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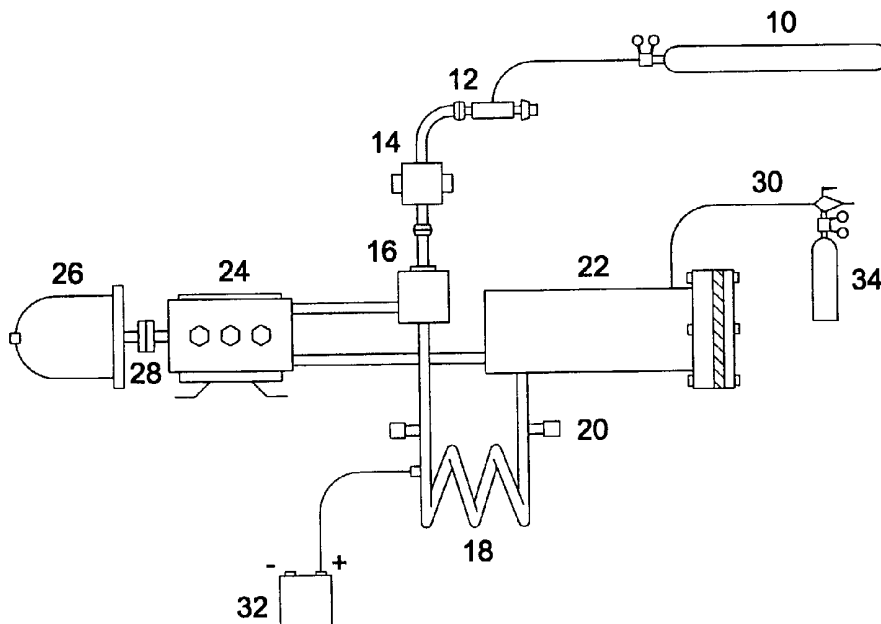
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(71) Applicant and
(72) Inventor: YENSEN, Robert, M. [US/US]; 4081 Minuteman Way, Boise, ID 83706 (US).

(54) Title: CONTROLLED-NUCLEAR-FUSION APPARATUS



(57) Abstract: Apparatus for heating plasmas, ions, and/or nuclei to high kinetic energies by entraining the plasmas, ions, and/or nuclei into a fluid and utilizing any combination of the following: (1) an electrically conductive and/or electrically charged fluid to suspend the plasmas, ions, and/or nuclei, (2) hydraulically/hydrostatically compressing the fluid, and/or (3) applying a frequency/frequency overlay(s) to the fluid and/or plasma. Means is provided to exhaust the plasmas, ions, nuclei and/or nuclear products from the fluid.



WO 02/05292 A2

Patent Application of

Robert M. Yensen

for

CONTROLLED-NUCLEAR-FUSION APPARATUS

BACKGROUND - Field of the Invention

This invention relates to an apparatus that compresses and/or heats nuclei for such periods of time that nuclear products, precursor fusion events, and/or nuclear fusion can occur in a controllable fashion.

BACKGROUND - Discussion of Prior Art

The release of energy from the nuclear fusion of light nuclei has been demonstrated adequately by the hydrogen bomb and, indirectly, by observations of the sun. Many billions of dollars have been spent developing fusion devices, however, the control of nuclear fusion has been elusive. Eventual control of nuclear fusion has the advantages of inexpensive fuel (e.g. hydrogen) with high energy output, limited atomic radiation (especially relative to fission), and limited nuclear waste materials. To date, fusion devices have not been able to confine a dense enough plasma, at high enough temperatures, for a long enough period of time. These devices are typically large and expensive (e.g. Tokamak) and have, economically, consumed more energy than they produce - only exceeding "scientific break-even" in isolated instances (which rendered the device unusable).

Nuclear fusion is achieved by heating nuclei until their kinetic energy is sufficient to overcome the repulsive forces (Coulomb repulsion) and fuse into heavier elements. Mass is converted to energy ($E = mc^2$) when resultant nuclei weigh less than the component nuclei (i.e. resultant nuclei up to atomic number 80). In order to contain a plasma at fusion temperatures ($10^8 - 10^9$ Kelvin) and not lose energy through conduction, nor melt the container, a confinement scheme is used to suspend the plasma. Typically, fusion devices rely on either magnetic confinement or "inertial confinement" during heating.

Magnetic confinement has the intrinsic disadvantage that the (light) nuclei can only be confined in two dimensions, e.g. Tokamak and other tori-shaped devices. Due to the magnetic field (ironically), the linearity of the confinement (two dimensions), the distribution of molecular speeds, and other factors, the nuclei become unstable at high temperature and are difficult to
5 confine. Compounding the problem, molecular confinement in two dimensions has a reduced probability of (potential) collisions, versus three dimensions. While combinations of magnets have been employed to create "three-dimensional" confinement schemes, true three-dimensional confinement, by magnetism, appears highly difficult.

Even though the plasma may be successfully suspended, energy loss through radiation
10 becomes a serious problem as heating continues. Synchrotron radiation, first described in cyclotron research, is caused by a magnetic field inducing circular motion (acceleration) in particles. Synchrotron radiation of 5 webers/m² (5×10^4 watts/m²) can be expected at 50 keV (Rose and Clark 1961:249). A similar phenomenon known as bremsstrahlung (radiation) occurs when an electron passes close to a nucleus and is accelerated (decelerated) by the nuclear charge
15 (Rose and Clark 1961:228), somewhat analogous to a space-probe planetary fly-by with velocity change.

R.W. Bussard, U.S. patent 4,363,775 (September 1982), U.S. patent 4,367,193 (January 1983), and U.S. patent 4,370,296 (January 1983) devised small toroid devices with a major radius
20 of 50 centimeters (cm) for plasma confinement. These devices, like their larger counterparts, have only two-dimensional (magnetic) confinement and (with a field of 100 K gauss) would induce significant energy loss through synchrotron radiation. Bussard also describes a device, U.S. patent 4,826,646 (May 1989), that intentionally injects electrons into a magnetic field with the intent of using the electron charges to cause the positively charged ions to produce collision
25 reactions. The strong magnetic field, and the placing of electrons in the proximity of positive ions, virtually guarantees high energy losses to both synchrotron and bremsstrahlung radiations. In U.S. patent 4,836,972 (June 1989), U.S. patent 4,859,399 (August 1989), U.S. patent 5,019,321 (May 1991), U.S. patent 5,049,350 (September 1991), U.S. patent 5,174,945 (December 1992), Bussard has further refined his toroid device by having a plurality of cooled
30 toroidal field coils. These magnetic fields, however, would still produce significant synchrotron radiation - and still not have true three-dimensional confinement, as the plasma is to take on a toroidal form. Bussard's U.S. patent 5,160,695 (November 1992) describes plasmas of ions and *electrons* that have spherical and cylindrical plasmas converge, causing a radial recycling of electrons and plasma which is intended to stimulate ion-acoustic electrostatic waves. In this case,
35 bremsstrahlung losses would become a major problem in achieving fusion conditions.

