Magnetic Treatment of Diesel Fuel

By Suzanne Nightingale

Fuel, fuel constituents and fuel stability

Diesel fuel is an inherently unstable organic fluid. It varies in physical and chemical characteristics, depending on the origin of the source material and the refining processes. Diesel contains thousands of different constituents (see Figure 1) that do not exist in a homogeneous form. The absence of homogeneity contributes to large and small fuel particle sizes. Figure 2 shows photomicrographs (courtesy Caleb Brett) of bunker fuel particles. The chemical

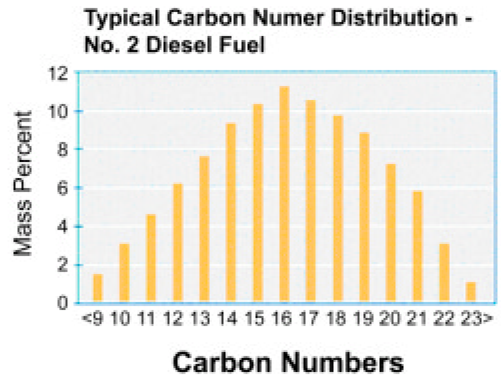

Figure 1. Carbon Number Distribution in No. 2 Diesel

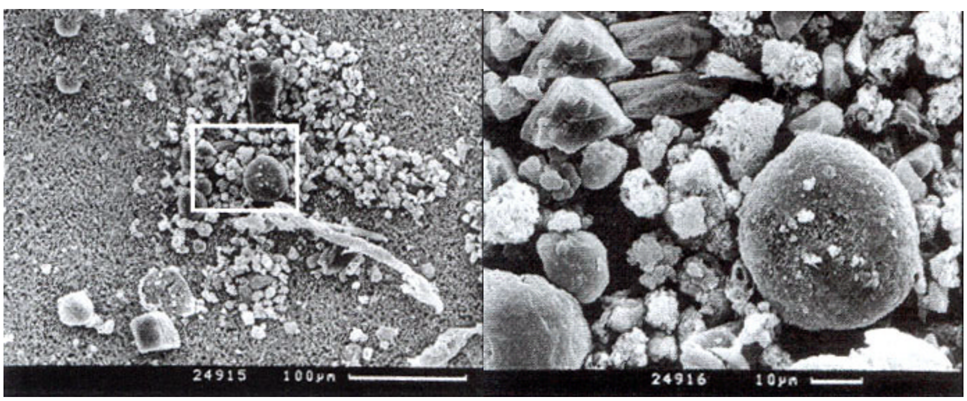

Figure 2 Photomicrograph of fuel particles. Scale on left is 100 micron. Right 10 micron.

characteristics, physical make up and state affect fuel stability, filterability, and ultimately, combustion efficiency and undesirable emission by-products.

Researchers have found many polar molecules among the thousands of different molecules produced through middle-distillate refining, cracking and blending. Figure 3 shows the charge distribution on a benzene molecule. Asymmetrical charge distributions are a source of dipole moments. 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.

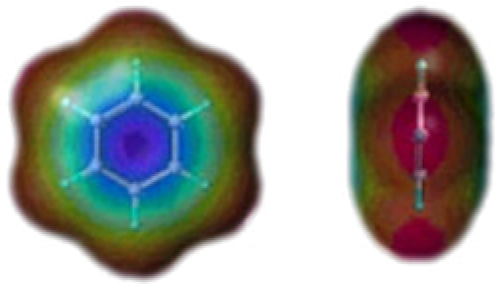

Figure 3. Charge Distribution on a Benzene Ring

The research papers published in these books describe the many fuel instability reactions inherent in diesel. Modern refining processes, oxidation, temperature changes, heat, pressure, microbial activity, water, etc., all contribute to polymerization and an increase in size, mass and polarity of clusters of agglomerated fuel. These factors all result in the formation of various sediments, less than ideal atomization, and combustion pollutants.

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 agglomerated molecules affects intermolecular spacing and makes it difficult for fuel to atomize optimally, contributing to incomplete combustion, the major cause of undesirable diesel emissions.

