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

by

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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*** $\boldsymbol{\sigma} = L/(\boldsymbol{\pi} \cdot \boldsymbol{\Lambda})$.

Upper Bounds on Isp

MetaStable Crystalline **Hydrogen**	$<$	3,576 sec
MetaStable Crystalline **Deuterium**	$<$	2,529 sec
MetaStable Crystalline **Helium**	$<$	1,788 sec

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 (Narrative)

Cook's accidental discovery of a "cryscapade" and Tuck's independent attempts to replicate Ball Lightning artificially

This presentation concerns a proposal to approach the creation of a solid crystal of MetaStable Helium (**MSH**) via cooling of a mass of pressure-ionized helium in the physical state of a liquid metal or Liquid Metallic Plasmoid (**LMP**).

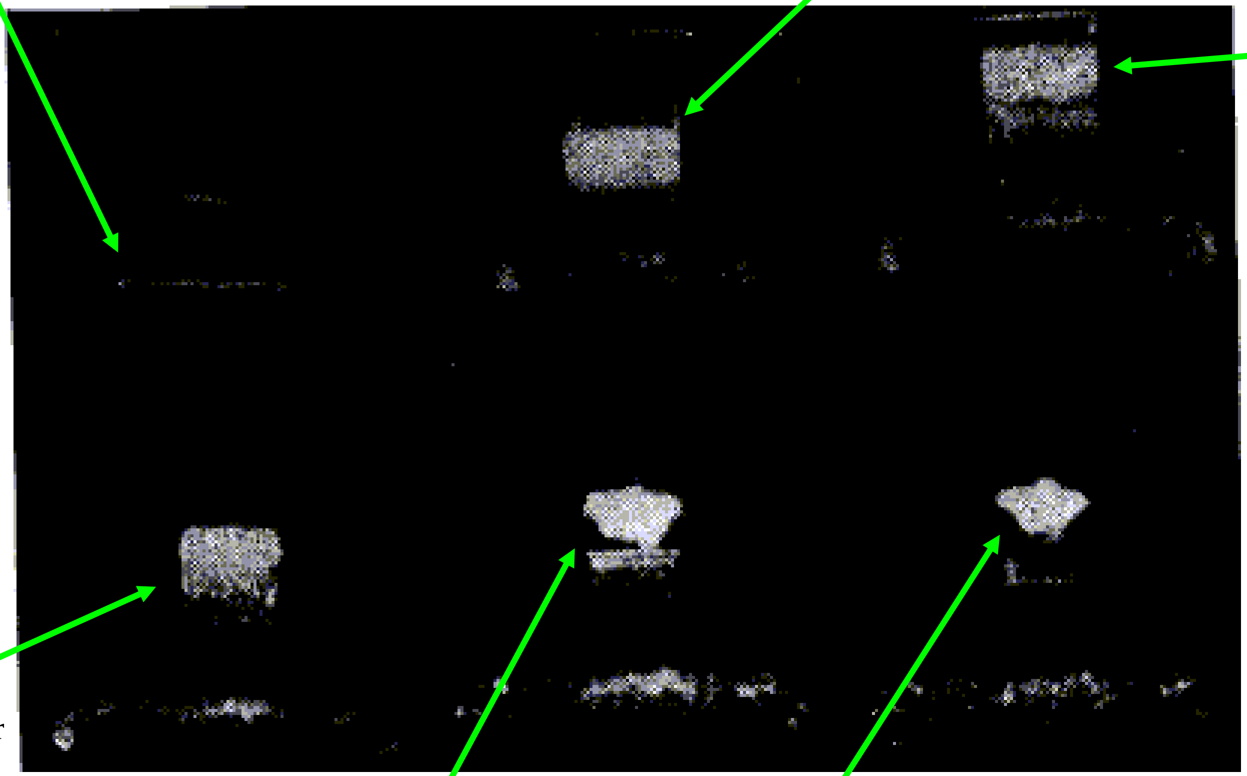
The case for the existence of LMPs can be based upon two experimental findings (both involving use of a self-destructive explosive apparatus) and five independent theoretical predictions of the reality of LMPs.

After his retirement from leading decades of hot fusion research at LANL, the late James Tuck (co-inventor of the Theta Pinch) took up the scientific study of Ball Lightning and published a review on the subject in *Nature* in the late 1960's and a more comprehensive Los Alamos Report in 1971. He later showed R. Bass and others slow-motion movies of an explosion which he had created by short-circuiting a submarine battery (undertaken because sailors had reported sighting fireballs while submerged). The film showed small floating fireballs moving toward the camera. Because of anecdotal evidence that Ball Lightning can roll off a table and bounce, Tuck concluded that these plasmas must have either "surface tension" or volumetric coherence or both; he ascribed the latter to "dynamic Madelung forces," which are the same long-range, summed electrostatic forces that provide solid-state crystalline stability.

