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(54) **Heat extracting crucible for rapid solidification casting of molten alloys.**

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FR-A-2 410 368
GB-A- 903 530
GB-A-1 428 691
GB-A-1 517 283
US-A-4 077 462

Technical Report AFMR-TR-78-70 "Amorphous Glassy Metals and Microcrystalline Alloys For Aerospace Applications", pages 13 to 17 by E.W. Collings R.E. Maringerl, C.E. Mobley

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Courier Press, Leamington Spa, England.

Description

The present invention relates to an apparatus for rapid solidification casting of high temperature and/or reactive metallic alloys.

Melt-spinning is one well established rapid solidification technique which has frequently been used to cast amorphous metal ribbons. To melt-spin a stable liquid jet of molten material is formed by ejection of the liquid through an appropriate orifice or nozzle, and then the jet of molten material is solidified on a moving heat sink. This technique is further described on pages 13 through 17 of a technical report, AFMR-TR-78-70 entitled "Amorphous Glassy Metals and Microcrystalline Alloys for Aerospace Applications" by E. W. Collings, R. E. Maringer, and C. E. Mobley. This report points out that while melt-spinning is particularly suited for producing the wire ribbon fibers of many nonreactive low melting alloys, the requirement of a stable crucible/orifice and jet severely limit the process utilization. The report states that titanium filaments have not be melt-spun since a stable crucible material is unavailable, and that operating difficulties with the orifice and jet have been encountered in attempts to melt-spin such materials as boron, beryllium and other reactive alloys.

The FR—A—2 410 368 discloses an apparatus for casting metal filaments directly from the melt comprising a crucible with means for supplying heat to melt the metal, with a nozzle with a chill wheel and with means for controlling the ejection of the molten metal. Because of the interaction between the melt and the crucible it cannot be used to cast high temperature and/or reactive metallic alloys.

High temperature nickel-base, nickel, chromium, titanium, aluminum alloys have been melted in watercooled copper crucibles. For example, GB—A—1,517,283 discloses the use of a water-cooled crucible for melting and containing nickel-base alloys. The metal is removed from the crucible by spinning the crucible about its axis to generate atomized particles of liquid which move out radially from the edge of the crucible. This patent offers no teaching that the metal can be extracted from the crucible through an orifice of limited dimensions.

GB—A—1,428,691 discloses melting materials in water-cooled molds. The melt is then solidified *in situ*. Again, this patent offers no teaching of a technique for the extraction of liquid metal from a water-cooled mold through a constricted orifice. Thus, while the above examples show a method for melting materials in water-cooled crucibles, they provide no teachings of the use of these crucibles for melt-spinning.

Figure 2 of GB—A—903,530 in combination with page 1 line 87 to page 2 line 8, discloses a crucible, parts of which are water-cooled to form a deposit of semi-solidified melt, but the problem of the invention, that an interaction between the crucible and the melt is avoided, is not solved by GB—A—903,530 since there only parts of the crucible are covered with semi-solid, spongy metal of the melt—with the purpose to serve as a valve seat for the valve stem—whereas the liner of the crucible is not protected with such a deposit of solidified material of the melt so that the melt could interact with the liner. As a consequence GB—A—903,530 would not put a person skilled in the art in a position to find the subject matter of the invention. Cross reference is made to the EP-application 81 108 161.1 disclosing a layer-protected crucible.

The objective on which the invention is based, is to provide an apparatus suitable for casting metal filaments or powders directly from the melt, but preventing interaction between the melt and the crucible.

The apparatus according to the invention comprises a crucible which is constructed of thermally conductive material for holding a metal charge, means for supplying heat to melt the metal charge contained in said crucible to form a melt of molten metal, a nozzle forming an integral part of said crucible for ejection of a stream of molten metal, means for rapidly quenching the stream of molten metal and means for controlling the ejection of the molten metal, and is characterized in that one or more cooling passages are arranged internal to said crucible for passing a cooling medium therethrough to provide a solidified layer of the melt for preventing interaction between the melt and said crucible.

Fig. 1 is a schematic representation of one molten material supply of the present invention which employs a single electrode.

