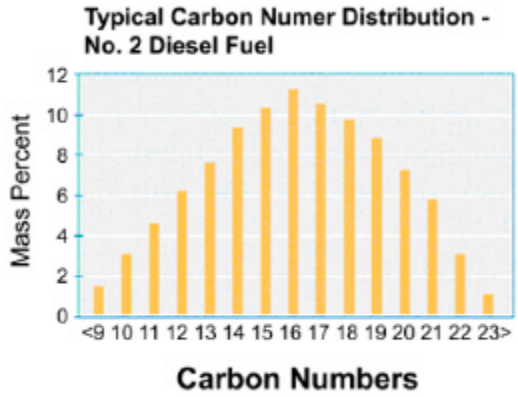
**Magnetic Treatment of Diesel Fuel**
**By Wouter Lisseveld**

**FUEL CONSTITUENTS AND STABILITY**




liquids are dense, disordered structures in which atoms are in constant motion.
A simple but good example of the influence of molecular shape on the physical behaviour of the corresponding liquid is provided by the paraffins — simple chains of carbon atoms bonded to hydrogen. As the chain gets longer, we change from gases, like methane ($CH_4$) and ethane ($C_2H_6$) at ambient temperatures and pressures, to runny liquids (for the $C_6$–$C_{10}$ fraction — as in petrol/gasoline) to viscous liquids for $C_{12}$–$C_{20}$ to tars (which are so viscous that they begin to resemble solids) for longer molecules. Indeed, if the molecular motion becomes so slow that in effect the atoms and molecules have ceased to diffuse, we will have a material whose structure is that of a liquid, but many of whose physical properties are those of a solid; The behaviour of molecules and materials is determined in many instances not by what happens in their interior, but what happens on their surface. Chemical reactions often take place at surfaces

Diesel fuel is an inherently unstable fluid. Its physical and chemical characteristics vary, depending on the origin of the petroleum and the refining processes. Diesel contains thousands of different constituents (see Figure 1) that do not exist in a homogeneous form. The result of these different carbon number is large and small fuel particle sizes (carbon number = number of carbon atoms.). Figure 2 shows high-magnification photographs (courtesy of Caleb Brett) of heavy fuel oil particles. Diesel fuel exists in liquid and solid phases simultaneously. Particles are smaller than in heavy fuel oil, but similarly heterogeneous.

