

[72] Inventors **Richard L. Johnson**
Manhattan Beach;
Bernard Siegel, Palos Verdes Estates, both
of Calif.
 [21] Appl. No. **40,973**
 [22] Filed **May 27, 1970**
 [45] Patented **Jan. 11, 1972**
 [73] Assignee **The United States of America as**
represented by the Secretary of the Air
Force

FOREIGN PATENTS

702,937 2/1941 Germany..... 117/107

Primary Examiner—James H. Tayman, Jr.

Attorneys—Harry A. Herbert, Jr. and William J. O'Brien

[54] METAL EXPLOSION APPARATUS 1 Claim, 2 Drawing Figs.

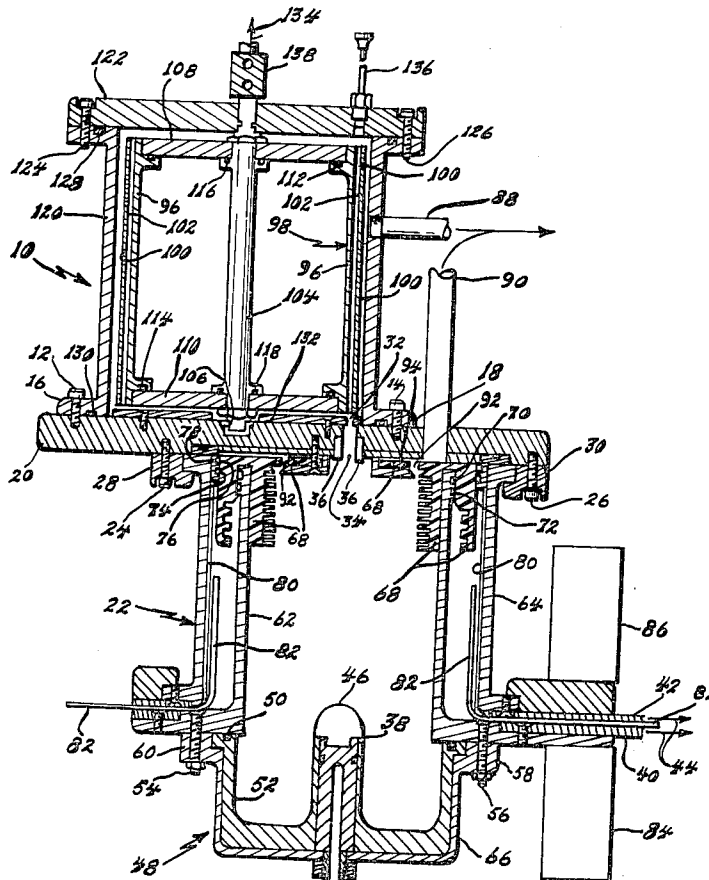
[52] U.S. Cl..... **23/277 R,**
23/252 R, 118/49.1, 13/18, 204/298, 75/5 C,
264/10, 317/79
 [51] Int. Cl..... **C23c 13/12,**
B01j 1/00
 [50] Field of Search..... **23/252,**
277; 118/49.1; 13/18; 204/298; 75/5 B, .5 C;
314/5; 264/10; 18/2.4

[56] References Cited UNITED STATES PATENTS

2,640,860	6/1953	Herres.....	13/18 X
2,795,819	6/1957	Lezberg et al.	264/10
3,213,826	10/1965	Lins et al.	118/49.1

ABSTRACT: A metal reactor consisting of two cylindrical sections fitted together one above the other in a vacuum-sealed relationship. A plurality of electrically conducting individual metal wire strips are positioned within the upper cylindrical section which in turn is rotated stepwise over an orifice located between the upper and lower cylinders. As the upper cylinder rotates, successive strips of the electrically conducting wire drop into the lower cylindrical chamber where the individual wire makes contact between two stationary electrodes. A high potential is imposed across the two electrodes causing electrical energy of sufficient magnitude to flow through the wire and effect the explosion thereof.

The apparatus overcomes a problem often encountered in the metal wire single-explosion technique relied upon heretofore, especially in those instances where the exploding wire phenomenon was used for synthesizing chemical compounds. The invention provides the necessary means for accomplishing a series of successive and continuous explosions of metal wires without the necessity of breaking the vacuum seal in the explosion chamber, a technique which could not be accomplished by prior art wire explosion devices.