Fig. 2 is a schematic representation of the molten material supply of Figure 1 used in combination with a chill casting wheel.

Fig. 3 is a schematic representation of a molten material supply and a chill wheel which are enclosed in a chamber to provide a controlled atmosphere.

Fig. 4 is a schematic representation of a second molten material supply which employs two electrodes where the stream of molten metal is chilled and atomized by a gas stream.

Referring to Fig. 1 a heat extracting crucible 2 is employed for containing molten metal 4. A nozzle 6 is attached to heat extracting crucible 2 and forms an integral part thereof.

The heat extracting crucible 2 and the nozzle 6 are preferably made of a high conductivity material such as copper, brass or graphite. In order to increase the heat extracting capacity of the heat extracting crucible 2, the crucible has a channel 8 for the passage of water therethrough. The water inlet 10 and outlet 12 allow the water to flow through the channel 8.

The molten metal 4 is ejected through the nozzle 6. The flow of the molten metal 4 is controlled by a shutter 14. The shutter is guided by a track 15.

Heat is supplied to melt a metal charge and/or to the molten metal 4 by an arc 16 which is struck between an electrode 18 and the charge of the molten metal 4. The electrode 18 is attached to an electrode holder 20 which is water-cooled. A potential is supplied by voltage supply 22 between the electrode holder 20 and the heat extracting crucible 2. It should be appreciated that other heating means such as an e-beam or a laser beam could be employed to supply heat to the molten metal 4.

The heat extracting crucible 2 has a crucible cover 24 attached thereto. The crucible 2 and the crucible cover 24 form a chamber 25 which provides control of the atmosphere over the molten metal 4. The crucible cover 24 has sidewalls 26 which are watercooled by cooling coils 28.

The crucible cover 24 has a removable top 30. The top 30 is connected to the sidewalls 26 via a flange 32. Electrode holder 20 passes through the removable top 30 and is electrically insulated from the top by seal 34. A gas outlet 36 in the removable top 30 is connected to a two-way valve 38. The valve 38 in one position allows gas to be evacuated from the chamber 25 by a vacuum pump not shown and in the second position allows an inert atmosphere such as argon to be supplied to the chamber 25.

Fig. 2 is a schematic representation of the molten metal supply of Fig. 1 used in combination with a rotating chill wheel 40 having a circumferential edge 42. The chill wheel 40 is rotated by a motor 44. The heat extracting crucible 2 may be positioned relative to the chill wheel 40 by two orthogonal slide mechanisms 46 and 48. When the nozzle 6 is positioned near the peripheral edge 42 of the chill wheel 40, the shutter 14 is opened by the shutter release 50.

When it is advisable to control the atmosphere in which the ribbon is cast as well as the atmosphere under which the material is melted, a second chamber 52 encloses the chill wheel 40 and the heat extracting crucible 2, as is illustrated in Figure 3. The electrode holder 20 passes through the removable top 30 of the melt chamber 25. The removable top 30 also serves as the top of the second chamber 52. The removable top 30 has an inlet 56 for evacuating the melt chamber and a valve 58 to block the inlet 56. Likewise an outlet 60 having a valve 62 is used to provide a controlled atmosphere by the inlet of a gas such as argon. Inlet 64 and outlet 67 respectively allow evacuation and refilling of the second chamber 52 with a gas such as argon. The valves 66 and 68 control the flow of gas respectively through the inlet 64 and outlet 67.

When the molten metal 4 is fully molten, a skull 69 will be between the crucible 2 and the molten material 4. When the shutter 14 is removed from the nozzle 6, a stream will impinge on the peripheral edge 42 of the chill wheel 40.

Rather than employing a shutter 14, it is possible to use other means to constrain the flow of molten material through the nozzle 6. One such other means would be to place a small plug of low melting material in the nozzle 6. As the melt reaches temperature, the low melting material would soften; and when the argon pressure is increased in the melt chamber 25, the plug would be dislodged from the nozzle 6, and a stream would flow through the nozzle 6.

