3 **Untried** 'Optimal' Hot & Cold Fusion Reactors

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TOPOLOTRON

DISCLAIMER

Robert W. Bass has not studied professional literature of *Magnetic Confinement of Fusion Plasmas* seriously since **1978**, and only made a very superficial review in **1992**, so everything here on the **Topolotron** is based upon his typed reports & publications, **1959-1978**.

REQUEST: Please contact Bass and inform him of any post-1978 literature citations [such as relevant independent rediscoveries] that he should know about.

United States Patent [19]

Bass et al.

[11] **4,235,668**

[45] **Nov. 25, 1980**

[54] **CONFINEMENT OF HIGH TEMPERATURE PLASMAS**

[75] Inventors: **Robert W. Bass**, Provo; **Helaman R. P. Ferguson**, Orem, both of Utah; **Harvey J. Fletcher**, Coltsneck, N.J.; **John H. Gardner**, Provo, Utah; **B. Kent Harrison**, Provo, Utah; **Kenneth M. Larsen**, Provo, Utah

[73] Assignee: **Brigham Young University**, Provo, Utah

[21] Appl. No.: **515,858**

[22] Filed: **Oct. 18, 1974**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 300,781, Oct. 25, 1972, abandoned.

[51] **Int. Cl.**[2] **G21B 1/00**

[52] **U.S. Cl.** **176/3**; 315/111.7

[58] **Field of Search** 176/1-3, 176/5; 315/111.7

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,009,080	11/1961	Loos	176/3
3,088,894	5/1963	Koenig	176/1
3,219,534	11/1965	Furth	176/1
3,278,384	10/1966	Lenard et al.	176/1
3,663,362	5/1972	Stix	176/2
3,677,890	7/1972	Hartman	176/1
3,692,626	9/1972	Ohkawa	176/3

OTHER PUBLICATIONS

Soviet Physics—Technical Physics, vol. 7, No. 3, 9/62, pp. 187-191 by Skornyakov.

Physics of Fluids, vol. 9, 1966, pp. 2295, 2296 by Yoshikawa et al.

Technology Review, 12/76, pp. 20-24, 33-39, 41-43.

MATT-1050, 8/74, pp. 526-529.

ERDA-28, 1/75, pp. 1-3, 8-10.

Bulletin of the American Physical Society, 11/16/71, p. 1239, by Bass.

Proceedings of the Utah Academy of Sciences, Arts, & Letters, vol. 50, part 2, 1973, by Gardner et al., pp. 1-11.

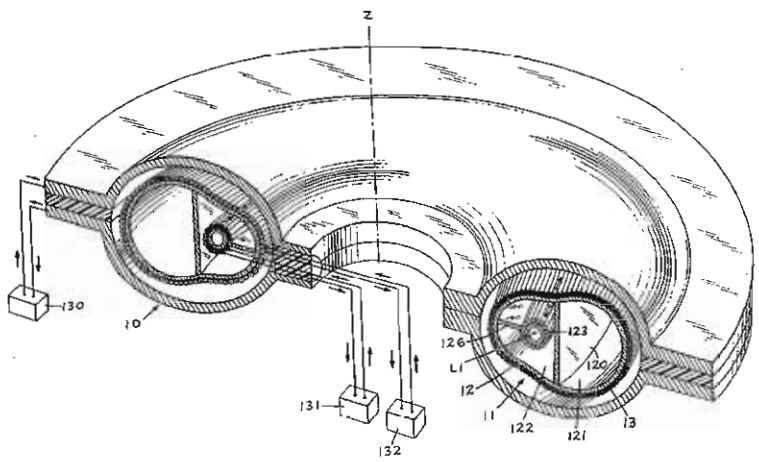
Primary Examiner—Harvey E. Behrend

Attorney, Agent, or Firm—Jules P. Kirsch

[57] **ABSTRACT**

A high temperature plasma is confined in the shape of a topological torus by a topologically stable magnetic field which is everywhere constant on and tangent to the surface of the torus. There are exactly an even finite number of closed magnetic field lines on the plasma surface and all other magnetic field lines on the surface are asymptotic to the closed field lines. This magnetic field configuration is achieved by a set of current carrying conductors appropriately arranged with respect to the plasma and carrying suitably selected currents.

10 Claims, 12 Drawing Figures



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CHALLENGE # 1

- Bass published words “kidney-bean” & “bean-shaped cross-section” on page 1,239 of November, **1971**, *Bulletin* of American Physical Society (APS)
- He challenges entire fusion-plasma field to show ANY usage of these phrases in print **prior** to November, **1971**!!
- He conjectures that others who saw his drawing, and now apparently are trying to get on his bandwagon without understanding it, **still don’t get the point**: poloidal field must vanish at inside bumps on bean and surface field must be smooth there [no cusps or leaks!].

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HISTORY

- Late **1959,** 42-page highly mathematical typed letter to PPPL Theoretical Division.
- Multilithed version of same distributed in **1961** as Aeronca *Technical Report* 61-1.
- Paper G3, *Bulletin* APS, Nov. 6-9, **1963**.
- Patent Application, *Bass et al*, Oct. 25, **1972**.

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Corporate Reports

"Stability in Hydrodynamics and Magnetohydrodynamics," *Aeronca Technical Report* 61-1, **1961** (based upon a 42-page, typed, highly-mathematical letter sent by R.W. Bass to PPPL in late 1959, mentioned in 1992, to D. Baker of LANL, by J. Johnson that he, and C. Oberman, both of PPPL, had recalled that "Bass was interested in such questions [*re* **non-conservative** stability criteria] long ago"].

Inventions:

Principal Inventor of the **TOPOLOTRON** (see Abstracts by R.W. Bass in *Bulletin,* **APS**, November, **1963** and November, **1971**, as well as **related papers by others** in ***IEEE Transactions on Plasma Science,*** vol. PS-4 (**1976**), No. 3, pp. 162-165, and in ***Physics of Fluids,*** vol. 19 (**1975**), No. 11, pp. 1810-1819) and Patents 1-3.

Patents

[Continuation/Division of Application Submitted Oct. 25**, 1972**] **:**

1. *Confinement of High Temperature Plasmas,* U.S. Patent **4,235,668**, issued Nov. 25**, 1980**.
2. *Confinement of High Temperature Plasmas*, U.S. Patent **4,236,964**, issued Dec. 2**, 1980**.
3. *Topologically Stable Confinement of High Temperature Patents, granted in* Argentina, Australia, Belgium, Brazil, Canada, Chile, Denmark, France, Germany, Great Britain, Israel, Italy, Japan, Mexico, New Zealand, Netherlands, Russia, Sweden, Switzerland.

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Publications

1. "A Simple Necessary & Sufficient Condition for Structural Stability of Non-Conservative Toroidal Plasma Equilibria," *Bulletin,* APS, **1963** (Paper G3, November 6-9, San Diego).
2. "The ULTRON Configuration," *Bulletin,* APS, Ser. II, vol. 16 (**1971**), No. 11.
3. "The TOPOLOTRON, a Device for the Magnetic Confinement of Plasmas," with J.H. Gardner *et al,* P*roceedings*, Utah Academy of Sciences, Arts & Letters (**UASAL**), vol.50 (**1973**), Pt. 2, pp. 1-11.
4. "Topological Global Stability of the Topolotron," with L. Fearnley *et al, Proc.,* UASAL, vol.50 (**1973**), Pt. 2, pp. 12-18.
5. ”Uniqueness of the Topolotron Design Relative to Structural Stability," with B.K. Harrison *et al, Proc.,* UASAL, vol.50 (**1973**), Pt. 2, pp. 19-26.
6. "Numerical Methods of Solving Stokes' Equation, with Application to the Topol-otron," with H.R.P. Ferguson *et al, Proc.,* UASAL, vol. 50 (**1973**), Pt. 2, pp. 27-42.
7. “Global Characteristics of the Vector Field of the Topolotron," with K.M. Larsen *et al, Proc.,* UASAL, vol. 50 (**1973**), Pt. 2, pp. 43-46.
8. "Physical Realizability of the Topolotron Configuration," with H.M. Nelson *et al, Proc.,* UASAL, vol. 50 (**1973**), Pt. 2, pp. 47-57.
9. "A Topological Approach to Optimal Plasma Confinement," R.W. Bass, **invited half-hour *Address,* Semi-Annual Meeting**, APS, Salt Lake City, UT, June, **1974**.
10. “A Nonlinear Energy Principle with Applications to the Topolotron,’ *Bull.* APS, Ser.II, vol. 20 (1975), No. 10, p. 1311.