**Figure 1. Carbon Number Distribution in No. 2 Diesel**

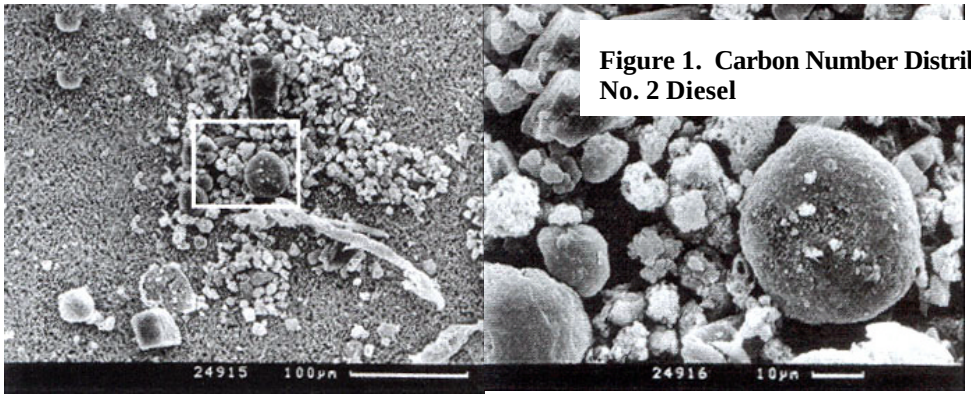


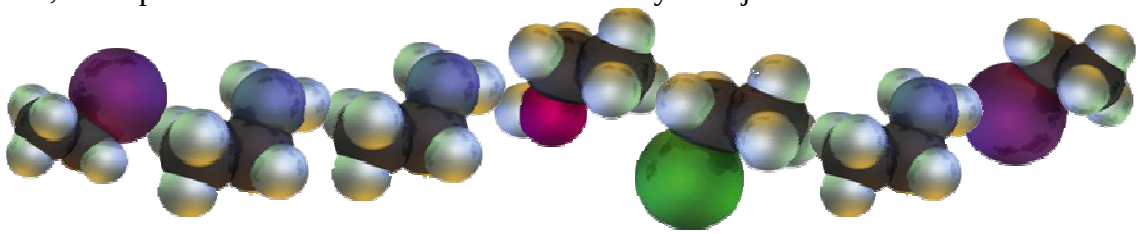

**Figure 2 Photomicrograph of fuel particles. Scale on left is 100 micron. Right 10 micron.**

These chemical characteristics, physical size of particles and other features of the fuel affect stability, filterability, and combustion efficiency. Studies have shown incomplete combustion is a major cause of diesel air pollution, especially soot and particulates, which are a major health concern.

Particulates consist mainly of carbonaceous conglomerations that can be traced to incomplete combustion. Poor fuel mixing in the cylinder will produce large quantities of particulates. In the cylinder, injected fuel encounters an advancing flame plume and combustion takes place in phases, and under different oxygen conditions. Pyrolytic reactions crack the hydrocarbons that have yet to pass through the flame, forming particulate clumps. These clumps of unburned fuel pass through the flame plume. Researchers at West Virginia University have found that at temperatures above 500 ° C, the particles are composed solely of clusters of carbon, while at temperatures below this, higher molecular weight hydrocarbons condense onto the clumps. In regions of the cylinder with more oxygen (that are more fuel lean), the particulate clumps tend to oxidize, resulting in more complete combustion, and fewer particulate emissions.

Field trials of fuel line magnetic treatment devices show great promise in reducing particulate emissions from all types of high and medium speed diesel engines. A short series of dynamometer emission tests, comparing untreated and treated fuel and measuring engine emissions, indicate more complete combustion takes place after the fuel has been treated in a magnetic field. The explanation for this phenomena seems to derive from interactions between fuel constituents that result in poor combustion. However, poor combustion is so common that it is assumed to be the norm in diesel engines. Hence, engine operators do not readily recognize when combustion can be optimized. Stricter emission regulations, on the other hand, are forcing a closer look at combustion byproducts, and it would be natural to trace these byproducts back to their source.

One possible key to the phenomena of efficient combustion may be polar constituents in diesel fuel. Researchers have found many polar molecules among the thousands of different molecules produced through the diesel refining and blending process. In many cases, these polar molecules have been traced directly to objectionable emissions.



For example, the process of catalytic cracking takes heavier hydrocarbon molecules and breaks long chains into smaller ones, breaks condensed rings apart, and breaks branched chains off of rings. In the process, condensation reactions produce totally new compounds that are more polar, and may have free radicals and be more unstable. One common component of diesel that increases dramatically with cracking is aromatic compounds. In fuel, aromatics oxidize to form high molecular weight deposits –sludge and gum. Nitrogen, Oxygen and sulfur-containing aromatics cause fuel to darken. Aromatics do not burn well, producing carbon deposits and soot.

Benzene is a common building block of aromatics. Figure 3 shows the charge distribution on a benzene molecule. Asymmetrical charge distributions are a source of magnetic dipole moments, making these compounds receptive to manipulation in a magnetic field.

Phenomena associated with polar molecules are described by Professors George Mushrush, of George Mason University, and James Speight, of Western Research Institute, who have collaborated on the publication of *Petroleum Products: Instability and Incompatibility*, c1996, part of the Taylor and Francis Applied Energy Technology Series. In the same series is *Chemistry of Diesel Fuels*, edited by Dr. C. Song, at Penn State, Dr. C. Hsu, of Exxon Mobil Research and Engineering Company, and Dr. Isao Mochida, of Kyushu University's Institute of Advanced Material Study.

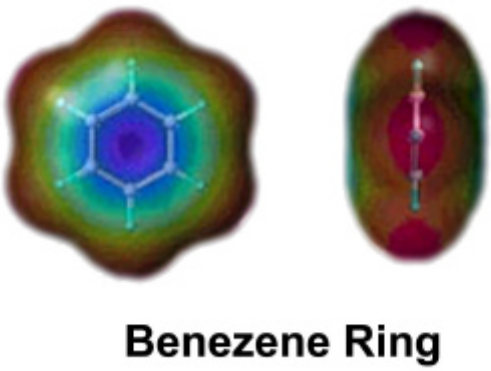



**Figure 3. Charge Distribution on a Benzene Ring**

The research papers published in these books describe the many fuel instability reactions inherent in diesel. Mushrush and Speight describe how common instability and oxidation reactions taking place during transport and storage alter the polarity of molecules, leading to polymerization and various degrees and types of sedimentation, including gel-like slime commonly found on fuel filter elements.

