet to flow in a direction perpendicular to any plane through the axis of the pipe and the jet could not escape at shock wave intersections. Since the explosive pipe weld uses a preset angle the jet flows in a direction somewhere between the extremes described above, and a good weld is achieved with two point initiation at all locations except in that area where the detonation waves come together. This may be due to the fact that jets coming from both directions collide at the intersection point, interfering with welding action by entrapment of jetting material and should be avoided.

A means for overcoming this problem in accordance with the present invention comprises employment of at least a dual explosive system, with the initiating explosive arranged in contact with the main welding explosive body, the crux of the present invention. In this system the main welding explosive charge has a detonation velocity about 25% slower than that of the initiating explosive and the initiating explosive is wrapped centrally around the sleeve. Thus the detonation wave travels more rapidly around the center of the sleeve than toward the edges of the sleeve. This results in a wedge-shaped detonation front as illustrated in FIG. 7.

The angles between the detonation waves as they sweep toward the edge of the sleeve at the detonation wave intersection approach an angle approximately the same as the average angles at detonation wave intersections as desired. This intersection configuration turns the direction of the jet (toward being parallel with the pipe axis) enough to avoid jet entrapment, and leakage problems are no longer encountered at the shock wave intersection.

The collar defines angles of about 1° to 30° with the exterior of the pipe sections with a preferred angle being about **8°**, with a detonation velocity of the welding explosive body of approximately **22,000** feet per second. As a general rule, the greater the detonation velocity of the high explosive, the greater should be the angles. However, the angles, amount of high explosive and detonation velocity are all important. A suitable angle is about **5°** to about **15°**. The detonation velocity of initiating explosive means may be about **27,500** feet per second.

The use of the selected angle between the tapered bottom surface of the collar and the adjacent pipe surface is necessary and important because of the necessity to establish necessary impact conditions in the shortest time and therefore the shortest distance possible from the collar to the abutted pipe ends. For example, parallel geometry for the collar and pipe take a longer time and require a greater distance from the collar to the pipe which the present invention avoids. Tapering the collar or sleeve also requires a lesser amount of explosive to propel the collar or sleeve. This allows reduction of the explosive layer or mass (ring) thickness. The total amount of explosive is reduced with numerous benefits both from an economic and safety standpoint.

The ends of pipe sections **11** and **12**, respectively, may be buffed to clean metal for about **2** inches from each of the ends and the ends butted. A mandrel may then be centrally located thereunder. When it is determined that the pipe sections are accurately aligned and the ends thereof in full abutment, the mandrel may then be expanded against the interior of the pipe sections.

Ordinarily it is preferred to have the pipe ends butt squarely with no taper, although pipe with inward tapers on the outer surface at its ends may be used. The space or notch formed by tapered pipe ends between the pipe ends may result in a smooth welded collar and may avoid the formation of an outward slight bulge to the welded collar. This slight bulge, if any, has no effect on the strength or integrity of the welded pipe and may be hardly noticeable.

Thus, the present invention is quite important and useful. Pipe sections may be welded together with a minimum expenditure of equipment, effort and time. Pipe sections **12–14** inches in diameter and of greater or lesser diameter are easily welded together. The invention is, therefore, new, useful and unobvious since heretofore manpower and/or machines were necessary to weld pipe together.

The nature and objects of the present invention having been clearly described and illustrated and the best mode and embodiment contemplated set forth, what we wish to claim as new and useful and secure by Letters Patent is:

What is claimed is:

1. A dual high explosive for use in the explosive welding of abutting cylindrical members which comprises:

a welding explosive mass circumferentially located on a metallic substantially cylindrical sleeve surrounding the abutting members;

said welding explosive mass comprising a circumferential body of high explosive and having a greater thickness at its center than at its ends transversely disposed of said center such that upon initiation the maximum explosive impact is exerted inwardly toward said sleeve;

initiating explosive means arranged on said body at least at its center and extending circumferentially therearound in explosive contact with said body;

at least two equidistantly spaced apart detonators in operable contact with said initiating explosive means and adapted to be connected to a source of energy, said detonators being arranged for causing a symmetrical blast load to be applied to said members upon energization thereof; and

said initiating explosive means having a detonation velocity substantially greater than that of said welding explosive mass such that upon detonation of said initiating explosive and said welding explosive by the simultaneous energization of said detonators there emanates from each of said detonators at said spaced apart locations at least a pair of opposed wedge-shaped wave fronts which travel in opposite directions about said sleeve and impact at about halfway between said detonators with a corresponding one of the wave fronts emanating from the other of said detonators and wherein the apex of each of said wave fronts is caused by said initiating explosive and the remaining portion of each of said wave fronts which flanks the apex thereof is caused by said welding explosive upon detonation thereof, for causing said collar to weld to said abutting members.

2. A high explosive shape according to claim **1** including two detonators arranged on said initiating explosive means **180°** apart.

3. A high explosive shape according to claim **1** wherein said initiating explosive means has a detonation velocity of about **30%** greater than that of said welding explosive.

4. A high explosive shape according to claim **1** wherein said initiating explosive means is symmetrically located relative to said welding explosive.

5. A high explosive shape according to claim **4** wherein said initiating explosive means comprises **63%** by weight PETN, **7%** by weight nitrocellulose and **30%** polymeric materials.

6. A high explosive shape according to claim **5** wherein said initiating explosive means comprises a strip.

7. A high explosive shape according to claim **1** wherein said welding explosive body includes a circumferential indentation at its center and said indentation includes at least said initiating explosive means disposed therein.

8. A high explosive shape according to claim **7** wherein said circumferential indentation extends perpendicularly relative to the axis of said cylindrical members in the direction from the center of said welding explosive body to said metallic sleeve.

9. A high explosive shape according to claim **1** wherein said welding explosive body comprises a substantially V-shaped notch at its center which is filled at least with said initiating explosive means.

10. A high explosive shape according to claim **1** wherein said initiating explosive means comprises from about **1%** to about **10%** by weight of said welding explosive body.

11. A dual high explosive according to claim **1** wherein each of said wave fronts comprises a leading portion created by said initiating explosive and a flanking portion created by said welding explosive, wherein said leading portion always precedes said flanking portion of said wave front by a predetermined time differential.

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