IS THE COULOMB FUSION-'BARRIER' A RESONANTLY-TRANSPARENT MIRROR? REFUTATION OF THE CONVENTIONAL COLD-FUSION 'QM-IMPOSSIBILITY' "PROOF"

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"**... information can be made memorable only when it is slightly coloured by prejudice**,"
Sir Kenneth Clark, in *All There is to Know,* (ed. A. Coleman), Simon & Schuster, 1994.

The University of Utah announced the millennial advent of a potentially unlimited, cheap, clean, non-polluting new energy source on March 23, 1989. The alleged discovery of a room-temperature electro-chemically induced form of nuclear fusion power by Dr. Martin Fleischmann, *FRS*, and Dr. Stanley Pons stunned the high-energy physics Establishment and the controlled thermonuclear fusion Establishment. Many other scientists and engineers throughout the world were electrified at the startling news. Frantic efforts to duplicate the **FP** Effect were initiated at numerous laboratories, in some cases by reluctant scientists more interested in previous ongoing activities than in their interruption to satisfy demands for confirmation or refutation. After some well-publicized 'failures-to-confirm' at highly reputable, well-equipped laboratories, a discussion panel of the American Physical Society voted 9-to-l that the subject of cold fusion (CF) was 'dead'. Subsequent commentary by Establishment physicists was almost universally dismissive, based on the proposition that "cold fusion *contradicts* the Laws of Physics!" with the obviously mandatory qualification "as those Laws are presently understood" often negligently omitted.

The initial dismissive skepticism, among sincere if possibly hasty or underinformed critics, was based upon two principal objections:

Objection 1. Deuterium fusion (as elucidated for the past half-century in the *H-bomb* and in the international quest for *controlled* civilian thermonuclear power) **either** produces *neutrons* **or** *tritium* in copious amounts with roughly equal probability, or (in extremely rare cases) energetic gamma-ray photons, but neither of these three *SUPPOSEDLY 'DIAGNOSTIC'* SIGNATURES was present in the FP Effect in amounts even remotely proportional to the excess heat allegedly generated.

Objection 2. Deuterons in a palladium lattice are not significantly closer together than in a molecule of deuterium gas, where the amazing but well-established phenomenon of quantum-mechanical '**tunneling**' can bring two positively-charged 'heavy' hydrogen nuclei to overcome their electrostatic repulsion and move near enough for the **strong nuclear force** to bring about their fusion into an excited helium-4 nucleus; but in deuterium gas such an event is never observed.

The second objection is much more fundamental, and the exposure of the fatal fallacy in this *sole* objection is the central purpose of this article, which slights many other important questions in favor of focusing upon a single issue: was the initial *theoretical* skepticism truly justified? (Newcomers to this field will find a well-illustrated tutorial introduction in Fig. 3-1, Fig. 3-2, Fig. 3-3, and Fig. 3-4 on pp. 46-48 of F. David Peat's *Cold Fusion,* Contemporary Books, Chicago, 1990; this should be followed by pp. 19-20, 107, 109, 116-117, 124, 130 & 231 of Eugene F. Mallove's *Fire From Ice,* Wiley, 1991.)

DISCLAIMER (Added 5-7-94): There are a host of issues pertaining to nuclear physics, solid-state physics, material-science practicalities, etc. which are only peripherally mentioned or not addressed here; several readers of a prior draft expected to find an account of a complete theory, which is not my objective. *Added in Proof:* The just-appeared, and hereafter indispensable/invaluable extensive review of CF theories by Chechin, Tsarev, Rabinowitz & Kim [*Int. J. Theor. Phys*., vol. 33 (1994), pp. 617-670, which cites some 173 papers, agrees with the view that the "main difficulty in CF is in surmounting, i.e., tunneling through the Coulomb barrier *V(r)"* (p. 632); while of enormous value, this monumental review fails to cite or discuss what I would choose as the single most seminal paper on the subject [Leaf Turner, "Peregrinations on CF", *J. Fusion Energy,* vol. 9 (1990), pp. 447-450], and errs grievously in finding fatally flawed by "a basic defect" the Turner-Bush Transmission Resonance approach [in my ICCF4 paper I *did include* the nuclear well in a TR model] and in mistakenly concluding that "this approach appears futile" because, echoing Jändel, "the unaddressed and unresolved issue in Bush's theory is that it takes too long for the wave function to become large"; if the present paper does no more than provide a (trivially easy) rebuttal to the unwarranted dismissal of the Turner-Bush approach it will achieve its purpose. My intent was to address the initial skepticism on this point, but the 4-author March, 1994 theory review just cited shows that after 5 years this *initial sticking point* lingers on as a *perennial stumbling block!* (The review, although calling Schwinger's NEAL "the most notable theoretical support for CF," complains that "Schwinger's LV (Lattice Vibration) approach appears applicable only for $\delta V \ll V$", i.e. in the notation used here, only in the quadratic-approximation region of the *bottom* of the potential well *V(r),* near $r = 0$; but in my ICCF4 paper I attempted to extend Schwinger's quantized harmonic oscillator to a *globally* rigorous *anharmonic* quantized oscillator using a *periodic* **Madelung** potential $V(r) \equiv V(-r) \equiv V(r+2L)$ defined firstly on $-L < r < L$, which *predicts* the correct size of the rms vibration amplitude $\Lambda \ll L$ and so the correct value of the *Schwinger Ratio* [$\sigma :\equiv L/\Lambda$] for the zero-point fluctuations [**ZPF**] near $r = 0$, yet in a global WKB calculation improves his approximate [harmonic-oscillator] **ZPF** tunneling probability $\Theta \simeq exp(-\sigma^2/2)$ by 10^{57} because it is 40% deeper and much *flatter* at the bottom, and therefore *steeper* near the barriers than a naive Coulomb potential well treated as quadratic and extrapolated too far from the classical equilibrium value of $r = 0$.)

Assuming that an excited helium-4 nucleus has been created, there are well-understood physical reasons for the subsequent decay modes of this excited particle, which explain the conventional *branching ratios* observed, as in the first objection, to follow from a three-dimensional collision between two isolated, rotating deuterons in a vacuum; the exposure of the fallacy in jumping to the [false] conclusion that the branching ratios *must be the same* inside of a crystal lattice as in a vacuum was first made soundly by Nobel Laureate, and UCLA Physics Professor Emeritus, Dr. Julian Schwinger as exposited by this peerless theoretician himself in the first issue of *"Cold Fusion"* Magazine (May, 1994). [A brief summary of Schwinger's definitive refutation of Objection 1, including reference to Selection Rules, will be found below in Appendix A.]

Schwinger himself also made a truly giant fundamental step toward refuting Objection 2, in a series of 1989-submitted papers on the subject of Nuclear Energy in an Atomic Lattice (NEAL). However, this basic step needs augmentation by another giant step, first suggested in an eerily prophetic paper presented at the Santa Fe Workshop, May 22-25, 1989 and also in a Letter to the Editor of *Physics Today,* by Los Alamos thermonuclear-fusion plasma researcher Dr. Leaf Turner, and later developed and elaborated into his Transmission Resonance Model (TRM) by Dr. Robert T. Bush of Cal Poly (Pomona); the TRM soon gained incontrovertible but unjustly widely doubted *"fine structure"* experimental evidence in its favor in FP-type experiments by Bush using automated closed-cell calorimetry apparatus constructed by his colleague and (for the past 5 years) cold-fusion collaborator, Dr. Robert D. Eagleton (some of whose friends distinguish between them in conversation as 'Bob Tritium' and 'Bob Deuterium').

At the request of *Fusion Facts* Editor Hal Fox in a private conversation at ICCF2, Bush advanced the ground-breaking opinion that the 'light water' electrolysis results of Dr. Randall Mills could be better explained by conventional nuclear physics and his TRM than by Mills' novel and revolutionary but controversial *("di-hydrino")* revision of chemistry. This soon led Bush to discover and to establish with experimental evidence (duplicated abroad after dissemination of his preprints) the profound generalization of the FP Effect to Cold Alkali Fusion (CAF) wherein Bush has seemingly incontrovertibly transformed rubidium nuclei into strontium nuclei by means of a proton from ordinary hydrogen (supplied by ordinary or 'light' water) using an FP type of cell but with the palladium cathode replaced by a porous nickel cathode, and the rubidium supplied in the form of rubidium carbonate dissolved in water. (The daughter-product strontium has its isotopic abundance ratio drastically altered from that of natural strontium, precluding contamination-error, but consistent with the isotopic-abundance ratio of the parent rubidium!)

Later, using a patent-pending process of mine entitled Quantum Resonance Triggering (QRT) [explained below], as well as his own TRM, Bush generalized his CAF process to include nearly 350 nuclear-fusion reactions which he predicts can be induced by his far-reaching principle of **Transmission Resonance Induced Nuclear Transmutations** (TRINT). See Fig. 1.

Anyone familiar with Secretary of Energy O'Leary's well-founded dismay at the fact that the Department of Energy (DOE) had to spend more than $12 Billion during the two years preceding her accession to management of the DOE in cleanup of radioactive hazards at various continental atomic installations should call to her attention the fact that (at my urging) Bush labored for many hours to include in his TRINT process the safe reduction to harmlessness of every single known long-lived radioactive element listed in the *Handbook of Chemistry and Physics.*

It was a great personal thrill and one of the supreme satisfactions of my own life that as a licensed practitioner of Intellectual Property Law before the U.S. Patent & Trademark Office (PTO) I had the unique historical privilege of drafting Patent Applications for Bush & Eagleton pertaining to both the CAF process (which Fleischmann has called *'millennial,* if confirmed') and the more general and, admittedly, awesomely portentous TRINT process (originally financed by Proteus Processes & Technology, Inc. a Denver company founded by Mr. Joseph N. Ignat and Mr. Ronald N. Flores, and now under license to ENECO as regards power-generation applications), which I hope will enable us to bequeath to our grandchildren a less radioactively-endangered world.

