Alternative Fuel/ Vehicle Emissions

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U.S. Corn Production Seen Dropping, Though More to Be Used for Ethanol

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DES MOINES, Iowa -- The U.S. Department of Agriculture expects corn production this year to be down 7% from the record breaking heights of 2007.

The report released Friday projects about 12 billion bushels of corn will be harvested this year. Wet weather has slowed corn plantings, causing the greatest delay since 1995. The USDA reports that only 27% of the nation's corn crop had been planted through May 4.

The report is unwelcome news for those looking for relief in corn prices. The crop's price has skyrocketed over the last year to more than $6 a bushel, amid an ethanol boom and more demand for exports.

The U.S. ethanol industry will consume four billion bushels of corn during the 2008-09 marketing year, a one-billion-bushel increase from 2007-08, the U.S. Department of Agriculture said Friday in its monthly supply and demand report.

Supply is expected to remain tight, but lower exports and feed demand from livestock producers are expected to more than offset the rising needs of ethanol producers. "Feed and residual use is projected down 14% as corn feeding declines with increased production of distillers grains, higher corn prices and reduced red meat production," the USDA said in the report.

The increase in corn usage by ethanol producers was generally expected. An energy bill recently approved by Congress and signed into law mandates the production of 15 billion gallons of corn-based ethanol annually by 2015.

The new USDA forecast for U.S. corn production for the 2008-09 marketing year is 12.125 billion bushels, down from the 13.074 billion produced last year.

"Corn exports are projected down 16% as U.S. supplies face increased world competition with increased foreign production and a sharp drop in [European Union]imports," the USDA said.

U.S. corn exports are predicted to drop to 2.1 billion bushels, down from 2.5 billion in the 2007-08 marketing year.

--The Associated Press contributed to this article.

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Gasoline

From Wikipedia, the free encyclopedia

Gasoline or **petrol** is a petroleum-derived liquid mixture consisting mostly of aliphatic hydrocarbons and enhanced with aromatic hydrocarbons toluene, benzene or iso-octane to increase octane ratings, primarily used as fuel in internal combustion engines. Most Commonwealth countries or former Commonwealth countries, with the exception of Canada, use the term "petrol" (abbreviated from *petroleum spirit*). The term "gasoline" is commonly used in North America where it is often shortened in colloquial usage to "gas". This should be distinguished in usage from genuinely gaseous fuels used in internal combustion engines such as liquified petroleum gas (which is stored pressurised as a liquid but is allowed to return naturally to a gaseous state before combustion). The term *mogas*, short for *motor gasoline*, distinguished automobile fuel from *aviation gasoline*, or avgas. The word "gasoline" can also be used in British English to refer to a different petroleum derivative historically used in lamps; however, this use is now uncommon.

Contents

History

Early uses

Before internal-combustion engines were invented in the mid 19th century, gasoline was sold in small

bottles as a treatment against lice and their eggs. At that time, the word *Petrol* was a trade name. This treatment method is no longer common, because of the inherent fire hazard and the risk of dermatitis.

In the U.S., gasoline was also sold as a cleaning fluid to remove grease stains from clothing. Before dedicated filling stations were established, early motorists would buy gasoline in cans to fill their tanks.

The name *gasoline* is similar to that of other petroleum products of the day, most notably petroleum jelly, a highly purified heavy distillate, which was branded *Vaseline*. The trademark *Gasoline*, however, was never registered, and thus became generic.

Gasoline was also used in kitchen ranges and for lighting, and is still available in a highly purified form, known as *camping fuel* or *white gas*, for use in lanterns and portable stoves.

During the Franco-Prussian War (1870–1871), *pétrole* was stockpiled in Paris for use against a possible German-Prussian attack on the city. Later in 1871, during the revolutionary Paris Commune, rumours spread around the city of *pétroleuses*, women using bottles of petrol to commit arson against city buildings.

Etymology

The word "gasolene" was coined in 1865 from the word gas and the chemical suffix -ine/-ene. The modern spelling was first used in 1871. The shortened form "gas" was first recorded in American English in 1905.[1] Gasoline originally referred to any liquid used as the fuel for a gasoline-powered engine, other than diesel fuel or liquefied gas. Methanol racing fuel would have been classed as a type of gasoline.[2]

The word "petrol" was first used in reference to the refined substance as early as 1892 (it previously referred to unrefined petroleum), and was registered as a trade name by British wholesaler Carless, Capel & Leonard[3]. Although it was never officially registered as a trademark, Carless's competitors used the term "Motor Spirit" until the 1930s. [4]

In Germany and some other European countries, gasoline is called *Benzin*. The usage does not derive from Bertha Benz, who used chemist shops to purchase the gasoline for her famous drive from Mannheim to Pforzheim in 1888, but from the chemical benzene.

Chemical analysis and production

Gasoline is produced in oil refineries. Material that is separated from crude oil via distillation, called virgin or straight-run gasoline, does not meet the required specifications for modern engines (in particular octane rating; see below), but will form part of the blend.

The bulk of a typical gasoline consists of hydrocarbons with between 5 and 12 carbon atoms per molecule.

Many of these hydrocarbons are considered hazardous substances and are regulated in the United States by OSHA. The Material Safety Data Sheet for unleaded gasoline shows at least fifteen hazardous chemicals occurring in various amounts. These include benzene (up to 5% by volume), toluene (up to 35% by volume), naphthalene (up to 1% by volume), trimethylbenzene (up to 7% by volume), MTBE

(up to 18% by volume) and about 10 others.[5]

The various refinery streams blended together to make gasoline all have different characteristics. Some important streams are:

- *Reformate*, produced in a catalytic reformer with a high octane rating and high aromatic content, and very low olefins (alkenes).
- *Cat Cracked Gasoline* or *Cat Cracked Naphtha*, produced from a catalytic cracker, with a moderate octane rating, high olefins (alkene) content, and moderate aromatics level. *Here, "cat" is short for "catalyst".*
- *Hydrocrackate* (Heavy, Mid, and Light), produced from a hydrocracker, with medium to low octane rating and moderate aromatic levels.
- *Virgin or Straight-run Naphtha* (has many names), directly from crude oil with low octane rating, low aromatics (depending on the crude oil), some naphthenes (cycloalkanes) and no olefins (alkenes).
- *Alkylate*, produced in an alkylation unit, with a high octane rating and which is pure paraffin (alkane), mainly branched chains.
- *Isomerate* (various names) which is obtained by isomerising the pentane and hexane in light virgin naphthas to yield their higher octane isomers.

(The terms used here are not always the correct chemical terms. They are the jargon normally used in the oil industry. The exact terminology for these streams varies by refinery and by country.)

Overall a typical gasoline is predominantly a mixture of paraffins (alkanes), naphthenes (cycloalkanes), aromatics and olefins (alkenes). The exact ratios can depend on

- the oil refinery that makes the gasoline, as not all refineries have the same set of processing units.
- the crude oil used by the refinery on a particular day.
- the grade of gasoline, in particular the octane rating.

Currently many countries set tight limits on gasoline aromatics in general, benzene in particular, and olefins (alkene) content. This is increasing the demand for high octane pure paraffin (alkane) components, such as alkylate, and is forcing refineries to add processing units to reduce the benzene content.

Gasoline can also contain some other organic compounds: such as organic ethers (deliberately added), plus small levels of contaminants, in particular sulfur compounds such as disulfides and thiophenes. Some contaminants, in particular thiols and hydrogen sulfide, must be removed because they cause corrosion in engines.

Volatility

Gasoline is more volatile than diesel oil, Jet-A or kerosene, not only because of the base constituents, but because of the additives that are put into it. The final control of volatility is often achieved by blending with butane. The Reid Vapor Pressure test is used to measure the volatility of gasoline. The desired volatility depends on the ambient temperature: in hotter climates, gasoline components of higher molecular weight and thus lower volatility are used. In cold climates, too little volatility results in cars failing to start. In hot climates, excessive volatility results in what is known as "vapour lock" where combustion fails to occur, because the liquid fuel has changed to a gaseous fuel in the fuel lines.

In the United States, volatility is regulated in large urban centers to reduce the emission of unburned hydrocarbons. In large cities, so-called reformulated gasoline that is less prone to evaporation, among other properties, is required. In Australia summer petrol volatility limits are set by State Governments and vary between capital cities. Most countries simply have a summer, winter and perhaps intermediate limit.

Volatility standards may be relaxed (allowing more gasoline components into the atmosphere) during emergency anticipated gasoline shortages. For example, on 31 August 2005 in response to Hurricane Katrina, the United States permitted the sale of non-reformulated gasoline in some urban areas, which effectively permitted an early switch from summer to winter-grade gasoline. As mandated by EPA administrator Stephen L. Johnson, this "fuel waiver" was made effective through 15 September 2005 [7] (http://www.epa.gov/katrina/activities/week1.html#aug31johnson). Though relaxed volatility standards may increase the atmospheric concentration of volatile organic compounds in warm weather, higher volatility gasoline effectively increases a nation's gasoline supply because the amount of butane in the gasoline pool is allowed to increase.[8] (http://i-r-squared.blogspot.com/2006/09/here-comes-winter-gasoline.html)

Octane rating

For more details on this topic, see octane rating.

An important characteristic of gasoline is its octane rating, which is a measure of how resistant gasoline is to the abnormal combustion phenomenon known as detonation (also known as knocking, pinging, spark knock, and other names). Deflagration is the normal type of combustion. Octane rating is measured relative to a mixture of 2,2,4-trimethylpentane (an isomer of octane) and n-heptane. There are a number of different conventions for expressing the octane rating; therefore, the same fuel may be labeled with a different number, depending upon the system used.