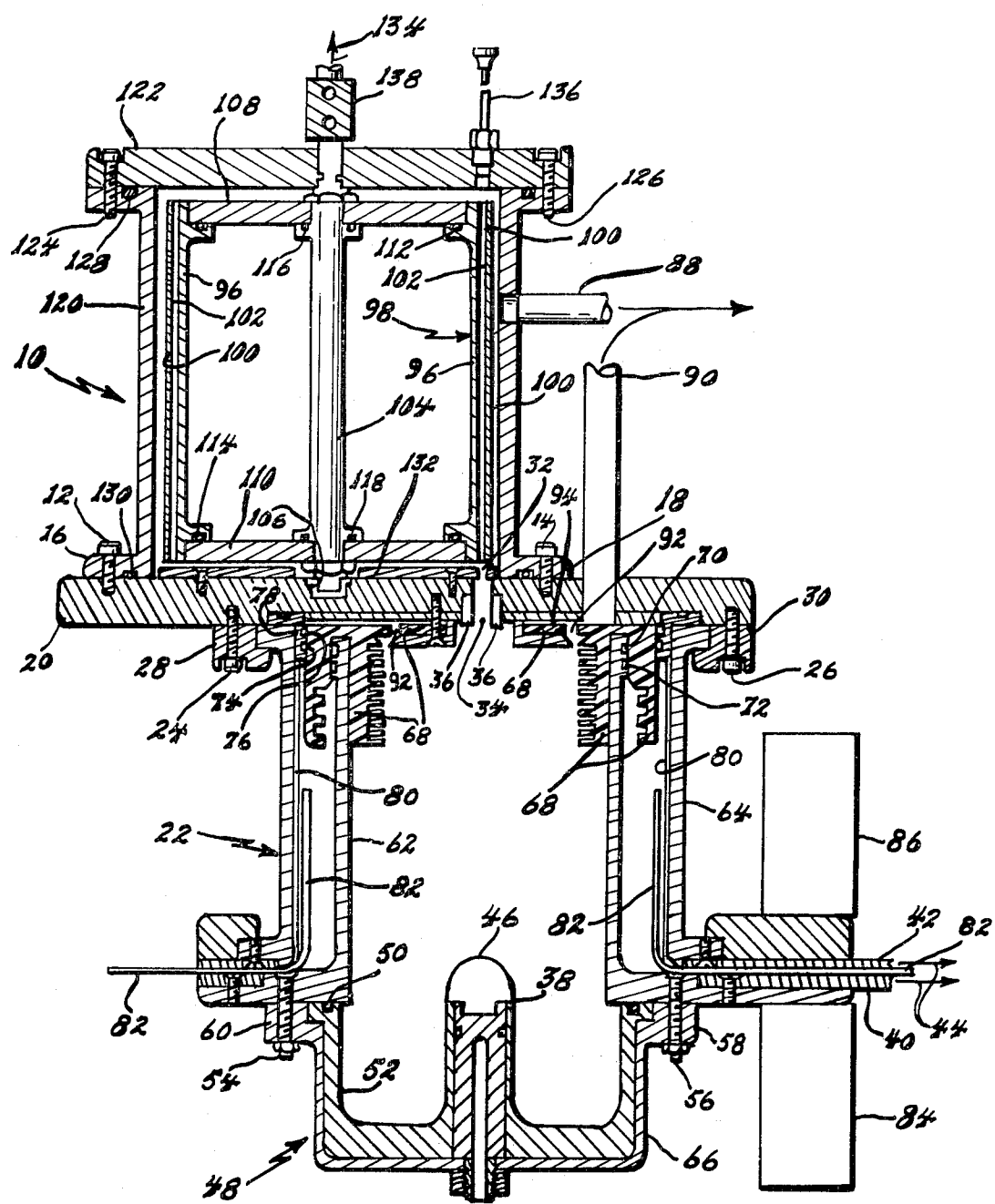


FIG. 1

INVENTORS
RICHARD L. JOHNSON
BERNARD SIEGEL
BY *Harry A. Herbert Jr.* and *William F. O'Brien*
ATTORNEYS