"Alkylated pyridines, quinolines, tetrahydroquinolines, indoles, pyrroles and carbazoles are all polar nitrogen species found in diesel fuels." (See Mushrush and Speight, p 183-196). Mushrush and Speight have observed that some of these precursors incorporate additional oxygen, sulfur or nitrogen functional groups, thereby becoming more polar, and undergoing phase separation. The increasing size of clusters of molecules affects intermolecular spacing and result in: (1) the formation of various sediments, (2) discoloration of fuel (3) formation of slime and varnish in the fuel system (4) lost engine efficiency (5) carbon deposits on fuel injectors, pistons, rings, exhaust components (6) engine wear and (7) hazardous emissions. [1] Because polarity produces magnetic dipoles, these clusters can be manipulated and disassembled by the strong magnetic field in a

[1] Chemical Engineers at Ondeo Nalco have compiled a body of knowledge published as the Fuel Field Manual, (Kim Peyton editor, revised edition, c2002, ISBN 0071387862). This publication substantiates and describes in more detail the many physical and chemical phenomena of polar molecules in the aromatic, olefinic, naphthenic and asphaltenic groups making up diesel fuels. These phenomena are cited as causes of handling, storage, filtration and combustion performance problems. (Peyton, p 71 – 136)

treatment device, eliminating slime, producing greater engine efficiency and cleaner combustion.

**IRON IN OIL FUEL CONSTITUENTS**

In Crude Oil Waxes, Emulsion and Asphaltenes (c1997, Pennwell, ISBN 0878147373), J.R. Becker, a chemical testing consultant specializing in oil field technology, refers to the successful use and application of magnetic treatment in oil production facilities by most major oil and oilfield supply companies around the world (i.e., Shell, Pemex, Caltex, Halliburton, etc.). He includes in his text observed magnetic phenomena with asphaltene flocculations, wax and scale. Becker observed that protoporphyin (the constituent of many substances, including both oil and blood, that imparts a red color) contains caged iron atoms that respond to magnetic fields in such a way as to inhibit aggregations of molecules. Figure 4 depicts his theory of the structure responsible for observed phenomena The presence of trace quantities of iron makes many substances susceptible to influence from magnetic fields.

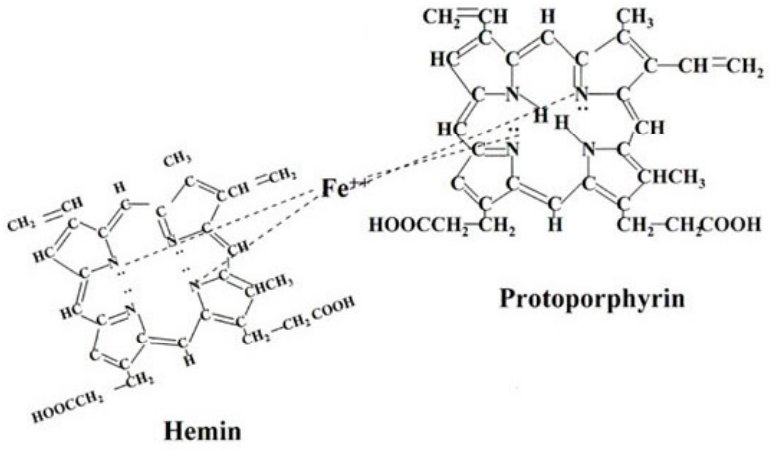



**Figure 4 Caged Hemin in Protoporphyrin Molecule**

Many university researchers, including Florida A&M and Florida State University, have studied effects of high magnetic field on human blood. They found that the magnetic field induces orientation effects on red blood cells, causing them to orient with their desk plane parallel to the applied field. They also found that magnetic fields have an effect on the normal and sickle hemoglobin. [Motta, M., Pai, V. M., Haik, Y. and Chen C. J. "High Magnetic Field Effect on Human Deoxyhemoglobin Light Absorption," Journal of Bioelectrochemistry and Bioenergetics, Vol. 47, pp. 297-300, 1998.] Orientational effects may be attributed to the diamagnetic anisotropy.

