United States Patent

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[54] **METHOD AND APPARATUS FOR CHEMICALLY TRANSFORMING GASES**
4 Claims, 4 Drawing Figs.

[52] U.S. Cl. **204/171,** 204/323, 204/165, 204/170
[51] Int. Cl. **C07b29/06,** C07c 5/18, B01k 1/00
[50] Field of Search 204/164, 165, 168, 170, 171, 312, 323

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ABSTRACT: In a system in which a gas in a supersonic stream is chemically transformed by a principal electric discharge, an auxiliary discharge first ionizes the gas in the stream.

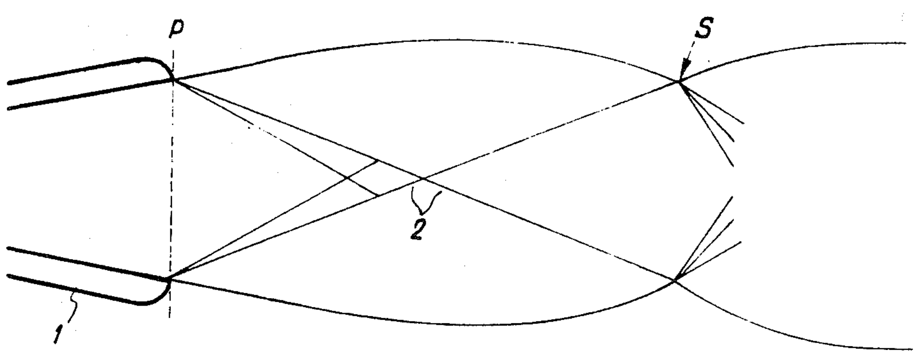
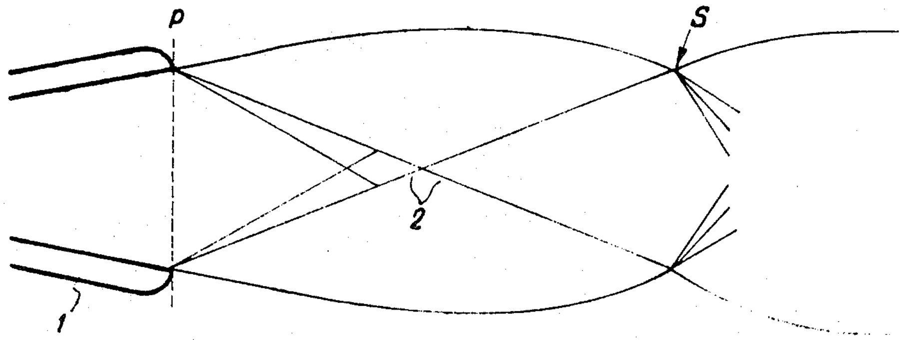


