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# Santilli's Magnecoles and Their Applications

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**Abstract:** Since the beginning of the industrial revolutions across the different parts of the globe, scientists are constantly trying to get access to clean; affordable and reliable energy which thus has been a cornerstone of the world's increasing prosperity and economic growth. Our use of energy in the twenty-first century must also be sustainable. Energy efficiency and conservation, as well as decarbonizing our energy sources are essential to this revolution. Reducing carbon emissions on the timescale needed to mitigate the worst risks of climate change will not be driven by our inability to find cost-effective sources of fossil fuels. Here, we are reviewing the work done by Prof. R. M. Santilli on his new chemical species of "Magnecoles" which primarily consists of bonds of magnetic types enabling pollution free and environmentally benign emission of exhaust. Also, different applications have also been discussed here.

**Keywords:** Magnecole, Carbondioxide Emission, Global Warming, Flame

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## 1. Introduction

All organisms modify their environment, and humans are no exception. As the human population has grown and the power of technology has expanded, the scope and nature of this modification has changed drastically. The growth of the human population, and growth in the resource base used by humanity, is maintained by a suite of human enterprises such as agriculture, industry, fishing, and international commerce. These enterprises transform the land surface (through cropping, forestry, and urbanization), alter the major biogeochemical cycles, and add or remove species and genetically distinct populations in most of Earth's ecosystems. Many of these changes are substantial and reasonably well quantified; all are ongoing. The rates, scales, kinds, and combinations of changes occurring now are fundamentally different from those at any other time in history; we are changing Earth more rapidly than we understand it. We live on a human dominated planet and the momentum of human population growth, together with the imperative for further economic development in most of the world, ensures that our dominance will increase. Finally, humanity's dominance of Earth means that we cannot escape responsibility for managing the planet [1].

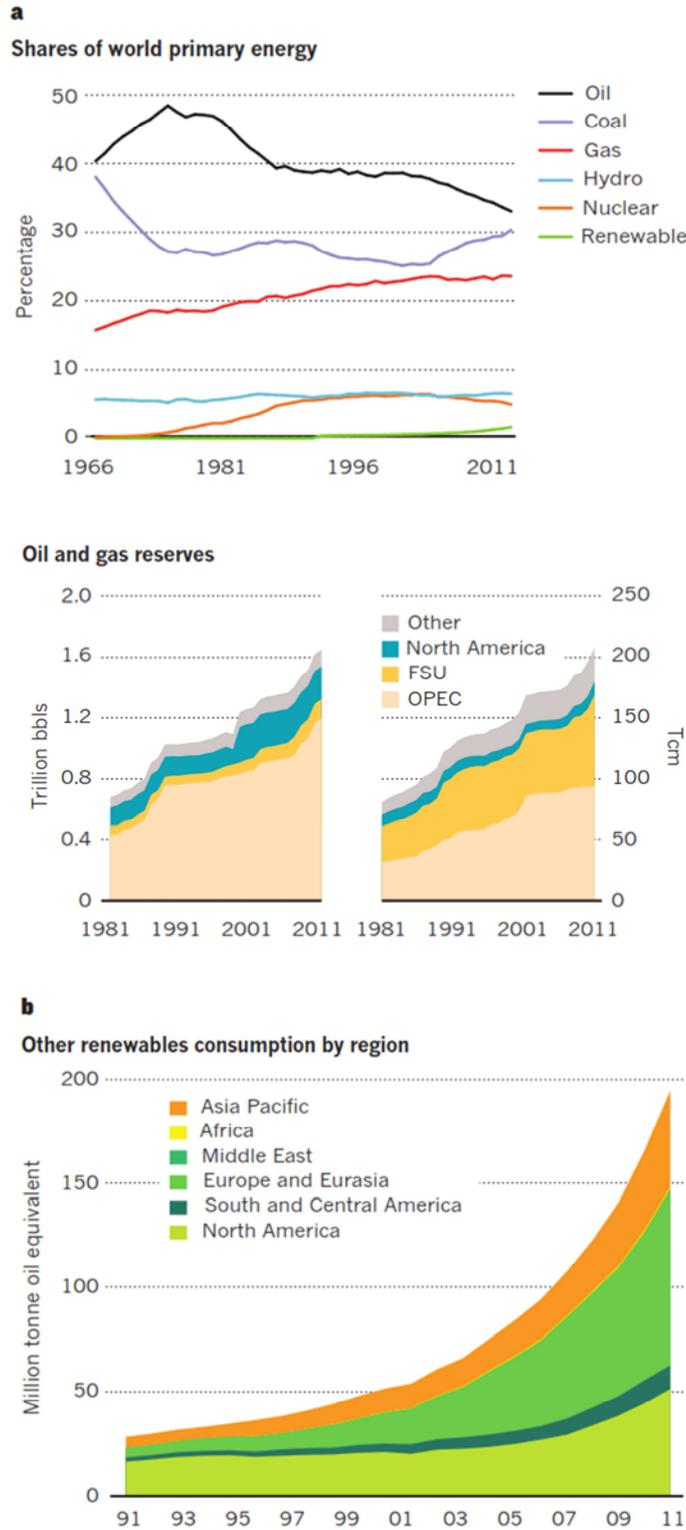
At the beginning of the industrial revolution, the population of the world was 700 million. Today, the population is 7 billion and is estimated to grow to 9 billion by 2050, and about 10 billion by 2100 [2]. Most of this population growth will be in Asia and Africa, where rapidly rising economic growth will place additional demands on energy supply. The International Energy Agency (IEA) based in Paris has projected that the world's energy demand will increase from about 12 billion tone oil equivalents (t.o.e.) in 2009 to either 18 billion t.o.e. or 17 billion t.o.e. by 2035 under their 'current policies' or 'new policies' scenarios, respectively. Carbon-dioxide emissions are expected to increase from 29 gigatonnes per year (Gt.yr<sup>-1</sup>) to 43 Gt.yr<sup>-1</sup> or 36 Gt.yr<sup>-1</sup> under the current and new policies, respectively. The actual path we follow will depend on how efficiently and effectively we use existing and new sources of energy [3].