Along another tact, Bussard, U.S. patent 4,370,295 (January 1983), describes a fusion device that has fission reactions surrounding the fusion area using a toroidal confinement. As noted above, synchrotron and bremsstrahlung radiation losses are not adequately addressed and it is not clear how the release of fast neutrons from putative fusion events would be controlled to
40 avoid meltdown of the fissile material.

M. Yamada, H.P. Furth, T.H. Stix and A.M.M. Todd, U.S. patent 4,363,776 (December 1982), describe a device with the object of producing a "spheroid torus" or "spheromak." While suggestive of being three dimensional, it still retained the toroidal-plasma shape and employs magnetic confinement - which results in synchrotron radiation losses
45

Implosion devices, usually by laser, require great precision. They must attain extremely high temperatures because confinement times are correspondingly short. Such devices have problems of re-fueling, uneven energy release, and tend to destroy (parts of) themselves. While

the Lawrence Livermore National Laboratory has successfully reached fusion events using massive lasers for inertial confinement, which lasted 5×10^{-11} seconds (Tipler 1991:1355), this is still far from break-even. The billions of dollars required to build such a device (in football-field sized building) reduces the potential number (and portability) of such devices.

5 Ohkawa, U.S. Patent 4,269,658 (May 1981), describes an implosion device that compresses the plasma in two dimensions. Like the two-dimensional tori, it has reduced collision opportunities. Radiation losses are not well addressed, and because confinement is by magnetic field, synchrotron radiation would be a problem. This device was to be a cylinder with movable walls to compress the plasma. A heavy metallic cylinder was to rotate at 600 rpm, so it
10 would have to overcome the centrifugal force, plus the intrinsic inertia, in order to mechanically compress the plasma. The apparatus was to have hammers that would strike the walls in order to move them inward.

Sonoluminescence, discovered in 1933, is a phenomenon in which sound waves from
15 transducers (or other mechanical devices) create a cavitation in a liquid, usually water. The resulting collapse of the cavity heats gasses, specifically nitrogen and xenon, that might have been introduced therein, and light is emitted. The phenomenon classifies as an implosion device, but to date, has not achieved any appreciable fusion. Fast neutrons have not been detected, indicating that the light emitted is a non-nuclear event. Dr. W. Moss, of Lawrence Livermore
20 National Laboratory (according to Fisher 1998), suggests that *if* sonoluminescence were thermonuclear "... *it wouldn't be much of an energy source ... If I were to tile the world with SL [sonoluminescence] devices ... all the energy put together would be enough to heat a cup of water one degree.*" Using a frequency to create cavitations and/or to compress a gas is fundamental physics (e.g. propeller cavitation, "ultra-sonic" cleaning, sonoluminescence, etc.),
25 appreciated, but inadequate for producing (practical) nuclear reactions.

OBJECTS AND ADVANTAGES

30 The objective of the present invention is a device to produce and study nuclear element products and reactions, pre-fusion conditions and products, and/or produce nuclear fusion (and energy) by compressing plasmas, ions, gasses, nuclei, elements, and compounds at various temperatures, - and as such, also has the object of producing materials (e.g. elements, compounds, ions, isotopes, etc.) as a result of these conditions.

35

Some principal advantages of the present invention are: (1) true three-dimensional confinement, (2) absence of magnetic effects on charged particles, particularly electrons, thereby reducing temperature loss through synchrotron radiation, (3) low levels of electrons in the plasma, thereby reducing temperature loss through bremsstrahlung radiation, (4) small machine
40 size, (5) highly portable, (6) readily scaleable to virtually any size. (7) low energy consumption, (8) low cost to fabricate and produce, and (9) wide application for studying related phenomenon.

1. True three-dimensional confinement

45 Toroidal confinement schemes confine plasmas in "linear" ring shapes. Because of this linearity, the plasma can become unstable at high temperature. Even when parts of these rings are magnetically pinched off and portions of the rings become (very roughly) three-dimensionally confined (i.e. a "magnetic mirror"), the squeezed parts of the ring are weaker, so plasma tends to escape through the weak end points.

The probability of (possible) collisions in a two dimensional confinement is less than in a three dimensional confinement (per unit area, at a given temperature and density). Inertial confinement systems, such as the laser system of Lawrence Livermore National Laboratory, recognize the value of three-dimensional confinement. They attempt to have impact from enough directions at the same time to approximate a three dimensional confinement. This is virtually impossible - and is not true three-dimensional confinement. Achieving fusion under these complex circumstances is clearly to their credit.

The present invention, however, achieves true three-dimensional confinement, and solves plasma instability, by forming a plasma "bubble" within a fluid of similar charge. Due to the electric charge and fluid cohesion, "unbalanced" plasma bubbles will automatically transition to a "balanced" spherical shape. Bubble walls closer to the center of the charged plasma will be repulsed with proportionally greater force than distant walls and the bubble will adjust its shape to have the greatest mean distance from the plasma, (e.g. a sphere).

2. Absence of magnetically produced synchrotron radiation

Toroidal systems use intense magnetic fields to confine plasmas. Synchrotron radiation is the result of magnetic field-induced circular particle motion (at near the speed of light). The resultant radiation is largely compressed into brief pulses in the direction of particle movement (Rose and Clark 1961:228,253; Tipler 1991:962). While synchrotron radiation is of relatively low frequencies (below 10^{13} cycles/second), it can radiate substantial amounts of energy away from the confined plasma region into the toroidal chamber (e.g. Tokamak) and is particularly problematical for toroidal devices and other magnetic confinement devices.

In the present invention, magnetic fields are extremely low (virtually absent) resulting in minimal synchrotron radiation. Any synchrotron radiation produced will be readily reflected/refracted by the confinement fluid of the given example (mercury).

3. Minimal plasma electrons reduces bremsstrahlung

Bremsstrahlung radiation, like synchrotron radiation, is the result of the acceleration (deceleration) of a charged particle. In the case of bremsstrahlung, however, an electron passes close to a nucleus, i.e. inner electron shell region. As the plasma temperature rises, the bremsstrahlung increases along with the mean radiation frequency. At fusion temperatures the mean radiation frequency is in the x-rays range. Plasmas at fusion temperatures can have significant losses to bremsstrahlung, particularly in the cases where photons are used (note the photo-electric effect). Devices such as the Lawrence Livermore National Laboratory inertial laser system, therefore, have very short confinement times, so must rely on very high temperatures. Toroidal systems have difficulty removing electrons from the system due to their size and failure to provide an adequate escape mechanism. In some cases, electrons are intentionally injected to promote plasma heating. The magnetic confinement system acts on the electrons in the system incurring synchrotron radiation, as noted, which leads to increased bremsstrahlung.