Unfortunately, Bush's TRM concept was harshly criticized, during and after ICCF2, by Dr. M. Jändel, who published a stinging and seemingly fatal deflation of the TRM in Dr. George Miley's open-minded *Fusion Technology,* a professional journal of the American Nuclear Society (ANS). Briefly, Jändel's apparently devastating criticism is:

Objection 3. Even if the conditions for Resonant Transparency of the Coulomb Barrier could be met, the tunneling of one lattice-bound deuteron through the electrostatic repulsion barrier to the vicinity of an adjacent lattice-bound deuteron is so unlikely that one would have to wait for 'billions of years' for any significant amount of tunneling to occur.

In the forthcoming *Proceedings* of ICCF4, I have presented scientific arguments which I find persuasive (not having yet received any competent criticisms) that Objection 3 also can be overcome, by use of yet another idea first used in this context by Schwinger, namely the so-called Zero-Point Fluctuations (ZPF) of a lattice at Absolute Zero temperature, which Schwinger wryly calls VCFI (Very Cold Fusion Indeed).

The primary purpose of this article is to provide an accessible overview of what I proffer as decisive refutations of Objections 2 & 3. (Technical details will be found in Appendices B and F below.)

As most readers by now know, *water* contains about one part in 5,000 of *heavy water,* which can be extracted economically by fractional distillation. The *heavy water* can be electrolytically decomposed into Oxygen and Deuterium (Heavy Hydrogen). In an FP cell using an electrolyte consisting of salted heavy water, the deuterium atoms are attracted into the cathode, where each atom becomes ionized (or loses its orbital electron) and becomes a bare deuterium nucleus or *deuteron.* A deuteron consists of one positively charged *proton,* and one electrically neutral *neutron.* (Free neutrons decay in a few minutes into a proton and an electron, and for present purposes can be regarded as the result of collapsing an electron onto a proton.) The proton and neutron are (relatively loosely) bound together by the *strong nuclear force,* which operates only over such short ranges that it is negligible in comparison to electrical and magnetic forces except in the vicinity of a nucleus. So in the present context the essential features of the problem are maintained if one regards deuterons as positively charged particles of Atomic Mass Number Two which can be regarded as 'point particles' that have no properties other than charge and mass when separated by distances typical of atoms, molecules, and basic cells of crystal lattices.

In Fig. 2 the electrostatic potential, also called the *Coulomb potential,* of an isolated *bound* (or lattice-fixed) deuteron is displayed. This potential has the value $V = e/|r|$ at a radial distance r, where $|r|$ denotes the unsigned or *absolute* value of r, and where e is the charge on an electron. In Fig. 2, r is measured in units of the lattice-period length $L = 2.83 \times 10^{-8}$ cm, and V is measured in units of $E_C \equiv e/L$. As is well known, if a second (conceptually *free,* or unbound) deuteron is brought into this picture, it experiences a repulsive force equal to the negative of the slope of the curve (that is, the force is the negative *gradient* of the potential *energy* $e \cdot V$, or $\mathscr{F} = -e^2/|r|^2$). Notice that as the free deuteron gets closer to the bound deuteron, the magnitude of the repulsion increases beyond all limits, i.e. tends to become *infinite.* (In reality, when the free deuteron has reached within a distance of the bound deuteron's *nuclear radius* $r_n = 2.1 \times 10^{-13}$cm, *i.e.* when r satisfies $-r_n \leq r \leq r_n$, or equivalently when $|r| \leq r_n$, then the repulsion is overcome by the strong nuclear force and dwindles to zero and then reverses sign and becomes an attraction -- but this detail is too small for a drawing to scale, because $r_n/L = 7.4 \times 10^{-6} \cong 10^{-5}$.)

Everyone who has heard about *quantum weirdness* knows that on the atomic scale particles behave contrary to what we expect from experience with macroscopic objects, such as charged ping-pong balls. A low-energy deuteron approaching from the right, with an initial velocity whose kinetic energy is measured in *electron volts* (eV) rather than in kilovolts (keV) or megavolts (MeV), must slow down and then reverse course and be reflected back toward its origin with the same final speed as its initial speed, but with the direction of motion reversed. See Fig. 2A and Fig. 2B, which may become clearer in the sequel, upon a second reading. However, even though the *barrier height* is almost infinite, there is a finite chance (computable by quantum mechanics) that instead of being reflected elastically (as might be an ideal ping-pong ball bouncing from an infinitely hard surface), the deuteron will somehow 'tunnel' through the *'energetically-forbidden region'* [of negative kinetic energy and imaginary speed] and be found on the other side of the barrier, moving toward the left with the same ultimate kinetic energy as which it began. To nineteenth-century physicists, this would be an incredible miracle. Neither Einstein nor Schrödinger ever fully accepted what the co-discoverer of quantum-mechanics in its wave-mechanical version called "this damned quantum jumping!"

A detailed `understanding' of how quantum tunneling can be possible is a highly debatable subject. But patrons of *Radio Shack* who have purchased *tunnel diodes,* or users of any transistor-based solid-state electronic devices (such as modern TVs or computers) are beneficiaries of the fact that *quantum tunneling* is an objectively real phenomenon. Other quantum weirdnesses must be invoked to explain even certain macroscopic phenomena, such as superfluidity and superconductivity. When palladium is saturated with either hydrogen or deuterium, and cryogenically refrigerated, it becomes a superconductor, which cannot be explained by classical physics.

Inside of a palladium lattice, free deuterons typically have energies measured in tenths of an eV, or at most a few eV, as discussed by Dr. Stan Pons at ICCF4. Advanced undergraduates at Princeton who use the recent excellent text on *Quantum Mechanics* by the Einstein Professor of Science, Dr. P.J.E. Peebles, find that after an initial study of the subject of only 52 pages they have learned enough to compute the *tunneling probability* under discussion. It turns out that if the deuteron's energy is less than several hundred eV, the tunneling probability is so *infinitesimally* small that for all practical purposes it is negligible. At the end of his lucid 9-page demonstration of the negligible likelihood of CF's possibility (in the scenario associated with Fig. 2), Dr. Peebles exhibits admirable **intellectual honesty** by musing aloud as to whether or not he could have overlooked some aspect of solid state physics (such as had produced the **unpredicted** discovery of high temperature superconductivity) which could have led to a less pessimistic conclusion. But after rehearsing some qualitative reasons found convincing by unspecified other "people" (presumably including Caltech theorist Dr. Steven Koonin, and University of Illinois authorities Dr. Gordon Baym *et al.*, Peebles gives up and moves on.

The purpose of this article is to show readers how important overlooked *tacit assumptions* may be, in the arena of logical arguments, even when advanced by eminently qualified scholars, and to point out *critically important* features of the problem <u>absent</u> from Fig. 2 but very much present in a more realistic model, and which raise the tunneling probability from negligibly small to 100 percent! (The critical expert reader should be patient while the needed improvements are introduced one-at-a-time.)

The first inadequacy of Fig. 2 is that it neglects the other bound deuterons in the lattice. (As a first approximation, the effects of the mobile electrons are ignored.) As a start, and referring to Fig. 3, consider one ("infinitely") rigidly *bound* deuteron on the left at $r = -L$, and another such rigidly bound deuteron on the right at $r = L$. (This perfect rigidity is an oversimplification, but adequate for the present.) Suppose that the free deuteron is initially at a position r on the open interval $-L < r < L$. The electrostatic potential which affects the free deuteron is now the *sum* of the potentials from each rigidly bound deuteron, namely

$$V(r) = \{e/(L + r)\} + \{e/(L - r)\} \equiv 2 \cdot L \cdot e/(L^2 - r^2) \equiv V(-r),$$

where the second, identically equivalent, form requires a bit of high-school algebra to verify. Notice that because $r^2 \equiv |r|^2 \equiv |-r|^2$ it no longer matters whether r is positive or negative, and the potential has *mirror symmetry* when one considers reflection in an imaginary mirror placed along the vertical line erected through the *origin* (at $r = 0$).

Now draw a horizontal line representing the initial kinetic energy $\mathscr{E}$ of a free deuteron in Fig. 2, Fig. 2A and Fig. 2B, when starting 'infinitely' far off to the right and therefore completely uninfluenced by the potential. When such a particle moves from the right toward the repulsive bound deuteron, it loses kinetic energy but gains potential energy, their sum remaining equal to the initial value $\mathscr{E}$.

Similarly, draw a horizontal line at the same level $\mathscr{E}$ in Fig. 3 and Fig. 3A representing the *total* energy of a free deuteron moving under the influence of the potential of bound positively-charged particles on its left and right. In Fig. 3 and Fig. 3A, if the free but energetically-excited deuteron is started with this total energy at the origin, then according to *classical physics* [neglecting quantum weirdness], this free deuteron gets "trapped in the potential well", and becomes itself bound, but bound at an *'excited energy level',* in the following sense. By a fundamental Law of Physics, to which classical physics knows no exceptions, namely, the *conservation of energy,* the sum of the free deuteron's *kinetic energy* $\underline{K}$ (or energy of motion) and *potential energy* $e{\cdot}V$ (or energy of position) must remain *constant,* and therefore equal to its initial value $\mathscr{E}$. As discovered by Isaac Newton, and taught in high-school, $\underline{K} = (1/2){\cdot}m_D{\cdot}\, v$ where v is the *speed* of motion, or rate of change of position r, and M_D is the mass of a deuteron. Thus, in Fig. 2A, Fig. B and Fig. 3A, no matter what the value of position r (and corresponding speed v),

$$\underline{K} + e{\cdot}V(r) \equiv \mathscr{E}.$$

This simple relationship has profound consequences. In the first place, since $\underline{K} \geq 0$, the position r must be *restricted* to the domain in which $e{\cdot}V(r) \leq \mathscr{E}$. See Fig. 2A, Fig. B and Fig. 3A to see graphically how this affects allowed values of r.