World War II and octane ratings

World War II Germany received much of its oil from Romania. From 2.8 million barrels in 1938, Romania's exports to Germany increased to 13 million barrels by 1941, a level that was essentially maintained through 1942 and 1943, before dropping by half, due to Allied bombing and mining of the Danube. Although these exports were almost half of Romania's total production, they were considerably less than what the Germans expected. Even with the addition of the Romanian deliveries, overland oil imports after 1939 could not make up for the loss of overseas shipments. In order to become less dependent on outside sources, the Germans undertook a sizable expansion program of their own meager domestic oil pumping. After 1938, the Austrian oil fields were made available, and the expansion of Nazi crude oil output was chiefly concentrated there. Primarily as a result of this expansion, the Reich's domestic output of crude oil increased from approximately 3.8 million barrels in 1938 to almost 12 million barrels in 1944. Even this was not enough.

Instead, Germany had developed a synthetic fuel capacity that was intended to replace imported or captured oil. Fuels were generated from Coal, using either the Bergius process or the Fischer-Tropsch process. Between 1938 and 1943, synthetic fuel output underwent a respectable growth from 10 million barrels to 36 million. The percentage of synthetic fuels compared with the yield from all sources grew from 22 percent to more than 50 percent by 1943. The total oil supplies available from all sources for the

same period rose from 45 million barrels in 1938 to 71 million barrels in 1943.

By the early 1930s, automobile gasoline had an octane reading of 40 and aviation gasoline of 75-80. Aviation gasoline with such high octane numbers could only be refined through a process of distillation of high-grade petroleum. Germany's domestic oil was not of this quality. Only the additive tetra-ethyl lead could raise the octane to a maximum of 87. The license for the production of this additive was acquired in 1935 from the American holder of the patents, but without high-grade Romanian oil even this additive was not very effective.

In the US the oil was not "as good," and the oil industry had to invest heavily in various expensive boosting systems. This turned out to have benefits: the US industry started delivering fuels of increasing octane ratings by adding more of the boosting agents, and the infrastructure was in place for a post-war octane-agents additive industry. Good crude oil was no longer a factor during wartime, and by war's end, American aviation fuel was commonly 130 to 150 octane. This high octane could easily be used in existing engines to deliver much more power by increasing the pressure delivered by the superchargers. The Germans, relying entirely on "good" gasoline, had no such industry, and instead had to rely on ever-larger engines to deliver more power.

However, German aviation engines were of the direct-fuel-injection type, and could use methanol-water injection and nitrous oxide injection, which gave 50% more engine power for five minutes of dogfight. This could be done only five times or after 40 hours run-time, and then the engine would have to be rebuilt. Most German aero engines used 87 octane fuel (called B4), while some high-powered engines used 100 octane (C2/C3) fuel.

This historical "issue" is based on a very common misapprehension about wartime fuel octane numbers. There are two octane numbers for each fuel, one for lean mix and one for rich mix, rich being always greater. So, for example, a common British aviation fuel of the later part of the war was 100/125. The misapprehension that German fuels have a lower octane number (and thus a poorer quality) arises because the Germans quoted the lean mix octane number for their fuels while the Allies quoted the rich mix number for their fuels. Standard German high-grade aviation fuel used in the later part of the war (given the designation C3) had lean/rich octane numbers of 100/130. The Germans would list this as a 100 octane fuel while the Allies would list it as 130 octane.

After the war the US Navy sent a Technical Mission to Germany to interview German petrochemists and examine German fuel quality. Their report entitled "Technical Report 145-45 Manufacture of Aviation Gasoline in Germany" chemically analyzed the different fuels, and concluded that "Toward the end of the war the quality of fuel being used by the German fighter planes was quite similar to that being used by the Allies."

Energy content

Gasoline contains about 34.6 megajoules per litre (MJ/l) or 131 MJ/US gallon. This is an average, gasoline blends differ, therefore actual energy content varies from season to season and from batch to batch, as much as 4% more or less than the average, according to the US EPA.

Volumetric energy density of some fuels compared with gasoline:[6]

Fuel type	MJ/l	MJ/kg	BTU/Imp gal	BTU/US gal	Research octane number (RON)
Regular Gasoline	34.8	44.4[7]	150,100	125,000	Min 91
Premium Gasoline					Min 95
Autogas (LPG) (60% Propane + 40% Butane)	26.8				
Ethanol	23.5	31.1[8]	101,600	84,600	129
Methanol	17.9	19.9	77,600	64,600	123
Gasohol (10% ethanol + 90% gasoline)	33.7		145,200	120,900	93/94
Diesel	38.60	45.41	166,600	138,700	25(*)
Aviation gasoline (high octane gasoline, not Jet fuel)	33.5	46.8	144,400	120,200	
Liquefied natural gas	25.3	~55	109,000	90,800	

(*) Diesel is not used in a gasoline engine, so its low octane rating is not an issue; the relevant metric for diesel engines is the cetane number

A high octane fuel such as LPG has a lower energy content than lower octane gasoline, resulting in an overall lower power output at the regular compression ratio an engine ran at on gasoline. However, with an engine tuned to the use of LPG (ie. via higher compression ratios such as 12:1 instead of 8:1), this lower power output can be overcome. This is because higher-octane fuels allow for a higher compression ratio - this means less space in a cylinder on its combustion stroke, hence a higher cylinder temperature which improves efficiency according to Carnot's theorem, along with fewer wasted hydrocarbons (therefore less pollution and wasted energy), bringing higher power levels coupled with less pollution overall because of the greater efficiency.

The main reason for the lower energy content (per litre) of LPG in comparison to gasoline is that it has a lower density. Energy content per kilogram is higher than for gasoline (higher hydrogen to carbon ratio). The weight-density of gasoline is about 737.22 kg/m^3.

Different countries have some variation in what RON (Research Octane Number) is standard for gasoline, or petrol. In the UK, ordinary regular unleaded petrol is 91 RON (not commonly available), premium unleaded petrol is always 95 RON, and super unleaded is usually 97-98 RON. However both Shell and BP produce fuel at 102 RON for cars with hi-performance engines, and the supermarket chain Tesco began in 2006 to sell super unleaded petrol rated at 99 RON. In the US, octane ratings in fuels can vary between 86-87 AKI (91-92 RON) for regular, through 89-90 (94-95) for mid-grade (European Premium), up to 90-94 (RON 95-99) for premium unleaded or E10 (Super in Europe)

Usage

The U.S. used about 521 billion litres (137 billion gallons) of gasoline in 2006, of which 5.6% was mid-grade and 9.5% was premium grade.[9]

Additives

Lead

The mixture known as gasoline, when used in high compression internal combustion engines, has a tendency to ignite early (*pre-ignition* or *detonation*) causing a damaging "engine knocking" (also called "pinging" or "pinking") noise. Early research into this effect was led by A.H. Gibson and Harry Ricardo in England and Thomas Midgley and Thomas Boyd in the United States. The discovery that lead additives modified this behavior led to the widespread adoption of the practice in the 1920s and therefore more powerful higher compression engines. The most popular additive was tetra-ethyl lead. However, with the discovery of the environmental and health damage caused by the lead, and the incompatibility of lead with catalytic converters found on virtually all US automobiles since 1975, this practice began to wane in the 1980s. Most countries are phasing out leaded fuel; different additives have replaced the lead compounds. The most popular additives include aromatic hydrocarbons, ethers and alcohol (usually ethanol or methanol).

In the U.S., where lead was blended with gasoline (primarily to boost octane levels) since the early 1920s, standards to phase out leaded gasoline were first implemented in 1973. In 1995, leaded fuel accounted for only 0.6 % of total gasoline sales and less than 2,000 tons of lead per year. From January 1, 1996, the Clean Air Act banned the sale of leaded fuel for use in on-road vehicles. Possession and use of leaded gasoline in a regular on-road vehicle now carries a maximum $10,000 fine in the United States. However, fuel containing lead may continue to be sold for off-road uses, including aircraft, racing cars, farm equipment, and marine engines until 2008 . The ban on leaded gasoline led to thousands of tons of lead not being released in the air by automobiles. Similar bans in other countries have resulted in lowering levels of lead in people's bloodstreams.[9] (http://www.findarticles.com/p/articles/mi_m0907/is_4_59/ai_n15727540) [10] (http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1247386).

A side effect of the lead additives was protection of the valve seats from erosion. Many classic cars' engines have needed modification to use lead-free fuels since leaded fuels became unavailable. However, "Lead substitute" products are also produced and can sometimes be found at auto parts stores.

Gasoline, as delivered at the pump, also contains additives to reduce internal engine carbon buildups, improve combustion, and to allow easier starting in cold climates.

In some parts of South America, Asia, Europe and the Middle East, leaded gasoline is still in use. Leaded gasoline was phased out in sub-Saharan Africa with effect from 1 January 2006. A growing number of countries have drawn up plans to ban leaded gasoline in the near future.

MMT

Methylcyclopentadienyl manganese tricarbonyl (MMT) has been used for many years in Canada and recently in Australia to boost octane. It also helps old cars designed for leaded fuel run on unleaded fuel without need for additives to prevent valve problems.

US Federal sources state that MMT is suspected to be a powerful neurotoxin and respiratory toxin, and a [11] (http://cvma.ca/eng/publications/FinalMMTReport.pdf) large Canadian study concluded that MMT impairs the effectiveness of automobile emission controls and increases pollution from motor vehicles.

In 1977, use of MMT was banned in the US by the Clean Air Act until the Ethyl Corporation could prove that the additive would not lead to failure of new car emissions-control systems. As a result of this ruling, the Ethyl Corporation began a legal battle with the EPA, presenting evidence that MMT was harmless to automobile emissions-control systems. In 1995, the U.S. Court of Appeals ruled that the EPA had exceeded its authority and, as a result, MMT became a legal fuel additive in the US.[3] MMT is nowadays manufactured by the Afton Chemical Corporation division of Newmarket Corporation [12] (http://www.aftonchemical.com/Products/MMT/History+of+MMT®.htm).

Ethanol

In the United States, ethanol is sometimes added to gasoline but sold without an indication that it is a component. Chevron, 76, Shell, and several other brands market ethanol-gasoline blends.