TOPOLOTRON

Unpublished Typescripts [available for inspection]

Under Review for Publication

or to be Revised for Submission in the Near Future

1. A *Truly* Nonlinear **MHD** Energy Principle for *Arbitrary* Beta
2. A Dispersion Relation for Small-Amplitude Waves, Shocks, and Stability Criteria in Nonconservative Electro-Magneto-Thermo-Fluid-Dynamics **(EMTFD)**
3. Routh-Hurwitz Stability Criteria Applied to **EMTFD** Configurations
5. A Sufficient Aspect-Ratio Condition for MHD-FLR Stability of a Toroidal High-Beta Theta Pinch [**submitted** to *Fusion Technology*]
8. Topolotron's Unique, Maximal Immunity to Global Interchange Instabilities
9. Necessity of Smoothness Assumptions in the Peixoto-Pliss Theorem Regarding Structurally Stable [robust] Flows on Tori
10. The Singularities of Arbitrary Axisymmetric Plasma Equilibria [**sub'd** *Phys.Fl.*]
11. Necessary & Sufficient Conditions for Global Line-Tying in Axisymmetric Topolotron Configurations [**ALSO** **sub'd** to *Phys.Fl*. In 1978; **BOTH** were rejected]
12. Stokes-Grad-Shafranov-Helmholtz Equation for Diffuse Profile or Force-Free MHD Equilibria

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TWO independently considered **Basic Motivating Ideas**:

1. **Topological Stability** of “phase portrait” of magnetic field lines defined by confining **Magneto-Static** Vector Field, viewed as a geometric “flow” when parameterized by arc-length of assigned directionality, both on plasma Surface & external Vacuum Volume.

2. **Robust Dynamic Stability**, meaning globally uniform exponential-asymptotic stability of an ElectroMagnetoThermoFluidDynamic (**EMTFD**) pseudo-equilibrium.

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Idealized mathematical models of two preceding aspects (static & dynamic) leads via *totally* ***rigorous*** *mathematical analysis* to an absolutely **UNIQUE** configuration**!**

This UNIQUE configuration can be ***avoided*** **only** by ***denial*** of **at least one** of the **THREE basic assumptions:**

1. Axially-symmetric cusp-free [everywhere smooth] ***toroidal*** **diamagnetic** pseudo**-equilibrium** [*either* neglecting or *compensating for* cross-field diffusion].

2. Standard thin-skin ***sharp*** **boundary** approximation.

3. MFD-FLR **surface tension** for sufficiently high aspect ratios [closest approximation to a *naturally stable* infinitely-long straight cylindrical near-unity-beta theta-pinch or correctly stabilized Scyllac. [Scyllac would have worked perfectly except that stabilizing feedback controls were designed in ignorance of Modern State-Space Control Theory, in which one must check *a priori* that Kalman's **Controllability Matrix** has full rank or **redesign** actuators!]

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KRUSKAL PARADOX: Qualitatively different physical results predicted according to whether or not **Rotational Transform Angle** is **rational** or **irrational**.

Such infinitesimal sensitivity is **physically impossible** in a macroscopic engineering device.

Solution: ***Neither*** on plasma surface ***nor*** in external vacuum volume may a rotational transform angle be definable**: concept must become irrelevant**.

Independently published Theorems in **Topological Dynamics** of **Pliss** (Leningrad) and **Peixoto** (Brazil) imply that vector field tangent to a smooth torus can have topological stability ONLY if there are a **finite, even, number** of topological circles which serve as **Limit Cycles** for all other field lines, each of which MUST be asymptotic toward or away from such a limit-cycle, once a consistent directional orientation of the flow defined by arc-length has been chosen.

In simplest case, poloidal field must vanish at each bump on inside of a kidney-bean shaped cross-section [e.g. the *Limacon* of Pascal] and therefore **square-root** defining pressure-equilibrium (and so “direction” along poloidal field-lines) must **CHANGE SIGN** at said bumps**!**

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FIG. 3A

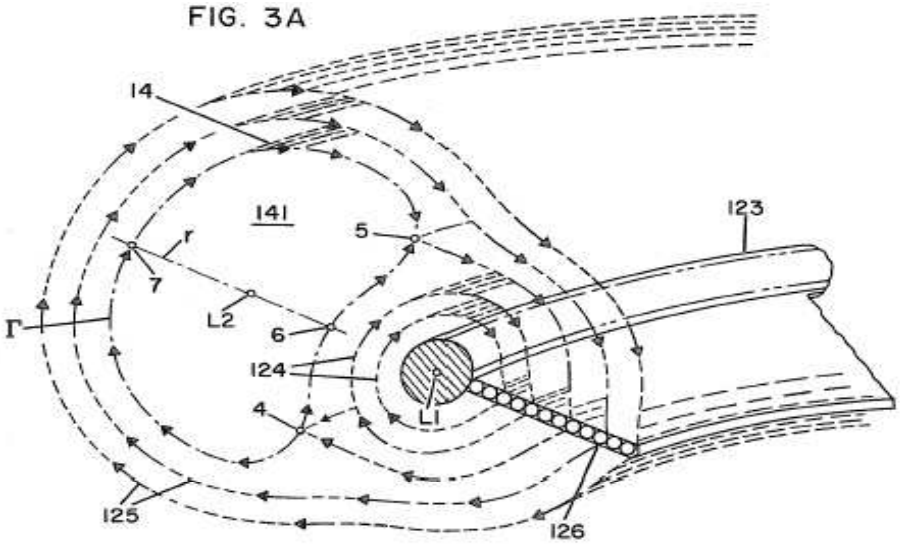
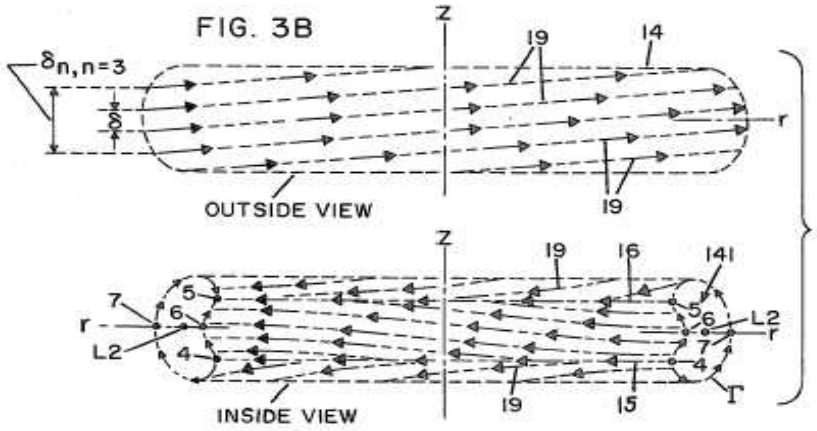


FIG. 3B



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For **topological stability** of field-line configuration in external **vacuum**, it is ESSENTIAL (according to physical doctrine of "line-tying") that EVERY field line in the external vacuum should **cut** a current-carrying conductor at an angle other than perpendicular**!**

Accordingly it's **imperative** that the cross-section, when defined by radial coordinates (r, θ), where the independent variable is arc-length σ, have the form of periodic functions $r = R(\sigma) \equiv R(\sigma + L)$, $\theta = \Theta(\sigma) \equiv \Theta(\sigma + L)$, of period L (where L is the total arc-length of the kidney-bean curve), should prevent the conductor 126 from shrinking to being an isolated conductor like 123, which is disconnected from the axis of symmetry and its vertical conductor. We at BYU didn't fully realize this until after Patent prosecution was out of our hands [and we couldn't fulfill legal obligation to Disclose Best Mode Known].