Another means to control the ejection of a molten material is illustrated in Fig. 4. A water-cooled stopper rod 70 is employed to block the passage of the nozzle 6. When the stopper 70 is raised, a stream will issue from the nozzle. The stream can be rapidly quenched by impinging the stream with a jet of gas 78 from a gas nozzle 80 thereby atomizing the stream and promoting its cooling to form a rapidly-cooled powder product. An insulating nozzle sleeve 72 lines the nozzle 6. The nozzle sleeve 72 may be heated by an induction coil 74 in the event that the nozzle sleeve is coupleable to the magnetic field of the induction coil, or alternatively a graphite susceptor 76 may be contacted to the nozzle sleeve, spare and heat induced into the graphite susceptor 76.

For the configuration in Fig. 4, two electrodes are employed. The electrodes 18 are held in electrode holders 20, and mounted through the removable top 30 by pivotable sealed joints 77. A voltage from a supply (not shown) is applied between the two electrode holders. An arc is struck between the electrodes 18 and the molten material 4.

Example

An arc furnace similar to the furnace shown in Fig. 3 was employed. Both the melt chamber and the second chamber enclosing the rotating wheel were evacuated to 10^{-4} Torr (1.33×10^{-2}Pa) and subsequently back-filled with high purity argon. The pressures in both chambers were equalized at about 20 cm of mercury. A charge weighing between about 50 to 100 grams was melted employing a non-consumable tungsten electrode.

The melt was ejected through the nozzle by sliding away the shutter while increasing the pressure in the furnace by about 10 cm of mercury. Typical orifice sizes for the nozzle were between about 0.06 inch (0.15 cm) and 0.1 inch (0.25 cm). The lower limit assures that it is possible to maintain a stream which does not chokeoff, while the upper limit assures the flow will be sufficiently restrained to establish a filament of uniform cross-section.

Several metallic glass-forming alloys containing reactive metal such as titanium, zirconium, niobium and chromium were ejected onto the rotating wheels to form continuous ductile ribbons of good quality. Examples of the

alloys cast were $Ti_{50}Cu_{50}$, $Zr_{70}Ni_{30}$, $Zr_{70}Ni_{15}Cu_{15}$, $Nb_{60}Ni_{40}$, and $Fe_{40}Ni_{30}Cr_{10}B_{20}$.

Claims

1. Apparatus for rapid solidification of a molten metal comprising a crucible (2) which is constructed of thermally conductive material for holding a metal charge,

means (18) for supplying heat to melt the metal charge contained in said crucible to form a melt of molten metal (4), a nozzle (6) forming an integral part of said crucible (2) for ejection of a stream of molten metal,

means (42, 80) for rapidly quenching the stream of molten metal and

means (14, 70) for controlling the ejection of the molten metal, characterized in that one or more cooling passages (8) are arranged internal to said crucible for passing a cooling medium therethrough to provide a solidified layer of the melt for preventing interaction between the melt and said crucible.

2. The apparatus of claim 1 wherein said thermally conductive material is electrically conductive, said means (18) for supplying heat to melt the metal charge is one electrode associated with said crucible (2) employed for striking an arc (16) between said electrode and the metal charge contained in said crucible; and said means (42) for rapidly quenching the stream of molten metal is a chill surface provided by a heat extracting member (42) for deposition of molten metal thereon for quenching into filament, together with means (44) for advancing said chill surface.

3. The apparatus of claim 2 wherein said means (14) for controlling the ejection of the metal stream comprises a shutter which, when closed, blocks the flow of metal through said nozzle and a sealed crucible cover (24) to provide a crucible chamber (25) for controlling the pressure in the melt chamber, thereby providing a means for increasing the hydrostatic pressure on the melt to assist in the ejection of the melt through said nozzle.

4. The apparatus of claim 3 wherein said nozzle (2) has an internal diameter of between about 0.25 cm and 0.15 cm.

5. The apparatus of claim 3 wherein said nozzle (2) has an insulation insert having a passage therethrough, said passage having a diameter between about 0.25 cm and 0.15 cm.