Quite independently and evidently unknown by Tuck, Melvin Cook, late Emeritus Prof. of Metallurgy at the University of Utah, had in 1958 already arrived at the same explanation for the evident stability in shape and volume of fireballs which he had accidentally discovered during high-explosive experiments at the China Lake Naval Weapons Center. Using a streak framing camera, Cook & McEwan photographed a fireball every 4 microseconds for about 15 such time intervals, during which the size and shape of the fireball remained unaltered, even though its energy density greatly exceeded that of the ambient atmosphere. There are a half dozen such photos on the cover of the *Journal of Applied Physics*, Vol. 29, Nov. 1958, showing six successive time-lapse photos at 4 microsecond intervals. The leftmost photo shows a beaker of dithekite right after its detonation. The next three photos show a plasma exiting the beaker. The final two photos show this plasmoid remaining constant in volume and shape, even though its energy density is a hundred times that of the ambient atmosphere. If it were a gaseous plasma it would be expanding at the local acoustic speed. Cook therefore deduced that it was in the physical state of a liquid metal, in which the long-range summed electrostatic forces of cohesion exceeded the thermal expansive forces. He dubbed this fluid-crystal-plasmoid a "Cryscapade" and published a semi-empirical "dynamic-Madelung-force" quantitative theoretical explanation in his books on the science of high explosives.

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 (Narrative)

Cook's discovery abstracted schematically

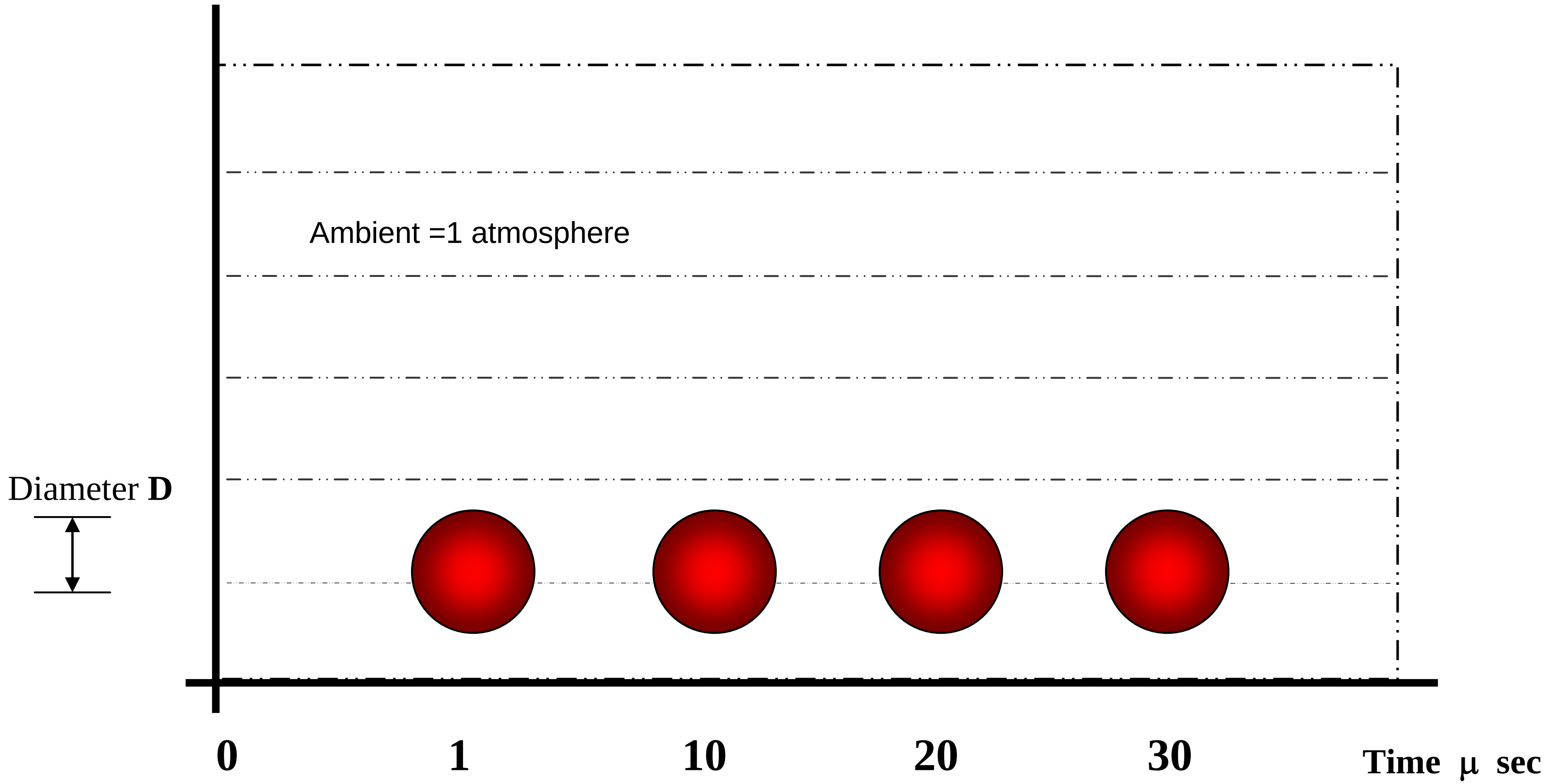
Cook, who held a doctorate in physical chemistry from Yale, received in 1967 from the Swedish Royal Academy the first **Nitro-Nobel Medal** for the best work on the physical chemistry of high explosives in the century since Alfred Nobel discovered dynamite. His monograph on the subject was published by the American Chemical Society and reprinted by the Krieger Reprint Corporation, which also more recently has published a new book by Cook on the *Science of Industrial Explosives*. In both of his books there are extensive Appendices treating his discovery and proposed theoretical explanation of an LMP using the terminology of a "cryscapade."

