Nov. 22, 1960 A. P. SHEPARD 2,961,335
METHOD AND APPARATUS FOR APPLYING HEAT-FUSIBLE COATINGS ON SOLID OBJECTS
Filed April 13, 1956 2 Sheets-Sheet 1

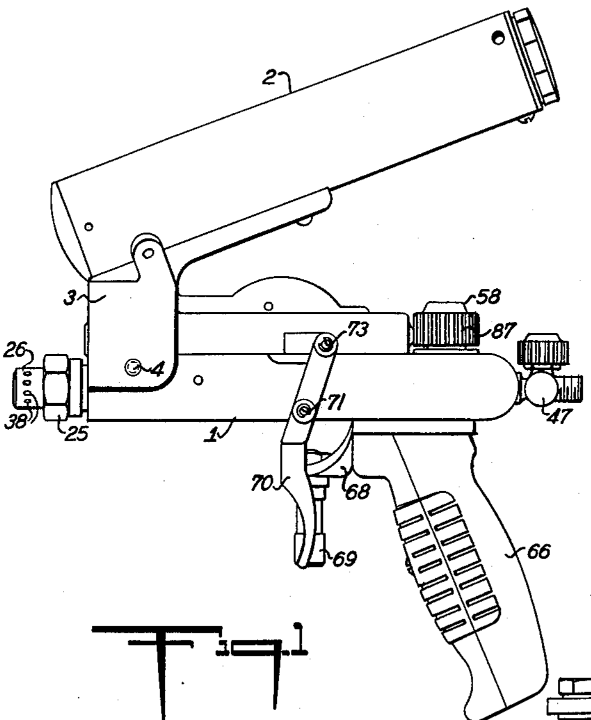

Fig.1

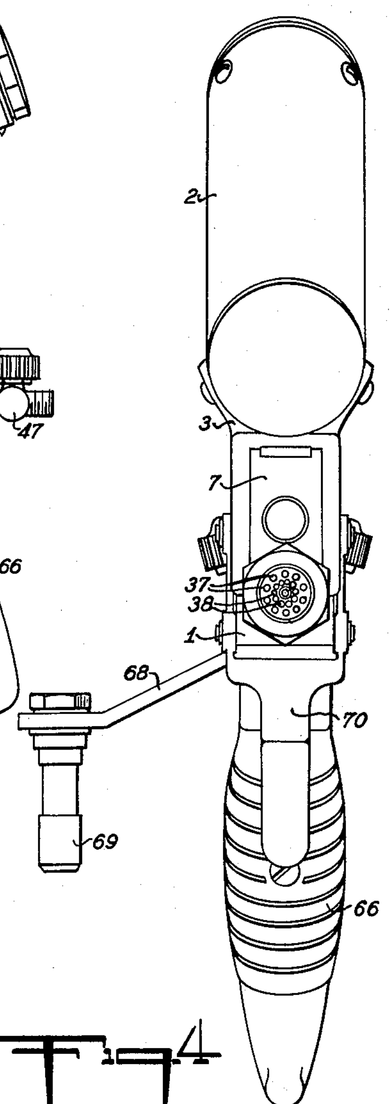

Fig.4

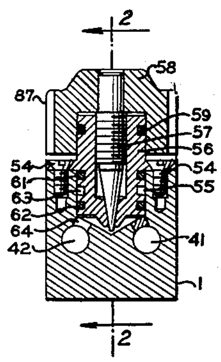

Fig.3

INVENTOR
ARTHUR P. SHEPARD
BY Burgess, Dinklage & Sprung
ATTORNEY

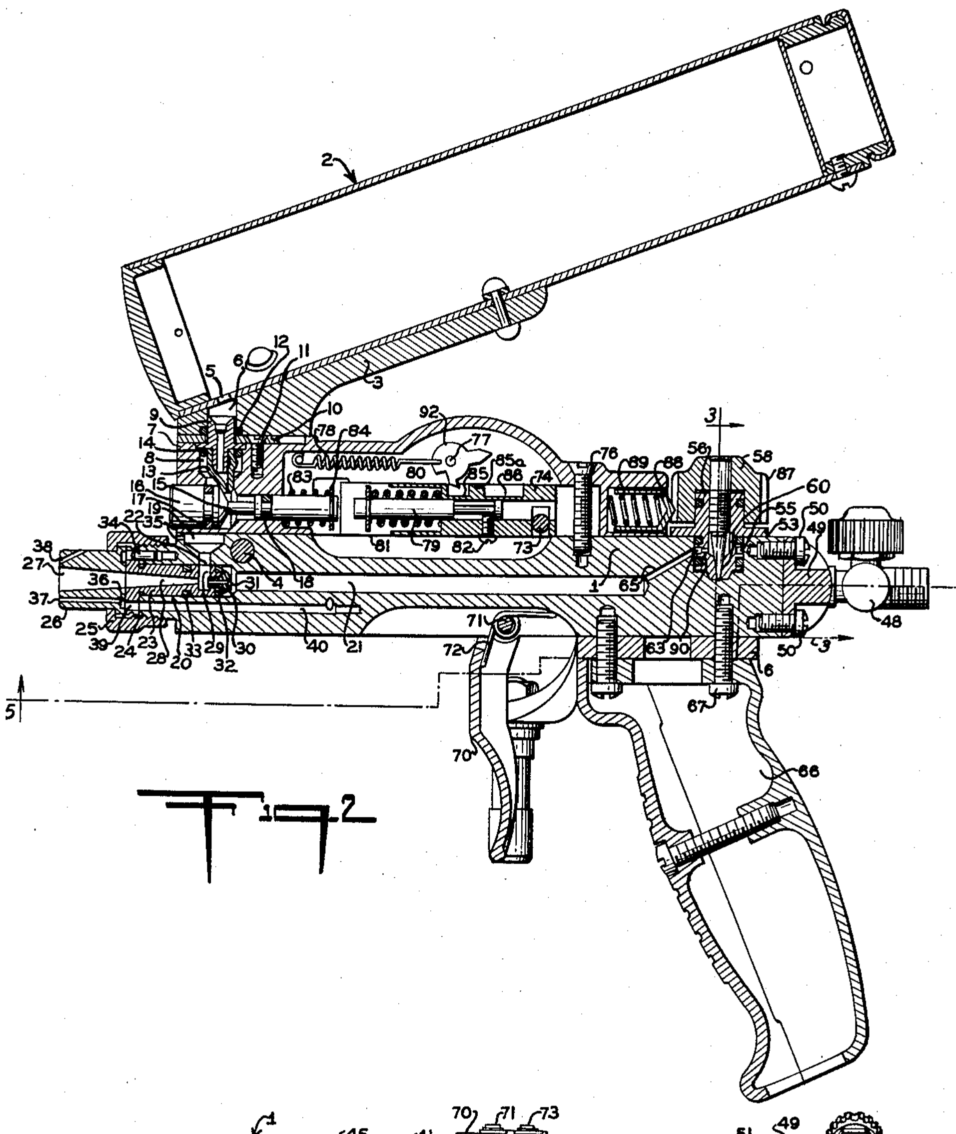

Fig. 2

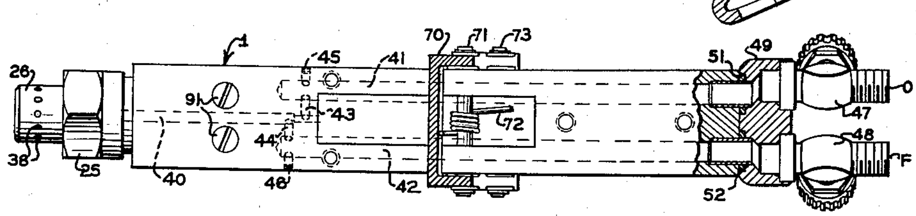

Fig. 5

INVENTORS
ARTHUR P. SHEPARD
BY Burgess, Dinklage & Sprung
ATTORNEY

United States Patent Office

2,961,335

Patented Nov. 22, 1960

2,961,335

METHOD AND APPARATUS FOR APPLYING HEAT-FUSIBLE COATINGS ON SOLID OBJECTS

Arthur P. Shepard, Flushing, N.Y., assignor to Metallizing Engineering Co. Inc., a corporation of New Jersey

