

Sept. 1, 1970

J. E. JACKSON

3,526,362

METHOD FOR SHIELDING A GAS EFFLUENT

Original Filed Jan. 16, 1968

5 Sheets-Sheet 1

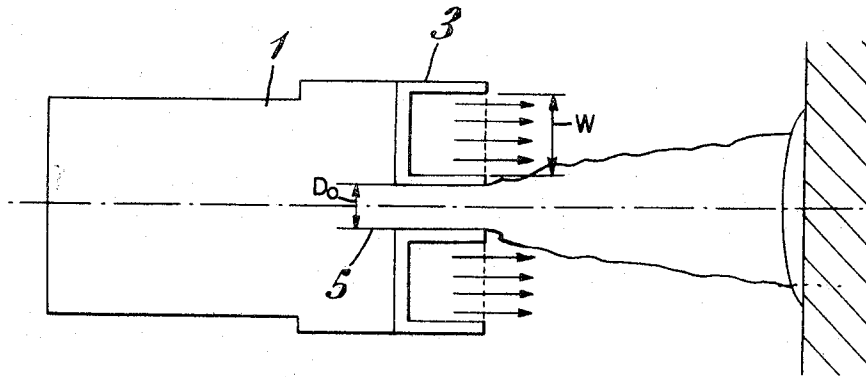


FIG. 1

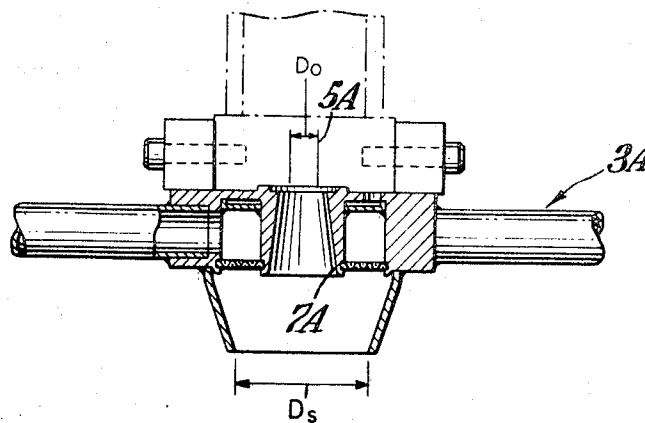


FIG. 1A

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Sept. 1, 1970

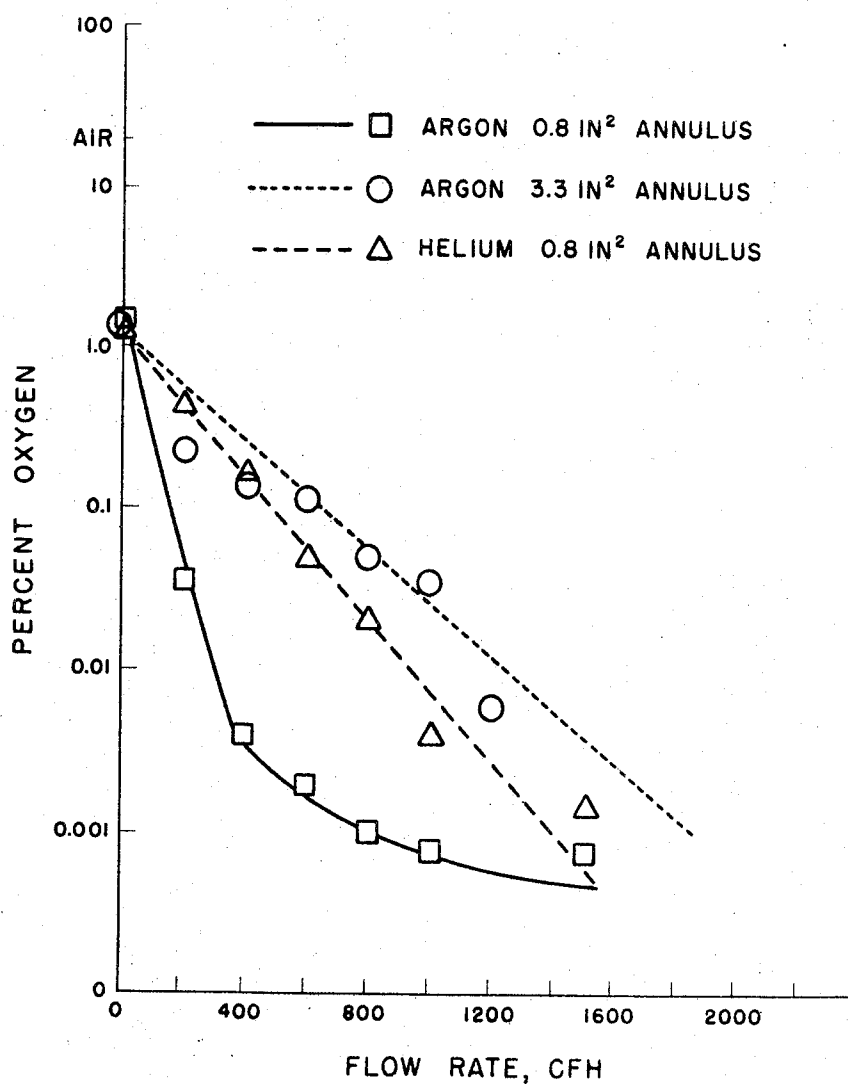
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5 Sheets-Sheet 2