In several states, ethanol is added by law to a minimum level which is currently 5.9%. Most fuel pumps display a sticker stating that the fuel may contain up to 10% ethanol, an intentional disparity which allows the minimum level to be raised over time without requiring modification of the literature/labeling. The bill which was being debated at the time the disclosure of the presence of ethanol in the fuel was mandated has recently passed. This law (Energy Bill 2005) will require all auto fuel to contain at least 10% ethanol. Many call this fuel mix gasohol.

Dye

In the United States the most commonly used aircraft gasoline, avgas, or aviation gas, is known as 100LL (100 octane, low lead) and is dyed blue. Red dye has been used for identifying untaxed (non-highway use) agricultural diesel. The UK uses red dye to differentiate between regular diesel fuel, (often referred to as DERV), which is undyed, and diesel intended for agricultural and construction vehicles like excavators and bulldozers. Red diesel is still occasionally used on HGVs which use a separate engine to power a loader crane. This is a declining practice however, as many loader cranes are powered directly by the tractor unit.

Oxygenate blending

Oxygenate blending adds oxygen to the fuel in oxygen-bearing compounds such as MTBE, ETBE and ethanol, and so reduces the amount of carbon monoxide and unburned fuel in the exhaust gas, thus reducing smog. In many areas throughout the US oxygenate blending is mandated by EPA regulations to reduce smog and other airborn polutants. For example, in Southern California, fuel must contain 2% oxygen by weight, resulting in a mixture of 5.6% ethanol in gasoline. The resulting fuel is often known as *reformulated gasoline* (RFG) or *oxygenated gasoline*. The federal requirement that RFG contain oxygen was dropped May 6, 2006 because the industry had developed VOC-controlled RFG that did not need additional oxygen.[13] (http://www.epa.gov/otaq/rfg_regs.htm#usage)

MTBE use is being phased out in some states due to issues with contamination of ground water. In some places it is already banned. Ethanol and to a lesser extent the ethanol derived ETBE are a common

replacements. Especially since ethanol derived from biomatter such as corn, sugar cane or grain is frequent, this will often be referred to as *bio*-ethanol. A common ethanol-gasoline mix of 10% ethanol mixed with gasoline is called gasohol or E10, and an ethanol-gasoline mix of 85% ethanol mixed with gasoline is called E85. The most extensive use of ethanol takes place in Brazil, where the ethanol is derived from sugarcane. Over 3,400 million US gallons (13,000,000 m^3) of ethanol mostly produced from corn was produced in the United States in 2004 for fuel use, and E85 is slowly becoming available in much of the United States. Unfortunately many of the relatively few stations vending E85 are not open to the general public.[14] (http://www.eere.energy.gov/afdc/infrastructure/locator.html) The use of bioethanol, either directly or indirectly by conversion of such ethanol to *bio*-ETBE, is encouraged by the European Union Directive on the Promotion of the use of biofuels and other renewable fuels for transport. However since producing bio-ethanol from fermented sugars and starches involves distillation, ordinary people in much of Europe cannot ferment and distill their own bio-ethanol at present (unlike in the US where getting a BATF distillation permit has been easy since the 1973 oil crisis.)

Health concerns

Many of the non-aliphatic hydrocarbons naturally present in gasoline (especially aromatic ones like benzene), as well as many anti-knocking additives, are carcinogenic. Because of this, any large-scale or ongoing leaks of gasoline pose a threat to the public's health and the environment, should the gasoline reach a public supply of drinking water. The chief risks of such leaks come not from vehicles, but from gasoline delivery truck accidents and leaks from storage tanks. Because of this risk, most (underground) storage tanks now have extensive measures in place to detect and prevent any such leaks, such as sacrificial anodes. Gasoline is rather volatile (meaning it readily evaporates), requiring that storage tanks on land and in vehicles be properly sealed. The high volatility also means that it will easily ignite in cold weather conditions, unlike diesel for example. Appropriate venting is needed to ensure the level of pressure is similar on the inside and outside. Gasoline also reacts dangerously with certain common chemicals.

Gasoline is also one of the sources of pollutant gases. Even gasoline which does not contain lead or sulfur compounds produces carbon dioxide, nitrogen oxides, and carbon monoxide in the exhaust of the engine which is running on it. Furthermore, unburnt gasoline and evaporation from the tank, when in the atmosphere, react in sunlight to produce photochemical smog. Addition of ethanol increases the volatility of gasoline.

Through misuse as an inhalant, gasoline also contributes to damage to health. Petrol sniffing is a common way of obtaining a high for many people and has become epidemic in many poorer communities such as with Indigenous Australians and Indigenous groups in America, Australia, Canada, New Zealand and some Pacific Islands.[10] In response, Opal fuel has been developed by the BP Kwinana Refinery in Australia, and contains only 5% aromatics (unlike the usual 25%) which inhibits the effects of inhalation.[11]

Usage and pricing

In 2003 The United States of America consumed 476,474,000,000 (http://earthtrends.wri.org/text/energy-resources/variable-291.html) litres per year (476.474 gigalitres) or about 360 million US liquid gallons (1.36 gigalitres) of gasoline each day. Western countries have

among the highest usage rates per person. Some countries, e.g. in Europe and Japan, impose heavy fuel taxes on fuels such as gasoline. Because a greater proportion of the price of gasoline in the United States is due to the cost of oil, rather than taxes, the price of the retail product is subject to greater fluctuations (vs. outside the U.S.) when calculated as a *percentage* of cost-per-unit, but is actually less variable in *absolute* terms.

Stability

When gasoline is left for a certain period of time, gums and varnishes may build up and precipitate in the gasoline, causing "stale fuel." This will cause gums to build up in the cylinders and also the fuel lines, making it harder to start the engine. Gums and varnishes should be removed by a professional to extend engine life. Motor gasoline may be stored up to 60 days in an approved container. If it is to be stored for a longer period of time, a fuel stabilizer may be used. This will extend the life of the fuel to about 1-2 years, and keep it fresh for the next uses. Fuel stabilizer is commonly used for small engines such as lawnmower and tractor engines to promote quicker and more reliable starting.

Alternatives

Main article: Alternative fuel

- Biodiesel, for diesel engines.
- Biobutanol, for gasoline engines.
- Bioethanol and E85.
- Hydrogen fuel
- Battery electric vehicles
- Conventional Diesel fuel
- Ethanol or butanol

Note: Many of these are better for the environment than gasoline, but they are still not 100% clean.

See also

- Comparison of automobile fuel technologies
- Ethanol fuel
- Diesel
- Filling station
- List of automotive fuel brands
- Internal combustion engine
- Diesel engine
- Oil price increases of 2004-2006
- Aviation fuel
- Aftermarket fuel economy device
- Octane rating

Notes

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External links

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- CNN/Money: Global gas prices (http://money.cnn.com/pf/features/lists/global_gasprices/)
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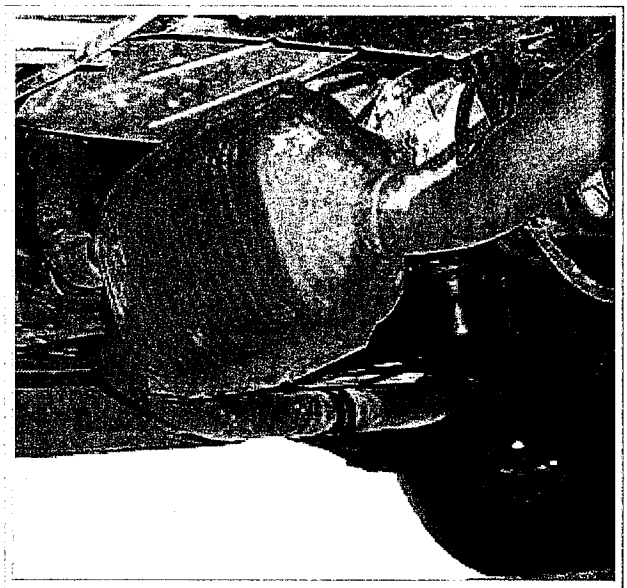
Retrieved from "http://en.wikipedia.org/wiki/Gasoline"

Categories: Articles lacking sources from May 2007 | All articles lacking sources | All articles with unsourced statements | Articles with unsourced statements since May 2007 | Engine technology | Petroleum products

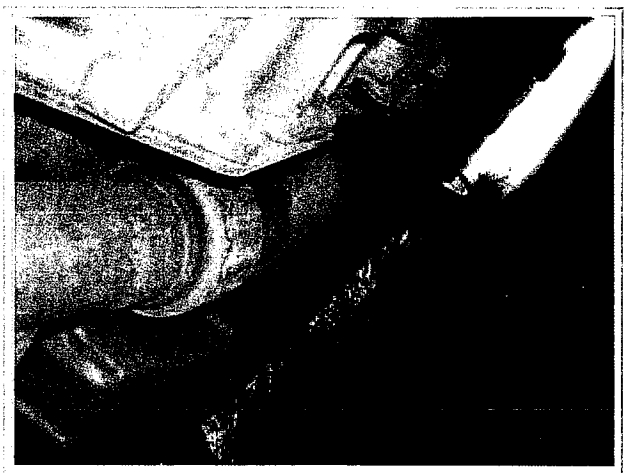
Catalytic converter

From Wikipedia, the free encyclopedia

A **catalytic converter** (colloquially, "cat" or "catcon") is a device used to reduce the toxicity of emissions from an internal combustion engine. First widely introduced on series-production automobiles in the US market for the 1975 model year to comply with tightening EPA regulations on auto exhaust, catalytic converters are still most commonly used in motor vehicle exhaust systems. Catalytic converters are also used on generator sets, forklifts, mining equipment, trucks, buses, trains, and other engine-equipped machines. A catalytic converter provides an environment for a chemical reaction wherein toxic combustion by-products are converted to less-toxic substances.



Catalytic converter on a Dodge Ram Van.



Catalytic converter on a Saab 9-5.