The present invention has lowered bremsstrahlung due to reflection/refraction by the charged fluid (mercury, for given example), and by reduction of electrons in the plasma. As fusion temperatures are approached, bremsstrahlung becomes less and less well reflected/refracted by mercury, but a strong positive electric charge on mercury would create an electron sink, resulting in extremely low electron levels from which to induce bremsstrahlung radiation.

4. Small machine size

The size of the present invention could range from that of an ordinary refrigerator to a much larger - or much smaller - device. The given example is a tiny fraction of the size of Tokamak or inertial devices because it does not require large magnetic confinement equipment or high energy lasers. Compared to a thermonuclear bomb, it has the advantage of steady production of confined plasmas and/or energy.

5. Low energy consumption

The present invention, for given example, could be designed to operate on less than 2 kilowatts. The approximate energy consumption in such an example would be: (a) 1.2 kilowatts to maintain conductive fluid circulation, (b) 400 watts for plasma gun power supply, and (c) 10 watts - based on one hour of operation time - for field capacitor charge.

6. Scalable

The present invention could be scaled up to a larger commercial device by adding additional units and/or venturi and/or by increasing system size, etc. Scaling up of the present invention would also follow the laws of economy of scale, making a large device more efficient. (It is thought that the scaling up of Tokamak and laser/inertial devices would also experience economies of scale. Their initial minimal size, however, is enormous and, under current practice, would be cost prohibitive for most governmental, institutional and/or industrial entities.) The present invention's initial minimum size is a clear advantage, and it is readily scaleable to virtually any size.

7. Low production cost per unit

Because of the present invention's minimum initial size and low cost to fabricate, commercial manufacturing could make the machine widely available to the scientific and industrial communities. Limited access to the larger toroidal and inertial machines reduces opportunity to conduct research and test new applications.

8. High portability

Clearly the small size of the present invention allows for applications in places not currently available for Tokamak and/or laser/inertial type devices, such as in small towns, rural settings, on ground vehicles, ocean vessel operations, aerospace (where, because there is no radioactive fissile material, it obviates the restriction on nuclear devices in space), and/or remote operations.

9. Wide applications for studying related and unrelated phenomenon

The low cost, portability, and adaptability of the present invention allows the opportunity for a large section of society to study, and potentially to commercialize, various applications of fusion type phenomenon and unrelated non-fusion type phenomenon, such as the putative production of metallic hydrogen (Nellis 2000:84), radiation production and analysis (beta rays, neutrons beams, bremsstrahlung radiation, etc.), and confinement of various nuclei (particles and/or compounds) under high temperature and pressure conditions.

Further objects and advantages of the present invention will become apparent as the following drawings and descriptions are considered.

LIST OF REFERENCE NUMERALS

Fig. 1 Controlled-Nuclear-Fusion Apparatus

- 5 **10** Nuclei source (i.e. hydrogen, deuterium, tritium, helium-3, etc.)
12 Fine control valve, suitable for introducing a gas into a high vacuum
14 Plasma generator (i.e. Crookes tube, plasma gun, plasma focus device, etc.),
electrical break provided between plasma generator (**14**) and aspirator (**16**)
16 Aspirator, entrainment mechanism, or other device, to entrain/capture plasma
in a circulating, electrically charged fluid
10 **18** Length of tube, connects aspirator with plasma separator
20 Points for introduction of a frequency over-lay (arbitrarily selected
here, location(s) may vary)
22 Plasma separator, where plasma is separated from the circulating fluid and the
fluid is recycled back through the aspirator
15 **24** Pump, to circulates fluid through aspirator (**16**), tubing (**18**), and plasma
separator (**22**)
26 Motor, to drive pump (**24**)
28 Pump/motor coupling, to provide electrical break
30 Capillary tube, used to pressurize system, provide electrical break, and exhaust
20 plasma
32 Capacitor (backed by appropriate power supply) to electrically charge the
fluid
34 Compressed gas bottle to hydraulically/hydrostatically apply pressure to the
fluid

25

Fig. 2 Aspirator, typical (**Fig. 1, 16**)

- 40** Plasma beam
42 Aspirator body
44 Tube with nozzle end - arranged so that Bernoulli effect causes "cavitations"
30 where plasma is trapped
46 Fluid from pump
48 Exit of captured plasma

Fig. 3 Plasma Separator, typical (**Fig. 1, 22**)

- 35 **30** Capillary tube, used to pressurize system, provide electrical break, and exhaust
plasma
50 Fluid inlet, from tubing coil (**Fig. 1, 18**)
52 Fluid exit, to pump (**Fig. 1, 24**)
54 Retention bolt
40 **56** Viewing port
58 Separator plate - plasma bubbles "float" to top of separator where said plasma
is removed through capillary tube (**Fig. 1, 30** and **Fig. 3, 30**)

45

SUMMARY OF INVENTION

5 The invention herewith relates to an apparatus which, in the present example, traps nuclei and/or plasma within a fluid which is electrically conductive and heats the nuclei by compressing their volume(s) three dimensionally.

The nuclei (i.e. hydrogen, helium, lithium, etc. and/or their isotopes - heavier nuclei not being excluded) are ionized by any method (Crookes tube/high voltage, ultraviolet light exposure, radio frequency (RF) radiation, microwave radiation plasma focus and/or other).

10 The nuclei are entrained into a conductive fluid by a pump, fluid/gas state change, aspirator, entrainment mechanism, and/or other means.

The present invention suspends the nuclei by positively charging the fluid, and heats the plasma adiabatically as the ("hot," "electron-free") plasma goes from a low pressure environment to a relatively high pressure medium.

15 Further heating and/or molecular alignment may be accomplished by nuclear magnetic resonance (NMR), laser, maser, acoustic compression (e.g. transducer), mechanical compression, electric charge, and/or other.

DESCRIPTION OF THE INVENTION - Main Embodiments

20

The present invention consists of a source, such as compressed gas bottle, solid or gas state change, chemical reaction, and/or other which is connected to a device that ionizes the molecules, such as an ion generator, laser, radio frequency (RF), and/or other. The charged nuclei are entrained into the conductive fluid by an aspirator, entrainment mechanism, injection, solid or gas state change, and/or other. The trapped plasma bubbles proceed from the entraining device toward a plasma separator via a conduit of any type. A method is provided to pressurize the conductive fluid and apply hydraulic/hydrostatic pressure to the conductive fluid. To allow for further heating and/or molecular alignment, a method is provided to apply frequency/frequency over-lay(s) by NMR, laser, maser, transducer, mechanical compression, electric charge, and/or other - or in various combinations.

30

Fusion is intended to take place between the entrainment device (e.g. the aspirator) and the plasma separator. The energy released would be harnessed by any practical method, e.g. MHD, steam turbine, photovoltaics, etc. (not shown).