FIG. 1



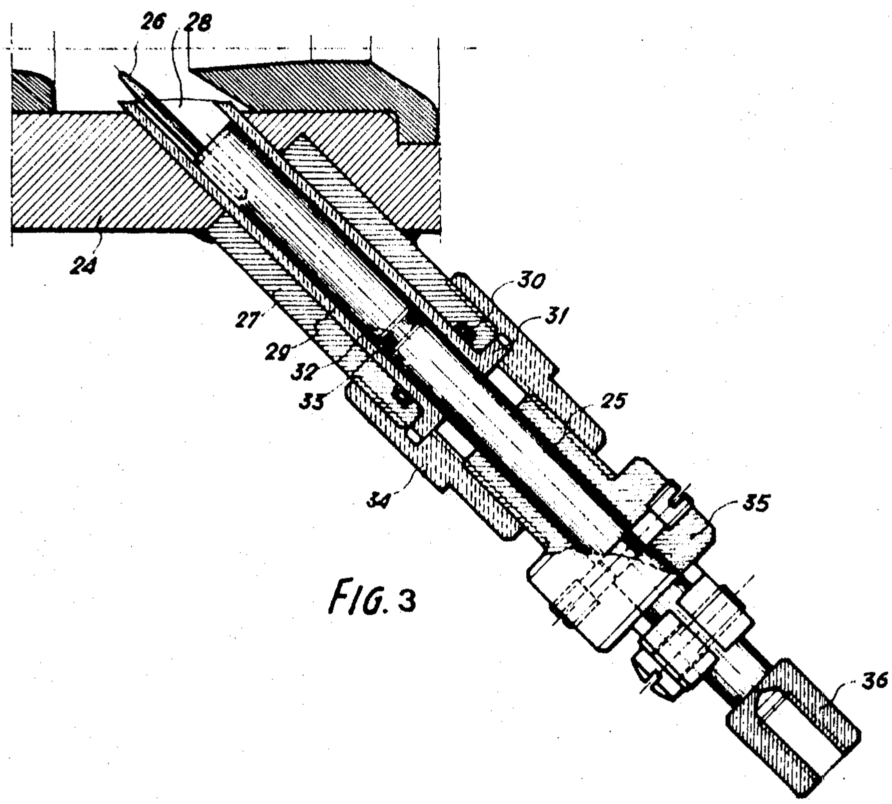


FIG. 3

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FIG.2

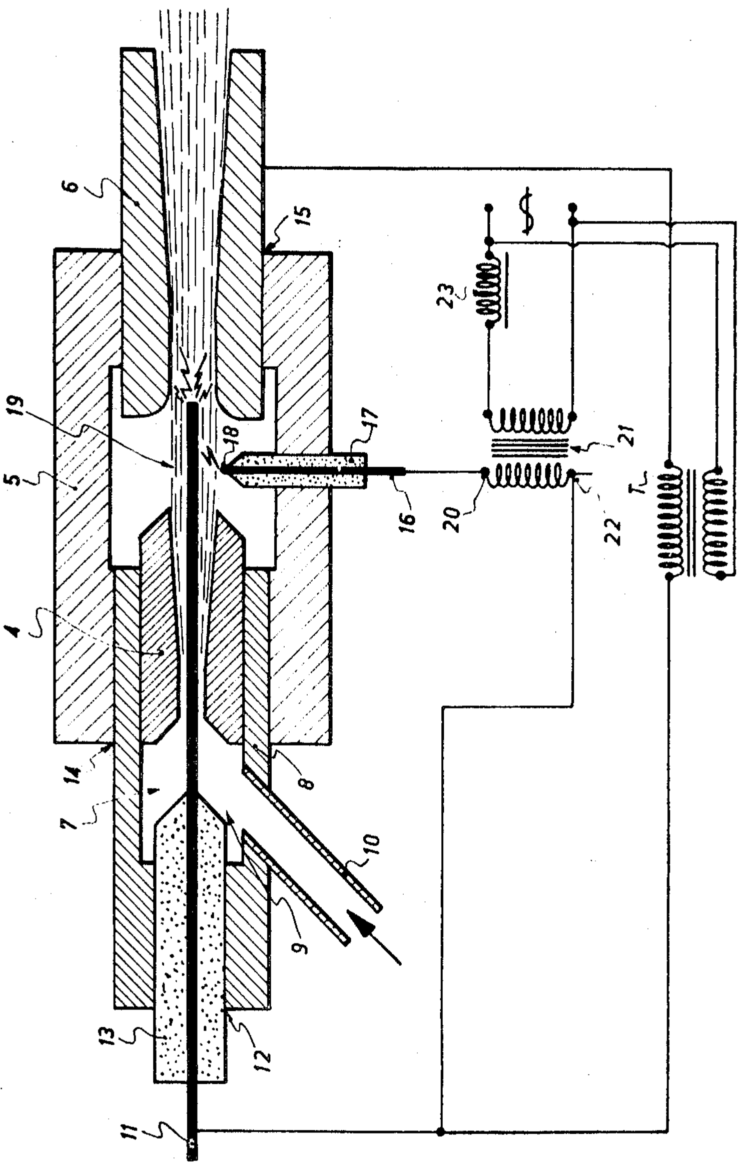

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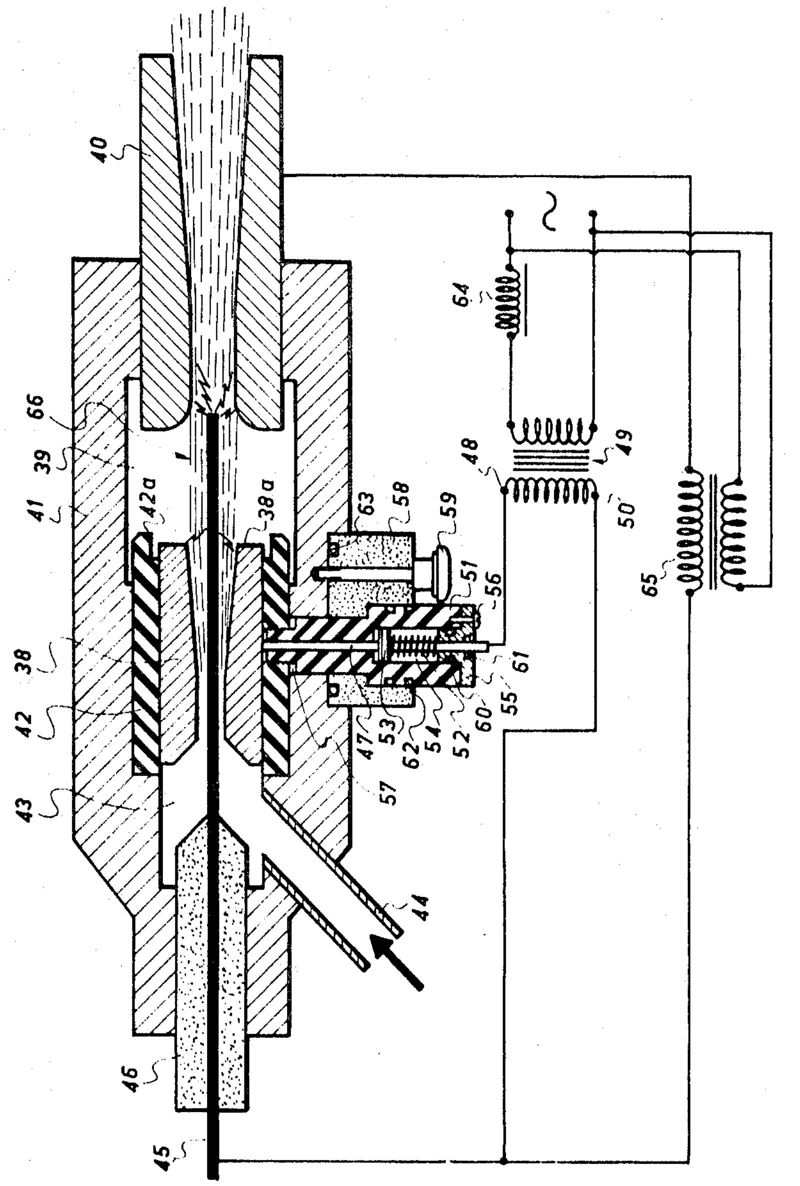
FIG. 4



