7. 2. LOW ENERGY NUCLEAR REACTIONS (LENR)

This is a most promising source of new energy, the most well known device being the Rossi reactor recently purchased for commercialization. Again the standard model of electromagnetism has no coherent explanation for the phenomenon, in which nuclear fusion occurs in simple apparatus with release of useful heat. Some of the devices used to produce this heat are well known and available in all detail. The technique has been subject to numerous independent assessments and checks for repeatability and reproducibility. Initially it was known as cold fusion, famously discovered by Pons and Fleischman in the University of Utah. Their discoveries were supported initially by the State of Utah. It was difficult initially to prove that cold fusion was reproducible and repeatable, so there ensued a very long debate which is still going on. However the LENR technique is being commercialized, and subject to control of the heat produced, will be available for domestic use. LENR devices are already being used for military and other applications and have been subjected to the usual testing and certifying. Some academic departments are also dedicated to LENR, and many conferences, journals and newsletters dedicated to the subject. In the economics department in the University of Utah, models are being developed to research the effect of LENR on future economies. The availability of cheap and clean energy is a pre requisite for economic growth. Stephen Bannister for example is currently preparing a Thesis on this topic in the University of Utah's Department of Economics, a Thesis which compares the first industrial revolution in Britain with the second industrial revolution expected to occur as the result of the energy techniques described in this chapter. During one such conference approximately a year and a half ago one of the authors of this book (MWE) was asked to devise a theoretical explanation for low energy nuclear reactions in terms of ECE theory in order to devise a solid and coherent framework for its development within the scope of a unified field theory. There are many theories of LENR but no consensus as to the origins of the energy needed to cause a nuclear reaction in simple apparatus in the laboratory.

The initial response to this request was UFT 226 on www.aias.us, in whioh a general theory of particle collisions was developed. This is overviewed briefly in this section.

Consider two particles of four momenta p^μ and p_1^μ :

$$p^\mu = \left(\frac{E}{c}, \underline{p} \right), \quad p_1^\mu = \left(\frac{E_1}{c}, \underline{p}_1 \right) \quad - (44)$$

In the minimal prescription on the semi classical level the collision of these particles is described by:

$$p^\mu \rightarrow p^\mu + p_1^\mu \quad - (45)$$

$$E \rightarrow E + E_1 \quad - (46)$$

$$\underline{p} \rightarrow \underline{p} + \underline{p}_1 \quad - (47)$$

where E is the relativistic energy

$$E = \gamma m c^2 \quad - (48)$$

and $\underline{p}$ the relativistic momentum:

$$\underline{p} = \gamma m \underline{v} . \quad - (49)$$

The Lorentz factor is defined by:

$$\gamma = \left(1 - \frac{v^2}{c^2} \right)^{-1/2} \quad - (50)$$

where $\underline{v}$ is the velocity of a particle of mass m and where c is the speed of light in vacuo. Eq. (49) implies the Einstein field equation:

$$E^2 = p^2 c^2 + m^2 c^4 \quad - (51)$$

which can be written as:

$$E^2 - m^2c^4 = (E - mc^2)(E + mc^2) = c^2p^2. \quad -(52)$$

From Eqs. (45) and (51):

$$(E + E_1)^2 = c^2(p + p_1)^2 + m^2c^4 \quad -(53)$$

which is the classical relativistic description of particle interaction in the minimal prescription. From Eq. (53):

$$(E + E_1)^2 - m^2c^4 = c^2(p + p_1)^2 \quad -(54)$$

so the relativistic kinetic energy is:

$$T = E + E_1 - mc^2 = \frac{c^2(p + p_1)^2}{E + E_1 + mc^2}. \quad -(55)$$

This kinetic energy is a limit of the ECE fermion equation, which is derived from the Cartan geometry used in this book. The concepts of particle mass m and m_1 are limits of the more general R factor of the ECE wave equation described in UFT 181 and UFT 182. After a series of approximations described in UFT 226, and similar to those used in the derivation of the fermion equation described already in this book, the energy E can be expressed as:

$$E = \frac{c^2(p + p_1)^2}{2mc^2 + E_1} + mc^2 \quad -(56)$$

and the kinetic energy as:

$$T = E + E_1 - mc^2 \sim E - mc^2 \quad -(57)$$

In order to quantize the theory the fermion equation is used as described in UFT 226 to give the hamiltonian operator:

$$H\phi = (H_1 + H_2)\phi \quad -(58)$$

where:

$$H_1\phi = \frac{1}{2m}\left(\underline{\sigma}\cdot\left(-i\hbar\underline{\nabla} + \underline{p}_1\right)\underline{\sigma}\cdot\left(-i\hbar\underline{\nabla} + \underline{p}_1\right)\right)\phi \quad -(59)$$

and

$$H_2\phi = \left(-\underline{\sigma}\cdot\left(-i\hbar\underline{\nabla} + \underline{p}_1\right)\frac{E_1}{4m^2c^2}\left(-i\hbar\underline{\nabla} + \underline{p}_1\right)\right)\phi \quad -(60)$$