35

The plasma separator has a method to exhaust spent plasma and/or fusion products from the system.

The *present example* of the invention consists of a compressed gas (deuterium) bottle (Fig. 1, 10) which is connected to a vacuum system through a fine control valve (Fig. 1, 12). The hydrogen isotope enters said vacuum system through said valve and is ionized by an ion gun or a plasma generator (Fig. 1, 14) which "shoots" generated plasma into an aspirator or entrainment mechanism (Fig. 1, 16). Said aspirator or entrainment mechanism entrains said plasma into electrically charged mercury. Said mercury is charged by capacitor(s) (Fig. 1, 32) backed by an appropriate power supply (not shown). The mercury is pressurized hydraulically/hydrostatically by a device such as a high pressure pump or a compressed gas bottle (Fig. 1, 34) connected through a capillary tube (Fig. 1, 30). This compresses the plasma bubbles as they transition from low to high pressure and heats the plasma adiabatically. Frequency/frequency over-lay(s) may be applied at any point (Fig. 1, 20) subsequent to plasma entrainment in the mercury. Precursor fusion events/fusion will take place as the mercury flows toward a plasma separator (Fig. 1, 22) -

45

where the plasma, products, etc. are removed through said (same) capillary tube used to pressurize the fluid (Fig. 1, 30) and the mercury is re-circulated by a fluid pump (Fig. 1, 24).

5 OPERATION OF THE INVENTION

Objective

The objective is to heat light nuclei (in the present example) to sufficiently high temperatures that the nuclei over-come their repulsive forces (Coulomb repulsion) and fuse into a heavier element or elements.
10

Operation Example

Consider the fusion criteria and assume a deuterium-deuterium reaction (preferred here over the more fusible deuterium-tritium reaction due to the radio-activity and radio-active products of the latter):
15

- (I) temperature in excess of 100 million degrees Kelvin (K), or about 10 keV,
- (II) molecular density on the order of 10^{20} ions per meter³, and
- (III) confinement for greater than 1 second

20 such that, when the criteria are multiplied, their product exceeds:

$$50 \times 10^{20} \text{ keV seconds/meter}^3$$

(Close 1991:44).

25

(I) Temperature

There are many ways to select the variables to meet the criteria. For example, select deuterium at a starting pressure of 0.001 mm-Hg, select mercury (Hg) as the conductive fluid, and place a positive electrical charge on the mercury.

30

First, consider the vapor pressures of mercury at various temperatures:

Temperature (Celsius/ Fahrenheit)	Vapor Pressure Mercury (millimeters mercury - mm-Hg)
-30 C / -22 F	0.000 004 78 mm-Hg
-20 C / - 4 F	0.000 018 10 mm-Hg
-10 C / +14 F	0.000 060 60 mm-Hg
0 C / +32 F	0.000 185 00 mm-Hg
+10 C / +50 F	0.000 490 00 mm-Hg
40 +20 C / +68 F	0.001 201 00 mm-Hg
+30 C / +86 F	0.002 777 00 mm-Hg

35

(Weast 1965:D-96).

Note that, at -30 Celsius, a vacuum of up to 4.78 E-6 mm-Hg can be produced before the mercury will boil. The selected pressure of 0.001 mm-Hg will not boil the mercury at +10 C (+50 F).
45

Next, consider Bernoulli's equation:

$$P1 + 1/2(D1)(V1)^2 = P2 + 1/2(D2)(V2)^2$$

5 where P = fluid pressure (in kilo-pascals, kPa), D = fluid density (kilograms/meter³ x 0.001), and V = fluid velocity (meters/second).

The density of mercury (D1 and D2) is 13,600 (13,595.5 @ 0 Celsius) kg/meter³. With a starting velocity (V1) of .1 meter/second, a starting pressure (P1) of 2794 psi (19,259.13174 kPa - using 14.696 psi/atmosphere and 101.3 kPa/atmosphere), and an ending velocity (V2) of (approximately) 53.218 748 917 meters/second, the final pressure (P2) is (approximately) 10 0.000133 kPa (or 0.001 mm-Hg).

If the deuterium is heated to 25,273 K (0.0022 keV), then entrained into the mercury, the deuterium plasma will be adiabatically heated as it transitions from 0.001 mm-Hg to 144,438 mm-Hg (2794 psi).

15 Referring to the adiabatic formulas, valid as long as the transformations are reversible, for pressure:

$$(P1)(V1)^{\gamma} = (P2)(V2)^{\gamma}$$

20 and, for temperature:

$$(T1)(V1)^{\gamma-1} = (T2)(V2)^{\gamma-1}$$

25 where P = pressure (mm-Hg), V = volume (litres), T = temperature (Kelvin), and r = molar specific heat, or 5/3 for deuterium, (i.e. [2 + degrees-of-freedom]/[degrees-of-freedom]).

Given, from the example, if P1 = 0.001 mm-Hg, V1 = 1 litre, T1 = 25,273 K, and P2 = 144,438 mm-Hg (2794 psi), then:

$$V2 = 1.27 \text{ E-5 litres}$$

30

and solving for T2:

$$T2 = 46,401,156 \text{ K (or 4.0 keV)}.$$

35 In a plasma, the molecular speeds are normally distributed as described by the Maxwell-Boltzmann distribution:

$$\int 4\pi (m/2\pi kT)^{3/2} v^2 e^{-(mv^2/2kT)}$$

40 where m = molar mass in kilograms/mole, i.e. atomic mass units (AMU) x 0.001, k = molar gas constant (8.31441 joules/Kelvin x moles), v = velocity in meters/second, and T = temperature Kelvin.

45 At 46,401,156 K (4.0 keV), 9.25% of the ions are exceeding 1,108,167 meters/second, or 10 keV, which equates to a temperature of 116,002,890 K. This is (considered to be) a high enough percentage of the nuclei exceeding 10 keV to satisfy the first criteria (I) for fusion.

(II) Molecular density

The second criteria, molecular density, can be determined from the ideal gas law:

$$PV = nRT \text{ or } n = (PV)/(RT)$$

5 where P = atmospheres (ATM), V = litres, R = 0.0821 (litres x ATM)/(Mol x K), T = temperature Kelvin, and n = moles (Mol). Then solving for n (moles) and multiplying by Avogadro's number (6.022045 E+23) yields the number of molecules.

In this example, P = 0.001/760, V = 1 litre, and T = 25,273 K, solving for n and converting to molecules/litre, the beginning density is:

10 $n = 3.82 \text{ E}+14 \text{ molecules/litre}$

or,

$$n = 3.82 \text{ E}+17 \text{ molecules/meter}^3$$

and, dividing by V2 (1.27 E-5 litres, above), the ending density is:

15

$$3.00 \text{ E}+19 \text{ molecules/litre, or}$$

$$3.00 \text{ E}+22 \text{ molecules/meter}^3$$

satisfying the second criteria (II) for fusion.