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METHOD AND APPARATUS FOR CHEMICALLY TRANSFORMING GASES

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention relates to a process and apparatus for ionizing a gaseous stream moving at supersonic speed and wherein a high-power electric discharge is produced to cause a chemical transformation of the gas or gases constituting the stream.

In a conventional process of this type, a stream of gas is brought to supersonic speed and is subjected to an electronic discharge produced by an electrode positioned along the axis of the gas stream and connected to a high-voltage generator. If the voltage variations during alternation are examined in an alternating discharge at the boundaries of the elements between which the discharge is produced, it is found that the voltage rises to a value V_1, then drops suddenly, and finally remains constant at an average value V_2 until the end of the alternation. This phenomenon is repeated at each alternation. These voltage variations may be explained by the fact that, since the gas stream is nonconductive, the voltage rises until it has reached the point where the electrons produced have sufficient energy to ionize the gas. At this point, the gas becomes conductive and the voltage drops suddenly to value V_2 which corresponds to the value of the voltage required to maintain the discharge in the ionized gas. Thus, a high starting voltage V_1 must be attained at each alternation although a much lower maintenance voltage V_2 suffices to maintain the discharge. Experience has shown V_1 to be substantially equal to about 3 V_2. Therefore, if a constant discharge is to be produced in a supersonic stream of gas, voltage generators must be employed which have a capacity of generating three times as much voltage to start the electric discharge as is required to maintain it. It is also necessary to limit the electric current by incorporating into the discharge circuit either resistances, which results in a loss of power, or self-induction coils, which makes the cos Φ of the installation poor. On the contrary, if the gaseous stream constantly includes carriers of the electric charge, i.e. if it is ionized, it is possible to utilize a generator which delivers a voltage not much higher than V_2 to produce the desired electric discharge.

In another known process of this type, a first electric discharge is produced in a supersonic gaseous stream between a tuyere, from which the stream is discharged, and an axially extending electrode, and use is made of the ionization of the gas resulting from the first electric discharge to produce a second electric discharge in a recompression collector beyond the shock wave, i.e., in a zone where the stream is again subsonic to cause certain chemical transformations in the gaseous stream.

However, it has been found that in certain chemical reactions, for instance in the transformation of butane into acetylene, a discharge in the latter zone caused a further chemical transformation so that, at the outlet of the recompression collector, a large proportion of carbon and hydrogen was found. In other words, the reaction had proceeded to the complete decomposition of the gas, the elements being considered undesirable byproducts in this reaction.

It is one of the primary objects of this invention to produce electric charge carriers in a gaseous stream moving at supersonic speed before producing an electric discharge in this stream capable of causing chemical transformations in the gas or gases of the stream.

It is another object of the invention to produce well-defined compounds in the chemical transformations.

The above and other objects and advantages are accomplished according to the present invention by ionizing a gaseous stream moving at supersonic speed by means of an auxiliary electric discharge, and producing a principal electric discharge in the ionized stream to cause chemical transformations in the gas. The gaseous stream is discharged from a supersonic tuyere or nozzle and the chemically transformed gas is received in a collector chamber. The invention provides a supersonic cell between the tuyere and the gas collector and this cell has a constriction at the level where the shock waves produced at the tuyere outlet cause deviation in the direction of the gas stream. An auxiliary electric discharge is produced between an axially positioned principal electrode, which is enveloped by the gaseous stream, and an auxiliary electrode positioned outside the gaseous stream. In this manner, the ions produced by the auxiliary electric discharge and entrained by the gaseous stream along its periphery are carried into the interior of the stream by the constriction in the cell.

According to one embodiment of the present invention, the auxiliary electric discharge is produced upstream of the constriction but close to the collector element.