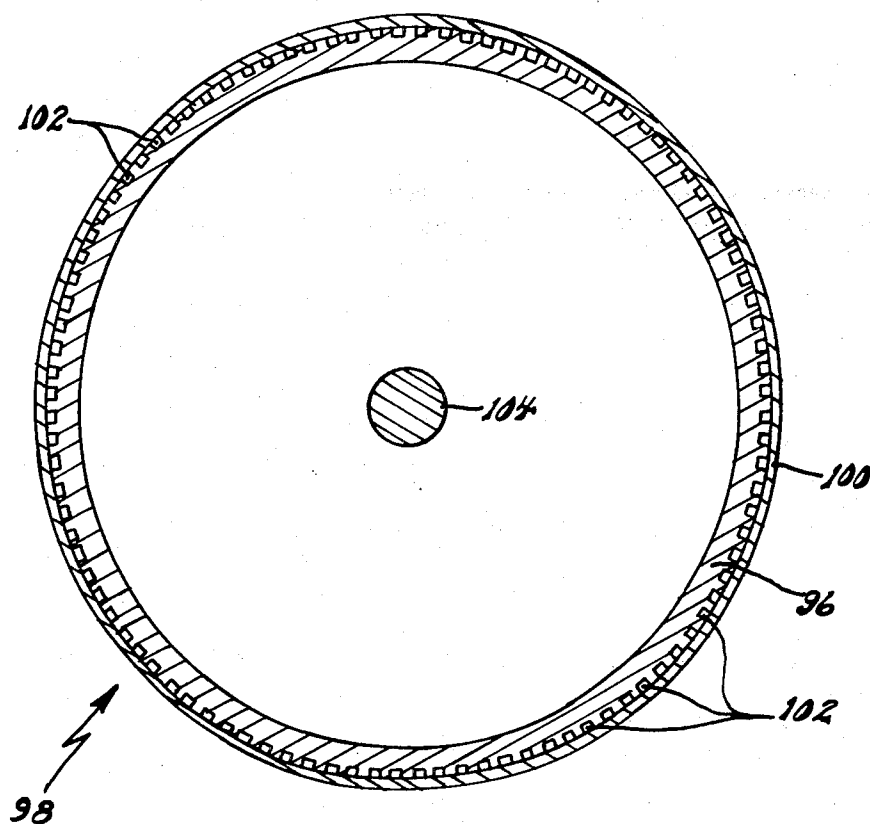


FIG. 2

INVENTORS
RICHARD L. JOHNSON
BERNARD SIEGEL
BY *Harry A. Herbert Jr.*
William F. C. B. A. S.
ATTORNEYS

METAL EXPLOSION APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to a metal explosion apparatus. More particularly, this invention concerns itself with an apparatus for achieving a series of successive metal wire explosions, in which a large number of metal wires can be explosively converted into a very high-temperature vapor.

The exploding wire phenomenon in which a conducting metal, usually a metal wire or metal foil, is exploded is well known. Generally, the explosion of the metal wire is achieved by transferring the stored energy of a bank of capacitors to the electrically conducting metal wire in a time interval so short that the energy is conserved in the conductor until explosive vaporization or liquification results. This phenomenon can be utilized for a number of becomes Most of the applications are primarily physical but the phenomenon also has chemical applications. Among the chemical uses are the synthesis of chemical compounds, the elucidation of high temperature reaction mechanisms and the elucidation of the structure and bonding in metal-hydrogen solid solutions. Also, it can be used in diagnostic studies of the chemical effects of metal explosions and various gases. A practical limitation to the effective use of the exploding wire phenomenon in the chemical disciplines has arisen however, because of the relatively small amounts of chemical compounds that can be generated by a single-wire explosion. This problem becomes especially serious when the chemical application is that of product synthesis.