Liquid fuels derived from oil became the main form of energy for transportation largely because of their high energy densities (Figure 1) associated with their high energy content. However, a search for alternatives to oil for transportation energy is required to deal with the growing concerns over the rising and volatile price of oil, the vulnerability to supply disruptions, and balance-of-trade issues.

With increases over the past 30 years in the number of extreme weather events, such as temperature extremes,

floods, wildfires, droughts and storms, the overall loss trend is beginning to exceed \$150 billion per year [4]. There is increasing evidence that these changes are linked with

climate change [5]. As U. S. A. President Obama [6] said in his speech last month, climate change is happening -- and the effects are already being felt across the country.



**Figure 1.** Statistical review of world energy. *a.* Fossil energy comprises roughly 86% of the world’s main energy consumption. Although the consumption of oil has increased by 31% between 1980 and 2008, the known reserves have increased comparably owing to improvements in exploration and extraction technologies. Much of the world’s shale-gas reserves are not ‘proven’ and are not included. The fractional sum of non-carbon emitting sources of energy remained constant during the same time period. *b.* Growth of renewable energy was offset by the decline in nuclear power generation. Renewable energy sources in power generation grew by 17.7%. Wind generation (25.8%) accounted for more than half of renewable power generation for the first time. Renewables accounted for 3.8% of global power generation, with the highest share in Europe and Eurasia (7.1%) [3].

2012 was the hottest year on record; the worst drought in generations covered more than half the country; record wildfires swept across western states; and an intensified Superstorm Sandy devastated communities in the East. (See The President's Plan to Fight Climate Change for more information.) U. S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather examines current and potential future impacts of these climate trends on the U.S. energy sector. Researchers have identified several critical issues, including power-plant disruptions due to drought and the disruption of fuel supplies during severe storms. They've also pinpointed potential opportunities that would make our energy infrastructure more resilient to these risks.

The map above shows how the following three extreme climate trends have caused major issues to the energy sector across the country over the past ten years [6]:

1. Increasing air and water temperatures;
2. Decreasing water availability across regions and

seasons; and

3. Increasing intensity and frequency of storm events, flooding and sea level rise.

The effects of these climatic changes (Table 1) are:

- Climate change has created an increased risk of shutdowns at coal, natural gas and nuclear power plants. Why? Changes in the climate mean decreased water availability -- which affects cooling at thermoelectric power plants, a requirement for operation.
- There are also higher risks to energy infrastructure located along the coasts thanks to sea level rise, the increasing intensity of storms, and higher storm surge and flooding.
- Power lines, transformers and electricity distribution systems face increasing risks of physical damage from the hurricanes, storms and wildfires that are growing more frequent and intense.

**Table 1.** Relationship between climate change projections and implications for the energy sector as per US Department of Energy Report [7].

Energy sector	Climate projection	Potential implication
Oil and gas exploration and production	• Thawing permafrost in Arctic Alaska	• Damaged infrastructure and changes to existing operations
	• Longer sea ice-free season in Arctic Alaska	• Limited use of ice-based infrastructure; Longer drilling season; new shipping routes
Fuel transport	• Decreasing water availability	• Impacts on drilling, production, and refining
	• Increasing intensity of storm events, sea level rise, and storm surge	• Increased risk of physical damage and disruption to offshore and coastal facilities
Thermoelectric power generation (Coal, nuclear, geothermal and solar CSP)	• Reduction in river levels	• Disruption of barge transport of crude oil, petroleum products, and coal
	• Increasing intensity and frequency of flooding	• Disruption of rail and barge transport of crude oil, petroleum products, and coal
	• Increasing air temperatures	• Reduction in plant efficiencies and available generation capacity
	• Increasing water temperatures	• Reduction in plant efficiencies and available generation capacity; increased risk of exceeding thermal discharge limits
Hydropower	• Decreasing water availability	• Reduction in available generation capacity; impacts on coal, natural gas, and nuclear fuel supply chains
	• Increasing intensity of storm events, sea level rise, and storm surge	• Increased risk of physical damage and disruption to coastal facilities
	• Increasing intensity and frequency of flooding	• Increased risk of physical damage and disruption to inland facilities
	• Increasing temperatures and evaporative losses	• Reduction in available generation capacity and changes in operations
Bioenergy and biofuel production	• Changes in precipitation and decreasing snowpack	• Reduction in available generation capacity and changes in operations
	• Increasing intensity and frequency of flooding	• Increased risk of physical damage and changes in operations
	• Increasing air temperatures	• Increased irrigation demand and risk of crop damage from extreme heat events
Wind energy	• Extended growing season	• Increased production
	• Decreasing water availability	• Decreased production
Solar energy	• Sea level rise and increasing intensity and frequency of flooding	• Increased risk of crop damage
	• Variation in wind patterns	• Uncertain impact on resource potential
Electric grid	• Increasing air temperatures	• Reduction in potential generation capacity
	• Decreasing water availability	• Reduction in CSP potential generation capacity
	• Increasing air temperatures	• Reduction in transmission efficiency and available transmission capacity
Energy demand	• More frequent and severe wildfires	• Increased risk of physical damage and decreased transmission capacity
	• Increasing intensity of storm events	• Increased risk of physical damage
	• Increasing air temperatures	• Increased electricity demand for cooling; decreased fuel oil and natural gas demand for heating
	• Increasing magnitude and frequency of extreme heat events	• Increased peak electricity demand

- Air conditioning costs will rise due to increasing temperatures and heat waves, along with the risks of blackouts and brownouts in regions throughout the country.