In accordance with another embodiment of this invention, the supersonic tuyere is brought to an electric potential such that the potential difference between the nozzle constituting the auxiliary electrode and the axial electrode is higher than the potential difference between the axial electrode and counter electrode provided by the apparatus. The auxiliary electric discharge is produced at the end of the supersonic tuyere between the tuyere and the axial electrode surrounded by the gaseous stream. The principal electric discharge is produced in that part of the recompression collector where the shock wave is produced.

In yet another embodiment of the invention, the voltage producing the auxiliary discharge is of a different phase than the voltage producing the principal discharge so that the intensity of the auxiliary discharge is at a maximum when the voltage producing the principal discharge reaches a value approximating the voltage necessary to sustain the discharge in the ionized gas.

In the apparatus of the present invention, a supersonic tuyere is connected in a fluidtight manner to an expansion chamber leading to an element of gas recompression positioned in line with the outlet of the tuyere. An electrode is positioned axially in the tuyere and extends to the inlet of the gas recompression chamber. The apparatus comprises an auxiliary electrode which produces an electric discharge through the gaseous stream between the axially positioned electrode, which is surrounded by the stream of gas, and the auxiliary electrode.

In accordance with one embodiment of the apparatus of this invention, the auxiliary electrode is positioned in the gas expansion chamber and is constituted by a support of electrically conductive material. The support is glidably but fluidtightly arranged in a guide mounted in the wall of the expansion chamber, and is electrically insulated from the guide, from the expansion chamber and from the recompression chamber wall. The auxiliary electrode support has an extension at one end projecting into the expansion chamber, the extension being of a metal suitable for producing and sustaining an electric discharge between this metallic extension and the axially positioned electrode.

The extension is preferably a pointed metallic pin fixed to the end of the conductive support and being eccentric in respect of its axis. The pointed pin may be inclined to the support axis and fixed to the center of the support end.

According to another embodiment of the invention, the conductive support may be arranged for rotation about its axis in the guide.

In yet another embodiment, the distance between the noninsulated points of the auxiliary electrode from the nearest points of the supersonic tuyere and from the recompression chamber wall exceeds the distance separating the noninsulated points of the auxiliary electrode from the axial electrode.

In accordance with still another feature of the present invention, the auxiliary and the axially positioned electrodes are connected to the terminals of the same high-voltage source.

In one preferred embodiment, the tuyere may be of an electrically conductive material to constitute the auxiliary electrode, and is electrically insulated from the remainder of the apparatus, electrically insulating means being provided to connect the tuyere to an electric current generator. This means may be constituted essentially by a rod of electrically conductive material disposed in a protective guide of electrically insulating material. This protective guide may define a cavity holding biasing means, such as a spring, to maintain the rod constantly in contact with the supersonic tuyere.

With this method and apparatus, ionization of the gas is first produced by the spark from the auxiliary electrode across the gas stream and upstream of the principal electric discharge, between an axially positioned electrode surrounded by the gas stream and an auxiliary electrode electrically insulated from the other components of the apparatus.

The introduction of ions into the interior of a gaseous stream moving at supersonic speed encounters certain obstacles due to the very high velocity of the gas molecules. Experience has shown that a gas jet or a gas stream moving at supersonic speed has physical characteristics quite different from those of a gas at rest or moving at slow speed. More particularly, an electric discharge or spark enters a supersonic gas jet with great difficulty and is produced more readily between the auxiliary electrode, which is positioned outside the gas stream, and the compression chamber walls, the pressure in the chamber being low. Furthermore, the ions produced by the discharge have a tendency, due to the high speed of the jet, to remain localized on the periphery of the gas stream. Finally, in a gas moving at supersonic speed, a turbulence cannot be carried back up the high-velocity stream and any such turbulence will, therefore, appear only downstream.

We have found that, in first ionizing a supersonic gas jet and then subjecting the ionized jet to an electric discharge of greater power in the zone of the shock wave, the discharge will be concentrated in the shock wave, i.e., in a surface having practically no thickness (a few microns), which surface constitutes an extremely sharp transition barrier between the supersonic flow and the subsonic flow. It is thus possible to produce acetylene in high yields from saturated hydrocarbons containing at least four carbon atoms, such as butane.

This may be done by placing the end of the axially positioned electrode at the inlet of the recompression collector. If the electrode end is in the zone of the gas stream where the shock wave is formed due to the laws of aerodynamics, it facilitates the formation and stabilization of the shock wave which attaches itself to the electrode end. The largest part of the energy of the electric discharge is thus concentrated in the surface of the shock wave, and the gases to be chemically transformed are subjected to the discharge for an extremely short time, i.e., the time required for the spark to pass through the shock wave. Therefore, the transformation of an important fraction of a hydrocarbon, for instance butane, into acetylene may be obtained without a prolonged action of the spark on the material, which avoids the possible decomposition of the acetylene by the action of the electric discharge, as has occurred in many conventional processes of this type.