Next, notice in Fig. 3A that as r increases from $r = 0$, the potential energy $e{\cdot}V(r)$ increases toward $\mathscr{E}$, and when r reaches a value r_t (called the classical turning point) such that at this point $e{\cdot}V(r_t) = \mathscr{E}$, then necessarily at this same point $\underline{K} = 0$, i.e. at a turning point, the deuteron's speed $v = 0$. By applying high-school algebra to the last displayed equation for V, set equal to $\mathscr{E}/e$, find $(r_t)^2 = L^2 - (2{\cdot}L{\cdot}e^2/\mathscr{E})$. But again from high school we know that whenever $\mathscr{E} > 2{\cdot}(e^2/L)$ this *quadratic equation* has TWO distinct "real" (or non-imaginary) solutions found by taking square roots:

$$r_t = \pm\sqrt{L^2 - (2{\cdot}L{\cdot}e^2/\mathscr{E})} \equiv \pm L{\cdot}\sqrt{1 - [(2{\cdot}e^2/L)/\mathscr{E}]}\,.$$

If for simplicity we define r_t to be the *positive* square root, then $(-r_t)$ is the other solution. This means that the deuteron is "trapped" in the region $-r_t < r < r_t$, as shown in Fig. 3A. As the deuteron moves from right to left, it slows down until the left-hand turning point $(-r_t)$ is reached, at which point its motion has been momentarily brought to a standstill. But then the repulsion from the left-hand bound deuteron, previously overcome by the leftward momentum, encounters zero momentum and so is free to act alone, dominating the weaker repulsion from the more-distant right-hand bound deuteron, and accelerating the free deuteron towards the right. As the deuteron crosses the origin $r = 0$, the repulsion from the deuteron on the right becomes larger than that from the deuteron on the left, and it begins to decelerate. When the deuteron approaches the right-hand turning point r it again slows down completely and then reverses its motion. This cycle is then repeated endlessly.

This back-and-forth motion is similar to the motion of a shallow-angle frictionless *pendulum* under gravity, or that of a lead ball in outer space and attached by an astronaut to *springs* held apart by a rigid frame on its left and right, in which the *restoring force* $-Kr$ is proportional to the displacement r, and the constant of proportionality K is called the *spring constant.* Again according to Isaac Newton, the ball of mass m_D has an *acceleration a* which satisfies his famous equation of motion

$$m_D \cdot a = -Kr.$$

In freshman calculus this differential equation is solved in terms of periodic *trigonometric functions,* such as $sin(\theta) \equiv sin(\theta + 2\pi)$, and shown to have the functional form $r = A \cdot sin(2\pi[t/T])$ as a function of time t. If the position r is plotted against time t, the curve is *sinusoidal,* with a maximum *amplitude* $A = \sqrt{2\mathscr{E}/K}$. This kind of motion is *periodic* in time with a *period* T (measured in seconds), where in freshman physics it is shown that $T = 2\pi \cdot \sqrt{m_D/K}$. Such a motion is called *simple harmonic motion,* and any system which exhibits this behavior is called a *harmonic oscillator.*

For small-amplitude oscillations, i.e. for small initial energies $\mathscr{E}$, the bottom of the potential energy well in Fig. 3 and Fig. 3A can be well-approximated as a *quadratic* function, which defines a parabola:

$$e \cdot V = e \cdot V_{MIN} + (1/2) \cdot K \cdot r^2 + \cdots .$$

In this case, it is easy to show [see Appendix C] that the spring constant is given by $K = 4 \cdot (e^2/L^3)$. For every small value of $\mathscr{E} >$ MINIMUM $\{e \cdot V(r)\} \equiv e \cdot V(0) \equiv 2 \cdot (e^2/L)$, it will be true in classical physics that the free deuteron oscillates in a simple harmonic motion about the origin, as in Fig. 3A.

Physicists have a short-hand picture in which the deuteron is visualized as being trapped on the horizontal line-segment $e \cdot V = \mathscr{E}$ between the points $e \cdot V(-r_t)$ and $e \cdot V(r_t)$, and as sliding back and forth at this *energy level* $\mathscr{E}$ while executing harmonic motion.

In classical physics the energy level $\mathscr{E}$ (so long as it is larger than V_{MIN} as explained already) is completely arbitrary. The top peaks in Fig. 3 would be infinite except that they have been truncated to allow for the strong nuclear force. If the nuclear radius were neglected, then any value of $\mathscr{E}$, no matter how great, would produce a trapped deuteron. More realistically, this occurs only for energy levels between

$$\mathscr{E}_{MIN} = e \cdot V_{MIN} \equiv 2 \cdot (e^2/L), \ \& \ \mathscr{E}_{MAX} = e \cdot V_{MAX} \equiv e \cdot V(L - r_n) \equiv (1/2) \cdot \mathscr{E}_{MIN}/(r_n/L) + \cdots ,$$

where the omitted terms are negligible, so that in comparison $\mathscr{E}_{MAX} \cong 5 \times 10^4 \cdot \mathscr{E}_{MIN}$. Thus in classical physics there is a *continuum* of possible energy levels at which deuterons could be trapped, corresponding to the *continuous infinitude* of values of $\mathscr{E}$ which satisfy $\mathscr{E}_{MIN} \leq \mathscr{E} \leq \mathscr{E}_{MAX}$.

However, when *quantum weirdness* is taken into account, this picture becomes radically modified, as shown in Fig. 3B. Below any given energy level, there is only a *finite number* of other energy levels which are "permissible", or "allowed by the laws of quantum mechanics as presently understood"! These *discrete* energy levels for excited bound deuterons are determined by a *resonance* condition which will now be explained.

Toward the bottom of the well, where the curve can be closely approximated by the bottom of a parabola, the *only acceptable energy levels* E_n are given by the formula for the energy levels of a *quantized* harmonic oscillator (involving Planck's constant h):

$$E_n = (n + [1/2]) \cdot h/T, \ (n = 0, 1, 2, 3, \ldots),$$

where T is the harmonic oscillator's *period* defined above, and where n is an arbitrary non-negative *integer* (or whole number). Another way to express the preceding is to factor out the (1/2) and write:

$$E_n = (2n + 1)\cdot h/(2T), \ (n = O, 1, 2, 3, ...).$$

Note that for every integer n, the integer $(2n + 1)$ is necessarily an *ODD* number; in Fig. 3A, the value of $n = 9$ has been illustrated, so that $2n + 1 = 19$ is an odd number.

This oddness is the key to understanding the physical possibility of CF. In my patent-pending QRT process, which purports to show how the energy level may be raised from the ZPF level $n = 0$ to a value of $n \geq 1$ at which Resonant Transparency becomes sufficiently likely, the user takes the lattice-period *length* L and divides it by the bound particle's root-mean-square *(rms)* amplitude of vibration Λ when the lattice is at Absolute Zero temperature [both of which lengths L and Λ can be determined from x-ray crystallography or well-established theory] and so forms what I call the *Schwinger Ratio* $\sigma = L/\Lambda$ which is a pure number that Schwinger has prophetically identified as summing up ("albeit crudely") all the forces at work in the lattice. Now claim 2 of my pending patent calls for the user to divide the Schwinger Ratio by $\pi = 3.14159...$, and check whether or not the result is an *odd* integer (or near to oddness). If so, the lattice and particle are suitable. If not, my QRT theory claims that there is no way to excite the bound particle (at $n = 0$) to a higher energy level ($n \geq 1$) by collision *inside the lattice* with a similar particle!

In Appendix D (which the reader may not find easy before finishing the paper) I have tested the validity of my Coulomb-Madelung potential by correctly predicting the Schwinger Ratio for $Pd\cdot D_{1.0}$, and then used it to extrapolate to those of some 6 other cases for which I could not find measured data, thus now having results on 7 cases:

$$(Pd\cdot D_{1.0},\ Pd\cdot D_{2.0},\ Pd\cdot H_{1.0},\ Ni\cdot D_{1.0},\ Ni\cdot H_{1.0},\ Ti\cdot D_{2.0},\ Ti\cdot H_{2.0}).$$

Define $\sigma_{QRT} \equiv \sigma/\pi$. Then for the 7 cases my pending QRT patent criterion (filed in June, 1991), when applied *de novo,* predicts:

$$\sigma_{QRT} = (9.00, 3.00, 7.57, 8.74, 7.35, 3.00, 2.52) \cong (9, 3, 8, 9, 7, 3, 2.5),$$

which corresponds *perfectly* to experimental experience in that it predicts that *either* deuterons or protons may work with nickel, and that deuterons (but only marginally protons) may work with titanium, while only deuterons should work with palladium! When I derived the QRT criterion, I used only classical *conservation of energy,* classical *conservation of momentum,* and a single *ad hoc* ("Old QM") quantizing principle *(Duane's Rule,* discussed below), and expressed amazement at the "coincidence" (?) that the criterion succeeded, to almost 4 decimal places, with $Pd\cdot D_{1.0}$ & $Pd\cdot D_{2.0}$; but I failed to test the criterion further. Recently Dr. Mario Rabinowitz of EPRI told me that he doubted that my QRT criterion could possibly be correct, and when I asked why, he said: "replace the deuteron mass m_D by half its value, to give a proton mass, $m_P = m_D/2$, and your theory will still predict CF, in which case you are in **deep trouble**!" So I can now claim that the reader ought to take my work seriously since it has passed 'the Rabinowitz acid test', plus six other *gratuitous* tests, with flying colors! [*cf* App. D]

Returning to Fig. 3 and Fig. 3A, if one uses the methods of the eminent scholars referred to above to compute the probability of tunneling out of the well, for energy levels below a few hundred eV, the answer is once again negligibly small. So what has been gained by going from Fig. 2 to Fig. 3? Not enough, but progress in the right direction is being made.

There are three more modifications in the direction of greater realism that remain to be introduced before the pessimistic tunneling probabilities can be overcome.

