Advances on Alternative Fuels with Santilli Magnecular Structure

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ABSTRACT

Santilli, the Italian-American physicist, for the first time in the history of Science, presented the theoretical and experimental evidence on the existence of the new chemical species of magnecules. This new species mainly consist of individual atoms, radicals and conventional molecules bonded together with stable clusters under the new attractive force primarily originating from toroidal polarization of orbitals of atomic electrons under strong magnetic field. The main contribution in this area was the production of Magnegas^{TM} (Patented and International Patents Pending), new clean fuels developed by Santilli, which are produced as by-products of recycling nonradioactive liquid feedstock such as antifreeze waste, engine oil waste, town sewage, crude oil, etc., and generally vary with the liquid used for their production. A new technology, called Plasma Arc Flow^{TM}, flows the waste through a submerged electric arc between conventional electrodes. The arc decomposes the liquid molecules into their atomic constituents, and forms a plasma in the immediate vicinity of the electrodes at about 10, 000^{0} F. The technology then moves the plasma away from the electrodes, and controls its recombination into environmentally acceptable fuels. In fact, the exhaust of magnegases shows: absence of carcinogenic or other toxic substances; breathable oxygen up 14 percent; and carbon dioxide down to 0.01 percent. Since, in addition, the new fuels can be produced everywhere, and have environmentally acceptable exhausts, Magnegases offer promising possibilities to satisfy our ever increasing energy needs, as well as to contain the alarming environmental problems caused by fossil fuels. Thus, it was thought worthwhile to present some of the industrial applications of environmentally benign fuel consisting magnecular bonds. Also in the present communications, some of the experimental evidences of Santilli's new chemical species i. e. Magnecules which had been published recently have been summarized.

Keywords- Magnecule, Clean fuel, Plasma Arc Flow Reactor, MagneHydrogen, MagneGas.

1. INTRODUCTION

According to official data by recent U.S. Department of Energy (DOE) release [1], about 74 millions barrels of fossil oil, corresponding to about four billions gallons of gasoline, are consumed in our planet per day in an estimated number of half a billion cars, one million trucks, one hundred thousand planes, plus industrial, agricultural, and military uses 74.18 million of barrel per day;

74.18 million of barrel per day
= (74.18 million barrels/24h)×(55 gallons/barrel)
= 4.08×10^{9} gallons/24h
= 1.54×10^{13} cc/24h (using 4 quarts/gallon and 946 cc/quart)
= (4.08×10^{9} gallons) × (4 qrt./gallon) × (946 cc/qrt.)/day
= (1.5438×10^{13} gallons) × (4 qrt./gallon) × (946 cc/qrt.)/day
= (1.0850×10^{13} grams octane)/day
= (1.0850×10^{13} grams) / (114.23 grams/mole)
= 9.4984×10^{10} moles n-octane/day, (approx.)

In the present data, the additional large use of natural gas and coals, which would bring the daily combustion of all fossil fuel to the equivalent of about 120 million barrels of crude oil per day has not been included.

Some of the cataclysmic climatic events facing by the mankind due to the large environmental disturbances are:

- Global warming
- Ozone layer depletion
- Acid Rain
- Increase in the numbers of hurricanes and tornados
- Change in the pattern of rainfall and snow in many parts of the world
- Slow-down of the Gulf Stream,
- Many more.

The extremely serious environmental problems caused by the disproportionate combustion of fossil fuels is as follows: [2]

- The combustion of fossil fuels releases in our atmosphere about sixty millions metric of tons carbon dioxide CO_2 per day that are responsible for the first large environmental problem known as "global warning" or "green house effect". Of these only 30 millions metric tons are estimated to be recycled by our ever decreasing forests.
- The combustion of fossil fuels causes the permanent removal from our atmosphere of about 21 millions metric tons of breathable oxygen per day, a second, extremely serious environmental problem known as "oxygen depletion".

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- The combustion of fossil fuels releases in our atmosphere about fifteen millions metric tons of carcinogenic and toxic substances per day. This third, equally serious environmental problems is "atmospheric pollution", while in reality it refers to the primary source of the widespread increase of cancer in our societies.

Widespread mis-representations exist for ethanol, biogases, and other conventional fuels, that is, fuels possessing the conventional molecular structure, generally presented as cleaner than gasoline. Whenever facing the ever increasing cataclysmic climactic events caused by fossil fuel combustion, a rather widespread belief is that the solution already exists and it is given by "Hydrogen" for the large scale fuel uses of the future because hydrogen is believed to be "the cleanest fuel available to mankind".

However, Hydrogen is indeed an environmentally acceptable fuel, but only when its production and use verify the following conditions:

- CONDITION I: Hydrogen is produced via the electrolytic separation of water;
- CONDITION II: The electricity used for electrolysis originates from clean and renewable energy sources, such as those of hydric, solar or wind nature; and
- CONDITION III: The oxygen produced by the electrolytic process is freely released in the environment so that the subsequent hydrogen combustion leaves unchanged the existing oxygen content of our atmosphere.

However, the reality in the production and use of hydrogen is dramatically different than the above ideal conditions. In fact, hydrogen is today produced in its greatest percentage via reformation processes of fossil fuels such as methane CH_4, via the use of highly polluting electric power plants, and no oxygen is released in the atmosphere during production. The oxygen depletion caused by hydrogen combustion is a large multiple of that caused by gasoline combustion. The current methods of hydrogen production, transportation and use release in the atmosphere carcinogenic substances, green house gases and other contaminants those are at least twenty times bigger than the contaminants releases by the gasoline production and combustion.

Hydrogen, if implemented in large scale such as that of fossil fuels, cause the following very serious environmental problems:

- Alarming oxygen depletion caused by hydrogen combustion: The notion of "oxygen depletion" was introduced by Santilli at the 2000 Hydrogen World Conference in Munich as the permanent removal of breathable oxygen from our atmosphere and its conversion into water vapors.
- Alarming environmental problems caused by current hydrogen production: The reformation of methane and other fossil fuels for hydrogen production requires large amounts of energy because of the necessary breaking of strong molecular bonds such as CH_4. In this case, all byproducts of the reformation, such as the "green house gas" CO_2, are released into the environment.
- Alarming threat to the ozone layer caused by hydrogen seepage and losses: The inevitable release of free hydrogen that, being very light, instantly rises to the upper layer of our atmosphere all the way to the ozone layer, resulting in its depletion because hydrogen and ozone have one of the fastest known chemical reactions $H_2 + O_3 \rightarrow H_2O + O_2$.
- Alarming environmental problems caused by the need to liquify hydrogen: Hydrogen liquefies close to the absolute zero degree temperature, thus requiring large amounts of electric energy for its liquefaction, with consequential multiplication of pollution.
- Prohibitive hydrogen cost: Actual cost of hydrogen in a liquefied form for automotive use is at least 200 times the cost of fossil fuels.