In general, the chemical reactors used heretofore to accomplish the explosion of a metal wire included pole electrodes. The wire to be exploded was affixed to the electrodes by set-screws. The reactor was then sealed, evacuated and a suitable gas, such as methane, introduced into the reactor to a desired pressure. The wire was then exploded by a suitable firing system which included a capacitor arrangement for storage of sufficient electrical energy and a switching arrangement such as a mechanical Jennings vacuum switch. After firing, the reactor was opened for the recovery of a synthesized chemical product. However, the amount of metal that could be exploded was generally less than 2 grams, thereby setting an undesirably low maximum for the quantity of chemical product synthesized by these prior art devices. Obviously, the synthesis of a larger amount of a specific product could be accomplished with prior art apparatus only if the products of a large number of individual explosions were combined. This would entail an expensive, and cumbersome procedure, however, which would not readily lend itself to the synthesis of relatively large quantities of chemical compounds.

The problem of not being able to synthesize large quantities of chemical products with prior art reactors arose because of the necessity for opening up the reactor after each wire explosion in order to affix the next wire to be exploded to the electrodes. This procedure not only involved a time-consuming resealing procedure but also created the necessity for a prolonged reevacuation of the reactor to remove newly introduced air.

With the present invention however, the disadvantages encountered by employing a single-wire explosion technique have been overcome by providing an apparatus that permits a series of successive explosions of a plurality of individual metal wires in rapid fire order. The invention comprises an apparatus composed of an upper assembly for storing a plurality of metal wires and a lower assembly into which individual wires are dropped and exploded by a suitable firing mechanism. The upper assembly includes a cylindrical housing for storing a plurality of metal wires. It is rotatable about a central axis in such a manner as to permit individual metal wires to drop successively through an orifice into the lower assembly for subsequent explosion.

SUMMARY OF THE INVENTION

It has been found that successive and continuous explosions of a plurality of metal wires can be accomplished by utilizing the apparatus of this invention; thereby providing a solution to the problem of synthesizing relatively large amounts of chemical compounds in accordance with the well-known metal wire exploding technique.

The application of the exploding wire phenomenon to the synthesis of chemical compounds has not encountered widespread acceptance in the field of chemistry because of the relatively small production runs accomplished by using prior art apparatus. The single-wire explosion technique used heretofore is an expensive and cumbersome procedure because it was necessary to open the reactor and break the vacuum seal in order to insert additional wires. The reactor, as a consequence, had to be reevacuated to provide the necessary vacuum conditions before the introduction of the reactant gas. The present invention, however, provides a novel means by which the synthesis of chemical products through a metal wire explosion reaction can be accomplished with a high degree of efficiency.

Accordingly, the primary object of this invention is to provide an apparatus for effecting successive electrical explosions of a plurality of metal wires.

Another object of this invention is to provide vacuum-sealed apparatus capable of producing successive and continuous explosions of a large number of metal wires without breaking the initial vacuum seal of the apparatus.

Still other objects and advantages of the present invention will become more readily apparent upon consideration of the following detailed description thereof when taken in conjunction with the accompanying drawings.

DESCRIPTION OF DRAWINGS

In the drawings:

FIG. 1 is an elevational view in cross section of the metal wire explosion apparatus of this invention.

FIG. 2 is an enlarged top view in cross section of the rotating cylindrical housing element of FIG. 1.

Referring to FIG. 1 of the drawing, there is shown a preferred form of the apparatus of the invention. The apparatus comprises an upper storage assembly 10 affixed by means of bolts 12 and 14 acting upon flanges 16 and 18 to a baseplate 20. A lower explosion assembly 22 is laterally displaced below the upper assembly 10 and in turn is affixed to the bottom portion of the baseplate 20 by means of bolts 24 and 26 acting upon dogs 28 and 30. An orifice 32 is located at the bottom of the assembly 10 and is interconnected through a passageway 34 in the baseplate 20 to the lower assembly 22. Two stationary electrodes 36 and 38 are located in lower assembly 22 and are connected by means of conducting plates 40 and 42 to a bank of electrical capacitors not shown. It has been found that a bank of six 14'-microfarad storage capacitors of 20 kv. rating can provide a sufficient magnitude of electrical energy to operate effectively the apparatus of the invention. The conducting plates 40 and 42 are connected to the terminals of the bank of capacitors as indicated by the arrows at 44.