The *first* modification is to consider *all* of the bound deuterons in the lattice, not just the two adjacent bound deuterons. It is a time-honored (because successful) approximation to assume that there is an endless array of deuterons to both the left and the right of the original two. These *bound deuterons are* assumed to be *rigidly* fixed (i.e. not to be affected by the free deuteron), and located at the positions

$$r = \pm k \cdot L, \quad (k = 1, 2, 3, ...).$$

(If the reader balks at infinity, he may imagine k increasing up to $k_{MAX} = 10^{22}$ and then the position at k_{MAX} being conceptually identified with that at ($-k_{MAX}$), i.e. one may conceptually place the bound deuterons on a one-dimensional linear crystal lattice which is gradually bent round in a circle until it joins itself; many successful computations in solid-state physics have been carried out with such an approximation.)

The *second* improvement in the model is to render it, at macroscopic distances away from the lattice, electrically neutral, by placing negative charges ($-e$) between every pair of positive charges. In reality, the electrons are circulating in their own quantized loci, including "delocalized *band states",* but for present purposes it is adequate to place them *rigidly* in *averaged* positions, and unless the averaged positions fall *half-way* between the bound deuterons, then these idealized rigidly-bound electrons will not be in an equilibrium state. A consideration of the totality of positive and negative bound charges in a lattice was first undertaken fruitfully by Madelung, and so the potential resulting from all of the Coulomb forces, of both signs, everywhere in the lattice, is called a Coulomb-Madelung potential V_M. This potential can be represented in terms of known, almost-divergent but tabulated series called *Digamma Functions* (wherein the divergent harmonic series is asymptotically "summed" by using Euler's famous constant). By using known digamma-identities, Dr. David Park has kindly independently verified my new infinite series expression for V_M (presented to ICCF4) which converges so rapidly that it can be truncated after 44 terms and the remainder rigorously bounded by a simple algebraic formula which shows that the remaining terms, if they had been added up, would not change the numerical value of the answer until past the 17th decimal place.

The *third* significant modification is to notice that my new Coulomb-Madelung potential $V_M(r)$ is now a *periodic* function of distance r from the origin; in fact

$$V_M(r + 2L) \equiv V_M(r) \equiv V_M(-r), \quad (-\infty < r < +\infty).$$

The first two modifications increase the well-depth by some 40%. This can be seen in Fig. 4, where the bottom of the well is visibly deeper than when only the nearest two deuterons are considered. This is a tangible illustration of a point which Schwinger made very early in the history of FP Effect analyses, namely that the critics were ignoring the attractive forces from the entirety of the lattice. Indeed, if one computes the tunneling probability using only a single isolated (aperiodic) Coulomb-Madelung potential well, as if there were no adjacent wells, then the tunneling probability is improved by a factor of 10^{57}, or, as physicists would say, is enhanced by "57 orders of magnitude!". Nevertheless, the tunneling probability is still so small that not even this gigantic enhancement can affect the pessimistic assessment of Objection 2. (However, the new bottom 40% of the well added by including all of the Madelung forces is what enables *low energy* CF, as will be shown below, which completely justifies the complication of adding the Madelung forces to the Coulomb forces which were the sole forces considered by the pessimistic scholars quoted above.)

Moreover, the reader is now in a position to understand the enormous *conceptual error* which was committed in the formulation of Objection 2.

This is to note that the wells now form an endless *periodic array* of the form barrier-well-barrier ... Furthermore, in the microphysical domain of *quantum weirdness,* particles have some aspects of waves which cannot be dispensed with. In particular, the *momentum* of a particle can be analyzed as if it were a *plane wave,* travelling from left to right, or *vice versa*.

The reader who has had high-school physics doubtless knows about the distinction between *geometrical optics* (ray-optics) and *physical optics* (concerning *interference* phenomena, such as diffraction and refraction, and variations in light *intensity* which would not be predicted if light consisted strictly of little energy-bullets, or *photons,* which behaved like classical bullets); therefore light unquestionably has some true wave aspects.

However, after Einstein explained the photoelectric effect by making the contrary assumption that light waves of frequency $2\pi/T$ *sometimes* behave like a stream of tiny bullets of individual energies $E = h/T$, where the very small number $h = 10^{15}$ eV-seconds is *Planck's constant,* it was suggested by de Broglie that electrons of momentum p should correspondingly exhibit some wave-like properties, and with a wavelength λ, given by the *de Broglie wavelength* $\lambda = h/p$. This was soon verified by the discovery of electron diffraction in crystals, and used by Bohr to predict the lowest energy level and corresponding smallest allowed radius of an electron orbiting a proton to form a hydrogen atom, by assuming that only an integral number n of de Broglie waves can fit around the circumference of such an orbit. This is the "Old" Quantum Theory. In the "Semi-Classical" Quantum Theory obtainable from the "WKB approximate solution of Schrödinger's Equation" [see below], the arbitrary positive integer n gets improved to (n + [1/2]), in order to account for the ZPF at $n = 0$; but often the (1/2) is factored out, leaving an odd number ($2n + 1$), which accounts for the QRT *oddness* test above. If my QRT test be deemed valid, then CF is a practical method of tapping the ZPF energy!!!

The fact that waves and particles sometimes are measured to have properties that are indisputably those of classical particles and waves has led some popularizers of quantum weirdness to say that matter is composed of *'wavicles'* which are *neither* particles nor waves but are more abstract and non-analyzable entities which exhibit wave properties or particle properties depending upon the design of the measurement apparatus being used. The reader who has heard of the paradox of *Schrödinger's cat* knows that the standard version of Quantum Mechanics (QM) is based upon application of Schrödinger's equation, which is a wave equation. The square of the amplitude of Schrödinger's wave-function ψ was recognized as providing the probability-density required to compute the probability of measurement of an 'observable' quantum-mechanical variable in micro-physics.

Alfred Landé, one of the pioneers of QM, has proposed to derive Schrödinger's equation from three postulates, which he advocates as based upon experimental discoveries. One is that in a temporally *periodic* system of *period T,* changes in energy must be quantized as integral multiples of h/T. A second (used by Bohr), is that in rotationally periodic systems, characterized by having angular *periodicity* of *period* 2π, changes in angular momentum must be quantized as integral multiples of $h/(2\pi)$. The third axiom, which Landé felt had been unjustly ignored, is *Duane's Rule,* that in a spatially *periodic* lattice of *period*-length L, changes in linear momentum must be quantized in integral multiples of h/L. The original version of the TRM is essentially a corollary of Duane's Rule, which Bush interprets as the condition for a free particle to collide inelastically with a lattice in which it is moving linearly (as well as, paradoxically, providing the condition for a particle to find an array of lattice cells resonantly transparent, prior to a collision). This subject becomes very counter-intuitive, since a successful treatment of the Mössbauer Effect requires consideration of "coherent states" and *phonons* [quanta of sound waves], in which there is a finite (non-zero) probability that the recoil momentum of a nucleus emitting a gamma ray will be taken up by every single atom of the lattice simultaneously; the phonons travel at the speed of sound in the crystal, but according to accepted quantum mechanics they appear in an unanalyzed 'quantum jump' everywhere throughout the lattice all at once! (Feynman warns: to claim to "understand" QM is to deceive oneself!)

In his NEAL theory, Schwinger postulates that if two deuterons so close together that they can be regarded as an *excited* alpha particle (or helium-4 nucleus) shed the excess energy of 23.85 MeV required in order to become a stable ^{4}He-nucleus, they do it by exciting the *deuteron lattice* with 2.4 x 10^8 phonons of energy of size 0.104 eV each. With all due respect to Schwinger, I have modified his hypothesis to: 1 x 10^9 phonons (of energy 0.0237 each) go into the host *palladium lattice* instead, for the following reasons. My work satisfies me that if even a small but fixed fraction of the phonons *always* go into the deuterium lattice embedded in a palladium lattice, then eventually there will be a very slow chain-fusion reaction, which will grow toward a meltdown unless quenched by irregularities in the lattice structure which interrupt the connected chain of lattice cells. But if *all* of the phonons always go into the deuterium lattice, there will be a miniature fusion-bomb explosion. Accordingly, it is the *branching ratio* between these two possible reactions which is the criterion between *a fizzle* and a *meltdown.* According to energy-minimization arguments, the phonons *will* go into the *Pd* lattice, because then the mean potential energy of a *Pd* oscillator is only 22.8% of that of a *D* oscillator.

Since including the preceding predictions in my June, 1991 patent application, I was gratified to learn that in the fall of the same year Schwinger presented a UCLA progress report in which he said: "loading does not proceed with perfect spatial uniformity. ...It may happen that a ... region of the lattice attains ...such uniformity that it can function collectively in absorbing the excess nuclear energy released in an act of fusion. And that energy might initiate a chain reaction as the vibrations of the excited ions bring them into closer proximity. This burst of energy will continue until the increasing number of irregularities in the lattice produce a shut-down. The start up of another burst is an independent affair. It is just such intermittency -- or random turnings on and off -- that characterizes those experiments that lead one to claim the reality of CF."

At this point it is desirable to consider a basic result of QM in periodic lattices which is based upon an approximate solution of Schrödinger's equation called the WKB (Wentzel-Kramers-Brillouin) method [though it was published earlier by H. Jeffreys]. In deriving this result, the wave-picture as well as the particle-picture must be used. Since the momentum p of a deuteron of mass m_D and velocity v is given, according to Newton, by $p = m_D v$, which enables one to re-express the kinetic energy $\underline{K}$ as $K = p^2/(2 \cdot m_D)$, the *total energy* $\mathscr{E} \equiv \underline{K} + e \cdot V$ can be re-expressed as:

$$\mathscr{E} \equiv p^2/(2 \cdot m_D) + e \cdot V(r),$$

which provides an alternative version of the sum of kinetic and potential energies. It is another trivial exercise in high-school algebra to solve this quadratic equation for p; then, for a classically trapped particle, the linear momentum has two possible values:

$$p = \pm\sqrt{2m_D \cdot [\mathscr{E} - e \cdot V(r)]}.$$

Using this formula for *p* as a function of *r*, we can *average p* over one complete cycle of the oscillation between the turning points ($-r_t$) and r_t. (The averaging requires elementary integral calculus.) The result depends only on the given energy level $\mathscr{E}$.

