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DEPOSITION BY OXY-FUEL GAS FLAME

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2 Sheets-Sheet 1

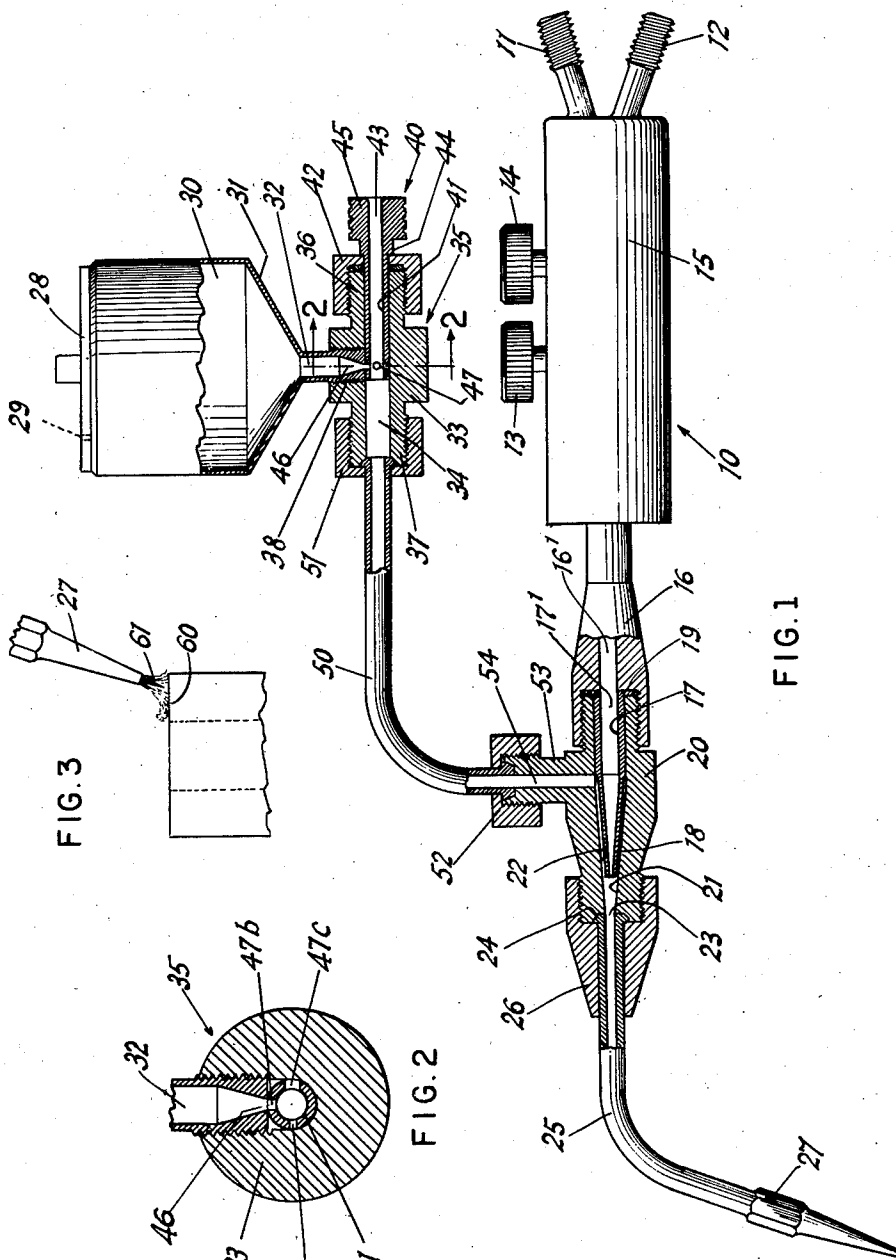


FIG. 1

FIG. 2

FIG. 3

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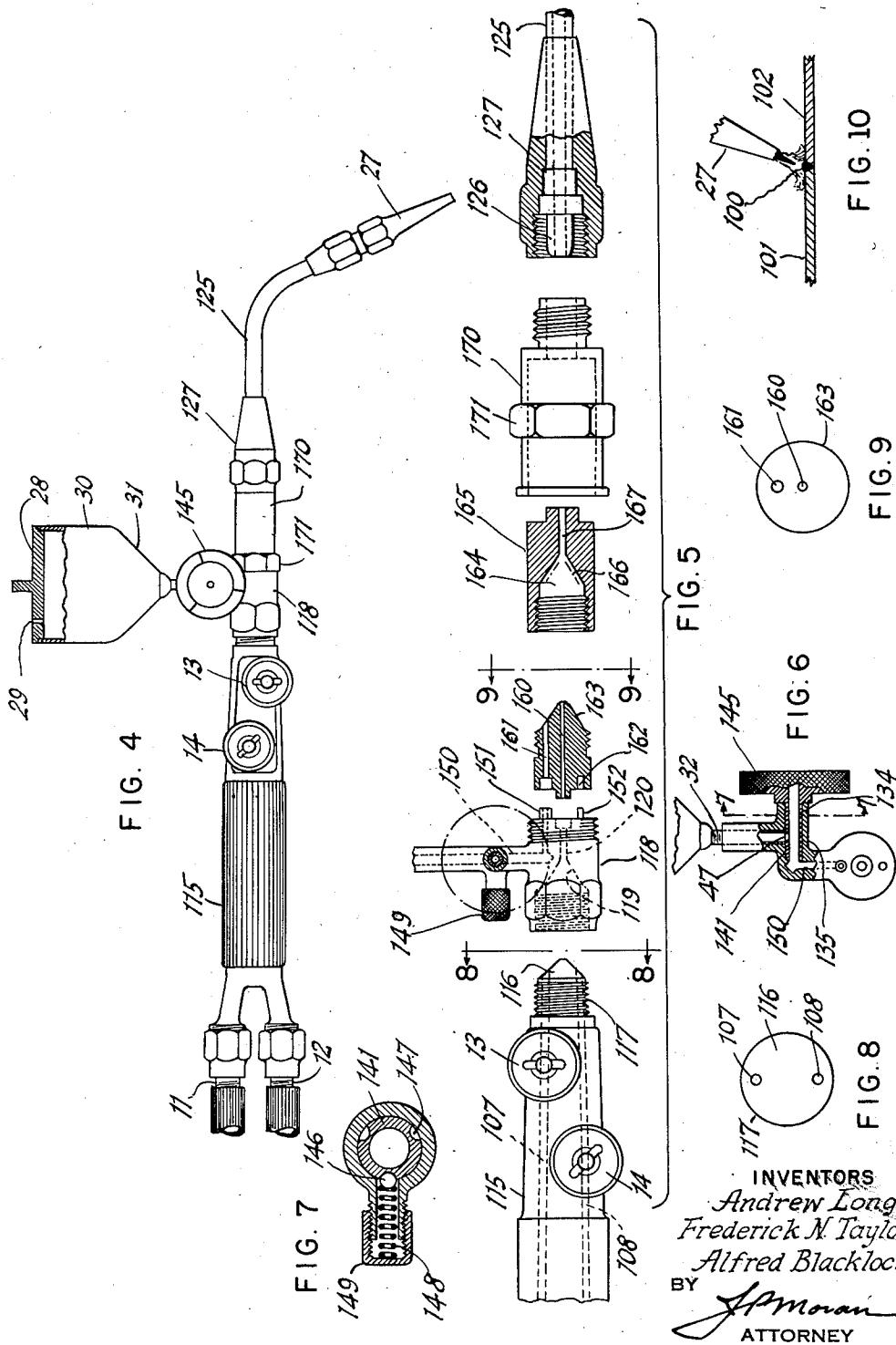
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13 Claims. (Cl. 117—22)

This invention relates to processes and apparatus for flame deposition of metal powder onto one or more base metal parts for increased resistance to corrosion or wear, to form a welded joint, or for other special purposes.

The art to which the present invention generally relates is known as "metal spraying." This term normally connotes a process of projecting globules of molten metal by means of a carrier gas at the surface to be covered, these globules solidifying as individual particles after deposition on a relatively cold base metal surface. Such molten globules may be formed by melting the coating metal by a high temperature heating flame, an electric arc, or equivalent arrangements, this melting operation fusing and superheating the coating metal during or immediately prior to its projection onto the surface to be coated.

In such metal spraying processes, the coating metal may be supplied to the heating flame or electric arc either in the form of a rod or wire or in the form of a metal powder. In known arrangements of the latter type, the metal powder is fed by a stream of compressed air or gas into a stream of mixed oxygen and fuel gas discharged from a nozzle, the oxy-fuel gas mixture being ignited at the nozzle to provide the melting flame. Where a flame melting and spraying blowpipe is employed, the discharge tip of the blowpipe is normally held a considerable distance from the surface to be sprayed, i. e. a distance on the order of six to eight inches, so that there will be a prolonged contact between the metal to be deposited and the flame and yet the powder melting flame will not be in effective heat transfer contact with the surface being sprayed. The stream of compressed carrier air or gas is intimately mixed with the oxy-fuel gas flame, causing the metal powder to be melted and thence projected in molten form onto the surface to be coated. As each molten globule tends to be flattened by its impact against the surface, the resultant structure is one of small individual solidified platings having relatively large spaces therebetween, and is characterized by entrapped oxides resulting from the passage of the molten globules through the air. Consequently the resultant plated structure is usually porous to an undesirable extent and only mechanically bonded to the subjacent base metal surface.

The known methods of applying molten metal coating to a surface by means of a stream of carrier air or gas generally require three separate operations. The first step is a thorough cleaning of the surface to be coated, this being effected by sand blasting or the like in order to clean and roughen the surface. The metal coating is then sprayed onto the surface in the form of fused and superheated metal globules carried in a stream of air or gas under considerable pressure. After the application of the coating metal is complete, a high temperature heating flame or electric arc must be played over the coated surface to cause the coating to adhere properly to the surface and to effect greater uniformity and continuity to the layer of coating material.

