

Sept. 11, 1962

E. F. GORMAN ETAL
METHOD AND APPARATUS FOR ARC WORKING WITH GAS
SHIELDS HAVING COHERENT-STREAMING

3,053,968

Filed April 25, 1960

9 Sheets-Sheet 1

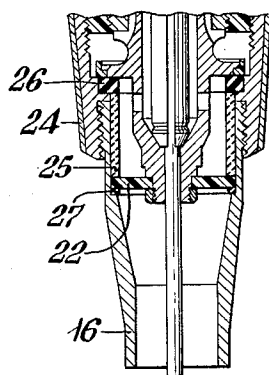


Fig. 1a.

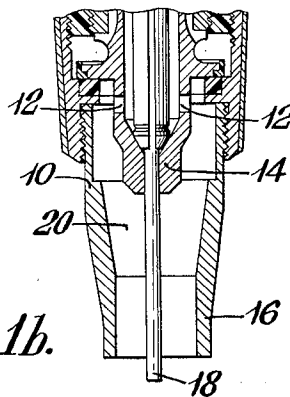


Fig. 1b.

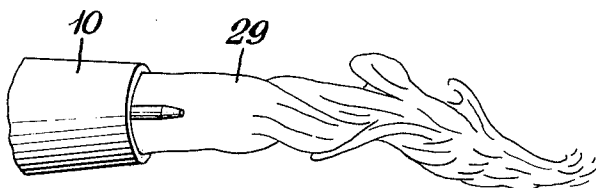


Fig. 2a.

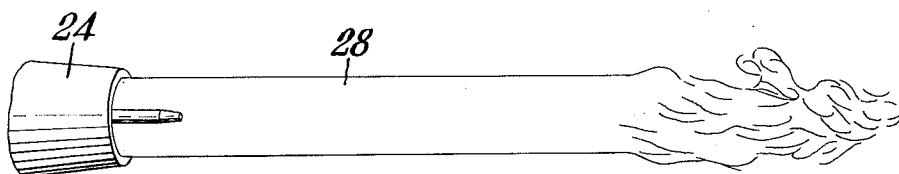


Fig. 2b.

INVENTORS
EUGENE F. GORMAN
ROBERT J. NELSON

BY *Barnwell R. King*
ATTORNEY

Sept. 11, 1962

E. F. GORMAN ET AL
METHOD AND APPARATUS FOR ARC WORKING WITH GAS
SHIELDS HAVING COHERENT-STREAMING

3,053,968

Filed April 25, 1960

9 Sheets-Sheet 2

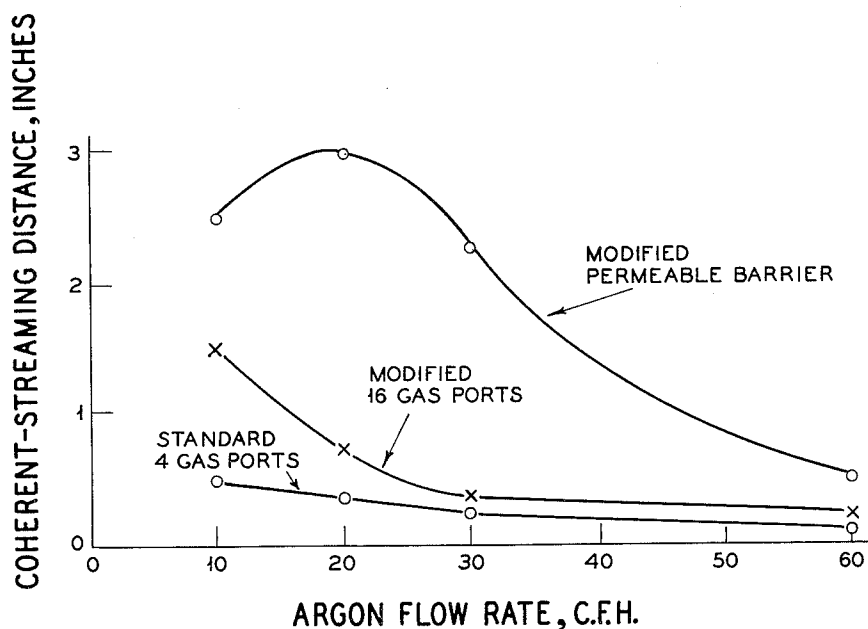


Fig. 3.

INVENTORS
EUGENE F. GORMAN
ROBERT J. NELSON

BY *Barnwell P. King*
ATTORNEY

Sept. 11, 1962

Filed April 25, 1960

E. F. GORMAN ETAL
METHOD AND APPARATUS FOR ARC WORKING WITH GAS
SHIELDS HAVING COHERENT-STREAMING

3,053,968

9 Sheets-Sheet 3

Fig. 4a.

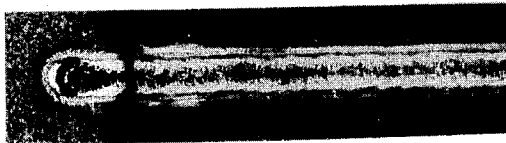
NOZZLE-TO-WORK ELEVATION - 5/8 INCH



STANDARD
4 GAS PORTS

Fig. 4b.

NOZZLE-TO-WORK ELEVATION - 5/8 INCH



MODIFIED
16 GAS PORTS

Fig. 4c.

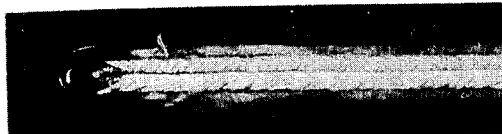
NOZZLE-TO-WORK ELEVATION - 5/8 INCH



MODIFIED
PERMEABLE
BARRIER

Fig. 4d.

NOZZLE-TO-WORK ELEVATION - 7/8 INCH



MODIFIED
16 GAS PORTS

Fig. 4e.

NOZZLE-TO-WORK ELEVATION - 7/8 INCH



MODIFIED
PERMEABLE
BARRIER

INVENTORS
EUGENE F. GORMAN
ROBERT J. NELSON

BY *Barnwell R. King*
ATTORNEY

Sept. 11, 1962

E. F. GORMAN ETAL
METHOD AND APPARATUS FOR ARC WORKING WITH GAS
SHIELDS HAVING COHERENT-STREAMING

3,053,968

Filed April 25, 1960

9 Sheets-Sheet 4

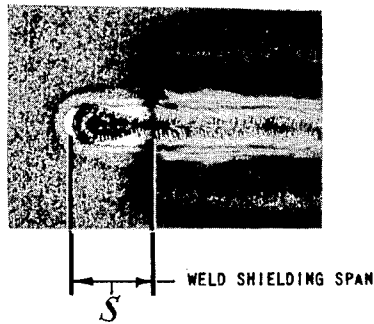


Fig. 5a

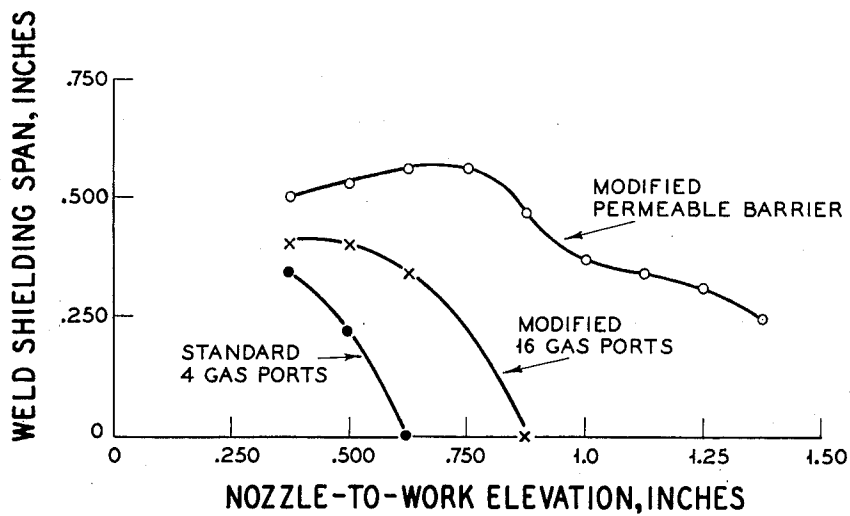


Fig. 5b.