This slide depicts in a slightly over-simplified manner the essence of Cook's discovery. Measurements of electron density showed that the fireball was ionized. However, if it had behaved like a gas, its diameter should have increased at the local speed of sound. In attempting to resolve this puzzlement, Cook realized that when a plasma is sufficiently [relatively] dense and at a sufficiently [relatively] low temperature, the electrostatic energy of cohesion must be subtracted from the conventional ionization threshold energy. For example, according to the Saha equation, a mono-atomic hydrogen gas will not become fully ionized unless its temperature exceeds 150,000 Kelvins. But Cook's fireball had a temperature of only a few thousand Kelvins! The explanation of the apparent discrepancy is that for dense plasmas, *pressure ionization* becomes more important than thermal ionization. Cook presents a semi-empirical energy-balance formula for the "dynamic lattice" of an LMP which shows thermal expansive forces overcome by electrostatic Madelung forces such as are considered in conventional solid-state physics. Cook's semi-empirical formula can be re-derived with more complete justification from the theory to be discussed next.

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 (Narrative)

There is a good review of the Statistical Mechanical Foundations of plasma kinetic theory in a chapter by Burton Fried of UCLA in the book *Plasma Physics in Theory and Application*, McGraw-Hill (1966), edited by Wulf B. Kunkel. Fried shows that the actual expression for the energy density of a fully ionized and electrically neutral plasma is a convergent infinite series, of which only the first term is significant when the interparticle distance d is much less than the Debye shielding length D. This first term has the form shown in which the particle density (multiplied by two for the two species of particles, electrons and ions, which are present in equal numbers because of assumed average charge-neutrality) is multiplied by the average kinetic energy of each particle. This of course defines the average temperature with Boltzmann's constant providing the factor of proportionality.

The similarity to the ideal gas law shows that if a plasma is in the state to which this equation applies, it will behave like a gas.

However, there are at least four published theories which attempt to estimate or approximate the sum of the neglected terms in the case wherein it may be significant.

In the case of a weakly non-ideal plasma, one may use the Deby-Hückel equation of state. Prof. Pozwolski of the University of Paris used this equation in publishing a theory of Ball Lightning's evident self-cohesiveness [in a European journal in the late 1970's], and, after learning about Cook's prior work, he sent a reprint of his paper to Cook pointing out the essential agreement between their respective theories.

However, in the case of a strongly non-ideal plasma, the Berlin-Montroll equation of state, though giving qualitatively similar results, is more accurate numerically and therefore for brevity is the only one to be presented explicitly here.

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)
(Narrative)

As can be verified from this equation of state, which is the same as that of the previous slide except for a dimensionless correction factor, the second term in the correction factor is negligible if (assuming only singly-ionized atoms) the ion density n is small in comparison to an appropriately-dimensioned constant 5.06 multiplying the **cube** of the temperature term kT [although the final pressure is now multiplied by 7/6 instead of 6/6].

But if the density is large in relationship to this factor proportional to the cube of the temperature, then the entire dimensionless factor changes sign!

In other words, the pressure become *negative*. Instead of providing a thermally expansive energy, the aggregate electrostatic forces have overcome the thermal or kinetic energy of the particles by providing a volumetrically *cohesive* potential energy!

At the time of this presentation to the 12^{th} Advanced Space Propulsion Workshop (ASPW2001), we thought that there had been only 4 independent discoveries of the theory of LMPs being exposited here.

However, fortunately there was present a Prof. of Physics from UNR, Friedwardt Winterberg, who recognized the LMP theory being presented as virtually identical to that in his 1978 paper "Electrostatic Theory of Ball Lightning," *Zeitschrift fur Meteorologie*, Vol. 28, pp. 263-269!

Winterberg had derived for a plasma an approximate Debye electrostatic potential in the form of a Yukawa potential, which [referring to the strong nuclear force rather than electrostatics] describes the Liquid Drop model of a nucleus and therefore suggests that a pressure-ionized plasma may indeed behave self-cohesively like a volume-conserving liquid metal.

Winterberg's critical density is of exactly the same form proportional to $(kT)^3$ as that mentioned above, except that the above-mentioned constant 5.03 becomes 9, i.e. a discrepancy of less than a factor of two (understandable in view of the approximations involved in using the Debye model of the plasma fluid).

Winterberg does mention that for more precise calculations one would need to include the effects of quantum-mechanical exchange forces, to which we now turn.