6. The apparatus of claim 1 wherein said thermally conductive material is electrically conductive, said means (18) for supplying heat to melt the metal charge is at least two electrodes associated with said crucible (2) for striking arcs between the melt and said electrodes, and said means (42) for rapidly quenching the stream of molten metal is a chill surface provided by a heat extracting member (40) for deposition of molten metal thereon for quenching into filament, together with means (44) for advancing said chill surface.

Patentansprüche

1. Vorrichtung zur schnellen Verfestigung eines geschmolzenen Metalles mit einem Schmelzbehälter (2), der aus wärmeleitfähigem Material besteht, zur Aufnahme einer Metallbeschickung, Einrichtungen (18) für die Zufuhr von Wärme, um die in dem Schmelzbehälter enthaltene Metallbeschickung zu schmelzen und so eine Schmelze von geschmolzenem Metal (4) zu bilden, einer einen integralen Bestandteil des Schmelzbehälters (2) bildenden Düse (6) zum Ausstoßen eines Stromes von geschmolzenem Metall, Einrichtungen (42, 80) zum raschen Abschrecken des Stromes von geschmolzenem Metall und Einrichtungen (14, 70) zur Steuerung des Ausstoßens des geschmolzenen Metalles, dadurch gekennzeichnet, daß ein oder mehrere Kühlkanäle (8) im Inneren des Schmelzbehälters zum Durchleiten eines Kühlmediums durch sie angeordnet sind, um eine verfestigte Schicht der Schmelze zu bilden und so eine Wechselwirkung zwischen der Schmelze und dem Schmelzbehälter zu verhindern.

2. Vorrichtung nach Anspruch 1, bei der das wärmeleitfähige Material elektrisch leitfähig ist, die Einrichtungen (18) für die Zufuhr von Wärme, um die Metallbeschickung zu schmelzen, eine mit dem Schmelzbehälter (2) verbundene Elektrode ist, die verwendet wird, um zwischen dieser Elektrode und der in dem Schmelzbehälter enthaltenen Metallbeschickung einen Lichtbogen (16) zu erzeugen, und die Einrichtungen (42) für das schnelle Abschrecken des Stromes von geschmolzenem Metal eine Kühloberfläche, die von einem wärmeabziehenden Teil (42) für die Ablagerung von geschmolzenem Metall darauf zur Abschreckung zu einem Faden gebildet wird, zusammen mit Einrichtungen (44) zum Vorrükken der Kühloberfläche sind.

3. Vorrichtung nach Anspruch 2, bei der die Einrichtungen (14) zur Steuerung des Ausstroßens des Metallstromes einen Verschluß, der, wenn geschlossen, den Metallfluß durch die Düse blockiert, und einen dichtend aufgesetzten Schmelzbehälterdeckel (24) besitzen, um einen Schmelzbehälterkammer (25) zur Steuerung des Druckes in der Schmelzkammer zu liefern und so eine Einrichtung zur Erhöhung des hydrostatischen Druckes auf die Schmelze zu ergeben und das Ausstoßen der Schmelze durch die Düse zu unterstützen.

4. Vorrichtung nach Anspruch 3, bei der die Düse (2) einen Innendurchmesser zwischen etwa 0,25 cm und 0,15 cm hat.

5. Vorrichtung nach Anspruch 3, bei der die Düse (2) einen Isoliereinsatz mit einem Durchgang durch ihn hindurch hat, wobei dieser Durchgang einen Durchmesser zwischen etwa 0,25 cm und 0,15 cm besitzt.

6. Vorrichting nach Anspruch 1, bei der das wärmeleitfähige Material elektrisch leitfähig ist, die Einrichtungen (18) zur Zuführung von

Wärme zum Schmelzen der Metallbeschickung wenigstens zwei mit dem Schmelzbehälter (2) verbundene Elektroden zur Bildung von Lichtbögen zwischen der Schmelze und diesen Elektroden sind und die Einrichtungen (42) zum schnellen Abschrecken des Stromes von geschmolzenem Metall eine von einem wärmeentziehenden Teil (40) gebildete Kühloberfläche zur Ablagerung von geschmolzenen Metall darauf zum Abschrecken zu einem Faden zusammen mit Einrichtungen (44) zum Vorrücken dieser Kühloberfläche sind.

