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Continuation-in-part of application Ser. No. 652,384, June 12, 1967, now abandoned, which is a continuation-in-part of application Ser. No. 461,874, June 7, 1965, now abandoned.

[54] ARC RADIATION SOURCES

4 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** ..... **315/111,** 219/121 P, 313/231
[51] **Int. Cl.** **H01j 7/24**
[50] **Field of Search** ..... 313/184, 231; 315/111; 219/121 P

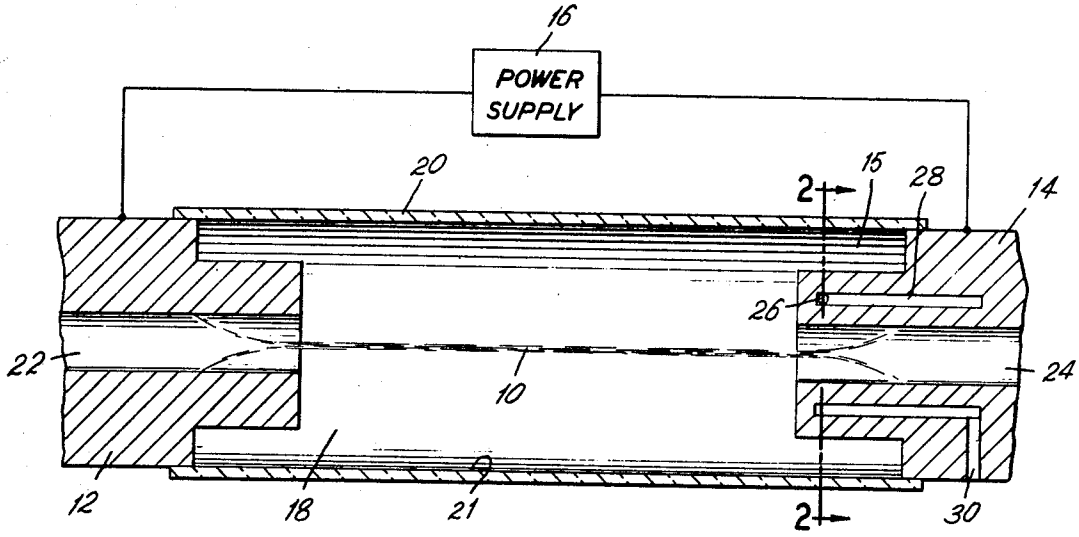
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ABSTRACT: A high pressure arc radiation torch provided with spaced tubular electrodes having axially aligned gas exit passages; an envelope of transparent material surrounding said electrodes in concentric relation and providing a pressurized gas chamber; one of said tubular electrodes extending into said chamber to form a relatively thin annular region substantially cylindrical in cross section between the outer surface of said tubular electrode and the inner surface of said chamber, and means for feeding gas into said annular region under conditions to provide strong swirl within the chamber resulting in a highly constricted arc column of substantial length.



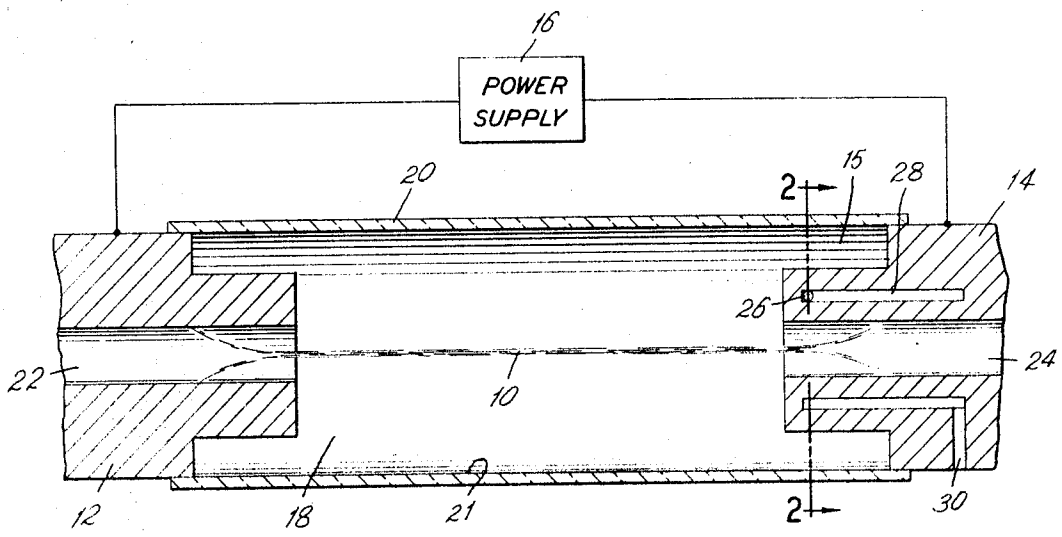


Fig. 1.