Contents

Functions

Three-way catalytic converters

A three-way catalytic converter has three simultaneous tasks:

1. Reduction of nitrogen oxides to nitrogen and oxygen: $2NO_x \rightarrow xO_2 + N_2$
2. Oxidation of (toxic) carbon monoxide to harmless carbon dioxide: $2CO + O_2 \rightarrow 2CO_2$
3. Oxidation of unburnt carcinogenic hydrocarbons (HC) to carbon dioxide and water: $2C_xH_y + (2x+y/2)O_2 \rightarrow 2xCO_2 + yH_2O$

These three reactions occur most efficiently when the catalytic converter receives exhaust from an engine running slightly above the stoichiometric point. This is between 14.8 and 14.9 parts air to 1 part fuel, by weight, for gasoline (the ratio for LPG, natural gas and ethanol fuels is slightly different, requiring modified fuel system settings when using those fuels). When there is more oxygen than required, then the system is said to be running lean, and the system is in oxidizing condition. In that case, the converter's two oxidizing reactions (oxidation of CO and hydrocarbons) are favoured, at the expense of the reducing reaction. When there is excessive fuel, then the engine is running rich. The reduction of NO_x is favoured, at the expense of CO and HC oxidation. If an engine could be held at the strict stoichiometric point for the fuel used, it is theoretically possible to reach 100% conversion efficiencies.

Since 1981, three-way catalytic converters have been at the heart of vehicle emission control systems in North American roadgoing vehicles, and have been used on "Large Spark Ignition" engines since 2001 in California, and from 2004 in the other 49 states. LSI engines are used in forklifts, aerial boom lifts, ice resurfacing machines and construction equipment. The converters used in these are three-way types designed to reduce combined NO_x+HC emissions from 12 gram/BHP-hour to 3 gram/BHP-hour or less, per the United States Environmental Protection Agency (EPA) 2004 regulations. A further drop to 2 gram/BHP-hour of NO_x+HC emissions is mandated in 2007 (note: NO_x is the industry standard short form for nitric oxide (NO) and nitrogen dioxide (NO_2) both of which are smog precursors. HC is the industry short form for hydrocarbons). The EPA intends to introduce emissions rules for stationary Spark Ignition engines, to take effect in January 2008.

Two-way catalytic converters

A two-way catalytic converter has two simultaneous tasks:

1. Oxidation of carbon monoxide to carbon dioxide: $2CO + O_2 \rightarrow 2CO_2$
2. Oxidation of unburnt hydrocarbons (unburnt and partially-burnt fuel) to carbon dioxide and water: $2C_xH_y + (2x+y/2)O_2 \rightarrow 2xCO_2 + yH_2O$

This type of catalytic converter is widely used on diesel engines to reduce hydrocarbon and carbon monoxide emissions. They also were used on spark ignition (gasoline) engines in USA market automobiles up until 1981, when they were replaced by three-way converters due to regulatory changes requiring reductions on NO_x emissions.

Reduction of the NO_x emissions requires an additional step. Platinum catalysis can be used. Instead of

catalysis, a true reactant — diesel fuel or ammonia pyrolyzed *in situ* from urea — can be used to reduce the NO_x into nitrogen.

Curiously, the regulations regarding hydrocarbons vary according to the engine regulated, as well as the jurisdiction. In some cases, "non-methane hydrocarbons" are regulated, while in other cases, "total hydrocarbons" are regulated. Technology for one application (to meet a non-methane hydrocarbon standard) may not be suitable for use in an application that has to meet a total hydrocarbon standard. Methane is not toxic, but is more difficult to break down in a catalytic converter, so in effect a "non-methane hydrocarbon" standard can be considered to be looser. Since methane is a greenhouse gas, more interest is rising in how to eliminate emissions of it.

Catalyst poisoning and deactivation

Catalytic converters become ineffective in the presence of lead due to catalyst poisoning. Therefore, vehicles equipped with catalytic converters must only be run on unleaded gasoline, and it is this fact, as much as concerns about the possibly harmful effects of lead emissions, which caused the end of pump-available leaded gasoline in countries where catalytic converters have been in common use for many years. Leaded "race only" fuel is still used for non-catalyst vehicles in some countries. Catalyst poisoning occurs when a substance in the engine exhaust coats the surface of the catalyst, preventing further exhaust access to the catalytic materials. Poisoning can sometimes be reversed by running the engine under a very heavy load for an extended period of time to raise exhaust gas temperature, which may cause liquefaction or sublimation of the catalyst poison. Common catalyst poisons are lead, sulfur, zinc, manganese, silicon and phosphorus.

Zinc, phosphorus and sulfur originate from lubricant antiwear additives such as ZDDP; sulfur and manganese primarily originate from fuel impurities or from additives such as Methylcyclopentadienyl Manganese Tricarbonyl (MMT), respectively. Silicon poisoning in automotive applications is the result of engine damage, such as a faulty cylinder head gasket or cracked casting, admitting silicate-containing coolant into the combustion chamber. In stationary engines silicon poisoning is more often caused by the use of methane landfill gas as a fuel.

Removal of sulfur from a catalyst surface by running heated exhaust gases over the catalyst surface is often successful; however, removal of lead deposits in this manner is usually not possible because of lead's high boiling point. In particularly bad cases of catalyst poisoning by lead, the catalytic converter can actually become completely plugged with lead residue.

A variety of conditions may cause the catalyst to overheat (heat deactivation) and potentially to melt down. Some factors that can cause this are:

- lubricating oil in the exhaust system (caused by engine wear, or by damaged rings or valves)
- an engine misfire or ignition failure (causing unburnt fuel to enter the exhaust)
- a cracked exhaust valve (again, causing unburnt fuel in the exhaust)

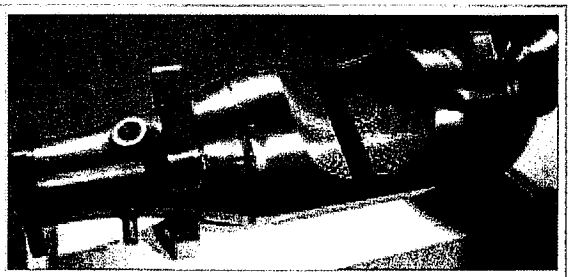
Overly rich fuel mixtures are not usually a problem - there is too little unused oxygen for the exothermic reaction to be large enough to cause damage. A slightly lean of stoichiometric mix is far more dangerous, as the oxygen level is elevated, allowing a very large exotherm, and many engine manufacturers design "rich excursions" as a catalyst protection measure in the engine control software. In the early days of catalyst-equipped cars, (primarily in the USA) before the advent of sophisticated

engine management systems, it was necessary for fuel/air mixtures to be significantly richer than had hitherto been the case to allow the catalyst to work effectively. This contributed to the very poor fuel consumption figures achieved by such cars.

Engine misfires can overheat and destroy the converter as the excessive amounts of unburned fuel are broken down within it, especially when the engine is under heavy loads. Vehicles equipped with OBD-II diagnostic systems are designed to alert the driver of a misfire condition, along with other malfunctions, using the Malfunction Indicator Lamp or "Check Engine" light. If the misfire and engine load can produce heating severe enough to cause catalyst damage, the MIL will flash until the misfire or engine load is reduced.

Technical details

The catalytic converter consists of several components:



Cross section of a Metal-core Converter

1. The core, or substrate. In modern catalytic converters, this is most often a ceramic honeycomb, however stainless steel foil honeycombs are also used. The purpose of the core is to "support the catalyst" and therefore it is often called a "catalyst support". The ceramic substrate was invented by Rodney Bagley, Irwin Lachman and Ronald Lewis at Corning Glass for which they were inducted into the National Inventors Hall of Fame in 2002.
2. The washcoat. In an effort to make converters more efficient, a washcoat is utilized, most often a mixture of silica and alumina. The washcoat, when added to the core, forms a rough, irregular surface which has a far greater surface area than the flat core surfaces, which is desirable to give the converter core a larger surface area, and therefore more places for active precious metal sites. The catalyst is added to the washcoat (in suspension) before application to the core.
3. The catalyst itself is most often a precious metal. Platinum is the most active catalyst and is widely used. However, it is not suitable for all applications because of unwanted additional reactions and/or cost. Palladium and rhodium are two other precious metals that are used. Platinum and rhodium are used as a reduction catalyst, while platinum and palladium are used as an oxidization catalyst. Cerium, iron, manganese and nickel are also used, though each has its own limitations. Nickel is not legal for use in the European Union (due to reaction with carbon monoxide). While copper can be used, its use is illegal in North America due to the formation of dioxin.

Conventional spark ignition engines

Catalytic converters are used on spark ignition (gasoline; liquified petroleum gas (LPG); flexible fuel vehicles burning varying blends of E85 and gasoline; compressed natural gas (CNG)) engines; and compression ignition (diesel) engines.

For spark ignition engines, the most commonly used catalytic converter is the **three-way** converter, which gets its name by dint of acting to convert the three main pollutants of concern — CO, HC, and NO_x— to less-toxic substances. The control of NO_x involves a *reduction* process that releases oxygen and the control of CO and HC involves an *oxidation* process that consumes oxygen. Therefore, a 3-way

converter contains two catalyst-coated stages: The first catalyst stage encountered by the exhaust is for reduction of NOx, which produces oxygen employed by the second stage to oxidize CO and HC. 3-way converters work most efficiently with exhaust from engines operated on a stoichiometric air-fuel mixture. Generally, such engines are equipped with closed-loop feedback fuel mixture control employing one or more oxygen (lambda) sensors. While a 3-way catalyst can be used in an open-loop system, NO_x reduction efficiency is low. Since NO_x emissions are now regulated throughout the world, open-loop fuel systems are obsolete in many jurisdictions. Closed-loop maintenance of the stoichiometric air-fuel ratio is most often attained by means of an engine management system with computer-controlled fuel injection, though early in the deployment of 3-way converters, carburetors equipped for feedback mixture control were used during the transition to fuel injection. Within a narrow ratio band surrounding stoichiometry, conversion of all three pollutants is very complete, sometimes approaching 100%. However, outside of that band, conversion efficiency falls off very rapidly. **Two-way** (or **oxidation**) converters act only to control CO and HC, and have therefore been abandoned on conventional spark ignition engines in most jurisdictions due to an inability to control NO_x.