Plasma Equation of State (Berlin-Montroll)

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

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

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

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

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

implies

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

Brush-Sahlin-Teller Equation of State
(Narrative)

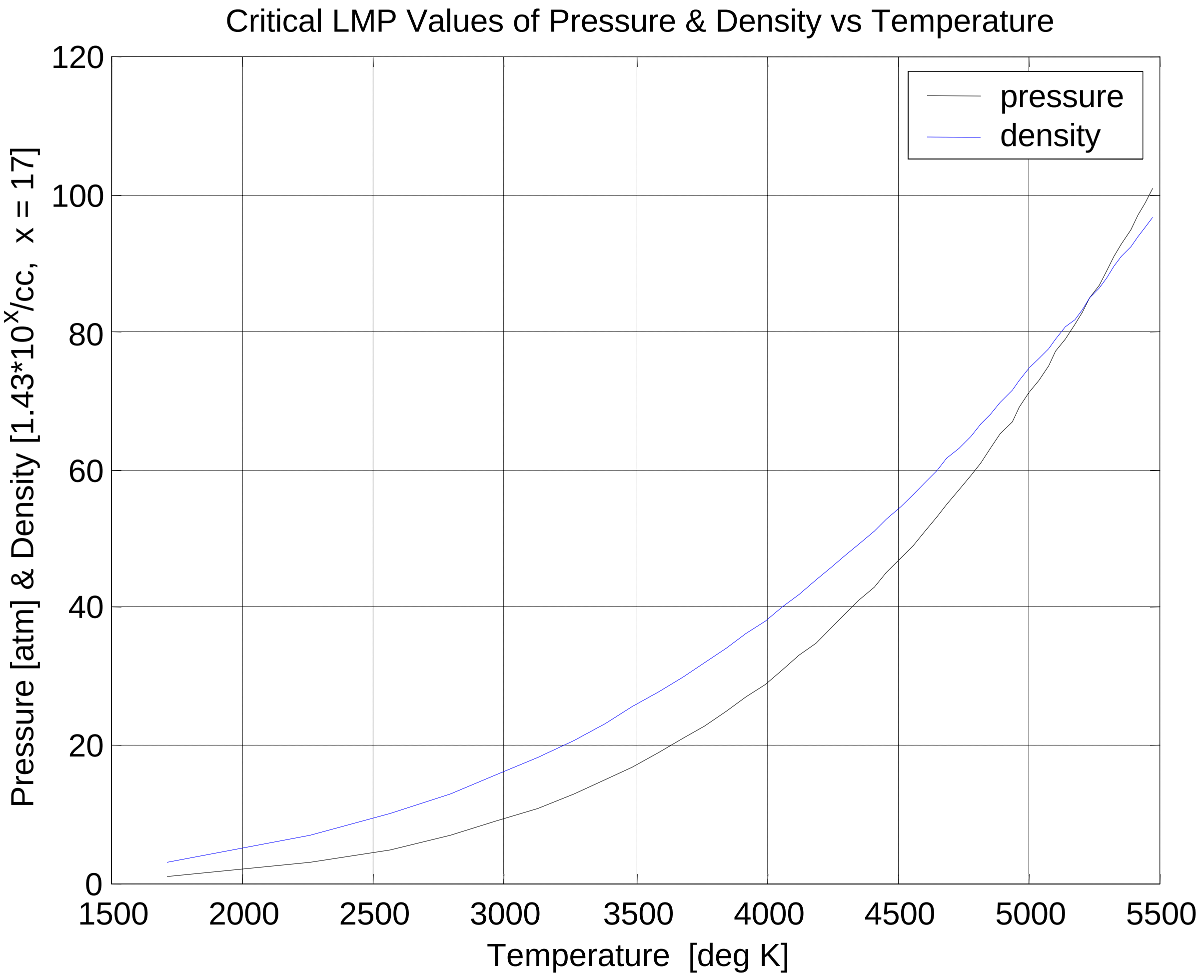
The late Harry Sahlin (who had privately endorsed the theory of Laser 'Spark' [fireball] Generation presented in US Patent 4,448,743, issued May 15, 1984, by Robert W. Bass) collaborated at LLNL with Edward Teller in fusion-bomb research using this correction to the purely electrostatic type of theories mentioned so far. In this more complicated theory quantum-mechanical exchange forces are not neglected. (See *J.Chem.Phys.*, Vol. 4 (1966), p. 2102, co-authored with physicist Stephen Brush of the U of MD.)

In connection with classified Navy research pertaining to underwater technology (and therefore presumably to the high pressures available at great depths), H.E. Wilhelm published a theory of pressure-ionized plasmas in a liquid metallic state entitled "Ionization and Cohesion in Dense Plasmas," *IEEE Trans. on Plasma Science*, Vol. PS-8 (March, 1980), pp. 9-14, based upon the Brush-Sahlin-Teller Equation of State. This equation is too complicated to present here, but a numerical example of the critical values of density and pressure in a hydrogenic plasma as a function of temperature is presented. It still turns out that around ninety percent of the cohesive energy is electrostatic, and the remaining ten percent correction based upon quantum mechanics is needed only for very precise modeling. The cubic dependence upon temperature is visually evident.

Note that if one employed 40 atmospheres pressure, the temperature would have to be below 4,500 Kelvins, and at room pressure (as in Ball Lightning) the temperature would be less than 2,000 Kelvins.