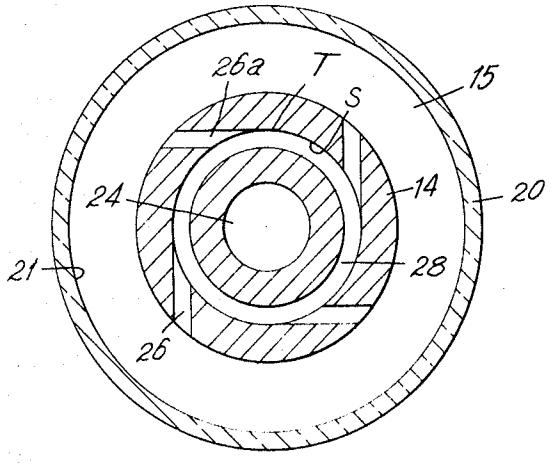


Fig. 2.

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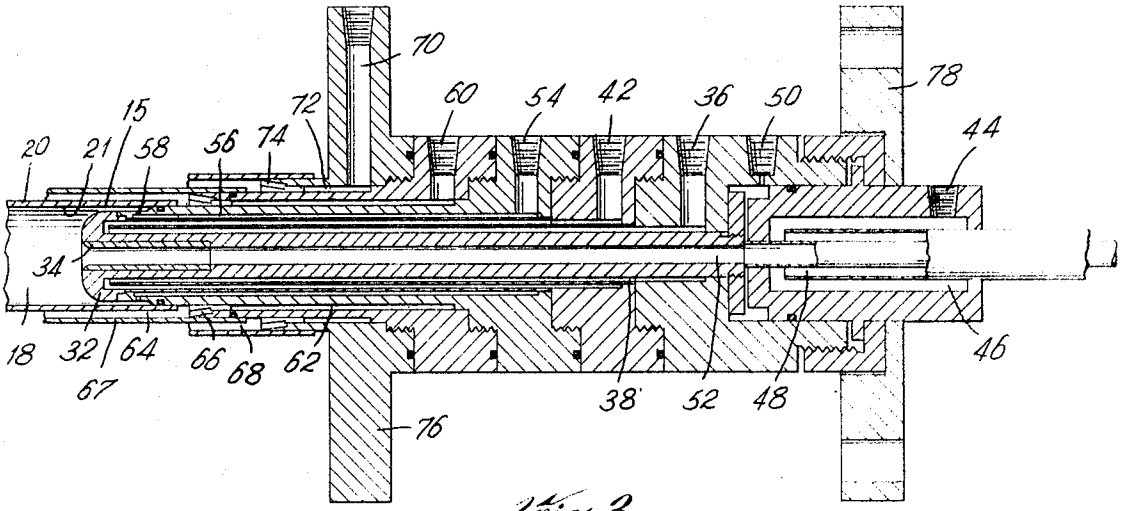


Fig. 3.