INFLUENCE OF PROCESS PARAMETERS
ON OXYGEN CONCENTRATION.

FIG. 2

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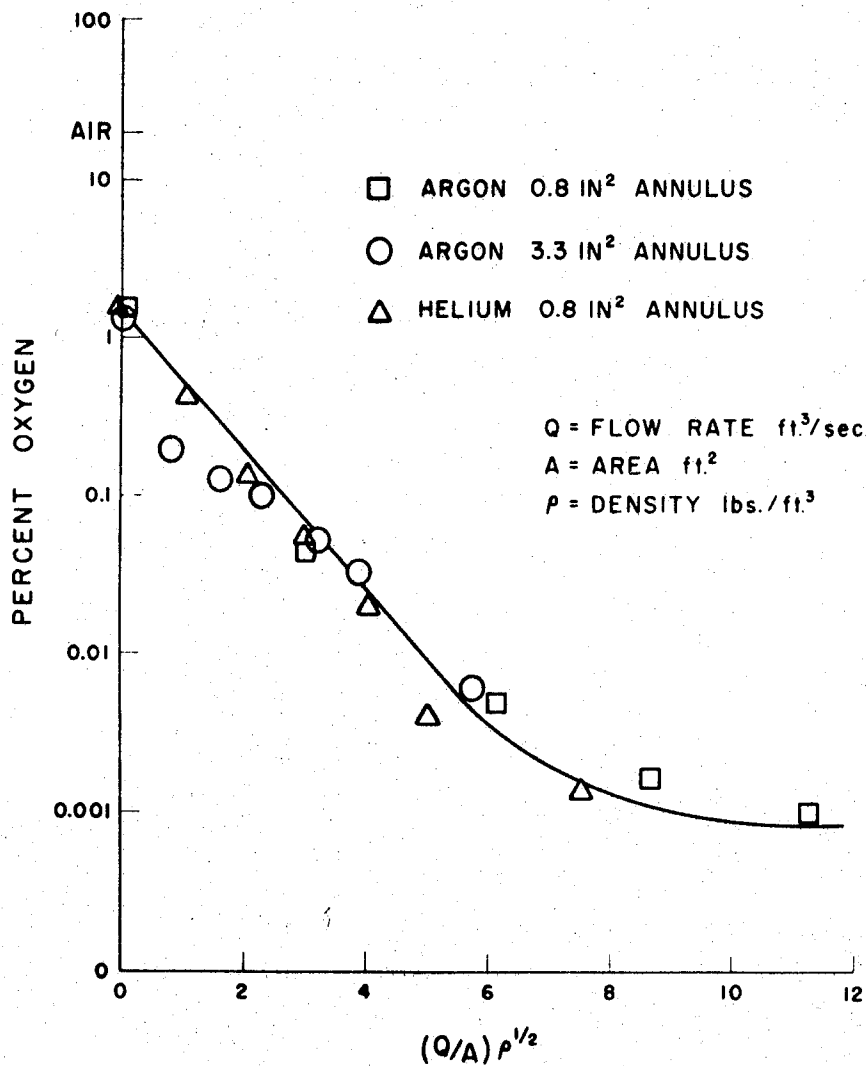
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METHOD FOR SHIELDING A GAS EFFLUENT

Original Filed Jan. 16, 1968

5 Sheets-Sheet 3



CORRELATION OF OXYGEN CONTENT
IN EFFLUENT OF COAXIAL JET
TORCH WITH PROCESS PARAMETERS.