A three-way catalyst reduces emissions of CO (carbon monoxide), HC (hydrocarbons), and NO_x (nitrogen oxides) simultaneously when the oxygen level of the exhaust gas stream is below 1.0%, though performance is best at below 0.5% O_2. Unwanted reactions, such as the formation of H_2S (hydrogen sulfide) and NH_3 (ammonia), can occur in the three-way catalyst. Formation of each can be limited by modifications to the washcoat and precious metals used. It is, however, difficult to eliminate these side products entirely.

For example, when control of H_2S (hydrogen sulfide) emissions is desired, nickel or manganese is added to the washcoat - both substances act to block the adsorption of sulfur by the washcoat. H_2S is formed when the washcoat has adsorbed sulfur during a low temperature part of the operating cycle, which is then released during the high temperature part of the cycle and the sulfur combines with HC. For "lean burn" spark ignition engines (e.g. compressed natural gas, or compressed natural gas with diesel fuel pilot injection), an oxidation catalyst is used in the same manner as in a compression ignition engine.

Recently, many systems have used a pre-catalyst in the system to reduce startup emissions and burn off hydrocarbons from the extra-rich mixture used in a cold engine. Upstream and downstream parts are now often separated in the system to provide an optimum temperature and space for extra oxygen sensors. The converter needs to be placed close enough to the engine to quickly reach operating temperature but far enough away to avoid heat damage.

Many three-way catalytic converters utilize an air injection tube between the first (NO_x reduction) and second (HC and CO oxidation) biscuits of the converter. This tube is fed by either an air pump or by an aspirator. The injected air provides oxygen for the catalyst's oxidizing reaction. These systems also sometimes include an upstream air injector to admit oxygen to the exhaust system before it reaches the catalytic converter. This precleans the extra-rich exhaust from a cold engine, and helps bring the catalytic converter quickly up to operating temperature.

Most newer systems do not employ air injection. Instead, they provide a constantly varying mixture that quickly and continually cycles between lean and rich to keep the first catalyst (NO_x reduction) from becoming oxygen loaded, and to keep the second catalyst (CO oxidization) sufficiently oxygen-saturated. They also utilize several oxygen sensors to monitor the exhaust, at least one before the catalytic converter for each bank of cylinders, and one after the converter. Some systems contain the

reduction and oxidation functions separately rather than in a common housing.

Diesel engines

For compression ignition (i.e., Diesel) engines, the most commonly used catalytic converter is the diesel oxidation catalyst. The catalyst uses excess O_2 (oxygen) in the exhaust gas stream to oxidize CO (Carbon Monoxide) to CO_2 (Carbon Dioxide) and HC (hydrocarbons) to H_2O (water) and CO_2. These converters often reach 90% effectiveness, virtually eliminating diesel odor and helping to reduce visible particulates (soot), however they are incapable of reducing NO_x as chemical reactions always occur in the simplest possible way, and the existing O_2 in the exhaust gas stream would react first.

To reduce NO_x on a compression ignition engine it is necessary to change the exhaust gas - two main technologies are used for this - selective catalytic reduction (SCR) and NOx (NO_x) traps (or NOx Adsorbers).

Another issue for diesel engines is particulate (soot). This can be controlled by a soot trap or diesel particulate filter (DPF), as catalytic converters are unable to affect elemental carbon (however they will remove up to 90% of the soluble organic fraction). A clogging soot filter creates a lot of back pressure decreasing engine performance. However, once clogged, the filter goes through a regeneration cycle where diesel fuel is injected directly into the exhaust stream and the soot is burned off. After the soot has been burned off the regeneration cycle stops and injection of diesel fuel stops. This regeneration cycle should not affect performance of the engine.

All major diesel engine manufacturers in the USA (Ford, Caterpillar, Cummins, Volvo, MMC) starting January 1, 2007 are required to have a catalytic converter and a soot filter inline, as per new EPA legislation. http://www.epa.gov/otaq/highway-diesel/regs/2007-heavy-duty-highway.htm

Oxygen storage in three-way converters

In order to oxidize CO and HC, the catalytic converter also has the capability of storing the oxygen from the exhaust gas stream, usually when the air fuel ratio goes lean. When insufficient oxygen is available from the exhaust stream the stored oxygen is released and consumed. This happens either when oxygen derived from NO_x reduction is unavailable or certain maneuvers such as hard acceleration enrich the mixture beyond the ability of the converter to compensate.

Note that diesel catalysts do not use this feature as there is sufficient O2 in the exhaust gas stream to handle the CO & HC reductions needed.

Regulations

Emissions regulations vary considerably from jurisdiction to jurisdiction, as do what engines are regulated. In North America any spark ignition engine of over 19 kW (25 hp) power output built later than January 1, 2004 probably has a three-way catalytic converter installed. In Japan a similar set of regulations came into effect January 1, 2007, while the European Union has not yet enacted analogous regulations. Most automobile spark ignition engines in North America have been fitted with catalytic converters since the mid-1970s and the technology used in non-automotive applications is generally based on automotive technology.

Diesel engine regulations are similarly varied, with some jurisdictions focusing on NO_x (Nitric Oxide and Nitrogen Dioxide) emissions and others focusing on particulate (soot) emissions. This can cause problems for the engine manufacturers as it may not be economical to design an engine to meet two sets of regulations.

Note that no jurisdiction has specific legislation mandating the use of catalytic converters, however with spark ignition engines a catalytic converter is usually the only practical way to meet regulatory requirements.

An important issue is that fuel quality varies widely from place to place, even within jurisdictions, as do the regulations covering fuel quality. In North America, Europe, Japan, and Hong Kong both gasoline and diesel fuel are highly regulated and there are campaigns under way to regulate CNG and LPG as well. In most of Asia and Africa this is not true - in some places sulfur content of the fuel can reach 20,000 parts per million (2%). Any sulfur in the fuel may be oxidized to SO_2 (sulfur dioxide) or even SO_3 (sulfur trioxide) in the combustion chamber. If sulfur passes over a catalyst it may be further oxidized in the catalyst, i.e. (SO_2 may be further oxidized to SO_3). Sulfur oxides are precursors to sulfuric acid, a major component of acid rain. While it is possible to add substances like vanadium to the catalyst wash coat to combat sulfur oxide formation, this will reduce the effectiveness of the catalyst— the best solution is further refinement of the fuel at the refinery to remove the sulfur. Regulations in Japan, Europe and —by 2007— North America tightly restrict the amount of sulfur permitted in motor fuels. However, the expense is such that this is not practical in many developing countries. As a result cities in these countries with high levels of vehicular traffic suffer damage to buildings due to acid rain eating away the stone/woodwork, and acid rain has deleterious effects on the local ecosystem.

Regulatory agencies

The agencies charged with regulating engine emissions vary from jurisdiction to jurisdiction, even in the same country. For example, in the United States, overall responsibility belongs to the United States Environmental Protection Agency (EPA), but due to special requirements of the State of California, emissions in California are regulated by the Air Resources Board. In Texas, the Texas Railroad Commission is responsible for regulating emissions from LPG fueled rich burn engines (but not gasoline fueled rich burn engines).

- California Air Resources Board - California, United States (most sources)
- Environment Canada - Canada (most sources)
- Environmental Protection Agency - United States (most sources)
- Texas Railroad Commission - Texas, United States (LPG fueled engines only)
- Transport Canada - Canada (trains and ships)

Criticisms

Catalytic converters have proven to be reliable devices and have been successful in reducing noxious tailpipe emissions. However, they may have some adverse environmental impacts in use:

- The requirement for a rich burn engine to run at the stoichiometric point means it uses more fuel than a "lean burn" engine running at a mixture of 20:1 or less. This increases the amount of fossil fuel consumed and the carbon dioxide emissions of the vehicle. However NOx control on lean

burn engines is problematic at best, and many lean burn engine manufacturers are considering rich burn variations. Another solution is to increase the amount of biofuels used - if 100% biofuel was used the engines would be CO_2 neutral.

- Catalytic converters are "estimated" to account for 50% of total nitrous oxide (dinitrogen oxide, 'laughing gas') emissions to atmosphere. While N_2O emissions in these concentrations are not harmful to human health, it is a potent greenhouse gas, accounting for around 7% of the overall greenhouse effect despite its small concentration in the atmosphere. The California Air Resources Board is investigating this issue, and will introduce legislation to address it if necessary.
- The manufacturing of catalytic converters requires palladium and/or platinum; a portion of the world supply of these precious metals is produced near the Russian city of Norilsk (about 15%), with significant negative environmental effects due to the lack of environmental protection legislation. [2] (http://minerals.usgs.gov/minerals/pubs/commodity/platinum/platimcs07.pdf)

It can be argued that catalytic converters have reduced toxic emissions and smog at the expense of increased greenhouse gases, however anyone making this argument should consider the California Air Resources Board reports on improvements in Air Quality that have been achieved over the last 30 years.

Catalytic converter theft

Due to the use of precious metals including platinum, which is worth up to $1,200 an ounce; palladium, which can fetch $320 an ounce; and rhodium, which can go for up to $6,000 an ounce on the market, catalytic converter theft is on the rise. (Note, however, that the loading of precious metals in a converter is low, and seldom over $50 per converter at 2007 spot prices). The problem is especially common among mid-90s to present Toyota sport-utility vehicles and trucks, due to their high ground clearance and bolt on catalytic converters, which are easy to remove. Welded-in converters are also at risk of theft from SUVs and trucks, for they can be removed within five minutes by means of a battery powered reciprocating saw. [1],

Diagnostics

Various jurisdictions now legislate on-board diagnostics to monitor the effectiveness of the emissions control system, including the catalytic converter and such diagnostics are often included in aftermarket retrofit kits as a matter of course, even if legislation does not directly require them.