We have also found that, under the above-described conditions, the auxiliary electric discharge is produced between the end of the supersonic tuyere and the axial electrode, and that the ions follow the exterior surface of the gas jet, i.e., the surface of the first supersonic cell which is formed at the outlet of the tuyere, and they penetrate into the jet stream at the first constriction they encounter, i.e., behind the first supersonic cell. Thus, the recompression collector and the tuyere may be positioned at a closer distance although this distance must be large enough to provide at least one entire supersonic cell and to avoid producing a direct electric discharge between the tuyere and the collector.

Another advantage of this invention is that there is no problem of positioning the auxiliary electrode since this may be the tuyere itself. Thus, gases of all types may be used and may form supersonic cells of variable lengths under different pressures while maintaining the auxiliary electrode, i.e., the tuyere, in the same position.

BRIEF DESCRIPTION OF THE DRAWING

The above and other objects, advantages and features of the present invention will become apparent from the following detailed description of certain embodiments thereof, taken in conjunction with the accompanying drawing wherein

FIG. 1 schematically shows a supersonic cell and the shock waves produced by a tuyere;

FIG. 2 is a sectional view of one embodiment of the apparatus, including a diagram of the electric circuit;

FIG. 3 is a sectional view showing the mounting of the auxiliary electrode in this embodiment of the apparatus; and

FIG. 4 is a view similar to that of FIG. 2 and showing another embodiment.

DETAILED DESCRIPTION

In the practice of the invention, it is essential to establish a stable steam of gas moving at supersonic speed, in which chemical reactions are produced by an electric discharge passing through the stream. The steam must not be disturbed in any manner, which forces the auxiliary electrode to be positioned near, but outside of, the gaseous stream. The gas stream cannot be considered as a cylindrical jet of uniform section. In practice, due to manufacturing imperfections, the tuyeres are not of the contemplated ideal cross section, and one or several supersonic cells similar to those indicated in FIG. 1 are produced.

As shown in FIG. 1, such a supersonic cell comprises a constriction *S* of the gas stream at a predetermined distance from the plane of the gas outlet of tuyere 1, at which point there is an inward refraction of shock waves 2 which are produced at the outlet of the tuyere, and a deviation in the stream due to the shock waves. For given operating conditions, one or more such supersonic cells may be produced by adjusting the distance between the plane of the outlet of tuyere 1 and the gas collector. Generally, the distance of the collector from the tuyere is so adjusted that a single such cell is produced.

We have found that certain properties of these cells facilitate passing an electric discharge through the stream of gas and to ionize the same homogenously by means of an auxiliary electric discharge while maintaining the auxiliary electrode outside the gas stream so as not to disturb its supersonic flow.

In fact, if the auxiliary electrode is placed close to the gas stream and upstream of the point of constriction of the stream, an electric spark may be passed through the stream between an electrode axially positioned in the center of the stream and the auxiliary electrode. The spark produces an envelope of ionized gas around the periphery of the gaseous stream. As soon as this ionized stream reaches the point of constriction, it is absorbed and dispersed into the interior of the gas stream beyond the point of constriction. Under the action of the refracted shock waves and the deviation of the jet due to the shock waves, as seen in FIG. 1, the ions are entrained and dispersed through the stream of gas moving at supersonic speed. A very short distance downstream of the point of constriction, the carriers of electric charges are thus distributed completely in the stream, and it is now possible to produce a powerful electric discharge in the gas without using very high voltages.

It will be appreciated that this result cannot be obtained without forming the described and illustrated supersonic cells, and that it is equally essential that the positioning of the auxiliary electrode must meet certain requirements.

First of all and to facilitate the electric discharge, the auxiliary electrode must be positioned as close as possible to the axial electrode without, however, disturbing the supersonic flow of the gas stream. It will be easiest to adjust the position of the auxiliary electrode so that it does not perturb the flow of the gas stream by measuring the gas pressure in the expansion chamber. If it is found that the pressure rises, the auxiliary electrode touches the periphery of the gas stream and perturbs the flow thereof.

Secondly, it is important that the ions reach the region where the principal electric discharge is produced, and that the auxiliary discharge is not completely or even partially produced between the auxiliary electrode and another component of the apparatus.

The lateral position of the auxiliary electrode along the gaseous stream is, therefore, a compromise between these two requirements, it being understood that it must always be placed at the level or upstream of the constriction zone. For the given life of the ions and a given speed of the gas stream, the ions flow only a predetermined distance to the zone where the principal electric discharge is produced. This condition defines the maximal distance between the zone of the principal electric discharge and the auxiliary electrode beyond which the auxiliary discharge loses all effectiveness. However, the auxiliary electrode may not be positioned too close to the gas collector to avoid an electric discharge between the two, without such a discharge penetrating into the gas stream.