Filed Apr. 13, 1956, Ser. No. 578,084

20 Claims. (Cl. 117—46)

This invention relates to a method and apparatus for applying heat-fusible coatings on solid objects from heat-fusible materials in divided, such as powdered, form. The invention more particularly relates to a method and to a gun construction for spraying heat-fusible material, using a fuel gas and a combustion supporting gas where said material is fed into the gun in finely divided, solid form.

Heat-fusible material spray guns of the powder type are devices in which powdered material is fed to a heating zone wherein it reaches a molten or at least heat-plastic condition, and from which it is propelled, at a relatively high velocity, onto the object to be coated. Most heat-fusible material spray guns of this type provide means for conveying the powdered material to be sprayed from a hopper to the heating zone by a relatively large volume stream of air (or other gas), in which the finely divided powdered material is entrained.

Such guns are most commonly used for spraying metal powders and hence are frequently referred to as powder-type metal spray guns.

All of the previously known powder spray guns and the methods of spraying the powder used thereby, have been subject to certain fundamental limitations. Such guns have been satisfactory only for spraying very low melting point materials, such as plastics, or for very low melting point metals, such as zinc. While such guns have been used commercially for spraying higher melting point metals, such as nickel-base alloys, they have been relatively unsatisfactory for this purpose due to the low deposit efficiency which results from their method of operation. Deposit efficiency is the ratio between the weight of the metal deposited on the solid object being sprayed and the weight of the metal fed into the device.

All previously known heat-fusible material spray guns and spraying methods have been further subject to the limitation that metal coatings produced by them are non-homogeneous and porous to the extent of being pervious, so that where homogeneous and impervious coatings are required, a subsequent heating and fusing step is necessary. Such subsequent heating and fusing operation has many undesirable aspects. The same limits the thickness of the coatings to thicknesses which will not run or drip upon subsequent heating and must be performed at the fusing temperature of the metal coating, which in many cases is sufficiently high to warp, scale or otherwise damage the coated object. Such subsequent fusing step must be carried out at the melting temperature of the coating and hence subjects the coating and coated object to a relatively high temperature, which frequently results in excessive shrinking and cracking of the fused coating upon cooling.

It is the object of this invention to overcome these and other hitherto existing limitations of presently known heat-fusible powder spraying methods and apparatus.

It is a further object of this invention to provide a method and apparatus for spraying heat-fusible, powdered materials having a wide range of melting points with a high deposit efficiency.

It is a further object of this invention to provide a method and apparatus for spraying heat-fusible, powdered materials of extremely high melting points, such as molybdenum, alumina and zirconia.

It is a still further object of this invention to provide a novel method and apparatus for producing impervious coatings equivalent to fused coatings from heat-fusible, powdered metals.

These and still further objects will be more fully understood from the following description:

The method and construction in accordance with this invention, which will be hereinafter more fully set forth, utilizes for the first time a new principle whereby the particles of powdered material to be sprayed are delayed in their passage through the heating zone, making possible a substantially higher rate of heat transfer between the hot gases in the heating zone and the particle. A heat exchange between a gas and a solid object is a function not only of the time of exposure of the object to the gas, but also of the relative velocity between the gas and object. It is important to understand with respect to the method and apparatus of the instant invention that the aforesaid delay of the particle in the heating zone is carried out in such a manner that not only is the time of the heating prolonged, but also so that the relative velocity between the hot gases of the heating zone and the particle of heat-fusible powder is substantially increased in such a manner that a total heat exchange of a materially higher order is produced.

In all previously known heat-fusible, powdered material spray guns, the powdered material is accelerated in the stream of gases, with material velocity in the direction of the gas stream prior to a point where the gases reach their highest temperature in the heating zone. The particles therefore pass through the heating zone at, or relatively near to, the velocity of the gases in such zone. In accordance with this invention, the particles are introduced into the gas stream in such a way that substantial acceleration does not take place in the gas stream prior to the point in the heating zone where the gases reach their highest temperature, but, on the contrary, the particles are substantially accelerated in the gas stream at the point of highest temperature. The result of this is twofold: (1) the particles are delayed in the heating zone adjacent the area of highest temperature, since their velocity is low due to lack of previous acceleration, and (2) a relatively high velocity exists between the hot gases in the heating zone adjacent their point of highest temperature and the particle, thereby causing a high impingement rate of the hot gas on the particles, further facilitating efficient heat transfer.

In accordance with the invention, finely divided, solid, heat-fusible material is sprayed by passing a combustible fluid and a combustion supporting fluid, such as gases, along a path of flow, with a substantial linear velocity in a direction toward a surface to be sprayed. The fluids are mixed and the mixture flame-combusted along the path of flow, and solid, divided, heat-fusible material entrained in a small volume of a carrier gas is passed into the central portion of the flame at a fraction of the linear velocity, such as $\frac{1}{25}$, and preferably $\frac{1}{50}$ of the linear velocity of the combustion gases, for passage through substantially the hottest portion of the flame. As the particles pass through this hottest portion of the flame, they are accelerated by the combustion gases in a direction toward the surface to be sprayed.

The spray gun for effecting the method in accordance with the invention has nozzle means, means for passing a combustible fluid and a combustion supporting fluid, such as gases, through said nozzle means, with a substantial forward linear velocity for flame combustion, a carrier means including a carrier conduit terminating substantially adjacent the outlet end of the nozzle means, and having a length in inches not in excess of about 2.65×10^3 times and preferably 2.65×10^2 times the outlet cross-sectional area in square inches of the nozzle means, and positioned for directing material passing therethrough in a forward direction into substantially the hottest portion of a flame formed upon combustion of fluids passing through the nozzle means. Means are provided for feeding divided, solid material into the carrier conduit, and means are provided for passing a small volume of a carrier gas through said carrier conduit in a forward direction, whereby divided, solid material fed into the carrier conduit is entrained in the small volume of carrier gas and conveyed forward into substantially the hottest portion of the flame at a fraction of the forward linear velocity of the combustion gases and for forward acceleration by the combustion gases.

The means for feeding divided material into the carrier conduit includes a storage container and a gravity flow duct connecting the storage container and the carrier conduit. The carrier means preferably include a powder entrance passage leading from the gravity flow duct into the carrier conduit, having a bleeder hole defined therethrough communicating the interior thereof with the ambient atmosphere.