FIG. 3

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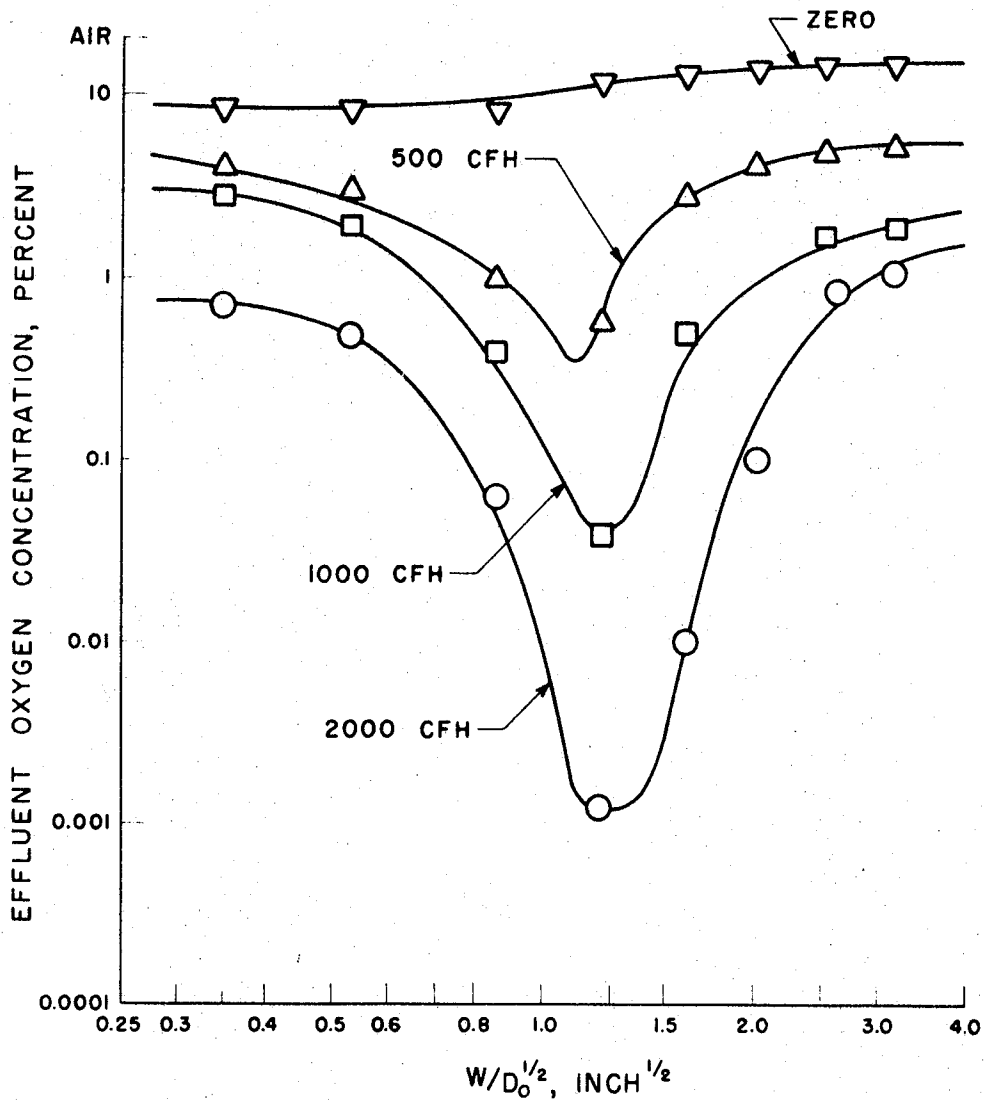
3,526,362

METHOD FOR SHIELDING A GAS EFFLUENT

Original Filed Jan. 16, 1968

5 Sheets-Sheet 4

CONDITIONS: $\frac{1}{8}$ " DIA. NOZZLE
450 CFH ARC TORCH GAS
150 AMPERES
1 INCH STANDOFF



EFFECT ANNULUS WIDTH PARAMETER AND
SHIELDING FLOW RATE ON SHIELDING
PERFORMANCE WITH A 1.0 INCH STANDOFF.