To overcome these environmental issues, there is urgent need of large scale production of new kind of fuels. Presently, Petroleum-derived liquid fuels are the overwhelming source of energy in the current transportation infrastructure. Now-a-days, natural gas and other bio-liquids are also used but their percentage is still very less (Figure 2). The origin of the alarming environmental problems increasingly affecting our planet are not due to fossil fuels per se, but rather to the strength of their conventional valence bond, since that strength has prohibited the achievement of full combustion during the past one hundred years of efforts.

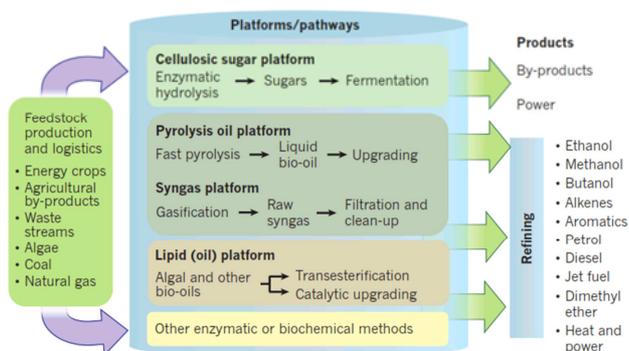


Figure 2. Methods of producing alternative fuels from various feed stocks to products. Various feed stocks are being explored, and the pathways for producing energy or fuel investigated [3].

## 2. Magnecules

Santilli magnecules in gases, liquids, and solids consist of stable clusters composed of conventional molecules, and/or diatomic radicals, 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 the intrinsic magnetic moments of nuclei and electrons (Figure 3 and 4) [7-10]. 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.

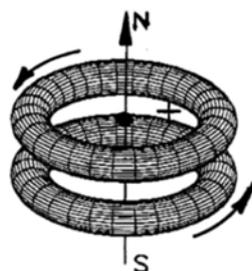


Figure 3. A schematic view of the simplest possible diatomic magnecule whose bond originates from the toroidal polarization of the orbits of peripheral atomic electrons.

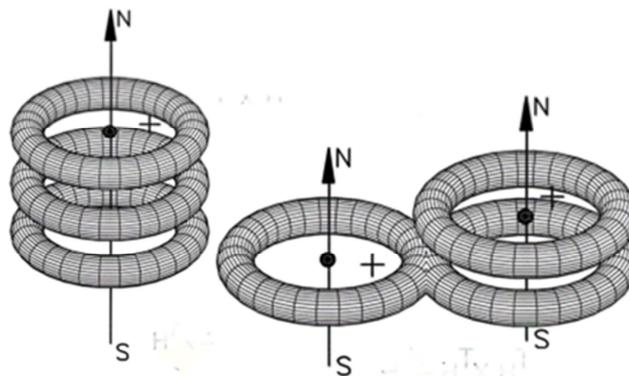
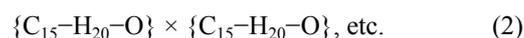
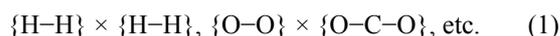


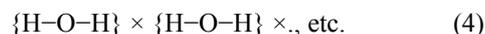
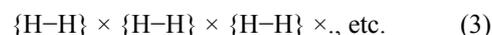
Figure 4. A schematic view of the simplest possible multiatomic magnecular bonds. A conceptual rendering of the cluster  $MH_3$  in  $MH$  which is predicted as being composed by magnecular species  $H \times H \times H$  (Top) and  $H - H \times H$  (Bottom).

Magnecules are also called:

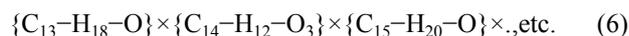
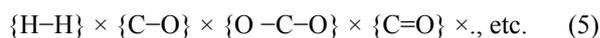
A) *elementary* when only composed of two molecules; If the conventional valence bond is denoted with the symbol “-” and the new magnetic bond with the symbol “x”, examples of elementary magnecules in gases and liquids are respectively given by



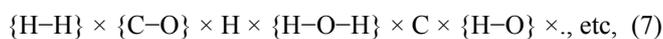
B) *magneplexes* when entirely composed of several identical molecules; examples of magneplexes in gases and liquids are respectively given by



C) *magneclusters* when composed of several different molecules and examples of magneclusters are given by



A generic representation of a gas magnecules requires the presence of individual atoms and diatoms (diatomic), such as:



One of the most important features of magnecules is their anomalous release of energy in thermochemical reactions, in view of its evident importance for the industrial development of new clean fuels such as magnegas. This feature is crucially dependent on the existence within the magnecules of individual atoms, such as H, C and O, and/or individual diatomic free radicals, such as H-O and H-C. In fact, at the breakdown of the magnecules due to combustion, these individual atoms and diatomic free radicals couple themselves into conventional molecules via known exothermic reactions such as

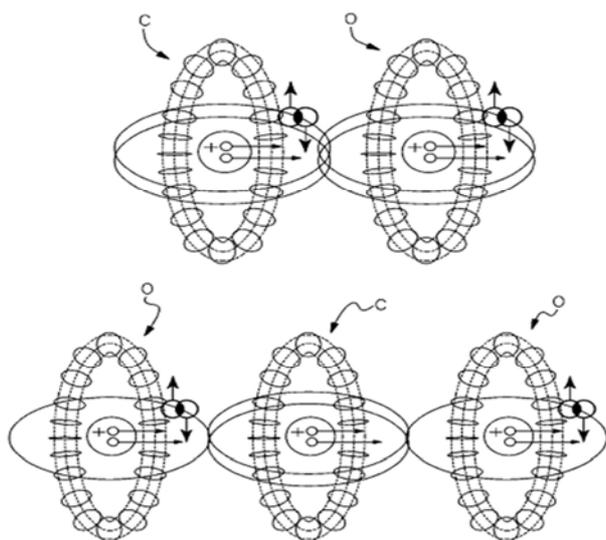


with consequential release during combustion of a large amount of energy that does not exist in fuels with a conventional molecular structure.