Such metal spraying processes have disadvantages which have detached from their commercial application. One disadvantage is the fact that the application of the coating involves the three successive operating steps mentioned above, requiring a substantial operating time. Another disadvantage is the relatively complicated controls involved. For example, the oxygen and fuel gas for the heating flame must be controlled as to pressure, volume, and proportions, to provide the desired type of heating flame. In addition, the stream of carrier air or gas must be similarly carefully controlled, as must also be the feeding of the metal into the carrier stream. In practice, it is very difficult to properly coordinate all of these factors, and proper coordination is a necessity if a coating with proper adhesion and relative freedom from porosity is to be obtained. These factors do not make the process particularly suitable for mechanization. The apparatus required for carrying out such processes is usually bulky and cumbersome and accordingly does not lend itself for use as a portable unit.

Another disadvantage is that known processes and apparatus using a metal powder are limited to the coating of a single metal surface, such as hard facing operations and the like, and cannot be used successfully, for example, in the fusion weld uniting of the adjoining surfaces of a pair of metal members. In commercial practice, such fusion welding with additional filler metal supplied is still limited to the filler metal being fed to the welding zone in the form of a wire or rod.

In accordance with the present invention, the foregoing disadvantages are overcome in a novel manner, and a metal powder spraying method and apparatus is provided which is applicable both to the localized surfacing of a single metal surface and to the fusion welding of metal parts. The invention has the further advantages that no prior cleaning of the work surface is ordinarily needed and the apparatus required consists primarily of a standard portable oxy-fuel gas welding torch unit with certain additions.

In general, the invention method comprises the steps of first maintaining an oxy-fuel gas heating flame, preferably of oxygen and acetylene in predetermined proportions, in effective heating relation with the surface of the workpiece or workpieces to have metal applied thereto until all of the surface area has reached a uniform red heat, i. e. at a temperature substantially below the base metal fusion temperature. The heating flame is then concentrated on a predetermined localized area of the base metal surface until this initial area reaches a "sweating" temperature, this term, as used herein, indicating a state of incipient surface fusion of the base metal. During such heating, a stream of air at atmospheric pressure is aspirated into the oxy-fuel gas mixture between an initial zone, in which the oxygen under pressure is mixed with a suitable fuel gas under pressure in predetermined proportions to form a combustible gas mixture and a mixture ignition point spaced from the mixing zone. When the initial surface area begins to sweat, finely divided metal powder, from a suitable source thereof, is introduced at a substantially uniform rate by gravity into the stream of aspirated air, for carrying the metal powder into the combustible mixture by the aspirated carrier air. It is highly important that the oxy-fuel gas blowpipe be positioned at a predetermined distance from the surface of the base metal at which the tip of the high temperature inner cone of the flame is slightly spaced from that surface while the outer cone of the flame bathes the area immediately surrounding the localized area to be sprayed. The metal powder is carried by the combustible mixture and carrier air through the inner cone of the heating flame and impinged onto the heated surface while it is being bathed with the outer flame cone. The metal power particles

are thus heated to a temperature approaching but lower than the metal melting point in passing through the flame and immediately after deposition are fused integrally with the incipiently fused local area of the work surface by the heat received by conduction from the subjacent and surrounding base metal surface areas and the continued heating effect of the flame. The operation is continued until a solid coating of a predetermined thickness free from porosity has been fused on the base metal surface. A molecular bond is formed between the base metal and the deposited metal. No further treatment is necessary to smooth the surface of the deposited metal.

The heating flame is then progressively moved over an adjacent incremental surface area which has been raised to the sweating temperature by the outer portion of the melting flame and the metal powder is impinged against and fused therewith as described. The coating operation may be cyclically repeated as a continuous operation until a smooth uniform coating of the desired thickness has been built up on the base metal. This coating may be either a facing on a single metal surface or may form a weld deposit integrally uniting two or more metal surfaces.

For a better understanding of the invention method and apparatus, reference is made to the following detailed description of a typical embodiment of the apparatus and a typical application of the method, as illustrated in the accompanying drawings. In the drawings:

Fig. 1 is an elevation, partly in section, of apparatus embodying the invention;

Fig. 2 is a section taken on the line 2—2 of Fig. 1;

Fig. 3 is a diagrammatic view illustrating the position of the blowpipe relative to the base metal;

Fig. 4 is an elevation of a modified construction of the blowpipe;

Fig. 5 is an enlarged exploded view partly in section of a portion of the construction shown in Fig. 4;

Fig. 6 is an end view, partly in section, of the powder control device;

Fig. 7 is an enlarged section on the line 7—7 of Fig. 6;

Figs. 8 and 9 are end views of certain parts taken on the lines 8—8 and 9—9 of Fig. 5; and

Fig. 10 is a sectional view of a welded joint made in accordance with the invention.