The most basic need for the very survival of our contemporary societies in view of the disproportionate use of fossil fuels and the increasingly cataclysmic climactic events caused by the pollutants in their combustion exhaust can be summarized as follows:

1. Develop "new" processes for the nonpolluting, large scale production of electricity,
2. Build a large number of large reactors for the large scale removal and recycling of the excess CO_2 in our atmosphere.
3. Develop "new" fuels that are not derivable from crude oil and are capable of achieving full combustion.

The need for fuels with a new chemical structure is set by the impossibility for all available fuels, those with conventional molecular structure, to achieve full combustion.

2. BACKGROUND

In memoir [3] of 1998, the Italian-American physicist Santilli presented mathematical, theoretical and experimental evidence on the existence of the new chemical species of magnecules defined as clusters of individual atoms (H, O, C, etc.), diatomic radicals (HO, CH, etc.) and ordinary molecules (H_2, CO, H_2O, etc.) bonded together by attractive forces between opposing magnetic polarities of toroidal polarizations of atomic orbitals, as well as the polarization of the magnetic moments of nuclei and electrons.

Santilli suggested the name "magnecules" in order to distinguish the new species from conventional "molecules" (namely stable clusters of atoms under the conventional valence bond), as well as to indicate the

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primary magnetic origin of the new bond. The symbol "×" is widely used to denote a valence bond (such as H – H) while the symbol "×" is used to denote a magnecular bond (such as H × H) [1, 2]. The main theoretical argument of Ref. [1, 3] is that the toroidal polarization of the electron orbitals creates a magnetic field (due to the rotation of the electrons within said toroid) which does not exist for the same atom when the electron orbitals have the conventional spherical distribution. When two so polarized atoms are at a sufficiently close distance, the resulting total force between the two atoms is attractive because all acting forces are attractive except for the repulsive forces due to nuclear and electron charges. However, the latter forces can be averaged to zero in first approximation since the individual atoms have a null total charge. Alternatively, individual atoms can be assumed in first approximation to have a null total charge distribution, resulting in the evident dominance of the attractive magnetic forces between two atoms with toroidal polarization of their orbitals [1, 3]. Memoir [3] also provided considerable experimental evidence for the existence of magnecules in liquids, and comments on the expected existence of magnecular bonds in solids.

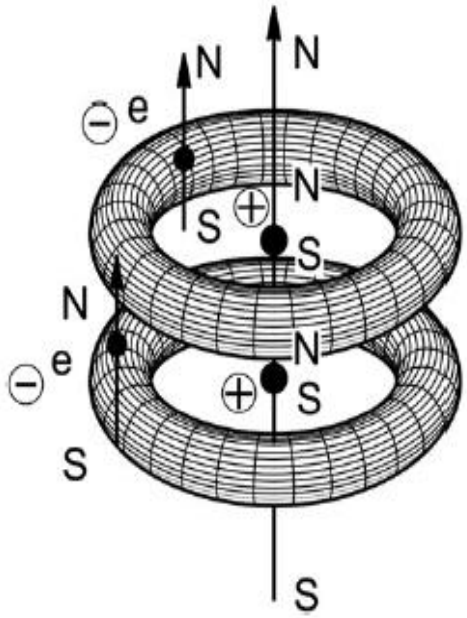

Figure 1 Conceptual rendering of Santilli's magnecules, here referred to the species H × H assumed at absolute zero degree temperature. Note that: the toroidal polarization of the electron orbitals creates a new magnetic field not existing for spherical distributions; all magnetic forces between said toroids as well as between the magnetic polarities of nuclei and electrons are attractive; and the repulsive forces between nuclear and electron charges can be averaged to zero in first approximation since the atoms are individually neutral, thus resulting in the dominance of a new non-valence bond Santilli calls "magnecular". Note that the new bond can be also called "axial" (or "perpendicular") in the sense that the magnetic force exists along the symmetry axis of the toroid (or the magnetic force is perpendicular to the symmetry plane of the toroid)

All types of magnegases (again referred to combustible gases produced under an electric arc) possess a new chemical structure first identified by Santilli [1, 3, 4], which is characterized by clusters of ordinary molecules, radicals and atoms bonded together by attractive forces of primary magnetic origin (Figure 1).

The possible types of bonds and mechanisms of creation and stability of the magnecules are [5]:

1. Valence bonds (for substructures);
2. Hydrogen bonds (for substructures);
3. Polymerization (for substructures);
4. Magnetic bonds due to polarized electronic orbits;
5. Electric polarization;
6. Van der Waals bonds;
7. Three-center bonds;
8. Two-dimensional quantum tunnel effect;
9. Delocalized electrons; etc.

As established by numerous Gas Chromatographic, Mass Spectrometric (GC-MS) tests under joint Infra Red Detectors (IRD) [1, 3, 6], these clusters constitute a new chemical species different than that characterized by conventional molecules (i.e., clusters with a valence bond), since the magnegas clusters are stable at ordinary conditions which remain unidentified among known molecules while exhibiting no infrared signatures (other than those of conventional molecular constituents), thus confirming that the bond is not of valence type.

As well known in physics (although less emphasized in contemporary chemistry), whether conventional or novel, stable clusters detected by GC-MS equipment cannot exist without an attractive force. The specific and concrete identification of the attractive bond of electro-magneclusters constitutes a central aspect in the study of magnegas, with implications similar to those of the valence for conventional molecules.

Extensive studies of this aspect have established that the primary attractive force responsible for the electro-magnecules is expected to be due to the magnetic polarization of the orbitals of valence and other electrons, from space to toroidal distributions. Conventional quantum electrodynamics establishes the existence of such a polarization whenever atoms and molecules are exposed to intense magnetic fields, as it is the case in the vicinity of the electric arc. Such a magnetic polarization creates magnetic *North-South* polarities along the symmetry axis of the toroid, which permit the stacking of atoms and molecules one after the other.

The above analysis has permitted a quantitative interpretation of the detection via GC-MS/IRD of clusters possessing molecular weight all the way to 1,000 a.m.u. in a light gas, such as magnegas from antifreeze waste, whose highest molecular weight should be 44 a.m.u. for CO_2 [6].

Electric contributions are expected to exist but their study has not been conducted to date. Conventional molecules are mostly preserved in the new clusters (as established by

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the preservation of their IR signature). Therefore, valence electrons cannot contribute to the bonding force of the new clusters. Ionic contributions, even though unquestionably present, are notoriously unacceptable for a bond, because they carry the same charge, thus resulting in a repulsive, rather than attractive force. Electric polarization (essentially due to a deformation of the charge distributions of atoms are also unquestionably present, although they are notoriously unstable and weak, while their geometry does not lend to large clustering when acting alone.

As a result of the expected dominance of magnetic over electric contributions, the new chemical species composing magnegas is called "magnecules" or "magneclusters". It is evident that the bonding of atoms and molecules into new clusters constitutes new means for storing energy in a combustible gas, in addition to the conventional valence means in ordinary fuels.