The combustible gases emerging from the nozzle have the conventional, high forward linear velocity component as, for example, occurs in torches. The exact value of this forward linear velocity component depends of course upon the particular nozzle construction and on the gas input pressure. The same, however, is generally of an order of magnitude of about 400 ft. per second with, for example, a gas input pressure of about 15 lbs. per square inch. The same, however, may vary to as low as 200 ft. per second or even lower, and may be as high as the speed of sound.

For purposes of illustration and not of limitation, the invention will be described in further detail with reference to two preferred constructional embodiments, as shown in the drawings, in which:

Fig. 1 is a side elevation of one embodiment of a heat-fusible material spray gun in accordance with this invention;

Fig. 2 is a vertical-longitudinal section of the embodiment of Fig. 1;

Fig. 3 is a partial cross-section of Fig. 2;

Fig. 4 is a front elevation of the showing in Fig. 1; and

Fig. 5 is a plan view, partially in section, of the underside of Fig. 2.

Referring to the drawings, **1** shows the body of the spray gun, on which is mounted the inclined, tubular material hopper **2**. Material hopper **2** is held by a saddle **3** fastened to body **1** by a through-pin **4**, which is threaded into saddle **3** at one end to hold it securely in place. The entire hopper **2** with its saddle **3** can be removed for convenience by removing threaded pin **4**. A hole **5** is provided in the hopper **2** in communication with the duct **6** in saddle **3**. A valve block **7** is securely mounted on top of body **1** and provided with duct **8**, which is in line with duct **6**. A nipple **9** is mounted between block **7** and saddle **3**, so as to connect ducts **6** and **8**. The nipple **9** is held in place by a plate **10** and screws **11**. A packing washer **12** is provided around nipple **9**.

A small piece of rubber tube **13** fits over the lower projecting end of nipple **9** and is held in place by a rubber ring **14**. A valve chamber **15** is provided in block **7** and is fitted with a piston **16**, having the packing rings **17** and **18**.

The piston **16** is operated by a valve-operating mechanism which will be more fully described hereafter.

The body **1** is provided with a powder feed chamber **19**, a longitudinal bore **20**, extending centrally through the front end of the body, back to and communicating with, a central duct **21** and a hole **22** communicating the powder chamber with the bore **20**.

A seat plug **23** in the form of a cylindrical flanged plug is fitted into the bore **20** with a sliding fit, and has a flange extending over the end of body **1**. The body **1** is provided with a threaded section **24**, onto which is threaded a nut **25**. A nozzle **26** is mounted on the flange of seat plug **23** and held in place by nut **25**, which simultaneously holds seat plug **23** in place.

The nozzle **26** has a central conical bore **27** which communicates with the central conical bore **28** of seat plug **23** in such a manner that the two form a continuous extended conical bore. A groove **29** is provided in seat plug **23** on the upper half only and communicates bore **28** with hole **22**. A jet screw **30** is centrally located in seat plug **23** and is screwed into a central threaded hole in seat plug. The jet screw **30** is provided with a small central jet hole **31** which is concentric with the bore **28** of seat plug **23**. Packing rings **32** and **33** are provided to seal seat plug **23** in the bore **20** at both sides of groove **29**.

A dowel pin **34** is provided between body **1** and seat plug **23** to hold it in a predetermined position.

A bleeder hole **35** is provided from powder chamber **19** to the front end of body **1**. The nozzle **26** is provided with an annular groove at its base **36** and a multiple number of parallel nozzle jet holes **37**, arranged in a circle. Nozzle **26** is also provided with air holes **38**, which are located alternately between holes **37** and terminate inwardly of holes **37**, nearer to bore **27**, and extend at a relatively steep angle to the outer surface of nozzle **26**.

The seat plug **23** is provided with a hole **39** through its flange, which communicates with annular groove **36**. Body **1** is provided with duct **40** which communicates with hole **39**. Body **1** is provided with duct **41** for combustion supporting gas and duct **42** for combustible gas. These ducts can be seen by referring to Fig. 5, which also shows more clearly the connecting ducts between ducts **41** and **42** with duct **40**.

The connecting duct between **40** and **41** is the connecting duct **43**, and the connecting duct between **40** and **42** is the connecting duct **44**. These ducts are provided by cross-drilling through body **1** and plugging the outer ends of these ducts with small steel screws at **45** and **46**. Valves **47** and **48** are provided and mounted on the rear of body **1** by means of mounting plate **49** and screws **50**. These valves are arranged to communicate with ducts **41** and **42** respectively, and these connections are sealed by packings **51** and **52** respectively.

A valve **53** is provided and mounted on body **1** by means of screws **54**. The details of this valve construction can best be seen in Fig. 3. A cylindrical bore **55** is provided in body **1** for mounting of this valve. The valve consists of a valve body **56**, into which is threaded a needle valve needle **57**, on which is secured valve handle **58**. Packing ring **59** seals between the inner bore of valve handle **58** and the body **56**. Body **56** is provided with a conical seat **60** into which the needle of the needle valve **57** fits. Body **56** is provided with packing rings **61** and **62** which are spaced on each side of a groove **63** on the outer cylindrical surface ob body **56**. A hole **64** is provided from the bottom of the bore **55** into duct **42** and/or a similar hole may be provided into duct **41**.

Referring to Fig. 2, a small duct **65** is provided in body **1** connecting bore **55** with central duct **21** and terminating in bore **55** in direct communication with annular groove **63** in valve body **56**. Hole **90** connects annular groove **63** with the bore in valve body **56**.

A handle **66** is mounted on body **1** by means of screws **67**. Screws **67** also hold mounting bracket **68**, which extends to one side of the gun and has stud **69** secure at its terminus. Mounting bracket **68** and stud **69** provide convenient means for mounting the gun when it is not being used by hand.

A trigger 70 is connected through a mechanism, hereinafter to be described, to valve piston 16. Pin 71 in body 1 pivotally supports the trigger 70. Spring 72 holds trigger 70 in a forward position away from handle 66. Trigger 70 extends upward on both sides of the body 1 and at its upper end is mounted across pin 73. Cross pin 73 engages a slot in hollow square piston 74. A housing 75 is mounted on body 1 by screw 76 and defines a square piston chamber between itself and the top area of body 1. A cam 92 is mounted on pivot pin 77 in housing 75 and is held in a neutral position, as shown in drawing, by spring 78.

A secondary piston 79 slides in a bore provided in piston cylinder 74, and is held in a forward position by spring 80, which presses against snap ring washer 81, which is fastened to piston 79. A screw 82, which is screwed into the bottom of piston cylinder 74, acts as a limit stop in both directions for secondary piston 79. Valve piston 16 has spring 83 engaging housing 75 at one end and snap ring washer 84 at the other end, so as to hold valve piston 16 in a rearward position.

The top of square piston 74 has a forward cutout section 85 and a rear cutout section 86 on its upper portion. These cutout sections, and the forward and rearward termini thereof, act to engage the cam projections of cam 92, as will be hereinafter more fully described.

Valve handle 58 is provided with milled grooves 87 which engage the pointed end of detent piston 88. Detent piston 88 slides in the space provided for it at the rear of housing 75 and is pressed rearwardly by spring 89.

Trigger 70 operates to open and close a powder feed valve which comprises rubber tube 13 and the piston 16. In the closed position, with the piston 16 in its rearward position, the piston squeezes the end of rubber tube 13 closed. This position is shown in Fig. 2. When piston 16 is moved to a forward position, it releases the squeezing pressure on the end of rubber tube 13, opening it and permitting powder to flow through the rubber tube.