Referring to the drawings, the metal spraying apparatus of the invention includes an oxy-fuel gas blowpipe or torch which, except for the means for introducing the carrier air stream and entrained metal powder into the oxy-fuel gas mixture, is of a well known construction. Thus, the blowpipe or torch 10 is illustrated as of the type commercially used for oxy-acetylene welding, including a mixer body or chamber 15 having, at its rear end, nipples 11 and 12 for attachment of the chamber 15 to separate sources of oxygen and acetylene under pressure, respectively. Valves 13 and 14 are provided in converging flow passages in chamber 15 for the purpose of controlling the volume of oxygen and acetylene, respectively, delivered to chamber 15, and thus the proportions of the resultant combustible mixture leaving chamber 15. The latter is provided, at its forward end, with a connecting pipe 16 internally threaded at its forward end for attachment of a discharge nozzle or tapering orifice member 17. Nozzle 17 is progressively reduced in diameter from a point intermediate its ends to its discharge end, as indicated at 18, its outer surface along the forward end 18 being generally frusto-conical. The nozzle passage 17' forms a registering continuation of the passage 16' in the pipe 16 and discharge opening from chamber 15.

The nozzle 17 is held in position in pipe 16 by an adapter member 20 screwed into the forward end of pipe 16 and engaging the flanged inner end 19 of nozzle 17. Adapter 20 is formed with a forwardly tapering frusto-conical chamber 21 concentric with and surrounding in closely spaced relation the forward end 18 of nozzle 17

so as to provide an annular frusto-conical chamber 22 between the tapered forward end of nozzle 17 and the inner wall surface of chamber 21. Nozzle 17 terminates short of the smaller end of chamber 21, and the latter has a comparatively small diameter discharge orifice 23 axially aligned with nozzle 17 and registering with the nipple 24 of a downwardly curved connecting pipe or stem 25. Stem 25 is secured onto the forward end of adapter 20 by a suitable coupling nut 26, and has detachably secured to its forward end the usual blowpipe discharge tip or nozzle 27 having a small diameter discharge opening at its lower end.

The metal powder to be deposited is contained within a supply hopper 30 mounted on blowpipe 10. A cover 28 having an opening 29 therein for an atmospheric connection closes the top of the hopper 30. The hopper is filled with a free flowing finely divided metal powder of the desired metallurgical composition. The hopper 30 has a conical bottom 31 converging toward a central discharge pipe 32 by means of which the hopper is supported on a coupling member 35. In operation, the blowpipe is preferably so held that hopper 30 will be substantially vertical so that the metal powder will flow by gravity downwardly through pipe 32. However, the device will operate satisfactorily even though hopper 30 is not exactly vertical, and the center line of the latter may be at substantial angle to the vertical.

The coupling member 35 is formed with a central body portion 33 and end nipples 36 and 37. Extending axially of the body and nipples is a cylindrical bore 34, concentric with the nipples. The body portion 33 also has a radially extending threaded inlet passage 38 in its upper side communicating with bore 34, and having pipe 32 threaded thereto.

Control of the flow of metal powder from hopper 30 into the coupling member 35 is provided by means of a valve 40. Valve 40 consists of a tubular stem 41 having a surface-to-surface fit within the rear end of bore 34 and extending forwardly of the discharge end of pipe 32. The stem 41 extends through a packing gland 42 threaded on nipple 36, and is provided with a knurled head 45 having a reduced shoulder 44 fitting against gland 36. The central passage provided by the stem 41 is continued as a coaxial passage 43 opening rearwardly to atmosphere through a knurled head 45.

The lower end of pipe 32 has its inner diameter progressively reduced to terminate in a discharge orifice 46. In a diametric zone aligned with the axis of orifice 46, stem 41 is formed with a series of circumferentially spaced radial apertures 47. There are three of these apertures, 47a, 47b and 47c, in the embodiment shown, although more or less than three may be provided, the sole criterion being that the circumferential extent of stem 41 between adjacent apertures be at least equal to the diameter of pipe orifice 46.

As shown in Fig. 2, the stem apertures 47 differ in flow area, aperture 47a being the smallest and aperture 47c the largest. By positioning a selected one of these orifices in alignment with orifice 46 of pipe 32, the rate of flow of metal powder from hopper 30 into coupling 35 may be pre-selected. For this purpose, the knurled head 45 may be suitably marked for cooperation with a locating indicia (not shown) on the outer surface of gland 42. The gravity flow of metal powder may be interrupted or shut off by turning knurled head 45 to an "off" position where orifice 46 is closed by an unperforated arc of the periphery of stem 41.