20

Multiplying temperature criteria (I) and density criteria (II):

$$(10.0 \text{ keV})(3.00 \text{ E}+22) = 3004 \text{ E}+20 \text{ keV/meter}^3$$

25

Assuming (energy) confinement could be held for 1 second, this is (about) 60 times greater than the product required for fusion.

30 (III-a) Confinement - plasma

Confinement by static charge has been universally disregarded (in the literature) because of the magnitude of charge necessary to exert pressure over even short distances. Typical is the note by Rose and Clark in Plasma and Controlled Fusion (MIT Press pp. 135):

35

"We remark in passing that pressure exerted by reasonable electric fields is very small compared with that exerted by a magnetic induction. For example, an electric field of 3×10^8 volts/m and an induction of 1 weber/m² have the same pressure. Even if such an electric field could be created ...thermonuclear plasma confinement by electric fields alone is not of interest to us."

40

In light of the present invention, however, the perception that static charges must be used to exert *compressive forces*, rather than to just provide confinement/containment forces, is erroneous.

The molecular bond of mercury is (approximately) 3.005 angstroms (Weast 1965:F-119), or 0.3005 nanometers (nm), which is 3.005 E-10 m. The reciprocal yields:

45

$$3.328 \text{ E}+9 \text{ Hg molecules/meter, or}$$

$$3.338 \text{ E}+7 \text{ Hg molecules/centimeter, and}$$

$$1.107 \text{ E}+15 \text{ Hg molecules/centimeter}^2.$$

By comparison, the deuterium nuclei spacing at 46,401,156 K is $3.00 \text{ E}+16$ molecules/centimeter³. This suggests a "surface" density of $(3.00 \text{ E}+16)^{2/3}$, or:

5 $9.65 \text{ E}+10$ molecules/centimeter².

So, the ratio of Hg to H molecules is:

10 $(1.107 \text{ E}+15 \text{ Hg})/(9.65 \text{ E}+10 \text{ H}) = 11,469 \text{ Hg} : 1 \text{ H}$.

By experiment, a mercury capacitor of 59.45 centimeters² measured a capacitance of (as high as) 2 micro-farads/59.45 centimeters², or:

15 $3.364 \text{ E}-8$ farads/centimeter²

(depending upon the thickness of the insulation material). Because, for purposes of this calculation, charges are carried on the surface of a conductor, the voltage necessary to strip (an average) of 1 electron from each surface molecule can be determined by:

20 farads = Coulombs/volts (1 Coulomb = $6.421 \text{ E}+18$)

then,

volts = $(1.107 \text{ E}+15)/(6.421 \text{ E}+18)$ Coulombs/ $3.364 \text{ E}-8$ farads = 5,126.

25 (Based on the above, it would take, approximately, 170,600,000,000 volts to "ionize" mercury to an average of 1 charge per molecule.)

The force necessary to suspend the plasma is a function of the surface area of the plasma bubbles, and, as noted above, the ratio of surface Hg molecules to plasma molecules is 11,469:1. A capacitor of 200 micro-farads could support:

30 $(0.0002 \text{ farads})(5,126 \text{ volts}) = 1.025 \text{ Coulombs}$

and,

$(1.025 \text{ Coulombs})(8.99 \text{ E}+9 \text{ newtons/Coulomb}) = 9.22 \text{ E}+9 \text{ newtons}$

$(9.22 \text{ newtons})(.225 \text{ newtons/pound}) = 2.07 \text{ E}+9 \text{ pounds}$

35 or about 1 million tons (at molecular distances).

(III-b) Confinement - radiation

40 The fusion criteria, again, was a multiplication of temperature, density, and time which exceeded 50×10^{20} keV seconds/meter³. When the Joint European Fusion Programme (JET) in Britain began during the 1970's, values fell short by a factor of 25,000. By 1990, the factor was within 20 (Close 1991:44). The present invention can reduce radiation losses, thereby increasing suspension times, by such factors. (Target densities and temperatures are predetermined by the

45 operating parameters of the invention, e.g. starting temperature, starting pressure, and ending pressure.)

As a suspended plasma gains kinetic energy (heats), energy losses occur (primarily) through electromagnetic radiation. Classic electromagnetic theory predicts that electric charges

will radiate electromagnetic waves when they are accelerated (or decelerated). This radiation takes the form of either synchrotron radiation, which is primarily in the 1 millimeter (near infra-red) range, or bremsstrahlung, which is in the 1 angstrom (x-ray) range.

5 Synchrotron radiation, which is of relatively long wavelengths, will be readily reflected by the mercury, and to some degree, will be re-absorbed in the plasma (Rose and Clark, 1961:236), so it is of little concern in these calculations (this is potentially a conceptual breakthrough in fusion technology).

10 If the bremsstrahlung radiation could also be confined, the plasma could be held at fusion temperatures for indefinite periods. Consider these factors: (1) the x-ray *cut-off wavelength*, (2) the molecular surface area of the mercury, (3) the angle of refraction, and (4) presence of electrons in the plasma.

First, consider the minimum (*cut-off*) wavelength of the bremsstrahlung spectrum described by:

15

$$\lambda_m = hc/E = hc/eV$$

where $hc = 1240 \text{ eV}\cdot\text{nm}$ (Tipler 1991:1153). Solving for wavelength equal to the molecular bond of Hg (approximately) 0.3005 nm , the temperature is:

20

$$\begin{aligned} eV &= hc/\lambda_m = 1240 \text{ eV}\cdot\text{nm}/0.3005 \text{ nm} = 4,126 \text{ eV} \\ (4,126 \text{ eV})(11,600.289 \text{ K/eV}) &= 47,868,081 \text{ K} \end{aligned}$$

and solving for wavelength at 10 keV:

25

$$\lambda_m = (1240 \text{ eV})/(10 \text{ keV}) = 0.124 \text{ nm}$$

30 then, from 4.126 keV to 10.0 keV, the minimum (*cut-off*) wavelength of bremsstrahlung ranges from 0.3005 to 0.124 nm, i.e. the plasma is hot enough to generate bremsstrahlung of short enough wavelength to penetrate the Hg bond - but does not yet have enough kinetic energy for the ionic nuclei to fuse. At the example temperature of 46,401,156 K, 44.82% of the molecules exceed 47,868,081 K (4.126 keV), as described by the Maxwell-Boltzmann distribution of molecular speeds. The remaining 55.18% (below 4.126 keV) produce bremsstrahlung which is readily reflected/refracted by the mercury.

35

Second, consider the molecular surface of the mercury. The Hg molecules are (approximately) 0.2 nm in diameter (Serway 1986:469) and the molecular bond is (approximately) 0.3 nm, for a total surface area of 0.25 nm^2 , then:

40

$$\text{Hg molecular surface area} = \pi r^2 = \pi(0.1 \text{ nm})^2 = 0.0314 \text{ nm}^2$$

and, dividing by the total surface area:

45

$$(0.0314 \text{ nm}^2)/(0.25 \text{ nm}^2) = 0.1256$$

therefore 87.44% ($1.00 - 0.1256$) of the surface area is penetrable by bremsstrahlung radiation.