FIG. 4

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METHOD FOR SHIELDING A GAS EFFLUENT

Original Filed Jan. 16, 1968

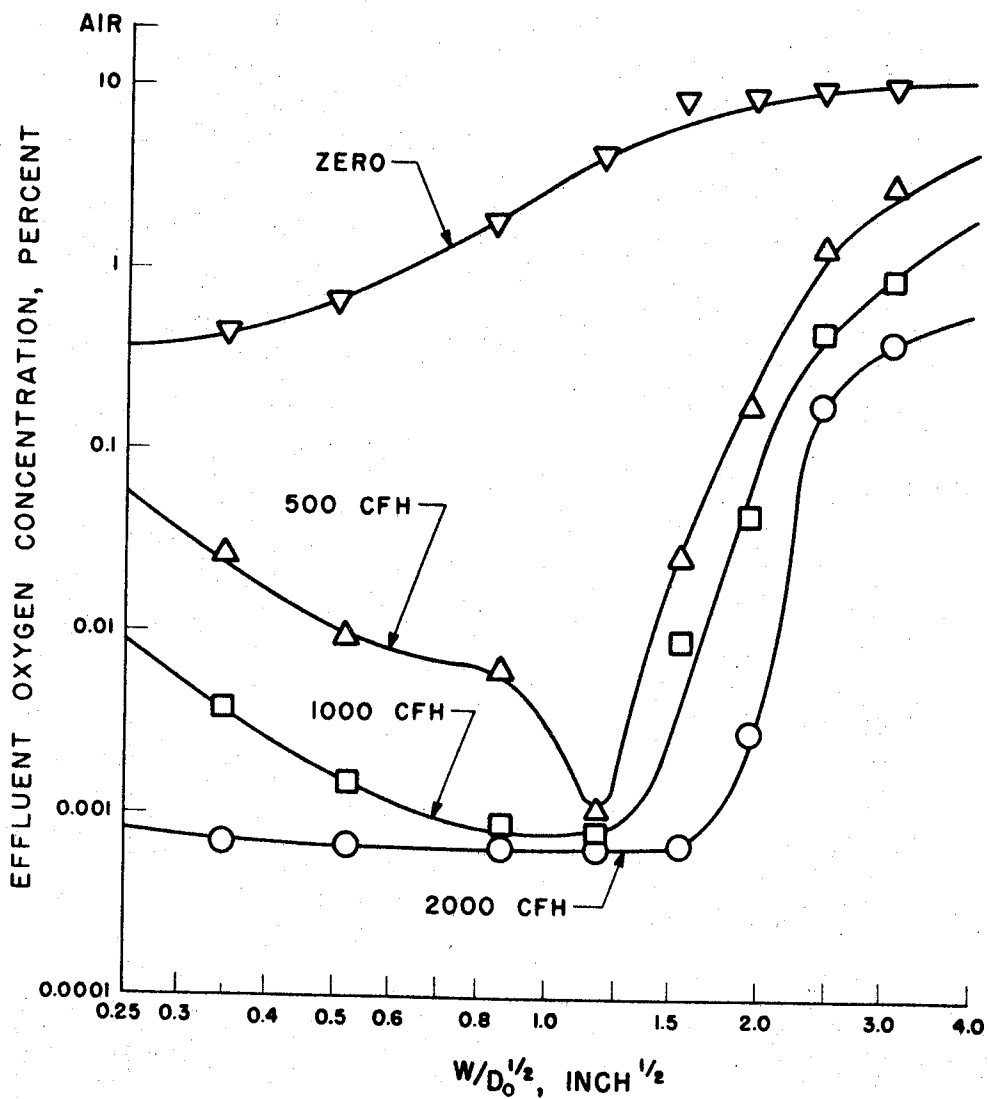
5 Sheets-Sheet 5

CONDITIONS: $\frac{1}{8}$ " DIA. NOZZLE

450 CFH ARC TORCH GAS

150 AMPERES

$\frac{1}{2}$ INCH STANDOFF



INFLUENCE OF SHIELDING FLOW RATE AND
ANNULUS WIDTH PARAMETER ON SHIELDING
PERFORMANCE WITH A 0.5 INCH STANDOFF.