Finally, magnecules are called:

- i) *isomagnecules* when having all single-valued characteristics and being reversible in time, namely, when they are characterized by isochemistry;
- ii) *genomagnecules* when having all single-valued characteristics and being irreversible in time, namely, when they are characterized by genochemistry; and
- iii) *hypermagnecules* when having at least one multi-valued characteristic and being irreversible in time, namely, when they are characterized by hyperchemistry.

### 3. New Molecular Internal Bonds



**Figure 5.** A schematic view for the cases of  $\text{C}=\text{O}$  and  $\text{O}-\text{C}-\text{O}$  of the polarization of internal atomic electrons, while preserving conventional valence bonds, and the consequential creation of new bonds in conventional molecules which are not of valence type, as later on verified experimentally via IR scans.

Magnecules can also be formed by means other than the use of external magnetic fields. For instance, magnecules can be produced by electromagnetic field with a distribution having a cylindrical symmetry; or by microwaves capable of removing the rotational degrees of freedom of molecules and atoms, resulting in magnetic polarizations. The magnetic polarization at the foundations of magnecules predicts the existence of these new internal bonds and permits their quantitative study. Recall that external magnetic fields can polarize the orbit of valence electrons, but cannot possibly break or alter valence bonds. Recall that, consequently, sufficiently strong external magnetic fields can polarize the orbits of all atomic electrons, and not only those of the valence electrons. Consider then a

conventional molecule such as  $\text{C}=\text{O}$ . When exposed to the extreme magnetic fields as existing in the PlasmaArcFlow technology, the orbits of all internal electrons can be polarized, individually, for the carbon and the oxygen, in addition to the polarization of the two pairs of valence bonds. One of the various possible geometries is that in which the plane of the polarization of the internal electrons is perpendicular to that of the two pairs of valence bonds. In this case we have the birth of a new bond of magnetic origin in the interior of a conventional molecule, which is evidently given by the alignment of the two polarities North-South and North-South in the carbon and oxygen, and the consequential attraction of opposite polarities of different atoms, as illustrated in Figure 5. For the case of the  $\text{O}-\text{C}-\text{O}$  molecule we can evidently have two internal bonds of magnetic type in addition to the valence bonds, which are also given by the alignment of the magnetic polarities, resulting in one new bond, as illustrated in Figure 5.

The above new internal molecular bonds have major industrial and consumer implications, in as much as they permit the production of fuels capable of releasing under combustion anomalous amounts of energy, with consequential reduction of pollutants in the exhaust, as already proved by magnegas.

### 4. Main Features for the Detection of Magnecules

The experimental detection of gas magnecules requires the verification of a number of characteristic features of magnecules identified in Definition. The main features are as follows:

- Feature 1: Appearance of unexpected heavy MS peaks.
- Feature 2: Unknown character of the unexpected MS heavy peaks.
- Feature 3: Lack of IR signature of the unknown MS peaks.
- Feature 4: Mutation of IR signatures.
- Feature 5: Mutation of magnecular weights.
- Feature 6: Accretion or emission of individual atoms, diatomic radicals or ordinary molecules.
- Feature 7: Anomalous adhesion.

### 5. Production of Magnegas

A new technology, called Plasma Arc Flow<sup>TM</sup>, flows the waste through a submerged electric arc between conventional electrodes. Different types of Plasma Arc Flow reactors have been shown in from Figure 6 to Figure 9. 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 K [9]. The flow of the liquid through the arc then continuously removes the plasma from the arc following its formation. Said plasma then cools down in the surrounding liquid, and a number of chemical reactions take place resulting in the formation of magnegas which bubbles to the surface of the liquid where it

is collected for industrial or consumer use. As soon as two or more molecules near each other possessing such an extreme magnetic polarization are created, they bond to each other via opposing magnetic polarities, resulting in the elementary magneucle.



**Figure 6.** 50 kW Plasma Arc Flow Mobile Refinery.



**Figure 7.** 100 kW Plasma Arc Flow Mobile Refinery.



**Figure 8.** Picture of a 250 kW Santilli's Hadronic Reactor (also called Plasma Arc Flow Recycler™) 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™ are completely self-contained. Consequently, they release no solid, liquid or gas to the environment and cause no noise or odor pollution.



**Figure 9.** Sterilization Recycler.

When the original waste is of fossil or organic type, magnecules are essentially constituted by conventional molecules  $H_2$ ,  $CO$ ,  $CO_2$ ,  $H_2O$ , plus individual atoms of  $H$ ,  $O$ , and  $C$ , as well as radicals such as  $HO$ ,  $CH$  and  $C-O$ , all these constituents being bonded together by strong magnetic fields originating from the toroidal polarization of the orbits of valence and other electrons. 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.

The MagneGas Recyclers have two operating modes:

"GASIFICATION MODE" is suitable to completely gasify target liquids for the maximum conversion of liquid to fuel and is most suitable for oily or hazardous wastes that require elimination. The waste is converted into MagneGas and carbon precipitates. In this mode the liquid is completely gasified.