INVENTORS
EUGENE F. GORMAN
ROBERT J. NELSON

BY *Barnwell P. King*
ATTORNEY

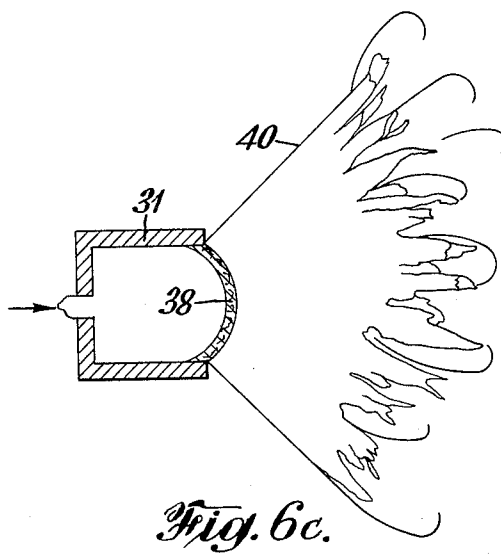
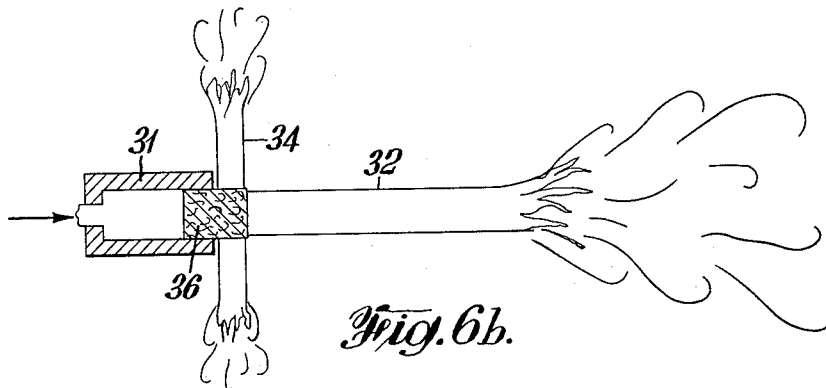
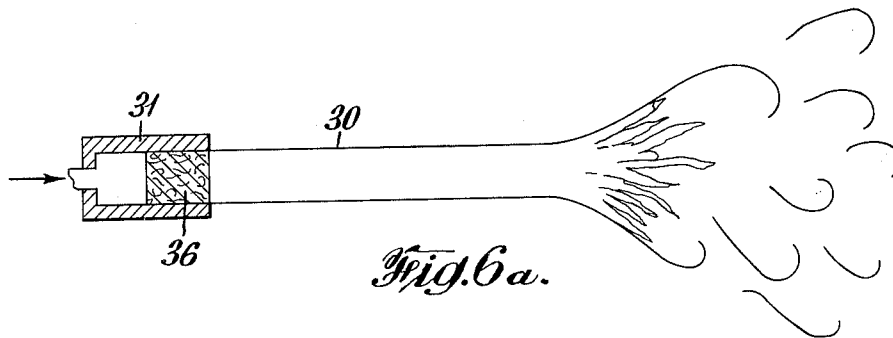
Sept. 11, 1962

E. F. GORMAN ETAL
METHOD AND APPARATUS FOR ARC WORKING WITH GAS
SHIELDS HAVING COHERENT-STREAMING

3,053,968

Filed April 25, 1960

9 Sheets-Sheet 5



INVENTORS
EUGENE F. GORMAN
ROBERT J. NELSON
BY *Barnwell R. King*
ATTORNEY

Sept. 11, 1962

E. F. GORMAN ETAL
METHOD AND APPARATUS FOR ARC WORKING WITH GAS
SHIELDS HAVING COHERENT-STREAMING

3,053,968

Filed April 25, 1960

9 Sheets-Sheet 6

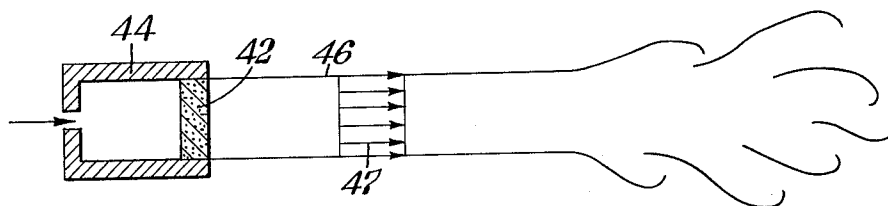


Fig. 7a

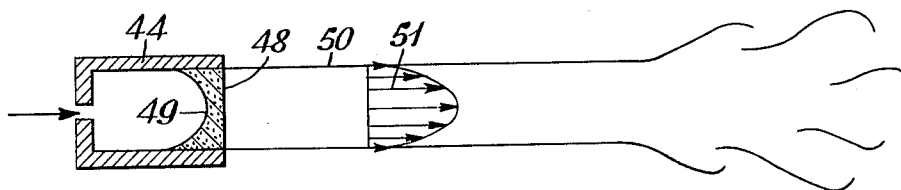


Fig. 7b.

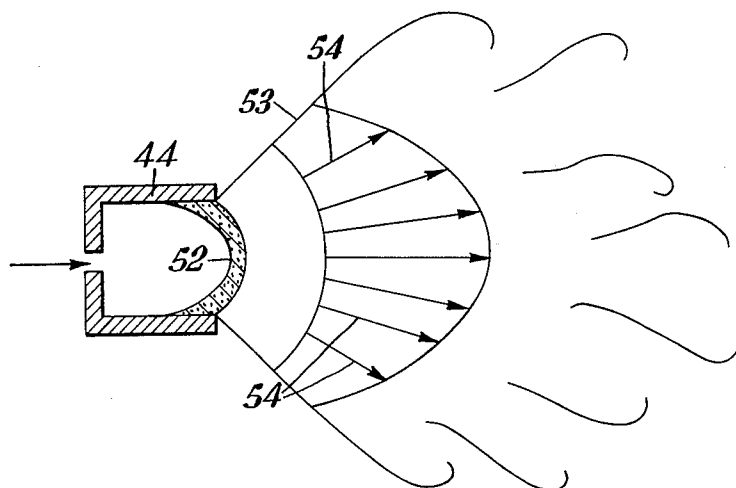


Fig. 7c.

INVENTORS
EUGENE F. GORMAN
ROBERT J. NELSON

BY *Barnwell P. King*
ATTORNEY

Sept. 11, 1962

E. F. GORMAN ET AL
METHOD AND APPARATUS FOR ARC WORKING WITH GAS
SHIELDS HAVING COHERENT-STREAMING

3,053,968

Filed April 25, 1960

9 Sheets-Sheet 7

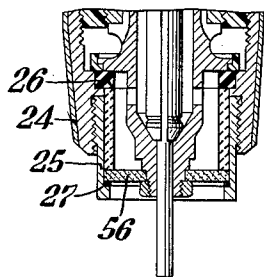


Fig. 8a.

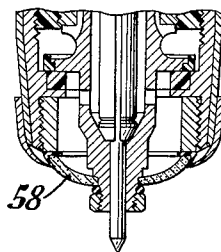


Fig. 8b.

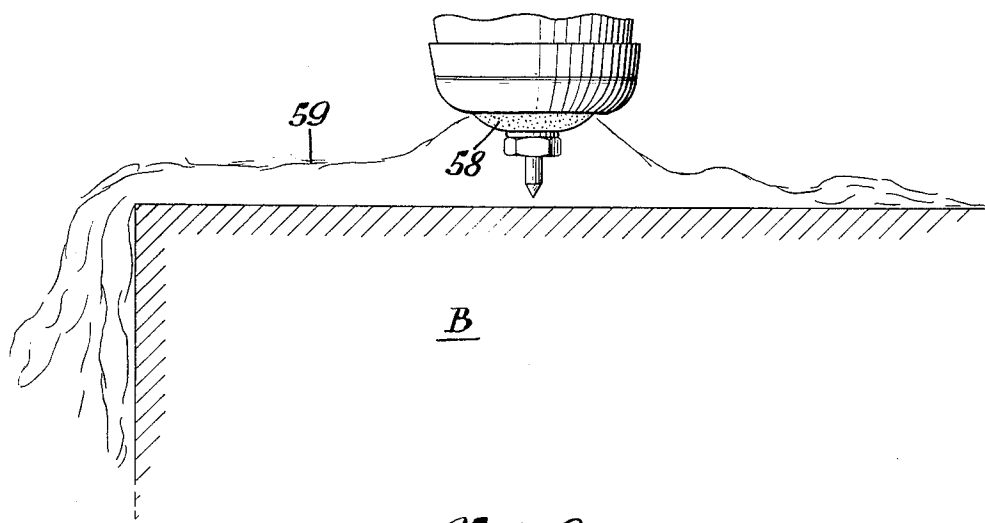


Fig. 9.

INVENTORS
EUGENE F. GORMAN
ROBERT J. NELSON

BY *Barnwell P. King*
ATTORNEY

Sept. 11, 1962

E. F. GORMAN ETAL
METHOD AND APPARATUS FOR ARC WORKING WITH GAS
SHIELDS HAVING COHERENT-STREAMING

3,053,968

Filed April 25, 1960

9 Sheets-Sheet 8

NOZZLE-TO-WORK ELEVATION - $\frac{3}{8}$ INCH

STANDARD-WITH NO.10 NOZZLE

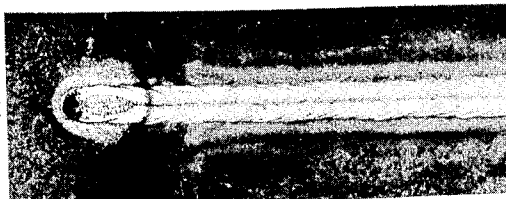


Fig. 10a.