The forward nipple 37 of coupling member 35 is connected by a curved pipe 50 to adapter 20. This pipe is connected by a gland 51 to nipple 37, and by a gland 52 to a radial stem 53 on adapter 20. The pipe 50 registers with a passage 54 arranged coaxially of stem 53 and communicating at its lower end with the rear portion of the annular chamber 22 of adapter 20. The reduced pressure created in the tapering annular chamber 22 by

5

the high velocity flow of the combustible mixture under pressure through passage 21 and orifice 23 aspirates a flow of atmospheric air through passage 43, stem 41, bore 34, pipe 50, passage 54, and annular chamber 22, into discharge orifice 23 of adapter 20. This stream of aspirated air mixes thoroughly with the combustible mixture discharged from the nozzle passage 18 in the space 21 and the resultant mixture of oxygen, aspirated air and acetylene discharges from the orifice 23 through the pipe 25 and discharge nozzle 27. This gaseous mixture can be readily ignited at the discharge end of the tip 27. Depending on the composition and melting point of the metal to be deposited, the valves 13 and 14 are operated to secure the desired type of flame, e. g. excess-acetylene, neutral, reducing or oxidizing, a neutral flame being used for the lower temperature nickel base alloys and an excess-acetylene flame for the high melting temperature cobalt base alloys.

When the blowpipe is to be used for metal deposition, the knurled head 45 is turned from an "off" position to cause one of the apertures 47a, 47b or 47c to register with the pipe orifice 46. The atmospheric pressure on the powder in the container 30 in conjunction with the stream of aspirated air flowing past the lower edge of the registering aperture 47 causes a steady stream of powder particles to be entrained in the aspirated air stream.

The physical character of the metal powder is highly important, if not essential, to successful operation of the blowpipe and process. To insure a steady flow of powder from the container into the aspirated air stream, the powder should be in a freely flowable form. For this reason a finely divided powder in the form of spherical or substantially spherical particles is preferred. The powder fineness should be substantially 100% through a 100 mesh U. S. Standard screen and a major portion between 100 and 200 mesh. If most of the powder should be finer than 200 mesh, there is a tendency for the powder to pack in the container and the powder flow be interrupted or an irregular stream of powder be entrained in the aspirated air.

In carrying out the process of the invention the hopper 30 is filled with powdered metal of the physical character described and the type to be deposited on the base metal surface and head 45 turned to an "off" position. The powder aperture size, nozzle 17, and discharge tip 27 are selected to provide the most effective combination of parts. The oxygen and acetylene at a pressure of from 10-15 p. s. i., for example, are then admitted to mixing chamber 15 through manipulation of valves 13 and 14, and the combustible mixture ignited at the discharge end of nozzle 27, the valves 13 and 14 being usually adjusted to provide a flame of the type normally used for welding operations, such as a neutral or slightly reducing flame. The blow pipe is then held as shown in Fig. 3 with the tip 27 closely spaced, for example one inch or less, from the work surface 60 so that the inner or high temperature cone 61 of the flame has its tip at or slightly spaced from the work surface while the outer cone of the flame bathes the surface area surrounding the axis of the inner cone. The flame is moved over the work surface to be covered until the entire area has reached a uniform red heat. When this condition has been effected, the oxygen, acetylene and aspirated air flame is concentrated on an initial localized surface area until such time as this area is in a sweating condition. The resulting state of incipient fusion of the base metal surface provides a sticky area capable of holding any powder particles impinging thereon. The valve 40 is then turned to position one of the orifices 47 in registry with orifice 46 of pipe 32, the particular orifice 47 being used being dependent upon the rate of powder deposition desired. The atmospheric air entering passage 43 and drawn into annular passage 22 by the aspirating action of the high velocity jet of combustible mixture issuing from nozzle 17, and entrained powder, mixes with the

6

combustible mixture in the space 21 and orifice 23. The powder particles and aspirated air assume the velocity of the combustible mixture while in the pipe 25 and discharge therewith from the nozzle tip 27. The powder particles are heated while in the high temperature flame but due to the very short path of travel before the powder impinges upon the sweating surface of the base metal, the powder particles are heated in the flame only to a temperature approaching but still below the melting temperature. As the powder strikes the sweating localized surface area, with the blowpipe flame playing thereon, the powder particles are caught on the surface of the base metal. The powder is rapidly fused and coalesced with the incipiently fused base metal surface, due to the high flame temperature at the work surface and heat absorption from the base metal. The outer cone of the flame spreads over the area surrounding the localized area on which the metal powder is being deposited and heats those areas to a sweating temperature. The blowpipe is then progressively moved over an adjoining area at a sweating temperature and the described operation repeated until the entire surface of the base metal is covered.