The difficulty, of course, is to create a plasma fully ionized at such "low" temperatures, in the light of the fact that all conventional ionization procedures require bringing the gas to a temperature of over 100,000 Kelvins in order to ensure that it is fully ionized.

In summary, however, it would seem unreasonable to doubt the existence of **LMP**s (in view of the vast anecdotal evidence for natural Ball Lightning, a photo of which was recently published in *Nature*, and the convincing experiments of Cook and Tuck), and there is no good reason to doubt the theory of LMPs sketched above, which theory was arrived at independently by **FIVE** qualified scientists (**Cook, Tuck, Pozwolski, Winterberg, Wilhelm**), who started from accepted first principles and pursued different paths of reasoning and yet reached an essentially identical theory!



Brush-Sahlin-Teller Equation of State

Blauer-Bass LMP Proof-of-Principle Process-Prototype Protocol (Narrative)

The late Jay Blauer, a renowned expert in both shock-tube technology and high-energy chemical laser technology, suggested to Bass that by appropriate adaptation of the Laser Spark technology in the cited Bass Patent a definitive demonstration of the reality of LMPs under controlled conditions may be presented.

The cited 1984 Bass Patent was sponsored by the late Darryl Gammill upon the recommendation of his colleague Harry A. King III, and resulted in the published prediction of a double-electrostatic layer in the plasma-gas interface [R.W. Bass, I. Oh & W. Schrader, *Fusion Technology*, Vol. 6 (1984), pp. 35-43]. This was done independently of a similar prediction by P. Lalousis & H. Hora, *Laser & Particle Beams*, Vol. 1 (1983), pp. 283-304] prior to its experimental observation [A. Ludmirsky et al, *IEEE Trans. on Plasma Science*, Vol. PS-13 (1985)].

The cited patent provides an equation which optimizes the relationship between the following experimental parameters: (1) ambient gas pressure; (2) amount of initially projected energy; (3) focal spot radius of this initial energy; (4) wavelength of the radiant energy supply; (5) transparency of the plasma; (6) rate of bremsstrahlung radiation energy losses; and (7) duration of the energy projection, so as to create a fully ionized fireball of the type known as a “laser spark” and similar to the steady-state plasmas in the optical plasmotron of Raizer and the free-floating plasma-filament of Kapitza (rather than the transient plasma fireball of Bekefi).

Blauer proposed to modify the equation of Bass relating the 7 cited factors to the conventional energies of dissociation and ionization (as in the Saha Equation) by following Cook *et al* in <u>subtracting</u> from the usual ionization threshold energy the cohesive electrostatic potential energy from the five-times-rediscovered LMP theory already presented. Depending upon the wavelength of the laser selected, there are available crystal salts transparent to said wavelength, from which the small windows or ports shown in the figure may be fabricated. The inner concentric cylinder and the outer concentric cylinder are made of metal or similarly strong material and are gas-tight at high pressures. The inner cylinder has its end sealed by a metal foil which can be abruptly removed by pulsing a large current through the wire which welds it to the end of the inner cylinder, which is filled with gas at a relatively high pressure. (Here the word *relatively* must be stressed, for even a single atmosphere’s pressure is high relative to the hard vacuum in the outer cylinder.)

When the modified Laser Spark process is initiated, it is expected to create an LMP within the inner cylinder. The shock tube is then opened by a current pulse and the high-pressure gas will flow out explosively into the external vacuum chamber.

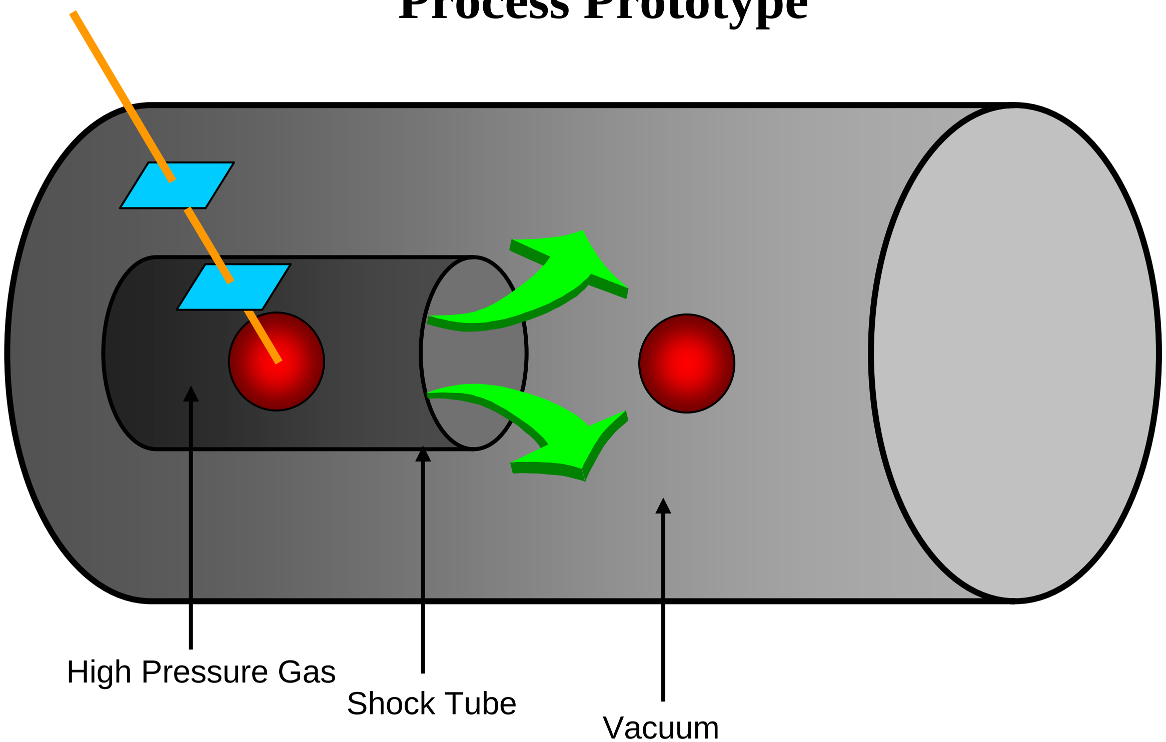
If the preceding protocol is successful, the fireball will remain at a constant diameter even though the ambient gas is rapidly becoming as rarified as a near-vacuum (assuming a sufficiently large initial vacuum volume).