In the open position of rubber tube 13, powder is permitted to flow by gravity from hopper 2 through hole 5, duct 6, the passage in nipple 9, through rubber tube 13, through valve chamber 15 and into powder chamber 19.

When trigger 70 is pulled rearwardly toward the handle 66, pin 73 is moved in a forward direction, causing cylinder piston 74 to move in a forward direction, carrying with it secondary piston 79, which also therefore moves forward. Piston 79 engages and also pushes forward valve piston 16 and hence opens the valve. When valve piston 16 is all the way forward, at the limit of its stroke, piston cylinder 74 continues to move forward. This additional movement is permitted since after secondary piston 79 stops moving forward, spring 80 is compressed. During the forward movement of cylinder piston 74, the rearward terminus of cutout section 85 engages the lower projection of cam 92 and rotates it clockwise until the rearward projection of cam 92 engages the rear terminus of cutout section 86 of piston cylinder 74. This stops the forward motion of the piston cylinder 74, and at this point the lower projection of the cam 92 is positioned just above the groove 85*a* in the partition separating the cutouts 85 and 86. As the trigger 70 is released, the piston cylinder 74 is urged rearwardly by the spring 80. It, however, can only move a very short distance rearwardly before it is stopped by the engagement of the lower projection of the cam 92 in the groove 85*a*, preventing further rearward movement. The valve therefore remains in a locked, open position even after the trigger 70 is released.

To release the valve the operator simply again squeezes the trigger 70 toward the handle 66 a second time. This causes forward motion of the piston cylinder 74, which is permitted, since the cam 92 can rotate slightly in a clockwise direction and since the lower projection of the cam can slide out of the open, rearward end of the groove 85 into the cutout section 86. The lower projection of the cam 92 is already past the highest point on the partition separating the cutouts 85 and 86 so that the rearward terminus of the cutout section 85 will not rotate the cam to a position where its rear projection will stop the forward motion of the piston cylinder 74 by contacting the rearward terminus of the cutout section 86. The operator then releases the trigger and the cylinder piston 74 and the trigger 70 will return all the way to the original position as shown in Fig. 2. The rearward motion of the piston cylinder 74 will merely cause the cam 92 to rotate in a counter-clockwise direction when the lower projection strikes the partition separating the cutouts 85 and 86, and after riding over this projection the spring 78 will cause the cam to snap back with its lower projection in the cutout 85. The spring 80 will act to push the cylinder piston 74 rearwardly only until the secondary piston 79 disengages the piston valve 16. Thereafter the rearward motion is caused by the action of the spring 72, which urges the trigger 70 forward and thus the pin 73 rearwardly.

The trigger and powder valve mechanism thereby permits the operator to open the valve by pulling a trigger a first time, and the valve will remain open even after the trigger is released. The valve is closed by pulling the trigger a second time and then releasing it.

In operation, the powdered material to be sprayed is placed in hopper 2, and fuel gas and combustion supporting gas hoses are connected in the conventional manner to valves 48 and 47 respectively. Sources of fuel gas and their hoses and fittings are not shown, since these are conventional and well known for use with such equipment. With the powder valve just described, closed, and the powder feed valve 53 closed, the gun is first lighted by slightly opening valves 48 and 47 and lighting the gases as they emerge from nozzle jets 37.

The fuel gas flows through valve 48, into and through conduit 42, through connecting conduit 44 and into conduit 40. The combustion supporting gas flows through valve 47 and into and through conduit 41, through connecting conduit 43 and also into conduit 40, where it mixes with the fuel gas. The mixed gases flow from conduit 40 through hole 39 and into annular groove 36, and from thence through multiple nozzle jets 37 where they are ignited upon emergence.

The discharge of the gases from nozzle jets 37 causes reduced pressure at the face of nozzle 26, which causes objectionable turbulence at the face of the nozzle, which in turn tends to cause deposit of fusible material on the face of the nozzle. When the nozzle is lighted, however, the relieved pressure at the face of the nozzle is substantially reduced by the induced flow of a small amount of atmospheric air through holes 38, which terminate at the face of the nozzle in alternate positions between nozzle jet holes 37. While the flow of air through holes 38 is very small, it is sufficient to completely eliminate the tendency for material to collect and build up on the face of nozzle 26.

To start the powder flow, valve 53 is first adjusted. The detent piston 88, engaging the grooves 87 in valve handle 58, provides a convenient means for determining the setting of the valve by counting the number of clicks from a fully closed position. The detent also securely holds the valve in a predetermined position. When valve 53 is open, a small amount of fuel gas flows from conduit 42 through hole 64, through the valve 53, and past needle 60, into the bore of valve body 56, through hole 90, into annular chamber 63, and from thence through conduit 65 into central duct 21. From central duct 21 a very small amount of gas is permitted to flow through jet hole 31 in jet screw 30. This jet of fuel gas extends across groove 29 and exhausts out through powder conduits 28 and 27 to the center of the flame.

To start the powder feeding, the operator pulls back on trigger **70**, which opens the powder feed valve as hereinabove described. The powder then flows from powder chamber **19** into groove **29**, where it is picked up by the jet of fuel gas emerging from jet hole **31**. The powder is then carried forward through conduits **28** and **27** and emerges at the nozzle face in the center of the flame.

Hole **35** is provided into powder chamber **19** to maintain atmospheric pressure in said chamber. This is of importance since otherwise a partial vacuum is created by the action of jet **31**, which varies with the flow of powder and hence causes an excessive variation in the powder feed. Most metal powders feed satisfactorily by gravity from hopper **2** down through the various passages to powder chamber **19** and groove **29**. The hopper **2** has been mounted at an angle so that the material feeds satisfactorily for all positions of the gun through 90° from horizontal to practically vertically down.

Some powders, however, due to their configuration, size and other properties, do not feed as readily as other powdered materials. In cases where the powders tend to pack or feed unevenly, it is advisable to shake or vibrate the gun slightly. An extremely small amount of vibration or shaking is required to cause smooth flowing of even those powders with the worst flowing characteristics. For this purpose, and when needed, a small vibrator, for instance an electric vibrator such as an electric buzzer, is attached to the bottom of the gun body, such as by screws **91**. Such vibrators are well known in the art and hence this construction has not been shown in the drawings, nor is the vibrator described in detail.

While the hopper **2** may be made of any suitable structure and material, it is an advantage to make it of clear plastic material so that the operator can see the amount of powder remaining in the hopper.

In place of the hopper **12** a separate, as for example, a larger capacity hopper may be supported above the gun and connected to the duct **6** by means of a flexible hose, as for example, a flexible rubber hose. The powdered heat-fusible material in the hopper, which is for example suspended from the ceiling, will feed through the flexible hose by gravity into the duct **6**. This construction relieves the operator of the strain of holding the weight of the heat-fusible material and allows the use of a much larger capacity container. With such an arrangement the gun may be operated between a position pointing almost vertically down to a position pointing almost vertically up.