Becker also describes quantum phenomena associated with hydrogen bonding, Van der Waals forces, London dispersion forces and ionic interactions in aggregation and polymerization. Relating these known forces to observed successful treatment of crude with magnetic devices, he explains the evident electrostatic behavior. Essentially, there

are numerous quantum phenomena at work in molecules that make them responsive to magnetic fields.

The understanding of chemical bonding has evolved in the last ten years, as more details are known about the behavior of electron orbitals. Traditionally, two forms of chemical bonds were recognized – ionic and covalent. Physicists have discovered additional types of bonds arising from electron behavior. Figure 5 shows London Forces in an

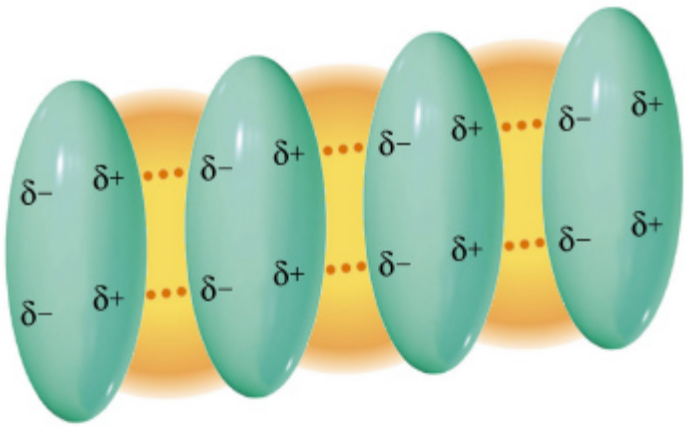



**Figure 5. London Forces in an Alkane Molecule**

Alkane molecule (a common hydrocarbon component). London bonding forces are the result of electron movement in polar or non-polar molecules that produce temporary dipole moments (positive-to-negative charge variations on a given molecule). These London Forces are considered the weakest kind of attractive forces (as much as 1/100$^{th}$ the strength of ionic or covalent bonds).

Figure 6 shows Becker's structure for an asphaltene-maltene sheath. Polysulfide protoporphyrin (the same molecule that eggshells brown on some eggs) is surrounded by an alkyl-substituted fused pyrrole. The spine like projections are aliphatic tails of the sheath. London forces produce the interactions of the spine like alkyl projections with similar alkyl groups in the liquid. This sheath can be disturbed by a magnetic field.

Becker's model of how magnetic fields disturb weak intermolecular bonds can be applied to diesel fuel's large molecules, because the same bonding forces are believed to be at work in the reactions described in Speight, Mushrush and other diesel instability researchers. So, instead of seeing only ionic or covalent bonds present in diesel fuel, researchers are beginning to recognize weaker bonds at work in molecular arrangements and aggregations. Field trials and laboratory testing of in-fuel magnetic treatment devices indicate the magnetic field has great potential to alleviate many of the

