

Magnegas - An Alternative Technology for Clean Energy

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Abstract: In the process of Hydraulic fracturing millions of gallons of water, sand and chemicals are pumped underground to break apart the rock to release the gas. In Hydraulic fracturing certain fluids and materials are used to create small fractures in order to stimulate production from new and existing oil and gas wells. This creates paths that increase the rate at which fluids can be produced from the reservoir formations, in some cases by many hundreds of percent. Although it helped in triggering this year almost 42% of decline in crude prices, on the other hand the completion of drilling process leaves behind pits with waste of the overall process. As the sludge or waste of the process is water based liquid with chemicals and hydrocarbon oil remains of the mineral stock, it is a potentially hazardous material for environment. In this view the Plasma Arc Flow Technique to convert this liquid waste into useful MAGNEGASTM (MG) proposed by Professor Ruggero Maria Santilli is much beneficial in reducing the oil waste as well as in minimizing the environmental problems. In the present paper, origin of the concept of a new Magnecular Fuel via Hadronic Chemistry, its composition, technique, characterization and its applications in the diversified Industries are discussed.

Keywords: Magnecules, Hadronic Chemistry, Plasma Arc Flow Technique

1. Introduction

The majority of the current energy requirement of the mankind has been fulfilled by the conventional source of energy i.e. molecular combustion of fossil fuels, hydrogen or nuclear fission, etc. However, combustion of fossil fuel generates large amount of green house gas like CO₂ and hydrogen combustion depletes atmospheric O₂ by forming H₂O. Also, most of the environmental pollution caused by fossil fuel is due to chunks of un-combusted fuel that may be carcinogenic primarily because consisting of incomplete combustion of fuel. Gaseous fuels like CNG and LPG are comparatively supposed to be cleaner fuels than those of solid fossil fuels. But, majority of the Natural gas wells in United States use Hydraulic Fracturing where millions of gallons of water, sand and chemicals are pumped underground to break apart the rock and release the gas. Fracking and horizontal drilling in which wells are bored sideways through petroleum deposits have revived U.S. oil and gas output, helping to trigger this year's 42 percent decline in crude prices.

The hydraulic fracturing market is estimated to grow from

\$41,546.9 million in 2014 to nearly \$72,629.4 million by 2019, at a CAGR of over 11.8% [1]. Hydraulic fracturing is used after the drilled hole is completed. Hydraulic fracturing is the use of fluid and material to create small fractures in a rock formation in order to stimulate production from new and existing oil and gas wells. This creates paths that increase the rate at which fluids can be produced from the reservoir formations, in some cases by many hundreds of percent. Water and sand make up 98 to 99.5 percent of the fluid used in hydraulic fracturing. In addition, chemical additives are used. The exact formulation varies depending on the well. Acid, corrosion inhibitors, biocides and many other chemicals are used to satisfy different purposes [2]. Use of biocides [3] and other toxic chemicals is raising serious concern as the sludge waste extracted from the process is posing environmental risks [4]. Scientists are worried that the chemicals used in fracturing may pose a threat either underground or when waste fluids are handled and sometimes spilled on the surface. The completion of drilling process leaves behind pits with waste of the overall process. US EPA defines a "sump" as an open pit or excavation that receives fluids such as mud, hydrocarbons, or

waste waters from oil and gas drilling and producing operations. These sumps are storing the waste generated from oil drilling process including hydraulic fracturing techniques. As the sludge or waste of the process is water based liquid with chemicals and hydrocarbon oil remains of the mineral stock, it is a potentially hazardous material for environment. As it contains the biocides and other toxic chemicals, there is a little chance of its biodegradation or bio consumption. Further, it can percolate to nearby farms and water bodies causing health issues.

Therefore, looking at the necessity and the current day demand, some new source of clean energy is required, that must be cheaper and abundant. The fuels developed should be such that can be used in existing engines without any or major modifications. These requirements have been fulfilled by changing the approach of conventional hydrocarbon fuel (in which the energy is obtained by breaking the valence bond by the process of molecular combustion) to a novel Magnecular fuel [5-8] having bonds of magnetic origin (in which one does not need significant amount of energy to break the magnecular bond and hence comparatively larger energy output can be gained without breaking of covalent bonds. The origin of this new magnecular fuel lies in the first ever concept of *Santilli's Isoelectronium* [9-12] as described in the historical papers based on Hadronic Chemistry containing the isochemical models of Hydrogen and Water molecules [12, 13]. Therefore, in section 2, first, a brief description of Hadronic Chemistry, its need and its covering over conventional quantum chemistry is described. Then in section 3, a detailed description of the Magnecules, its types, classification, characteristics, technology and mechanism of Magnegas production is given. Followed by, in subsection 3.1, the spectroscopic verification of the new fuel of magnecular origin is justified. Then in subsection 3.2, various applications of magnecular fuel have been elaborated. Subsection 3.3 contains the description of superiority of magnecular combustion over a molecular combustion whereas, in subsection 3.4 the use of magnegas as an additive to the conventional coal based combustion process for improved efficiency is described. Finally, in subsection 3.5, the use of Plasma Arc Flow technique in the synthesis of Magnegas from waste of Hydraulic Fracturing process is described.

2. Hadronic Chemistry

The Hadronic Chemistry is a covering of quantum chemistry where we study the addition of the effects in the electronic overlap as shown in figure 1 solely valid at distances of the order of 1fm (only) [5, 9] (see also review [14-17] and short communications [18-20]) those are assumed to be Nonlinear - dependence of operators on powers of the wave functions greater than one, Nonlocal - dependence on integrals over the volume of wave-overlapping that, as such, cannot be reduced to a finite set of isolated points, Nonpotential - consisting of contact interactions caused by the actual physical contact of wavepackets at 1fm mutual distance with consequential zero range, for which the notion

of potential energy has no mathematical or physical meaning, Non-Hamiltonian - lack of complete representability of systems via a Hamiltonian, thus requiring additional terms and, consequently, Non-Unitary - the time evolution violating the unitary condition $U \times U^\dagger = U^\dagger \times U = I$. It is named after a fundamental particle 'Hadron'. Therefore, the foundations of Hadronic Chemistry is the origin of New Magnecular Fuel called Magnecules (Magnegas) [5-8].