The construction in accordance with this invention results in an apparatus capable of carrying out an entirely new method of heating and applying powdered material coatings. Powder ducts **27** and **28** cooperate to form a continuous conical section expanding toward the outlet and, together with the arrangement of jet hole **31** and groove **29**, comprise carrier means which carry and introduce a large amount of powder into the center of the flame at a very low velocity. This velocity is so low as to be negligible in comparison with the velocity of gases of the flame. The result is that the acceleration of the particles takes place in the flame and through its hottest area. This results in thermal efficiency of a much higher order, as previously described. Materials of melting points as high as those of molybdenum, among the metals, and alumina and zirconia, among the ceramics, can be satisfactorily sprayed. Another result is substantially increased deposit efficiency. Still another result is that an entirely new method of applying coating, which will be hereinafter referred to as semifusing, is now possible for the first time.

It is important to note how this carrier means differs from conduits in previous metal spray guns and hence produces this result. To understand this, reference must be made to the manner in which finely divided materials are carried or suspended by a flow stream of gas.

If powdered material is carried by a smooth, streamlined flow of gas, the particles soon reach the velocity of the gas, and thereafter drop by gravity at a rate depending upon their size, surface condition, and weight. Pure streamlined flow velocity does not in itself hold particles in suspension any more than still gas. Particles will be carried by such a stream therefore a distance, depending upon the velocity, the requirement simply being that if they will settle out in a time of T seconds, that the velocity must be high enough to carry them whatever distance is required in T seconds. Very high linear velocities are required of streamline flow if it is to carry materials very far. Furthermore, assuming pure streamline flow, particles would be dropped out of the stream all along the path of the conduit, regardless of how high the velocity. This would result simply because those particles near the bottom of the conduit would reach the bottom in a short period of time.

As a practical matter, therefore, to convey powdered materials in a gas stream, streamlined flow must be avoided and turbulent flow provided which, for example, occurs due to skin friction when gas is passed through a conduit. In turbulent flow there are small, high local velocities in random directions, in addition to the general stream velocity in a forward direction. The result of this is continual random acceleration of the particles in all directions, and if these accelerations are sufficiently high and sufficient in number, the powder will not settle out at all. This results from the fact that if any particle does reach the floor of the conduit, it would shortly thereafter be accelerated in some direction other than down, and hence be picked back up into the stream. The provision of continuing turbulence through a conduit, however, requires a continual expenditure of energy through the conduit, and this energy must come from the conveying gas.

As a result of these considerations, a relatively large amount of carrier gas is required, capable of delivering a large amount of energy wherever powdered materials are to be conveyed through long conduits, such as hoses.

The length of the carrier means, in accordance with the instant invention, is adjusted to be just long enough with respect to the energy provided in the form of gas emerging from jet **31**, to use most of this energy in the form of turbulence as the gas and powder reach the exit. By converting most all of the energy into turbulence, no substantial linear velocity component remains. Furthermore, the entrained particles are evenly distributed over the area of the emerging stream. If the relative length of the carrier means is longer than this length, the material will be dumped into the conduit and will not emerge from the exit end in an even stream, but will be concentrated at the bottom of the stream. If the conduit is shorter than this required length relative to the input energy, this energy will exist in the form of either a pressure or a velocity component at the outlet. If a pressure component remains, it will rapidly change to velocity as the gas throttles from the opening. Therefore, in either case, the remaining energy will be in the form of forward velocity, and the particles will enter the flame at a relatively high forward velocity. The carrier means also has the requirement of being so proportioned as to convert the velocity energy entering it almost entirely into turbulent energy by diffusion before the gas reaches the outlet.

There is a further limitation which must be applied to the carrier means in accordance with this invention and that is that its length be short enough so that, in addition to meeting the above requirements, these requirements be met with a relatively small amount of carrier gas with respect to the fuel gas and combustion supporting gas mixture. Otherwise, even though the first conditions are met and the carrier stream emerges from the nozzle with practically all of its energy expended, the volume of such stream will have a detrimental effect upon the temperature of the flame in the heating zone. If the carrier gas contains a relatively large amount of air or other noncombustible gas, then a large volume of such gas will have the effect of chilling, as well as diluting, the gases of the flame and hence lower the flame temperature. If the carrier gas is either a fuel gas or a combustion supporting gas, it will nevertheless also chill and dilute the mixed gases of the flame, since it will enter the flame as a stream and adversely affect the flame gas mixture so that improper amounts of fuel gas and combustion supporting gas will exist at local zones of the flame, and temperature of the heating zone will be lowered. This condition cannot be satisfactorily corrected by providing a proper mixture of combustible and combustion supporting gas for use as a carrier gas because such mixture would tend to ignite and burn back into the carrier means.

In accordance with this invention it has been found that a carrier means should not be over about 10″ long and preferably should be less than 3″. It has also been found that the ratio of length in inches of the carrier conduit to the total cross-sectional area, in square inches, of the fuel gas and combustion supporting gas mixture nozzle jets should not be more than 2.65×10^3 and preferably should be 2.65×10^2, and that the ratio of the outlet cross-section of the carrier conduit to the total cross-sectional area in square inches of the nozzle jets should not be more than 20:1 and preferably 4.6:1. A minimum cross-sectional size should of course be used for the carrier conduit which is determined by the particle size of the material sprayed and the necessary capacity of the gun.

In the preferred construction of the apparatus in accordance with this invention the passages and jets are so constructed that with the carrier gas control valve adjusted approximately ten clicks of the detent open, counting from a full closed position, the apparatus passes approximately 2.5 cubic feet per hour (measured at atmospheric temperature and pressure) of acetylene gas. The preferred construction is such that this induces, through the siphon action of the carrier gas jet, approximately 2.5 cubic feet per hour of air. In this case, the total carrier gas is therefore approximately 5 cubic feet per hour (measured at atmospheric temperature and pressure). In the most preferred embodiment of this invention it has been found advisable to maintain these flow amounts within a range of plus or minus approximately 40%.

In the preferred embodiment of this invention and with the construction which uses the gas flows described in the above paragraph, it is most preferred to construct the area of the exit end of the carrier conduit to be an area of 0.27 sq. in. and to construct the fuel gas mixture nozzle so that the total area at the exit of the fuel gas mixture jets is a combined area for all of the jets of approximately .0066 sq. in. For the most preferred construction it is preferred to obtain this area by using ten jets. In the most preferred construction the inlet passages and pressures are adjusted to obtain a flow of mixed fuel gas and combustion supporting gas of 65 cubic feet per hour (measured at atmospheric temperature and pressure).

When the apparatus is constructed and operated, using the above described most preferred construction and adjustments, a mixed fuel gas jet velocity results which is over fifty times as great as the carrier gas velocity emerging from the nozzle, and hence fifty times as great as the powdered material velocity.

In the most preferred construction in accordance with this invention it is additionally advantageous to produce a certain amount of turbulence at the exit tip of the nozzle for the purpose of still further slowing down the forward component of the carrier gas velocity. This result is achieved by locating the fuel gas mixture nozzle jets in a position such that they are all approximately mutually parallel. This result is contributed to by the bleeder jets in the nozzle which are located at a substantial angle to the axis of the nozzle, and with their exit ends located alternately between said mixed fuel gas jets and preferably slightly nearer to the center of the nozzle than said fuel gas jets. While these atmospheric air bleeder jets reduce turbulence immediately adjacent to the face of the nozzle itself, as previously discussed, they contribute to turbulence in an area adjacent to the point of their convergence in the center of the axis of the nozzle, and slightly forward of the nozzle tip. In the general locality of the convergence of these atmospheric air bleeder jets the velocity of the introduced atmospheric air is extremely low and such air must be accelerated by the burning fuel gases, with the result that turbulence occurs in this general locality. The effect is that the powder discharging from the carrier duct at the tip of the nozzle is slowed down, and in some cases actually stopped in the general locality of the convergence of said atmospheric air bleeder jets.