Third, consider the angle of refraction. Just as a highway becomes reflective when the angle of vision becomes high enough, the surface of the Hg will reflect/refract short wavelengths if the angle is high enough. Because the Hg molecules have dimension (0.2 nm diameter) and their relative distances are close (0.3 nm), then at 23.58°, the bottom of one Hg molecule comes into alignment with the top of another - which would not allow radiation penetration, and all radiation would be reflected/refracted:

$$\arcsine\left(\frac{0.2}{0.5}\right) = 23.5782^\circ$$

10 Solving for (wavelengths equal to or greater than) 0.124 nm (10 keV), the angle of reflection/refraction now becomes 40.39°:

$$\arcsine\left(\frac{0.2 + 0.124}{0.5}\right) = 40.3910^\circ$$

15 Assuming the radiation is omni-directional, being emitted equally throughout the plasma, then radiation is a function of volume. The volume taken out of a sphere by a cone projected at 40.39° is 82.37%.

To summarize the foregoing, the present invention eliminates 67.72% (100% - 32.28%) of the bremsstrahlung losses (44.82% of radiation can penetrate x 82.37% of radiation has high enough angle of incidence x 87.44% of Hg surface is "penetrable" = 32.28% penetration). This is a marked improvement in plasma radiation (bremsstrahlung) confinement, relative to fusion devices built to date. But, to achieve significant confinement times, the bremsstrahlung losses must be reduced by "exponential" amounts - at fusion temperatures these reductions most probably will not be sufficient.

So then, fourth, consider the presence of electrons in the plasma which induce bremsstrahlung (and other electromagnetic radiations). In tori devices, the electrons are not given opportunity to escape the plasma. Magnetic induction suspends the plasma away from the walls and, in some cases, the plasma is intentionally "sheathed" in electrons in an attempt to further heat the plasma. Magnetic confinement not only creates radiation, but traps the source of the radiation (electrons) - doubly working against its own utility (confinement).

Electrons, in the present invention, have large opportunity to exit the plasma. Electrons in a (given) plasma are "disassociated," i.e. only being loosely held by the positive charges of the plasma nuclei and are spread throughout the plasma. When two positive nuclei have an "encounter," there is (about) equal probability that a "near" electron would follow one nuclei rather than another. In the present invention, the nuclei are suspended by the charged mercury, so the mercury would also have (about) equal probability of attracting a near electron.

At the starting temperature of 25,273 K, the ionic nuclei are traveling at 16,357 meters/second (average). Assuming an initial bubble diameter 2 mm (noting that the bubble will be elongated as it leaves the aspirator and, without compression, would become a bubble of, say, 8 to 10 mm in diameter), each nuclei can traverse from one side of the (elongated) bubble to the other, encountering the bubble wall (mean free path disregarded) 8,120,000 times per second:

$$45 \quad (16,357 \text{ meters/second}) / (0.002 \text{ meters}) = 8.12 \text{ E}+6 / \text{second}.$$

or, assuming a spherical bubble:

$$(16,357 \text{ meters/second}) / (.008 \text{ meters}) = 2.04 \text{ E}+6/\text{second}$$

Assuming a similar number of “wall encounters” for an electron and (approximately) a 50% (0.5) probability of being absorbed, then:

5	Seconds	Probability of Plasma Retaining Electron
	1.0 E-6	$(0.5)^{2.04} = 0.243$
	2.0 E-6	$(0.5)^{4.08} = 0.059$
10	3.0 E-6	$(0.5)^{6.12} = 0.014$
	...	
	10.0 E-6	$(0.5)^{20.44} = 0.000\ 000\ 702.$

15 By the end of the first few millionths of a second (while the plasma is still relatively cool and the bremsstrahlung wavelengths are long enough to be well reflected), the electrons are rapidly exiting the plasma. Not only are the suspension distances short (similar to the nuclei spacing), but as the bubble diameter shrinks from 2.0 to 0.047 mm, the ratio of surface area to plasma volume increases 42.8 times, further increasing the electron’s probability of exiting the plasma. As the temperature climbs from 25,273 K toward 4 keV, the nuclei accelerate from 16,357 to
20 700,866 meters/second and events occur exponentially faster:

$$(700,866 \text{ meters/second}) / (0.000\ 047 \text{ meters}) = 1.49 \text{ E}+10/\text{second}.$$

25 This effect is so powerful that even if the probability of the electron being attracted to the mercury were (below) 1%, rather than 50%, the out-come is rapidly the same. (Due to the large numbers and the presence of virtual particles, there will always be electrons in the plasma, however minimal. Care should also be taken to exclude neutrals from the plasma.)

30 It should be noted here that spark gap distances at 5,000 volts are (about) 1.3 mm (Weast 1965:E-49). Because this is (greater than) the starting radius of the plasma bubbles in the present example, it might seem that no calculation may be necessary, i.e. the electrons would instantaneously “jump” to the mercury and the plasma would be “drained” of electrons. However, the Hg does not need to be charged to 5,000 volts to suspend the plasma - the Hg only
35 needs to be more densely charged than the plasma, therefore some lower voltage would be adequate. This has the advantage that, in perspective, the longer the suspension/containment time that can be attained, the lower the temperature necessary to achieve fusion events, the lower the voltage necessary to suspend the plasma, and the smaller the bubbles can be (before Gaussian charge exclusion effects become significant).

40 Spark gap distances an order of magnitude smaller than the bubble diameters appears adequate to quickly drain the plasma of free electrons, yet avoid Gaussian charge exclusion effects. At 46 million K, 65 volts appears adequate for suspension, spark gap distances would be about .019 mm, starting bubble size would be about 8 mm, and suspension distance would be at least 1.5 E-6 mm (5 times the Hg bond).

45 The present invention has true three-dimensional confinement which increases nuclei collision probabilities, does not rely on magnetic confinement and so produces less radiation (synchrotron and bremsstrahlung - relative to magnetic suspension devices), confines energy loss by reflecting/refracting a large percentage of the radiations produced (100% of the synchrotron

and 68% of the bremsstrahlung), and “exponentially” reduces electrons in the plasma - thereby (“exponentially”) reducing bremsstrahlung (relative to magnetic confinement or inertial devices). Confinement times are significantly increased, and based on the experience of prior devices, this should (be enough to) satisfy the third criteria (III) for fusion. Q.E.D.