NOZZLE-TO-WORK ELEVATION - $\frac{3}{8}$ INCH

MODIFIED-WITH FLAT GAS LENS
AND NO.10 NOZZLE

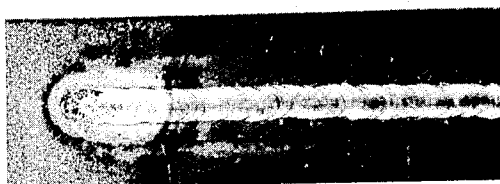


Fig. 10b.

VERTEX-TO-WORK ELEVATION - $\frac{1}{2}$ INCH

MODIFIED-WITH PARABOLIC
GAS LENS

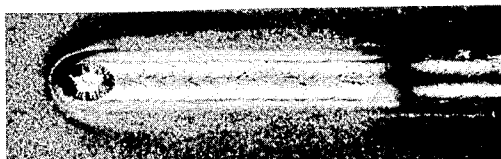


Fig. 10c.

INVENTORS
EUGENE F. GORMAN
ROBERT J. NELSON

BY *Barnwell R. King*
ATTORNEY

Sept. 11, 1962

E. F. GORMAN ETAL

3,053,968

METHOD AND APPARATUS FOR ARC WORKING WITH GAS

SHIELDS HAVING COHERENT-STREAMING

Filed April 25, 1960

9 Sheets-Sheet 9

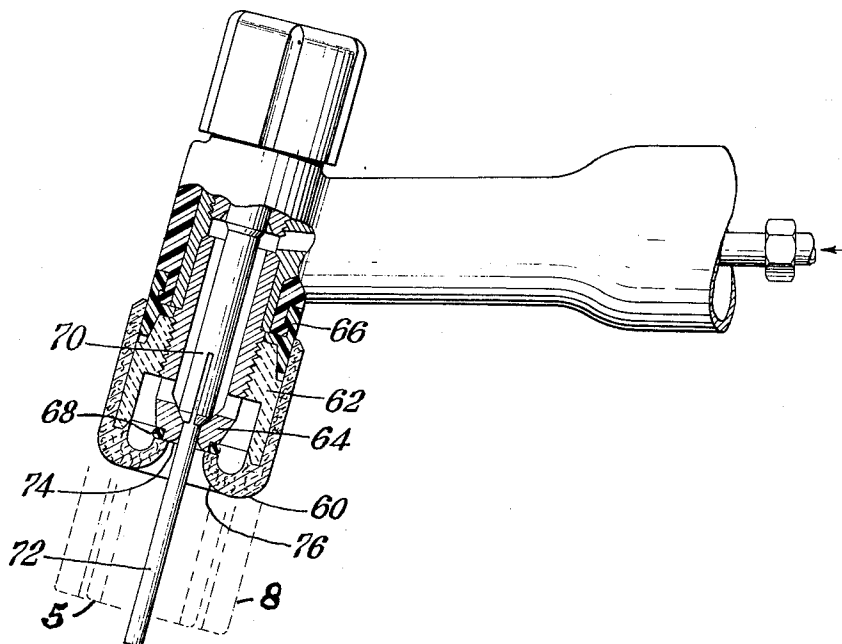


Fig. 11.

INVENTORS

EUGENE F. GORMAN
ROBERT J. NELSON

BY *Barnwell P. King*
ATTORNEY

1

3,053,968

METHOD AND APPARATUS FOR ARC WORKING WITH GAS SHIELDS HAVING COHERENT-STREAMING

Eugene F. Gorman, Rutherford, and Robert J. Nelson, Elizabeth, N.J., assignors to Union Carbide Corporation, a corporation of New York

Filed Apr. 25, 1960, Ser. No. 24,550

34 Claims. (Cl. 219-74)

This invention relates to arc working, and more particularly to electric arc welding in a stream of shielding gas that protects the operation from natural air of the atmosphere.

Heretofore, the standard recommendation for obtaining optimum weld shielding has been to employ long nozzles or gas conduits having high L/De ratios. The impracticality of such recommendation is evident when it is observed that commercial torches seldom provide any significant length for gas passage. Welding trials have led us to the observation that improved weld shielding can be obtained from a gas stream which remains coherent for long distances after leaving the torch nozzle. With this point in mind, we determined the basic factors which influence the flow patterns of gases exiting from conduits.

We have observed that gross variations in weld shielding are encountered, depending on the method used to supply gas to nozzles. The problem of entering gas distribution has been investigated, but the methods developed, involved the use of large bulky chambers sometimes with baffles to gradually reduce turbulence in gas prior to its entry into a downstream conduit or nozzle as shown in Mikhailapov Patent No. 2,544,711.

In some cases, a plate with widely spaced drilled holes has been proposed, but without much benefit. Prior to the present invention, therefore, it has been necessary to use torches with very long conduits in order to obtain desirable shielding performance, which is inconvenient due to excessive length, bulk, and weight. Present demand, however, is strongly in favor of torches of very short lengths, small bulk, and light weight to permit maximum accessibility to confined work spaces, particularly for manual welding. As a result, welding operators prior to our invention had to pay critical attention to keeping the torch nozzle very close to the weld in order to obtain acceptable shielding.

The main object of this invention is to provide novel means and methods for more effectively shielding with as little gas and as short a cup (nozzle) as possible in electric arc working, such as arc welding operations, to improve the latter.

Another object of the invention is to provide a method of and means for projecting a gaseous atmosphere of controlled purity and/or composition through a predetermined relatively long distance in the form of a coherent or "solid" gas stream in the sense that the stream retains a desired form, purity, and composition without mixing with the ambient of contiguous atmosphere other than by non-turbulent aspiration.

Such method is used for the purpose of establishing a controlled atmosphere throughout a zone remotely located with respect to a discharge point. The controlled flow-pattern of the gas stream is characterized by a smooth and continuous, though not necessarily uniform, distribution of velocities as represented by vectors which show both the magnitudes and the directions of gas velocities throughout the stream cross-sections when a macroscopic rather than a microscopic scale is used. This characteristic distribution of gas velocities is applicable throughout all points in the stream cross-section starting at least at that section where the stream exits from the projecting device

2

vice and including all subsequent stream cross-sections up to and including a distance of at least 1 inch from the end of the projecting device. Such qualifying conditions, however, are specified for a test condition wherein the stream is projected into free space and away from any physical obstruction which would distort the test flow pattern of the gas stream. When these conditions are met in the test run, the device is then qualified to provide an extremely high degree of atmosphere control over any zone which falls within the boundaries of the gas stream and up to a distance of at least 1 inch from the point of discharge thereof.

We have found that:

(1) The most important factor which must be considered in the design of relatively short gas conduits or nozzles for use in projecting coherent-streams of gas is the state of velocity of the gas entering the nozzle.

(2) Very short nozzles can be used when gas enters in a favorable state. Conversely, the use of long nozzles is required only when gas enters in an unfavorable state.

(3) A favorable state exists when gas enters a nozzle or downstream conduit at a velocity no more than about 5 times the required conduit velocity and preferably less than 3 times the conduit velocity.

(4) Permeable barriers are the most effective devices for producing favorable states of entering gas flow.

(5) It is now possible by virtue of the invention to use special permeable barriers or gas lenses instead of nozzles to project coherent streams of gas through very long distances before turbulent break-up of the gas stream occurs.

(6) With shaped gas lenses, phenomenally large areas of complete weld shielding can be obtained along with unrestricted visibility of the welding operation and flexibility in the manipulation of a torch or shielding device.

(7) With the aid of gas lenses, it is now possible to effect complete control over the magnitudes, directions, and distributions of velocities through gas streams so as to produce coherent-streaming independent of Reynolds numbers or L/De ratios.