NOT EVERY KIDNEY BEAN CROSS-SECTION IS ACCEPTABLE!

To render a Topolotron **invulnerable** to vacuum-volume topological instability of the magneto-static field, certain **linear constraint relationships between the Fourier coefficients of the periodic functions *R*(σ) & Θ(σ)** turn out to be both Necessary And Sufficient Conditions (**NASC**s) in order to complete the design. In 1978 my two papers giving complete & rigorous derivation of all external singularities of **any** axisymmetric plasma configuration in terms of closed form expressions, and the just-said NASCs for discriminating vulnerable from invulnerable Topolotrons, were both rejected for publication by *Physics of Fluids*. So now, unintentionally, the **final wrinkle** needed for **utter perfection** of the Topolotron configuration remains my unsought Trade Secret!!!

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Consider electrical *resistivity* $\eta = 1/\sigma$, thermal *conductivity* κ, hydrodynamic *viscosity* μ, and finite *light-speed c* in the combination $\alpha_{00} = \eta.\kappa.\mu.(1/c)$. In cylindrical coordinates, the **EMTFD** *dispersion relation* for the **complex frequency** *s* is a function of naught but the four preceding parameters and integers *m*, *k* giving azimuthal & longitudinal dependence in the usual form $\exp(i.[m.\theta + k.z])$, $i^2 = -1$, plus radial Helmholtz numbers $\lambda^2 = \lambda^2_{m,k}$ defined as (real) eigen-functions of the negative Laplacian operator $-\nabla^2$. The dispersion relation for the small-waves motion of the pseudo-equilibrium then becomes a **6**th degree monic polynomial in *s* whose constant term $\alpha_0 = \lambda^2 + \alpha_{00}.\lambda^{4\ +\ \cdots,}$ so that it is impossible to satisfy the Routh-Hurwitz stability criteria $Re\{s\} \leq -\delta < 0$ for all roots if **any one** of the above 4 non-conservative or ***transport*** [as in displacement-current] ***coefficients*** vanishes! But when all 4 transport coefficients are present, the dispersion relation factors into the product of 3 quadratic polynomials, which provide **physical waves** known since **Alfven** as "slow" and "fast" ***magnetosonic*** waves, and as what I now call ***electromagnetosonic*** waves. The **Routh-Hurwitz stability criteria** are satisfied if **each** of these 3 [monic] quadratic polynomials has only positive coefficients, which will be the case for **sufficiently high plasma densities & temperatures**, provided that the ratio of the square of the density to the cube of the temperature is sufficiently high, and that the **Aspect Ratio** exceeds 240 **:** 1.

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CHALLENGE # 2

Explain **failure** of:

1. Harold Furth's "**Fat Sloth**," helically-symmetric configuration:
   HINT: crescent-moon cross-section whose pointed tips have cusps & so **leaks**.
2. **Tormak** axially-symmetric configuration**:**
   HINT: has vertical cusps above & below and a lateral planar-cusp & so **leaks**.
3. Skornyakov's 1962 "**Tornado Trap**," explicitly designed to provide **both** MHD fluid-stability and magneto-static topological stability**:**
   HINT: pull bumps on Kidney Bean cross-section into crescent-moon-like cusps and let them touch a conductor at North & South Poles of a configuration otherwise demonstrated, both theoretically AND experimentally, to be an **excellent** magnetic confinement configuration for ***low temperature*** **plasmas** (allowed to touch metal).

CHALLENGE # 3

Bass gave detailed Advocacy of & Presentations *re* Topolotron concept in **1969** at Gulf General Atomic (**GA**), Oak Ridge National Lab (**ORNL**) and Princeton Plasma Physics Lab (**PPPL**), providing definitive **cure** for later-diagnosed **diseases** of Magnetic Braiding, Nonlinear Chaos, Volumetric Ergodicity, etc. with explicit detail of "**Resistive Instability**" & "**Second Stability**" near **β = 1**, but was ignored until these issues were later ***rediscovered*** by others. **WILL HISTORY REPEAT?**

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Challenge # 4

According to a British expert “nobody knows how to bend a straight theta pinch into a torus while retaining all of the advantages of a straight theta pinch,” though when Tokamak-designer Artsimovich visited the USA he wrote that the late James Tuck’s Scylla was “the most impressive” plasma confinement concept that he had seen.

Because energy production per unit volume is proportional to β^2, then for the **same capital cost** of a magnetic field, a stabilized theta pinch of $\beta = 90\%$ can produce **THIRTY SIX** times **more energy** than the most optimistically projected $\beta = 15\%$ “second stable” Tokamak !!

Accordingly Tokamak advocates should **admit** that if they desire a smooth, cusp-free, toroidal magneto-static configuration which is topologically stable, and **also** has truly robust EMTFD dynamic stability, then they should either switch to Topolotrons or else **point out a mathematical error** in BYU’s published rigorous demonstrations that the **optimal static & dynamic design desiderata demand** a **UNIQUE** solution in the category of an **Invulnerably Robust BYU Topolotron!!**

PLASMASPHERE

Initial History

When Bass was working on the BYU Topolotron project, he was approached by Tesla Technology expert Robert Golka with an account of Tesla's claim to have created artificial Ball Lightning in 1899, together with the late James Tuck's LANL-Reported theory of **Ball Lightning** as involving **"dynamic Madelung forces"** as well as anecdotal observational evidence suggesting some kind of **Surface Tension** in natural fireballs (which allegedly rolled off tables & bounced). Also Bass had been exposed to the Poissor concept of the late electronic-TV inventor Philo Farnsworth, his immediate predecessor in **electrostatic-inertial** fusion research at BYU, which was then being continued by Farnsworth's final collaborator Andrew Gardner.

This led Bass to consideration of Raizer's Optical Plasmotron and the well-documented phenomenon of laser-created fireballs in what have been called **"laser spark"** plasma-creation demonstrations.

Finally Bass learned about Nobel Laureate Pyotr Kapitza's claim to have created **hot plasmas in genuine steady state** but just an order of magnitude short of the temperatures required for thermonuclear fusion reactions, which temperature Kapitza openly despaired of improving without a deeper understanding of the micro-physics involved, which led Kapitza to advocate purely empirical trial-&-error R&D.

PLASMASPHERE

Publications

1. "Nikola Tesla's Theory of Ball Lightning (Colorado Springs, 1899)," with R.K. Golka, *Simpozij "Nikola Tesla,"* Zagreb-Smiljan/Gospic, 7-10 Jula 1976, Jugoslavenska Akademija Znanosti I Umjetnosti, pp. 603-613.
2. "Tesla's Ball Lightning Theory, a BGK-Wave Soliton-Pair Langmuir-Debye Sheath Surface-Tension Hypothesis, the Farnsworth Effect, and the *Hydrotron* Electrostatic-Inertial Self-Confined Plasmoid Concept," with R.K. Golka, *Proceedings,* Annual Controlled Fusion Theory Conference, May 4-6, 1977, San Diego, Paper J3.
3. "Computer Simulation on Double Layers for Inertial-Electrostatic Confinement of Plasmas," with I. Oh & W. Schrader, *Fusion Technology,* vol. 6 (1984), pp. 35-43.
4. "Proof of Implausibility of Kapitza's Single-Well Potential Hypothesis in a Plasma Confinement," with I. Oh & W. Schrader, *Transactions,* American Nuclear Society (1984), p. 140.

Report

"The Pyrosphere Fusion Reactor Concept: A BGK-Soliton-Pair Explanation of the Destriau/Schelly-Eyring/Farnsworth/Kapitza-Raizer-Bekefi Effect Observed in the Solid/Liquid/Migma/Plasma State," presented [by invitation] to the Advanced Fusion Reactor *Concept Review Committee,* U.S. *DOE,* October 17, 1978.