Therefore, magnecules have a primary relevance for the study of the combustion of magnegas. It is also evident that a deeper understanding of the magnetic origin of the new clusters in magnegas will permit an increase of their energy content, since the size and strength of magnecules is directly proportional to the magnetic field used for its formation.

Numerous independent measurements on magnegas [2, 6, 7] have established that the IR of conventional molecules is "mutated" with the presence of new additional peaks. Since all valence electrons are generally used in the molecules, the new IR peaks can only be explained via the creation of new internal bonds of non-valence type. Again, the magnetic origin of these new bonds has resulted to be plausible, and essentially consists in the toroidal polarization of the orbitals of internal electrons under external, strong magnetic fields. For the case of C=O, these internal toroidal polarizations imply the creation of the pair of magnetic polarities (*North-South)-(North-South*). The creation of internal magnetic bonds then alters the entire thermo-chemical horizon, beginning with new values of binding energies for conventional molecules.

It is evident that a deeper understanding of the new internal bonds in conventional molecules may permit a corresponding increase of energy storage in fuels, since, again, their number and strength depends on the intensity of the external magnetic field used for their creation.

3. ARINGAZINS STUDIES ON TOROIDAL ORBITS OF THE HYDROGEN ATOM UNDER AN EXTERNAL MAGNETIC FIELD

The intensity of the magnetic field which causes considerable deformation of the ground state electron orbit of the H atom, one can formally compare Bohr radius of the H atom in the ground state, in zero external magnetic field $a_0 = \hbar^2 / m.e^2 \approx 0.53\times10^{-8}\,\text{cm} = 1\,\text{amu}$; with the radius of orbit of a single electron moving in the external static uniform magnetic field, $\vec{B}$.

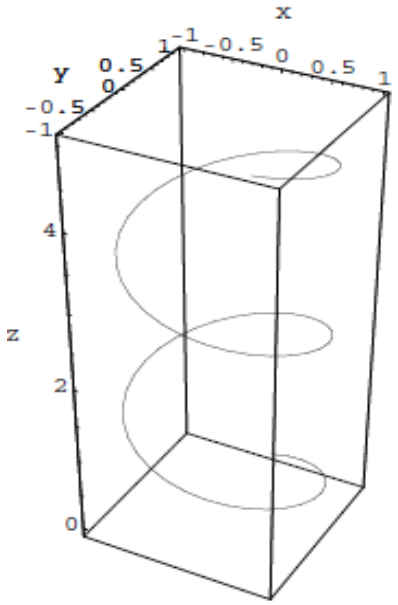

Figure 2 Classical orbit of the electron in an external static uniform magnetic field $\vec{B} = (0,0,B)$ pointed along the z axis. The electron experiences a circular motion in the x, y plane and a linear motion in the z direction (a helical curve)

The mean radius of the orbital of a single electron moving in a static uniform magnetic field can be calculated exactly by using Schrodinger's equation, and it is given by

$$R_n = \sqrt{\frac{n+1//2}{\gamma}} \qquad (1)$$

where,

$$\gamma = \frac{e.H}{2.\hbar.c}\,; \qquad (2)$$

B is the intensity of the magnetic field pointed along the z axis, $\vec{B}$ = (0; 0; B), $\vec{r} = (r, \varphi, z)$, in cylindrical coordinates, and n = 0; 1;.,.,.,., is the principal quantum number. Thus, the radius of the orbit takes discrete set of values (eq. 1), and is referred to as *Landau radius*. This is in contrast to the well known classical motion of electron in the external magnetic field (a helical curve is shown in Figure 2, with the radius of the orbit being of a continuous set of values. The classical approach evidently can not be applied to study dynamics of the electron at atomic distances.

Corresponding energy levels *E*n of a single electron moving in the external magnetic field are referred to as Landau energy levels,

$$E_n = E_n^{\perp} + E_{k_z}^{\square} = \hbar\Omega\left(n + \frac{1}{2}\right) + \left(\frac{\hbar^2 k_z^2}{2m}\right) \qquad (3)$$

where,

$$\Omega = \frac{e.H}{m.c} \qquad (4)$$

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is so called cyclotron frequency, and $\hbar k_z$ is a projection of the electron's momentum $\hbar\vec{k_z}$ on the direction of the magnetic field, $-\infty < k_z < +\infty$, m is the mass of electron, and -e is the charge of electron.

Arigazin [8, 9, 10] applied the concept of Landau orbit of single electron to Hydrogen atom under strong magnetic field. General Schrodinger equation for the electron moving around a fixed proton (Born-Oppenheimer approximation) in the presence of the external magnetic field is:

$$-\frac{\hbar^2}{2m}\left(\partial_2^2+\frac{1}{r}\partial r+\frac{1}{r^2}\partial_\varphi^2+\partial_z^2+\frac{2me^2}{\hbar^2\sqrt{r^2+z^2}}-\gamma^2r^2+2i\gamma\partial_\varphi\right)\psi=E\psi \tag{5}$$

where, $\gamma=\frac{e.H}{2\hbar c}$. The main problem in the non-relativistic study of the hydrogen atom in the external magnetic field is to solve the above Schrodinger equation and find the energy spectrum. It should be noted that variable in eq. 5 i. e. r, φ and z can not be separated directly because of the presence of Coulomb's interaction $e^2/\sqrt{r^2+z^2}$, which does not allow us to make a direct separation in variables r and z. In special case of very strong magnetic field, i. e. $B \gg B_0 = 2.4\times10^9$ Gauss, the transverse plane the Coulomb interaction of the electron with the nucleus is not important in comparison with the interaction of the electron with the external magnetic field. Arigazin [8, 9, 10] in his paper using the Coulomb approximation as given eq. 6 i.e.

$$\psi(r,\varphi,z) \approx \sqrt{\frac{\gamma}{\pi}}ze^{-\gamma r^2/2-|z|/a_0}=\sqrt{\frac{1}{2\pi R_0^2}}ze^{-\frac{r^2}{4R_0^2}-\frac{|z|}{a_0}} \tag{6}$$

shown that the associated probability density is evidently of a cylindrical (axial)symmetry and can be described as two Landau orbits of radius R_0 in different (r,φ) planes, one at the level $z=-a_0$ and the other at the level $z=+a_0$ with the nucleus at z = 0. Presence of two Landau orbits occurs in accord to the wave function (eq. 6), which equals z = 0 and is symmetrical with respect to the inversion, zero at $z \to z_0$. The electron moves simultaneously on these two orbits.