In the drawings:

FIG. 1a is a fragmentary cross-sectional view of an arc welding torch illustrating the invention;

FIG. 1b is a similar view of a torch (Linde HW-13) of the prior art;

FIG. 2a is a perspective view of a streaming pattern of gas leaving the prior art torch of FIG. 1b;

FIG. 2b is a similar view of a streaming pattern of gas leaving the torch of FIG. 1a of the invention;

FIG. 3 is a graph of coherent-streaming distance-argon flow rate characteristic curves comparing the invention with the prior art;

FIG. 4a is a plan view (photograph) of an inert-gas-shielded-non-consumable electrode weld made with the prior art torch of FIG. 1b;

FIGS. 4b, 4c, 4d and 4e are similar views of welds made with torches comprising the invention;

FIG. 5a is a view similar to FIG. 4b showing the "weld shield span";

FIG. 5b is a graph of weld shielding span-nozzle-to-work elevation characteristic curves comparing the invention with the prior art;

FIG. 6a is a view partly in cross-section and partly in side elevation showing a gas lens positioned in the end of a gas supply conduit for axial stream directional control;

FIG. 6b is a similar view of a gas lens positioned in the end of a gas supply conduit for axial and radial directional control;

FIG. 6c is a similar view of a diverging stream obtained with a convex gas lens (permeable barrier);

FIG. 7a is a cross-section of a nozzle provided with a gas lens for flat profile gas velocity control and which also produces an axially directed stream;

FIG. 7b is a similar view of a nozzle provided with a gas lens for parabolic profile gas velocity control, and which also produces an axially directed stream;

FIG. 7c is a similar view of a nozzle provided with a gas lens for parabolic profile gas velocity control and which also produces a diverging stream;

FIG. 8a is a fragmentary view mainly in cross-section of a torch provided with a flat gas lens;

FIG. 8b is a similar view of a torch provided with a parabolic gas lens;

FIG. 9 is a fragmentary view mainly in side elevation of a gas stream pattern from a parabolic gas lens;

FIG. 10a is a plan view (photograph) of a prior art weld;

FIG. 10b is a similar view of a weld made with a torch provided with a flat gas lens;

FIG. 10c is a similar view of a weld made with a torch provided with a parabolic gas lens; and

FIG. 11 is a fragmentary view partly in cross-section of a torch illustrating the invention.

In prior standard inert gas shielded arc welding torches, gas is supplied to the downstream conduit or nozzle through one or more gas ports. Such ports invariably have a total cross-sectional area considerably less than that of either the nozzle or the immediate downstream conduit. Laboratory experiments, however, have shown that a downstream conduit can exert a significant influence on the gas supplied to it only when it is filled with the moving gas stream. If the area of the gas ports is less than that of the downstream conduit, then the conduit will not be adequately filled with the moving gas stream for an appreciable distance beyond the gas ports.

Contrary to prior knowledge, we have found that for all practical purposes, gas exits from the gas ports at atmospheric pressure. From that point on, therefore, flow calculations should be made on the basis of incompressible, i.e., fully expanded, flow. For example, a static pressure of only 0.18 p.s.i. will produce a velocity of 125 ft. per second with argon, or 396 ft. per second with helium, for the case of isentropic flow through a nozzle. Starting at such a low pressure, the gas can expand by an amount equal to only 1.2 percent of its original volume. Thus, it can be seen that gas from a small area stream will not expand to fill a large area conduit. Instead, the gas velocity must be reduced by an appropriate amount to allow the gas to spread out. The observations to date, however, are that a moving gas stream has very little tendency to slow down, even when it meets a physical obstruction such as a conduit wall or baffle.

As shown in FIG. 1b, the HW-13 Linde torch 10 (made and sold by Union Carbide Corporation), is typical of most prior standard tungsten-inert-gas shielded arc welding torches in that the gas ports consist of four holes 12 of $\frac{3}{32}$ inch diameter which are drilled in a collet body 14. The illustrated torch is provided with a No. 10 ($\frac{5}{16}$ inch inside diameter) nozzle 16 and a $\frac{1}{8}$ inch diameter tungsten electrode 18. The total cross-sectional area of the gas ports 12 is 0.028 sq. in. At a flow (Q) of 10 c.f.h., N.T.P. (normal conditions of temperature and pressure—68 deg. F., 14.7 p.s.i.a.), the average velocity (V) of gas exiting from the gas ports is:

$$V = \frac{Q}{A} = \frac{10 \text{ cu. ft./hr.}}{0.028 \text{ sq. in.}} \times \frac{1 \text{ hour}}{3600 \text{ sec.}}$$

$$\times \frac{144 \text{ sq. in.}}{1 \text{ sq. ft.}} = \frac{10}{0.028} \text{ times}$$

$$4 \times 10^{-2} \text{ ft./sec.}$$

$$V = 14.2 \text{ ft./sec.}$$

However, the cross-sectional area of the downstream conduit 20 at a point just below the collet body 14 is 0.509 sq. in. At incompressible flow the average gas velocity at this downstream point for such area should be no more than 0.78 ft./sec. when the conduit is running full at 10 c.f.h. Thus, such use of such small gas port area causes the gas to enter the conduit 20 at a velocity which is 18.2 times higher than that required by the downstream area.

Studies by us of gas flow patterns inside and outside of conduits have shown that the general mechanism, and perhaps the only one, by which a small-area high-velocity stream is converted into a large-area low-velocity stream is by turbulent transition. The high kinetic energy of the small stream, $\frac{1}{2}MV_a^2$, must be reduced to the lower value of the large stream, $\frac{1}{2}MV_b^2$. The difference between these two terms represents excess kinetic energy, $\frac{1}{2}M(V_a^2 - V_b^2)$, which must be dissipated in some way.

Take as an example the above cited case wherein argon gas is fed through portholes 12 at an average velocity of 14.2 ft. per second into a nozzle 16 requiring an entering velocity of only 0.78 ft. per second. The excess kinetic energy per cu. ft. of argon is:

$$\text{K.E.} = \frac{1}{2} \times \frac{0.103 \text{ lbs.}}{32.2 \text{ ft./sec.}^2} \times [(14.2 \text{ ft./sec.})^2 - (0.78 \text{ ft./sec.})^2] = 0.32 \text{ ft. lb.}$$

This amounts to $(18.2)^2 = 330$ times the kinetic energy required in the downstream conduit. This surplus energy actually creates turbulence which then must be dissipated by friction within the gas itself and between the gas and conduit wall surfaces. Generally, a distance of between 1 and 8 inches of conduit length is required merely for dissipation of such surplus energy, even when a baffle is employed.

From these observations we deduce that coherent-streaming cannot be produced by a conduit until most of the excessive kinetic energy has been eliminated and the conduit becomes filled with the moving gas stream. When such preliminary conditions are obtained at or near the point of entry into the gas conduit, there exists a state of gas flow which is favorable to the development of a coherent stream. The length of nozzle required to produce coherent-streaming is largely determined by the amount of excess kinetic energy which must be dissipated.

A series of modifications was made in which additional gas ports of the same diameter were drilled in the collet body in order to reduce the entering gas velocity. Another approach was to insert a gas-permeable barrier (porous plastic) 22, FIG. 1a, in torch 24 in a gas-tight sealing mount comprising a ceramic collar 25 and rubber gaskets 26 and 27 disposed at the ends thereof. For this latter modification, the point of gas entry into the nozzle 16 is the downstream face of the permeable barrier 22.

Gas stream flow patterns obtained with the so modified torches were compared with that of the prior standard torch. The flow patterns were made visible by first adding oil vapor to the gas and by passing the exiting gas stream through a strong beam of light, which is a great improvement over use of the results obtained with Schlierin apparatus. For each torch system, measurements were made of the coherent-streaming distance; that is, the distance through which the gas could be projected as a "solid" stream into space without mixing with the air.

Table 1 shows the data obtained during such tests with an argon flow rate of 20 c.f.h. through an HW-13 torch fitted with a No. 10 nozzle and a $\frac{1}{8}$ inch diameter electrode.

TABLE 1

Effect of Reduced Gas Velocity Upon Entering a Nozzle

Gas Supply System		Area or Velocity Ratio ¹	Coherent-Streaming Distance, ² in.
Type	Area, sq. in.		
Drilled holes:			
Standard, 4 holes.....	0.028	18.2	1/2
Modified, 8 holes.....	0.056	9.1	5/8
Modified, 16 holes.....	0.112	4.5	3/4
Permeable Barrier.....	3 0.155	3.2	3

¹ Based on a conduit cross-sectional area of 0.509 sq. in. at a point just below the collet body.

² Obtained with 20 c.f.h. argon through a No. 10 nozzle.

³ Assuming that the unobstructed downstream face area of barrier (0.444 sq. in.) to contain 35% open area.

It can be seen from Table 1 that with each reduction in entering gas velocity, the coherent-streaming distance is significantly increased. Whereas the standard 4-hole construction (18.2 area or velocity ratio) yielded a coherent-streaming distance of only 1/2 inch, the 16-hole construction (4.5 ratio) produced a distance of 3/4 inch, one and a half times that of the standard prior torch. With the permeable barrier (3.2 ratio), a distance of 3 inches was obtained, six times that of the standard torch. From the trend shown in such table, it appears that significant increases in the coherent-streaming are obtained when the entering gas-velocity ratio was reduced to 5 or less. The increases were phenomenal, however, when the permeable barrier was used. It would appear then that in addition to providing the reduced entering velocity into the nozzle, the permeable barrier also exerted some additional control over the gas to promote coherent-streaming.

FIGS. 2a and 2b are line drawings based on actual photographs of typical old and new gas flow patterns at approximately full scale. Note that the coherent-streaming flow pattern 26 of gas leaving torch 24, FIG. 2b, is considerably longer than that 29 leaving torch 10, FIG. 2a.