Because of the flammability of hydrogen, I propose to experiment first with the inert noble gas, helium. If the inner cylinder is at least under 20 atmospheres pressure, then the target could be a pellet of solid helium, which could be fully ionized by a conventional laser-spark and then cooled by expansion to ambient gas pressure with the parameters so chosen that in this final state the critical conditions for an LMP are met!

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 Manufacturing Process (Narrative)

Assuming that the LMP protocol has been perfected, the next step is to create an LMP of helium in such a large outer chamber that (combining size with evacuation pumps) the LMP is for practical purposes in a vacuum.

Using off-the-shelf feedback-stabilized magnetic levitation systems, the LMP is then maintained in isolation from any other matter in a refrigerated vacuum chamber and allowed to cool by radiation.

The LMP theory presented indicates that as it cools the LMP shrinks in size and its internal cohesive energy becomes greater. The electrostatic cohesive energy then outbalances any destabilizing forces and the LMP becomes increasingly more dense.

It is not known yet from any available theory whether or not the LMP will crystallize as its temperature equilibrates with room temperature, but there is a good reason for expecting this, especially if an aligned magnetic field is added to the process in such as way as to polarize all electron spins identically up or down, because it has been argued that if such a spin-polarized metastable crystal were <u>somehow</u> brought into existence then it <u>would</u> be stable and safe to handle under ordinary conditions.

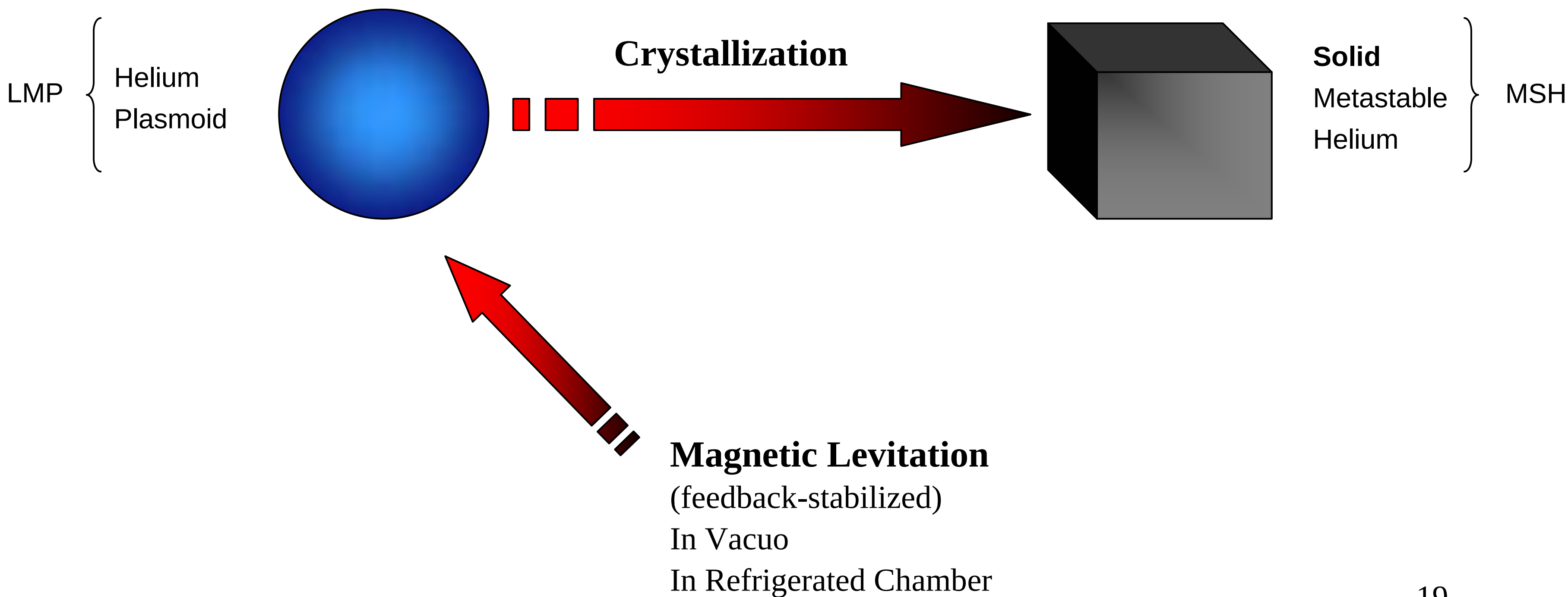
In 1973 J. Zmuidzinas of JPL proposed that spin-polarized solid metastable helium would be an ideal rocket propellant, with an energy density between 40 and 100 times that of the best conceivable high-explosive or liquid-propellant combination. Because of conservation of quantized angular momentum, the transition of an excited helium atom, having both electron spins aligned, down to the ground state, where they are opposed, is not allowed. *In vacuo* an excited triplet state has a half-life of 2.5 hours. In 1985 M.L Tapper of JPL published a study of "Ground-state energy calculations for He IV-A," *J.Phys. C: Solid State Phys.*, Vol. 18, pp. 4217-4226, using both classical and many-body quantum calculations to estimate the cohesive energy of the He IV-A crystal at zero pressure and to indicate that *FCC* may be the preferred lattice structure and that the solid would be thermodynamically stable up to nearly 600 Kelvins. This work was continued by R. A. LaViolette *et al* of INEL in "First principles calculation of the electronic structure of condensed spin-polarized excited triplet-state helium," *Phys.Rev. B: Condensed Matter*, Vol. 52 (1995), pp. R5487-90, who found *BCC* an even more favorable lattice structure, with over 1 eV of binding as a metallic *s-p* ferromagnet with a 1-eV indirect gap and a 4-eV direct gap, between the occupied spin-up and the unoccupied spin-down bands; the "surprising existence of such a gap" suggests that condensed He* might indeed be a metastable solid. However in a private communication LaViolette indicates that his present best estimate of melting point is impractically far below that of liquid nitrogen.