In the modification illustrated in Figs. 4-9 a more compact construction of blow pipe is illustrated. In this embodiment the body member 115 is provided with valves 13 and 14 controlling the flow of oxygen and fuel gas through separate passages 107 and 108 in the body member. As shown in Figs. 5 and 8, these passages terminate at opposite points in the conical end 116 of a threaded section 117 which fits into an adapter member 118 leaving a forwardly tapering space 119 in which the oxygen and fuel gas mix before discharging through a central orifice passage 120. The powder supply system is mounted directly on the adapter member 118, as shown in Figs. 4-7, and consists of a covered container 30 for the powdered metal which discharges through the conical bottom 31 and pipe 32 into the horizontal bore 134 of a stem 135 extending vertically and then laterally from the adapter member. A tubular stem 141, having circumferentially spaced apertures 47 therein adapted to register with the lower end of the pipe 32, controls the supply of metal powder to the bore 134 by various settings of the knurled head 145. The tubular stem 141 is held in the various aperture registering positions by a spring pressed ball 146 fitting into corresponding recesses 147 in the stem at a point longitudinally spaced from the apertures. The spring 148 is held in position by a cap nut 149. The bore 134 communicates with a vertical passage 150 in the stem 135, the lower end of the passage 150 being bent at right angles and terminating in a boss 151 radially spaced from the recessed end of the orifice passage 120. A positioning pin 152 projects at the opposite side of the orifice 120. The passages 120 and 150 and pin 152 register with corresponding parallel passages 160 and 161 and a recess 162 respectively in a plug member 163. The plug member 163 fits into a mixing chamber 164 of a barrel member 165, as indicated in broken lines in Fig. 5, to define a forwardly tapering annular chamber 166 in which the powder and carrier air discharged from the passage 161 and oxygen-fuel gas mixture from the passage 160 are intimately mixed. The powder laden combustible gas stream discharges from the chamber 166 through a central passage 167. The parts are held in their assembled position by a sleeve member 170 and nut 171 engaging the forward threaded end of the adapter member 118. A curved pipe 125 having a shouldered fitting 126 and sliding coupling sleeve 127 is threaded on the forward end of the sleeve member 170, and provides a conduit for conveying the powder-laden gas stream to the discharge tip 27.

The operation of the modified blowpipe construction shown in Figs. 4-9 is substantially similar to that in the construction shown in Figs. 1 and 2, the oxygen and

a fuel gas, such as acetylene, being supplied in controlled quantities to the mixing space 119 and the mixture delivered through the central passage 160 to a discharge passage 167 at one end of a tapered annular aspirating chamber 166, which causes a flow of atmospheric air to be aspirated through the bore 134 and entrain the finely divided powdered metal passing through aperture 47 from the container 30.

The described process is particularly characterized by the fact that the powder is not melted in passing through the heating flame. This has been proven by tests in which the powder flow is initiated before the base metal surface has reached a sweating temperature. In such case, the powder particles projected against such surface area have been found to bounce off the surface, and on examination clearly show that the powder particles are still in a solid unfused condition. The rapid melting of the powder after its deposition results from the surface being in an incipient fused condition and the high temperature of the heating flame.

In one example of the use of the process for hard-facing a block of carbon steel SA 212 with Coast Metals Inc. HN 2B alloy (a nickel base alloy containing boron and silicon), the HN 2B powder was successfully deposited in a quarter inch layer on the base metal after the base metal had been preheated to a sweating temperature of between 1100 and 1200 C. When the base metal surface was brought to a sweating temperature, the metal spray from the blow pipe readily deposited thereon and fused with the steel. A smooth uniform surface was obtained on the deposited metal with complete freedom from porosity and cracks and with a hardness of 61 Rockwell C. Microphotographs of sections showed a solid layer of the deposited metal on the carbon steel with a relatively thin fusion area between the boundary surfaces thereof.

The strength of the bond between the powder and the base metal, after fusion has been effected, is of the order of at least 40,000 p. s. i., thus indicating the presence of a strong molecular bond between the surface and the metal deposit thereon.

The deposit may be merely a coating on one surface, such as in a hard facing operation, or may be a weld deposit 100 butt welding two plates 101 and 102, as shown in Fig. 10.

It will be understood that the deposited powder need not be only a single metal. For example, should an alloy coating or a weld of a predetermined composition be desired, the constituent metals, in powder form, may be mixed in the desired proportions before being placed in the hopper 30. Alternatively, two or more hoppers could be connected to the passage 54 of adapter 20 by suitable modification of the latter, with suitable proportioning valve apertures, such as 47.