Additional measurements of the coherent-streaming distance for various standard and modified torch systems were made with argon flows ranging from 10 to 60 c.f.h. The results of such tests are shown in the characteristic curves of FIG. 3. From such curves, it is evident that the superior systems remain so throughout the full range of flows, although the coherent-streaming distances for all systems become less for increased flow rates. Similar improvements in coherent-streaming occurs when gases other than argon are employed, such as He, N₂, O₂, and CO₂. Thus, the techniques for producing extended coherent-streaming are applicable to any gas. Because of the greater convenience in making tests, the torches and hence the gas streamers were placed in the horizontal position. The drooping which occurs at the low flow end of the permeable barrier curve is caused by gravity and slight drafts acting on the greatly extended coherent-stream at low velocity. In general, flow rates adequate to produce gas velocities greater than 1 ft./sec. are required to get sufficient stiffness in the gas stream to overcome gravity and draft effects for streaming distances greater than 1 inch.

Non-consumable electrodes, inert-gas shielded arc welding tests were made with the various torch systems. Bead-on-plate welds were made on 1/16 inch thick cold rolled steel at 150 amperes DCSP, 10 volts, 25 i.m.p., and with a flow of 25 c.f.h. of argon. FIGS. 4a, 4b and 4c are photographs at approximately 2× magnification of two sets of welds. The first set of welds, FIGS. 4a-4c, was made with the torch nozzle elevated 5/8 inch above the surface of the weldment. The second set, FIGS. 4d and 4e, was made with the torch nozzle elevated 7/8 inch above the work surface. The degree of

weld shielding obtained in each case can be ascertained by the extent of bright, undischolor surface at the end of the weld. At such point, the torch was stopped and weld current shut off, but argon flow was maintained as the welds were allowed to cool.

It can be seen that at a nozzle-to-work distance of 5/8 inch, the prior standard torch yielded very little weld protection, FIG. 4a. In this case the shielding was dependent almost entirely on the gas pumping action of the arc. When the nozzle was elevated an additional 1/8 inch, air was in contact with the electrode tip and arc pumped into the weld to produce rough surfaced, badly contaminated welds. The 16-hole system produced good shielding at 5/8 inch elevation, FIG. 4b, while the torch with the permeable barrier yielded excellent protection over a broad area which includes the weld puddle and a large portion of the heat affected zone, FIG. 4c.

When the nozzle elevation was increased to 7/8 inch, the 16-hole system was beyond its limit, FIG. 4d, whereas the permeable barrier continued to produce good shielding, FIG. 4c. This latter system produced excellent shielding at distances in excess of 1 1/4 inch, but arc stability became a problem due to excessive extension of the electrode. This difficulty can be eliminated by extending the collet body to provide electrode cooling closer to the arc end of the electrode.

FIG. 5a shows the weld shielding span distance S, and FIG. 5b shows a graph of the weld shielding span versus nozzle-to-work elevation obtained under these test conditions. It can be seen that the reduction of gas velocities upon entering a short nozzle leads to two important process improvements:

(1) Greatly increased nozzle-to-work elevation at which good weld shielding can be obtained.

(2) Significantly increased weld shielding span for all nozzle-to-work elevations.

One important by-product of the use of enlarged gas port areas is the elimination of the "jetting" problem. In standard HW-13 torches, an annular clearance hole of 0.130 inch diameter is provided in the collet body through which all electrodes of 1/8 inch and smaller diameters are inserted. With 3/32 inch or smaller diameter electrodes, gas jets at high velocity through the annular clearance, resulting in serious impairment and frequently the complete destruction of weld shielding. During our tests we found that the use of the 16-hole system unexpectedly eliminated the jetting problem, regardless of the size of the electrode employed. The increased area of the gas ports provided a path of least resistance, such that little or no gas emerged through the clearance hole.

In contrast, when permeable barriers were placed in the torch, the gas path through the barrier was generally one of relatively high resistance. As a consequence, the problem of gas jetting increased. Also, jetting could occur at any point where the gas leaked past the barrier. We found that to successfully employ permeable barriers, it is necessary to mount them in a leak-tight seal, FIG. 1a, to reduce electrode clearance and to ensure that there are no cracks or relatively large voids in the barrier material through which jetting might occur. In Sigma welding with the permeable barrier mounted in HW-13 torch, it was also necessary to prevent gas jetting through the wire contact tip. This was accomplished by inserting the wire liner into a seat in the guide tube tip to act as a gas seal. In retrospect, perhaps one of the main reasons why earlier tests with permeable barriers were not particularly successful was that the jetting problem was not recognized.

A wide variety of tests was made by us during which the patterns of gases exiting from the surfaces of permeable barriers were examined. These tests were originally made to determine the degree to which the turbulence in a gas stream could be reduced prior to discharging the gas into a nozzle. Included in these tests were filter materials of high density and ultra-fine porosity such

that they normally would not be considered for use in an arc welding torch as they were considered to be insufficiently permeable and too restrictive to the flow of gas. These materials were carefully mounted in a test device in a tight sealing arrangement in order to evaluate the materials' performance without interference on account of jetting. Unexpectedly, we found that it was possible to obtain a degree of gas flow control far beyond the mere moderation of turbulence. It was also possible to effect complete control over the flow pattern of gas exiting from a special class of permeable barrier, regardless of the degree of turbulence in the gas as supplied to the barrier. Coherent-streaming through very long distances could be obtained with the permeable barrier alone, thus eliminating the need for any downstream conduit.

We also found that if the permeable barrier were properly constructed, then gas exited from the barrier in a direction which is perpendicular to the barrier's local surface. This phenomenon is independent of the direction or condition at which the gas flowed into the barrier. FIGS. 6a, 6b, and 6c show means for controlling the directions of gas streams with various shapes of permeable barriers. FIGS. 6a and 6b show gas streams 30 and 32-34 obtained with a cylindrical plug or lens 36 made of densely packed felt fiber. When mounted flush with the end of the gas supply conduit 31, an axial stream is obtained. When the plug is partially extended, both axial and radial gas streams 32 and 34, respectively, are simultaneously obtained. Finally, as shown in FIG. 6c, a convex barrier or lens 38 made of felt produces a diverging stream 40. Surprisingly, this latter stream remains coherent for an appreciable distance beyond the external (discharge) surface of the barrier or lens.

The degree of directional control which a permeable barrier imposes on the gas is primarily related to the fineness of the voids rather than the thickness of the barrier. For example, it is possible to use a single layer of fine mesh wire filter cloth instead of a relatively thick section of densely packed fibers, or porous media made of metal ceramics or fritted glass. Thus far, tests have revealed such a trend. A 60-mesh copper wire cloth (0.010 in. square opening, 0.0075 in. diameter wire) exerted a slight direction control. A 200-mesh copper wire cloth (0.03 in. square opening, 0.002 in. diameter wire) exhibited a high degree of directional control. In general, the smaller the size of opening, the greater will be the directional control over the gas flowing through the permeable barrier. The flow control effects of such permeable barriers are additive in that multiple layers can be assembled, preferably spaced a short distance apart from each other, with the result that a greater degree of directional control can be obtained.

Thus, wire cloths with larger openings can be used if they are stacked in multiple layers. For example, three layers of 60-mesh wire cloth spaced $\frac{1}{8}$ in. apart yield results which are equivalent to a single layer of 200-mesh wire cloth. In the case of porous metal compacts, fibrous packings, etc., when thicknesses of $\frac{1}{16}$ in. and $\frac{1}{8}$ in. are used, the tests showed that mean pore dimensions of the order of 0.004 in. or less are still required for good results. The Kel-F plastic material used for the welding tests shown in Table 1 was $\frac{1}{16}$ in. thick with a mean pore diameter of 0.005 in.

A comparison between the performance obtained with fine mesh wire filter cloth, densely packed fibers, and sintered metal porous compacts gave further insight into the basic requirements for the control of coherent-streaming. We observed that the cloths yielded a uniform distribution in both the magnitude and direction of the gas velocity primarily because of their uniform pore size and close spacing of the pores. The fiber and porous metal barriers, however, often produced an irregular distribution in velocities unless particular care was taken during construction to insure a controlled distribution of gas permeability. At some points in these barriers, the packing

was too tight in relation to other points where the packing was too loose. The result was an irregular distribution of zones of low, medium, and high velocity flow which interfered with coherent-streaming. In some cases, the high velocity portions constituted jetting which disrupted the flow characteristics of the remaining portions of the gas stream. In other cases, there was such a great difference in the velocities as to result in a cluster of separate streams spaced from each other in a manner roughly analogous to the flow of water from a shower head or a garden sprinkler. Air penetrated between the separated streams to cause weld contamination.

In contrast, with a permeable barrier constructed to produce a smooth and continuous distribution of gas velocities, excellent coherent-streaming and hence, weld shielding, was obtained.