INVENTOR.

JOHN E. JACKSON

FIG. 5

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1

3,526,362

METHOD FOR SHIELDING A GAS EFFLUENT

John E. Jackson, Indianapolis, Ind., assignor to Union Carbide Corporation, a corporation of New York
Original application Jan. 16, 1968, Ser. No. 698,268, now Patent No. 3,470,347, dated Sept. 22, 1969. Divided and this application May 28, 1969, Ser. No. 842,072
Int. Cl. B44d 1/08

U.S. Cl. 239—1

4 Claims

ABSTRACT OF THE DISCLOSURE

A method wherein a gaseous effluent such as an arc effluent is protected from contamination by its surrounding environment by surrounding such effluent with a coaxial annular stream of gas having a width which is in the range of from 0.25 to about 4.0 times the square root of the diameter of the orifice, measured in inches, in the nozzle, and which has a value for the square root of the momentum flux of greater than 2.0 lb.^{1/2}/sec. ft.^{1/2}.

This application is a division of 698,268 filed Jan. 16, 1968, now Pat. No. 3,470,347.

This invention relates to a method for shielding a gas effluent from the environment around such gas effluent and more particularly to a method wherein such gas effluent is an arc effluent.

Gas flowing out of a nozzle, hereinafter referred to as gas effluent, has been used in many processes particularly in metal fabrication, welding, and coating processes. For example, oxy-fuel gas effluents with and without powder entrainment have been used to cut and treat metals. Gases have been used to shield electric arcs. Gases have also been introduced into electric arcs so that at least some of the gas becomes part of the arc and becomes an arc effluent. In many cases it is desirable to protect the gas or arc effluent from contamination by the natural environment around the gas or arc effluent.

This invention in its broadest aspects relates to a novel method for preventing contamination of a gas effluent by the natural environment around such gas effluent. Therefore, it should be understood that the teachings hereinafter set forth are applicable to all processes typified by the above referred to examples, while for sake of simplicity of describing those teachings and presenting a preferred embodiment of the invention the greater part of this specification will refer hereinafter to arc coating processes wherein arc effluents are utilized.

One of the most useful of the arc coating processes is a process wherein an arc is established between two electrodes and a gas is introduced into such arc and passed through a nozzle having a constricting orifice. The material to be deposited as a coating, usually in powder form, is introduced into the arc and carried to the work-to-be-coated by the arc effluent. The process is described in greater detail in U.S. Pat. 3,016,447 issued to R. M. Gage et al.

While this process is eminently useful, there are some undesirable shortcomings. Arc coating or plating, as it is sometimes referred to, suffers from contamination of the arc effluent by the surrounding air. As a result, the coating material becomes oxidized and produces an oxidized coating. When deposits of pure metal are made, the metallic coatings are porous, possess low ductility and are difficult to machine to accurate dimensions with good surface finishes. In addition, the chemical changes which the hot entrained coating material undergo in the presence of the contaminants may alter the desirable physical properties of the coating material.

Accordingly, it is a main object of this invention to

2

provide a method for minimizing contamination of a gas effluent with the surrounding environment.

It is another object to prevent the environment surrounding an arc effluent from being aspirated into said arc effluent.

Another object is to provide a method for arc coating wherein oxidation of the material entrained in an arc effluent is minimized.

A further object is to provide a method for producing substantially oxygen-free arc coatings on a substrate.

Yet another object is to prevent oxidation of powdered material entrained in an arc effluent.

These and other objects will either become apparent or will be pointed out when referring to the following description and drawings wherein:

FIG. 1 is a schematic diagram illustrating the concept of the invention;

FIG. 1A is a partial cross section view of the front end of typical torch apparatus for practicing the invention;

FIG. 2 is a curve illustrating the effect of the annular shielding gas stream flow rate on oxygen concentration in the gas effluent being shielded for various annulus areas and shielding gases;

FIG. 3 is a curve illustrating the effect of the parameters of the annular shielding gas stream on oxygen concentration;

FIGS. 4 and 5 are curves illustrating the effect of the ratio $W/D_o^{1/2}$ on oxygen concentration at different stand-off distances.