In view of the above, the point of constriction in the gas stream must be determined for given operating conditions of the supersonic tuyere. This determination may be made experimentally, either visually by producing an electric discharge between the axially positioned electrode and the outlet of the supersonic tuyere, or by measuring the operating pressure in the expansion chamber and progressively displacing the axial electrode; when the free end of this electrode reaches the level or plane of the constriction, a sudden rise in the pressure will be registered. In this way, the position of the electrode readily indicates the position of the point of the constriction of the gas stream in respect of the plane of the outlet of the tuyere for given operating conditions.

The position of the point or plane of constriction may also be calculated by known equations of the thermodynamics of flowing gases. In this manner, the desirable distance of the auxiliary electrode from the plane of the tuyere outlet may also be calculated as a function of the geometric characteristics of the tuyere and the aerodynamic behavior of the gas flow. It has been experimentally determined that this distance may be calculated by means of the equation

$$L=k\sqrt{\gamma\eta_2-1}$$

wherein $\gamma\eta$ is the Mach number attained by the stream of gas and k is a constant which depends solely on the diameter of the divergent outlet of the tuyere and its relation to the diameter of the electrode axially disposed within the gas stream.

The coefficient k may be defined by $k=f(D/d\times D$, wherein D is the diameter of the divergent tuyere outlet and d is the diameter of the axial electrode.

The Mach number is calculated from the pressure of the gas introduced into the tuyere and the pressure of the gas in the expansion chamber by the following well-known equations:

$$\gamma\eta^2=\frac{2}{\gamma-1}\left(\frac{T_0}{T}-1\right)$$

$$\frac{T_0}{T}=\left(\frac{P_Q}{P}\right)\frac{\gamma-1}{\gamma}$$

wherein T_o is the temperature of the gas before expansion, T is the temperature of the gas after expansion, P_o is the pressure of the gas before expansion, and P is the pressure of the gas after expansion, $\gamma=C_{p/cv}$, wherein C_p is the specific heat of the gas at constant pressure and C_V is the specific heat of the gas at constant volume.

If the function $f(D/d)$ has been experimentally determined for a given ratio D:d, the position of the auxiliary electrode may be calculated for any dimensions and aerodynamic conditions of the tuyere since the position of the constriction plane or point is determined by the same conditions. Thus, under the given conditions, homogenous ionization of a supersonic gas stream may be obtained.

Referring now more particularly to the embodiment of the apparatus shown in FIG. 2, there is shown a supersonic tuyere or nozzle 4 which carries gases at supersonic speed into an expansion chamber defined by wall 5 whence the gas stream 19 moves into a recompression chamber defined by wall 6. The expansion and recompression chambers are in axial alignment with the axis of the supersonic tuyere 4 which is mounted in a coaxial cavity 7 defined by cylindrical support 8. The length of cavity 7 exceeds that of the tuyere 4 so that an empty chamber 9 is formed in the support 8 rearwardly of the tuyere. A tubular inlet conduit 10 opens into chamber 9 wherethrough the gas to be treated is supplied to the tuyere. A principal electrode 11 is axially positioned within the outwardly flared axial bore of the tuyere 4, extending through axial bore 12 in the tuyere support 8 to the inlet of the recompression chamber constituted by the outwardly flared axial bore in the wall 6. Electrode 11 is perfectly centered along the aligned axes of the tuyere and the recompression chamber, being mounted in bore 12 by means of an electrically insulating plug 13 whose outer diameter corresponds exactly to the diameter of bore 12 so as to provide a fluidtight mounting for the electrode. The tuyere support 8 is fluidtightly mounted in the bore 14 of wall 5 and the tube 6, which defines the recompression chamber is also fluidtightly mounted in the bore 15 of the wall 5. Thus, the gas jet moves at supersonic speed through fluidtight treatment zones.

An auxiliary electrode 16 is mounted in the wall 5 by means of fluidtightly fitting, electrically insulating plug 17, extending radially into the expansion chamber between the outlet of the tuyere 4 and the inlet of the recompression chamber. The noninsulated end 18 of the auxiliary electrode is disposed perpendicularly to the jet 19 and close thereto.

The auxiliary electrode 16 is connected to one terminal 20 of a high-voltage generator constituted by transformed 21 whose other terminal 22 is connected to principal electrode 11. The electric supply circuit for the electrodes includes a self-induction coil 23 designed to limit the intensity of the auxiliary electric discharge. The principal electrode 11 and the electrically conductive wall 6 defining the recompression chamber are respectively connected to a source of alternating voltage constituted by transformer T which permits production of an electric discharge in the gas stream between electrode 11 and the recompression chamber wall.

According to one embodiment of the apparatus hereinabove described, the diameter of the flaring bore of tuyere 4 is 6.8 mm. at the outlet end, and the diameter of the rod electrode 11 is 3 mm. The throughput of the tuyere is 4 liters of butane per second when the butane gas is supplied to the tuyere through inlet pipe 10 at a pressure of 5 atmospheres. Under these operating conditions, the pressure in the expansion chamber is 150 mm. Hg, i.e., 0.2 atmospheres. The Mach number X attained by the gaseous stream is accordingly calculated at 2.62.