Now I shall quote two *Theorems* from the WKB or 'semi-classical' approximation to QM, whose proofs can be found in Bohm's classic *Quantum Theory* at pages 281-286:

Theorem 1. A necessary and sufficient condition for $\mathscr{E} = E_n$ to be a permissible energy level of a bound deuteron in an isolated potential well defined by the potential *V(r)* is that E_n should satisfy the semi-classical quantization condition:

$$4 \cdot \langle |p| \rangle = (n + [1/2]) \cdot h/L, \ (n = 0, 1, 2, 3, ...),$$

where by definition the *average* linear momentum $\langle |p| \rangle$ is given by the definite integral

$$\langle |p| \rangle \equiv \frac{1}{L}\int_0^{r_t} |p(r)|\, dr \equiv \frac{1}{L}\int_0^{r_t} |\sqrt{2m_D \cdot [\mathscr{E} - e \cdot V(r)]}|\, dr.$$

Corollary: if we define the *mean* de Broglie wavelength $\langle\lambda\rangle$ of the trapped particle as $\langle\lambda\rangle \equiv h/\langle |p| \rangle$, and if we define the *well-width* as $L_w \equiv 2L$ (which is an exaggerated over-estimate of the actual well-width $2r_t$), then the above *quantization* condition can be reformulated as a simple *resonance* condition between the well-width and the quarter-value of the trapped particle's de Broglie wavelength:

$$L_W \equiv 2L \equiv (2n + 1) \cdot (\langle\lambda\rangle/4),$$

namely the *ratio* of these two lengths should be an *odd integer!* See Fig. 3A.

The reader familiar with elementary integration can check the validity of the preceding theorem in the case of the energy levels of the quantized harmonic oscillator quoted above. [Hint: Redefine $\mathscr{E}$ as ($\mathscr{E}$ + $e \cdot V_{MIN}$) and replace $e \cdot V(r)$ in the conservation of energy as last displayed above by $e \cdot V_{MIN} + (1/2) \cdot K \cdot r^2$ before solving for the turning point; or see Appendix E.] In the case of a quantized *quartic* anharmonic oscillator, the WKB approximation makes an *error* in energy level E_n of 18% in the case $n = 0$ in comparison to the exact QM solution, and then makes errors of less than 1.5% for all other values of *n*; the higher the value of *n*, the more accurate is the approximation (see David Park, Introduction to the Quantum Theory, 3rd Ed., McGraw-Hill, 1992, pp. 114-115). For present purposes, we may regard the WKB method as sufficiently accurate for all *positive* integers *n*.

In order to explain the next result, we must consider the wave picture instead of the particle picture. The physical situation is exactly the same as that in the preceding theorem, with one important exception. The potential well is *NOT* isolated, as in Fig. 3, but is part of a *periodic chain* of barrier-well-barrier cells, as in Fig. 4. Now far from a resonance of the type just defined, an incident wave-function ψ_{inc} gets diminished in amplitude as it passes from left to right through the barrier-well-barrier configuration shown in Fig. 5. But at a resonance, the wave function inside the well is large, and the transmitted wave has the same intensity as the incident wave, as shown in Fig. 6. To quote from Bohm: "...a very intense wave is trapped in the well, reflecting back and forth between the barriers in such a phase as to continually reinforce itself, and leaking out very slowly ....To a first approximation, the wave inside the barrier resembles a bound-state wave function, because it is large in such a restricted region ....In fact, the metastable states of the well with barriers resemble bound states much more closely than do those of the well without barriers, mainly because their lifetimes are much longer as a result of the very small transmissivities of the barriers."

Theorem 2. (Turner-Bush-Bass). A necessary and sufficient condition for $\mathscr{E} = E_n$ to be the energy level of a free deuteron encountering *resonant transparency* of a periodic linear array of chained barrier-well-barrier cells defined by a spatially *periodic* potential function $V(r) \equiv V(r + 2L)$ is that E_n should satisfy the Transmission Resonance Condition (TRC):

$$L_W \equiv 2L \equiv (2n + 1)\cdot(\langle\lambda\rangle/4).$$

Note that from a *local* rather than a correct *global* viewpoint, the condition for resonant transparency appears at first glance to be identical with the condition for a particle to be in an excited bound state, which can be seen by comparing Fig. 3B with Fig. 6.

This is the source of the mistaken pessimism of the eminent scholars quoted above, who have mistakenly computed only the local *barrier penetration probability* Θ, rather than the global *resonant transmissivity* $\mathbb{T}$. (Experts should consult Appendix F below.)

In my presentation to ICCF4, I announced the computation of the numerical values of 600 Resonant Transparency energy levels between E_0 = 6.26 eV and E_{600} = 140.96 eV, with 88 such levels between E_0 and E_{88} = 13.74 eV. This WKB-computed Resonant Transparency Spectrum is between 4.5 and 4.8 times more "dense" than the TRM spectrum earlier computed by Bush using a cruder approximation technique than the WKB method. In attempting to correlate Bush's empirical data showing 6 out of an ascending sequence of 16 theoretically-predicted rounded peaks and cusped valleys in relative excess enthalpy as a function of cell current, which should be a parameter that determines free deuteron energy in the deuteron current being dragged past bound deuterons by being dragged through the beta-phase (or "fully loaded") palladium-deuterium lattice, I came to the preliminary, tentative conclusion that to correlate Bush's quantum numbers n[illegible] with my own, I should use n[illegible] $\equiv 1 + k \cong 1 + (27/31)\cdot k$, for k = 6, 7, ..., 11 in the Bush TRM and assume his quantum numbers n[illegible] refer to my own spectrum $n = 31 + 27\cdot(k - 6)$ for the same values of k:

BUSH: n[illegible] = (7, 8, 9, 10, 11, 12) ⟺ BASS: n = (31, 58, 85, 112, 139, 166).

Accordingly, the stunning Bush hill-valley TRM experimental data can be cited as additional evidence in favor of the present more refined WKB calculations.[cf Apps. D,G]

An improvement in computational accuracy would be to replace the WKB work in my ICCF4 paper by work based on exact numerical solutions of Schrödinger's equation, in a mathematical approach advocated at ICCF4 by Drs. Yeong Kim and Jin-Hee Yoon of Purdue in a joint paper with Dr. Alexander Zubarev of Hebrew University, Israel and Dr. Mario Rabinowitz of EPRI; however, I predict that unless they use my Madelung potential $V_M(r)$ [rather than tabulated *Coulomb* Wave Functions], and unless they include *periodicity* of the potential in their approach, they will never find the *low-energy* branch of the

Resonant Transparency energy-level spectrum which I disclosed at ICCF4. Further improvements can be obtained by generalization from a one-dimensional lattice to three dimensions, and by considering the screening effects of conduction electrons from the host palladium lattice, using e.g. the Thomas-Fermi-Mott equation as done by R.H. Parmenter & W.E. Lamb, Jr. *(Proc. Nat. Acad. Sci.,* vol. 87 (1990), pp. 8652-8654).

After receiving an earlier draft, one of the world's most knowledgeable experts on CF wrote me on May 1, 1994: "The observations of Dr. Bush which show a [fine] structure in the current *[vs]* excess-heat relationship, although impressive, have not been confirmed by anyone else. Failure of other careful and detailed studies to see this behavior creates great doubt about the existence of his proposed resonance behavior. Would your approach suffer from the same problem?" With all due respect, I cannot agree that any published studies known to me were conducted in a sufficiently short experimental *duration,* over a sufficiently *large* current *range,* with sufficiently *fine* incremental changes in *current,* with calorimetry systems having a sufficiently *short settling time,* at similar *macrophysical* conditions (temperature, pressure, etc.) for me to conclude that there is "great doubt" about the objective reality of the TRM-forecast fine structure. Firstly, my own experience as a practitioner of Patent Law amply confirms the judicial *dicta* distilled from 200 years of intellectual-property case law that "negative results by competitors are to be given no credence." Secondly, if one re-processes the IMRA JAPAN data of Kunimatsu *et al* (ICCF3) so as to display, instead of a vertical scatter-blur, an average value plus an error bar delimiting the scatter-range, on a *linear* rather than a log plot, there emerges what seems to my eyes to be a *cusped valley* reminiscent of one such local-minimum region of the 6 distinct cusped-valleys of the TRM Fine Structure type. Thirdly, the fact that others can have unintentionally violated *any one* of the *many* criteria required in order to observe (or to definitively *rule out)* the TRM predictions can be explained easily if one is aware of the many subtle pitfalls sketched in Appendix G below. Accordingly I judge the alleged *"problem"* to be illusory, and my theory does not *"suffer"* from it, but has its validity enhanced by citation of Bush's TRM data as confirmatory of the QRT principle!

Thus Theorem 2 and the preceding numerically computed and experimentally confirmed Resonant Transparency Spectrum completely refute Objection 2, as promised.