To contribute to the cooperative result of reduced powder velocity at nozzle exit, the carrier duct itself is most preferably of conical shape, with a slight taper outward towards the nozzle exit, so that the duct diverges as the carrier gas passes through it. This, of course, also contributes to the reduction of velocity of the carrier gas as it proceeds toward the nozzle exit.

It is important to note that the atmospheric air nozzle jets must have their entrance ends exposed to air or other gas which is substantially at atmospheric pressure, otherwise the desirable result described above will not accrue. In most previously known metal spray guns an additional air or other blast gas nozzle is mounted outside of the mixed fuel gas nozzle to provide a blast of air or other gas for propelling the particles of molten or heat-plastic material. It should be particularly pointed out that in accordance with this invention no such air nozzle, nor any other blast gas, is required, and that in fact with the construction in accordance with this invention, such air blast has been found detrimental, particularly where relatively large amounts of air or other gas are used at high pressure. Not only is such air blast detrimental to the function of the atmospheric air bleeders as described, but also has a detrimental effect on the flame itself and upon the action of the flame in accelerating the particles in accordance with this invention as previously discussed.

The carrier means in accordance with this invention comprises a carrier conduit, an injection jet passage, and a powder entrance passage. In accordance with a preferred embodiment of this invention, the carrier means also comprises an atmospheric air passage between said powder entrance passage and the atmosphere. Such atmospheric air passage permits a small amount of air from the atmosphere to enter with the powder. Such atmospheric air intermingles with the gas emerging from said injection jet passage. The purpose of permitting the addition of atmospheric air to the gas emerging from the injection jet passage is twofold. First, such air increases the total volume of carrier gas and hence aids in the carrying of powder, and second, such air, which is accelerated by the jet emerging from the injection passage, aids in the diffusion and hence in the distribution of energy of the carrier gas in the carrier means. In the special case where gas emerging from the injection passage is a combustible gas, such added atmospheric air also has the advantage of contributing oxygen to the mixture, so that the carrier gas is at least more nearly a mixture of combustible and combustion supporting gases at the point of emergence from the nozzle than would otherwise be the case. In such a case, there is a still lesser effect of the carrier gas in reducing the temperature of the flame at the heating zone.

It should be particularly noted that the structure in accordance with this invention avoids the disadvantage inherent in some prior constructions, in which the particles of material to be sprayed are dumped directly into a combustible mixture of fuel gas and combustion supporting gas prior to its emergence from the nozzle. Such prior construction has several inherent disadvantages. One such disadvantage is that the material particles are too readily oxidized during the combustion process, due to the fact that each particle of powder becomes surrounded and intimately associated with a film of the combustible gas mixture. This leads to very intense temperatures on the surface of the powdered particle and also to an intimate contact with the pure combustion supporting gas, which by its nature is an oxidizing gas.

Another disadvantage of such constructions is their tendency to back-fire or flash back into the nozzle due to the fact that the introduction of powder and any resultant unevenness of flow of the powder tends to disrupt the relatively delicate balance between the emergence velocity of the gas mixture, the flame propagation rate of such mixture, and eddy currents caused by turbulence at the nozzle tip. As is well known, nozzles operating with efficient combustible mixtures are sensitive to such backfiring when the relatively delicate balance of this condition is disturbed.

It should also be noted that the construction in accordance with this invention also overcomes the disadvantage of prior constructions in which a stream of powdered material is added to a flame from a point external of the flame, such as by pouring or feeding the powder into the side of the flame. It is obvious that such constructions cannot distribute the powder evenly in the flame and hence efficient and uniform transfer of heat from the flame to the particles cannot take place with high thermal efficiency.

The construction in accordance with this invention may be used advantageously for applying coatings which are used in the "as-sprayed" state, in that no subsequent fusing is performed. Such coatings applied in accordance with this invention are considerably more dense and less permeable than coatings applied with previously known metal spraying techniques and equipment. It is believed that one of the primary reasons for the improved properties of such coatings is the higher thermal efficiency which results in accordance with this invention, together with conditions which minimize oxidation of the particles under conditions of such relatively high particle temperature.

The method and gun in accordance with the invention are particularly well adapted to spray powdered materials which are relatively resistant to oxidation. Even though the oxidizing conditions are minimized in accordance with the invention, the temperatures reached are higher than those of previously known methods, and relatively oxidizable materials, such as zinc and aluminum, will spray with a relatively lower deposit efficiency and will result in a relatively higher oxide content in the coating. It is preferable in accordance with the invention to spray materials such as aluminum bronzes, stainless steels, nickel chrome alloys, boron nickel base self-fluxing alloys, alumina, zirconia and other ceramics which produce excellent coatings with high deposit efficiency.

For ordinary coatings, it is preferred to use acetylene gas and oxygen for the combustible fuel mixture. When using acetylene and oxygen it is preferred to use powdered materials which have been manufactured or screen-graded so that all of the particles pass through a 100 mesh U.S. standard screen, and more preferably a 120 mesh U.S. standard screen. It is also preferred to use powdered materials when using acetylene which do not have more than about 20% which pass through a 325 mesh U.S. standard screen.

For extremely fine, dense coatings of oxidation-resistant metals, it is preferred to use hydrogen and oxygen for the combustible fuel mixture. Where hydrogen is used, it is preferred to use metal powders which have been manufactured or screen-graded so that all of the particles pass through a 170 mesh U.S. standard screen and more preferably through a 270 mesh U.S. standard screen. It is additionally of advantage if the extreme fines of a size of the order of less than 10 microns are eliminated from the powdered materials being used. With the method in accordance with this invention, using hydrogen as the fuel gas and fine gradings as above described, of powdered metals, such as nickel-chrome alloys, boron and nickel base self-fluxing alloys, stainless steel alloys and aluminum bronze alloys, extremely fine, dense coatings can be produced which have a low order of permeability to gases and liquids.

The base materials sprayed with an unfused coating in accordance with the invention, using hydrogen as the combustible gas and using heat-fusible particles having a particle size below 200, and preferably below 270 mesh, constitute novel products, in that the coatings are entirely different from coatings previously obtained. In this connection the base materials may be any of the conventional base materials previously sprayed, such as a relatively high melting point base metal, as for example iron or steel, or a ceramic base. The spray coating may be of any material conventionally sprayed, such as metal, and preferably an oxidation-resistant metal, such as aluminum bronzes, stainless steels, chrome nickel alloys, alumina, zirconia, etc. The unfused coatings on these bases, as contrasted to previously obtained powder sprayed, unfused coatings, are very dense and practically impermeable.

The methods and apparatus in accordance with this invention may also be used to produce coatings of self-fluxing alloys, which may be thereafter fused to form completely homogeneous impervious coatings.

The purposes of a flux in a metal heating process are: (1) to reduce or dissolve oxides of the metals, (2) to float off or coagulate oxides of the metals, and (3) to reduce the surface tension of the metals and hence increase their wettability. A "self-fluxing" alloy is one in which a fluxing agent, capable of performing one or more of the above enumerated fluxing actions, is incorporated as an alloy constituent of the alloy.