Santilli applied the mathematical structure of hadronic mechanics to chemical systems thereby achieving results amenable to exact representation of molecular data, precise experimental verifications and novel industrial applications.

In fact, in path breaking papers [12] and [13], Santilli and Shillady have achieved new models for the structure of Hydrogen and water molecules which, apparently for the first time,

1. exhibited a basically new, strongly attractive, non-Coulomb force among pairs of valence electrons in singlet coupling
2. explained, why these molecules have only two Hydrogen atoms,
3. achieved an exact representation of binding energy from unadulterated first axiomatic principle,
4. achieved a representation of the electric and magnetic dipoles of the water molecule which is accurate both in numerical values as well as in the sign, and
5. proved the reduction of computer time by at least a factor of 1000 folds.

For detailed historical and technical descriptions on hadronic chemistry, the reader is advised to study monograph [5] and original papers quoted therein.

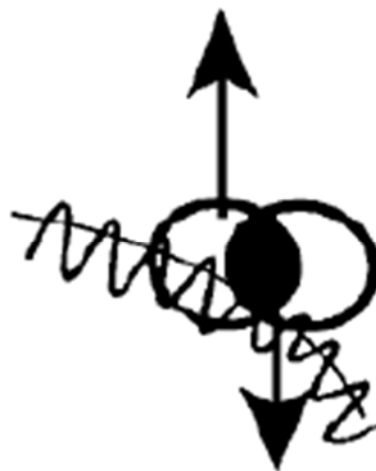


Figure 1. A schematic view of the the deep overlapping of the wavepackets of valence electrons in singlet coupling resulting in conditions which are known to be non-linear, non-local, and non-potential (due to the zero-range, contact character of the interactions), thus not being representable via a Hamiltonian (non-Hamiltonian structure). As a result, the ultimate nature of valence bonds is outside any representational capability of quantum chemistry. Santilli has build hadronic chemistry for the specific scope of representing the conditions herein considered of the bonding of valence electrons (see the monograph *Hadronic Mathematics, Mechanics and Chemistry Volume V* [5]).

The first breakthrough was the proposal of an isochemical model of Hydrogen molecule through the concept of a singlet

quasiparticle state of two valence electrons at a short distance of say 1fm. The assumption was that, pairs of valence electrons from two different atoms bound themselves at short distances into a singlet (mostly, but not totally stable) quasi-particle state called an isoelectronium shown in figure 2, which describes an oo-shaped orbit around the respective two nuclei. The oo-orbital is suggested as shown in figure 2 to represent the diamagnetic character of the H-H molecule, thus being in agreement with experimental verifications.

Note that, once two valence electrons are bonded into the isoelectronium, there is no possibility for bonding additional valence electrons, that explains why Hydrogen (or water) molecule admits only two Hydrogen atoms.

Using the isomathematical lifting of the conventional Schrödinger wave equation Santilli and Shillady have shown for the first time in the history of chemistry the mathematical evidence of the existence of an attractive forces among two neutral atoms of hydrogen molecule and achieved the theoretical representation of strong valence bond namely a valence coupling between two identical electrons in singlet coupling with a strongly attractive force.

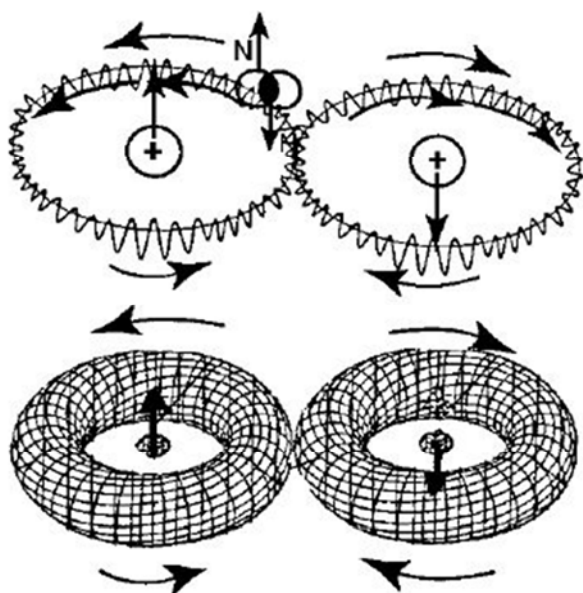


Figure 2. A view of isochemical model of the Hydrogen molecule at absolute zero degree temperature without any rotational degrees of freedom, with the Santilli-Shillady strong valence bond between the valence electrons pair into isoelectronium quasi-particle. Note the oo-shape orbital of the isoelectronium, thus allowing a representation of the diamagnetic character of the H-molecule since, under an external strong magnetic field, the two H atoms acquire parallel but opposite magnetic polarities with null value of the total magnetic field at sufficient distances.

Subsequent to the successful study of the isochemical molecular model of isoelectronium for Hydrogen molecules in the historical paper of (1999) [12], Santilli and Shillady proposed their second historical study [13] of hadronic chemistry for the water molecule resulting from the first axiomatic unadulterated principles of binding energy, sign and values of electric and magnetic moments and other data [13].