In Eq. (58):

$$\underline{\sigma}\cdot(\underline{p} + \underline{p}_1)\,\underline{\sigma}\cdot(\underline{p} + \underline{p}_1) = p^2 + p_1^2 + \underline{p}_1\cdot\underline{p} + \underline{p}\cdot\underline{p}_1 + i\underline{\sigma}\cdot(\underline{p}_1\times\underline{p} + \underline{p}\times\underline{p}_1) \quad -(61)$$

so the first type of hamiltonian becomes:

$$H_1 = -\frac{\hbar^2}{2m}\nabla^2 + \frac{p_1^2}{2m} + \frac{i\hbar}{2m}\left(\underline{p}_1\cdot\underline{\nabla} + \underline{\nabla}\cdot\underline{p}_1\right) + \frac{\hbar}{2m}\underline{\sigma}\cdot\left(\underline{p}_1\times\underline{\nabla} + \underline{\nabla}\times\underline{p}_1\right) \quad -(62)$$

and operates on the wave function to give energy eigenvalues. As described in UFT 226 the hamiltonian operator may be simplified to give:

$$H_1 = -\frac{\hbar^2}{2m}\nabla^2 + \frac{p_1^2}{2m} + \frac{i\hbar}{2m}\left(\underline{\nabla}\cdot\underline{p}_1 + 2\underline{p}_1\cdot\underline{\nabla}\right) + \frac{\hbar}{2m}\underline{\sigma}\cdot\underline{\nabla}\times\underline{p}_1 \quad -(63)$$

In the generally covariant format of this theory the concept of mass is generalized to curvature R using the Hamilton Jacobi equation:

$$(p^\mu - \hbar\kappa^\mu)(p_\mu - \hbar\kappa_\mu) = m_0^2c^2 \quad -(64)$$

as in UFT 182 on www.aias.us. Eq. (64) may be written as:

$$p^\mu p_\mu = \hbar^2 R_1 + m_0^2c^2 \quad -(65)$$

Using this theory it is possible to consider the four momentum p_1^μ of particle 1 interacting with a matter wave 2 defined by the wave vector κ_2^μ. Particle 1 is also a matter wave:

$$p_1^\mu = \hbar\kappa_1^\mu . \quad -(66)$$

In UFT 182 it was shown that the interaction is described by:

$$\left(\Box + R_2 + \left(\frac{m_{10}c}{\hbar}\right)^2\right)\phi_1 = 0 \quad -(67)$$

where the R_2 parameter is:

$$R_2 = \left(\frac{m_2 c}{\hbar}\right)^2 \quad -(68)$$

and where the concept of interacting mass is defined as:

$$m_2 = \frac{\hbar}{c}\left(2\left(\frac{\omega_1\omega_2}{c^2} - \kappa_1\kappa_2\right) - \left(\frac{\omega_2^2}{c^2} - \kappa_2^2\right)\right)^{1/2} \quad -(69)$$

Therefore in this general ECE theory it is possible to think of a quantum of space time energy being absorbed during a LENR reaction. This idea generalizes the Planck concept of photon energy to particle energy.

A low energy nuclear reaction can be exemplified as follows:

$$ {}^{64}Ni + p = {}^{63}Cu + 2n \quad -(70)$$

Here, ${}^{64}Ni$ has 36 neutrons and 28 protons, and ${}^{63}Cu$ has 34 neutrons and 29 protons. So ${}^{64}Ni$ is transmuted into ${}^{63}Cu$ with release of two neutrons. The theory must explain why this nuclear reaction occurs. Nickel is transmuted to copper with the release of usable heat and this reaction can be made to occur in simple apparatus in the laboratory. It does not need the vast amount of expenditure of conventional nuclear fusion research. Using the theory of this section the interacting mass is:

$$ m = \frac{\hbar}{c}\left(\frac{\omega^2}{c^2} - \kappa^2\right)^{1/2} \quad -(71)$$

and the total mass of the nickel atom during interaction increases to:

$$ M = \left(m^2 + m_0^2\right)^{1/2} \quad -(72)$$

with concomitant energy:

$$ E_0 = Mc^2 \quad -(73)$$

so that a nuclear reaction occurs, a LENR reaction.