As distinguished from known processes in which the powder is carried to the base metal surface by a separate stream of air or gas under a substantial superatmospheric pressure, the present invention is further characterized by a powder flow in a given blowpipe which is regulated primarily by the pressure and velocity of the combustible gas mixture, since the rate of aspirated air flow through the coupling 35 for entrainment of powder therein is determined by the velocity of the combustible mixture issuing from nozzle 18. Furthermore the metal depositing operation is effected in one continuous step, and does not involve a plurality of separate operations, such as known methods of first cleaning the base metal surface, then spraying molten metal thereagainst, and finally fusing the surface and deposited metal to coalesce the deposited metal with the surface metal.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the invention principles, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A method of applying metal deposit to a metal surface comprising the steps of mixing a combustible gas under controllable pressure with a combustion supporting gas under controllable pressure in a mixing zone to form a combustible mixture under controllable pressure; igniting such mixture at a point spaced from the mixing zone; maintaining the resultant controllable velocity flame in closely spaced effective heat transfer relation with such surface to elevate the temperature thereof to the incipient fusion temperature, while aspirating additional gas into the mixture between the mixing zone and the ignition point; and, when the surface temperature attains the fusion value, controllably entraining powdered metal, from a source of supply of the latter, into such additional gas for impingement onto the heated metal surface by such flame at a rate controlled by the pressure induced velocity of the mixture.
2. A method of applying a metal deposit to a metal surface comprising the steps of mixing a combustible gas under pressure with a combustion supporting gas under pressure in a mixing zone to form a combustible mixture under pressure; igniting such mixture at a point spaced from the mixing zone; maintaining the resultant flame in effective heat transfer relation with such surface to elevate the temperature thereof while aspirating additional gas, at substantially atmospheric pressure, into the mixture between the mixing zone and the ignition point; and after the metal surface has attained its incipient fusion temperature, entraining powdered metal, from a source of supply of the latter, into such additional gas for impingement onto the heated metal surface by such flame while continuing to play such flame on the surface.
3. A method of applying a metal deposit to a metal surface comprising the steps of mixing a combustible gas under pressure with a combustion supporting gas under pressure in a mixing zone to form a combustible mixture under pressure; igniting such mixture at a point spaced from the mixing zone; maintaining the resultant flame in effective heat transfer relation with such surface to elevate the temperature thereof to the incipient fusion value while aspirating atmospheric air into the mixture between the mixing zone and the ignition point; and, when the surface temperature attains the incipient fusion value, entraining powdered metal, from a source of supply of the latter, into such atmospheric air for impingement onto the heated metal surface by such flame.
4. A method of applying a metal deposit to a metal surface comprising the steps of mixing a combustible gas under controllable pressure with a combustion supporting gas under controllable pressure in a mixing zone to form a combustible mixture under controllable pressure; igniting such mixture at a point spaced from the mixing zone; maintaining the resultant controllable velocity flame in closely spaced effective heat transfer relation with such surface to elevate the temperature thereof to the incipient fusion value while aspirating atmospheric air into the mixture between the mixing zone and the ignition point; and, when the surface temperature attains the incipient fusion value, controllably entraining powdered metal, from a source of supply of the latter, into such atmospheric air for impingement onto the heated metal surface by such flame at a rate controlled by the pressure induced velocity of the mixture.
5. A method of applying metal deposit to a metal surface comprising the steps of mixing a combustible gas under pressure with combustion supporting gas under pressure in a mixing zone to form a combustible mixture under pressure; igniting such mixture at a point spaced from the mixing zone; maintaining the resultant flame in closely spaced effective heat transfer relation with such surface to elevate the temperature thereof to the incipient fusion value while aspirating atmospheric air into the mixture between the mixing zone and the ignition point; and after the metal surface has attained its incipient fusion

temperature, controllably entraining powdered metal, from a source of supply of the latter, into such atmospheric air for impingement onto the heated metal surface by such flame, while continuing to play such flame on the surface and on the powdered metal on the latter.

6. A method of applying metal deposit to a metal surface comprising the steps of mixing a combustible gas under controllable pressure with a combustion supporting gas under controllable pressure in a mixing zone to form a combustible mixture under controllable pressure; igniting such mixture at a point spaced from the mixing zone; playing the resultant controllable velocity flame in closely spaced effective heat transfer relation over all of such surface to elevate the temperature thereof to a red heat while aspirating atmospheric air into the mixture between the mixing zone and the ignition point; when the surface has attained a red heat, maintaining the flame in closely spaced effective heat transfer relation with a localized surface area to heat the latter to the incipient fusion temperature; after such localized surface area has attained its incipient fusion temperature, controllably entraining powdered metal, from a source of supply of the latter, into such atmospheric air for impingement onto the localized surface area by such flame at a rate controlled by the pressure induced velocity of the mixture, while continuing to play such flame on the localized surface area and then progressively impinging metal powder onto succeeding localized surface areas as the latter are successively heated to the incipient temperature.

7. A method of applying a metal deposit to a metal surface comprising the steps of mixing oxygen under pressure with a fuel gas under pressure in a mixing zone to form a combustible mixture under pressure; igniting such mixture at a point spaced from the mixing zone; maintaining the resultant flame in closely spaced effective heat transfer relation with such surface to elevate the temperature thereof to the incipient fusion value while aspirating atmospheric air into the mixture between the mixing zone and the ignition point; and, when the surface temperature attains the incipient fusion value, entraining powdered metal, from a source of supply of the latter, into such atmospheric air for impingement onto the heated metal surface by such flame.

8. A method of applying a metal deposit to a metal surface comprising the steps of mixing oxygen under controllable pressure with a fuel gas under controllable pressure in a mixing zone to form a combustible mixture under controllable pressure; igniting such mixture at a point spaced from the mixing zone; maintaining the resultant controllable velocity flame in closely spaced effective heat transfer relation with such surface to elevate the temperature thereof to the incipient fusion value while aspirating atmospheric air into the mixture between the mixing zone and the ignition point; and, when the surface temperature attains the incipient fusion value, controllably entraining powdered metal, from a source of supply of substantially spherical powdered metal particles of a fineness of substantially 100% through a 100 mesh U. S. Standard screen with a major portion between 100 mesh and 200 mesh, into such atmospheric air for impingement onto the heated metal surface by such flame at a rate controlled by the pressure induced velocity of the mixture, while continuing to play such flame on the surface.