FIGS. 7a, 7b and 7c illustrate ways of controlling the distribution of gas velocities by varying the thickness and hence the gas permeability of the lenses. As shown in FIG. 7, a flat disk-shaped lens 42 in the outlet of a cylindrical gas chamber 44 produces a coherent-stream 46 of gas having essentially constant velocity throughout the cross-sectional area, as indicated by vectors 47. In FIG. 7b, lens 48 having a flat downstream face and a concave upstream face 49, produces a coherent-stream 50 having a parabolic distribution of velocities 51. Concave-convex lens 52, FIG. 7c, produces a divergent coherent-stream 53 having a parabolic distribution of velocities 54. Streams with a parabolic velocity profile are more stable, and produce longer coherent-streaming distances than streams with a flat velocity profile. Such streams will often be preferred to insure maximum control of atmospheric composition, particularly at points where the stream impinges on a solid surface.

When gas lenses are employed, coherent-streams can be produced regardless of the Reynolds numbers of L/De value which have frequently been used in the past as mathematical specifications for flow conditions. Our findings are that such numbers do not insure laminar or non-turbulent flow, but rather they indicate a possibility for laminar flow. In laboratory tests, it was possible to obtain coherent-streaming distances of 3 to 6 inches under conditions which would correspond to Reynolds numbers of the order of 5000 and L/De ratios equal to zero. At the present time, there are strong indications that coherent-streaming through appreciable distances can be obtained at Reynolds numbers at least up to 15,000 with the aid of gas lenses.

It must be noted, however, that the calculation of Reynolds numbers applies only to a gas stream cross-section within conduit walls. Hence, when permeable barriers or gas lenses are used without a downstream conduit, e.g., $L/De=0$, then Reynolds numbers do not apply.

From these tests it is apparent that the use of a special class of permeable barriers results in a degree of control over gas flow patterns far beyond that which could be obtained with conduits or nozzles. This special class consists of devices made from permeable materials which produce a relatively smooth and continuous distribution of gas velocities, in terms of both magnitude and direction, across the downstream surface of the permeable material even when gas is supplied to the barrier in a state of gross turbulence. Since these permeable barriers act on gas in much the same manner as a glass lens acts in shaping a beam of light, the analogous term "gas lens" has been applied to them by us.

FIG. 8a shows an arc torch comprising flat gas lens 56, and FIG. 8b shows an arc torch comprising a parabolic lens 58, each being of constant thickness. Gas streaming and weld shielding made with the flat lens 56 alone yield results that are comparable to those previously obtained when the lenses were mounted inside and upstream of the nozzle 16, FIG. 1a.

FIG. 9 is based upon a photograph of a diverging gas stream 59 obtained with the parabolic lens 58. Such lens

yields a phenomenal increase in the surface area of protection on body B.

FIGS. 10a, 10b, and 10c are photographs of welds made with three basic systems: (1) standard HW-13 and No. 10 nozzle, (2) modified HW-13 torch and No. 10 nozzle with flat gas lens, and (3) modified HW-13 torch with parabolic gas lens. Bead-on-plate welds were made on $\frac{1}{16}$ inch thick cold rolled steel with argon flow of 60 c.f.h. The welding conditions were 15 i.p.m., 130 amperes DCSP, and 10 volts. Very short nozzle-to-work distances were employed in order to obtain good weld shielding, FIG. 10a, even with the standard torch. The nozzle-to-work distance for the first two torch systems was $\frac{3}{8}$ inch. The vertex of the parabolic gas lens was positioned at $\frac{1}{2}$ inch above the work. It can be seen from these pictures that all systems yielded good shielding at such short elevations and at the high gas flow rate used. There is, however, a substantial difference in the extent of weld protection obtained with the different systems. The use of a nozzle with a flat gas lens produced a broader coverage, FIG. 10b, than that obtained with the prior standard nozzle alone. The parabolic gas lens, however, produces a substantially broader coverage, FIG. 10c, than ever obtained with any prior system of comparable size.

The maximum area of perfect shielding which can be obtained with a simple nozzle under the best conditions is only slightly larger than the area of the nozzle. The parabolic lens, however, was $1\frac{1}{8}$ inch in diameter at the torch junction, yet it produced an area of perfect shielding of 3 inches diameter. Thus, the area of perfect shielding obtained with the parabolic lens is approximately 8 times the lens area. The performance is similar to that of a leading-trailing shield, but with none of the usual restrictions on arc visibility, torch manipulation or accessibility to the weld joint. Such parabolic lens is, thus, of great value for the gas shielded arc welding of reactive metals such as titanium, molybdenum, etc.

The significance of such results is that entirely new shielding devices are now possible. Such devices produce both maximum quality of weld shielding and maximum flexibility of operator usage. They can be tailored to any system where a controlled streaming pattern of gas or gases is desired. For welding, the lens can be used with or in place of prior standard or multi-wall torch nozzles. They may also be used as auxiliary gas shielding devices with the same or different gases as are used in the torch.

As a result of the foregoing, we have discovered that:

(1) In the standard HW-13 torch, gas enters the nozzle at velocities approximately 18 times greater than the required nozzle velocity for a given flow rate.

(2) With the standard HW-13 torch, good weld shielding is obtained only when the nozzle-to-work distance is $\frac{1}{2}$ inch or less.

(3) Various methods for reducing the velocity of gas entering a nozzle can be successfully employed including the use of additional gas ports in the torch collet body and the use of a permeable barrier mounted inside the torch nozzle.

(4) Good weld shielding at nozzle-to-work distances of up to $\frac{3}{4}$ inch or less was obtained when the entering gas-velocity ratio was reduced to 4.5.

(5) Good weld shielding at nozzle-to-work distances of over $1\frac{1}{4}$ inches is obtained when the entering gas-velocity ratio is reduced to 3.2.

(6) Excellent weld shielding is also obtained when a permeable barrier is used alone as a nozzle.

(7) Permeable barriers when properly constructed as gas lenses can be used to control the magnitude, direction and distribution of gas velocities in the exiting gas stream.

(8) Complete control of gas flow patterns can be obtained with permeable barriers or gas lenses made of densely packed fibers, fine mesh wire filter cloths or porous compacts made of metal, ceramics or fritted glass when either the interstices or mean pore openings in

such materials were of the order of 0.010 inch or less.

(9) Coherent-streaming distances of the order of 3 to 6 inches can be obtained by the invention at flow conditions equivalent to Reynolds numbers of over 5000 and L/De ratios down to zero.

(10) Parabolic-shaped gas lens attached to an HW-13 torch produces a broad area of perfect shielding equal to eight times the lens area.

(11) With the parabolic lens used in place of or as a nozzle, there is essentially no interference with arc visibility and joint accessibility in contrast to that which must be tolerated when prior nozzles are used.

According to the invention apparatus for producing a favorable state of entering gas flow into a relatively short nozzle comprises barriers which have a multiplicity of very small pores, such pores having mean pore diameters of 0.020 inch or less as determined on the basis of the following calculation:

$$MPD = 4 \times \frac{A}{P}$$

where

A =average plane area of pores, inches.

P =average perimeter of pores, inches.

Such barriers can be made of any suitable material having a multiplicity of very small (tiny) openings, holes, pores, or interstices either randomly or uniformly spaced. The openings may be interconnected as in fiber or granular compacts or they may be not interconnected as in a thin plate with a multiplicity of drilled holes.

The permeable barriers also can be made from fibers, powders, granules, beads of material preferably able to withstand temperatures of 300 degrees F. or more, either metallic or nonmetallic, or from solids which have been perforated mechanically as by drilling or punching, or by chemical means as by etching.

Also contemplated by the invention are:

Permeable barriers in the form of a wall, layer, or membrane of either constant or smoothly varying thickness not to exceed $\frac{1}{4}$ inch and preferably less than $\frac{3}{32}$ inch;

Permeable barriers comprising one or more separate walls, layers or membranes and preferably spaced apart from each other a short distance of the order of at least five mean pore diameters of 0.020 inch;

Permeable barriers wherein the total equivalent cross-sectional area of said pores is equal to or greater than 20 percent of the total cross-sectional area of the permeable barriers;

Permeable barriers wherein the pores are closely spaced with respect to neighboring pores with an average center-line spacing of not more than 10 mean pore diameters or 0.040 inch maximum according to whichever is the smaller dimension with respect to the given pore size; and

Permeable barriers (gas lenses) having mean pore diameters of 0.010 inch or less.

As shown in the drawing, FIG. 11, gas lens 60 is attached to a holder (preferably non-permeable) 62 which is threaded onto the torch collet body 64 until tight contact is made with the gas seals 66, 68 to prevent jetting. Also, individual close fitting electrode collets 70 are provided for each size of electrode 72 to prevent jetting through the collet body—electrode clearance hole 74. Such lens embodies many of the best features of the invention and has curved surfaces 76 to provide a composite gas stream simultaneously having divergent, constant area and converging flow characteristics. The diverging portion of the stream provides maximum area of work surface shielding from a minimum size of gas lens. The constant area and converging portions of the gas stream provide maximum coherent-streaming distances.

Also shown in dotted outline for comparison on FIG. 11 are two relatively small standard nozzles (Linde) No.