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Unpublished Typescript

Preliminary Optimization of a Compact, Economical Low-Technology Aneutronic 1-MW PLASMASPHERE™ Fusion Reactor Design [submitted to *Fusion Technology,* 1984]

Patent

Generation, Insulated Confinement, and Heating of Ultra-High Temperature Plasmas, U.S. Patent **4,448,743**, submitted October 15, 1979 and issued May 15, **1984**; also granted in Canada, Mexico, and Japan.

United States Patent [19]

Bass

[11] **4,448,743**

[45] **May 15, 1984**

[54] **GENERATION, INSULATED CONFINEMENT, AND HEATING OF ULTRA-HIGH TEMPERATURE PLASMAS**

[75] Inventor: **Robert W. Bass,** Provo, Utah

[73] Assignee: **Applied Fusion Research Corporation,** Denver, Colo.

[21] Appl. No.: **84,837**

[22] Filed: **Oct. 15, 1979**

[51] **Int. Cl.**[3] **G21B 1/00**

[52] **U.S. Cl.** **376/103;** 376/152

[58] **Field of Search** 176/1, 3, 5, 9; 376/103, 104, 151, 152

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,346,458 10/1967 Schmidt 176/1

OTHER PUBLICATIONS

Laser Plasmas and Nuclear Energy, Henrich Hora (1975) Plenum Press, pp. 31-33, 64-72.

Laser & Electro-Optik, vol. 6 (3/74), Hora, pp. 26-27.

JETP Letter, vol. 21, No. 2. (1/20/75), pp. 68-70, Basov et al.

Primary Examiner—Sal Cangialosi

[57] **ABSTRACT**

Improved generation, insulated confinement and heating of ultra-high temperature steady-state plasmas in such devices as the optical plasmotron of Raizer and the freely floating plasma filament of Kapitza wherein the temperature of the plasma is increased by increasing the static pressure of the ambient medium (or decreasing the frequency of the radiant energy supply) while increasing the radiant energy supply's power and wherein the relationships between the ambient pressure, the amount of initially projected ionizing energy, the focal spot radius of this initial energy, the wavelength of the radiant energy supply, the transparency of the plasma, the rate of bremmstrahlung radiation energy losses, the power of the radiant energy supply and the ratio of the static pressure increase (or frequency decrease) are so optimized as to enable attainment of plasma temperatures more than an order of magnitude greater than hitherto attainable by any process of such a type.

5 Claims, 13 Drawing Figures

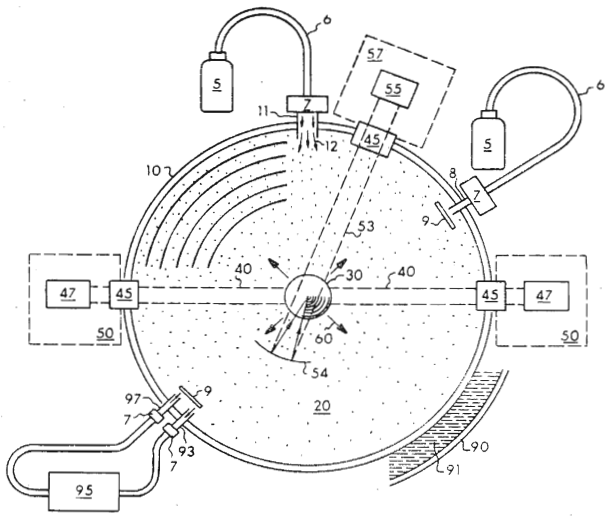

Fig. 1

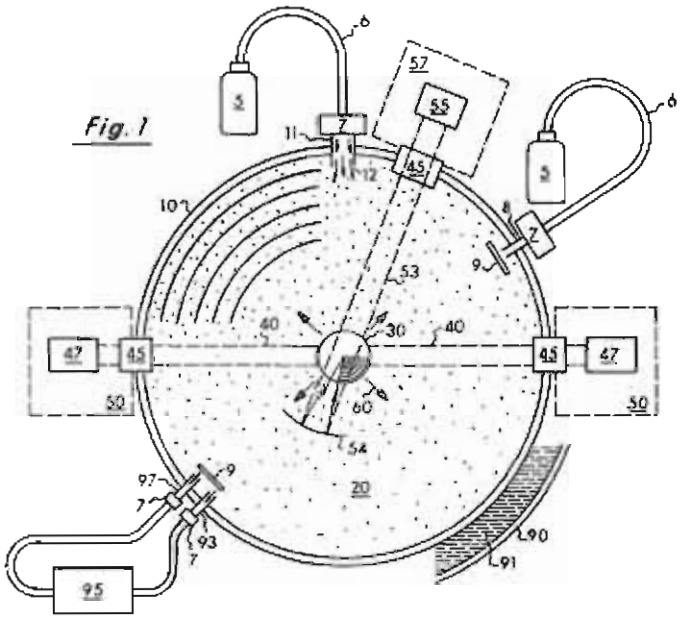

Fig. 2

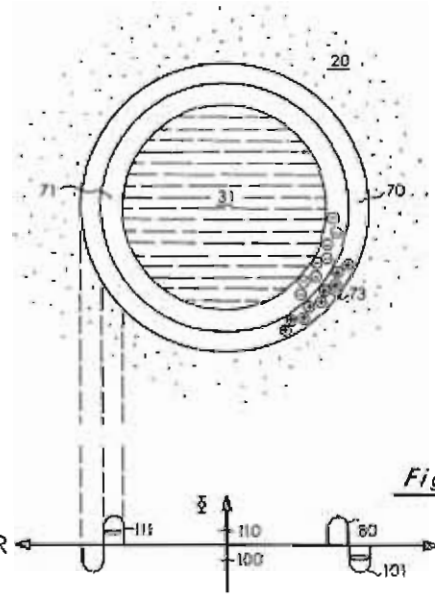

Fig. 3

PLASMASPHERE

The Plasmasphere purports to be a perfection of Kapitza's Free Floating Plasma Filament concept, based upon correction of a fatal flaw in his Boundary Layer Theory, and provides the **optimal spherical-geometry inertial-electrostatic fusion-temperature plasma confinement**. Kapitza thought that only electrons were confined and that positive nuclei went in & out of his 80 million Kelvins, meter-long, 3-cm diameter, cold-gas-confined, plasma column, maintained in steady state for literally weeks on end by 25 kW of microwave radiation.

With appropriate microwave energy compensating for bremsstrahlung radiation energy loss, an almost perfectly insulating **charge-separation layer** can be maintained in the interface between a thermonuclear-fusion temperature plasma and an external high-pressure cold-gas confinement layer. Solution of the Poisson-Boltzmann or Vlasov Equations both analytically and by confirmatory computer simulation of a **TRUE double-layer** establishes that a temperature discontinuity of a billion Kelvins can be maintained by a boundary layer only millimeters in thickness.

Kapitza visualized a radial electrostatic potential in the form of a plateau inside the plasma, followed by a slope to a new plateau which would of course reflect particles of one sign only. But the shock between a hot plasma and a cold gas will create a radial potential of the form of a plateau inside the plasma, followed by an adjacent hill leading to a slope into a deep well, followed by ascent to a lower plateau outside the plasma, which must be at zero potential inside the non-ionized cold gas.

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In 1984 Bass published a theoretical demonstration of the implausibility of Kapitza's Single-Layer theory (which Kapitza had announced in his 1978 Nobel Prize Acceptance Speech) and, also in 1984, together with physicist Inki Oh & numerical analyst William Schrader, Bass published both an analytical solution showing a true Double Layer and a computer simulation verifying the analytical solution.