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)

Magnetic Fields, Fuel and Oil

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. He notes that protoporphyin may contain 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.

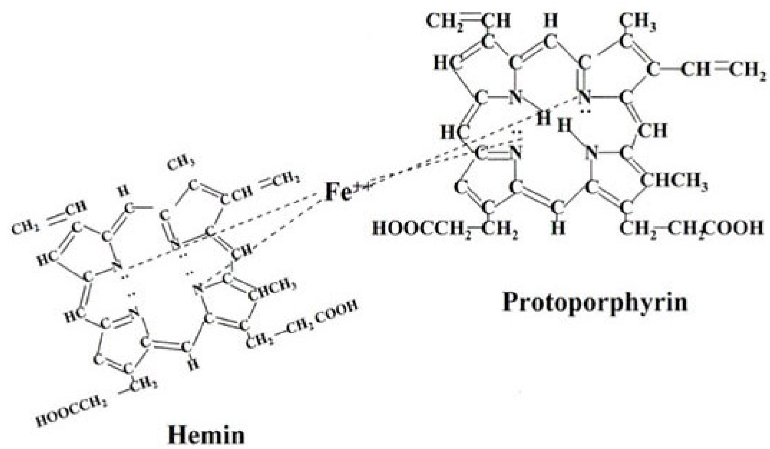

Figure 3 Caged Hemin in Protoporphyrin Molecule

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.

The understanding of chemical bonding has evolved in the past ten years, as more details are known about the behavior of electron orbitals. Figure 5 shows London Forces in an

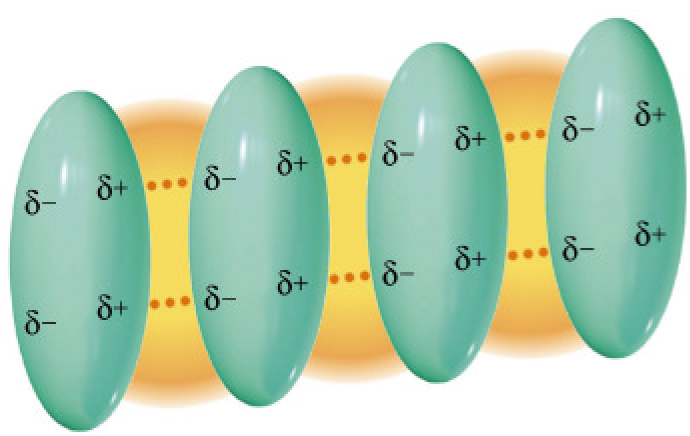

Figure 4. London Forces in an Alkane Molecule

Alkane molecule. London forces are the result of electron movement in polar or non-polar molecules that produce temporary dipole moments. They are considered the weakest kind of forces (as much as 1/100th the strength of ionic or covalent bonds).

Figure 6 shows Becker's structure for an asphaltene-maltene sheath. Polysulfide protoporphyrin 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.