That constituted the first model of the water molecule as shown in figure 3, admitting the exact analytic solution from

first principle in scientific history. This model exhibits a new explicitly attractive “strong” force among the atoms of the H-O diatomic radical, which is absent in conventional quantum chemistry. The equation obtained after isolifting, also explains the reason why the water molecule admits only two H-atoms. The model yields much faster convergence of series with much reduced computer times and resolves many other insufficiencies of quantum theory. Finally, the model is evidently extendable with simple adjustments to an exact solution of other dimers involving the Hydrogen, such as H-C.

Independent studies of variational calculations of isochemical models of Hydrogen and Water molecules of Santilli and Shillady in 1999 and 2000 were carried out by,

1. Aringazin and Kucherenko in their paper on Exact solution of the restricted three-body Santilli-Shillady model of H₂ molecule [23] studied the exact analytical solution of the restricted isochemical model of H₂ molecule with fixed nuclei proposed by Santilli and Shillady.
2. Aringazin independently in his paper on variational solution of the four-body Santilli-Shillady model of H₂ molecule [24] using Ritz variational approach to the four-body isochemical model of H₂ molecule suggested by Santilli and Shillady, without restriction that the isoelectronium is stable and point-like particle, the ground state energy and bond length of the H₂ molecule is calculated.
3. Pérez-Enriquez, Marn and Riera in their paper on Exact Solution of the Three-Body Santilli-Shillady Model of the Hydrogen Molecule [25] suggested new approach to the 3-body Santilli-Shillady model of the hydrogen molecule by proposing the argument that the isoelectronium follows restricted motion namely, The formation of the quasi-particle from the two electrons involves an effective mass transformation (iso-renormalization) and secondly, the isoelectronium must orbit in a spheroidal shaped region of space (isoelectronium is restricted to defined region of space).

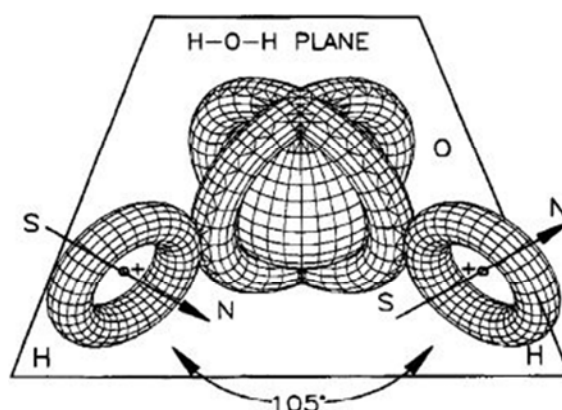


Figure 3. A view of a water molecule H₂O at absolute zero degrees of temperature without any rotational degrees of freedom, showing the H-O-H plane, the angle 104.5° between the H-O and O-H dimers and, above all, the natural occurrence according to which the orbital of the H atoms are not spherical, but of toroidal character for their coupling with Oxygen, thus providing direct verification of the isochemical model of the Hydrogen molecule of Figure 2.

3. The New Chemical Species of Santilli Magnecules

Current energy requirement of mankind has been fulfilled by the conventional source of energy i.e. molecular combustion of fossil fuels, hydrogen or nuclear fission. However, combustion of fossil fuel generates large amount of green house gas like CO₂ and hydrogen combustion depletes atmospheric O₂ by forming H₂O. Also, most of the environmental pollution caused by fossil fuel is due to chunks of un-combusted fuel that may be carcinogenic primarily because consisting of incomplete combustion of fuel. Therefore the current day demand is clean energy source that is cheap and abundant.

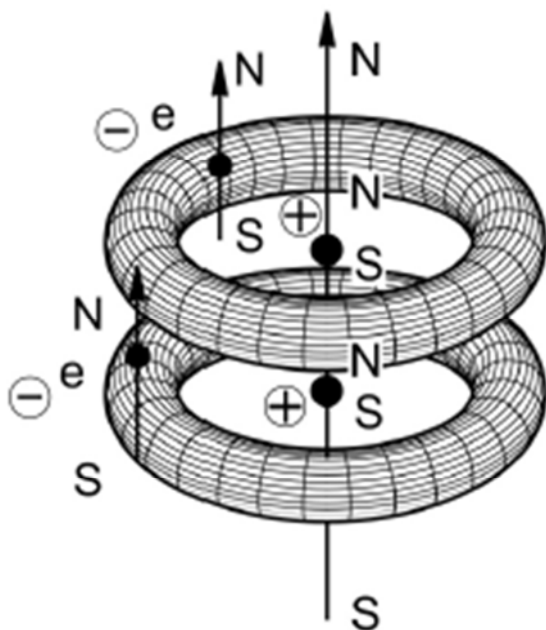


Figure 4. A schematic view of the simplest possible di-atomic magnecule whose bond originates from opposing magnetic polarities of toroidal polarizations of the orbits of peripheral atomic electrons caused by very strong external magnetic fields whose bond is NOT that of valence.

The fuels developed should be such that can be used in existing engines without any or major modifications. This requirement has been fulfilled by changing the approach from quantum mechanics to hadronic mechanics to hadronic chemistry. Italian-American physicist Professor R. M. Santilli [5-10] in 1998 for the first time proposed a new novel fuel characterized by hadronic mechanics/chemistry known as MAGNECULES [5-8].

Magnecules shown in figure 4, are novel chemical species having at least one magnecular bond. Principle of synthesis of magnecules is similar to the magnetization of a ferromagnet where the orbits of unbounded electrons are polarized. The atoms are held together by magnetic fields originating due to toroidal polarization of the atomic electron orbits. Rotation of the electrons within the toroid creates magnetic field which is absent for the same atom with conventional spherical distribution of electron orbitals. When two such polarized

atoms are sufficiently close to each other and in north-south north-south alignment, the resulting total force between the two atoms is attractive. The polarization is brought about by high magnetic field which is obtained as in the case of high voltage DC arc as shown in left side figure 5. Thus, Santilli Magnecules in gases, liquids, and solids consist of stable clusters composed of conventional molecules, and/or individual atoms bonded together by opposing magnetic polarities of toroidal polarizations of the orbits of at least the peripheral atomic electrons when exposed to sufficiently strong external magnetic fields, as well as the polarization of intrinsic magnetic moments of nuclei and electrons as shown on right side of figure 5. A population of magnecules constitutes a chemical species when essentially pure, i.e., when molecules or other species are contained in very small percentages in a directly identifiable form.