Later, Israeli physicists Eliezer & Ludmirsky directly **measured** the electrostatic potential in the thin boundary layer of a hot plasma expanding into ambient cold gas, and found exactly the true **hill-plus-valley profile** that Bass had earlier published**!**

The late venture capitalist Darryl Gammill, and his Attorney-Advisor Harry A. King III, who held an M.S. in Mechanical Engineering as well as a J.D., started Applied Fusion Research Corp. (AFRC) to acquire the Plasmasphere Patent Rights, and then AFRC paid the world's oldest Fission-Reactor Designer, Stone & Webster (S&W), $500K to make a Parts List showing that a 1 MW Plasmasphere demo (based upon a 9-cm-diameter fusion plasma and an ambient 60-meter diameter cold gas blanket) could be constructed with Commercial Off-The-Shelf (COTS) components. S&W then gave AFRC a Fixed Price Bid of $5 Million that they would procure the parts "within 6 months" and then assemble a working Plasmasphere anywhere in the world "within two weeks," and turn it over to AFRC, guaranteed functional**!!** But AFRC could never raise the required capital, and then Gammill died prematurely in a terrible automobile accident, and his company AFRC expired, and now the Plasmasphere Patent has expired as well.

PLASMASPHERE

The preceding account should be expanded to include thanks to the late "pope of plasma physics," Marshall Rosenbluth, who found that Bass had **initially** underestimated the bremmsstrahlung loss on the **outside** of his double layer, though this flaw was not fatal and was overcome by merely raising the total external microwave power requirements.

Also it is gratifying to acknowledge that, when EPRI hired Rosenbluth's eminent collaborator Norman Rostoker to critique AFRC's proposal, he became sufficiently impressed that he actually applied to the DoE for funding to duplicate Kapitza's experimental demonstration, and commented in writing that it was a **major "scandal"** that Kapitza's work had been ignored both in his native Russia and in the Western World as well. But alas, even though Rostoker had received the APS Plasma Physics Division's highest accolade, the James Clerk Maxwell Award, his well-informed & wise words fell on deaf ears!

Thus it seems fair to say that it is today merely the result of an unfortunate confluence of several historical accidents that the Plasmasphere Fusion Reactor had not been reduced to actual practice decades ago.

MetaStable Helium & Hydrogen *Crystals* (**MSH**, **MSP**, **MSD**) via Liquid Metallic Plasmoid (**LMP**) Precursors

by

Dr. Robert W. Bass

Innoventek Inc.

NanoscaleEngineering of *Crystalline* **M**eta**S**table **E**lements (**MSE**s):
MetaStable Helium & Hydrogen *Crystals* (**MSH**, **MSP**, **MSD**)
via Liquid Metallic Plasmoid (**LMP**) Precursors,
Enabling Revolutionary Energetics Technologies & Challenging Nanotechnology

ABSTRACT

Though inadequately appreciated, it is well established experimentally & understood theoretically how gasses may be ***pressure ionized*** rather than thermally ionized and thereby constitute self-confined, self-cohesive **P**lasmoids in the physical state of volume-conserving **L**iquid **M**etals (**LMP**s) rather than conventional expansive gaseous plasmas.

The same theory which correctly predicts the properties of LMPs shows that as they cool radiatively while levitated magnetically *in vacuo* they must shrink in size while increasing in density and internal "negative" pressure or self-cohesiveness.

Crystallization of an LMP will provide revolutionary ways of **generating (MSD)**, **transmitting (MSP)**, and **storing (MSH)** energy.

There remain three **challenges to Nanoscale Engineering** theory & practice:

(1) predict at what temperature [hopefully, above room temperature] the LMP will crystallize;

(2) predict the MetaStable Element (**MSE**) crystal's nanoscale geometry & lattice-period length L;

(3) engineer adjustment of L by inclusion of trace impurities to facilitate/avoid Quantum Resonance Triggering (**QRT**) of desired/undesired Cold Nuclear Fusion [in MSD or MSP] by producing ratios of L to Zero Point Fluctuation (**ZPF**) *rms* amplitudes Λ which when divided by π are closer to ***odd*** or ***even*** integers, i.e. NANOSCALE-engineer the ***Schwinger Ratio*** $\sigma = L/(\pi \cdot \Lambda)$.

MetaStable Deuterium (MSD) as Cold Fusion Fuel

Credibility of the Low Energy Nuclear Reaction (**LENR**)

ANEUTRONIC **d + d ==> ^{4}He + 24 MeV** (lattice phonons)

has been enhanced since ASPW2001 by new developments:

(1) **ICCF9** Tsinghua University, Peking, China on May 20-24, 2002.

(2) Cold Fusion session, **American Physical Society** in Austin, TX on March 7, 2003.

(3) Invited Submission to **DARPA** by **SRI Int'l** of White Paper proposing to perform the so-called **Bass Protocol** definitive proof of CF for presentation at **ICCF10** in August, 2003: http:www.lenr-canr.org/acrobat/BassRWfivefrozen.pdf

(4) Posting by **NRL** of lengthy review of a decade of **CF** evidence from 3 separate NRL labs with explicit call for other government agencies to take appropriate notice.

(5) New **archive** lenr-canr.org with important CF papers now readily available.

Turner/Bush/Bass theory (related to work of Parmenter, Chubb, Kim, Li *et al*) of Resonant Transparency of Coulomb Barrier in Periodic Lattices

Quantum Resonance Triggering

Coulomb/Madelung/Fermi-Thomas/Mott Potential $V = V(r)$, $-\infty < r < +\infty$.
Bound Positively-Charged Particles at $r = \pm k.L$, $k = 1,2,3, \ldots$

Averaged electrons at mid-point between bound particles,
except for $-L < r < L$, where three unit-charges are smeared out as an electron cloud.

Schwinger Ratio = $L/(\pi \cdot \Lambda)$, Λ = rms amplitude of **Zero Point Fluctuations**

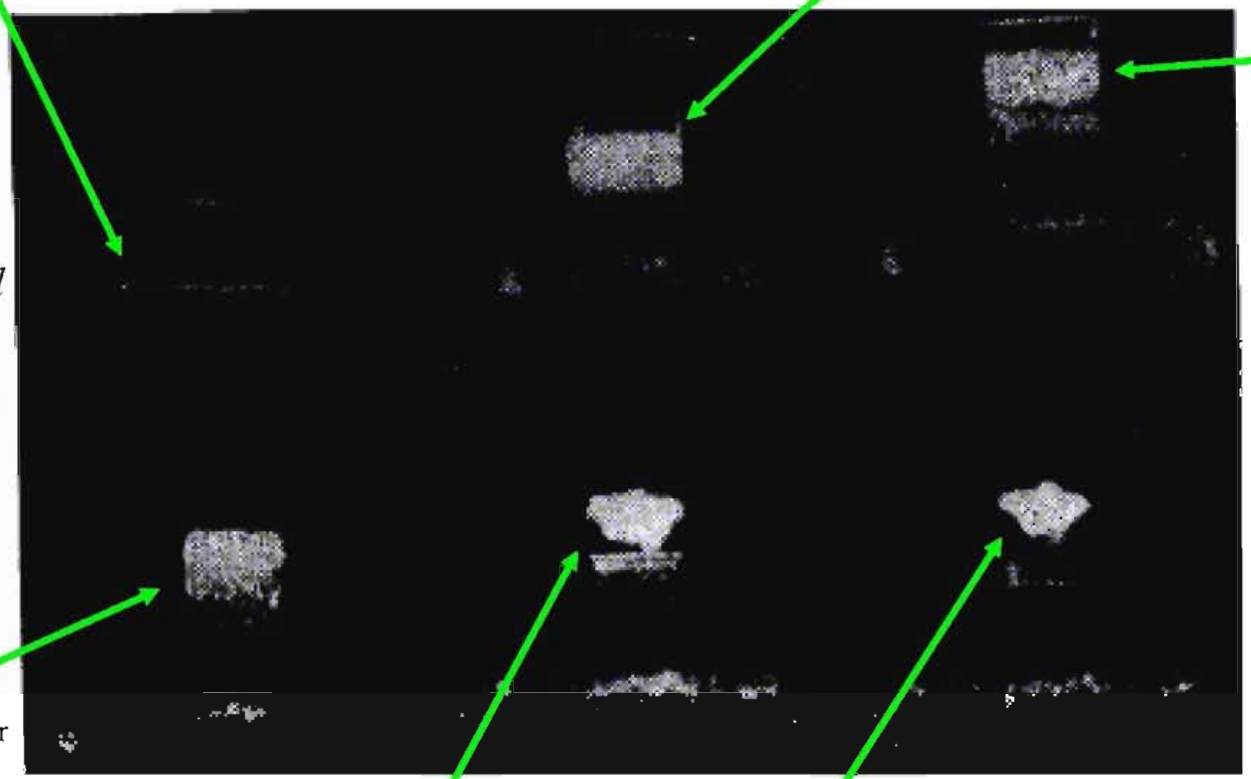
Potential validated by predicting Schwinger Ratio within one-third of one percent of measured reality, i.e. a 99.7% accurate PREDICTION of an empirical measurement!