This is a simple first theory, which is a plausible explanation of LENR. In UFT 227 a more general theory was considered to develop an expression for the mass M of a fused nucleus when reactants 1 and 2 produce products 3 and 4. Total energy momentum is conserved as follows:

$$p_1^\mu + p_2^\mu = p_3^\mu + p_4^\mu. \quad -(74)$$

As shown in UFT 227 this equation can be expressed as:

$$(E_1 + E_2)^2 - (\underline{p}_1 + \underline{p}_2)\cdot(\underline{p}_1 + \underline{p}_2) = \underline{M}^2 c^4 \quad -(75)$$

where:

$$\underline{M}^2 = m_1^2 + m_2^2 + 2m_1 m_2 \left(\gamma_1 \gamma_2 - (\gamma_1^2 - 1)^{1/2} (\gamma_2^2 - 1)^{1/2} \cos\theta\right) \quad -(76)$$

in which the angle θ is defined as

$$(\underline{p}_1 + \underline{p}_2)\cdot(\underline{p}_1 + \underline{p}_2) = p_1^2 + p_2^2 + 2p_1 p_2 \cos\theta. \quad -(77)$$

In the non relativistic limit:

$$v_1 << c, \; v_2 << c \quad -(78)$$

Eq. (76) becomes:

$$\underline{M}^2 = m_1^2 + m_2^2 + 2m_1 m_2 = (m_1 + m_2)^2 \quad -(79)$$

so in this limit M is the sum of m_1 and m_2. Otherwise there is a mass discrepancy or difference:

$$\Delta m = (m_1^2 + m_2^2 - \underline{M}^2)^{1/2} \quad -(80)$$

which gives rise to the energy released in nuclear fusion as heat and light.

This classical relativistic theory was quantized in UFT 227 using the fermion equation for the fusion of two atoms 1 and 2. The attractive nuclear strong forces are denoted $\bar{V}_1$ and $\bar{V}_2$, their sum being:

$$\bar{V} = \bar{V}_1 + \bar{V}_2 \quad -(81)$$

The total relativistic energy of nuclei 1 and 2 is:

$$E = E_1 + E_2 \quad -(82)$$

and their fused mass is M. The vector sum of their relativistic momenta is:

$$\underline{p} = \underline{p}_1 + \underline{p}_2 . \quad -(83)$$

The fermion equation for this nuclear fusion reaction is:

$$\left((E - V) + c\,\underline{\sigma}\cdot\underline{p}\right)\phi^L = \underline{M}c^2\phi^R \quad -(84)$$

$$\left((E - V) - c\,\underline{\sigma}\cdot\underline{p}\right)\phi^R = \underline{M}c^2\phi^L \quad -(85)$$

which can be developed as the Schroedinger type equation:

$$H\phi = E\phi \quad -(86)$$

where the hamiltonian operator is:

$$H = H_1 + H_2 \quad -(87)$$

where:

$$H_1 = \underline{M}c^2 + V - \frac{\hbar^2\nabla^2}{2m} \quad -(88)$$

and:

$$H_2 = \frac{1}{4\underline{M}^2c^2}\,\underline{\sigma}\cdot\underline{p}\,V\,\underline{\sigma}\cdot\underline{p} \quad -(89)$$

giving the nuclear energy levels.

In UFT 227 the well known Woods Saxon potential was used to model Eq. (86). It is described by:

$$V = -V_0 \left(1 + \exp\left(\frac{r - R}{a} \right) \right)^{-1} \quad -(90)$$

where V_0 is the potential well depth, a is the surface thickness of the nucleus, and R is the nuclear radius. It can be approximated roughly by the harmonic oscillator potential:

$$V = \frac{1}{2} k r^2 - V_0 \quad -(91)$$

where k is the spring constant of Hooke's law, so Eq. (86) becomes:

$$H_1 \phi = \left(-\frac{\hbar^2 \nabla^2}{2m} + \frac{1}{2} k r^2 + m c^2 - V_0 \right) \phi . \quad -(92)$$

The nuclear energy levels of the fused nucleus in this approximation are the well known energy levels of the harmonic oscillator:

$$E = \left(n + \frac{1}{2} \right) \hbar \omega \quad -(93)$$

where:

$$n = 0, 1, 2, \ldots \quad -(94)$$

and where:

$$\omega = \left(\frac{k}{m} \right)^{1/2} . \quad -(95)$$

In a rough approximation as described in UFT 227 the attractive nuclear strong force can be written as:

$$\underline{F}_N \sim \frac{1}{4a} \left(1 - \frac{r - R}{a} \right) \underline{e}_r \quad -(96)$$

and the spin orbit energy from the nuclear fermion equation (86) is:

$$H_{SO}\phi = \frac{\hbar}{16m^2c^2a^2}\,\underline{\sigma}\cdot\underline{L}\,\phi \quad -(97)$$

The spin orbit energy can be used to explain many features of nuclear physics and is its most important property.