Magnecules are called-

1. Elementary- when composed only of two molecules, e.g.: $\{H-H\} \times \{H-H\}$; and so on where '-' denotes conventional valence bond and 'x' denotes magnecular bond
2. Magneplexes- when entirely composed of several identical molecules e.g.: $\{H-O-H\} \times \{H-O-H\} \times \{H-O-H\} \times \{H-O-H\} \times \dots$; and so on
3. Magnecusters- when composed of several different molecules e.g.: $\{H-H\} \times \{C-O\} \times \{O-C-O\} \times \{C=O\} \times \{H-H\} \times \dots$; and so on

Magnecules are also classified as-

1. Isomagnecules- when having all single-valued characteristics and being reversible in time, namely, when they are characterized by isochemistry,
2. Genomagnecules- when having all single-valued characteristics and being irreversible in time, namely, when they are characterized by genochemistry; and
3. 1q¹Hypermagnecules- when having at least one multi-valued characteristic and being irreversible in time, namely, when they are characterized by hyperchemistry.

Santilli magnecules are characterized by following characteristics, namely:

1. Large atomic weights which are ten times or more than the conventional molecules.
2. Large peaks in macroscopic percentages in mass spectra, which do not belong to conventional molecules.
3. These peaks show same infra-red and ultra-violet signature as expected from the conventional molecules and/or radicals constituting the magnecule.
4. Said infrared and ultraviolet signatures are generally altered with respect to the conventional versions.
5. Magnecules have an anomalous adhesion to other substances.
6. They can break down into fragments under high energetic collisions, with subsequent recombination with other fragments and/or conventional molecules.
7. They can build up or lose individual atoms, radicals or

molecules during collision.

8. They have an anomalous penetration through other substances indicating a reduction of the average size of conventional molecules as expected under magnetic polarizations.
9. Gas magnecules show an anomalous solubility in liquids due to new magnetic bonds between gas and liquid molecules caused by magnetic induction.
10. Magnecules can be formed by molecules of immiscible

liquids.

11. A gas with magnecular structure does not follow the perfect gas law.
12. Substances with magnecular structure have anomalous physical characteristics, as compared to the conventional molecules.
13. Magnecules release more energy in thermochemical reactions than that released by the same reactions among unpolarized molecular constituents.

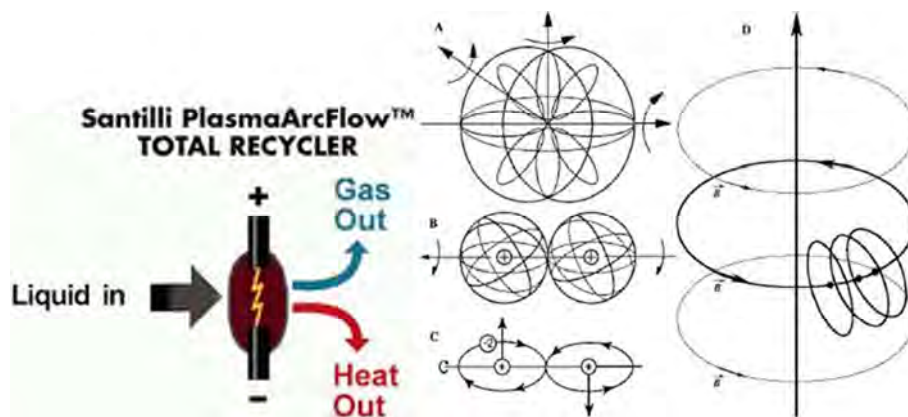


Figure 5. Figure on the left shows the schemmatic view of the Plasma Arc Flow Reactor whereas, figure on right gives the mechanism of creation of Magnecules for the case of the Hydrogen Molecule. It consists of the use of sufficiently strong external magnetic fields which can progressively eliminate 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 right hand side of the figure 5 outlines the geometry of the magnetic field in the immediate vicinity of an electric arc as in hadronic molecular reactors. 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. The reason for these results is the intrinsic geometry of the Plasma Arc Flow.