The above electron charge distribution supports the study made by Santilli [4] who proposed the polarized toroidal electron orbit in the hydrogen atom under the action of strong magnetic field, but the Coulomb approximation suggests the electron charge distribution in the form of two identical coaxial round orbits separated by relatively big vertical distance (Figure 3). Note that the size of the hydrogen atom in the z direction is predicted to be about 10 times bigger than that in the transverse plane, i. e. $R_0 = 0.53\times10^9\,\text{cm} = 0.10a_0$, the hydrogen atom is thus highly elongated in the z direction.

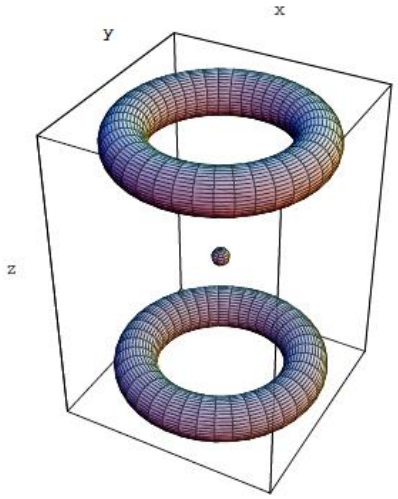

Figure 3 Schematic view on the hydrogen atom in the ground state, at very strong external magnetic field $\vec{B}=(0,0,B), B \gg 2.4\times10^9$ Gauss, due to the Coulomb approximation approach. One electron moves simultaneously on two Landau orbits of radius R_0 which are shown schematically as torii in the different (x; y) planes, one torus at the level $z=-a_0$ and the other at the level $z=+a_0$ with the nucleus at z = 0. Each torus represents the (x; y) probability distribution but with small Landau radius, $R_0 \ll a_0$. The spin of the electron is aligned anti-parallel to the magnetic field

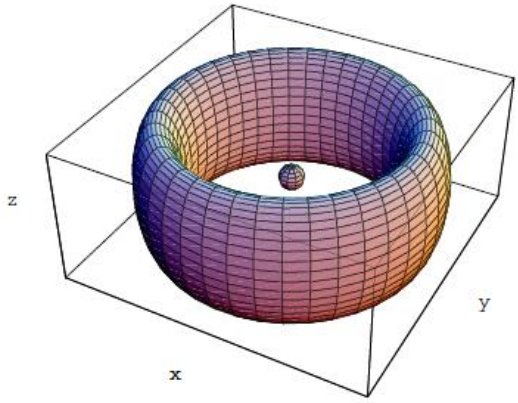

Figure 4 Schematic view on the hydrogen atom in the ground state, at very strong external magnetic field $\vec{B}=(0,0,B), B \gg 2.4\times10^9$ Gauss, due to the Modified Coulomb approximation approach. The electron moves on the Landau orbit of small radius $R_0 \approx 0.53\times10^{-8}$ cm, which is shown schematically as a torus. The vertical size of the atom is comparable to R_0. Spin of the electron is aligned anti-parallel to the magnetic field

Arigazin [8, 9, 10] pointed out that Coulomb approximation is rather a crude one. Indeed, the energy in the z-direction does not depend on the magnetic field intensity while it is obvious that it should depend on it and approximated the effective potential $C(z)$ with a better accuracy. Upon proper mathematical treatment to

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Coulomb Approximation, the modified Coulomb potential approach provides qualitatively correct behavior and much better accuracy, and suggests a single Landau-type orbit shown in Figure 4 for the ground state charge distribution of the hydrogen atom. This is in full agreement with Santilli's study [4] of the hydrogen atom in strong magnetic field. Thus, Aringazin [8, 9, 10] on the Schrodinger equation of the hydrogen atom under a strong, external, static and uniform magnetic field have confirmed the toroidal configuration of the electron orbits are crucial for the existence of the new chemical species of Magnecules, in agreement with that studied by Santilli [3].

This physical picture is at the foundation of the new chemical species of magnecules proposed by Santilli. As a result of the action of a very strong magnetic field, atoms attain a great binding energy as compared to the case of zero magnetic field.

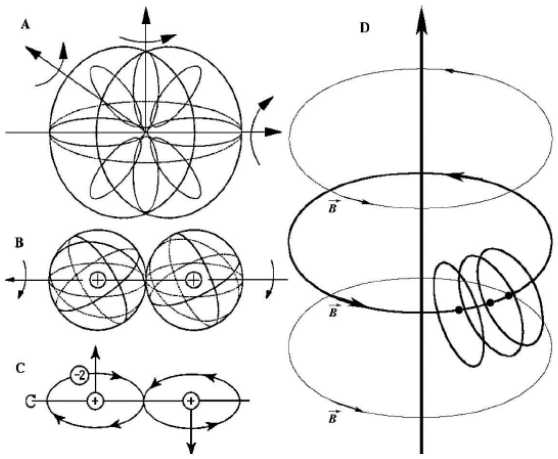

Figure 5 A schematic view of the main mechanism underlying the creation of magnecules, here illustrated for the case of the hydrogen molecule. It consists in the use of sufficiently strong external magnetic fields which can progressively eliminate all rotations, thus reducing the hydrogen molecule to a configuration which, at absolute zero degrees temperature, can be assumed to lie in a plane. The planar configuration of the electron orbits then implies the manifestation of their magnetic moment which would be otherwise absent. The r.h.s. of the above picture outlines the geometry of the magnetic field in the immediate vicinity of an electric arc as described in the text for the case of hadronic molecular reactors. Note the circular configuration of the magnetic field lines around the electric discharge, the tangential nature of the symmetry axis of the magnetic polarization of the hydrogen atoms with respect to said circular magnetic lines, and the consideration of hydrogen atoms at orbital distances from the electric arc 10^{-8} cm, resulting in extremely strong magnetic fields proportional to $(10^{-8})^{-2} = 10^{16}$ Gauss, thus being ample sufficient to create the needed polarization

4. PRODUCTION OF MAGNECULES

At its simplest, the creation of magnecules can be understood via the old method of magnetization of a para-magnetic metal by induction. Consider a paramagnetic metal which, initially, has no magnetic field. When exposed to a constant external magnetic field, the para-magnetic metal acquires a permanent magnetic field that can only be destroyed at a sufficiently high temperature varying from metal to metal and called *the Curie Temperature* [11].

The mechanism of the above magnetization is well known. In its natural unperturbed state, the peripheral atomic electrons of a para-magnetic metal have a space distribution that results in the lack of a total magnetic field. However, when exposed to an external magnetic field, the orbits of one or more unpaired electrons are polarized into a toroidal shape with end polarities opposite to those of the external field. This mechanism is called magnetic induction, and results in a stable chain of magnetically polarized orbits from the beginning of the metal to its end with polarities *North-South/North-South/North-South/*. . . . This chain of polarizations is so stable that it can only be destroyed by high temperatures.

The creation of magnecules can be essentially understood with a similar polarization of the peripheral electron orbits, with the main differences that: no total magnetic polarization is necessary; the polarization generally apply to all electrons, and not necessarily to unpaired electrons only; and the substance need not to be para-magnetic.