Self-fluxing alloys are well known in the art, as for example, the spray-weld alloys of the boron-silicon-nickel type. Such an alloy may, for example, consist of 0.7–1% carbon, 3.5–4.5% silicon, 2.75–3.75% boron, 3–5% iron and, if desired, 16–18% chromium and nickel making up the balance.

Where dense, completely impermeable coatings have been desired, it has been necessary in the past to first spray the coatings of self-fluxing alloys, and thereafter fuse them as described above. This process has the disadvantage that only relatively thin coatings can be applied, due to the fact that the coatings will run and drip when melted. The result is the disadvantage that relatively high temperatures are required for fusing the coatings and such temperatures cause distortion, oxidation and other damage to the base on which the coatings are applied. Another disadvantage of this process is the fact that it may not be used on base material, such as brass, bronze or any other alloy which cannot be safely heated to the melting temperature of the self-fluxing alloy. Such process has also been subject to the disadvantage that even when the coating does not run or drip, it has a tendency to pull away from the edges.

All these aforesaid disadvantages are overcome by a preferred embodiment of this invention.

In accordance with this preferred embodiment of the invention, the base material which may consist of any base material conventionally sprayed, which is prepared for spraying in the conventional manner, is heated to a temperature of about 1000 to 400° F. and preferably 800 to 600° F. below the melting point of a self-fluxing alloy to be sprayed, and thereafter the self-fluxing alloy, in initially, finely divided, solid form is sprayed in accordance with the invention, as described above. It is preferable to first pre-coat the base by heating the same to a temperature of several hundred degrees Fahrenheit, as for example to a temperature between 300 and 500° F., and to apply a coating of the self-fluxing alloy, using the method in accordance with the invention, to a thickness from about one thousandth of an inch to a hundredth of an inch, and thereafter to further heat the pre-coated base and to spray the self-fluxing alloy. This preferred method of applying a first coating at a lower temperature is desirable because such a preliminary coating is applied at a temperature low enough that oxidation will not occur on the base of the surface prior to the application of the coating. This preliminary coating then protects the base surface from oxidation when the base is heated to the higher temperatures for the application of the subsequent layers. Coatings produced in accordance with the above described method may be referred to as semi-fused coatings, and bases having these coatings are entirely novel.

Semi-fused coatings may be applied in this manner to any thicknesses desired, since the coatings never entirely reach their melting point. Semi-fused coatings are substantially as dense as fully fused coatings produced by previously known methods, as measured by the fact that they will not shrink further when subsequently melted and cooled. Coatings produced by previously known methods shrink about 20% as a result of the fusing operation.

Semi-fused coatings have substantially as high a hardness as coatings produced by previously known fusing methods.

Semi-fused coatings are practically impermeable to gases and liquids as are the previously known, fully fused coatings.

Semi-fused coatings are not quite as completely fused nor as homogeneous when examined metallographically as are fully fused coatings made by previously known processes. However, this slight lack of homogeneity does not appear to be a disadvantage, as may be seen from the above enumerated characteristics of these coatings.

The self-fluxing alloys which are sprayed to produce the semi-fused coatings in accordance with the invention may constitute any known or conventional self-fluxing alloys. In one example, using self-fluxing boron silicon nickel base alloys, it has been found preferable to heat the base to a temperature of about 1000 to 1600° F. and preferably 1200 to 1400° F. and to build up the coating on the thusly heated base. In connection with the preferred embodiment for pre-coating to prevent oxidation, a heating of the base to temperatures between 300 and 500° F. has been found preferable.

Coatings produced in accordance with this invention of relatively oxidation-resistant materials, as herein enumerated, may be produced to deposit efficiencies between 95% and 99%, whereas with previously known methods and apparatus used, it has not been possible to obtain deposit efficiencies above about 70%, and it has been more common to obtain much lower deposit efficiencies. In some cases slightly higher deposit efficiencies up to a maximum of about 80% have been obtained with previously known methods, but only by reducing the material flow to such an extent, relative to the combustible gas mixture being used, that the operation has become uneconomical even though the deposit efficiency has been somewhat increased. In accordance with the methods and apparatus of this invention not only are higher deposit efficiencies obtained, but greater spraying rates are obtained, using the same amount of combustible gas mixture.

The following examples are given to illustrate the invention and not to limit the same:

Example 1

A self-fluxing boron-silicon-nickel base alloy of the following composition is provided in powdered form, with particle size such that all will pass through a 120 mesh U.S. standard screen and not over 10% will pass through a 325 mesh U.S. standard screen:

Element	Minimum Percent	Maximum Percent
Carbon	0.7	1.0
Silicon	3.5	4.5
Boron	2.75	3.75
Iron	3.0	5.0
Chromium	16.0	18.0
Nickel	Balance	

A gun as described above and illustrated in the drawing is attached to a source of acetylene at a pressure of 15 lbs. per square inch gauge and a source of oxygen gas at a pressure of 20 lbs. per square inch gauge.

The powdered alloy is placed in the gun hopper. The gun is lighted as previously described, and the flame adjusted to be approximately neutral. The carrier gas valve is opened to approximately 10 clicks of the detent.

A 4" square by 1/4" thick mild steel plate, which is to be coated on one surface, is first grit-blasted, using a 50%–50% mixture of SAE G 25 and SAE G 40 steel grit, using a suction blast gun in the conventional manner and a blasting air pressure of approximately 80 p.s.i.

The clean surface of the plate is pre-heated, using the gun to a temperature of approximately 250° F.

The powder feed trigger of the gun is then operated to produce powder flow and the gun used to spray the coating of the alloy. The gun nozzle is held about 10" from the surface of the plate.

It is desired in this case to have a finished thickness after final grinding of .030". The coating is applied until it is between .045" and .050" thick.

The coating, which in this case will not get hotter than a few hundred degrees, is allowed to cool in air to near room temperature.

The surface is then ground to the desired thickness, using a silicon carbide wheel in the conventional manner.

Example 2

An alloy coating is provided exactly the same as set forth above in Example 1, except that before the grinding operation is performed a conventional heating torch is used to fuse the applied coating. In this case the coating is heated up all over to a temperature of 800° to 1000° F. The torch is then concentrated near one edge of the plate and moved slightly back and forth over a small area until the heated area begins to fuse. This will be detected by the operator by a shiny, glassy appearance, which will occur just as fusing takes place. The operator then moves the torch in a slight oscillating motion ahead of the glassy, fused area, over the surface of the plate until the entire area has been fused.

The fusing temperature for the alloy in this example is between 1900°–2100° F.

The plate is allowed to cool in the air until it reaches approximately room temperature. The fusing operation will cause a shrink of the coating of about 20%. This will still leave sufficient finish allowance for desired thickness of .030". The coating is then ground as described above in Example 1.

Example 3

A powdered alloy the same as used in Example 1, is provided, the same gun provided which is lighted in the same manner.

In this case it is desired to coat a plate similar to the plate in Example 1 by the process described herein as the "semi-fusing" process.

The plate is prepared for coating by blasting, as described in Example 1. It is then heated to a temperature of between 350° and 450° F. using the gun as a torch. The trigger is then pulled and a coating of alloy applied to a thickness of .003" to .005". The trigger is then operated to stop the powder feed and the plate further heated. This further heating is done with the gun as a torch in this case. Heating is continued until the plate and coating reach a temperature of between 1200° and 1400° F.