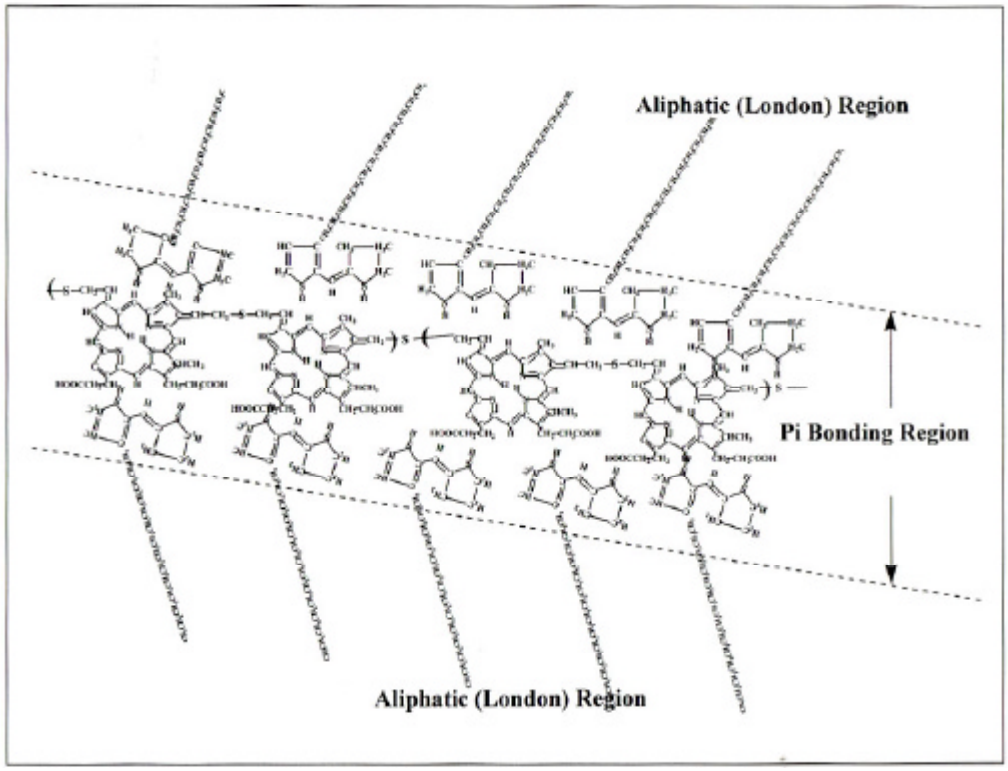



**Figure 6. Spine like alkyl projections resulting from London inductive forces.**

## MAGNETIC PRINCIPLES AND FUEL FLOW

Quantum researchers have found that all atoms are at least slightly magnetic. In the simplified model of an atom, the electrons rotate about their own axes (spin) and also orbit the nucleus. Electron spin produces the vast majority of an atom's magnetic field. In strongly magnetic materials, (such as permanent magnets) the magnetic field is a function of the coordinated electron spins of all of the atoms in that material.

Materials with canceling electron spins are weakly repelled by a magnetic field and referred to as "diamagnetic." Materials with unbalanced electron spins are slightly attracted by a magnetic field and referred to as "paramagnetic." In ferrous materials, a magnetic field may temporarily coordinate electron spin, adjusting all these tiny magnets to point in one direction, and creating a temporary magnet. In permanent magnetic materials, the magnetic domains have been permanently coerced to point into one direction creating a permanent magnetic field.

A basic tenet of electro-magnetism is that a magnetic field exerts a force upon any charged entity intersecting the magnetic flux lines. This phenomena is named the Lorentz Force, for the 19$^{th}$ Century Dutch physicist who discovered it. An application of the Lorentz Force is seen in the cathode ray tube inside a computer monitor or TV (non-

LCD type). The monitor uses an electro magnet and a high voltage source to produce a directed stream of particles that make the images on the screen. This accounts for the bulk and weight of the TV compared to a plasma display for LCD.

Fluids containing polar constituents are also influenced by magnetic fields, because polar molecules are, by definition, electrically charged. As fuel passes through a magnetic field, the Lorentz Force is exerted on these polar fuel constituents, shifting charge distributions and creating subtle changes in the weak bonding forces, such as London Forces.

The Lorentz Force is stated as

$$F = qV \times B$$

where ***q*** is the charge on a particle, **v** is its velocity, and **B** is the magnetic field.

Figure 7 shows flux lines and the flow of fuel through the magnetic field intersecting those lines. The magnetic field in the Algae-X fuel conditioner has a density of approximately 6,700 lines per square inch. The length of the pathway through the field (residence time for energy transfer) and velocity in the field depends on the Algae-X model and fuel flow rate in the system.

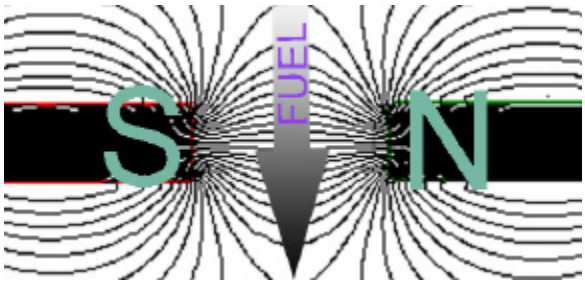



**Figure 7. Fuel flow through magnetic flux lines.**

The Lorentz Equation describes the force of a magnetic field on any charged particle intersecting the flux lines of that field. Maxwell's equations describe the process by which magnetic fields induce electric charges.