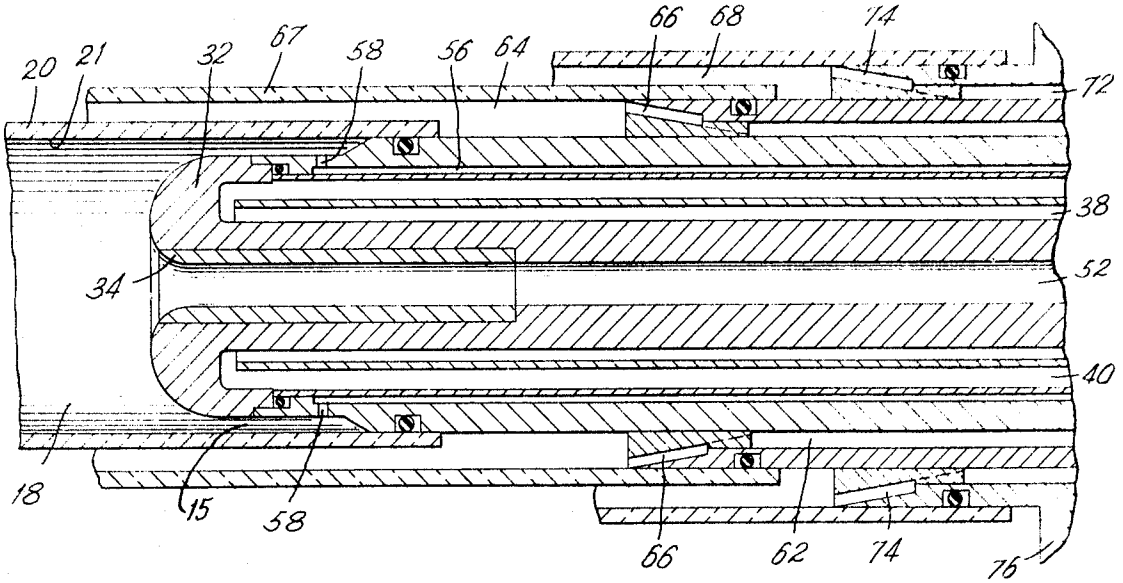


Fig. 3a.

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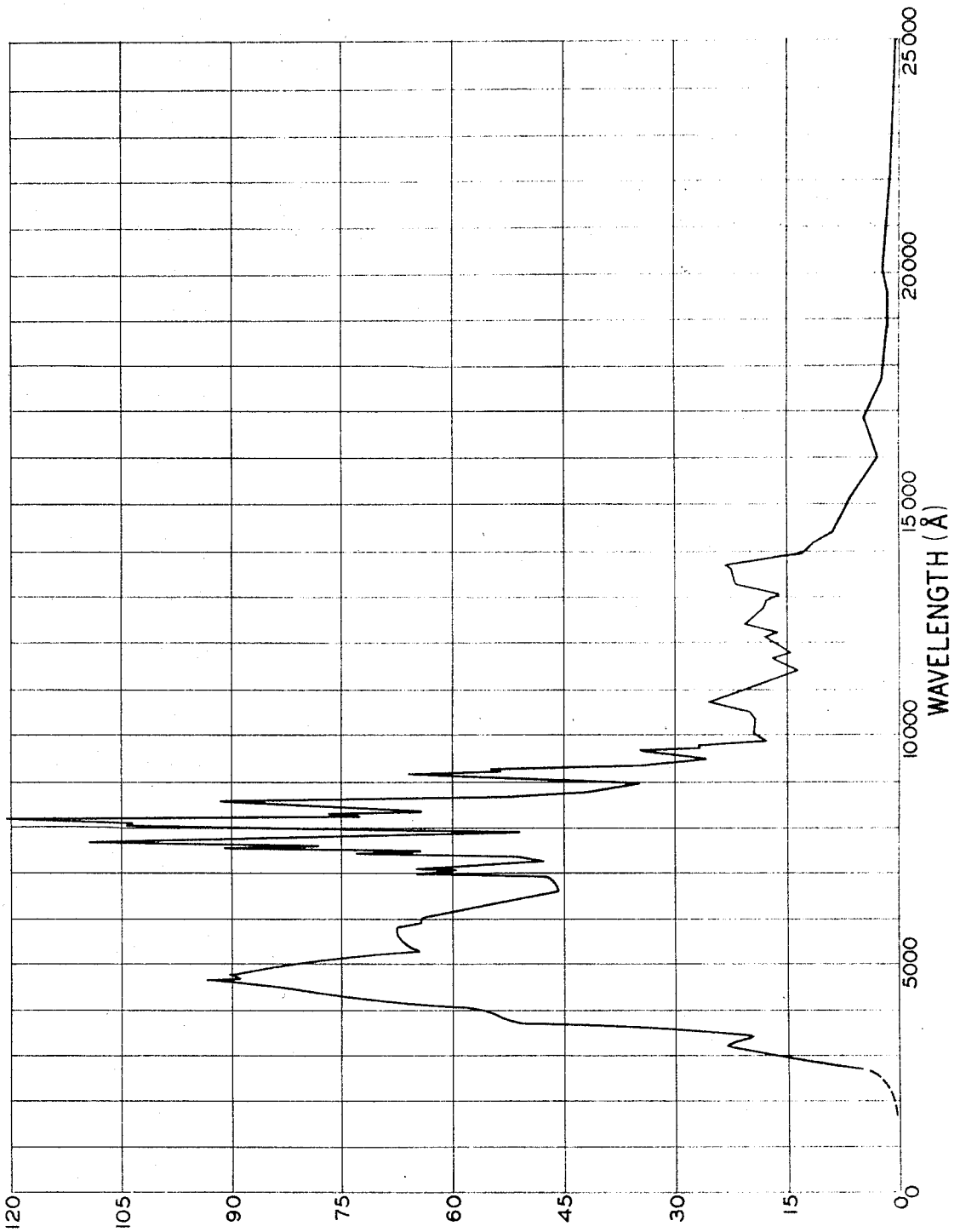