The electrodes 36 and 38 are positioned in axial alignment one above the other so that a wire falling through the orifice 32 must strike the bottom or target electrode 38 while simultaneously making electrical contact with the upper ring electrode 36 situated just below the orifice 32. The ring electrode 36 and the tip 46 of the target electrode 38 are preferably fabricated from tungsten. Tungsten is employed because of its erosion resistance. Softer metals, such as stainless steel, erode appreciably when subjected to the explosion condition generated within the lower explosion assembly 22.

The metal wires which are to be exploded are generally of about 30 mil in diameter. This diameter is very much smaller than the interval diameter of the upper ring electrode 36. Therefore, the wire cannot make direct contact with the ring

electrode 36 unless it tips over to one side. While this is possible, it is more likely that the high voltages imposed on the electrode make direct contact unnecessary. In all likelihood, electrical contact is made through a short spark gap. Although the actual distance between the tip of the target electrode 38 and the bottom of the upper ring electrode 36 is about 6 inches, the most efficacious length of the wire to be exploded must be determined empirically, and varies with the voltage applied to the two electrode terminals. At an applied voltage of 15 kv., the wire length can be approximately equal to the actual distance between the electrodes, but at lower voltages the wire length should be increased somewhat to avoid a high incidence of unexploded wires. Even those wires that do explode, however, produce short lengths of unexploded ends that fall into the lower assembly 22 or are blown into the upper assembly 10. These unexploded ends must eventually be removed from the powdered chemical products when the latter are recovered. Since it is desirable to minimize the size of such unexploded ends, it is preferred that minimum wire lengths, consistent with a high incidence of successful explosions, be utilized.

The lower portion 48 of the lower explosion assembly 22, is sealed to the top portion of the assembly by an O-ring 50 recessed in the inner wall 52 of portion 48. Removal of lower portion 48 is made easy by simply unfastening bolts 54 and 56 which act upon flanges 58 and 60. It is from portion 48 that one obtains the major portion of recoverably solid nonvolatile products. The inner walls 52 and 62 of the lower assembly 22 are preferably made of stainless steel to protect against the extreme explosion conditions. Because the electrical path between the electrodes 36 and 38 and the bank of capacitors (not shown) is through the outer walls 64 and 66 of the explosion chamber 22, the outer walls are made of aluminum. A rather complex-shaped Teflon section 68 fits over the stainless steel inner wall 62 of the upper portion of assembly 22. This arrangement electrically insulates the upper electrode 36 from the lower electrode 38. The Teflon section 68 is multigrooved as shown in order to minimize the tendency for continuous film formation on its surfaces.

The upper portion of assembly 22 is sealed from the outside environment by four O-rings 70, 72, 74 and 76; two of these O-rings namely 70 and 72, are recessed in the outer surface of the inner wall 62. The other two O-rings, namely 74 and 76 are recessed in a steel ring 78 that fits between the Teflon section 68 and the aluminum outer wall 64. The Teflon section 68 slides past O-rings 70, 72, 74 and 76. This arrangement was found preferable because the explosions tend to move the Teflon section and thus open the end-to-end seals. Air remains in the space between the aluminum outer wall 64 and the stainless steel inner wall 62. To prevent electrical contact between electrodes 36 and 38, it was necessary to insulate the inner wall 62 from the outer wall 64. This was accomplished effectively by the insertion of an insulator 80 comprised of four layers of 7.5'-mil Mylar.

The establishing of electrical contact between the electrodes 36 and 38 and the bank of capacitors (not shown) can be seen from the arrangement in the lower right-hand side of the drawing in FIG. 1 as indicated by the arrows. The two aluminum bus bar plates 40 and 42 are separated by an insulating strip 82, such as polyvinylchloride insulation. The upper bus bar 40 is a 1/8-inch plate, whereas the lower plate 42 is one-fourth inch. The lower plate is thicker because it supports the weight of the explosion apparatus.

The entire explosion apparatus can be conveniently mounted on a bank of capacitors. Preferably, three pairs of 14'-microfarad capacitors, placed at angles of 120° to each other are employed to provide the magnitude of electrical energy needed to effect a wire explosion. Three pairs of phenolic clamping bars are used to compress three pairs of bus bar plates. However, in the interest of better viewing, the drawing shows only one pair of phenolic clamping bars 84 and 86 compressing one pair of bus bar plates 40 and 42, which in turn are connected to a capacitor (not shown) as indicated by the arrows.