QRT Principle: A host-lattice pair is suitable for Cold Fusion (in the sense that the so-called "Coulomb Barrier" is actually a resonantly transparent mirror), if and only if the Schwinger Ratio is closer to an **ODD** than an Even **integer.**

DECISIVE TEST: Consider 4 possibilities, wherein host lattice is either Palladium or Nickel, and positive particles are either Protons or Deuterons. Then host-particle pair is suitable for Cold Fusion if and only if it satisfies the QRT Principle, which turns out to be the case for Protons and Deuterons in Nickel and Deuterons in Palladium NOT to be the case for Protons in Palladium! (I.E. heavy wateer but not ordinary water will work in an F&P electrolysis cell.) Thus Principle predicts **non-obvious** truth in 4 out of 4 cases!

MetaStable Helium and Metamatter

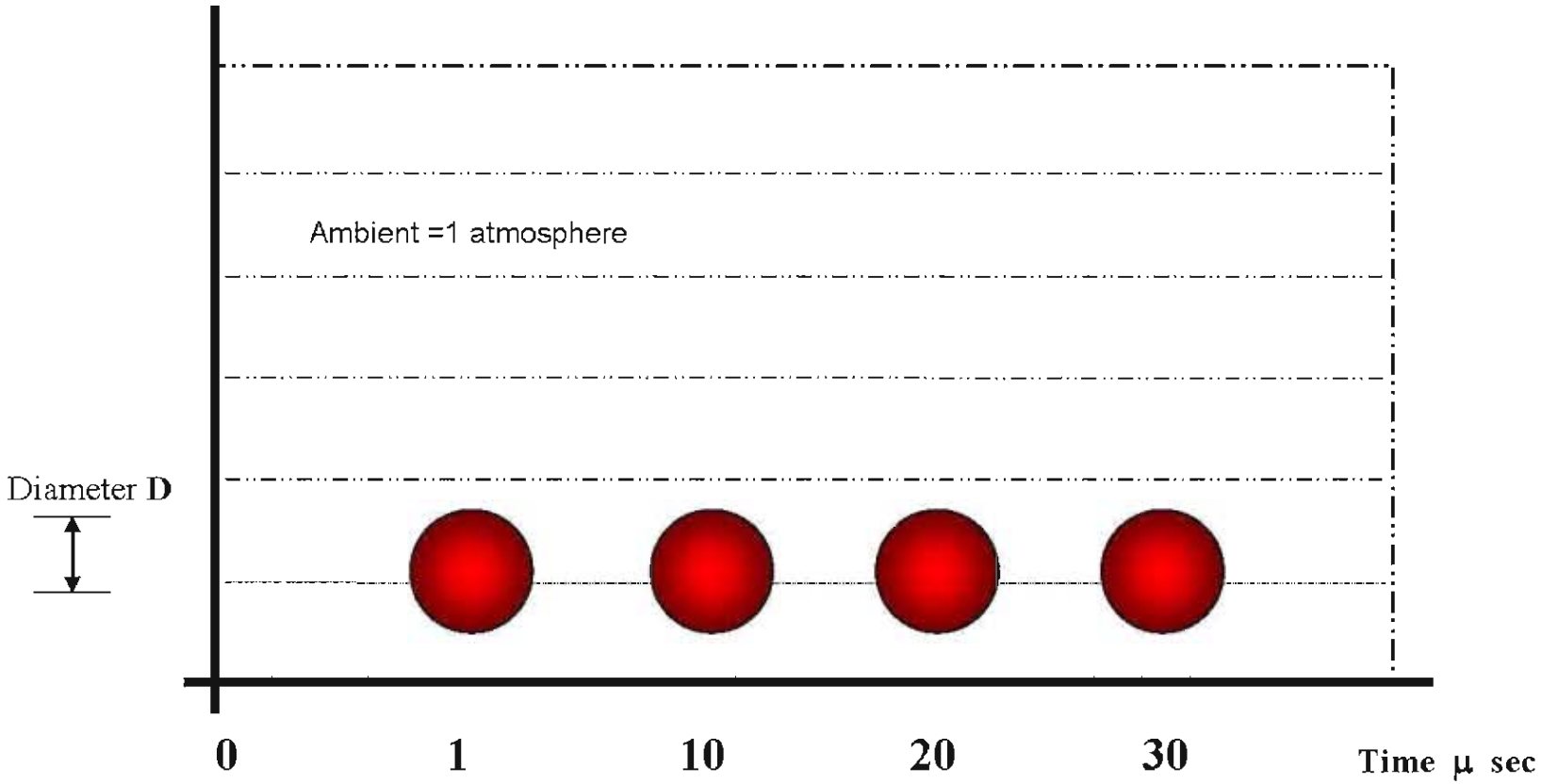
Time-lapse photograph from Melvin Cook's, "Cohesion in Plasma," *Journal of Applied Physics*, Vol. 29, p. 1612, Nov. 1958.



LMP

Liquid Metallic Plasmoid

Nitro-Nobel Medalist, **Melvin Cook** (Cover, *Journal of Applied Physics*, Nov. **1958**)



Measured Diameter **D** does **not** increase in time!

Accidental experimental discovery of self-cohesion in a dense plasma

Ideal Plasma Equation of State

Interparticle distance $d \ll D$ = Debye shielding length

$\boldsymbol{p}$ = pressure (joules/m^3)

$\boldsymbol{n}$ = particle density (per m^3)

$\boldsymbol{k}$ = Boltzmann's constant (joules/kelvin)

$$\boldsymbol{p = 2nkT}$$

Plasma Equation of State (Berlin-Montroll)

p = pressure (joules/m^3)

n = particle density (per m^3)