"STERILIZATION MODE" is intended solely to sterilize target liquid wastes such as sewage, agricultural wastes or any effluent where eliminating bacteriological activity is beneficial to convert the waste liquid into a fertilizer and irrigation water. This results in the production of MagneGas, carbon precipitates and the same quantity of sterilized liquid. In this mode the liquid is retained but completely sterilized.

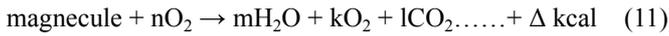
MagneGas is a cost competitive and clean burning fuel that is essentially interchangeable with Natural Gas or it can be co-combusted with existing hydrocarbon fuels and has the lowest Green House gas emissions when compared to fossil fuel. The Magnegas system occupies a small footprint and runs in a completely sealed environment. The fuel can be used for metal cutting, cooking, heating, or powering natural gas bi-fuel automobiles. MagneGas™ Recyclers shown in Figure 9 Can Process:

- Sewage
- Sludge
- Agricultural Waste

- Leachates
- Some Oil Based Liquids
- Some Industrial Waste Liquids

## 6. Combustion of Magnegas

It is evident that the combustion of magnegas requires the oxidation, first, of magnecules, and then that of conventional molecules  $H_2$  and  $CO$ . To begin, the known reactions  $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$  and  $CO + \frac{1}{2} O_2 \rightarrow CO_2$ , should be replaced by the reaction:



which may give increased energy released per each  $H_2$  molecule. Here,  $n$ ,  $m$ ,  $k$ ,  $l$ , are the stoichiometric numbers, and the original magnecule is assumed to consist of both  $H_2$  and  $CO$  molecules.

The energy balance for the combustion of magnecule is then given by:

$$E[\text{combustion}] = mE[H_2O] + (k-n)E[O_2] + lE[CO_2] - E[\text{magnecule}] \quad (12)$$

where  $E[H_2O]$ ,  $E[O_2]$ ,  $E[CO_2]$ , are ground state energies of the molecular constituents, and  $E[\text{magnecule}]$  is ground state energy of the the original magnecule.

A way to calculate this energy balance is to use dissociation energy of the magnecule,  $D[\text{magnecule}]$ . However, we should note that  $D[\text{magnecule}]$  is different for magnecules of different mass and composition.

In general, the thermodynamic relation between the Gibbs free energy of reaction,  $\Delta G$ , and the reaction equilibrium constant,  $K$ , is as follows:

$$-2.303 RT \log K = \Delta G \quad (13)$$

where

$$\Delta G = \Delta H - T \Delta S \quad (14)$$

$R = 1.986 \text{ cal.K}^{-1}.\text{mol}^{-1}$ ,  $T$  is temperature in Kelvin,  $\Delta H$  is the enthalpy of reaction and  $\Delta S$  is the entropy of the reaction. The latter is numerically large if the initial reactants have molecular structures more ordered than the end products, i.e. there is an increase of entropy  $S$  during the reaction.

Thus the combustion of magnegas is characterized by a very high value of the reaction constant (equilibrium) (perhaps even higher than  $K = 10^{40}$  at  $T = 25^\circ\text{C}$ ). In fact, the combustion of magnegas is a highly exothermic reaction, and the magnecules have a structure much more ordered than the product of the combustion. Therefore, during the combustion of magnegas we have a large increase of the entropy  $\Delta S > 0$ . These two factors lead to very high value of the reaction equilibrium constant  $K$  for the combustion of magnegas.

It is interesting to note that the oxidation of carbon to carbon monoxide, e.g.,  $C + CO_2 \rightarrow 2CO$ , is almost the only oxidation reaction for which  $\Delta G$  decreases with the increase

of the temperature. Here, the number of moles increases about twice during the reaction. As a result, the entropy greatly increases  $\Delta S > 0$ . Therefore, the  $CO$  molecule is more stable at high temperatures than at low temperatures (for example, it is about twice more stable at  $3000^\circ\text{C}$  than at  $1000^\circ\text{C}$ ). Another ecologically very important aspect in the combustion of magnegas is therefore the reduction of  $CO$  via the oxidation of carbon atoms present in magnecules, and its subsequent dissociation as in Eq. (9) to release the oxygen needed for the burning of hydrogen. Since the stability of  $CO$  increases with the temperature, a better quality of the exhaust is reached at lower original temperatures of magnegas. This result should be compared with the opposite occurrence for natural gas and for other fuels, which are generally pre-heated prior to combustion.

Another important characteristic of a reaction is the rate of reaction. Various tests [2a] have show that the combustion of magnecules is faster than the combustion of their molecular constituents. Santilli-Shillady isochemical models of molecular structures permits the following understanding of this additional anomaly. In conventional quantum mechanical equation in relative coordinates and reduced mass for two electrons in singlet coupling we have the following Schrödinger equation:

$$\left( \frac{p^2}{m} + \frac{e^2}{r} \right) \psi(r) = E\psi(r) \quad (15)$$

where  $m$  is the electron mass. The above equation shows the repulsive Coulomb force between the point-like charges of the electrons. But the electrons have extended wavepackets of the order of  $1\text{fm}$  whose mutual penetration, as necessary for the valence bond, causes nonlinear, nonlocal and nonpotential interactions at the foundations of hadronic mechanics (see the preceding chapter). The only known possibility for an invariant representation of these interactions is to exit from the class of unitary equivalence of Eq. (15) via an isounitary transformation that, for simplicity, we present below in its projection into a conventional nonunitary form

$$UU^\dagger \neq I, UU^\dagger = \hat{I} = 1/T \quad (16)$$

$$\begin{aligned} & U \left[ \left( \frac{p^2}{m} + \frac{e^2}{r} \right) \psi(r) \right] U^\dagger \\ &= \left[ \frac{1}{m} U p^2 U^\dagger + \frac{e^2}{r} U U^\dagger \right] (U U^\dagger)^{-1} [U \psi(r) U^\dagger] \\ &= \left[ \frac{1}{m} \hat{p} T \hat{p} T + \frac{e^2}{r} \right] \hat{\psi}(r) = E' \hat{\psi}(r) \end{aligned} \quad (17)$$

where one should note the different eigen value  $E'$  from the value  $E$  of Eq.(15) (due to the general non-commutativity of the Hamiltonian and the isounit).