Revendications

1. Appareil pour réaliser la solidification rapide d'un métal fondu comprenant un creuset (2) construit en un matériau conducteur de la chaleur destiné à recevoir une charge de métal, des moyens (18) pour fournir de la chaleur pour fondre le charge de métal contenue dans ledit creuset pour y former un bain de métal fondu (4), une tuyère (6) formant partie intégrante dudit creuset (2) utilisée pour l'éjection d'un courant de métal de métal fondu, des moyens (42, 80) pour refroidir rapidement le courant de métal fondu et des moyens (14, 70) pour contrôler l'éjection de ce métal fondu, caractérisé en ce qu'un ou plusieurs passage(s) (8) de refroidissement sont disposées à l'intérieur dudit creuset pour laisser passage à un agent de refroidissement en vue de l'obtention d'une couche solidifiée du bain servant à empêcher une interaction entre le bain et ledit creuset.

2. Appareil selon la revendication 1 dans lequel ledit matériau conducteur de la chaleur est conducteur de l'électricité, lesdits moyens (18) pour fournir de la chaleur pour fondre la charge de métal consistant en une électrode associée audit creuset (2) employée pour amorcer un arc (16) entre ladite électrode et la charge de métal contenue dans ledit creuset; et lesdits moyens (42) utilisés pour refroidir rapidement le courant de métal fondu consistent en une surface de refroidissement fournie par un élément extracteur de chaleur (42) destiné à recevoir un dépôt de métal fondu en vue de son refroidissement à l'état de filaments, associé à des moyens (44) pour faire avancer ladite surface de refroidissement.

3. Appareil selon la revendication 2 dans lequel lesdits moyens (14) pour contrôler l'éjection du courant de métal consistent en un volet obturateur qui, lorsqu'il est fermé, bloque l'écoulement de métal à travers ladite tuyère et un couvercle (24) de creuset étanche pour constituer une chambre de creuset (25), en vue de contrôler la pression dans la chambre de fusion, réalisant ainsi un moyen pour accroître la pression hydrostatique sur le bain pour favoriser l'éjection du métal fondu à travers ladite tuyère.

4. Appareil selon la revendication 3 dans lequel ladite tuyère (2) a un diamètre interne compris entre environ 0,25 cm et 0,15 cm.

5. Appareil selon la revendication 3 dans lequel ladite tuyère (2) comporte une pièce d'insertion isolante traversée par un passage, ledit passage ayant un diamètre compris entre environ 0,25 cm et 0,15 cm.

6. Appareil selon la revendication 1 dans lequel le matériau conducteur de la chaleur est également conducteur de l'électricité, lesdits moyens (18) pour fournir de la chaleur pour fondre la charge de métal consistent en au moins deux électrodes associées audit creuset (2) pour amorcer des arcs entre le bain métal fondu et lesdites électrodes, et lesdits moyens (42) pour refroidir rapidement le courant de métal fondu consistent en une surface de refroidissement formée par un élément (40) extracteur de chaleur prévu pour recevoir le dépôt de métal fondu en vue de son refroidissement sous forme de filaments, en association avec des moyens (44) pour faire avancer ladite surface de refroidissement.