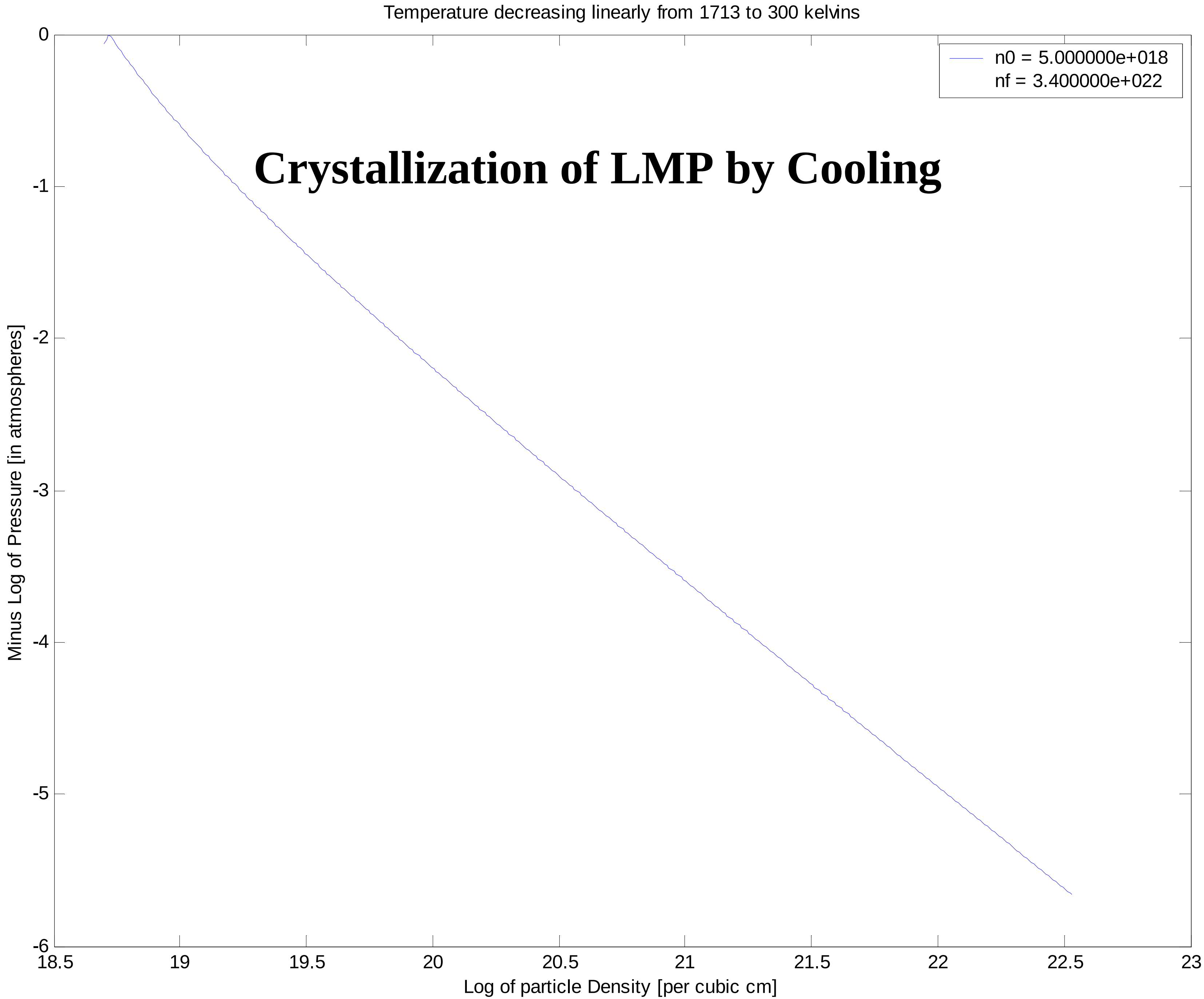
But if MSH could be manufactured in bulk it would have the same kind of specific impulse [3150 s] as electric propulsion and yet the high thrust of combustion propulsion (*cf.* R.H. Frisbee, JPL D-1194, Dec. 1983 Final Report on *Ultra High Performance Propulsion for Planetary Spacecraft*).