According to molecular orbital theory, a covalent bond is formed by the overlapping of atomic orbitals, to form molecular orbitals. An electron in a molecular orbital is influenced by more than one nucleus. Lehn, 1993, identified Sigma and Pi bonds as non-covalent intermolecular binding interactions. Sigma and Pi orbitals are influenced by the presence of a magnetic field and the induced charge.

It is generally accepted that Sigma bond and Pi bond strength are functions of the amount of overlap between the orbitals. The magnetic field has the ability to influence the behavior of orbitals enough to alter overlap, weak bonds, and polarity, and produce a reversal of these electromagnetic forces of cohesion. Variables in the equation are velocity of the molecules moving through the magnetic field, the angle at which they intersect the lines of flux, and flux density.

Figure 8 is a schematic depiction of the principle of Becker's explanation of how a magnetic field will influence the existing balance and excite electrons in a sufficient number of molecules to interrupt or reverse aggregation. The three vertical, long-chain molecules are shown in the cutaway of the fluid flow through the magnetic field. Two

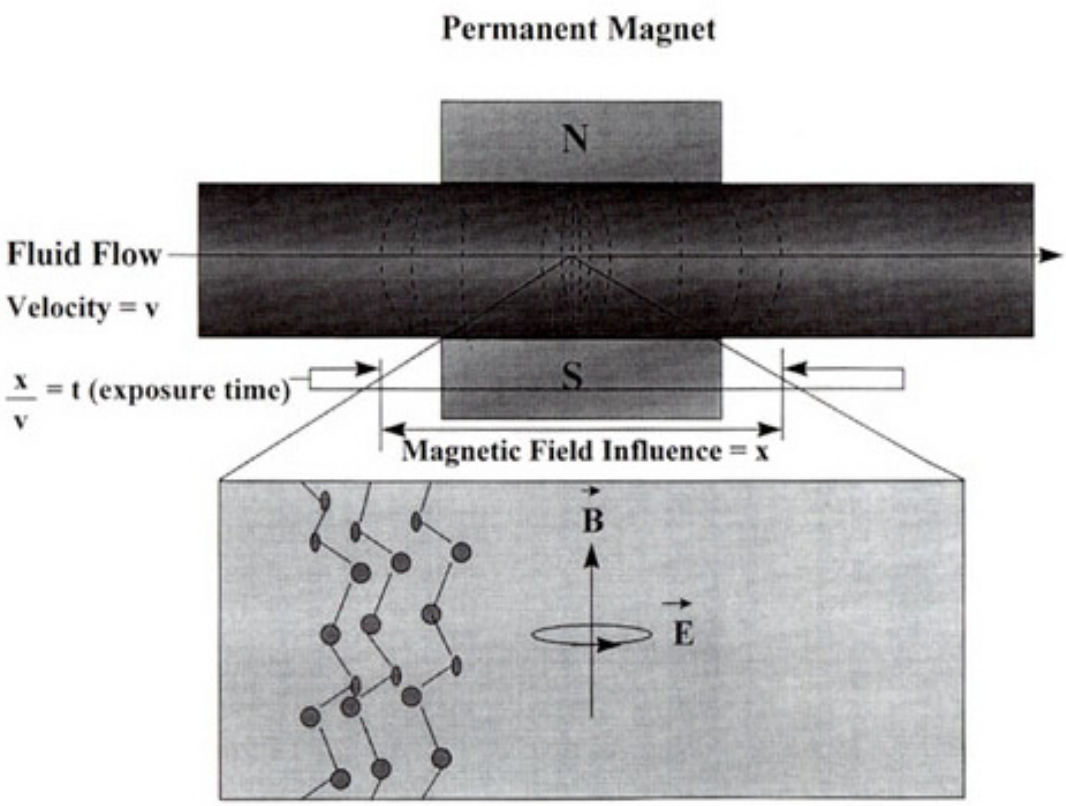



**Figure 8 Repulsion of Aggregations in Magnetic Field**

molecules on the left have nested and formed an aggregation and the third chain is resisting or breaking away from the aggregation because of the effect of the magnetic field.