5

Structural and Functional Distinctions

As opposed to sonoluminescence, in the present invention:

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- (1) the fluid is neither electrically charged nor electrically conductive,
- (2) no provision is made to ionize the gasses,
- (3) no provision is made to introduce and exhaust the gasses,
- (4) no provision is made to pressurize the system hydraulically/hydrostatically,
- 15 (5) the fluid is not selected for its ability to retain electromagnetic radiation, and
- (6) the fluid’s vapor pressure is intended to be exceeded.

15

The concept of using a frequency to apply compression to a gas within a fluid is fundamental to physics - appreciated - but inadequate by itself. Note also, that the acoustic frequency heats a bubble, then cools it, with each cycle.

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CONCLUSION

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The present invention provides a means for compressing and/or heating nuclei for such periods of time that nuclear products, precursor fusion events, and/or nuclear fusion occur(s) in a controlled fashion. That the invention is new and un-obvious is clear considering the many billions of dollars spent on attempts to design such a device - and the unanimous rejection of the approach to such a concept, design, and/or process described herewith.

30

This apparatus can have many embodiments. The nuclei source could be compressed gas, fluid/gas state change, chemical reaction, and/or etc. The nuclei could be ionized by any of many methods, including plasma gun, Crookes tube, radiation, plasma focus device, and/or etc. Entrainment of the plasma into the fluid could be by aspirator, pump, fluid/gas state change, etc. The fluid could be an electrically conductive fluid or any fluid capable of holding an electrical charge. If the fluid also has an appropriately low vapor pressure and resistance to radiation absorption, these would be considered a plus. The fluid may be circulated by any means to include piston pump, turbine pump, gravity, centripetal force, and/or etc. Energy produced may be harnessed by any viable method including MHD, steam turbine, photovoltaics, etc. Plasma or plasma product separation from the fluid may be accomplished by flotation, screening, centripetal force, etc. Frequency/frequency over-lay(s) may be by NMR, laser, maser, transducer, mechanical compression, electric charge, and/or other. Accordingly, the scope of the invention should be determined not by the embodiment(s) illustrated, but by the appended claims and their legal equivalents.

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REFERENCES**CLAIMS**

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Claim 1. Apparatus for investigating and/or actuating nuclear fusion, pre-fusion reactions, and/or potential nuclear fusion reactions, that incorporates means to entrain and/or confine nuclei or plasma three-dimensionally within a fluid and/or which incorporates means to exhaust these nuclei and/or resultant transformations.

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Claim 2. Apparatus for investigating and/or actuating nuclear fusion, pre-fusion reactions, and/or potential nuclear fusion reactions, that incorporates means to entrain and/or confine nuclei or plasma three-dimensionally within a fluid and/or which incorporates means to exhaust these nuclei and/or resultant transformations,

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... and which incorporates an electrically conductive and/or electrically charged fluid.

Claim 3. Apparatus for investigating and/or actuating nuclear fusion, pre-fusion reactions, and/or potential nuclear fusion reactions, that incorporates means to entrain and/or confine nuclei or plasma three-dimensionally within a fluid and/or which incorporates means to exhaust these nuclei and/or resultant transformations,

20

... and which incorporates a means for heating by reducing the volume occupied by the light nuclei or plasma through hydraulic/hydrostatic pressure.

Claim 4. Apparatus for investigating and/or actuating nuclear fusion, pre-fusion reactions, and/or potential nuclear fusion reactions, that incorporates means to entrain and/or confine nuclei or plasma three-dimensionally within a fluid and/or which incorporates means to exhaust these nuclei and/or resultant transformations,

25

... and which incorporates a frequency/frequency over-lay, and/or energy boost.

Claim 5. Apparatus for investigating and/or actuating nuclear fusion, pre-fusion reactions, and/or potential nuclear fusion reactions, that incorporates means to entrain and/or confine nuclei or plasma three-dimensionally within a fluid and/or which incorporates means to exhaust these nuclei and/or resultant transformations,

30

... and which incorporates an electrically conductive and/or electrically charged fluid,

35

... and which incorporates a means for heating by reducing the volume occupied by the light nuclei or plasma through hydraulic/hydrostatic pressure.

Claim 6. Apparatus for investigating and/or actuating nuclear fusion, pre-fusion reactions, and/or potential nuclear fusion reactions, that incorporates means to entrain and/or confine nuclei or plasma three-dimensionally within a fluid and/or which incorporates means to exhaust these nuclei and/or resultant transformations,

40

... and which incorporates an electrically conductive and/or electrically charged fluid,

... and which incorporates a frequency/frequency over-lay, and/or energy boost.

Claim 7. Apparatus for investigating and/or actuating nuclear fusion, pre-fusion reactions, and/or potential nuclear fusion reactions, that incorporates means to entrain and/or confine nuclei or plasma three-dimensionally within a fluid and/or which incorporates means to exhaust these nuclei and/or resultant transformations,

45

... and which incorporates a means for heating by reducing the volume occupied by the light nuclei or plasma through hydraulic/hydrostatic pressure,
... and which incorporates a frequency/frequency over-lay, and/or energy boost

- 5 Claim 8. Apparatus for investigating and/or actuating nuclear fusion, pre-fusion reactions, and/or potential nuclear fusion reactions, that incorporates means to entrain and/or confine nuclei or plasma three-dimensionally within a fluid and/or which incorporates means to exhaust these nuclei and/or resultant transformations,
... and which incorporates an electrically conductive and/or electrically charged fluid.
10 ... and which incorporates a means for heating by reducing the volume occupied by the light nuclei or plasma through hydraulic/hydrostatic pressure,
... and which incorporates a frequency/frequency over-lay, and/or energy boost.

- Claim 9. Apparatus of any of Claims 2-8, and which incorporates a means to enhance
15 entrainment and/or pressure with laser, maser, microwave, and/or other radiation frequencies and/or apparatus shapes that augment fluid dynamic pressure.

- Claim 10. Apparatus of any of Claims 2-9, which confines light nuclei or plasma two
20 dimensionally within a fluid tube or mechanical structure, excluding rotating cylinders with magnetic field the length of the bore using mechanical hammer for diameter reduction, U.S. patent 4,269,658.