On-board diagnostics take several forms, depending upon the legislation and the type of emissions control product being monitored, the three main types are:

- temperature
- oxygen
- NO_x

Temperature sensors

Temperature sensors are used for two purposes. The first is as a warning system, typically on obsolete 2-Way catalytic converters such as are still sometimes used on LPG forklifts. The function of the sensor is to warn of temperature excursions above the safe operating temperature of 750°Celsius of the 2-Way catalytic converter. Note that modern catalytic converters are not as susceptible to temperature damage,

many modern 3-Way platinum based converters can handle temperatures of 900°C sustained, while many modern 3-way palladium based converters can handle temperatures of 925°C sustained. Temperature sensors are also used to monitor catalyst functioning - usually two sensors will be fitted, one before the catalyst and one after to monitor the temperature rise over the catalytic converter core. For every 1% of CO in the exhaust gas stream the exhaust gas temperature will rise by 100°C.

Oxygen sensors

The Oxygen sensor or "lambda sensor" is the basis of the closed loop control system on a spark ignited rich burn engine, however it is also used for diagnostics. Oxygen sensors only work when at operating temperature, when they output a voltage based on the O_2 level in the exhaust gas to the computer. Typically a single wire oxygen sensor will take 3-5 minutes to reach operating temperature. The more expensive heated sensors (3 to 5 wires) can reach operating temperature in 1 minute.

The simplest sort of diagnostic an oxygen sensor can perform is related to the closed loop control system. If the system makes a change to the air-fuel ratio based on oxygen sensor readings, and the readings do not change the sensor will light an indicator on the instrument panel warning the operator that there is a problem with the vehicle. There is always a delay before this happens, usually 5 minutes of engine operation. Most systems do not store the state, so turning off the engine and turning it back on will reset the system, and if the error is transient (i.e. fuel filter is partially blocked) the light will not come back on. However, if the problem is recurring the light will come on as soon as the sensor reaches operating temperature and a manufacturer-defined driving pattern known as a drive-trace is completed. Until this procedure has finished, the diagnostic computer will set a parameter called a readiness monitor to "unready". The readiness monitor system was implemented in order to ensure that diagnostic computers would not falsely report working emissions systems in vehicles whose computer's error memory had recently been cleared. Such diagnostics have been factory fitted to automobiles since 1985 in North America and factory fitted to off-road Spark Ignition engines since 2004 (however such systems have been available as retrofit kits for off-road SI engines since 1997).

The second sort of diagnostic is more complex and is a result of the California OBD-II rule (though temperature sensors are sometimes used for this). In vehicles with OBD-II, a second oxygen sensor is fitted after the catalytic converter to monitor the O_2 levels. The on-board computer makes comparisons to the readings of the two sensors. If both sensors give the same output, the catalytic converter is non-functioning, and must be replaced. It will also spot less serious damage to a catalytic converter, such as the use of racing fuel in an on-road vehicle. Lead is still legal in racing fuel, and use of as little as half a tank of leaded fuel will cause enough damage for the computer to notice, and warn the operator that the converter is not functioning properly.

NO_x sensors

NO_x sensors are extremely expensive and are generally only used when a compression ignition engine is fitted with a Selective Catalytic Reduction Converter, or a NO_x Adsorber Catalyst in a feedback system (though many SCR systems do not use a NO_x sensor, but instead rely on the engine map being programmed into the Engine Control Unit or computer). When fitted to an SCR system there may be one or two sensors. When one sensor is fitted it will be pre-catalyst, when two are fitted the second one is post catalyst. They are utilized for the same reasons, and in the same manner as an Oxygen Sensor - the only difference is the substance being monitored.

See also

- Exhaust system
- Automobile emissions control
- Diesel particulate filter
- SCR
- NOx Adsorbers
- Roadway air dispersion modeling
- Catalysis

Notes

1. ^ [1] (http://www.chroniclet.com/2007/07/31/underhanded-thieves/)

External links

- Johnson Matthey plc - The Inventors of the Catalytic Converter (http://ect.jmcatalysts.com/)
- Howstuffworks: "How Catalytic Converters Work" (http://www.howstuffworks.com/catalytic-converter.htm)
- Source for Electronic Catalytic Convertor Info (http://www.hydrodrive.8k.com/toc.htm)
- Detecting Clogged Converter (http://www.misterfixit.com/cat.htm)

Patents

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- Lachman, I. M. et al., -- U.S. Patent 3,885,977 (http://patft.uspto.gov/netacgi/nph-Parser?patentnumber=3885977) -- *"Anisotropic Cordierite Monolith" (Ceramic substrate) -- November 5, 1973*
- Srinivasan Gopalakrishnan -- GB patent 2397782 (http://v3.espacenet.com/textdoc?DB=EPODOC&IDX=GB2397782) -- *"Process And Synthesizer For Molecular Engineering Of Materials" -- March 13, 2002*

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Categories: Automotive technologies | Automotive accessories | Engine technology | Pollution control technologies | Air pollution control systems | NOx control

THE WALL STREET JOURNAL. ONLINE

September 13, 2007

Court Roils Auto-Rules Debate

Vermont Wins Right To Limit Emissions; Nationwide Ripples

By MIKE SPECTOR and JEFFREY BALL
September 13, 2007; Page A9

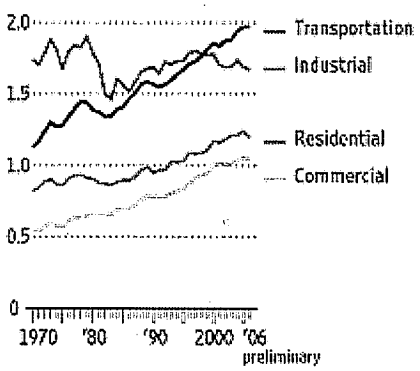
A federal judge's ruling that Vermont can limit greenhouse-gas emissions from cars and trucks will have national implications in the intensifying debate over fuel economy and global warming.

Federal District Judge William K. Sessions III rejected auto makers' arguments that Vermont's auto-emissions law amounts to a backdoor state attempt to regulate automotive fuel economy -- a power that under federal law is reserved for Washington. The judge's reasoning: The Vermont law's impact goes beyond fuel economy to cover other areas, making it more than a fuel-economy mandate.

The ruling could have repercussions nationally, but is likely to draw an industry appeal.

Riding High

Total energy-related carbon-dioxide emissions by end-use sector, in billions of metric tons of CO_2



Source: Energy Information Administration

California, a national environmental bellwether, is in similar litigation over its attempt to require cuts in greenhouse-gas emissions from automobiles sold there. The ruling in the federal district of Vermont would appear to give California momentum. Judge Sessions wrote he "remains unconvinced automakers cannot meet the challenges of Vermont's and California's" greenhouse-gas rules. Still, a federal judge in California could decide that case differently.

California Gov. Arnold Schwarzenegger said the Vermont ruling "marks another important victory in the fight against global warming. California and other states that want to take aggressive action will no longer be blocked by those who stand in our way."

More broadly, the ruling is likely to increase pressure on Congress to toughen federal fuel-efficiency rules, known as the Corporate Average Fuel Economy, or CAFE, standards -- and to regulate greenhouse-gas emissions from sectors beyond autos. The auto industry argues against sharp changes in those rules, saying they would hurt the industry. But a potential patchwork of differing state rules bearing on fuel economy could prove even costlier for the industry, and could push it to soften its stance in Washington.

California has special dispensation under federal law to enact emissions rules that are tougher than the federal government's, a nod to California's record of dirty air. Other states can replicate California's standards. But California first must get a federal waiver, and its latest request is pending. Because Vermont's effort is an extension of California's, the Vermont court decision could be rendered moot if California doesn't get its waiver. Meanwhile, other states are hoping to follow California's lead -- all told, about a third of the nation's auto market.

Auto makers argue that overly aggressive mileage rules would force them to build smaller vehicles that consumers won't buy. The industry is considering appealing the Vermont decision, said Dave McCurdy, head of the Alliance of Automobile Manufacturers, the industry's main Washington lobbying group. "Federal law is designed to ensure a consistent fuel-economy program across the country."

Kevin Holewinski, a lawyer at Jones Day in Washington who defends companies in global-warming suits but isn't involved in the auto-related litigation, took issue with the ruling and predicted the industry will appeal it. "The state's overstepping its authority," he said, agreeing with the auto makers' argument that the Vermont law amounts to a state fuel-economy mandate even if it also has other environmental effects. "Suggesting that there are these collateral consequences, I think, quite frankly, is wholly beside the point," he said.

A spokeswoman for the White House Council on Environmental Quality said the Bush administration's "relevant agencies are reviewing this decision." She cited recent moves by the administration to curb automotive gasoline use.

Matt Pawa, a lawyer for environmental groups that joined Vermont in defending against the industry's lawsuit, said the ruling represented a "great victory for global warming, Vermont, the planet, California and the auto industry."

Governors of 13 states that plan to implement the California greenhouse-gas rules issued a letter yesterday to the chief executives of the top six auto makers by sales in the U.S., calling on them to stop suing to block regulations.

The Vermont regulations would increase mileage steeper and faster than measures that are being considered in Congress. Regulating tailpipe emissions effectively forces auto makers to improve mileage, since greenhouse gases are produced when vehicles burn fossil fuels such as gasoline.

Congress, meanwhile, is considering legislation that would force auto makers to achieve an average of 35 miles a gallon for their fleets of cars and trucks over the next decade or so, as much as a 40% increase over current standards but less aggressive than the rules states are pursuing. The Bush administration is fast-tracking similar new rules for year end.

At the heart of the Vermont and California disputes is whether a state law limiting greenhouse-gas emissions from automobiles is tantamount to a fuel-economy standard.