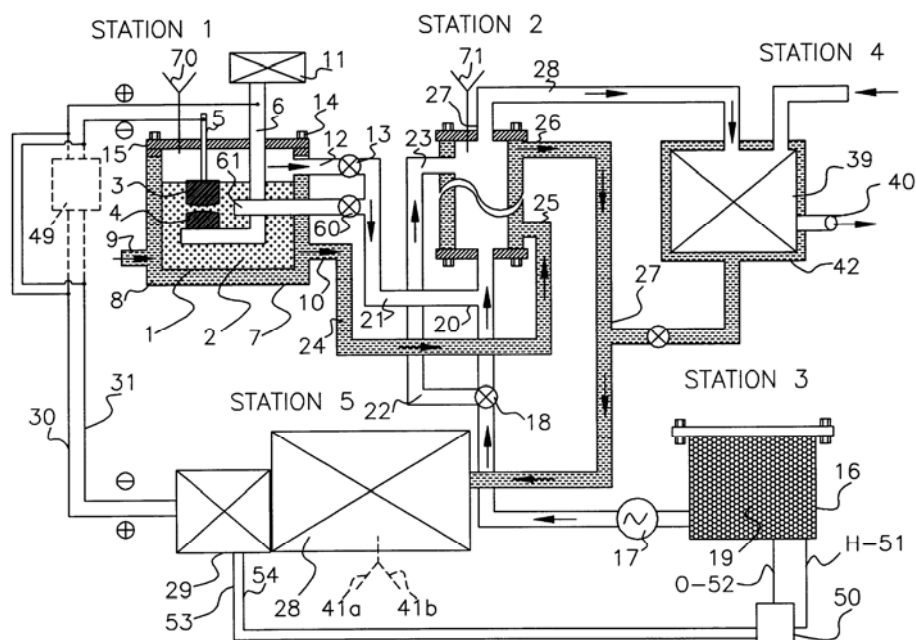


Figure 6. Complete embodiment of the mechanism of Magnecular Fuel production comprises of the five stations as shown in figure above; 1-Pressure Vessel, 2-liquid waste as feedstock, 3,4-Carbon-base cylindrical electrodes, 5,6-copper rods, 7-second pressure metal vessel, 8-coolant tap water or seawater, 9-Inlet, 10-Outlet, 11-Automated feeder circuit for maintaining the submerged electric arc between 3 & 4, 12-Outlet for produced combustible gas, 13-Pressure regulator, 14-Jacket bolt, 15-fastened lid, 16-Connecting pressure vessel, 17-pump, 18-flow control valve, 19-Gaseous additive from station 3, 20 to 28-Inlet outlet Pressure pipes, 29-DC electric generator, 30, 31-connecting cables, 39-Treatment station, 40-Magnefule exit, 41a and 41b-outlets for condensed, filtered and processed drinking water and with salt respectively, 42-Heat exchanger for cooling of Magnefuel, 49-AC/DC converter (rectifier), 50-Electrolytic separation equipment, 51 to 54-connecting cables, 60 and 61-outlet valves, 70-Inlet for chemical elements at station 1 and 71-at station 2.

All the above characteristic features disappear when the magnecules are brought to a sufficiently high temperature (Curie Magnecular Temperature), which varies from species to species.

A method for the production of a clean burning liquid fuel Magnegas plus heat from a liquid feedstock requires a pressure resistant vessel containing a liquid feedstock and the vessel housing a submerged electric arc between carbon-base electrodes as shown in figure 6. By activating the submerged electric arc between said carbon base electrodes produce, by thermochemical reactions, a combustible gas which bubbles to a surface of the liquid feedstock, and transmitting said combustible gas via high pressure pipes into a tower for a catalytic liquefaction processing into a clean burning liquid fuel called Magnegas (MG) [5-8, 26]. The heat produced by the reactor is acquired by the liquid feedstock and it is used via its recirculation through external heat exchangers that can power a turbine for the production of electricity. Of course this requires an additional input to the steam to reach the supercritical temperatures.

3.1. Spectroscopic Studies on the Existence of New Type of Magnecular Bond

Current spectroscopic technologies offer variety of analytic instruments, like Gas Chromatography (GC), Liquid Chromatography (LC), Capillary Electrophoresis Chromatography (CEC), Supercritical Chromatography (SCC), Ion Chromatography (IC), Infrared Spectroscopy (IR), Raman Spectroscopy (RS), Nuclear Magnetic Resonance Spectroscopy (NMRS), X-Ray Spectroscopy (XRS), Atomic Absorption Spectroscopy (AAS), Mass Spectrometry (MS), Laser Mass Spectrometry (LMS), Flame Ionization Spectrometry (FIS), and others.

Only some of these instruments are suitable for the detection of magnecules and, when applicable, their set-up and use are considerably different than those routinely used with great success for molecules. So far, all the spectroscopic tools are devised to detect the normal distribution of electrons around nucleus. This was in accordance with all the established theories and experimental evidences for atomic status and molecular structures based on the conventional covalent and coordinate bonds. Sigma and pi bonds are also obvious parts of these theories. But, in magnecules, the toroidal polarization of the electron orbital 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 orbital has 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. This addition of unusual property due to toroidal motion also reflects in the spectroscopic determination of magnecules. In fact, all up to date equipments are not able to interpret the magnecular bonds. Insufficiency in interpretation is due to the limitations of design of instruments.

Much of the attempts to obtain spectroscopic data using conventional tools are done to the date and the anomalies are themselves interesting and debatable. But apart from all these anomalies, basic difference between the conventional chemical bonds and magnecular bond makes everyone to confirm its existence important physical properties and industrial applications. Some of the conventional equipments with modifications to determine the magnecular species are as below: Among all available chromatographic equipment, that suitable for the detection of gas magnecules is the GC with column having ID of at least 0.32mm operated with certain conditions. By comparison, other chromatographs do not appear to permit the entrance of large magnecules. If attempted they may prove to be potentially destructive of the magnecules to be detected. Among all available spectroscopic equipment, one preferable is the IR. But the understanding should be such that an instrument is used in a negative way, that is, to verify that the magnecule considered has no IR signature. NMRS do not appear to be capable of detecting magnecules despite their magnetic nature, because NMRS are most effective for the detection of microscopic magnetic environment of H-nuclei rather than large structures. One of the prominent instruments to study magnecules is low ionization MS because other instruments seems to be destroying the magnecular structure in the time duration of detection.