8 (½ inch I.D.) and No. 5 (⅝ inch I.D.). Such nozzles would provide considerably smaller zones of workpiece shielding about the arc and must be used at relatively short nozzle-to-work distances. Despite the fact that they are relatively small nozzles, they still have considerable bulk which, in combination with their limited shielding performance, imposes interference with arc visibility and torch maneuverability, particularly when welding in confined spaces. In contrast, the gas lens 60 of the invention has substantially less bulk, and since it provides broad area shielding and permits welding at relatively long lens-to-work distances, it eliminates such prior standard nozzle limitations.

The invention is not restricted to electric arc welding with a non-consumable or refractory electrode, but is equally applicable to sigma welding in which a consumable wire electrode is used, as well as other kinds of operations in which gas protection from the atmosphere is involved.

What is claimed is:

1. Process in which work is shielded from ambient air with a stream of gas flowing in the form of a beam, which comprises dividing a flow composed of such gas into a multiplicity of separate paths, the gas of which upon discharge merges substantially without turbulence, fully expanded, to create such beam, such paths being characterized by very small cross sectional areas and close spacing with respect to neighboring paths, resulting in coherent streaming of such gas the length of such beam prior to discharge into space being less than 3 inches by virtue of the merger substantially without turbulence of such separate paths in the creation of such beam, and applying the so discharged beam of gas against the surface of said work, to thereby obtain maximum effective shielding of such work with such gas.

2. Process of arc working with an electrode, the arc-end of which is shielded with a stream of gas flowing in the form of a column surrounding such electrode, which comprises dividing such stream into a multiplicity of separate paths, the gas flowing through which upon discharge merges without turbulence, fully expanded, to create such column, such paths being characterized by small cross sectional areas and close spacing with respect to neighboring paths, said separate paths resulting in coherent-streaming of such gas in free space around the end of such electrode, the length of such column prior to the discharge into free space being less than 20 times the equivalent diameter of such column by virtue of the merger without turbulence of such separate paths in the creation of such column.

3. Process of welding with an elongated consumable wire electrode, the arc-end of which is shielded with a stream of gas flowing in the form of a column surrounding such electrode, which comprises dividing such stream into a multiplicity of separate paths the gas through which upon discharge merges without turbulence, fully expanded, to create such column, said paths being characterized by small cross sectional area and close spacing with respect to neighboring paths, resulting in coherent-streaming of such gas in free space around the end of such electrode, the length of such column prior to discharge into free space being less than 5 times the equivalent diameter of such column by virtue of the merger without turbulence of such separate paths in the creation of such column.

4. Gas stream-shielded arc working in which the arc is energized between an electrode and a workpiece, which comprises shielding the end of such electrode and the arc and the adjacent metal being welded with a stream of arc shielding gas flowing in a direction parallel to the longitudinal axis of such electrode, characterized in that such stream is divided into a multiplicity of separate paths immediately (less than 3 inches) prior to the discharge thereof into free space around such electrode to thereby provide coherent-streaming of the so-discharged fully expanded gas in a direction that is controlled for a sub-

stantial distance therefrom, effectively shielding the operation from the air.

5. Gas stream shielded arc working in which the arc is energized between an electrode and a workpiece, which comprises shielding the end of such electrode and the arc and the adjacent metal being welded with a diverging stream of arc shielding gas, characterized in that such stream is divided into a multiplicity of separate paths immediately (less than 3 inches) prior to the discharge thereof into free space around such electrode to thereby provide coherent-streaming of the so-discharged, fully expanded gas effectively shielding the operation from air.

6. Gas stream shielded arc working in which the arc is energized between an electrode and a workpiece, which comprises shielding the end of such electrode and the arc and the adjacent metal being welded with a converging stream of arc shielding gas, characterized in that such stream is divided into a multiplicity of separate paths immediately (less than 3 inches) prior to the discharge thereof into free space around such electrode to thereby provide coherent-streaming of the so-discharged fully expanded gas, effectively shielding the operation from air.

7. Gas stream shielded arc working in which the arc is energized between an electrode and a workpiece, which comprises shielding the end of such electrode and the arc and the adjacent metal being welded with a composite stream of arc shielding gas, which simultaneously includes divergent, constant area and convergent flow characteristics in such composite stream characterized in that such stream is divided into a multiplicity of separate paths immediately (less than 3 inches) prior to the discharge thereof into free space around such electrode to thereby provide coherent-streaming of the so-discharged fully expanded gas, effectively shielding the operation from air.

8. Gas stream shielded arc working in which the arc is energized between an electrode and a workpiece, which comprises shielding the end of such electrode and the arc and the adjacent metal being welded with a stream of arc shielding gas with a constant velocity throughout the stream cross section, characterized in that such stream is divided into a multiplicity of paths of equal gas permeability immediately (less than 3 inches) prior to the discharge thereof into free space around such electrode to thereby provide coherent-streaming of the so-discharged fully expanded gas in a direction that is controlled for a substantial distance therefrom, effectively shielding the operation from air.

9. Gas stream shielded arc working in which the arc is energized between an electrode and a workpiece, which comprises shielding the end of such electrode and the arc and the adjacent metal being welded with a stream of arc shielding gas with a parabolic distribution of gas velocity in the stream cross section, characterized in that such stream is divided into a multiplicity of paths of suitably varying gas permeability immediately (less than 3 inches) prior to discharge thereof into free space around such electrode to thereby provide coherent-streaming of the so-discharged fully expanded gas in a direction that is controlled for a substantial distance therefrom, effectively shielding the operation from air.

10. Gas stream shielded arc working in which the arc is energized between an electrode and a workpiece, which comprises shielding the end of such electrode and the arc and the adjacent metal being welded with a composite stream of arc shielding gas which simultaneously includes divergent, constant area and convergent flow characteristics in such composite stream, said composite stream having a constant velocity throughout the stream cross section, characterized in that such stream is divided into a multiplicity of paths having equal gas permeability immediately (less than 3 inches) prior to the discharge thereof into free space around such electrode to thereby provide coherent-streaming of the so-discharged fully expanded gas, effectively shielding the operation from air.

11. Gas stream shielded arc working in which the arc

13

is energized between an electrode and a workpiece, which comprises shielding the end of such electrode and the arc and the adjacent metal being welded with a composite stream of arc shielding gas which simultaneously includes divergent, constant area and convergent flow characteristics in such composite stream, said composite stream having a parabolic distribution of gas velocity in the stream cross section, characterized in that such stream is divided into a multiplicity of paths having suitably varying gas permeability immediately (less than 3 inches) prior to the discharge thereof into free space around such electrode to thereby provide coherent-streaming of the so-discharged fully expanded gas, effectively shielding the operation from air.

12. A gas-shielded arc torch comprising an elongated electrode, an electrical contact for said electrode, means supporting said contact, said means having an annular chamber and arc shielding gas passages for delivering arc shielding gas to such chamber, and a gas lens surrounding said electrode and constituting a wall of such chamber, for fully expanding and directing such gas around said electrode in the direction of the arc end thereof.

13. A gas-shielded arc torch as defined by claim 12, in which said gas lens is shaped so that gas components are directed thereby to converge toward said electrode flow parallel to the axis thereof, and diverge away from said electrode.

14. A gas-shielded arc torch as defined by claim 12, provided with means for preventing jetting of such gas adjacent said electrode.

15. A gas-shielded arc torch comprising an electrical contact member including a collet body provided with radial gas ports, an elongated electrode mounted in such collet body, and a gas cup surrounding such gas ports in spaced relation for receiving gas therefrom and discharging such gas around the arc end portion of said electrode, characterized in that said ports are sufficient in size and number to substantially reduce resistance to the flow of such gas therethrough compared with flow through other paths including undesirable jetting paths adjacent said electrode, and deliver the gas to said cup in a favorable state, the combined area of said ports being equal at least to 20% of the nozzle total exit area whereby the velocity of the gas discharged from such ports is effectively reduced to moderate turbulence.

16. A gas-shielded arc torch comprising an electrical contact member including a collet body provided with radial gas ports, an elongated electrode mounted in such collet body, and a gas cup surrounding such gas ports, in spaced relation for receiving gas therefrom and discharging such gas around the arc end portion of said electrode, characterized in that a gas permeable barrier is mounted within said gas cup around said electrode for transforming gas delivered thereto by such ports into a favorable state upon discharge therefrom, and means sealing the spaces between said ports against gas leakage including undesirable gas jetting adjacent said electrode.

17. A gas-shielded arc torch comprising an electrical contact member including a collet body provided with radial gas ports, an elongated electrode mounted in such collet body, and a gas cup surrounding such gas ports in spaced relation for receiving gas therefrom and discharging such gas around the arc end portion of said electrode, characterized in that a gas lens is mounted in the outlet of said cup around said electrode, and means sealing the spaces between said ports against gas leakage including undesirable gas jetting adjacent said electrode.