Judge Sessions ruled that though carbon dioxide, which is produced by burning fuel, "represents the bulk" of greenhouse-gas emissions from autos, Vermont's rules "embrace much more than a simple requirement to improve fuel economy, cloaked in the rhetoric of reducing carbon dioxide emissions." He explained that automotive air conditioners also produce greenhouse gases that would be regulated by the Vermont law. He also rejected auto makers' arguments that the Vermont law would cost too much. "History suggests that the ingenuity of the industry, once put

in gear, responds admirably to most technological challenges," he wrote.

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October 5, 2007 5:21 p.m. EDT

Auto Industry to Appeal Vermont Emissions Ruling

By MIKE SPECTOR
October 5, 2007 5:21 p.m.

Detroit's Big Three auto makers and Japan's **Toyota** Motor Corp. said they would appeal a decision by a Vermont judge that would have allowed the state to set its own aggressive regulations on tailpipe emissions.

The much-expected move, filed in a legal notice Friday afternoon by the Alliance of Automobile Manufacturers, the auto industry's chief lobbying group in Washington, prolongs an ongoing legal battle over whether states have the right to set their own regulations on greenhouse gas emissions from cars. The appeal notice will soon be forwarded to the Second Circuit Court of Appeals in New York, where an official appeal will be filed.

At issue in the Vermont case is whether a state's rules on tailpipe emissions equates to fuel-economy regulation and thus usurps rule-making power reserved for Washington under federal law. Auto makers have maintained that improving mileage is the only way to effectively reduce tailpipe emissions. Improving mileage curbs tailpipe emissions because greenhouse gases are produced when vehicles burn fossil fuels such as gasoline.

Federal District Judge William K. Sessions III rejected the industry's argument after a trial earlier this year, saying the impact of Vermont's proposed rules was not limited to improving vehicle efficiency. The judge ruled last month that while the carbon dioxide produced by burning fuel constitutes the bulk of tailpipe emissions, Vermont's proposed rules painted a broader brush -- also regulating polluting car air conditioners, for instance.

Vermont and a handful of other states are seeking to implement similar tailpipe emissions standards to those advocated by California, which would require auto makers to achieve upwards of 40 miles a gallon for their fleets of cars and trucks as soon as 2014, according to some estimates. Increases would begin in 2009. Auto makers have also sued California to prevent the state from instituting such regulations.

California has special dispensation under the federal Clean Air Act to set greenhouse gas emissions rules that are tougher than the federal government's, a nod to the state's exceptionally dirty air. California is awaiting a waiver from the Environmental Protection Agency to allow the state to set its tough tailpipe emissions rules. Should that waiver be rejected, it could render Vermont's push moot.

The auto industry's appeal represents yet another battle-front for auto makers in the ongoing

national debate over improving vehicle efficiency amid concerns over high fuel prices, foreign-oil dependence and global warming. Lawmakers in Washington could pass a bill sometime in the next two months mandating improved fuel economy, forcing car companies to achieve fleet averages of 35 miles per gallon over a decade or so, about a 40% increase from current standards. But the rules being mulled by California, Vermont and other states could hike mileage standards much steeper and faster.

"Auto makers are eager to continue fulfilling their role in reducing emissions and increasing energy security," said Dave McCurdy, head of the auto alliance, in a statement, "however this appeal is urgent as this legislation applies to model year 2009 vehicles, which consumers will start seeing in early 2008 -- just a few months from now."

Detroit's Big Three auto makers -- **General Motors** Corp., **Ford Motor** Co. and Chrysler LLC -- especially fear quick and sharp increases in mileage rules amid continued financial duress in their core North American operations. The auto makers fear government rules on fuel economy will force them to build smaller vehicles consumers don't want and require billions in investments to retool manufacturing plants. Toyota, along with several smaller car companies, has joined Detroit in the fight.

Judge Sessions dismissed the cost issue in his ruling last month. "History suggests that the ingenuity of the industry, once put in gear, responds admirably to most technological challenges," he wrote.

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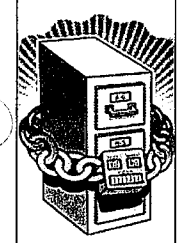

Auto Industry to Appeal Vermont Emissions Ruling

By MIKE SPECTOR
November 6, 2007 9:55 a.m.

Detroit's Big Three auto makers and Japan's Toyota Motor Corp. said they would appeal a decision by a Vermont judge that would have allowed the state to set its own aggressive regulations on tailpipe emissions.

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California Takes Auto Emissions Battle To Court
By Samantha Young, Associated Press Writer
Manufacturing.Net - October 23, 2007

SACRAMENTO, Calif. (AP) — The state's attorney general said Monday that he would sue the Environmental Protection Agency in an attempt to force it to decide whether to let California and 11 other states impose stricter standards on certain vehicle emissions.

The lawsuit, expected to be filed Wednesday in federal court in Washington, D.C., comes 22 months after California first asked the EPA to let the state impose tougher regulations on emissions of greenhouse gases from cars, pickup trucks and sports utility vehicles.

California wants to implement a 2002 state law that would require automakers to begin making vehicles that emit fewer greenhouse gas emissions by model year 2009. It would cut emissions by about a quarter by the year 2030. But the law can take effect only if the EPA grants the state a waiver under the Clean Air Act.

"Unfortunately, the Bush administration has really had their head in the sand," Attorney General Jerry Brown said. "In this case, there has been an unreasonable delay."

The EPA held hearings this summer on California's waiver request, and administrator Steven Johnson told Congress he would make a decision by the end of the year. The schedule has not changed, EPA spokeswoman Jennifer Wood said Monday.

The agency is also crafting national standards that it will propose by the end of the year, Wood said.

Gov. Arnold Schwarzenegger in April warned the EPA he would sue if the agency failed to act on the waiver within six months. That deadline is Tuesday.

"We feel like it's a reasonable request," Schwarzenegger spokesman Aaron McLear said. "They've delayed for a long time, and it's time to take action."

Connecticut, Pennsylvania and Washington also plan to join California's lawsuit against the EPA, officials in those states said.

While the federal government sets national air pollution rules, California has unique status under the Clean Air Act to enact its own regulations — with permission from the EPA. Other states can then follow either the federal rules or California standards, if they are tougher.

Eleven other states — Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont and Washington — are ready to implement California's emissions standards if it gets the waiver. The governors of Arizona, Florida and New Mexico have said their states will adopt the standard.

The Association of International Automobile Manufacturers, which represents Honda, Nissan, Toyota and 11 other foreign car companies, has sued to block the standards from taking effect.

It argues that the tougher standards would raise the cost of cars and could force manufacturers to pull some sports utility vehicles and pickup trucks from showrooms. Their case is pending in federal court in Fresno.

The Alliance of Automobile Manufacturers has asked the EPA to deny the waiver, arguing there should be one federal standard for tailpipe emissions.

Associated Press writers Stephen Singer in Hartford, Conn., Rachel La Corte in Olympia, Wash., Marc Levy in Harrisburg, Pa. and Tim Korte in Albuquerque, N.M., contributed to this story.

THE WALL STREET JOURNAL. ONLINE

November 8, 2007 2:15 p.m. EST

California Sues EPA Over Emissions Decision

Associated Press
November 8, 2007 2:15 p.m.

SACRAMENTO -- California sued the federal government on Thursday to force a decision about whether the state can impose the nation's first greenhouse gas emission standards for cars and light trucks.

More than a dozen other states are poised to follow California's lead if it is granted the waiver from federal law, presenting a challenge to auto makers who would have to adapt to a patchwork of regulations. "Our position is that it's time for EPA to either act or get out of the way," said Lee Moore, a spokesman for New Jersey Attorney General Anne Milgram.

California's lawsuit against the Environmental Protection Agency, filed in U.S. District Court in Washington, D.C., was expected after Gov. Arnold Schwarzenegger vowed last spring to take legal action.

At issue is California's nearly two-year-old request for a waiver under the federal Clean Air Act allowing it to implement a 2002 state anti-pollution law regulating greenhouse gasses. Eleven other states have adopted California's standard as a way to combat global warming and five others are considering it.

"The longer the delay in reducing these emissions, the more costly and harmful will be the impact on California," the state attorney general's office said in its 16-page complaint.

Mr. Schwarzenegger and other state officials say implementing the law is crucial for California's ability to meet the provisions of a separate global warming law that passed last year, garnering world-wide attention. That law seeks to reduce greenhouse gas emissions 25% by 2020.

Arizona, Connecticut, Illinois, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont and Washington plan to join California's lawsuit against the federal government, said Gareth Lacy, spokesman for California Attorney General Jerry Brown.

California asked the EPA to grant its waiver in December 2005. EPA administrator Stephen Johnson said last summer that he would make a decision by the end of this year.

Mr. Schwarzenegger sought quicker action and vowed to sue. The state's lawsuit was expected to be filed in late October but was delayed after state officials became preoccupied with the Southern

California wildfires.

The EPA criticized the state's actions Thursday.

"The administrator has stated numerous times that he plans to make a decision by the end of the year," EPA spokeswoman Jennifer Wood said. "It's unfortunate that California is more interested in getting a good headline than allowing us to make a decision."

Yet state officials say they need the matter resolved soon because the auto-emissions law applies to vehicles in the 2009 model year, which can be marketed by companies as early as this coming January. Cars, pickups and sport utility vehicles sold in California would be required to produce fewer greenhouse gases, with the goal of reducing auto emissions 25% by 2030.

Further delay by the EPA would interfere with the state's ability to enforce the law on time, according to the complaint. "Congress generally intended that the U.S. EPA make determinations of this type in a matter of weeks or months, not years," the complaint says.

While the federal government sets national air pollution rules, California has unique status under the Clean Air Act to enact its own regulations if it gets approval to do so by the EPA. Other states can follow federal rules or California's standards if they are tougher. The EPA has granted about 50 such waivers over the past 40 years for the use of catalytic converters, leaded gasoline regulations and other measures.

The complaint filed Thursday claims the EPA failed to act in a reasonable length of time on California's latest waiver request.

In addition to the states that plan to join California's lawsuit, the governors of Colorado, Florida and Utah have said their states plan to adopt the standard.