Although the DoD's JASON group in 1984 evaluated MSH as having "the same lifetime as a snowball in hell," causing the USAF to discontinue the project, they also admitted that they had <u>neglected</u> **collective effects** and that it would be "possible to postulate a kind of snow that doesn't melt" which, to continue the metaphor, is <u>precisely</u> what the **collective-effect cohesiveness** of the hitherto overlooked LMP state provides!

As the melting point of a metastable crystal of helium (or protium or deuterium) now appears to be more readily ascertainable by experiment than by theory, the desirability of moving from theory to experiment at this point in history is self-evident. There seems to be no room for reasonable doubt that an LMP can be created *in vacuo* under controllable conditions; practical utility depends upon whether or not crystallization of the LMP takes place above room temperature or below it.

Metastable Helium (MSH) Manufacturing Process




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

Metamatter for Energy Storage, Transmission & Generation

(Narrative)

If the Blauer-Bass protocol for creating an LMP from helium works and can be reduced to practice as a manufacturing process, the next step is to try it starting with hydrogen (protium) and heavy-hydrogen (deuterium).

Accordingly we should consider in addition to **MSH** as an ideal energy-storage medium, the crystals of **MSP** and **MSD** as possible room-temperature superconductors and as a speculative new cold fusion fuel.

Indeed, C.F. Richardson and N.W. Ashcoft, in "High Temperature Superconductivity in Metallic Hydrogen: Electron-Electron Enhancements," *Phys.Rev. Lett.*, Vol. 78 (1997), pp. 118-121, have "investigated the possibility of superconductivity in a dense phase" of metallic hydrogen, a prospect also predicted by M. Rabinowitz's phenomenological theory of superconductivity & superfluidity in materials whose interparticle distance is small relative to the corresponding deBroglie wavelength [cf. e.g. *Int. J. Theo.Phys*., Vol. 33 (1994), pp. 389-399 & *Chem.Phys.Lett*., Vol. 224 (1994), pp. 489-492].

Finally, note that since 1996 W. A. Nellis *et al* of LLNL have been creating liquid metallic molecular hydrogen and deuterium; cf. *The Sciences*, July/August 1996, p. 12. For further references, see the cover story on the May 2000 issue of *Scientific American* [pp. 84-90], which headlines: "The Stuff of Jupiter's Core Might Fuel Fusion Reactors." These experiments involve liquid hydrogen or liquid deuterium at initial pressures of 93 to 120 gigapascals and having the pressure suddenly increased to 140 to 180 gigapascals by means of target-destructive gas-gun experiments; of course, the mention of **fusion pellets** [page 89 *loc cit*] refers to ablative compression inertial-confinement fusion (ICF).

However, the Nov. 12-16, 2000 session of 22 Invited Papers at a Winter Meeting of the American Nuclear Society [ANS. *Trans.* Vol. 83, pp. 355-379] concerning the controversial subjects of Low Energy Nuclear Reactions (**LENR**) and Cold Fusion (**CF**) raises the prospect that crystalline MSD might be the "perfect" lattice needed to bring CF from a sporadic and poorly controllable process to a useful application, in accordance with the conclusion to C. Beaudette's recent book *Excess Heat: Why Cold Fusion Research Prevailed*, Oak Grove Press (2000), on page 301: "It may require that the [host lattice] be constructed one atom at a time in accordance with a tight specification." My proposal is that producing MSD via the indirect procedure of first producing an **LMP** of **MSD** and then **cooling** it to crystallization may be more cost-effeictive than the brute-force application of hundreds of megabars of direct pressure for an equivalent objective.

LMP → MSH { Ideal Rocket Propellant }

($\mathbf{He} = {}^{4}_{2}\mathrm{He}$)

Metastable Helium

LMP → MSP { Ideal Room Temperature Superconductor }

($\mathbf{P} = {}^{1}_{1}\mathrm{H}$)

Metastable Protium

LMP → MSD { Ideal Fusion Fuel }

($\mathbf{D} = {}^{2}_{1}\mathrm{H}$)

Metastable Deuterium

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