To illustrate these differences, consider a dia-magnetic substance, such as the hydrogen at its gaseous state at ordinary pressure and temperature. As well known, the hydrogen molecule is then a perfect sphere whose radius is equal to the diameter of a hydrogen atom, as illustrated in Fig. 5.A.

The creation of the needed magnetic polarization requires the use of external magnetic fields capable, first, to remove the rotation of the atoms, as illustrated in Fig. 5.B, and then the removal of the internal rotations of the same, resulting in a planar configuration of the orbits as illustrated in Fig. 5.C. Once the above polarization is created in two or more hydrogen molecules sufficiently near each other, they attract each other via opposite magnetic polarities, resulting in the elementary magnecules. Additional elementary magnecules can then also bond to each other, resulting in clusters with a number of constituents depending on the conditions considered. A most efficient industrial production of gas and liquid magnecules is that via the Plasma Arc Flow Reactor™, as shown in Figures 6 and 7.

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Figure 6 Picture of a 50 kW Santilli's Hadronic Reactor (Plasma Arc Flow Recycler^{TM}) mounted on a trailer for mobility to conduct test recycling where liquid wastes are located. This recycler can produce up to 84, 000 scf (up to 2.4 million liters) of magnegas per week corresponding to about 560 gasoline gallon equivalent (2,100 gasoline liter equivalent) of magnegas per week

Figure 7 Picture of a 250 kW Santilli's Hadronic Reactor (also called Plasma Arc Flow Recycler^{TM}) with the panels of its completely automatic and remote controls, to recycle liquid waste into magnegas usable for any fuel application, a large amount of heat and carbonaceous precipitates used to produce the electrodes. This Reactor can produce up to 5000, 000 scf (140 millions liters) of magnegas per week of 24 hours work per day corresponding to 3, 000 gasoline gallon equivalent (11, 000 gasoline liter equivalent) of magnegas per week computed on the basis that: 1) Gasoline contains about 110, 000 BTU/g (about 29, 000 BTU/liter); 2) Magnegas has the low energy content of 750 BTU/scf (26 BTU/liter); and 3) the "gasoline gallon equivalent" is given by about 150 scf of magnegas ("gasoline liter equivalent" is given by about 29 liters of magnegas). Plasma Arc Flow Recycler^{TM} are completely self-contained. Consequently, they release no solid, liquid or gas to the environment and cause no noise or odor pollution

The reason for these results is the intrinsic geometry of the Plasma Arc Flow^{TM} itself. Recall that this technology deals with a DC electric arc submerged within a liquid waste to be recycled. The arc decomposes the molecules of the liquid into its atomic constituents; ionizes the same; and creates a plasma of mostly ionized H, C and O atoms at about $3{,}500^0$ K.

5. APPLICATIONS OF MAGNECULES

Some of the important properties of magnecules include: increased energy density; increased energy output under thermo-chemical reactions; increased adhesion with other substances; increased penetration within other substances; and other properties which are new when compared to corresponding properties of the conventional molecules constituting magnecules and any of their combination. Consequently, the new chemical species of magnecules has new industrial and consumer applications, advancement in this arena discussed brief in the section.

5.1 MagneGas

In 2001, Santilli released monograph [1] in which the first industrial realization of the new species of magnecules consisting of the gaseous fuel produced and sold worldwide under the trade name of MagneGas (MG) by the U. S. publicly traded company Magnegas Corporation (see www.magnegas.com for details) was provided in detail. Plasma Arc Flow reactor use a submerged DC arc to achieve complete recycling of liquid waste into a clean burning combustible gas called MG, heat usable via exchangers, solid precipitates.

Figure 8 A picture of a Ferrari 308 GTSi 1980 and two Honda Civic cars converted by the author to operate with the new clean burning magnegas without catalytic converter, yet surpassing all EPA exhaust requirements, having no carcinogenic or other toxic substance in the exhaust, reducing of about 50% the CO_2 emission due to gasoline combustion, reducing the operating temperature of about 25%, and emitting in the exhaust 10% to 14% breathable oxygen

Such kind of highly efficient and cost effective flow reactor was suitable to recycle antifreeze waste, oil waste, sewage and other contaminated liquids [12].

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The first application of MG is its use as a new clean fuel for automobile (see Figure 8). When exhaust of MG was tested, interestingly it surpasses all EPA requirement even without catalytic convertor, emits no carcinogenic, CO or other toxic chemicals, reduced carbon dioxide emission due to combustion of gasoline by about 40 %, and emits 14-20 % breathable oxygen (see Figure 9).

In the same monograph, the second very important application of MG depicted was in the metal cutting industry, wherein it was found that MG cuts the metal much smoother, without edges and at least 50% faster than conventional acetylene (See Figure 10). Independent certifications by various users have established that:

1. magnegas has a pre-heat time at least half that by acetylene (which is currently used for metal cutting and has an energy content of 2,300 BTU/cf);
2. magnegas cuts metal at least 50% faster than acetylene;
3. the cut produced by magnegas is much smoother without edges as compared to that by acetylene;
4. magnegas exhaust does not contain carcinogenic or other toxic substances, while that of acetylene is perhaps the most carcinogenic and toxic of all fuels;

Figure 9 A picture of the readings of a 4-ways exhaust analyzer testing the exhaust of the Ferrari 308 GTSi of a preceding picture operating on magnegas "without" catalytic converter. Note: the presence of 14% breathable oxygen in the exhaust; about half the CO_2 produced by the same car when running on gasoline; the very few detected hydrocarbons originate from engine oil seeping through the piston rings because magnegas cannot contain hydrocarbons since it is synthesized at the 5, 000^0 C of the arc at which temperature no hydrocarbon can survive; the very small content of CO in the exhaust is due to poor combustion because CO is fuel for magnegas, while it is a byproduct of the combustion for fossil fuels, as a result of which detecting CO in the exhaust of a car running on magnegas is the same as detecting gasoline in the exhaust of a car running on gasoline

5. magnegas is dramatically safer than acetylene, which is unstable and one of the most dangerous fuels currently used; and
6. magnegas cost about half that of acetylene.

Carbon dioxide (CO_2) is the primary greenhouse gas emitted through human activities. In 2012, CO_2 accounted for about 82% of all U. S. greenhouse gas emissions from human activities. Carbon dioxide is naturally present in the atmosphere as part of the Earth's carbon cycle (the natural circulation of carbon among the atmosphere, oceans, soil, plants, and animals).

Human activities are altering the carbon cycle both by adding more CO_2 to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere. While CO_2 emissions come from a variety of natural sources, human-related emissions are responsible for the increase that has occurred in the atmosphere since the industrial revolution. The main human activity that emits CO_2 is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit CO_2.