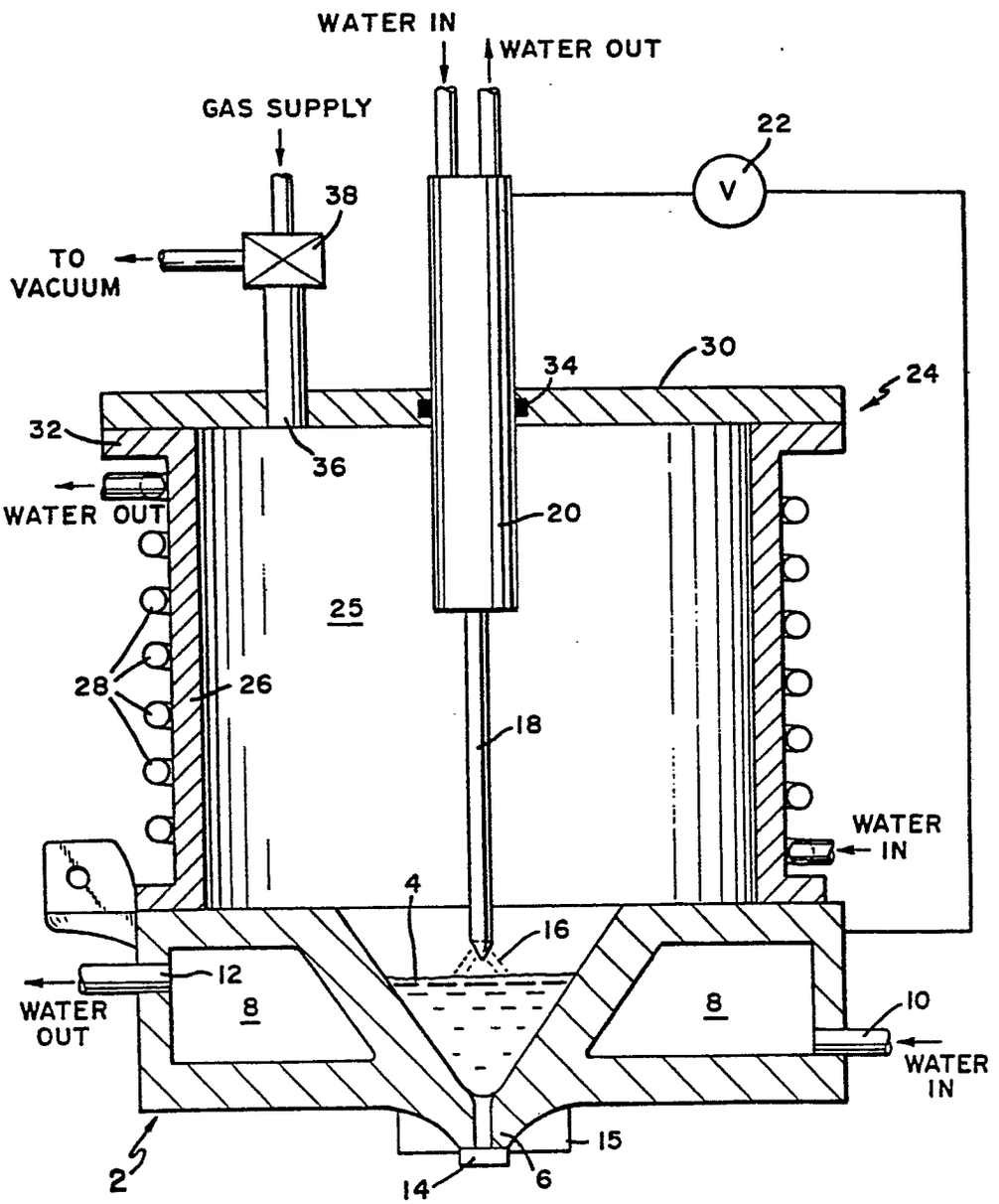

WATER IN
WATER OUT
GAS SUPPLY
22
V
38
TO VACUUM
30
34
24
32
36
WATER OUT
20
25
28
26
18
WATER IN
4
16
12
WATER OUT
8
8
10
WATER IN
15
2
14
6