9. Apparatus, for applying a metal deposit to a metal surface, comprising, in combination, a blowpipe having a gas mixing chamber, means for connecting said chamber to a source of oxygen under pressure and to a source of fuel gas under pressure for mixing of the gases in said chamber to form a combustible mixture under pressure, means severally controlling the flows of oxygen and fuel gas into said chamber, and a combustible mixture discharge nozzle receiving the combustible mixture from said chamber; an aspirator connected between and in communication with said chamber and said nozzle for flow

of the combustible mixture therethrough from the chamber to the nozzle; conduit means directly connected at one end to said aspirator and having its opposite end open to atmosphere for aspiration of atmospheric air into the mixture flowing through said aspirator; and a container for powdered metal having a discharge outlet connected to said conduit means at a point spaced from said opposite end for entrainment of powdered metal into the air stream aspirated into the combustible mixture, said container being vented to atmosphere above the level of powdered metal therein.

10. Apparatus, for applying a metal deposit to a metal surface, comprising, in combination, a blowpipe having a gas mixing chamber, means for connecting said chamber to a source of oxygen under pressure and to a source of fuel gas under pressure for mixing of the gases in said chamber to form a combustible mixture under pressure, means severally controlling the flows of oxygen and fuel gas into said chamber, and a combustible mixture discharge nozzle receiving the combustible mixture from said chamber; an aspirator connected between and in communication with said chamber and said nozzle for flow of the combustible mixture therethrough from the chamber to the nozzle; said aspirator having a central passage connected to said mixing chamber and discharging toward said nozzle, and an annular passage surrounding said central passage, said passages intercommunicating at the discharge end of said central passage; conduit means directly connected at one end to said annular passage and having its opposite end open to atmosphere for aspiration of atmospheric air into the mixture flowing through said aspirator; a container for powdered metal having a discharge outlet connected to said conduit means at a point spaced from said opposite end for entrainment of powdered metal into the air stream aspirated into the combustible mixture, said container being vented to atmosphere above the level of powdered metal therein; said conduit means, in the operative position of blowpipe, extending substantially horizontally past said discharge outlet, and said discharge outlet opening perpendicularly into said conduit means; and valve means controlling flow of the powdered metal from said container into said conduit means.

11. For use with a blowpipe having a gas mixing chamber, means for connecting said chamber to a source of oxygen under pressure and to a source of fuel gas under pressure for mixing of the gases in said chamber to form a combustible mixture under pressure, and a combustible mixture discharge nozzle receiving the combustible mixture from said chamber; an adaptor unit comprising, in combination, an aspirator having coupling means for connection to such chamber and to such nozzle for flow of the combustible mixture therethrough from the chamber to the nozzle; conduit means directly connected at one end to said aspirator and having its opposite end open to atmosphere for aspiration of atmospheric air into the mixture flowing through said aspirator; and a container for powdered metal having a discharge outlet connected to said conduit means at a point spaced from said opposite end for entrainment of powdered metal into the air stream aspirated into the combustible mixture, said container being vented to atmosphere above the level of powdered metal therein.

12. For use with a blowpipe having a gas mixing chamber, means for connecting said chamber to a source of oxygen under pressure and to a source of fuel gas under pressure for mixing of the gases in said chamber to form a combustible mixture under pressure, and a combustible mixture discharge nozzle receiving the combustible mixture from said chamber; an adaptor unit comprising, in combination, an aspirator having coupling means for connection to such chamber and to such nozzle for flow of the combustible mixture therethrough from the chamber to the nozzle; conduit means directly connected at one end to said aspirator and having its opposite end open

11

to atmosphere for aspiration of atmospheric air into the mixture flowing through said aspirator; a container for powdered metal having a discharge outlet connected to said conduit means at a point spaced from said opposite end for entrainment of powdered metal into the air stream aspirated into the combustible mixture, said container being vented to atmosphere above the level of powdered metal therein; and valve means controlling flow of the powdered metal from said container into said conduit means.

13. For use with a heating blowtorch for forming an oxy-fuel flame, an eductor unit for supplying powder to the flame, said eductor unit including coupling means for connecting the same to the gas mixing chamber of the blowpipe and being formed with a duct for the passage of a stream of the mixed gases therethrough; a nozzle component formed with a bore included in such duct; a complementary component formed with a bore coaxial with the bore of the nozzle component, said eductor component embracing said nozzle component and the bore of the eductor component forming, with the nozzle component, an annular space; conduit means directly connected at one end to such space and having its op-

12

posite end open to atmosphere for aspiration of atmospheric air into the mixture flowing through the duct; and a container for powder having a discharge outlet connected to said conduit means at a point spaced from said opposite end for entrainment of powder into the air stream aspirated into such mixture, said container being vented to atmosphere above the level of powdered metal therein.

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