Figure 10 Applications of Magnegas for welding and cutting purpose. Independent certifications by various users have established that: 1) magnegas has a pre-heat time at least half that by acetylene (which is currently used for metal cutting and has an energy content of 2,300 BTU/cf); 2) magnegas cuts metal at least 50% faster than acetylene; 3) the cut produced by magnegas is much smoother without edges as compared to that by acetylene; 4) magnegas exhaust does not contain carcinogenic or other toxic substances, while that of acetylene is perhaps the most carcinogenic and toxic of all fuels; 5) magnegas cutting does not produce the \ash-back" (local explosion of paint over metal) typical of acetylene; 6) magnegas is dramatically safer than acetylene, which is unstable and one of the most dangerous fuels currently used; and 7) magnegas cost about half that of acetylene

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The main sources of CO_2 emissions in the United States are described below.

- Electricity. Electricity is a significant source of energy in the United States and is used to power homes, business, and industry. The combustion of fossil fuels to generate electricity is the largest single source of CO_2 emissions in the nation, accounting for about 38% of total U.S. CO_2 emissions and 31% of total U.S. greenhouse gas emissions in 2012. The type of fossil fuel used to generate electricity will emit different amounts of CO_2. To produce a given amount of electricity, burning coal will produce more CO_2 than oil or natural gas.

- Transportation. The combustion of fossil fuels such as gasoline and diesel to transport people and goods is the second largest source of CO_2 emissions, accounting for about 32% of total U.S. CO_2 emissions and 27% of total U.S. greenhouse gas emissions in 2012. This category includes transportation sources such as highway vehicles, air travel, marine transportation, and rail.

- Industry. Many industrial processes emit CO_2 through fossil fuel combustion. Several processes also produce CO_2 emissions through chemical reactions that do not involve combustion, for example, the production and consumption of mineral products such as cement, the production of metals such as iron and steel, and the production of chemicals. Fossil fuel combustion from various industrial processes accounted for about 14% of total U.S. CO_2 emissions and 12% of total U.S. greenhouse gas emissions in 2012. Note that many industrial processes also use electricity and therefore indirectly cause the emissions from the electricity production.

Carbon dioxide is constantly being exchanged among the atmosphere, ocean, and land surface as it is both produced and absorbed by many microorganisms, plants, and animals. However, emissions and removal of CO_2 by these natural processes tend to balance. Since the Industrial Revolution began around 1750, human activities have contributed substantially to climate change by adding CO_2 and other heat-trapping gases to the atmosphere. The most effective way to reduce carbon dioxide (CO_2) emissions is to reduce fossil fuel consumption. Many strategies for reducing CO_2 emissions from energy are cross-cutting and apply to homes, businesses, industry, and transportation. Also, it has been reported that magnegas mixed with coal, and other fossil fuels such as gasoline, diesel, etc. reduced the CO_2 emissions as well as other toxic gases emission and thus can be used in future for large scale energy formation (see Figure 11 and Figure 12).

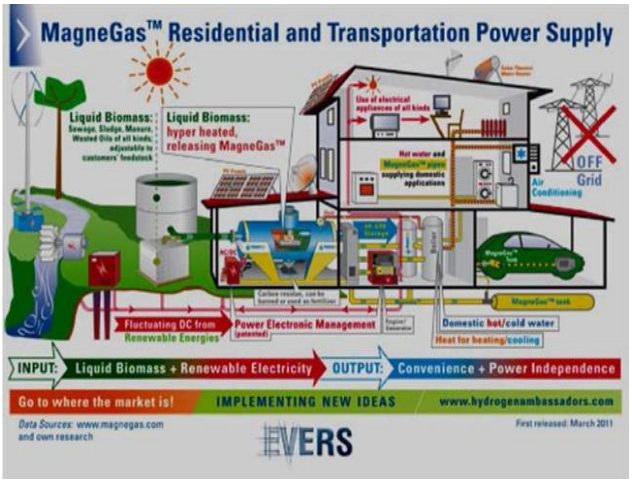

Figure 11 Future Scope I: *Applications* of Magnegas for residential, transportation and industrial power supply purpose

Figure 12 Future Scope II: Applications of Magnegas in Power Plant as future scope

5.2 MagneHydrogen™

In a paper from 2003, Santilli [2] presented theoretical and experimental evidence on the existence of a new species of Hydrogen .i. e. he called MagneHydrogen™ (See Figure 13). It was found that the prepared gas apparently consists of 99% Hydrogen, although spectroscopically its speci_c weight (or, equivalently, molecular weight) was estimated to be 7.47 times larger than that of conventional Hydrogen. This new species of MH is that originally presented by Santilli in Ref. [3], namely, a multiple of the specific weight under a high Hydrogen percentage is evidence of a new clustering of H-atoms which cannot possibly be of valence type due to the evident absence of the valence electrons necessary for a quantitative representation of the clustering of many different atoms. For the generation of MH, Santilli first developed the Plasma Arc Flow Reactor™ for the conversion of various liquids into a combustible gaseous fuel known as MagneGas™ (MG). The gasification is achieved via a submerged DC electric arc between carbon electrodes that, under sufficient powers (of the order of 300 kW or more) is capable of producing at atomic distances the high values of the magnetic field necessary for the polarization of electron

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orbitals into toroids (estimated as being of the order of 10^{12} Gauss. Santilli obtained the new species MH via the use of conventional Pressure Swing Adsorption (PSA) equipment for the separation of Hydrogen from MG. The purity and increased specific weight of MH depends on various factors, including the selected zeolites, the operating pressure, etc. [4].

From an industrial point of view, it is very important to be noted that, it is sufficient to achieve a species of MH with at least 3.3 the specific weight of hydrogen to have the same energy content of 1000 BTU/scf of Natural Gas (NG). In fact, under said conditions, MH would avoid the current needs to liquefy Hydrogen in order to achieve a sufficient range, since MH can be compressed like NG. Additionally, the magnecular structure of MH avoids the traditional seepage of Hydrogen through the walls, thus allowing long term storage that is currently prohibited by molecular Hydrogen due to current environmental laws. Above all, this particular type of MH has resulted to be cost competitive with respect to fossil fuels, of course, when produced in sufficiently large volumes.

1. the use of hydrogen rich wastes as liquid feedstock, such as city and farm sewage, antifreeze and or oil waste, etc., which implies an income, rather than a cost;
2. the possible utilization of steam at 400 produced by the cooling of the highly energetic processes of the reactors, which steam can be used for other income producing applications, such as desalting seawater via evaporation, production of electricity via turbines, heating of buildings, and other income producing uses; and
3. the unusually high efficiency of Santilli Hadronic Reactors of molecular types used for the process which brings the cost of electricity down to 0.005/scf.