Fig. 4.

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ARC RADIATION SOURCES

This application is a continuation-in-part of U.S. application Ser. No. 652,384 filed June 12, 1967 now abandoned, which is a continuation-in-part of U.S. application Ser. No. 461,874 filed June 7, 1965, now abandoned.

This invention relates to arc radiation sources, and more particularly to torches for radiating heat and/or light.

The invention provides a concentrated arc radiation source confined within a cooled, transparent envelope. The invention provides a high pressure arc radiation apparatus comprising spaced tubular electrodes having axially aligned gas exit passages; an envelope of transparent material surrounding said electrodes in concentric relation and providing a pressurized gas chamber; at least one of said electrodes extending into said chamber to form a thin annular region between the outer surface of said extended electrode and the inner surface of said chamber; and means for feeding gas into said annular region such that the gas travels axially into the chamber along the inner face of said envelope cooling the latter.

The gas should be injected into the chamber to create a strong swirling gas flow within the chamber. A strong swirl flow may be accomplished by feeding the gas into the chamber, under pressure, such that the following mathematical relationship is satisfied:

$$M_i x \frac{Dc}{Dq} x \left|\frac{V_p}{V_T}\right| \geq .25$$

wherein:

M_i = inlet Mach number (velocity of the gas entering the chamber divided by the velocity of sound at the operating temperature and pressure at the inlet),

D_c = 2 X shortest distance between the line of axis of the inlet holes and the axis of the chamber,

D_q = inside diameter of the envelop surrounding the electrodes,

$|V_T|$ = magnitude of the velocity of the gas emanating from the chamber inlet, and

$|V_p|$ = magnitude of the component of V_T perpendicular to the axis of the chamber.

In the drawings:

FIG. 1 is a view mainly in longitudinal-vertical section of a torch illustrative of the invention;

FIG. 2 is an enlarged transverse section taken on line 2–2 of FIG. 1;

FIG. 3 is an enlarged fragmentary view similar to FIG. 1, of an end portion of a working example of the torch; and

FIG. 3*a* is a similar but more enlarged view of such end portion.

FIG. 4 is a graph of typical wavelength/intensity conditions of operation of the radiation source of FIG. 3.

Referring to FIGS. 1 and 2, the concentration of the arc is effected and the arc is maintained within the exit passages of the tubular electrodes by maintained within the exit passages of the tubular electrodes by maintaining the product of the ratio of cross-sectional area of the pressure chamber to the total cross-sectional area of the exit passages multiplied by the ratio of the arc length to the inside diameter of the transparent envelope in the range between 25 and 200.

The use of the spaced tubular electrodes at each end of the chamber causes any contaminants (primarily electrode erosion) to be swept out the exit passages of the electrodes. This is advantageous over the use of a stick electrode in lieu of one of the tubular electrodes because there will be a tendency for such contaminants to accumulate at the end of the chamber having the stick electrode. In addition to using the spaced tubular electrodes, it is preferred to inject the gas into the pressure chamber from one end only. If the gas is injected into the chamber from both ends, contamination of the transparent envelope tends to occur at or near an area between the electrodes. Moreover, it is highly preferred to initially inject the gas into an annular ring formed between one of the electrodes' outer surface and the arc chamber inner surface as shown in

FIGS. 1—3*a*. By injecting the swirl gas such that it enters initially into the annular or ringlike space, it is believed that the swirling gas is given a significant axial velocity component which even for a low gas flow will extend for a substantial distance into the main arc chamber allowing a long arc column to be established. Arc lengths up to 7 inches long have been formed using this technique. The swirling gas moves axially along the inner wall of the arc chamber somewhat in the form of a sheath having a thickness comparable to that of the annular cylindrical ring thereby providing a substantial cooling effect.