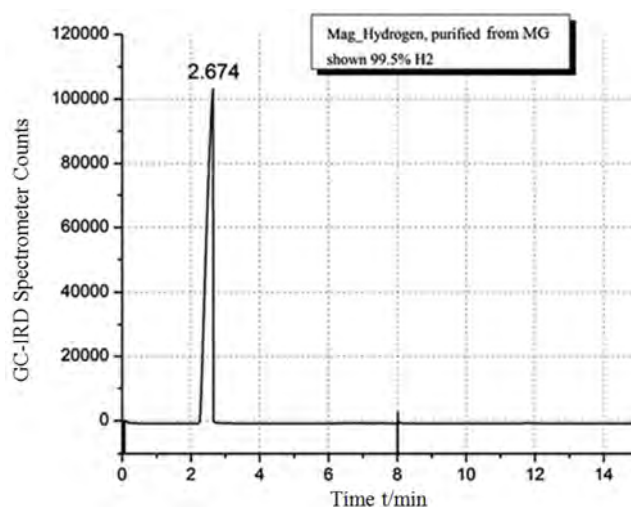


Figure 7. A scan of Magne Hydrogen via the GC-TCD of Ref. [4] showing no appreciable difference of MH with pure hydrogen.

Some of the best combination of instruments to detect magnecular species is GC coupled with MS, denoted as GC-MS and also IR coupled with this combination.

Thus best instrument for the detection of both molecules and magnecules in gases is the GC-MS equipped with the IRD denoted GC-MS/IRD. For the initial tests conducted [8] for magnecules, GC-MS scans have indicated the presence in the anomalous peaks of individual atoms of hydrogen, oxygen, and carbon evidently in addition to individual molecules. Any belief that magnegas is entirely composed by ordinary molecules, such as H_2 and CO , is disproved by experimental

evidence via GC-MS and IRD detectors. The anomalous behavior of magnecules from ordinary molecules can be understood from the observation that following the removal of magnegas from the GC-MS/IRD, the background continued to show the same anomalous peaks and reached the normal configuration only after a weekend flushing with an inert gas. When magnecule is passed through Pressure Swing Adsorption (PSA) equipment for the separation of Hydrogen from MG, a magnecules enriched with hydrogen is obtained, which is termed as Magnehydrogen [8]. Interestingly, this modified form of magnecules is energetically similar to hydrogen, but differs in physical properties to that of hydrogen. But being chemically pure, Magnehydrogen gives some readable data when studies spectroscopically as shown in figure 7. This is mainly because of the reduced complexities arising from bonding of other chemical species like CO, CO₂ etc.

3.2. Applications of Magnecules

The property of magnecules to undergo magnecular combustion with high energy output which is attributed to weak magnecular bond [8] is exploited for the industrial development of novel clean fuels such as MAGNEGASTM (See also independent review studies in [26-28] and short communications in [29, 30]). Consider the case of combustion of molecular hydrogen and oxygen to produce H₂O. The dissociation of H₂ and O₂ molecules consume 163.7 kcal/mol and thereafter the atom recombination to produce H₂O releases 221.25 kcal/mol hence the net release of energy is 57 kcal/mol. However, in case of magnecular hydrogen {H × H} and atomic oxygen O combustion (even if on considering H × H bond dissociation energy arbitrarily to be zero) the energy output is predicted to be approximately three times the value predicted by molecular structures with the same atomic constituents and combustion temperature [10].

3.2.1. Magnegas as Magnehydrogen

Recently, two different experimental confirmations have been reported of the new chemical species of Magnecules – Magne Hydrogen [8] with 99% Hydrogen content, and also having a multiple of the specific weight of conventional molecular Hydrogen. A number of features of the new species MH are pointed out therein, such as the increased energy content and the lack of seepage through the walls of a container. These features appear to be relevant for the Hydrogen industry.

The major industrial view point of this technology is Magnegas that can be obtained via combustion of carbon obtained via a submerged electric arc using Santilli's hadronic reactors of molecular type (Class III), also known as Plasma Arc FlowTM Reactor, that were first built by the R. M. Santilli in 1998 in Florida, U.S.A., and are now in regular production and sale the world over. Two of the commercially available Hadronic Reactors are shown in figures 8 and 9 respectively. Plasma Arc Flow Reactors use a submerged DC electric arc between carbon base electrodes to achieve the complete recycling of essentially any type of (nonradioactive) liquid

waste into the clean burning magnegas fuel, heat usable via exchangers, and carbonaceous precipitates used for the production of electrodes. The reactors are ideally suited to recycle antifreeze waste; oil waste, sewage, and other contaminated liquids, although they can also process ordinary fresh water. The best efficiency is achieved in these reactors for the recycling of carbon-rich liquids, such as crude oil or oil waste [3, 5].



Figure 8. Picture of a 250 kW Santilli's Hadronic Reactor [3] (also called Plasma Arc Flow Reactor) 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 million 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.



Figure 9. Picture of a 50 kW Santilli's Hadronic Reactor (Plasma Arc Flow Recycler) 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.

3.2.2. Magnegas as Metal Cutting Fuel

Apart from this, performance of magnecular fuel in metal cutting is more indicative of a plasma cutting feature, such as the metal cutting via plasma of ionized hydrogen atoms which recombine into H₂ when cooling in the metal surface, thus releasing the energy needed for metal cutting. The metal cutting ability is indicative of the presence of isolated atoms and dimers in the magnegas structure which recombine under combustion, to give performance similar to that of plasma cutters. Cutting and welding torch using acetylene requires a higher concentration of oxygen than is present in

air to enable the desired high temperature and facility of operation. In view of this, magnecular fuels are superior to acetylene [31]. The experimental observations for flame temperature carried out by two independent agencies [32, 33] confirmed the maximum flame temperature of magnegas to be 3670°C and 3400°C respectively. It clearly indicates its superiority to acetylene in field of cutting and welding metals.