The trigger is operated again and the alloy coating applied to the hot surface. The gun is held close enough to the plate so as to maintain the temperature of the plate and coating in the range between 1200° and 1400° F. during the remainder of the coating operation. The alloy is built up to a thickness of at least .040". In this case shrinkage will take place during application of the coating material. A thickness of .040" will, however, provide sufficient finish allowance to obtain final thickness of .030" after grinding.

The coating is allowed to cool in air until it reaches approximately room temperature.

It is then ground to finish size, as described in Example 1.

Example 4

A ceramic material is provided of commercial pure alumina, in fine particle size, such that it will all pass through a 325 mesh U.S. standard screen. This material is placed in the hopper of the gun.

The gun is provided and connected to acetylene and oxygen gas, as described above in Example 1. The carrier feed gas valve is adjusted approximately 4 clicks of the detent open.

A cylindrical 18–8 type stainless steel rod 1" in diameter and 6" long is provided. It is desired to coat this rod on its outside diameter for a length of 2" from one end.

The rod is placed in a lathe chuck and rotated so as to give a surface speed of approximately 50 ft. per minute. The end which is to be coated is prepared by grit-blasting, using the steel grit mixture described in Example 1 and a conventional blast gun with approximately 70 p.s.i. gauge air pressure.

The rod is heated to a temperature of approximately 250° F., using the gun as a torch. The trigger is then operated to feed the powdered alumina through the gun and the coating applied by directing the gun at the rod until the desired thickness, which in this case is .010" thick, is applied. The nozzle of the gun is held about 4" from the rod surface. The rod is then allowed to cool in air.

The foregoing specific description is for purposes of illustration and not of limitation and it is therefore my intention that the invention be limited only by the appended claims or their equivalents wherein I have endeavored to claim broadly all inherent novelty.

I claim:

1. Method for spraying finely divided, solid heat-fusible material which comprises passing a combustible fluid and a combustion supporting fluid along a path of flow with a substantial linear velocity in a direction toward a surface to be sprayed, flame-combusting the fluids along said path of flow, passing solid, divided, heat-fusible material entrained in a small volume of a carrier gas into the central portion of said flame at a small fraction of the linear velocity of the combustion gases for passage through substantially the hottest portion of the flame and acceleration in a direction toward said surface.

2. Method according to claim 1 in which said heat-fusible material entrained in said carrier gas is passed into the central portion of said flame at not more than $\frac{1}{25}$ the linear velocity of the combustion gases.

3. Method according to claim 1 in which said heat-fusible material entrained in said carrier gas is passed into the central portion of said flame at not more than $\frac{1}{50}$ the linear velocity of the combustion gases.

4. Method according to claim 1 in which said combustible fluid is acetylene, said combustion supporting fluid oxygen, and in which said solid, divided heat-fusible material has a particle size below about 100 mesh.

5. Method according to claim 1 in which said combustible fluid is hydrogen and said combustion supporting fluid oxygen, and in which said solid, divided heat-fusible material has a particle size below about 170 mesh.

6. Method according to claim 5 in which said solid, divided material has a particle size below about 270 mesh.

7. Method for coating a surface with a self-fluxing alloy, which comprises heating the surface to be coated to a temperature between 400 and 1000° F. below the melting point of the alloy to be sprayed, thereafter passing a combustible fluid and a combustion supporting fluid along a path of flow with a substantial linear velocity in a direction toward said surface, flame-combusting the fluids along said path of flow, passing said self-fluxing alloy in finely divided, solid form entrained in a small volume of carrier gas, into the central portion of said flame at a small fraction of the linear velocity of the combustion gases for passage through substantially the hottest portion of the flame, whereby the particles are fused and accelerated in a direction toward said surface and sprayed on said surface.

8. Method according to claim 7 in which, prior to said heating to a temperature of about 1000° to 400° F. below the melting point of the alloy, the surface is heated to a temperature of several hundred degrees which will not promote oxide formation and sprayed to a coat thickness between about one thousandth to one hundredth of an inch, and thereafter heated to said temperature of about 1000–400° F. below the melting point of the alloy and further sprayed.

9. Method according to claim 8 in which said alloy is a boron silicon nickel-base alloy, in which said heating is effected to a temperature between about 300–500° F. and in which the subsequent heating is effected to a temperature between about 1000 and 1600° F.

10. Method according to claim 9 in which the subsequent heating is effected to a temperature between about 1200 and 1400° F.

11. Method according to claim 7 in which said alloy is a boron silicon nickel-base alloy, and in which said heating is effected to a temperature between about 1000 and 1600° F.

12. A spray gun for spraying finely divided, heat-fusible material comprising a nozzle having a multiple number of nozzle ports arranged in the form of a ring, means for passing a combustible fluid and a combustion-supporting fluid through said nozzle with a substantial forward linear velocity for flame combustion, a carrier conduit extending through the center of said ring of nozzle ports, terminating adjacent the outlet end of said ports and having a length in inches not in excess of about 2.65×10^3 times the outlet cross-sectional area in square inches of said nozzle, a gas feed conduit for carrier gas coaxially positioned behind said carrier conduit and terminating with an orifice opening, coaxially directed toward said carrier conduit, means including a lateral flow passage extending in front of said orifice for feeding divided solid material into said carrier conduit, and means for passing a small volume of a carrier gas through said gas feed conduit whereby the carrier gas will pass through said orifice opening, entrain divided solid material fed through said lateral flow passage, carry the entrained divided solid material forward through said carrier conduit and into the hottest portion of a flame formed upon combustion of fluids passing through said nozzle, at a small fraction of the forward linear velocity of the combustion gases, for forward acceleration by the combustion gases.

13. A spray gun according to claim 12 including a storage container for solid, divided material and a gravity

flow duct connecting said storage container and said lateral flow passage.

14. A spray gun according to claim 13 including a bleeder hole defined through said lateral flow passage communicating the interior thereof with the ambient atmosphere.

15. A spray gun according to claim 12 in which said nozzle ports and the axis of said carrier conduit extend substantially parallel to each other, said carrier conduit slightly increasing in cross-sectional size in a forward direction.

16. A spray gun according to claim 12 including a multiple number of atmospheric air nozzles positioned adjacent said nozzle ports, arranged in the form of a ring coaxial with said ring of nozzle ports, and extending in a forwardly inclined converging direction in communication at the rear terminus thereof with the ambient atmosphere.

17. A spray gun according to claim 12 including a combustion gas conduit, a combustion-supporting gas conduit, a mixing passage communicating said combustion and combustion-supporting gas conduits with said nozzle ports, a gas flow passage communicating at least one of said combustion and combustion-supporting gas conduits with said gas feed conduit, and adjustable valve means controlling said gas flow passage.

18. A spray gun according to claim 17 in which said gas flow passage connects said combustion gas conduit and said gas feed conduit.

19. A spray gun according to claim 12 in which said carrier conduit has a length in inches not in excess of about 2.6×10^2 times the outlet cross-sectional area in square inches of said nozzle.

20. A spray gun according to claim 19 in which said carrier conduit has a length of less than 3 inches.

References Cited in the file of this patent

UNITED STATES PATENTS

2,389,702	Ullmer	Nov. 27, 1945
2,671,689	Wett	Mar. 9, 1954
2,544,259	Duccini et al.	Mar. 6, 1951