These parameters make it possible to calculate the distance the auxiliary electrode 16 should have from the plane of the tuyere outlet so that the auxiliary electric discharge takes place solely between the principal and auxiliary electrodes. Using the above-indicated equation and inserting the above dimensions and $fD/d=0.7$, the distance $L=0.7\times6.8\sqrt{(2.62)^2-1}=11.5$ mm.

In this example, tension V_1 equals 3,600 volts and tension V_2 equals 900 volts. Transformer T is capable of delivering an alternating voltage of 1,100 volts. Transformer 21 is capable of delivering an alternating current of 0.1 ampere at a voltage of 5,000 volts. The current intensity being limited by self-induction coil 23, the transformer is fed by a three-phase 220 V feed circuit, and another power source feeds the principal transformer T so that the intensity of the auxiliary electric discharge is at a maximum when the voltage used to produce the principal electric discharge reaches a value in the neighborhood of that needed to maintain the discharge in the ionized gas.

This example clearly illustrates the usefulness of the auxiliary electrode feeding the auxiliary electrode with a current of 0.1 A. at 5,000 v. permits the use of a current of 20 A. at 1,100 v. to produce the principal discharge. In the absence of an auxiliary discharge, it would have been necessary to use a transformer having an output of 20 A. at 3,600 v. to produce the principal discharge.

FIG. 3 illustrates the structure of a useful auxiliary electrode in detail, the electrode being mounted in the wall **24** defining the expansion chamber. The electrode is constituted by a cylindrical support rod **25** of electrically conductive material to whose one end is fastened a pointed metallic pin **26** of a material capable of sustaining the auxiliary electric discharges, the selected material being tungsten in the illustrated example. The point **26** constitutes the "active" portion of the auxiliary electrode because the discharge takes place between this portion and the principal electrode **11**. As shown, the point **26** is eccentric in respect to the axis of the electrode support rod **25**.

A metallic tube **27** is soldered to the wall **24** which defines an oblique bore forming a seat for the tube **27** and leading to the orifice **28** opening into the expansion chamber, the tube **27** serving as a guide for the auxiliary electrode support rod **25**. The support rod is encased in electrically insulating sheath **29** which is held in fluidtight engagement with the support rod by means of a toric gasket **30** positioned in an annular groove in the interior wall of tube **27**. The outer end of the insulating sheath **29** has a collar **31** forming an abutting should in engagement with the outer end of the tube **27**. The support rod **25** defines an annular groove **32** wherein there is positioned a toric gasket **33** to assure the fluidtight seal between the rod **25** and the guide tube **27**. A sleeve **34** is screwed over the outer end of tube **27** and engages the collar **31** of the insulating sheath so as to hold the same against displacement. A metallic head **35** is screwed into the threaded axial bore of sleeve **34** and its axial bore aligned with the axial bore in guide tube **27** forms the guide for the outer portion of rod **25**. A connector **36** connects the rod to the electric feed circuit described in connection with FIG. 2.

It will be understood that this mounting permit axial displacement of the rod **25** in guide tube **27** without in any way damaging the fluidtightness of the arrangement, and thus to adjust the point **26** in respect of the axis of the gaseous stream. Further adjustment is possible by rotating the electrode rod in its support, such rotation causing a displacement of the eccentric point **26** along the axial extension of the gas stream, thus enabling the auxiliary electric discharge to be "fine tuned" for best results.

The same result may be obtained, for instance, by arranging the auxiliary electrode perpendicularly, instead of obliquely, in the wall of the expansion chamber, and positioning the point **26** obliquely at the inner end of the support rod **25**, the point extending radially outwardly from the axis of the rod.

Another embodiment of the apparatus is shown in FIG. 4. This comprises a tungsten tuyere or nozzle **38** carrying a gas at supersonic speed to expansion chamber **39** whence it flows into a recompression chamber defined by tubular wall **40**. In this embodiment, the tuyere itself constitutes the auxiliary electrode and tungsten is particularly suited for this purpose because it is refractory and a good electrical conductor. However, other materials, such as steel or graphite, may also be used.

A cylindrical steel support **41** fluidtightly holds the nozzle and recompression chamber, the nozzle **38** being electrically insulated from the support **41** by sleeve **42** of mica or glass. It will be noted that the outer end **42***a* of the insulating sleeve projects beyond the plane of the nozzle outlet **38***a* to prevent parasitic discharges between the nozzle and the steel support **41**.

The general arrangement is in many respects similar to that of FIG. 4 and will, therefore, not be described again, the gas to be treated being again supplied through supply pipe **44** delivering the gas into chamber **43** rearwardly of the nozzle.