The invention contemplates injecting gas into such apparatus the combination of which will yield an arc radiation source wherein the arc has a current density of greater than 1000 amp/cm.^{2}, the arc itself being completely contained within the apparatus, and wherein the walls of the transparent envelope surrounding the arc are kept substantially free from contamination and are cooled by the strongly swirling gas.

In a modification, the pressure chamber is formed from two spaced concentric, transparent envelopes, so that the chamber walls can more readily withstand large internal pressures.

FIG. 1 represents a schematic of the apparatus of the invention. Referring to the drawing, an arc **10** is established and maintained between a pair of spaced electrodes **12** and **14** by electrically connecting the two electrodes to a power supply **16**. The lateral distance separating the electrodes is hereafter called the arc length. The electrodes are spaced from one another by a pressure chamber **18**, formed from an envelope **20** made of a transparent material, such as quartz. The electrodes have exit passages **22** and **24**, respectively, which are substantially centrally aligned and coaxial with one another. A portion of nozzle electrode **14** extends into the main arc chamber **18** to form a relatively thin annular region **15** between the outer surface of electrode **14** and the inner surface of envelope **20**.

A suitable gas is fed to the chamber **18** through electrode **14** by way of a plurality of inlets **26**, the gas being fed to inlets **26** by way of an annulus **28** and supply inlet **30** in such electrode. Inlets **26** to the chamber are arranged so that gas is injected approximately tangentially to the inner surface of the electrode.

This is more clearly shown in FIG. 2, which is a section taken along line 2–2 of FIG. 1. Thus, as shown, the gas leaves annulus **28** and enters into the cylindrical annular region **15** of chamber **18** by way of inlets **26** from whence it is given a significant axial velocity which causes it to continue in the axial direction after leaving the annular region **15**. Inlet **26***a*, for example, causes the gas to enter the annular region **15** of chamber **18** in a direction which is parallel to the locus of points passing through the tangent point T of the inner surface S of electrode **14**. This means of injecting the gas causes the gas to swirl around the inner surface **21** of the envelope **20** forming the pressure chamber **18**.

This swirling of the gas against the inner surface **21** of the transparent envelope **20** effectively cools the envelope so as to prevent its deterioration. This is an important feature of the invention, because of the strong tendency of the envelope (quartz) to deteriorate due to the combination of the high pressures in the chamber and the heat radiated by the very intense arc. The thin annular region **15** shown in proper perspective in the working examples of FIGS. 3 and 3*a* assists in extending the swirl flow pattern for the gas stream over a substantial axial distance.

As the swirling gas proceeds down to the end of the chamber opposite the inlets, a portion of the gas will flow out the exit passage **22**, while the remaining portion reverses its flow and exits out the passage **24**. This unique gas multiflow pattern has the advantage of providing a very clean radiation source. Substantially all of the contaminants (due principally from electrode erosion) are swept out the exit passages **22** and **24**. Minor contaminants migrate to and remain at the ends of the chamber.

Therefore, with the gas flow pattern of this invention, contamination of the transparent envelope in the area between the electrodes is prevented. Thus, if the gas were to be injected at both ends of the chamber, the gas flows would meet somewhere near the center of the chamber, reverse, and then exit out the passages **22** and **24**. This would cause the contaminants to coagulate at or near the center of the chamber, severely limiting radiation effectiveness of the arc due to resulting discoloration of the envelope.

The swirling gas flow pattern tends to constrict the arc by at least two mechanisms: first, the low pressure region at the axis is a preferred path for an arc discharge; next, there is a continual flow of gas towards the axis along the length of the arc column that counters the spreading of the plasma by thermal conduction. Since the gas prior to entering the arc column acts as an electrical insulator, it follows that the arc must flow through the vortex at the axis or center of the chamber. The resulting constriction of the arc means that increased currents will produce increased arc intensity as opposed to merely increasing the cross-sectional area of the arc as would occur if there were no constriction.