The energy levels of the fused nucleus are in excited states, and the nucleus disintegrates to give products 3 and 4 accompanied by energy:

$$\Delta E_0 = (m_1 + m_2 - M)c^2. \quad -(98)$$

In UFT 228 quantum tunnelling theory was introduced by writing the Einstein energy equation:

$$E^2 = p^2c^2 + m^2c^4 \quad -(99)$$

as

$$E = \gamma mc^2 = \frac{1}{\gamma m}(p^2 + m^2c^2). \quad -(100)$$

Eq. (100) becomes a Schroedinger equation:

$$H\phi = E\phi \quad -(101)$$

with the hamiltonian:

$$H = \frac{1}{\gamma m}(p^2 + m^2c^2) \quad -(102)$$

and energy levels:

$$E = \gamma mc^2. \quad -(103)$$

It follows that:

$$p^2 \phi = -\hbar^2 \nabla^2 \phi = m^2 c^2 (\gamma^2 - 1) \phi. \quad -(104)$$

The four momentum is defined by:

$$p^\mu = i\hbar \partial^\mu = \hbar \kappa^\mu \quad -(105)$$

where:

$$p^\mu = \left(\frac{E}{c}, \underline{p} \right), \quad -(106)$$

$$\partial^\mu = \left(\frac{1}{c} \frac{\partial}{\partial t}, -\underline{\nabla} \right) \quad -(107)$$

$$\kappa^\mu = \left(\frac{\omega}{c}, \underline{\kappa} \right). \quad -(108)$$

Here ω is the frequency of the matter wave, and $\underline{\kappa}$ the wave number.

Therefore:

$$p^2 \phi = \hbar^2 \kappa^2 \phi = m^2 c^2 (\gamma^2 - 1) \phi = \left(\frac{E^2}{c^2} - m^2 c^2 \right) \phi \quad -(109)$$

For a free wave / particle:

$$\kappa = \frac{mc}{\hbar} (\gamma^2 - 1)^{1/2}. \quad -(110)$$

For the purposes of the development of quantum tunnelling theory denote:

$$k = \frac{mc}{\hbar} (\gamma^2 - 1)^{1/2}. \quad -(111)$$

In the presence of potential energy V the operator (102) becomes:

$$H = \frac{1}{\gamma m}\left(p^2 + m^2c^2\right) + V \quad -(112)$$

so:

$$p^2\phi = \left(\gamma m\left(E - V\right) - m^2c^2\right)\phi \quad -(113)$$

and

$$\kappa^2 = \frac{1}{\hbar^2}\left(\gamma m\left(E - V\right) - m^2c^2\right). \quad -(114)$$

In quantum tunnelling theory E < V, so

$$E - V < 0. \quad -(115)$$

Define:

$$\kappa = \frac{1}{\hbar}\left(\gamma m\left(V - E\right)\right)^{1/2}. \quad -(116)$$

Denoting the rest wave number as:

$$\kappa_0 = \frac{mc}{\hbar} \quad -(117)$$

we arrive at the definition:

$$\kappa^2 + \kappa_0^2 = \frac{\gamma m}{\hbar^2}\left(V - E\right). \quad -(118)$$

Eq. (111) can be written as:

$$k^2 + \kappa_0^2 = \gamma^2 \left(\frac{mc}{\hbar} \right)^2 \quad -(119)$$

so:

$$\frac{\hbar^2}{2m} \phi = \frac{mc^2}{2} \left(\gamma^2 - 1 \right) \phi . \quad -(120)$$

In the non relativistic quantum limit, as shown in UFT 228:

$$\nabla^2 \phi = - \left(\frac{2mE}{\hbar^2} \right) \phi \quad -(121)$$

giving the transmission coefficient:

$$T = 8\kappa^2 k^2 \left(\left(k^2 + \kappa^2 \right) \cosh \left(4\kappa a \right) - \left(\kappa^4 + k^4 - 6\kappa k \right) \right)^{-1} , \quad -(122)$$

for a potential of type:

$$\begin{aligned} V &= 0, \quad x < -a, \\ V &= V_0, \quad -a < x < a, \\ V &= 0, \quad x > a, \\ & E < V_0 \end{aligned} \quad -(123)$$

in which:

$$k^2 = 2mE / \hbar^2 , \quad E = mc^2 \left(\gamma^2 - 1 \right) / 2 ,$$

$$\kappa^2 = 2m \left(V_0 - E \right) / \hbar^2 , \quad E = mc^2 \left(\gamma^2 - 1 \right) / 2 . \quad -(124)$$

It is found using this analysis that the single most important factor is the mass of the incoming factor. The extra ingredient given by ECE theory is the possibility of augmenting the standard quantum tunnelling theory by resonant absorption of quanta of space time energy - energy from space time.