3.2.3. Magnegas as Vehicular Fuel

Internal-combustion engines are bad polluters because they operate on fossil fuels, which contain a wide variety of components incapable of being fully combusted together within their brief residence in an engine. Combustion effluents of petroleum and even natural gas, contain undesirable hydrocarbon fragments and derivatives, often in particulate form, carbon monoxide, and gaseous oxides of nitrogen and/or of sulfur transformable to noxious droplet form (acid rain). Hydrogen was long-considered an ideal fuel because convertible completely to water via air combustion. Yet hydrogen is unsatisfactory as an internal-combustion engine fuel, because the high temperature and the rapidity of its combustion foster pre-ignition or flashback, which is greatly harmful to engine operation and structure. Also flashback is conducive to an increase of harmful Nitrogen Oxides in the atmosphere. Despite the intervening decade of research and development, no vehicle running on hydrogen as its main or sole fuel is yet commercial, notwithstanding much experimentation on fuel cell technology, which is fundamentally electrolytic and slow-generating. Polluting exhausts of fuels originating from fossil reserves as well as hydrogen are having their limitations.

Contrarily, in a paper from 2003, R. M. Santilli [34] presented theoretical and experimental evidence on the existence of a new species of Hydrogen that he called Magne Hydrogen (MH) structurally shown in figure 10, which results in clean combustion without liberation of harmful gases. Also, magnehydrogen supersedes hydrogen because of the some advantageous physical properties. It was found that the prepared gas apparently consists of 99 percent Hydrogen, although spectroscopically its specific weight (or, equivalently, molecular weight) was estimated to be 7.47 times larger than that of conventional Hydrogen. The gasification is achieved via a submerged DC electric arc between carbon electrodes that, under sufficient powers (of the order of 300kW or more) is capable of producing at atomic distances the high values of the magnetic field (estimated as being of the order of 1012 Gauss). Santilli obtained the new species MH via the use of conventional Pressure Swing Adsorption (PSA) equipment for the separation of Hydrogen from MG. 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 times the specific weight of H_2 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 Natural Gas. Additionally, the magnecular structure of MH avoids the traditional seepage of Hydrogen through the walls [7, 10, 31], thus allowing long term storage that is currently prohibited by molecular Hydrogen due to current environmental laws.

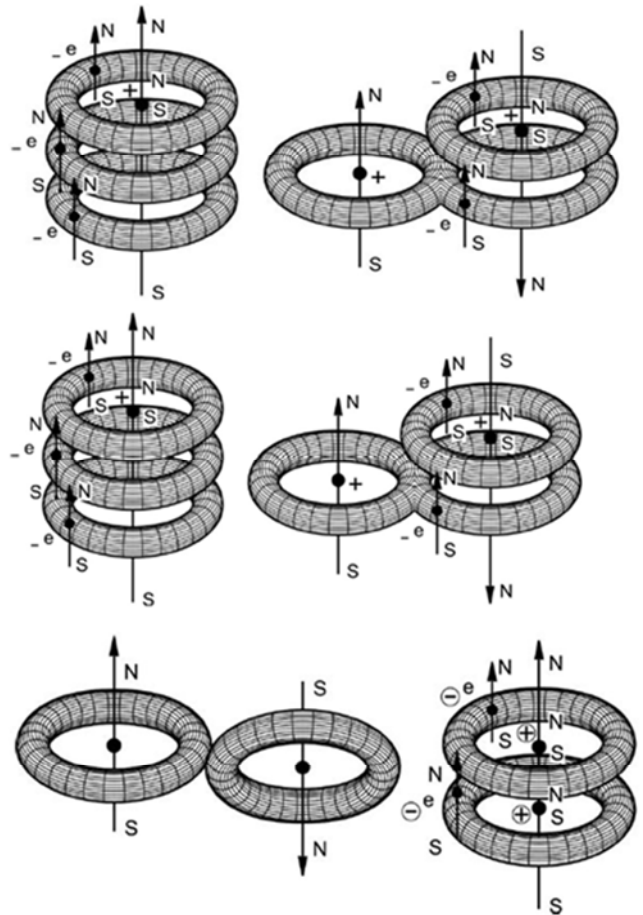


Figure 10. A conceptual rendering of the cluster Magne Hydrogen (MH) which is predicted as being composed by part of the molecular species $H-H$ and part by the magnecular species $H \times H$. The cluster in MH which is predicted as being composed by magnecular species $H \times H \times H$ and $H-H \times H$.

As magnecular fuel is magnetically polarized, magnegas and magnehydrogen show good binding affinity to other fuels, with which it is mixed. This gave rise to hybrid fuels like Hy-Gasoline, Hy-Diesel etc., where Hy stands for magnegas rich in hydrogen [7]. Magnegas (TM) fuel was shown by EPA accredited laboratory analysis results to be suitable for use as automotive fuel without catalytic converters while surpassing all current EPA requirements for combustion exhaust emissions, as shown in table 1 [35].

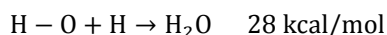
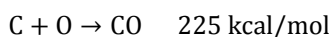
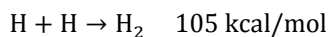
Table 1. Reproduced from the website of Magnegas technology Corp.