In a 1992 *Fusion Technology* paper, Dr. M. Jändel has pointed out an apparently fatal flaw in the Resonance Transparency arguments, mentioned above as Objection 3. To understand this objection, in a simplified but not misleading form, the reader needs to recall from the domain of quantum weirdness the famous *Heisenberg Uncertainty Principle,* which states that the product of the rms errors in the mean values of certain specifiably "canonically conjugate" *pairs* of physical variables can never be smaller than $h/(4\pi)$. The most famous such pairs are *position & momentum;* however, of equal importance is the pair consisting of *energy & time.* Letting $\hbar \equiv h/(2\pi)$, the Uncertainty Principle for measurements of energy E and time t asserts that if ΔE is the expected root-mean-square (rms) *error* in E, and if Δt is the expected root-mean-square (rms) *error* in t, then their product

$$\Delta E \cdot \Delta t \geq \hbar/2.$$

If we compute the sensitivity of the transmission resonance condition to variations in the value of the energy E near E_n, at which [Appendix F] the *transmissivity* $\mathbb{T} = 1$, and reduce the requirement on $\mathbb{T}$ to merely requiring $\mathbb{T} > 0.5$, then it will be found that E cannot differ from the exact value of E_n by more than a very tiny number, smaller than 10^{-200} eV. Then by Heisenberg's Principle,

$$\Delta t \geq \hbar/(2\Delta E) = (1/2)\ 10^{-15} \text{ eV-sec} \times 10^{200}\ (\text{eV})^{-1} = 5 \times 10^{184} \text{ sec.}$$

Therefore the uncertainty in the time at which the resonant-transparency tunneling has taken place, in comparison to 15 x 10^9 years ≅ 5 x 10^{17} sec, is greater than the currently accepted age of the universe!

This objection seems to be so potent that many of the staunchest followers of the Bush TRM work have given up on it, and sought for an alternative approach to eluding the Coulomb barrier. This includes Bush himself, with his "casimir-lattice" approach at ICCF4, though I trust his seeming recantation under fire was only temporary.

Happily, there is an easy refutation of Objection 3, which depends upon the fact that the positions of the bound deuterons to the left and right of the free deuteron are not actually at exactly $r = -L$ and $r = L$, because there is an irreducible quantum weirdness uncertainty in these positions, of expected rms amplitude Δ « « *L*. In his theory of **NEAL/VCFI**, Schwinger has provided tunneling calculations ("albeit crude") which indicate that *all* the forces at work in the lattice can be summed up in the ratio $\sigma = L/\Lambda \cong 28$, which I have called the *Schwinger Ratio* in his honor. Also I have tested the validity of my Coulomb-Madelung potential by using it to *predict* the Schwinger Ratio, and (considering that one is trying to approximate a harmonic oscillator by just two terms from 44 terms defining the potential of an intrinsically anharmonic oscillator) obtained the surprisingly "close" estimate that $\sigma \cong 23$. Now in computing my Resonant Transparency Spectrum, I have used the numerical value of *L* stated above. But upon careful examination, the averaged momentum in the resonance condition is not a function of *E* only; the Coulomb-Madelung potential, and so the integral used to average the momentum, is also a function of *L*, whose sensitivity to variations in *L* may be found by numerical differentiation with respect to *L* and multiplication of the result by the uncertainty in *L*, namely $\delta L \cong \Lambda = L/\sigma = L/28$. This provides an *additional uncertainty* in *E* not considered by Jändel, and at $n = 88$, this *additional* uncertainty δE augments the preceding infinitesimal value of ΔE by a significant amount: $\delta E_{88} = 0.08$ eV. Accordingly the uncertainty in the tunneling time is reduced to a mere

$$\Delta t \geq \hbar/(2\delta E) = 10^{-15} \text{ eV-sec x } (100/8) (\text{eV})^{-1} = 6.25 \text{ x } 10^{-15} \text{ sec.}$$

Thus Objection 3 has also been refuted, as promised.

CONCLUSIONS

The experts who have published 'proofs' that according to established QM the FP Effect is vanishingly *improbable* have committed 3 **identifiable errors** in their calculations:

1. Ignoring *periodicity,* they have treated as mathematically *local* a problem in QM which is intrinsically and inherently *global*.

2. They have overlooked the well-developed global theory of Resonant *Transparency* of multiple Coulomb barriers in a barrier-well-barrier chain.

3. They have overlooked unavoidably-present sources of *resonant-line broadening,* such as the ever-present ZPF.

All three errors are a consequence of ignoring the known foundations of solid state physics, including *Bloch's Theorem.* According to NRL solid-state theorist Dr. Scott Chubb, who together with his uncle Dr. Talbot Chubb has published a completely wave-mechanical approach to the FP Effect which they call Lattice Induced Nuclear Chemistry (**LINC**), in a *periodic* lattice Bloch's Theorem implies that no solution of Schrödinger's equation is relevant unless its logarithmic derivative is periodic of the same period. The Chubbs' theory is somewhat too sophisticated for me to use, but it contains *inter alia* a completely *three-dimensional* version of Duane's Rule, whose elementary one-dimensional application is the basic tool used above, and it incorporates phonon-mediated transfer of momentum from a nucleus to an entire lattice, as in the amazing but well-established Mössbauer Effect.

In the final analysis, the skeptics of the reality of the FP Effect failed because they treated the problem as if it were one regarding the random 3-D collision of isolated rotating particles in a vacuum, rather than one of symmetry and order in a solid-state *periodic* lattice environment.

Those who know Bob Bush personally have observed that his flamboyant personality and strong sense of humor are proportional to his creativity. When Hal Fox and I first heard Bob Bush speak on CF, in December 1989 at the San Francisco *ASME* session on it, he concluded his prescient remarks about the Resonant Transparency of the alleged 'Coulomb barrier' by noting that "CF is just one more startling evidence of the wave-nature of matter", and in parting quipped that "the critics who say that CF is 'all smoke & mirrors' are right about the mirrors!"

ACKNOWLEDGEMENTS

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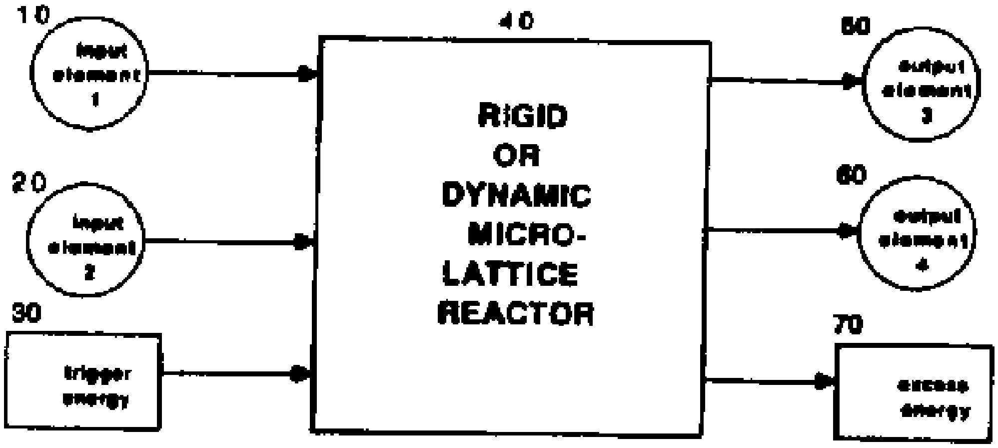
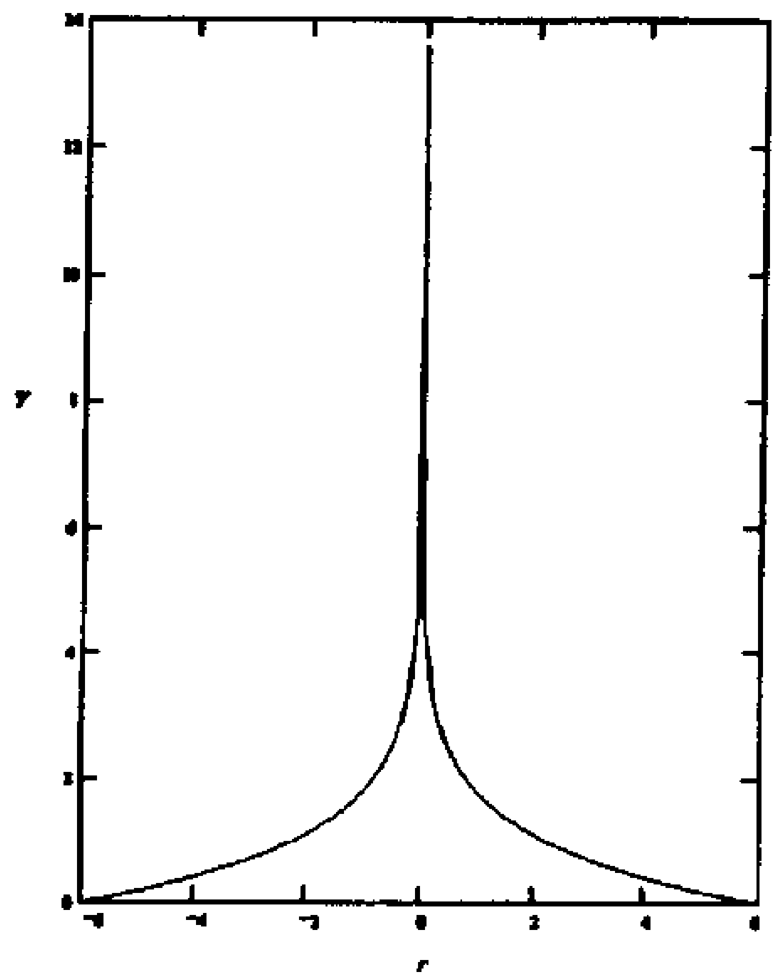
Appendices A through G will be made available in the second edition of this Source Book. They may also be had by writing to the Fusion Information Center, P.O. Box 58639, Salt Lake City, Utah, 84158-0639.