The objects of the invention are accomplished in a general way by a method wherein the gas effluent, which is to be protected from contamination by its natural environment, is surrounded with an annular shielding gas stream the width of which, measured in inches, should be in the range of from 0.25 to about 4.0 times the square root of the diameter of the orifice (measured in inches) in the nozzle through which said effluent passes. The gas flowing in the annular shielding gas stream is coaxial with the gas effluent and the square root of the momentum flux of the annular stream is at least 2.0 lb.^{1/2}/sec. ft.^{1/2} as given by the equation $(Q/A)\phi^{1/2}$ wherein Q is the flow rate in ft.³/sec. of the annular gas stream; A is the annular area in ft.² and ϕ is gas density in lb./ft.³.

This invention is predicated on the discovery that an annular shielding gas stream having a width and forward momentum flux within limits herein defined and which has uniform turbulent flow will remarkably shield a gas effluent so that the oxygen concentration in the gas effluent is essentially equal to that of the annular shielding gas stream. When the width of the annular gas stream is between 0.25 and 4.00 times the square root of the diameter of the orifice in the nozzle from which the gas effluent emerges, both measured in inches, and when the square root of the forward momentum flux of such gas stream is greater than 2.0 lb.^{1/2}/sec. ft.^{1/2} as defined by the equation $(Q/A)\phi^{1/2}$, the Reynolds number (Re) of the gas flow is usually greater than 2000. While it is possible to practice the invention with a Re less than 2000 the corresponding marginal shielding performance achieved is improved by increasing Re while keeping the ratio $W/D_o^{1/2}$ within the limits defined.

This invention is admirably suited to and useful for the shielding of an arc effluent wherein a powdered coating material is entrained and carried in a heated state to a workpiece which is to be coated with such material. In the process of arc coating an arc is usually established between a first and second electrode contained in an arc device. An arc gas is introduced into the arc to create an arc effluent. The coating material is introduced into the arc and arc effluent and is carried thereby to the work. Up until now the coatings achieved by such a

3

process were usually oxidized. When the present invention was used with the arc coating processes described, the oxygen contamination was substantially eliminated so that deposits essentially as pure as the starting coating material were achieved. The following table clearly illustrates the capabilities of the invention:

TABLE I.—OXYGEN CONTENT OF ARC TORCH DEPOSITS

Coating material	Oxygen content (percent)		
	Starting powder	Conventional coating	Coaxial jet shielded coating
Copper.....	.126	.302	.092
Nickel.....	.172	.456	.151
Tungsten.....	.027	.274	.030
Titanium.....	.655	>2.0	.730
Molybdenum.....	.419	.710	.160

As will be noted from the table, the oxygen content of deposits made with the invention is substantially and remarkably lower than that obtained with conventional coating, i.e., without coaxial jet shielding, and in most cases (in equal to or even less than the oxygen content in the starting powder.

A schematic representation of typical equipment for carrying out the invention is shown in FIG. 1. Attached to a conventional arc torch device 1 of the type mentioned above and shown in U.S. Pat. 3,016,447 is a coaxial jet shielding device 3 so that the arc effluent from the nozzle orifice 5 having a diameter D_0 in torch 1 passes through the center of the device 3. The coaxial jet shielding device 3 is selected so that the width measured in inches of the annular shielding gas streams is between 0.25 and 4.00 times the square root of the dimension D_0 , measured in inches. In this case the width W of the device 3 is the width of the annular shielding gas stream. In FIG. 1A the diameter D_s of device 3A is selected and correlated with the diameter D_0 of the nozzle 5A orifice so that the width of the annular gas stream which in this case is

$$\frac{D_s - D_0}{2}$$

falls within the range given below. It should be noted that in this embodiment of the invention, the inner surface 7A of device 3A does not restrict the jet discharging from nozzle orifice 5A but merely provides a passage through which the arc effluent emerges from device 3A. However, if surface 7A were made sufficiently small so that substantial constriction of the effluent jet resulted, then the inner diameter of this constriction becomes the orifice diameter for computation of the width parameter.

FIG. 4 indicates that at a 1 inch standoff distance, that is distance of the arc torch from the work, the effectiveness of the annular shielding gas stream increases for a given flow rate up to a maximum or preferred ratio of about 1.2 in. $^{1/2}$ and then begins to decrease until a ratio of about 4.0 in. $^{1/2}$ is reached at which point the effectiveness is marginal. FIG. 5 is a curve similar to FIG. 4 indicating that the effects illustrated in FIG. 4 are more pronounced when the standoff distance is $\frac{1}{2}$ inch. It has been found that the invention herein described is useful in processes where the standoff distance, measured from the end of the device, is up to about 40 to 50 times the nozzle orifice diameter.