Single tubes 88 and 90 have been welded to the upper and lower assemblies 10 and 22 of the apparatus in order to provide for gas flow manipulation. Direct gaseous contact between the two assemblies, however, is made only through the orifice 32 that separates them. Gases from the lower explosion assembly 22 reach tube 90 by passing through a series of holes 92 in the Teflon section 68. These holes are in contact with narrow space 94 as depicted in the drawing. The tube 90 is fitted with a valve, not shown, at a short distance from the apparatus. For runs aimed primarily at the formation of powdered nonvolatile products, it has been found convenient to close this valve during a production run, thereby preventing powders from blowing into the gas-handling system.

The sidewall 96 of the rotating hollow cylindrical housing 98 is positioned directly above the orifice 32. Details of the housing 98 can be discerned more readily by referring to FIG. 2. A plurality of slots 102 are placed in the outer periphery of the wall 96 of cylinder 98. The wall 96 is preferably made of stainless steel. The slots 102 are formed by making 1/14'-inch longitudinal grooves in the wall 96 and then enclosing these grooves with a thin steel sheath 100. An axle 104 forms a central support for the rotating cylinder 98 and fits into a lubricated bearing 106. The cylinder is situated such that each slot lines up with the orifice 32 when the cylinder 98 is rotated about the axle 104. The upper and lower plates 108 and 110 of the cylinder 98 are formed of alumina and vacuum sealed by O-rings 112, 114, 116 and 118. The outer wall 120 of the upper assembly 10 is made of stainless steel and is fitted with an easily removable aluminum lid 122 by means of bolts 124 and 126. The space in the center of the hollow rotating cylinder 98 is never in contact with either exploding wires or surrounding gaseous reactants and, therefore, is permanently filled with air. O-rings 128 and 130 seal the outer wall 120.

The slots 102 in the rotating cylinder 98 are slightly longer than the wires which are to be exploded. The wires touch the stainless steel plate 132 containing the orifice 32. The plate 132, in effect, comprises the floor for the slots 102. The wires drag against the plate 132 when the cylinder 98 is rotated. The torque necessary to rotate cylinder 98 having 100 slots 102, each slot being loaded with a wire, was determined to be about 13 inch-ounces. A 50'-inch-ounce stepping motor, now shown, was attached to the axle 104 of the rotating cylinder 98 as indicated by arrow 134.

A plunger arrangement 136 is positioned in the lid 122 of the upper assembly 10 to eject exploding wires which occasionally fuse to the bottom surface of lower plate 132. When the alumina of lower plate 132 is replaced by stainless steel, however, the fusion to plate 132 of the hot but unexploded wire ends is eliminated. Consequently, the mechanical plunger 136 during the wire-loading process prior to a production run, although useful, is not necessary.

With the aluminum lid 122 removed, but the apparatus otherwise assembled, the rotating cylinder 98 is aligned so that one of the slots 102 is centered directly above the orifice 32. The cylinder is then locked in this arrangement by pushing a long indexing rod through both slot 102 and the orifice 32. The metal wires to be exploded are then placed into the 99 remaining slots (or some fraction thereof). The wires should be perfectly straight in order to fall freely when rotated over the orifice. Wires with slight bends oftentimes do not fall through the orifice but remain in the slot. After the wires have been inserted in the cylinder 98, the indexing rod is removed. Using the plunger 136 to keep the rotating cylinder 98 in a locked position while affixing the lid 122 prevents the accidental dropping of wires through the orifice 32 to the lower assembly 22. The stepping motor not shown, is then connected to the axle 104 by a coupling means 138, and the plunger 136 is withdrawn into the cylinder lid 122. The entire system is then evacuated by pumping through exit tubes 88 and 90. The valve, not shown, in the lower tube 90 is then closed. Reactant gas is then introduced to a predetermined pressure via the upper tube 88 which is then closed by valving means not shown. The bank of capacitors, not shown, is then charged to a desired potential. Preferably, a circuit which

operates nominally at 100 milliamperes is used. With this system the capacitors can be charged to 15 kv. in less than 1 minute. The stepping motor is then activated and the cylinder 98 rotated one increment, so that the next slot is centered above the orifice 32. This causes the first wire to fall onto the target electrode 38 and thus to explode. If the gas introduced at the start is sufficient to account for chemical reaction of a number of wires, it is possible to continue firing into this gas by recharging the capacitors and further rotating the cylinder. Otherwise the now complex gas mixture must be withdrawn and replaced with fresh gas reactant.