TRINT PROCESS

Transmission Resonance Induced Nuclear Transmutation
(After figure in a Bush-Eagleton Patent Application)

FIG. 1



$V = e/r$

Coulomb Potential of Isolated Charged Particle

FIG. 2

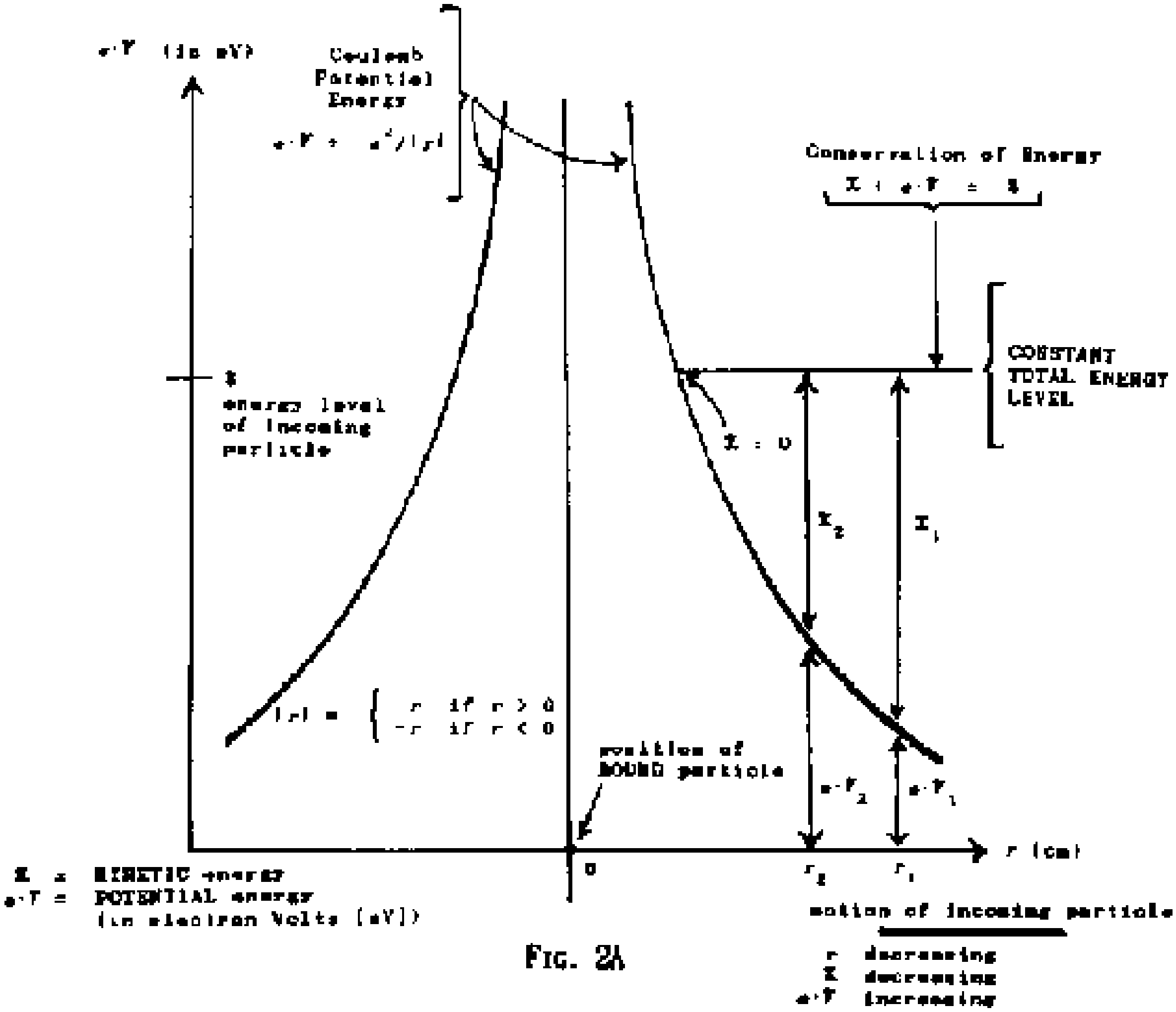

e·V (in eV)
Coulomb Potential Energy
e·V = e²/|r|
Conservation of Energy
K + e·V = E
CONSTANT TOTAL ENERGY LEVEL
E
energy level of incoming particle
K = 0
K2
K1
|r| = { r if r > 0; -r if r < 0 }
position of BOUND particle
e·V2
e·V1
r (cm)
0
r2
r1
K = KINETIC energy
e·V = POTENTIAL energy (in electron Volts [eV])
motion of incoming particle
r decreasing
K decreasing
e·V increasing

FIG. 2A

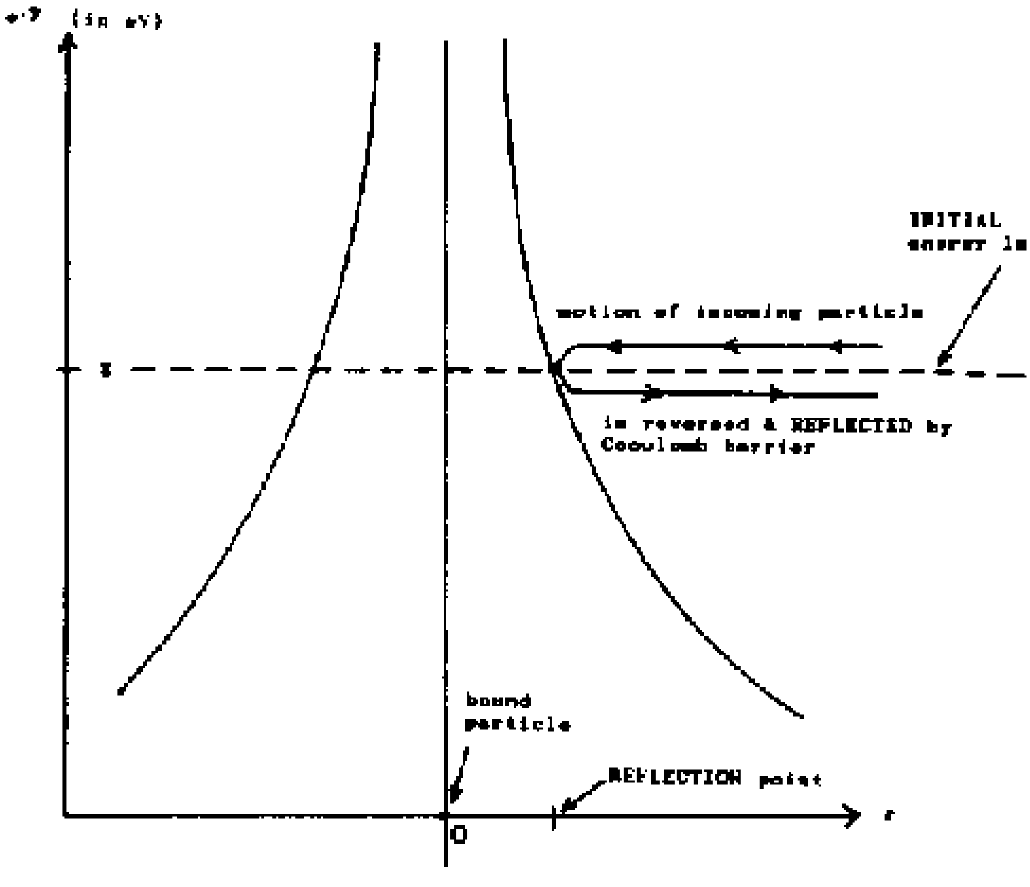
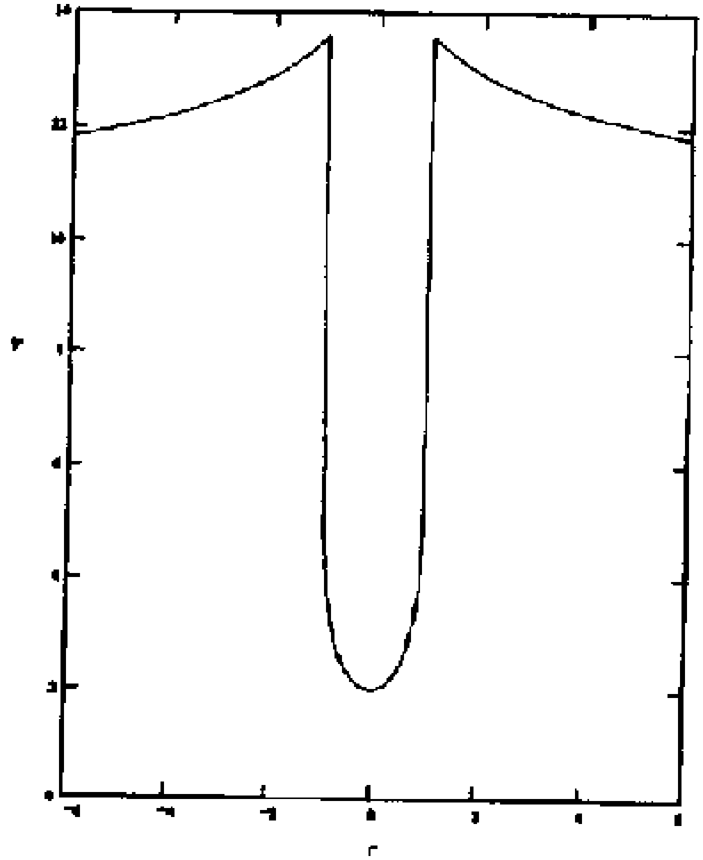

e·V (in eV)
INITIAL energy level E
motion of incoming particle
E
is reversed & REFLECTED by Coulomb barrier
bound particle
REFLECTION point
r
0