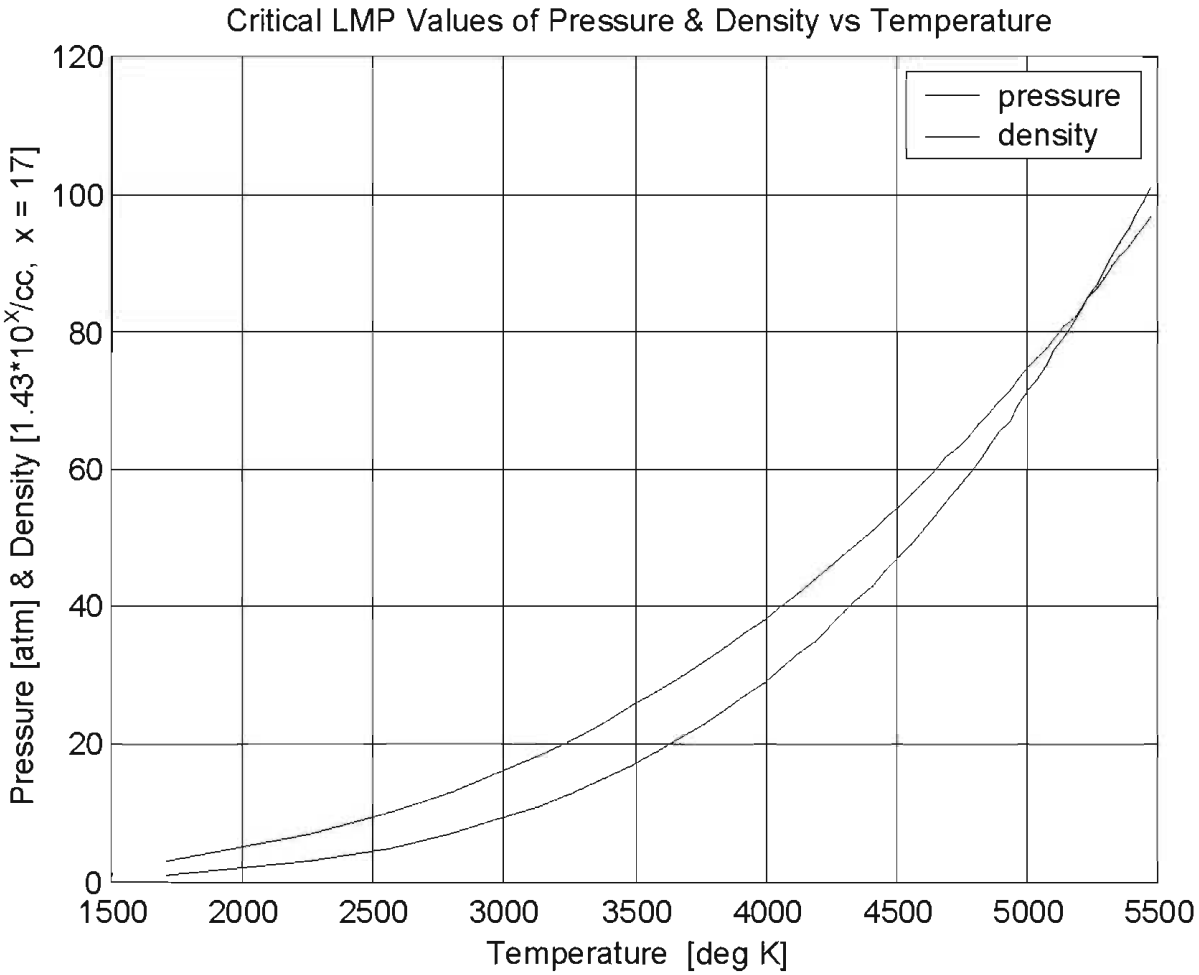
k = Boltzmann's constant (joules/kelvin)

e = electron charge (Coulombs [= { joule-m }$^{1/2}$])

$$p = \{ (7/6) - [(2\pi)^{1/2} \cdot (e^2/2)] \cdot (n^{1/3} / kT) \} \cdot 2nkT$$