At this point, Santilli and Shillady introduced the following realization of the non-unitary transform, that is, of the fundamental iso-unit of hadronic chemistry, Eq.(18) of FHC,

$$\begin{aligned}
 UU^{\#} = \hat{I} = \frac{1}{T} = \exp \left\{ \left[ \frac{\Psi(r)}{\hat{\Psi}(r)} \right] \int \Psi_1(r) \Psi_2(r) d^3(r) \right\} \\
 = 1 + \left[ \frac{\Psi(r)}{\hat{\Psi}(r)} \right] \int \Psi_1(r) \Psi_2(r) d(r) + \dots
 \end{aligned}
 \quad (18)$$

where  $\Psi$  and  $\hat{\Psi}$  are the solutions of the unitary and nonunitary equations, and,  $k = 1; 2$ , are the conventional quantum mechanical wave functions of the two electrons.

It is evident that, as desired, the above iso-unit represents interactions that are: nonlinear, because dependent in a nonlinear way in the wave functions; nonlocal, because inclusive of a volume integral; and nonpotential, because not representable with a Hamiltonian.

Santilli and Shillady solved the above equations. First, by inserting isounit of Eq.(18) in Eq.(17), they obtained the isoequation here projected on a conventional Hilbert space

$$\left[ \frac{p^2}{2m'} + \frac{e^2}{r} - V_0 \frac{e^{-br}}{1 - e^{-br}} \right] \hat{\Psi}(r) = E' \hat{\Psi}(r) \quad (19)$$

where  $m'$  represents the iso-renormalization of the mass caused by nonpotential interactions, and one recognizes the emergence of the attractive Hulthen potential

$$V_{\text{Hulthén}} = V_0 \frac{e^{-br}}{1 - e^{-br}} \quad (20)$$

But the Hulthen potential is known to behave like the Coulomb potential at short distances and be much stronger than the latter. Therefore, Eq.(19) admits the excellent approximation

$$\left[ \frac{p^2}{2m'} + V' \frac{e^{-br}}{1 - e^{-br}} \right] \hat{\Psi}(r) = E' \hat{\Psi}(r) \quad (21)$$

where the new constants  $V'$  reflects the "absorption" of the repulsive Coulomb potential by the much stronger attractive Hulthen potential. In this way, Santilli and Shillady achieved for the first time in the history of chemistry a valence coupling between two identical electrons in singlet coupling with a strongly attractive force, as requested by experimental evidence, which model is today known as the Santilli-Shillady strong valence bond.

In their natural conventional, and non-polarized states,  $H_2$  and  $O$  molecules have the usual (spherical) shape due to rotations. However, an inspection of the isochemical model of the water shows that such configurations are not suited for the reaction of  $H$  and  $O$  into  $HO$ . In particular, the orbitals of  $H$  require a toroidal configuration as a condition for their bonding to the oxygen, a similar occurrence holding for the oxygen too.

It then follows that magnetically polarized molecules of hydrogen and oxygen have a bigger reaction rate than the same molecules in un-polarized conditions, since they have a distribution of the valence electrons more suitable for the reaction itself. Evidently, a bigger reaction rate implies a bigger power.

Moreover, the combustion of a magnecule consisting of

$H$  and  $CO$ , does not require the necessary previous dissociation of the  $O_2 \rightarrow 2O$ , 119.1 kcal), because each  $O$ -atom in a magnetically polarized oxygen molecule (oxygen molecule is ready for the combustion). Therefore, the magnecular structure acts as a kind of catalysis, in which both  $O$ -atoms of the oxygen molecule start to react with the nearest pair  $H_2 \times H_2$ , or  $H_2 \times CO$ , or  $CO \times CO$  almost simultaneously; This occurrence also implies that less amounts of external energy is needed to activate the reaction, resulting, again, in an anomalous energy release in combustion. Usually, the activation energy is supplied by heat. Therefore, we can conclude by saying that the combustion of magnegas can be initiated at smaller temperature, in comparison to that of the simple mixture of hydrogen and  $CO$  gases. The reduction of pre-heating time of about one-half for magnegas as compared to that for acetylene, is in agreement with the above interpretation.

Due to the presence of magnecules viewed as heavy complexes of  $H$  and  $CO$ , one cubic foot of magnegas contains in fact larger number of  $H_2$  and  $CO$  molecules than it is for the respective simple mixture (i.e., without the clusters) of these two gases, at the same temperature and pressure. which are interacting with each other. Thus, the larger number of  $H_2$  and  $CO$  molecules per cubic foot of magnegas can be considered as one of the simple reasons of high energy content of magnegas which has been measured and calculated per cubic foot.

## 7. 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.

### 7.1. MagneGas

In 2001, Santilli released monograph [7] 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](http://www.magnegas.com) for details) was provided in detail. Plasma Arc Flow reactor [12-19] 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. Such kind of highly efficient and cost effective flow reactor was suitable to recycle antifreeze waste, oil waste, sewage and other contaminated liquids [12].