FIG. 1

FIG. 2

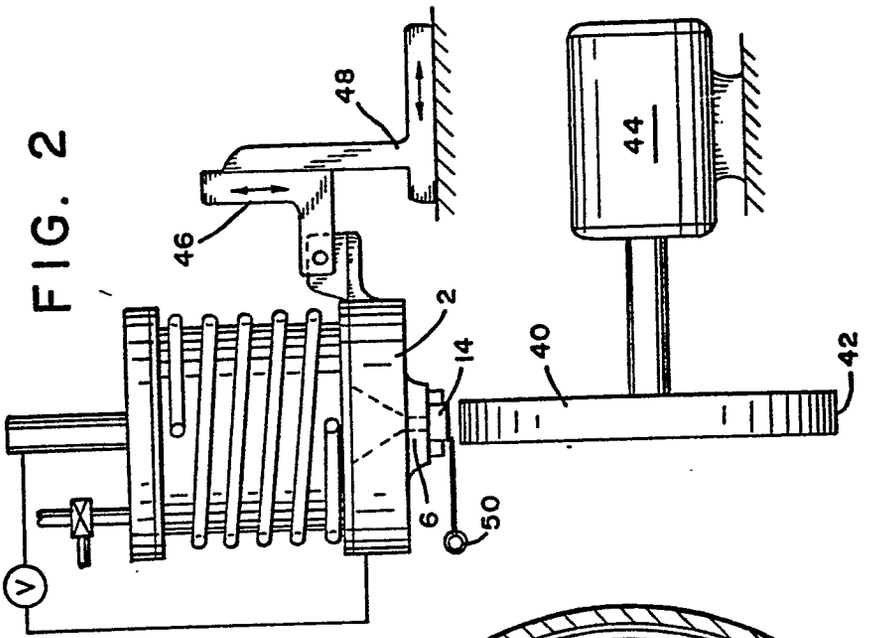

48
46
44
2
14
40
42
6
50
V

FIG. 3

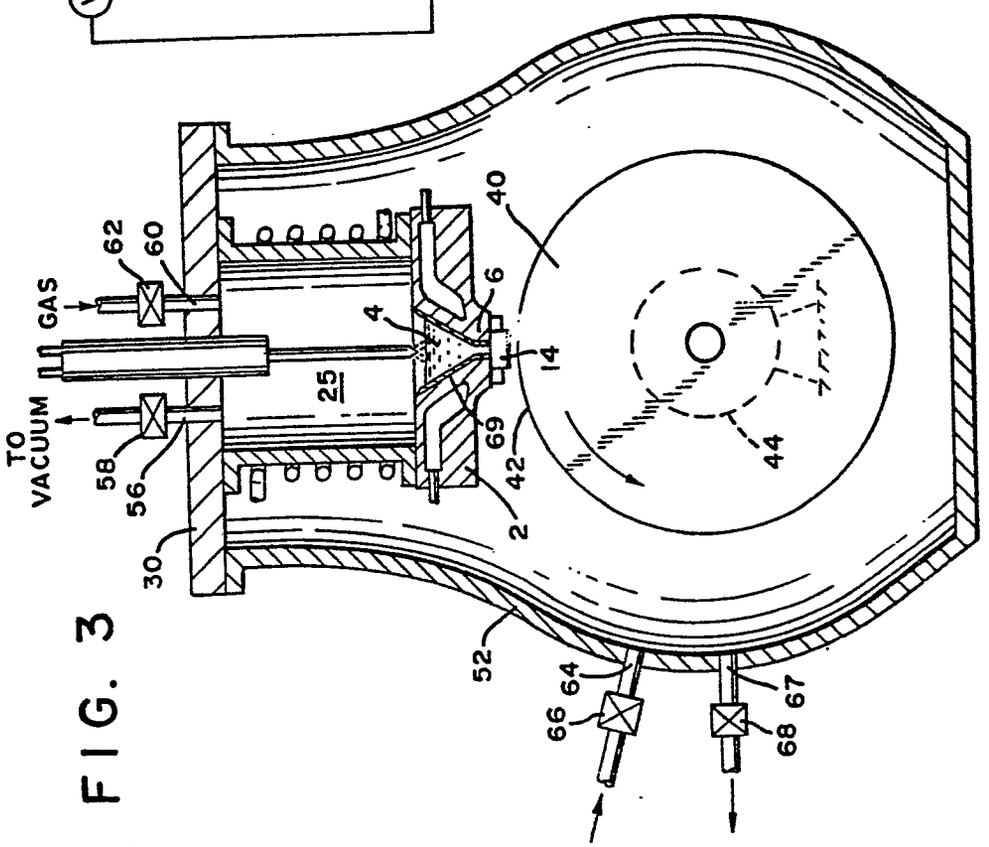

62
60
GAS
TO VACUUM
58
56
30
25
4
6
14
40
69
42
2
44
52
64
66
67
68

FIG. 4