The principal electrode **45** extends axially through the nozzle **38** to the inlet of the recompression chamber, in this manner to produce and to stabilize the shock wave at the recompression chamber inlet and to attach it to the inner end of the principal electrode **45**, due to the discontinuity in the gas flow created by the end of the electrode. Thus, the principal electric discharge is produced at this point of gas jet **66** and is concentrated in the shock wave, i.e., in a very small volume of gas having a thickness of the order of two microns. In other words, for all practical purposes, the discharge is concentrated on the surface of the gas stream. This concentration of the discharge on the surface may be explained by the blast due to the speed in the supersonic zone and by the fact that the shock wave constitutes for the discharge a barrier which may be very easily broken due to the transition to the subsonic zone in which the discharge is not readily produced. It is this very localized discharge which transforms the butane gas into acetylene when butane is fed to the system.

The electrode is fluidtightly centered in the tuyere **38** by means of insulating plug **46** which may be a cement consisting of asbestos and agglomerates.

A brass rod **47** electrically connects the tuyere **38** to terminal **48** of a high-voltage generator constituted by transformer **49** whose other terminal **50** is connected to principal electrode **45**. While brass is preferred because of its good electrical conductivity and high mechanical resistance, other conductive materials, such as copper or tungsten, may be used for rod **47**.

The connecting rod **47** must be effectively insulated from wall **41** wherein it is mounted to avoid any parasitic discharges therebetween. The illustrated insulation includes sleeve **51** which may advantageously consist of polyfluorethylene containing a glass fiber filler. This material provides not only very good insulation but also enables the rod **47** to glide readily in the sleeve. To assure good contact between the connecting rod and the tuyere **38**, a compression spring **52** is mounted in a seat **54** in the insulating sleeve, the spring pressing against a shoulder **53** and the spring seat being closed by plug **55** which is bolted to the sleever at **56**. The compression spring will hold the slidable connection rod **47** at all times in good contact with the tuyere.

The insulating sleeve **51** is screwed into the insulating sleeve **42** and a gasket **57** further assures fluidtight connection between the insulating parts. The insulating sleeve **51** is mounted in a cylindrical block **58** of similar material as plug **46**, this block being mounted on the support **41** by bolts **59**.

The interior of the apparatus is further fluidtightly separated from the surrounding atmosphere by gaskets **60** and **61** between the sleeve **51** and the plug **55**, and between the rod **47** and the plug **55**. Similarly, gaskets **62** are disposed between guide sleeve **51** and block **58**, and gaskets **63** are provided between the block and the wall **41**.

One of the advantages of this mounting is that the insulating sleeve for the connecting rod is screwed into the insulating sleeve for the tuyere, and may be readily disassembled without interfering with the fluidtight seal of the interior of the apparatus from the atmosphere. The block **58** may also be readily removed.

As in the other embodiment, the electric feed circuit for the electrodes includes a self-induction coil **64** and a principal transformer **65**. The auxiliary discharge is limited to a current of 0.2 A. at 2,500 v. The current fed by transformer **65** is a 20 A. at 1,100 v. The potential difference between the supersonic tuyere, i.e., the auxiliary electrode, and the principal or axial electrode is 2,500 v. while the difference between the axial electrode and the mass of the apparatus, i.e., the recompression chamber wall, is only 1,100 v.

While the invention has been described in connection with certain new preferred embodiments, it will be clearly understood that many variations and modifications may occur to those skilled in the art, particularly after benefiting from the present teaching, without departing from the spirit and scope thereof.

What is claimed is:

1. A method of producing chemical transformations in gases, comprising the steps of

1. moving a stream of gas at supersonic speed from a delivery zone to a collecting zone,
   a. shock waves being produced at the outlet of the delivery zone,
2. forming a supersonic gas cell in said stream between the delivery and collecting zone,
   b. the supersonic gas cell having a point of constricted cross section at which point the shock waves cause a deviation of the flow of the stream inwardly towards the axis of the gas stream,
3. positioning an axially extending principal electrode in the gas stream and surrounded thereby, the principal electrode extending through the delivery zone to the inlet of the collecting zone,
4. positioning an auxiliary electrode adjacent the gas stream,
5. producing an auxiliary electric discharge between said electrodes to ionize the gas along the surface of the stream,
   c. the gas ions on the surface of the stream being entrained inwardly into the stream at the point of constricted cross section, and
6. producing a principal electric discharge in the ionized gas stream by means of the principal electrode to produce a chemical transformation of the gas.

2. The method of claim 1, wherein the auxiliary electric discharge is produced at the point closest to the inlet of the collecting zone upstream of the point of constricted cross section.

3. The method of claim 1, wherein the auxiliary electrode surrounds the delivery zone and forms said steam at supersonic speed, the auxiliary and the principal electrode are brought to an electric potential such that the difference between their potentials exceeds the difference of the potential between the principal electrode and a counterelectrode wherebetween the principal electric discharge is produced, the auxiliary electric discharge is produced between an end of the auxiliary electrode and the principal electrode surrounded by the stream of gas, and the principal electric discharge is produced at the inlet of the collecting zone.

4. The method of claim 1, wherein voltages out of phase are applied to the auxiliary and principal electrodes whereby the intensity of the auxiliary electric discharge is at a maximum when the voltage applied to the principal electrode attains a value approximating that necessary to sustain the discharge in the ionized gas.

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