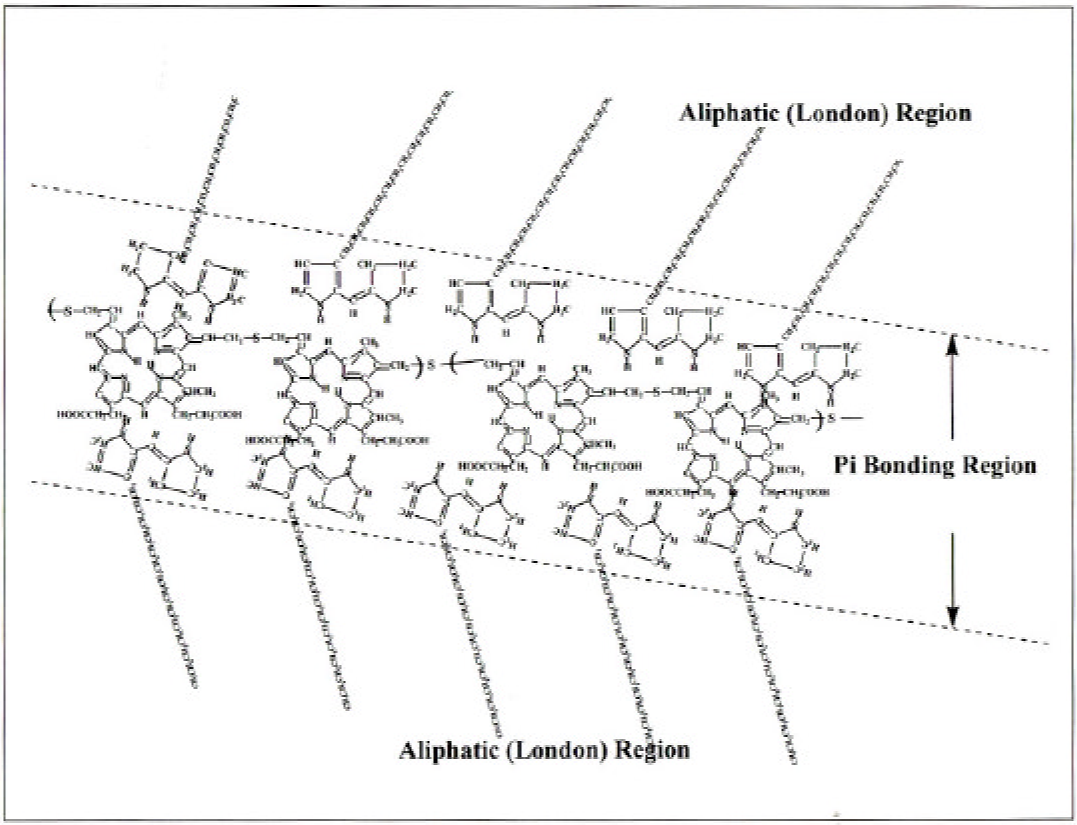

Figure 6. Spine like alkyl projections resulting from London inductive forces.

Becker's model of how magnetic fields disturb weak intermolecular bonds can be applied to large molecules and agglomerations in diesel fuels.

Magnetic Principles and Fuel Flow

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 magnetic materials, 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 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.

The principle that a magnetic field exerts a force upon any charged entity intersecting the magnetic flux lines, applies not only to electrons in conductors (such as copper wire) but also to fluids containing polar constituents. 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. 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.

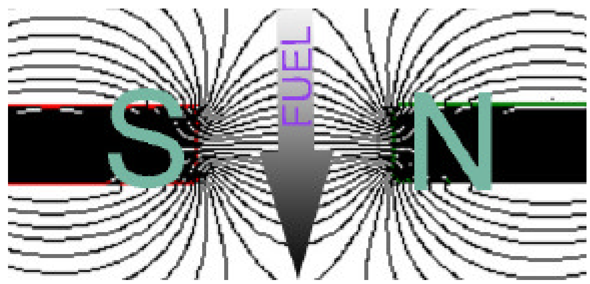

Figure 7. Fuel flow through magnetic flux lines.

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 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.