18. Method of projecting a gaseous atmosphere of controlled purity and composition in ambient atmosphere through a predetermined distance in the form of a coherent gas stream in the sense that such stream retains a desired form, purity and composition without mixing with the ambient atmosphere other than by non-turbulent aspiration, for the purpose of establishing a controlled

14

atmosphere throughout a zone remotely located with respect to the point of discharge, the controlled flow-pattern of such gas stream being characterized by a smooth and continuous, though not necessarily uniform, distribution of velocities as represented by vectors which represent both the magnitudes and the directions of gas velocities throughout the stream cross-sections when a macroscopic rather than a microscopic scale is used, such characteristic distribution of gas velocities being applicable throughout all points in the stream cross-section starting at least at that section where the stream exits from the projecting device and including all subsequent stream cross-sections up to and including a distance of at least 1 in. from such discharge point, wherein the stream is projected into free space and away from any drafts and physical obstructions which would distort a test flow pattern of the gas stream, such qualifying test assuring the formation of an extremely high degree of atmosphere control over any zone which falls within the boundaries of the gas stream and up to a distance of at least 1 in. from such point of discharge, which method comprises dividing such gas, prior to discharge into free space, into a multiplicity of separate minute paths of close spacing with respect to neighboring paths, the gas of which, upon discharge, merges without turbulence, fully expanded, to create such streams, the mean pore diameter of said paths being less than 0.020 inch with a mean pore spacing of 0.040 inch maximum.

19. Method employing relatively short gas conduits for projecting a gas stream therefrom into free space with controlled flow patterns in which gas is supplied to the conduit in a favorable state characterized by a velocity which is not more than five times greater than the downstream conduit velocity, and preferably less than three times the downstream conduit velocity, calculated on the basis of incompressible flow at 68 deg. F. and 14.7 p.s.i. abs. with the conduit running full so that there are no stagnant zones throughout the cross-section of the conduit, which comprises feeding such gas into a relatively short (less than 3 inches long) conduit through a multiplicity of separate paths the combined total effective area of which produce in the gas discharged from such path such favorable state in such conduit, and maintaining effective successive, downstream, cross-sectional areas of gas within such conduit no greater than that of the upstream areas thereof.

20. Apparatus for producing a favorable state of entering gas flow in a nozzle, comprising a permeable barrier wherein the total equivalent cross-sectional area of the pores in said permeable barrier is equal to or greater than 20 percent of the cross-sectional area of the permeable barrier through which gas enters to be discharged therefrom at a favorable state with reference to the downstream side thereof in such nozzle.

21. Apparatus for projecting coherent streams of gas from a relatively short conduit at Reynolds numbers

$$\left(Re = \frac{r}{u} V D e \right)$$

up to 15,000 in which gas enters the conduit in a favorable state and at a velocity no more than five times the required downstream velocity, which comprises a gas permeable barrier wherein the total equivalent cross-sectional area of the pores in said permeable barrier is equal to or greater than 20 percent of the cross-sectional area of the permeable barrier located in said conduit.

22. Apparatus for producing favorable states of entering gas flow into a relatively short nozzle, comprising a permeable barrier wherein the total equivalent cross-sectional area of the pores in said permeable barrier is equal to or greater than 20 percent of the total cross-sectional area of the permeable barrier which has a multiplicity of very small pores, such pores having mean pore

15

diameters of 0.020 in., or less as determined on the basis of the following calculation:

$$MPD = 4 \times \frac{A}{P}$$

where

A = average plane area of pores

P = average perimeter of pores

23. Apparatus for projecting a coherent stream of gas comprising the combination of a gas supply system, a gas-flow pattern forming nozzle connected to the extreme end of said gas supply system and a permeable barrier mounted in said nozzle, said nozzle having a smooth internal wall surface, and an L/De ratio of from $\frac{1}{2}$ to 20 with the cross-sectional area not increasing as the stream proceeds through and out of said nozzle.

24. Apparatus for projecting a coherent stream of gas comprising the combination of a gas supply system, a gas-flow pattern forming conduit located at the extreme end of the gas supply system, a gas lens associated with such conduit, said conduit having a smooth internal wall surface with an L/De ratio of from 0 to 20, said internal wall surface being non-divergent in the direction of flow of such gas stream.

25. Apparatus for projecting coherent streams of gas consisting of a combination of a gas supply system, a gas-flow pattern forming nozzle with a permeable barrier comprising a gas lens which is mounted in said nozzle or at the extreme end of said gas supply system, the downstream surface of said gas lens having a convex face such that a diverging gas stream is discharged thereby.

26. Apparatus for projecting a coherent stream of gas consisting of a combination of a gas supply system, and a gas lens located at the outlet end of such system which discharges a coherent stream of such gas therefrom, said gas lens having main pore diameters of 0.010 in. or less and also having a total equivalent cross-sectional area of the pores equal to or greater than 20 percent of the total cross-sectional area of the gas lens.

27. Apparatus comprising a gas lens for projecting a controlled flow pattern of gas characterized by a relatively smooth and continuous (though not necessarily uniform) distribution of velocity in terms of magnitude and direction across a downstream cross-section located approximately $\frac{1}{4}$ in. from the outside surface of said gas lens and throughout all subsequent cross sections further downstream for a distance of at least 1 inch from said lens.

28. Shaped permeable barriers comprising a gas lens for projecting a coherent gas stream in a controlled flow pattern of gas therefrom depending upon the shape of said lens, said gas lens having minimum pore diameters of 0.010 in. or less and also having a total equivalent cross-sectional area of the pores equal to or greater than 20 percent of the total cross-sectional area of the gas lens.

29. Apparatus comprising a gas chamber having a wall provided with a permeable barrier composed of ma-

16

terial containing a multiplicity of holes having minimum pore diameters of less than 0.020 in. and said holes occupying a total equivalent cross-sectional area equal to or greater than 20 percent of the total cross-sectional area of the permeable barrier so that such permeable barrier projects a coherent-stream of nitrogen gas of $\frac{1}{2}$ in. diameter through quiescent air for a distance of at least $\frac{1}{2}$ in. at a flow rate of 15 c.f.h. nitrogen, and means for supplying gas to such chamber.

30. An arc torch comprising an electrode, a gas cup surrounding said electrode in spaced relation, means for supporting said cup and electrode in spaced relation with each other, means for feeding gas to the space between said cup and electrode, and a gas lens comprising a gas permeable barrier mounted at the outlet of such space for discharging such gas as a coherent stream therefrom to shield the arc-end of said electrode from the surrounding air.

31. The combination with an arc torch as defined by claim 30, of electric arc power supply means connected to said electrode and to a workpiece which also is shielded by such coherent gas stream in the area of an arc energized between the end of said electrode and such workpiece by said electric arc power supply means.

32. Apparatus for discharging a coherent stream of gas to shield from the air an arc energized between two electrodes which comprises a gas chamber surrounding one of said electrodes, and means for supplying gas thereto, the outlet of such chamber being provided with a gas permeable barrier comprising a lens through which gas flows from such chamber, said lens acting to transform said flow into a coherent stream of gas around such arc, the external flow pattern of such stream being determined by the shape of said lens.

33. Apparatus as defined by claim 32, including means for feeding one of said electrodes through said chamber and lens toward such arc as such electrode is consumed thereby.

34. In a process for electric arc working materials wherein an arc is established between two electrodes and the arc effluent is applied against the material to be worked and wherein both the arc effluent and the zone of the material being treated is shielded with a stream of flowing gas the improvement which comprises dividing said flowing gas stream into a multiplicity of separate paths, such paths being characterized by having minimum pore diameters of 0.020 in. or less and close spacing with respect to neighboring paths resulting in coherent streaming of such gas, the length of such gas stream prior to discharge into space being less than 3 in. by virtue of the merger substantially without turbulence of such separate paths in the creation of such stream.

References Cited in the file of this patent

UNITED STATES PATENTS

1,669,362	Watson	May 8, 1928
2,544,711	Mickhalapov	Mar. 13, 1951
2,977,457	Houlderott et al.	Mar. 28, 1961

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,053,968

September 11, 1962

Eugene F. Gorman et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 59, for "of" read -- or --; column 2, line 39, for "through" read -- throughout --; column 4, line 58, for "17" read -- 27 --; column 5, line 56, for "streamers" read -- streams --; column 8, line 36, for "of", second occurrence, read -- or --.

Signed and sealed this 15th day of January 1963.

SEAL)
test:

NEST W. SWIDER
Testing Officer

DAVID L. LADD
Commissioner of Patents

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,053,968

September 11, 1962

Eugene F. Gorman et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 59, for "of" read -- or --; column 2, line 39, for "through" read -- throughout --; column 4, line 58, for "17" read -- 27 --; column 5, line 56, for "streamers" read -- streams --; column 8, line 36, for "of", second occurrence, read -- or --.

Signed and sealed this 15th day of January 1963.

SEAL)
test:

NEST W. SWIDER
Testing Officer

DAVID L. LADD
Commissioner of Patents