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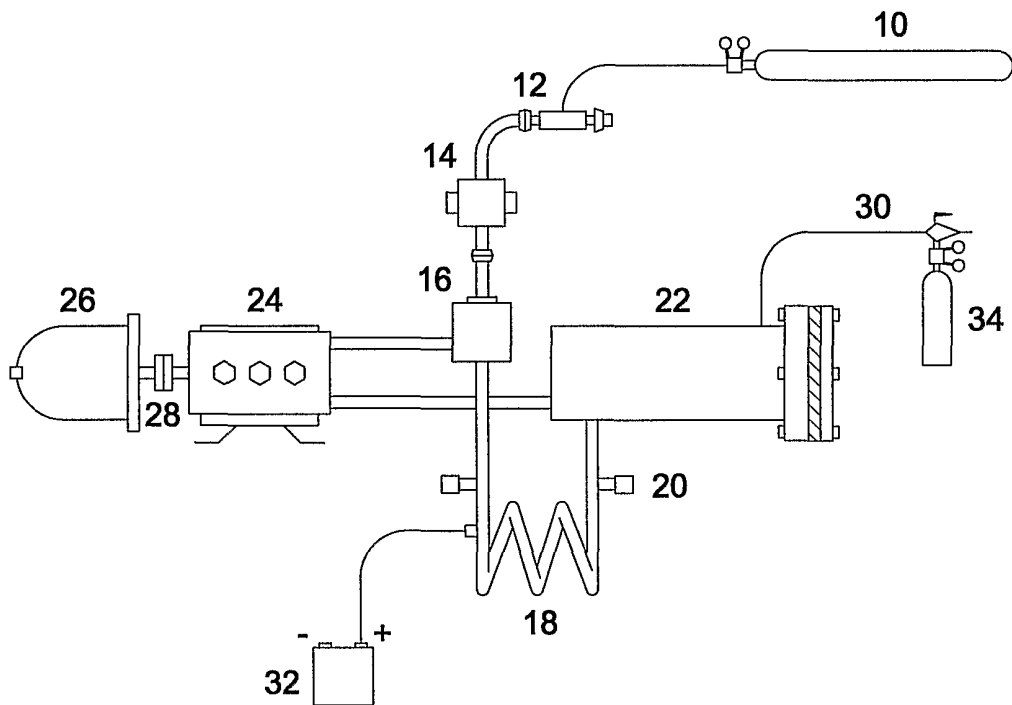


Fig. 1

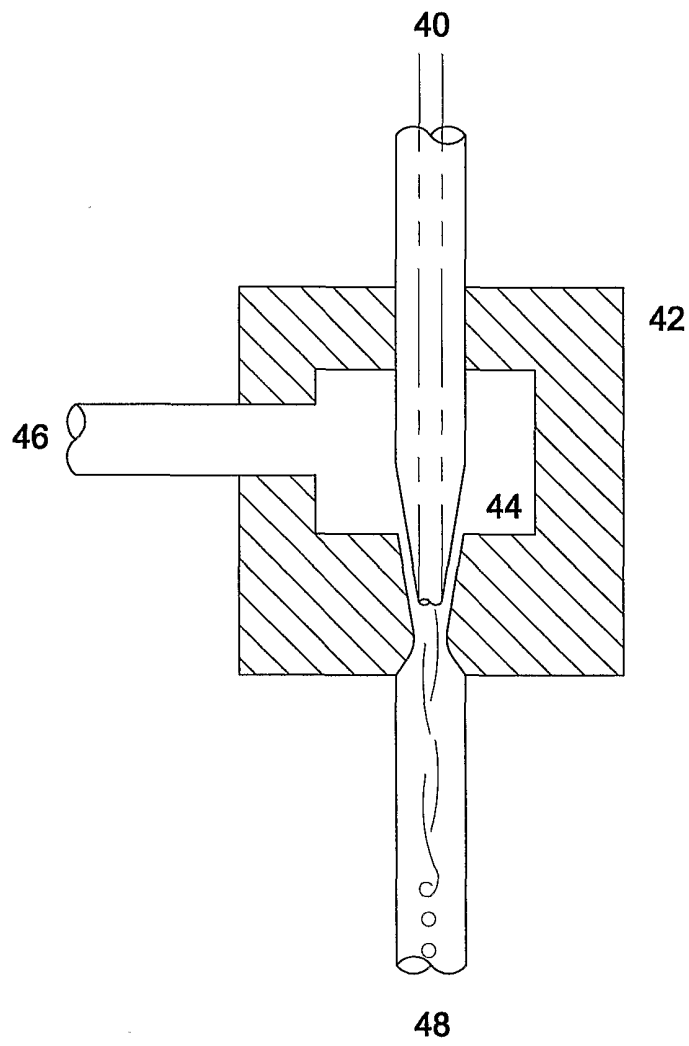


Fig. 2

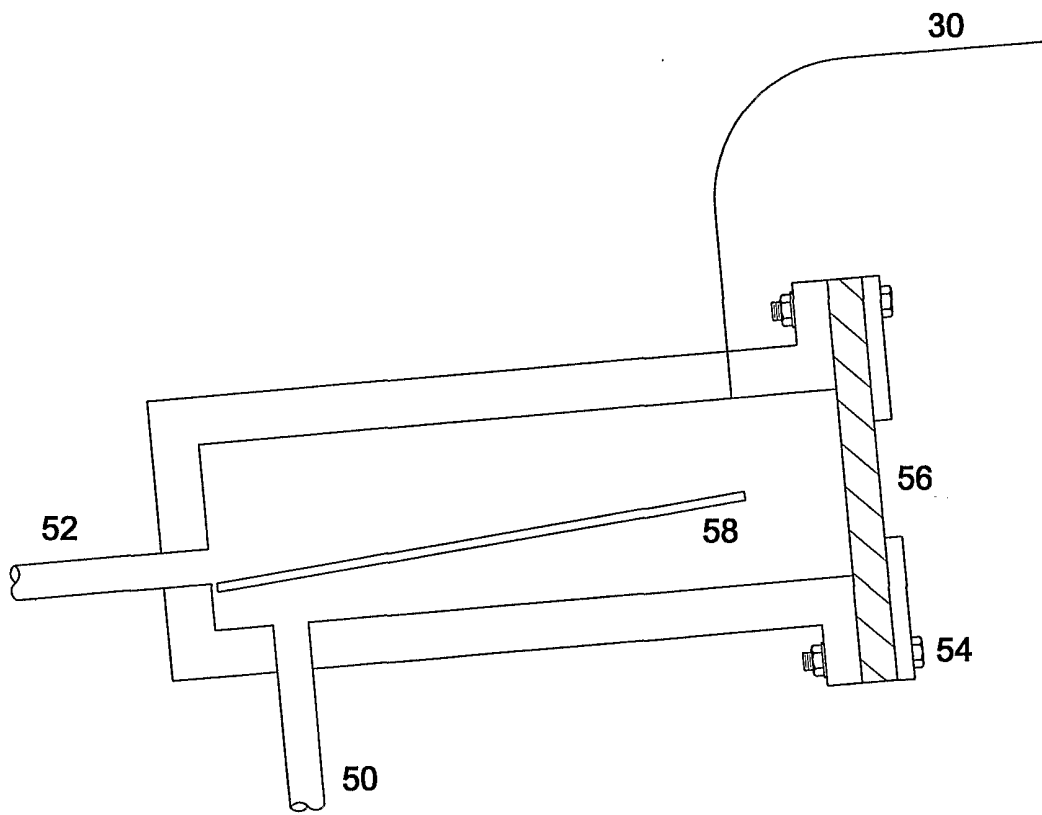


Fig. 3