Element	MagneGas (MG)	Natural Gas	Gasoline	EPA Standards
Hydro-carbons	0.026 g/mi	0.380 g/mi 2460% of MG emission	0.234 g/mi 900% of MG emission	0.41 g/mi
Carbon Monoxide	0.262 g/mi	5.494 g/mi 2096% of MG emission	1.965 g/mi 750% of MG emission	3.40 g/mi
Nitrogen Oxides	0.281 g/mi	732 g/mi 260% of MG emission	0.247 g/mi 80% of MG emission	1.00 g/mi
Carbon Dioxide	235 g/mi	646.503 g/mi 275% of MG emission	458.655 g/mi 195% of MG emission	No EPA standard exists for Carbon Dioxide
Oxygen	9%-12%	0.5%-0.7% 0.04% of MG emission	0.5%-0.7% 0.04% of MG emission	No EPA standard exists for Oxygen

(Note: g/mi is the unit of measuring combustion exhaust of vehicles in grams per miles as per US Motor Vehicle Emission and Fuel Standards)

3.3. Comparison of Magnecular Combustion over Conventional Molecular Combustion

The magnecules are gaining attention of the world mainly because of the energy content it is exhibiting. The existence of dimers and atoms in magnecule were doubted due to insufficiencies and limitations of the spectroscopic equipments. But it could not divert the attention from the matter, i.e. anomalous energy content! The presence of dimers and individual atoms in magnegas can only support the quantitative interpretation of large excess of energy contained in this new fuel. This energy is accounting to be of the order of at least three times the value predicted by quantum chemistry, which is released during combustion. The admission of dimers and atoms as constituents of magnecules readily explains this anomalous energy content because said dimers and atoms are released at the time of the combustion, thus being able at that time to form molecules with exothermic reactions. In the event magnecules would not contain dimers and atoms, their only possible constituents are conventional molecules, in which case no excess energy is possible during combustion. When subjected to high voltage with a specially designed arc, atomic orbitals of conventional molecules undergo toroidal polarizarion. This toroidal polarization induces a magnetic current which is responsible for forming a magnecular bond between various neighboring toroids. This new type of attractive force also explains why molecules are in association with magnecules of individual atoms, such as H, C and O, and/or individual unpaired dimers, such as H-O and H-C. At the breakdown of the magnecules due to combustion, these individual atoms and dimers couple themselves into conventional molecules via known exothermic reactions such as [3]



with consequential release during combustion of a large amount of energy that does not exist in fuels with a conventional molecular structure. If pure water is subjected electric arc produced with Plasma Arc Flow Reactors, quantum chemistry predicts that magnegas should be a mixture of 50% H₂ and 50% CO, with traces of O₂ and CO₂. Quantum chemistry predicts that the indicated composition consisting of 50% H₂ and 50% CO should have an energy

content of about 315 BTU/cf, which is insufficient to cut metal. This prediction is also disproved by the experimental evidence that magnegas cuts metal at least 50% faster than acetylene, which has energy content of 2,300 BTU/cf.

3.4. Use of Magnegas as an Additive in Coal Combustion Process

The affinity of magnegas and magnehhydrogen to fossil fuels made it best suitable to be used as additive. This is also true for its use along with coal. Increasing energy demand across the globe and dependency of major emerging economies compelled to use coal despite its dirty nature. Moreover, poor coal combustion efficiency of the old age plants is adding to the concern of insufficient combustion of coal in furnaces. This is causing serious air pollution along with huge loss of the fossil fuel due to lower than expected efficiency. Magnegas has shown some interesting results when burnt along with coal in its initial experiments. Major problem associated with coal is incomplete combustion of carbon. Addition of magnegas to coal helps in complete combustion of all combustible products in coal to the final oxidation products. Thus maximum heat is obtained and the efficiency is increased. This also reduces load on air quality as there is no incompletely burnt carbon or NO released in atmosphere. Complete combustion of carbon itself is a achievement for energy efficiency as every conversion of carbon monoxide to dioxide away from the furnace is a loss of 283.0 kJ/mol of energy. In table 2, mentioned is the tabulated representation of exhaust parameters for combustion of coal and coal along with magnegas.

Table 2. Report of exhaust gases for combustion of coal compared with coal+magnegas.

Factor	Coal	Coal + Magnegas
Oxygen	11%	13%
Carbon Dioxide(CO ₂)	15%	9% (40%)
Carbon monoxide (CO)	58 ppm	28 ppm (52%)
Nitrous oxide (NOx)	160 ppm	46 ppm (71%)
Stack temp	37100 C	~29900 C
	7000 F	54000 F

The same experimental results were reconfirmed by Future Energy pvt. ltd. which is claimed in a recently filed patent in Australia. It clearly shows that the quality of exhaust is seen to be improved by addition of magnegas to coal [36]. Magnegas as additive to coal in small power plants can help to improve the combustion efficiency of these units. Also, high temperature generated in use of magnegas converts fly ash

into a glassy material and does not allow it to emit and pollute. Tremendous increase in temperature due to addition of magnegas can be trapped and converted to further generate heat in the same manner as 'waste heat recovery' boilers are working presently in many metal industries.

3.5. Use of Plasma Arc Flow Technique in Synthesis of Magnegas from Waste of Hydraulic Fracturing Process

Fracking process leaves behind a vast quantity of sludge waste containing water along with remains of hydrocarbon oil. It also contains the various chemicals added to serve variety purposes. Up to 600 chemicals are used in fracking fluid, including known carcinogens and toxins. Thus the waste generated over years becomes an issue of environmental concern.

Interestingly, this otherwise nuisance causing waste is a best candidate to be potential raw material for generation of magnegas using Plasma Arc Flow technology. For a stock of magnegas to be competent with hydrogen and acetylene in thermal parameters, it is necessary to be generated from waste containing hydrocarbon remains. Thus the waste obtained in fracking process is best for synthesis of magnegas. Thus, the waste disposal along with generation of magnegas can be achieved by reducing load on environment.

4. Conclusion

Thus, the theoretical and experimental evidences 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 CO₂ 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.

They also have promising application as fuel additive for improving combustion of existing fossil fuel due to their high miscibility, higher combustion/co-combustion rate and thermal output. The magnecules can also act as detonator to the conventional fuel molecules resulting in near complete combustion of the latter like the volatile matter detonating the fixed carbon of pulverized coal. Judicial use of fossil fuel can be achieved by application of clean additives like magnegas. Further, reliable and sustainable methods for generation of energy from waste are the solution for present global problems. Thus, magnegas hold promising applications as sustainable energy requirements.

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