Batts and Fathoni conducted an extensive study of storage and thermal stability of diesel fuels, published in *Energy and Fuels* volume 5, 2-21, titled "A Literature Review on Fuel Stability Studies with Particular Emphasis on Diesel Oil." Investigators in the cited studies found that the process of natural sedimentation resulting from polarity is known to take days, weeks or months. Our experience has shown that the effects of circulating fuel through the Algae-X magnetic fuel treatment system are cumulative. Upon installation, sediment and sediment precursors are being disrupted and dispersed, fuel filterability is improved immediately, and combustion efficiency is enhanced. Over time, cumulative effects on the total fuel system are being observed. We see a gradual reduction and elimination of tank sludge and carbon deposits in the combustion chamber and exhaust trunk. Changes in the "delta p" over the fuel filter, and lower exhaust gas

temperatures, also occur immediately upon installation and normal everyday system operation.

Many university researchers, including Linus Pauling, have found a variety of causes for molecules to respond to magnetic fields by rotating to align themselves with magnetic North. This preference for alignment is described as diamagnetic aniosotropy. Pauling attributed the diamagnetic anisotropy to an induced current in the aromatic side chains of organic molecules. For instance, the diamagnetic anisotropy for benzene was calculated to be $-49.2 \times 10^{-6}$. [Pauling, L. "Diamagnetic Anisotropy of the Peptide Group," Proceedings of the National Academy of Science, Vol. 76, No. 5, pp. 2293-2294, 1979]. Figure 9, courtesy of Prentice Hall's *Organic Chemistry*, shows how variable charge distribution is on complex molecules. The molecules on the right and left exhibit stronger charges on the darker regions.

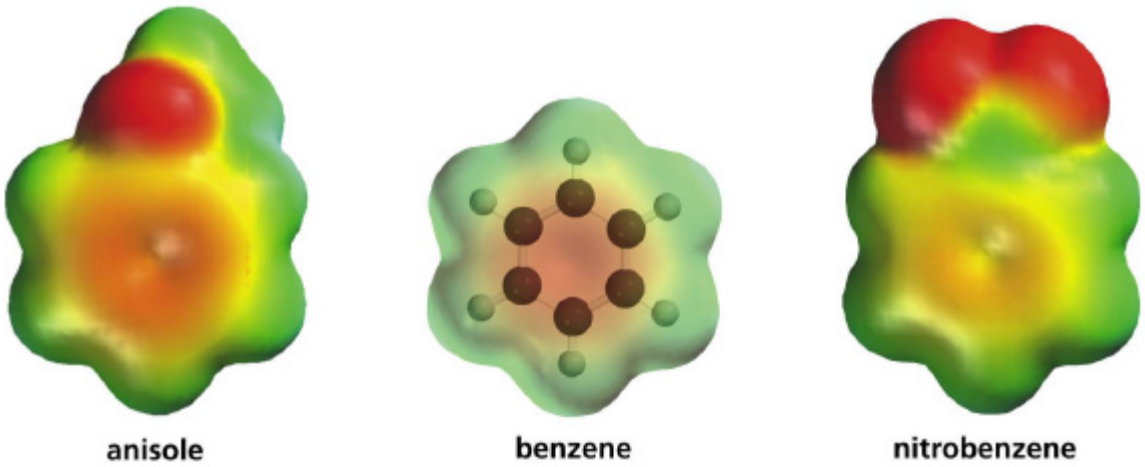



**Figure 9. Variations in Charge Distribution**

## CONCLUSION

Years of experience with magnetic treatment of diesel fuels have shown that this technology offers a viable, low-cost method for the reduction of diesel emission with only positive effects on engines, exhaust treatment systems and the environment. Today, all over the world, many thousands of diesel engines burning middle-distillate fuels are successfully using Algae-X Magnetic Fuel Conditioners. Every day they are enjoying the benefits of improved fuel economy, and reduced soot, particulates and other harmful emissions.

Results of improving fuel filterability and lowering exhaust gas temperatures are easy to demonstrate immediately. Ecologic Engine Testing Labs, in Costa Mesa, California, has quantified combustion improvements by method of a 13 Mode US EPA protocol, demonstrating a reduction of all gaseous and particulate emissions. Many independent customer evaluations over several years have resulted in numerous installations of our technology in the marine and on-highway industries and in transit fleets.