The curve of FIG. 2 illustrates that the molecular weight of the gas used has an effect on the resultant oxygen contamination of the arc effluent. It is evident that argon is more effective than helium and that at the same flow rate, it is more desirable to use a smaller annulus and achieve higher velocities.

In addition to being dependent on the width of the annular shielding gas stream, successful shielding performance according to the invention is dependent on what is called herein the square root of the momentum flux

4

and which I chose to define by the equation $(Q/A)\varphi^{1/2}$. The derivation of the term $(Q/A)\varphi^{1/2}$ is as follows:

If the term $(Q/A)\varphi^{1/2}$ were written as $(Q^2/A^2\varphi)^{1/2}$ or as

$$\left[(Q\varphi) \left(\frac{Q}{A} \right) \left(\frac{1}{A} \right) \right]^{1/2}$$

one ends up with momentum flux to the half power since $(Q\varphi)$ is the weight flow rate. (Q/A) is the velocity and $(1/A)$ is the area to the minus 1 power. In English units the weight density is divided by 32.2 to give a mass density. Under these conditions $(Q/A)\varphi^{1/2}$ of

$$2.0 \frac{\text{lb.}^{1/2}}{\text{sec. ft.}^{1/2}}$$

is equal to

$$0.352 \frac{\text{slugs}^{1/2}}{\text{sec. ft.}^{1/2}}$$

In FIG. 1 the area A is the cross sectional area of the annulus through which the shielding gas passes. In FIG. 1A the area is computed by $\pi/4 [D_s^2 - D_0^2]$.

FIG. 3 illustrates that in order to achieve a significant reduction in oxygen content in the arc effluent the value of $(Q/A)\varphi^{1/2}$ should be greater than 2 lb. $^{1/2}$ /sec. ft. $^{1/2}$.

The composition of the gas, of course, effects the momentum flux. FIG. 2 indicates that argon gas for example is a better shielding gas for purposes of this invention than is helium.

In a preferred embodiment of the invention, an arc torch having a tungsten electrode and nozzle with an $\frac{1}{8}$ in. orifice diameter was adapted to receive a coaxial jet shielding device of the type shown in FIG. 1A having a diameter at D_s of 1 inch. The annulus in the shielding device is preferably covered with porous metal, screens or other material to insure uniform flow around the cross section without velocity disturbances caused by the gas inlets. The invention is most useful when uniform turbulent flow is achieved as opposed to smooth laminar flow. An arc is established between the tungsten electrode and a second electrode in the arc torch. Powdered coating material is introduced into the arc and carried to a workpiece in the arc effluent. Shielding gas, preferably argon, is introduced into the coaxial jet shielding device 3 or 3A to produce a flow rate capable of providing the necessary momentum flux.

If the coaxial jet shielding device has an annulus which is too wide, very high flow rates are needed to achieve the desired momentum flux and the process becomes less attractive commercially. On the other hand, if the annulus is too narrow, the annular shielding gas stream becomes too thin and unstable and does not perform its function of reducing the amount of gas entrained by the central gas effluent. I have also found that the arc conditions such as arc amperage and arc gas flow rate have a negligible effect on the effectiveness of the annular shielding gas stream. For example, the arc gas was varied from 200 c.f.h. to 600 c.f.h. with very little change in the oxygen content in the arc effluent.

Having described the invention, the following examples are illustrative of conditions falling within the scope of the invention and are provided to assist those skilled in the art in understanding how to practice the inventive concept.

EXAMPLE I

An arc torch having a tungsten electrode surrounded by a nozzle having $\frac{1}{8}$ in. diameter and $\frac{3}{16}$ in. length was used as the coating device. Argon gas was introduced into the arc torch as an arc gas at a flow of 450 c.f.h. The arc current was 125 amperes at 78 volts. The torch standoff was $\frac{1}{2}$ in. Nickel powder having an oxygen analysis of .172% was introduced into the arc torch at the rate of 24 g.p.m. (grams per minute). The rate of deposition of the powder on the substrate was 15 g.p.m. A coaxial jet shielding device similar to that shown in FIG. 1A was attached to the arc torch. The annular

5

coaxial gas stream surrounding the arc effluent had a width of 0.312 in. Argon gas was introduced into the device at a flow rate of 2000 c.f.h. to produce a value for the square root of the momentum flux of

$$60 \frac{\text{lb.}^{1/2}}{\text{sec. ft.}^{1/2}}$$

The oxygen analysis of the coating formed was .150%, a reduction of .022%. The coating was very clean with excellent machinability.