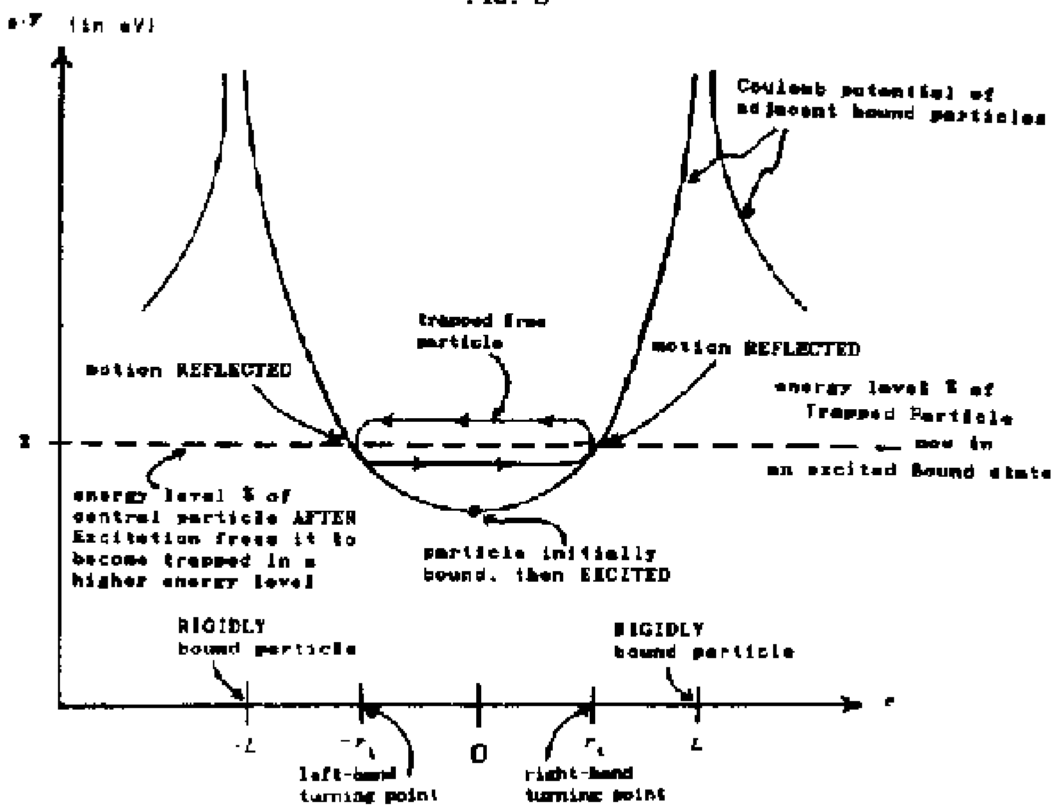
FIG. 2B



$V = V(r) = 2\cdot(e/L)\cdot(1/(1-(r/L)^2)) = V(-r)$

Coulomb Potential of Two Adjacent But Otherwise Isolated Particles

FIG. 3

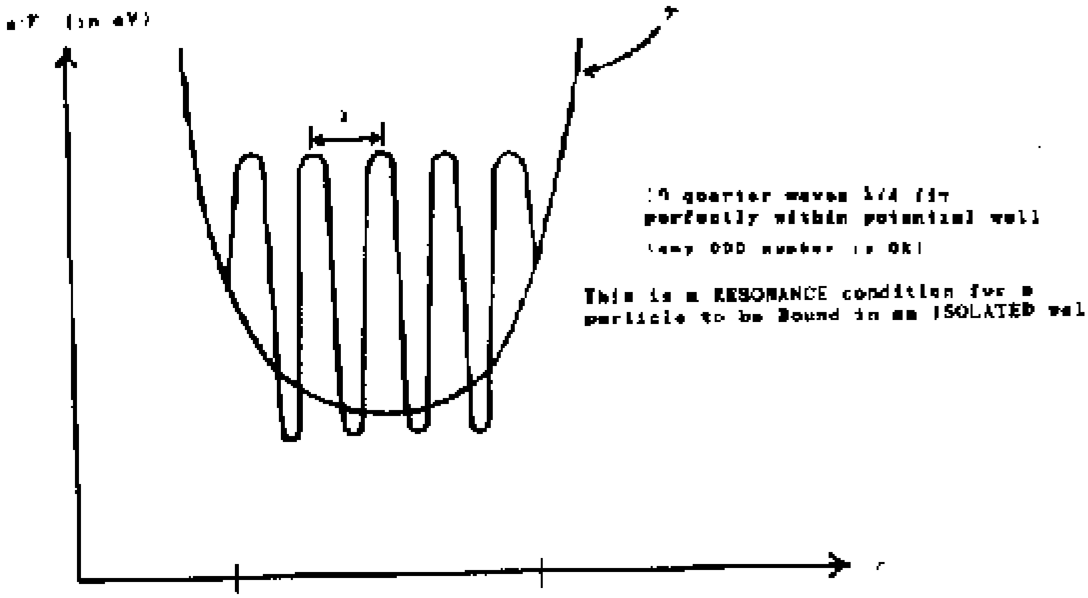


CLASSICAL TRAPPED PARTICLE

Initially in static Equilibrium State, then Excited Bound State

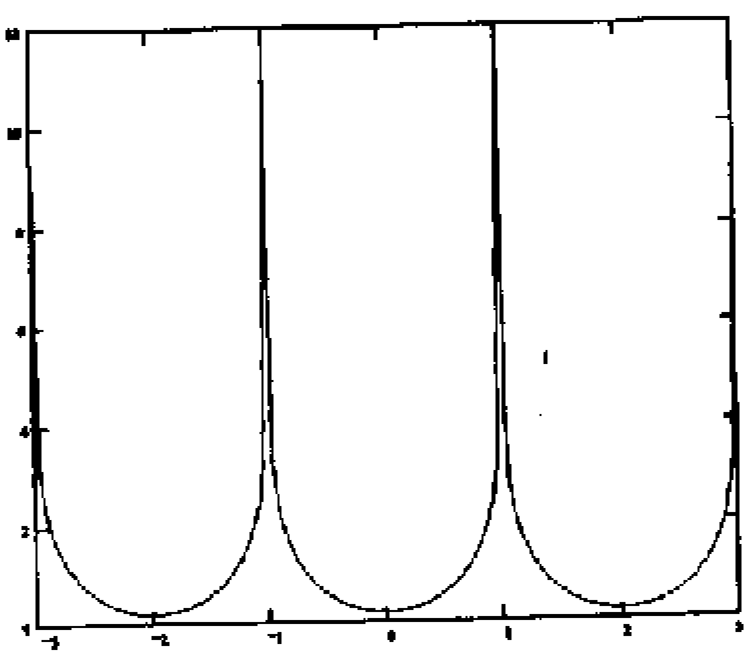
(adjacent particles idealized as bound with "infinite" rigidity)

FIG. 3A



WAVE-MECHANICAL TRAPPED PARTICLE
Free particle is Bound (in an Excited State) when the well-width
is an ODD multiple of one-quarter of the particle's
de Broglie wavelength

FIG. 3B



Periodic Coulomb-Madelung Potential of Infinitely Many
Positive & Negative Point Charges (of ALTERNATING Signs)

$L_w = 2L = 20 \cdot (\lambda/4)$ (20 is EVEN)

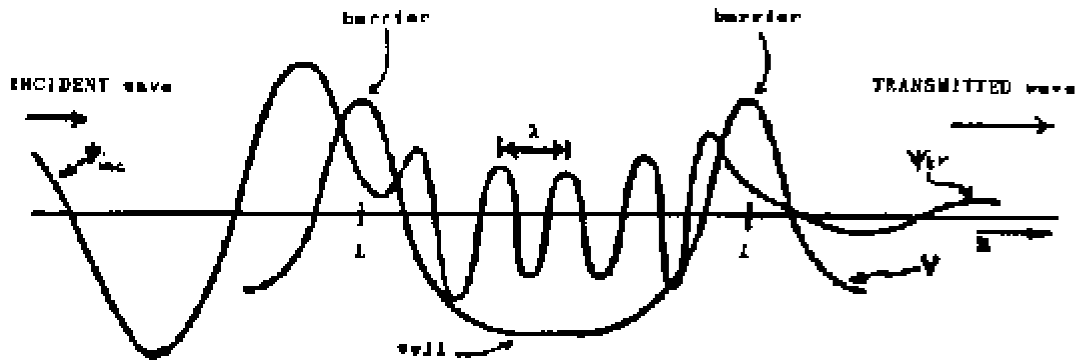


FIG. 5
(after BOHM)

Potential 'BARRIER-WELL-BARRIER' Configuration

WELL-WIDTH $L_w = 2L$ is EVEN multiple of Quarter-Wavelength ($\lambda/4$):

NO RESONANCE!

Intensity of Transmitted Wave LESS than Intensity of Incident Wave
(after many transmissions, wave is completely attenuated)

$L_w = 2L = 19 \cdot (\lambda/4)$ (19 is ODD)

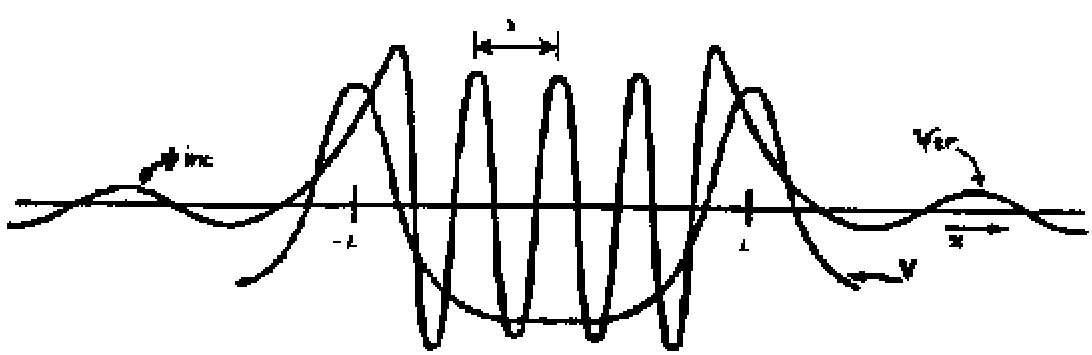


FIG. 6
(after BOHM)

Potential 'BARRIER-WELL-BARRIER' Configuration

WELL WIDTH $L_w = 2L$ is ODD multiple of Quarter Wavelength ($\lambda/4$):

PERFECT RESONANCE!

Intensity of Transmitted Wave EQUALS Intensity of Incident Wave

Perfect Resonant Transmission = Resonant <u>TRANSPARENCY</u>

(note similarities & differences with FIG. [illegible])