implies

$$p < 0 \quad \text{if} \quad n >> (kT)^3$$

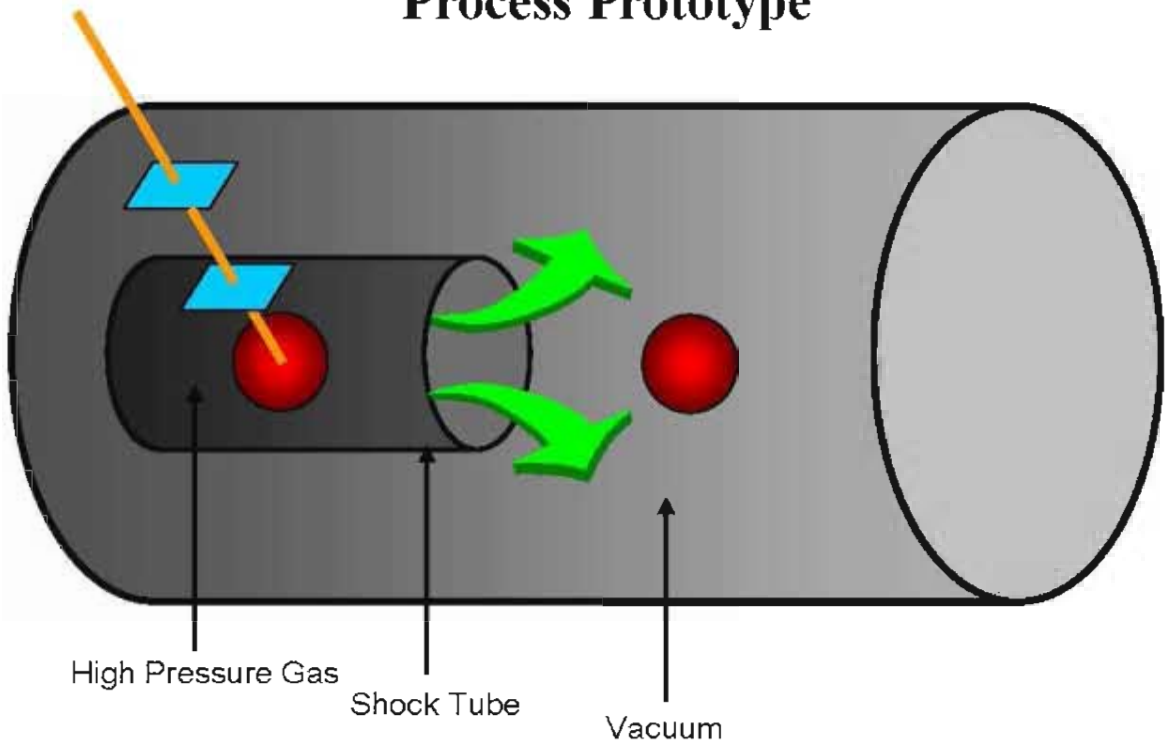


Brush-Sahlin-Teller Equation of State

LMP

Proof -of -Principle

Process Prototype



LMP= Liquid-Metallic Plasmoid

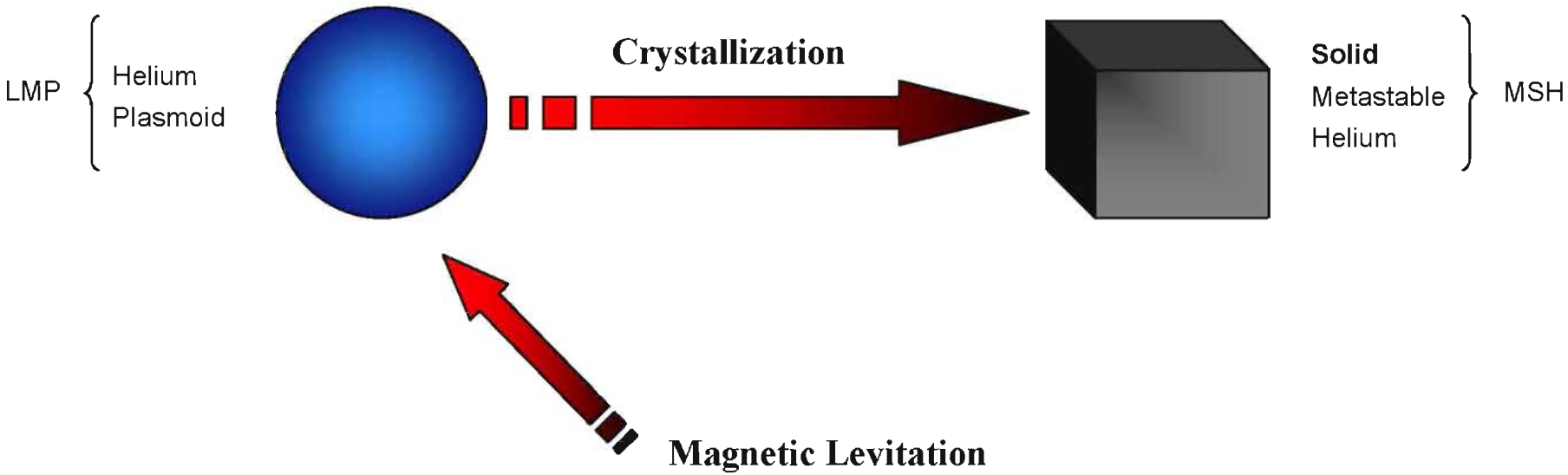
cooled LMP (He) =Metastable Helium=MSH

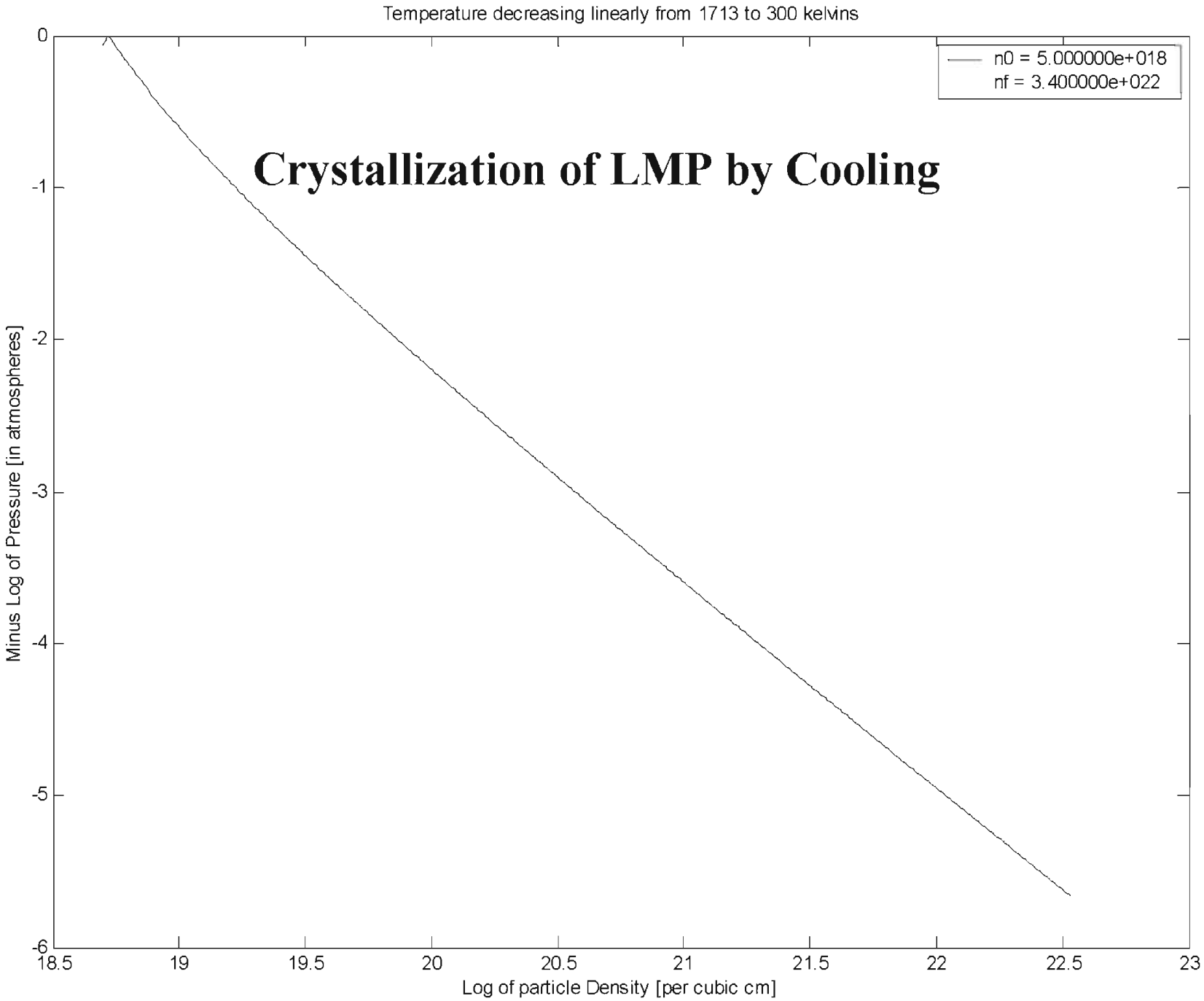
cooled LMP (D)=Metastable Deuterium=MSD

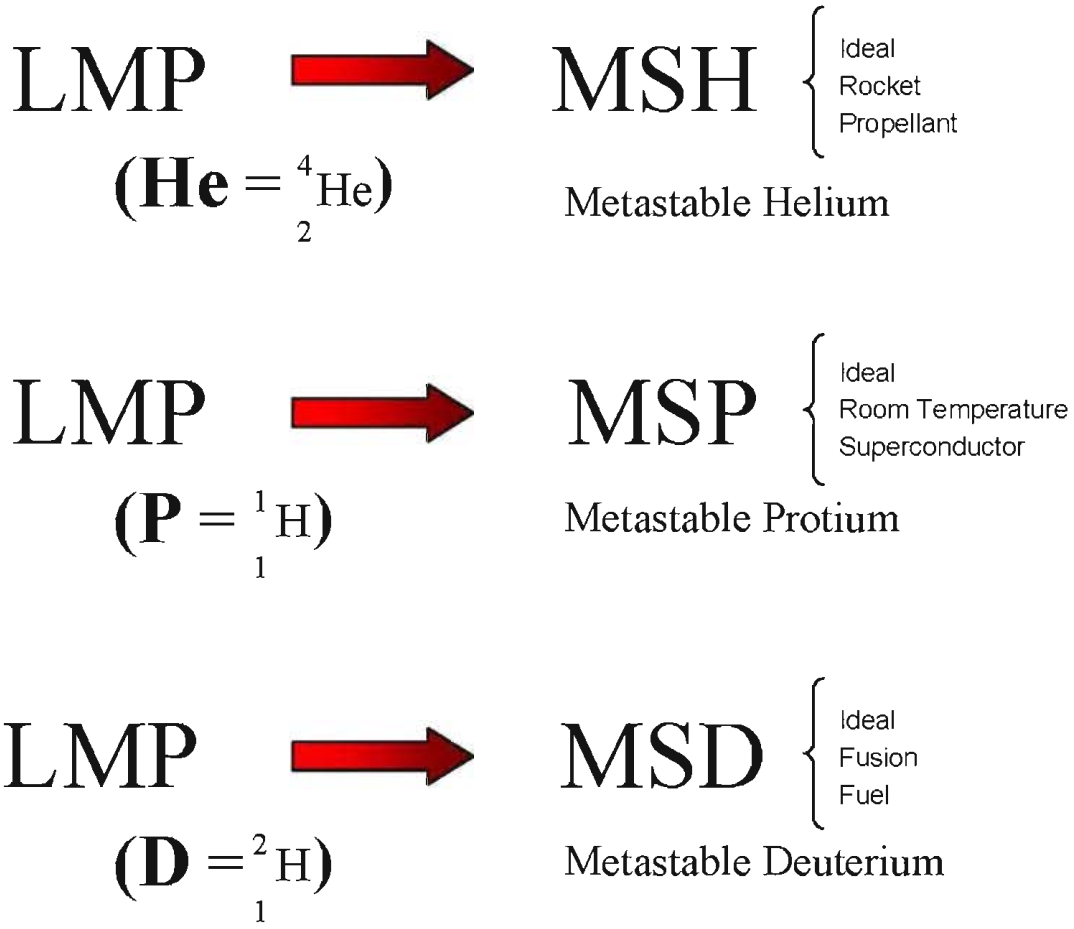
cooled LMP (H)=Metastable Protium=MSP

} Solid Crystals

Metastable Helium (MSH) Manufacturing Process




Temperature decreasing linearly from 1713 to 300 kelvins
n0 = 5.000000e+018
nf = 3.400000e+022
Crystallization of LMP by Cooling
Minus Log of Pressure [in atmospheres]
Log of particle Density [per cubic cm]
0
-1
-2
-3
-4
-5
-6
18.5
19
19.5
20
20.5
21
21.5
22
22.5
23



Three species of **Metamatter** which address different markets