EXAMPLE II

Apparatus similar to that used in Example I was used in this test with the exception that the nozzle length was $\frac{1}{8}$ in. Argon gas was introduced into the arc torch at a flow rate of 450 c.f.h. The arc current was 100 amperes at 80 volts. The standoff distance was $\frac{1}{2}$ in. Titanium powder having an oxygen analysis of .651% was introduced into the arc torch at the rate of 20 g.p.m. The rate of deposition of the powder on the substrate was 13 g.p.m. The coaxial jet had a width of 0.312 in. Argon was introduced into the coaxial jet at the flow rate of 2000 c.f.h. to produce a value for the square root of the momentum flux of

$$60 \frac{\text{lb.}^{1/2}}{\text{sec. ft.}^{1/2}}$$

The oxygen analysis of the coating formed was .730%. The machining characteristics and ability to take a high surface finish was outstanding.

EXAMPLE III

All apparatus was the same in this example as in Example II. The nozzle length in this example was $\frac{5}{32}$ in. The arc conditions were the same as in Example II. Molybdenum powder having an oxygen analysis of .419% was introduced at the rate of 33 g.p.m. into the arc torch. The rate of deposition was 20 g.p.m. The coaxial jet had a width of 0.312 in. Argon was introduced into the coaxial jet at the flow rate of 2000 to produce a value for the square root of the momentum flux of

$$60 \frac{\text{lb.}^{1/2}}{\text{sec. ft.}^{1/2}}$$

The oxygen analysis of the coating was .155. The reduction in oxygen was a remarkable .264%.

EXAMPLE IV

The conditions here were the same as in Example III. The arc current was 150 amperes at 80 volts. Tungsten powder having an analysis of .027 oxygen was introduced at the rate of .68 g.p.m. into the arc torch. The deposition

6

rate was 51 g.p.m. The width of the coaxial jet was 0.312 in. and its square root of the momentum flux was

$$60 \frac{\text{lb.}^{1/2}}{\text{sec. ft.}^{1/2}}$$

5 The oxygen analysis of the coating was .030%. The coating retained substantially the low oxygen level of the original tungsten powder making it more suitable for applications requiring high strength at room and high temperatures.

10 While the invention has been described with reference to certain preferred embodiments, it should be understood that certain modifications can be made thereto without departing from the spirit and scope of the invention.

15 What is claimed is:

1. A method for preventing contamination of a high velocity gas effluent from a nozzle by the environment around said gas effluent which comprises

20 surrounding said high velocity gas effluent with an annular coaxial gas stream the width of which measured in inches is in the range of from 0.25 to about 4.0 times the square root of the diameter of the orifice measured in inches, in said nozzle;

25 introducing gas into said annular coaxial gas stream at a flow rate to cause said annular coaxial gas stream to have a value for the square root of the longitudinal momentum flux that is greater than $2.0 \text{ lb.}^{1/2} \text{ sec. ft.}^{1/2}$ as given by the equation $(Q/A)\phi^{1/2}$ wherein Q is the flow rate in $\text{ft.}^3/\text{sec.}$ of the annular gas stream; A is the annular area in ft.^2 and ϕ is gas density in $\text{lb.}/\text{ft.}^3$.

30 2. Method according to claim 1 wherein the width of the annular coaxial gas stream is about 1.2 times the square root of the diameter of the orifice in said nozzle when both are measured in inches.

35 3. Method according to claim 1 wherein the Reynolds number of the coaxial gas stream is greater than 2000.

40 4. Method according to claim 1 wherein the gas in the annular coaxial gas stream is argon.

References Cited

UNITED STATES PATENTS

45 3,313,908 4/1967 Unger et al. 219—76
3,470,347 9/1969 Jackson 219—76

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U.S. Cl. X.R.

117—93.1; 219—76; 239—290; 266—23