The first application of MG is its use as a new clean fuel for automobile (see Figure 10). 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 11). The Plasma Arc Flow causes the removal of H and O from the arc immediately following their creation, thus preventing their recombination into H<sub>2</sub>O, with consequential dramatic increase of the efficiency, that is, of the volume of combustible gas produced per kWh. Different studies establish the environmental superiority of magnegas over natural gas and gasoline. The following comments are now in order:

- 1) Magnegas does not contain (heavy) hydrocarbons since it is created at 3,500 K. Therefore, the measured hydrocarbons are expected to be due to combustion of oil, either originating from magnegas compression pumps (thus contaminating the gas), or from engine oil.
- 2) Carbon monoxide is fuel for magnegas (while being a combustion product for gasoline and natural gas). Therefore, any presence of CO in the exhaust is evidence of insufficient combustion.
- 3) Its exhaust also does not contain other pollutants such as NO<sub>x</sub> and other carcinogenic gases, yet rich in oxygen.



**Figure 10.** 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<sub>2</sub> emission due to gasoline combustion, reducing the operating temperature of about 25%, and emitting in the exhaust 10% to 14% breathable oxygen.



**Figure 11.** 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<sub>2</sub> 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°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.



**Figure 12.** 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.

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 12). 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 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<sub>2</sub>) is the primary greenhouse gas emitted through human activities. In 2012, CO<sub>2</sub> 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<sub>2</sub> to the atmosphere and by influencing the ability of natural sinks, like forests, to remove CO<sub>2</sub> from the atmosphere. While CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub>. The main sources of CO<sub>2</sub> 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<sub>2</sub> emissions in the nation, accounting for about 38% of total U.S. CO<sub>2</sub> 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<sub>2</sub>. To produce a given amount of electricity, burning coal will produce more CO<sub>2</sub> 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<sub>2</sub> emissions, accounting for about 32% of total U.S. CO<sub>2</sub> 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<sub>2</sub> through fossil fuel combustion. Several processes also produce

CO<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> 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<sub>2</sub> and other heat-trapping gases to the atmosphere. The most effective way to reduce carbon dioxide (CO<sub>2</sub>) emissions is to reduce fossil fuel consumption. Many strategies for reducing CO<sub>2</sub> 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<sub>2</sub> emissions as well as other toxic gases emission and thus can be used in future for large scale energy formation (see Figure 13 and Figure 14).

## 7.2. Magne Hydrogen™

In a paper from 2003, Santilli [20] presented theoretical and experimental evidence on the existence of a new species of Hydrogen. i. e. he called MagneHydrogen™ (See Figure 15). It was found that the prepared gas apparently consists of 99% Hydrogen, although spectroscopically its specific 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. [9], 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 orbitals into toroids (estimated as being of the order of 10<sup>12</sup> 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. [21].

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.

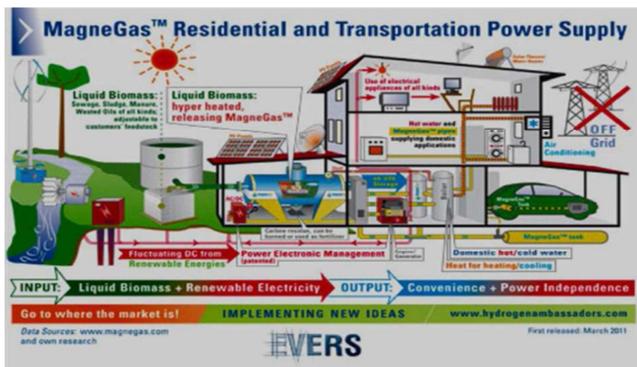


Figure 13. Future Scope I: Applications of MagneGas for residential, transportation and industrial power supply purpose.

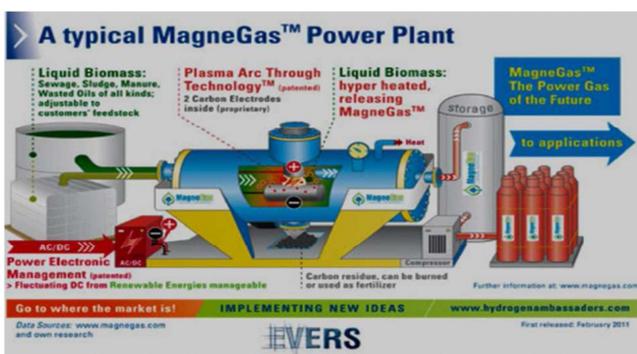


Figure 14. Future Scope II: Applications of MagneGas in Power Plant as future scope.

Similar to MagneHydrogen™, Santilli have also developed magnecular fuel from oxygen gas i. e. MagneOxygen™. These gases possess specific weight and energy content greater than the corresponding values of the same gases with conventional molecular structure. It has been found that use of MagneHydrogen™ and MagneOxygen™ in fuel cells implies: 1) an increase of fuel cells voltage, power and efficiency; 2) a decrease of storage volumes; and 3) a significant decrease in operating costs. The new forms of liquid hydrogen and oxygen is expected to find for rocket propulsion with increased trust, and consequential increased payload or decreased boosters' weight with the same payload.

**7.3. HHO Gas: Aquygen™**

Santilli then provided in Ref. [11] of 2006 theoretical experimental evidence on a third industrial application of the new species of magnecules i. e. HHO gas (see Figure 16), here referred to the gas commercially produced via certain electrolyzers (see Figure 17) and essentially consisting of 2/3 Hydrogen and 1/3 Oxygen, which contains a small percentage of H and O magnecular clusters.

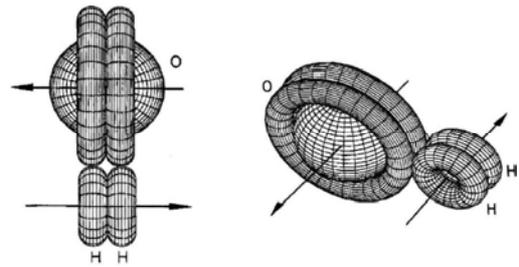


Figure 16. HHO Gas.