5.3 HHO Gas: Aquygen™

Santilli then provided in Ref. [13] of 2006 theoretical experimental evidence on a third industrial application of the new species of magnecules i. e. HHO gas (see Figure 14), here referred to the gas commercially produced via certain electrolyzers (see Figure 15) and essentially consisting of 2/3 Hydrogen and 1/3 Oxygen, which contains a small percentage of H and O magnecular clusters. Under these conditions, Santilli suggested in Ref. [6] the name of HHO (although a similar gas produced via a different electrolyzer is known as Brown's gas). The new HHO gas is regularly produced via a new type of electrolyzer and has resulted to be distinctly different in chemical composition than the Brown gas, even though both gases share a number of common features. American company Hydrogen Technology Applications™, Inc. (HTA), which company is the owner of all intellectual rights and is currently producing and selling the HHO gas on a world wide basis under the commercial name of Aquygen™ gas.

A important feature is that the HHO gas does not require oxygen for combustion since the gas contains in its interior all oxygen needed. feature suggests that the gas here considered does not possess a conventional molecular structure, namely, a structure in which the bond is of entire valence type.

Another feature of the gas is its anomalous adhesion (adsorption) to gases, liquids and solids, as verified experimentally below, thus rendering its use particularly effective as an additive to improve the environmental quality of other fuels, or other applications.

This feature is manifestly impossible for conventional gases such as hydrogen and oxygen, thus confirming again a novel chemical structure.

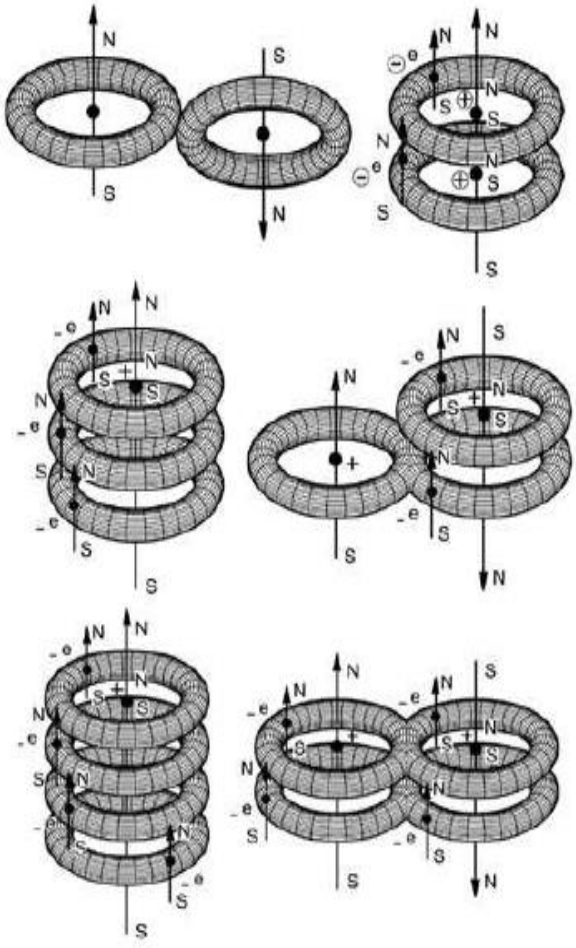

Figure 13 A conceptual rendering of the cluster MH_2 in MH which is predicted as being composed by part of the molecular species H - H (Top, Left) and part by the magnecular species H × H (Top, Right); A conceptual rendering of the cluster MH_3 in MH which is predicted as being composed by magnecular species H × H × H (Middle, Left) and H - H × H (Middle, Right); A conceptual rendering of the cluster MH_4 in MH which is predicted as being composed by the magnecular species H × H × H × H (Bottom, Left) and H - H × H - H (Bottom, Right)

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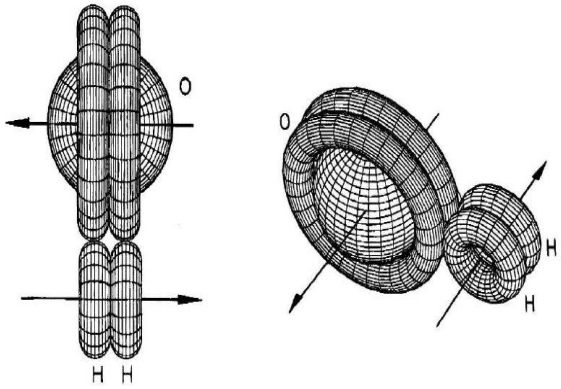

Figure 14 HHO Gas

Figure 15 The Model 1500 Aquygen Gas Generator runs on water and electricity only. It produces a stable hybrid hydrogen-oxygen gas, with many unique properties. The generator provides a superior gas for most conventional brazing, soldering and metal cutting operations. Gas Generator can be used in many exotic cutting, brazing, and fusing applications as well as glass treatment and blowing applications that cannot be performed by conventional methods and processes

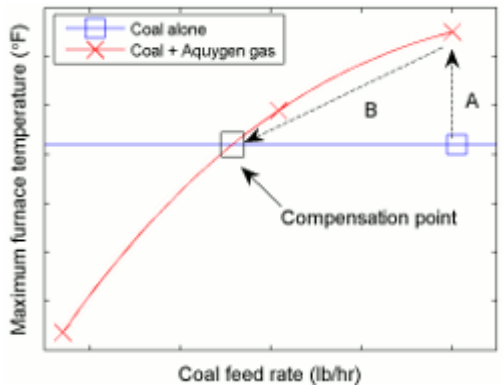

Figure 16 Aquygen^{TM} gas has been shown to increase combustion efficiency in coal-fired furnaces leading to a dramatic decrease in fuel consumption and significant reduction in emissions. It can be seen that there is increase in furnace temperature upon the introduction of Aquygen^{TM} gas (A) and the ability to obtain the same furnace temperature with a decreased coal feed rate (B)

Another important feature of this gas is that it does not follow the *PVT* of gases with conventional molecular structure, since the gas reacquires the liquid water state at a pressure of the order of 150 psi, while conventional gases acquire the liquid state a dramatically bigger pressures. This

Aquygen^{TM} gas supplements standard vehicle fuels such as gasoline and diesel, increasing BTUs while decreasing emissions. Aquygen^{TM} gas can also replace conventional soldering, brazing and cutting gases for use with standard equipment and techniques while producing superior results at less cost with no oxidation, no burn back, and minimal slag and, Aquygen^{TM} gas gives off no toxic fumes. Aquygen^{TM} gas has been shown to increase combustion efficiency in coal-fired furnaces leading to a dramatic decrease in fuel consumption and significant reduction in emissions, including CO_2, CO, NOx, SOx, and fly ash. Preliminary testing carried out at Western Research Institute (WRI), the leading energy research entity located in the number-one coal-producing state in the nation which has earned a name for reliable emissions testing and monitoring at power plants, showed an increase in furnace temperature upon the introduction of Aquygen^{TM} gas (A) and the ability to obtain the same furnace temperature with a decreased coal feed rate (B) which is as shown in Figure 16.