Because of the potentially hazardous nature of the metal explosion technique, the operation of the apparatus is preferably carried out by remote control. For example, after the apparatus is assembled and the wires inserted, it is enclosed in a wooden barricade which maybe mounted on wheels for convenient moving. The charging of the capacitors and activation of the stepping motor are effected from behind the barricade. Although the apparatus shown in the drawing is not automatic, the system is quite adaptable to automation. If multiple explosions are carried out in a single atmosphere of gaseous reactant, the interval between explosions is determined by the charging time and, in most situations, is less than a minute. If the gaseous content reactants are changed after each explosion, the interval between explosions would then be determined by the pumping capacity of the gas transfer system.

If the desired products of the explosion reactions are non-volatile solids, considerable time can be saved by recovering only the products that accumulate in the receptacle of the lower chamber 22 and on the top of the rotating cylinder. By simply unfastening the lower receptacle and recovering the solids deposited therein a major portion of the synthesized recoverable product can be recovered quite easily. The remainder is mainly blown up through the orifice 32 and can be found primarily on the upper surface of the rotating cylinder. The latter is also readily accessible and the product can be recovered by simply removing the aluminum lid 122 and lifting the cylinder 98 from its bearing. Smaller amounts of solid products are found elsewhere and can be recovered, if desired, by a complete stripping of the many parts of the apparatus.

During actual use of the apparatus of this invention, the multiple explosions of 30-mil tungsten in oxygen produced a powdered product that was shown to be 98 percent WO_3 ; the

remainder was primarily tungsten metal, along with traces of other materials. Multiple explosions of 30-mil tungsten wire in an atmosphere of phosphorous pentafluoride, at applied voltages of 8 to 15 kv., produced subfluorides of tungsten having a chemical composition WF_n , wherein n is an integer of from about 0.2 to about 0.4. The recoverable yield of powdered products, however, tended to decrease with increasing applied voltage. At 8 kv., 80 percent of the exploded metal was recovered as $WF_{0.3}$. It was found that 95 to 96 percent of the tungsten wire had actually exploded (either in PF_5 or O_2). The unexploded portion was found as short wire ends protruding out of the powdered products, and were readily separable from the latter.

While the invention has been described with regard to a preferred embodiment, it will be apparent to those skilled in the art that numerous variations and modifications may be made without departing from the spirit and scope of the invention. Thus, it is not intended to limit the invention in any way except as defined by the appended claims.

We claim:

1. A metal wire explosion apparatus comprising an upper feed assembly having a closed outer housing and a cylindrical housing rotatable about a longitudinal axis disposed within said outer housing, a plurality of longitudinal slots located on the outer periphery of said cylindrical housing for aligning metal wires parallel to said longitudinal axis, said slots being disposed around the circumference of a circle having said longitudinal axis as its center, means positioned in the top of said upper feed assembly for providing a positive feed force to said means for aligning, a lower explosion assembly secured to said upper feed assembly, means positioned in said upper assembly and said lower assembly for introducing an expelling a gaseous material, an orifice interconnecting said upper and lower assembly and in axial alignment with one of said slots for aligning whereby metal wires may be gravity fed to said lower explosion assembly, a first electrode positioned within said orifice, a second electrode positioned within said lower assembly and in axial alignment with said first electrode for contacting the end of a metal wire which is fed from said means for aligning through said orifice to said lower explosion assembly such that the metal wire extends between, and comes in simultaneous contact with, said first and second electrodes, and high-power electrical means connected with said electrodes for providing electrical energy of a magnitude sufficient to effect an explosion of a metal wire.

* * * * *

50

55

60

65

70

75