Under these conditions, Santilli suggested in Ref. [22] 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. 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 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

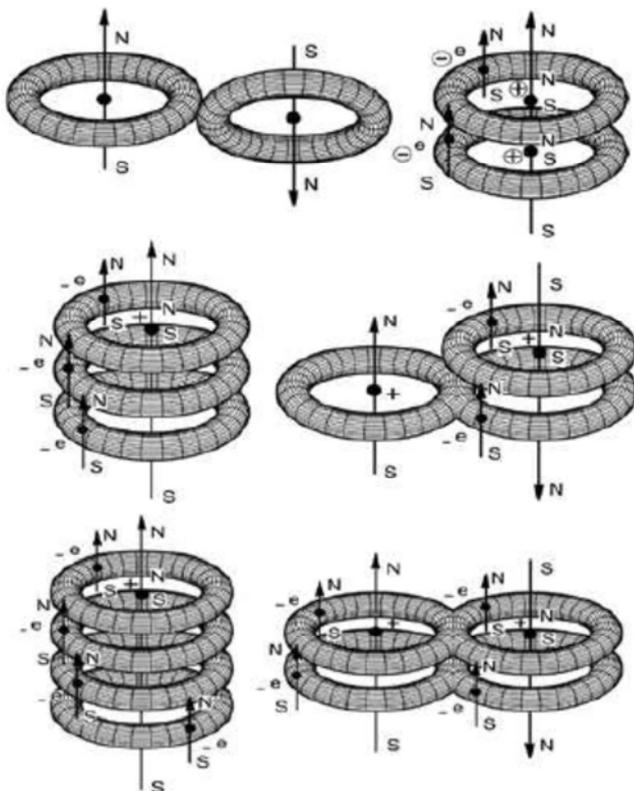


Figure 15. A conceptual rendering of the cluster  $MH_2$  in  $MH$  which is predicted as being composed by part of the molecular species  $H - H$  (Top, Left) and part by the magnecular species  $H \times H$  (Top, Right); A conceptual rendering of the cluster  $MH_3$  in  $MH$  which is predicted as being composed by magnecular species  $H \times H \times H$  (Middle, Left) and  $H - H \times H$  (Middle, Right); A conceptual rendering of the cluster  $MH_4$  in  $MH$  which is predicted as being composed by the magnecular species  $H \times H \times H \times H$  (Bottom, Left) and  $H - H \times H - H$  (Bottom, Right).



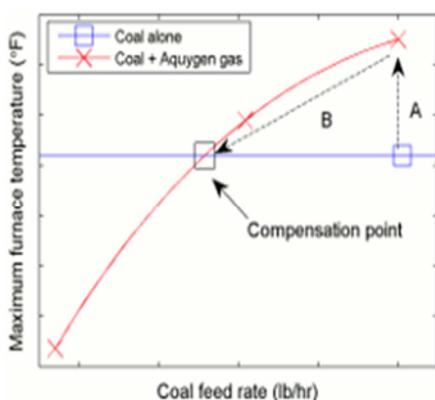
Figure 17. The Model 1500 Aquygen Gas Generator runs on water and electricity only. It produces a stable hybrid hydrogen-oxygen gas, with many unique properties. The generator provides a superior gas for most conventional brazing, soldering and metal cutting operations. Gas Generator can be used in many exotic cutting, brazing, and fusing applications as well as glass treatment and blowing applications that cannot be performed by conventional methods and processes.

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

Aquygen™ gas supplements standard vehicle fuels such as gasoline and diesel, increasing BTUs while decreasing emissions. Aquygen™ 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™ gas gives off no toxic fumes. Aquygen™ 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<sub>2</sub>, CO, NO<sub>x</sub>, SO<sub>x</sub>, 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™ gas (A) and the ability to obtain the same furnace temperature with a decreased coal feed rate (B) which is as shown in Figure 18.

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

1. Significant Reductions in NO<sub>x</sub>, CO, CO<sub>2</sub>, and SO<sub>2</sub>.
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.



**Figure 18.** Aquygen™ 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™ gas (A) and the ability to obtain the same furnace temperature with a decreased coal feed rate (B).

## 8. Applications of Magne Gas(MG) as a Cooking or Heating Gas - Safe for Indoor Use

Carbon Monoxide (CO) is one of the most dangerous poisonous gas produced by incomplete combustion of fuels i.

e. gasoline, kerosene, natural gas, propane and liquefied petroleum gas. It replaces oxygen in the blood stream causing suffocation. The results of breathing CO include loss of function, brain damage and even death. The greatest danger occurs when fossil fuels are burned indoors where they can concentrate and amplify the damage that they cause. Santilli MG is safe for indoor use. MG offer major safety advantages over fossil fuels such as natural gas and propane:

1. MG exhaust is comprised of water vapor, oxygen and carbon dioxide. Because its exhaust is free of toxic fumes and carcinogens, it is safe for indoor use.
2. Because MG exhaust has a positive oxygen balance, it does not present the dangers of oxygen depletion in closed environments that other fuels do.
3. MG is lighter than air, substantially reducing the danger of explosion compared to fossil fuels, that are heavier than air and tend to pool in and around work areas. Although it contains as much or more energy than fossil fuels, it is also less explosive.
4. Although MG is clear, it has a natural odour allowing it to be easily detected.
5. MG is magnetic, it can be easily compressed offering the same portability as propane.

## 9. Conclusions

In this paper, we have outlined the new chemical species of Santilli magnecules [9, 20-22] consisting of clusters of atoms, radicals and ordinary molecules whose primary characteristics are: stability at ambient temperature; a structural bond weaker than that of valence; and, consequently, an energy output bigger than that of molecular fuels with the same atomic composition.

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.

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