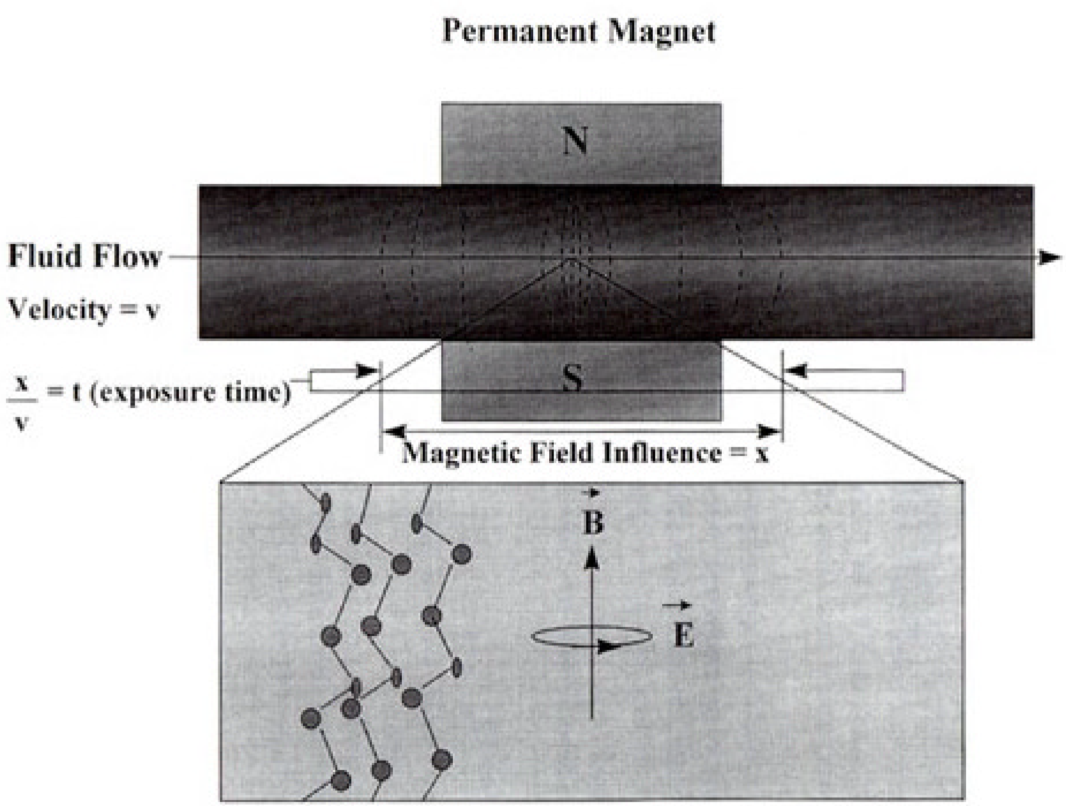

Figure 8 Repulsion of Aggregations in Magnetic Field

Batts and Fathoni's 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 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. This behavior was studied by many investigators. Linus 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 -49.2×10^{-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 shows charge distribution of benzene, anisol and nitrobenzene. This figure, courtesy of Prentice Hall’s *Organic Chemistry*, shows how variable charge distribution is.

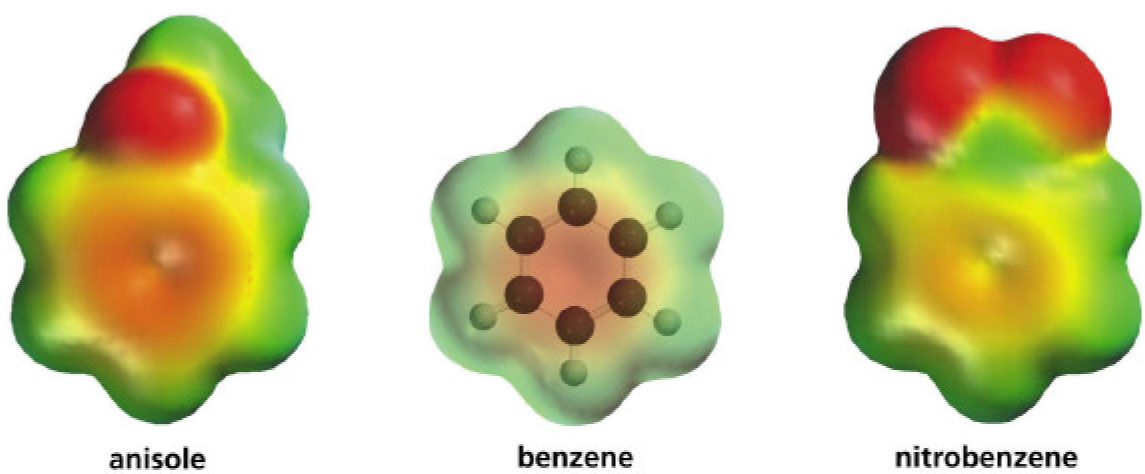

Figure 9. Variations in Charge Distribution

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.