In order to achieve a strong swirling, cool, dense gas flow the gas must be directed into the chamber at relatively high speeds at relatively high chamber pressures. In the present invention, this is accomplished in two ways: (1) by introducing the gas such that it satisfies the above-noted equation and (2) by maintaining a preferred relationship between the cross-sectional area of the chamber the total cross-sectional area of the exit passages **22** and **24**, the arch length and the inside diameter of the envelope. The second factor acts to supplement the first and is necessary for optimum results especially for longer arc lengths. In addition to inducing a strong swirl by satisfying the above-noted equation, the geometric relationship enables the arc termination areas to be optimumly maintained within the exit passages **22** and **24**. This eliminates the possibility of spurious arching which, if permitted, would eventually cause deterioration of the apparatus.

The method of injecting the gas so as to satisfy the above-noted equation insures that the flow pattern will have sufficient momentum to maintain a clearly defined vortex at the center of the chamber where the arc is maintained. This momentum, coupled with relatively high chamber pressures, additionally insures that the gas will be relatively dense and cool near the periphery of the envelope **20** forming the chamber. But this method of gas injection is not in and of itself sufficient to maintain the desired momentum in the flow pattern in terms of optimum performance.

The stability of the vortex established at the axis of the chamber is influenced not only by inlet mach number (M_i) as described in the aforementioned formulas but also by arc length, exit area, quartz cross-sectional area, gas flow rate and arc current. In order to optimize the swirl flow pattern so as to have a highly stable clearly defined vortex at the axis of the chamber with a constant degree of arc constriction, the product of the ratio of the cross-sectional area of the pressure chamber to the total cross-sectional area of the exit passages **22** and **24** multiplied by the ratio of the arc length to the inside diameter of the quartz tube should be in the range of 25 and 200. When the ratio becomes too low, there will be insufficient flow path length for the separate inlet streams to develop a smooth swirl pattern, while on the other hand, if the ratio is too large, just the opposite will be true and there will be a strong tendency for energy dissipation processes to dissipate the swirl strength as the gas flow spirals in toward the axis. A product relationship in the range of 25 and 200 results in a constant pressure and exit velocity for a fixed temperature thus maintaining a constant degree of arc constriction. Arc lengths much greater than 1 inch and up to 7 inches long have been satisfactorily achieved.

By using this method of gas injection with gas being injected at one end only, and by maintaining the prescribed area ratios, a remarkably clean arc radiation source is achieved wherein the arc has a current density of at least 1000 amp/cm^2.

FIGS. **3** and **3***a* depict preferred apparatus illustrative of the invention. In the drawing of FIG. **3**, only one end of the arc radiation apparatus is shown, the opposite end being identical - except for the gas inlet passages. Referring to both FIGS., electrode **32** has a tungsten insert **34** for providing a better arc attachment area. The electrode is cooled by passing cooling water from inlet **36** through annulus **38**, then through annulus **40** and thence out outlet **42**. The rear supporting structure of the apparatus is also cooled by passing water from inlet **44** into cavity **46** from whence the water passes out through annulus **48**. A pressure tap **50** is provided for measuring the gas pressure as the gas exits through the gas passage **52**.

The pressure chamber **18** is formed from an envelope **20** made of transparent material such as quartz. Gas is supplied to this chamber from inlet **54** by way of annulus **56** and a plurality of chamber inlets **58**. The annular region **15** of chamber **18** gives the gas a significant axial velocity component as discussed heretofore. Chamber inlets **58** are formed in the manner described with respect to inlet **26***a* of FIG. **2**. This gives a swirling pattern to the gas flow as it proceeds from annular region **15** down along the inner face **21** of envelope **20**. A portion of the gas then flows out through the exit passage of the electrode at the opposite end of the chamber. Much of the remaining portion of the gas reverses axial direction somewhere near the opposite end and exits out the central gas passage **52**. Smaller portions move toward the axis throughout the length of the chamber, thereby aiding the constriction of the arc.