Some of the major benefits of HTAs Aquygen^{TM} Gas Enhanced Coal Combustion Process include:

1. Significant Reductions in NOx, CO, CO_2, and SO_2.
2. Increased combustion efficiency fuel savings.
3. Meets “Clean Coal Technology” requirements.
4. Reduces coal plant y ash and associated disposal costs.
5. Reduces overall emissions and produces significant revenue from the generation of carbon credits.

6. RECENT EXPERIMENTAL CONFIRMATIONS OF MAGNECULAR STRUCTURE

Yang *et al.* recently published important research papers in which the experimental confirmation of new chemical species of MagneHydrogen^{TM} has been reported (see Figure 17-19) [7, 14, 15]. The first independent experimental verification of the new species of Santilli MagneHydrogen^{TM} was achieved via the use of a VSA station for the separation of MH from MG, the use of a GC-TCD for the measurement of the percentage of Hydrogen in the separated gas, and the use of conventional methods for the measurement of molecular weight. Experimentally it was confirmed that MH posses about 97.5 % pure Hydrogen, while having 3.89 times the specific weight of H_2, and a consequential energy content of 1167 BTU/scf.

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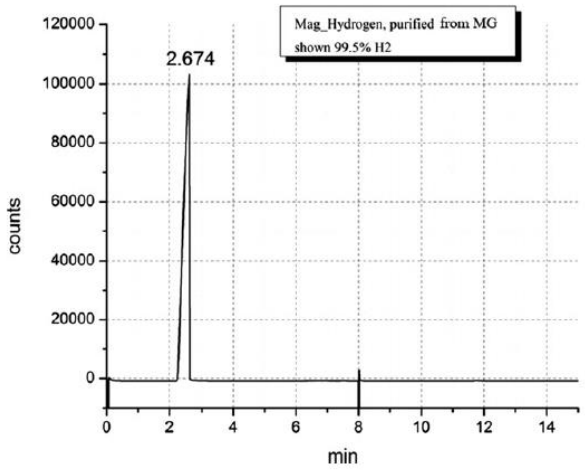

Figure 17 A scan of MagneHydrogen via the GC-TCD of Ref. [7] showing no appreciable difference of MH with pure hydrogen

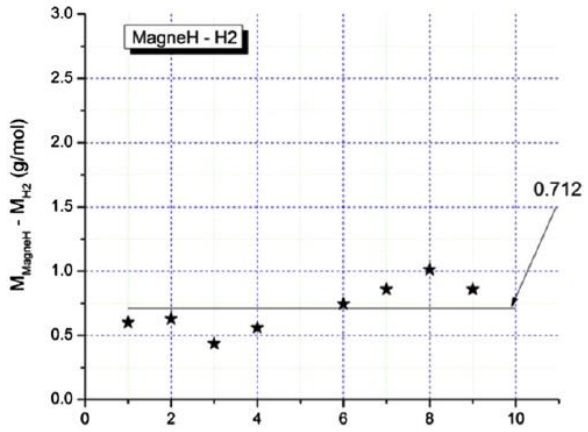

Figure 18 Statistical measurements on the molecular weight of MH with respect to that of H_4, which is represented by the abscissa, showing that the former is about 35% heavier than the latter, namely, the anomaly is about ten times the statistical error [14]

The second experimental verification of Santilli Magne-Hydrogen was achieved using a Vacuum Swing Adsorption (VSA) for the separation of MH from MG, and GC-TCD for the measurement of the conventional Hydrogen content, and a highly accurate balance for the measurement of the molecular weight of MH. It was established that the above identified species has the molecular weight of 2.71 a.m.u., thus being 35% heavier than conventional Hydrogen [7, 14, 15].

The theoretical confirmation of MagneHydrogen™ consisting individual hydrogen atom bonded together and having stable clusters under a new internal attractive forces originating from the toroidal polarization of orbitals of atomic electrons when placed in strong magnetic fields has been done by Zodape, *et al.* [16, 17] and Pandhurnekar [18, 19] recently.

The additional experimental confirmations of the new species of Santilli magnecules as presented in the original memoir [3] of 1998 has been recently published by Yang *et al.* Out of a large variety of tests with different magnecular gases, different equipment and different procedures, different main results on the basic of their studies are summarized as follows [7, 14]:

1. Magnecules consists of weakly bonded individual atoms, dimers, and conventional molecules;
2. Magnecules are stable at ambient temperature;
3. Magnecules progressive reduced with the increase of the temperature;
4. Termination of magnecular structure at a suitable Curie temperature;
5. Magnecules shows anomalous adhesion to disparate materials;
6. Anomalous mutation of magneculer clusters in time and under different detection procedures or equipment;
7. Anomalous accretion of magnecular clusters by individual atoms; and other features, etc.

7. CONCLUDING REMARKS

The theoretical and experimental evidence presented confirms Santilli's view that the chemical species of molecules, defined as stable clusters of atoms under a valance bond, does not exhaust all possible chemical species existing in nature. This conclusion is proved beyond scientific doubt, for instance, by macroscopic percentage of stable clusters, with atomic weight of several hundreds a.m.u., in light gases without an infrared signature where heaviest possible detected molecule is the CO_2 with 44 a.m.u.; the mutation of transparent oils into completely opaque substance without fluidity and other evidence provided by various scientists as well. Fuels synthesized under intense electric and magnetic fields can indeed release energy in amounts much bigger than those predicted by conventional chemical reactions. It is undeniable that the experimental confirmations of MGF exemplify a revolution in the sector of sustainable, efficient, clean fuels and over-unity power sources that do not emit harmful toxins or radioactive waste. These intriguing discoveries and experimental realizations have a significant degree of application potential in the industrial and technological sectors and, if properly implemented, may have a profoundly beneficial impact. Since, in addition, the new fuels can be produced everywhere, and have environmentally acceptable exhausts, magnegases offer serious possibilities to satisfy our ever increasing energy needs, as well as to contain the alarming environmental problems caused by fossil fuels.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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My sincere thanks to the theoretical physicist, Prof. R. M. Santilli who discovered new numbers, and then to the

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construction of new mathematics based on them. Thanks to the great scientist of this century for introducing our world with much cleaner fuel consisting entirely new kind of bondings of strong magnetic type i.e. Fuels with magnecular structure. I am also grateful to Santilli Foundation, Palm Harbor, Florida, USA and Mrs. Carla Santilli for financial support. Additional thanks are due to Dr. A. A. Bhalekar, Emeritus Professor, R. T. M. Nagpur University, Nagpur, India for initiating me to work in the field of Hadronic Chemistry and stimulating discussions for the better maturity of the paper. I would like to thanks all Indian participants of International Conference of Numerical Analysis and Applied Mathematics 2014 (ICNAAM 2014 conference) at Rhodes, Greece for helpful discussions especially Dr. S. S. Dhondge, Dr. V. M. Tangde and Dr. S. Zodape.

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