The present apparatus also provides for equalizing the pressure on the envelope **20** so as to enable high chamber pressures to be more readily used. This is accomplished by supplying gas from inlet **60** through annulus **62** from whence it passes into a cylindrical second chamber **64** surrounding chamber **18**, by way of an annular chamber inlet **66**. Chamber **64** is also formed from an envelope **67** made of a transparent material such as quartz. It is not necessary that this gas should have a swirling flow pattern; hence inlets **66** are not designed to give the swirl flow pattern.

The gas entering cylindrical chamber **64** flows to the opposite end of the chamber, from whence it exits through suitable outlets (not shown). In like manner, gas can be supplied to third chamber **68** by way of inlet **70**, annulus **72**, and an annular chamber inlet **74**. It should be understood that these additional chambers are not always necessary so that they may be omitted in some cases. It should also be noted that a liquid coolant such as distilled water could be fed to these chambers in place of gas.

To complete the description of the apparatus, flanges **76** and **78** are provided so that the whole apparatus can be bolted or otherwise tied to a supporting frame.

In the practice of the invention, inert gases of the class including argon, xenon and krypton are particularly suitable as the chamber gas. These inert gases have a high atomic number which yield a high probability of electronic transition that is necessary for good radiation. Also, in the practice of the invention, direct current of either polarity as well as alternating current can be used.

FIG. **4** is a curve showing the radiation intensities for various wavelengths achieved from an arc at typical operating conditions using the radiation source of FIG. **3**.

The following examples are provided to give typical conditions under which the invention may be practiced.

Example 1

Argon at 2720 s.c.f.h.
16 inlet holes of .024" diameter
507 p.s.i.g. on upstream side of inlets
310 p.s.i.g. on downstream side of inlets
Mach number (M_i) = .79 (calculated from pressure ratio)

$\left|\frac{V_p}{V_T}\right| = 1$

$D_q = 1$ inch

D_q=.774 inch
length of arc=2.9" between two 3/16" ID straight bore hollow electrodes
then

$$M_i \times \frac{D_e}{D_q} \times \left|\frac{V_p}{V_T}\right| = .79 \times \frac{.774}{1.00} \times 1 = .617 \geq .25$$

$$\frac{A_q}{A_e} \times \frac{L}{D_q} = 41$$

The arc voltage was 580 volts, and the arc current 147 amperes, for an input power of 85.2 kilowatts. About 19.7 kilowatts was radiated power exiting the transparent envelope.

Example 2

Argon at 693 s.c.f.h.
6 inlet holes of .024" diameter
400 p.s.i.g. on upstream side of inlets
290 p.s.i.g. on downstream side of inlets
Mach number (M_i)=0.63 (calculated from pressure ratio)

$$\left|\frac{V_p}{V_T}\right| = 1$$

D_q=1 inch
D_e=0.774 inch
length of arc=3.0" between two 3/32" ID straight bore hollow electrodes
then

$$M_i \times \frac{D_e}{D_q} \times \left|\frac{V_p}{V_T}\right| = 0.63 \times \frac{.774}{1} \times 1 = 0.49 \geq .25$$

$$\frac{A_q}{A_e} \times \frac{L}{D_q} = 171$$

The arc voltage was 550 volts, and the arc current 96 amperes, for an input power of 53 kilowatts. About 15 kilowatts was radiated power in the exit beam.

What we claim is:

1. A high pressure arc radiation torch comprising: two spaced tubular electrodes having axially aligned central gas exit passages; an envelope of transparent material surrounding said electrodes in concentric relation and providing a pressurized gas chamber; at least one of said tubular electrodes extending into said chamber to form a relatively thin annular region substantially cylindrical in cross section between the outer surface of said extended tubular electrode and the inner surface of said envelope; inlet ports tangentially disposed in the outer surface of the extended portion of said tubular electrode for discharging arc gas into said annular region and representing the sole means for introducing gas into the chamber; gas supply inlet means; gas passage means connecting said gas supply inlet means to said inlet ports, and means for energizing an arc between said tubular electrodes.

2. A high pressure arc radiation torch as defined in claim 1 wherein said transparent envelope is enclosed within another transparent envelope in concentric relation therewith forming an annular passage through which a coolant is passed.

3. A high pressure arc radiation torch as defined in claim 1 wherein at least said extended tubular electrode has a tungsten insert.

4. A high pressure arc radiation torch as defined in claim 3 wherein said gas passage means is concentric with the longitudinal axis of said extended tubular electrode.