The EPA initially refused to act on California's application, saying the agency did not have the authority to regulate greenhouse gases as a pollutant. That changed when the U.S. Supreme Court ruled in April that the EPA did indeed have that right.

As a result, the EPA is now developing greenhouse gas regulations that are scheduled to be released by the end of the year. Environmental groups say those regulations are unlikely to be stronger than California standards.

Auto makers continue to challenge the California standards in court.

They are appealing a ruling last month by a federal judge in Vermont who upheld the California rules in that state. They also are trying to persuade a federal judge in Fresno to toss out the emission standards mandated under California's 2002 law.

Associations for both domestic and foreign car companies say California's standards would raise the cost of vehicles and could force manufacturers to pull some sport utility vehicles and pickup truck models from showrooms.

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November 9, 2007

Utilities Back California In Auto-Emissions Suit

By JEFFREY BALL
November 9, 2007; Page A6

As California sued the Bush administration yesterday in an effort to regulate automotive carbon emissions, it had some powerful cheerleaders: Other industries, including electric utilities, that want to shift a coming climate-change cleanup burden away from themselves.

California's decision to sue the Environmental Protection Agency, in both federal district court and a federal appeals court in Washington, is the latest twist in a long-running attempt by state officials to force auto makers to produce cars that emit lower levels of emissions that contribute to global warming, mainly carbon dioxide. California's suit was endorsed by 14 other states, mainly in the Northeast and Pacific Northwest.

The auto industry opposes California's effort, saying it amounts to an illegal state effort to regulate automotive fuel economy, a power reserved for Washington under federal law.

The Alliance of Automobile Manufacturers said in a statement that California's lawsuit against the EPA "is not helpful" and that "a patchwork quilt of regulations at the state level is not the answer" to concerns about global warming.

But utilities are supporting California's effort and the oil industry is not opposing it. The inter-industry squabble that sets up with auto makers is a harbinger of the fight coming when Congress debates whether to cap global-warming emissions.

California has developed rules forcing a roughly 30% cut in greenhouse-gas emissions from new cars and trucks sold in the state by 2016. But to implement the regulations it needs a waiver from federal law.

California applied two years ago for its waiver and says in its suit against the U.S. Environmental Protection Agency the administration is taking too long to rule on the request.

The EPA has been saying it plans to issue a decision on California's waiver request by the end of the year.

What's bringing the other industries into this fight is simple self-interest. California's plan to curb greenhouse-gas emissions from cars and trucks is part of a broader campaign by the state to cut those emissions across its economy 25% by 2020. If the state fails to get a federal waiver to force

emissions cuts from auto makers, it would likely shift more of the burden to other industries.

That's why Pacific Gas & Electric Co., a unit of San Francisco-based **PG&E** Corp., is supporting California's waiver request. "PG&E's customers have a vital interest in ensuring that all sectors of our economy -- including the transportation sector -- contribute their fair share toward achieving greenhouse gas emission reductions," the utility wrote to the EPA in June.

The oil industry hasn't taken a formal position in California's fight against the EPA, but it also isn't opposing the state's goals.

"We are concerned about ensuring that the responsibility for reducing greenhouse-gas emissions is spread across all elements of the economy," says Joe Sparano, president of the Western States Petroleum Association, an industry trade group. He adds: "We are not at all opposed to improved mileage efficiency for automobiles."

Write to Jeffrey Ball at jeffrey.ball@wsj.com[1]

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AUTOMOTIVE TECH

Saving Gas and Lives

Can the U.S. improve fuel economy without sacrificing safety? BY MARK ALPERT

For years, the automobile industry has argued that congressional attempts to make cars and trucks more fuel-efficient would compromise passenger safety. The argument is based on the premise that the Corporate Average Fuel Economy (CAFE) standards imposed in 1975 resulted in a reduction of vehicle weights, which in turn caused about 2,000 traffic deaths a year that would not have occurred otherwise. But as Congress considers an energy bill that would further boost fuel economy—the combined average for cars and light trucks has been stalled at about 25 miles per gallon since the 1980s—transportation experts have disputed the contention that a lighter fleet would be less safe. What is more, new engine and transmission technologies could enable manufacturers to improve fuel efficiency without significantly cutting vehicle weights.

The current CAFE standards are 27.5 mpg for cars and 22.2 mpg for light trucks. In June the Senate passed a bill that would boost the fuel economy of new cars and trucks by about 40 percent. (In August the House of Representatives passed a bill that would leave CAFE standards unchanged; a House-Senate conference committee is expected to resolve the differences between the bills later this year.) Under the Senate proposal, the National Highway Traffic Safety Administration (NHTSA) would divide the fleet into classes based on size or weight and set fuel-economy standards for each class to achieve an overall average of 35 mpg by 2020. Tom Wenzel, a transportation scientist at Lawrence Berkeley National Laboratory, says the safety impact would depend on whether the regulations alleviate the present mismatch between cars and light trucks. According to Wenzel, the lower CAFE standard for trucks has fostered a proliferation of behemoth SUVs and pickups that cause thousands of deaths every year when they plow into cars.

A step in the right direction, Wenzel says, would be defining the vehicle classes by size rather than weight. Because the size of a vehicle's "crumple zone" can be crucially important for protecting passengers in a front-end crash, automakers should be discouraged from shrinking cars to enhance fuel economy. The best solution would be incorporating lighter, high-strength materials into auto frames and bodies, which would allow manufacturers to slash weight without trimming the vehicle's footprint.

Other experts note, however, that major weight reductions may not even be necessary. Says David Greene, a transportation researcher at Oak Ridge National Laboratory: "If manufacturers were to take the available technologies and apply them to fuel economy over the next 10 to 15 years, they could cost-effectively achieve a 40 to 50 percent improvement without making vehicles smaller." For example, some car engines already have variable valve lift and timing, which provides greater control over the flow of air into and out of the combustion chamber; until now automakers have employed this system primarily to boost horsepower, but it can also be used to increase fuel economy.

Another promising technology is a

FATAL MISMATCH: The size discrepancy between SUVs and cars, fostered in part by differing fuel-economy standards, has increased the number of traffic deaths in the U.S. A careful adjustment of the standards could reduce the disparity in vehicle weights.

STEVE GOOCH *The Oklahoman*/AP Photo

camless engine, which opens and closes its valves by computer signals instead of connecting them mechanically, via cams and camshafts, to the crankshaft. Valeo, a French automotive company developing camless systems, estimates that the technology could raise fuel efficiency as much as 20 percent. Innovations in transmissions, aerodynamics, tires and power-hungry accessories such as air conditioners can also upgrade fuel economy.

Greene predicts that the expense of meeting the new CAFE standards proposed in the Senate bill would probably range between $1,000 and $3,000 per vehicle, an up-front cost that could be recouped in fuel savings within five years if the price of gasoline remains above $3 a gallon. At the same time, the NHTSA could reduce the number of traffic fatalities by requiring the wider adoption of new safety features such as improved seat belts. "What we need are better safety regulations," Wenzel points out, "not inaction on CAFE."

CARBON SEQUESTRATION

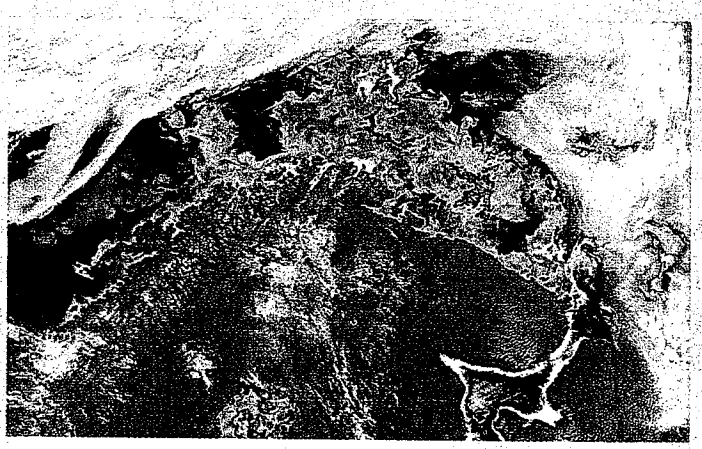
Oceangoing Iron

A venture to profit from a CO_2-eating algae bloom riles scientists BY SOURISH BASU

Researchers have debated for a long time whether dumping iron into the ocean could ameliorate climate change. Iron encourages the bloom of tiny algae called phytoplankton, which take in carbon dioxide (CO_2) dissolved in the ocean for photosynthesis; that process in turn draws atmospheric CO_2 into the surface waters. Most scientists remain skeptical of whether iron fertilization will lead to greater carbon sequestration. But a company called Planktos, based in Foster City, Calif., has been forging ahead with such plans. Its latest target: 10,000 square kilometers of the equatorial Pacific, 600 kilometers west of the Galápagos—by far the most ambitious and controversial iron-seeding plan yet.

Phytoplankton photosynthesize as much CO_2 as all the terrestrial plants combined. Although most of the fixed carbon returns to the ocean within a week when the phytoplankton die, perhaps up to a fifth of the biomass sinks to deeper waters, trapping carbon in the sea. For photosynthesis, phytoplankton need trace amounts of iron, and in the equatorial Pacific, the metal primarily comes from dust storms in the Gobi and Taklimakan deserts of Central Asia.

Citing a 2003 study by NASA and the National Oceanic and Atmospheric Administration (NOAA), Planktos claims that the amount of iron entering the equatorial Pacific has decreased by 15 percent since the early 1980s—presumably because of shifting wind patterns and fewer dust storms. As a result, the firm infers, phytoplankton populations there have decreased by 6 percent and CO_2 absorption by 3 percent. Through iron fertilization, Planktos wants to restore iron and phytoplankton to pre-1980 levels, which "will absorb 70 percent of the world's current CO_2 emission," affirms Planktos marketing chief William Coleman.



CARBON EATERS: Chlorophyll concentrations off the coast of Norway, depicted in false color from red (most dense) to purple (least dense), show a phytoplankton bloom in progress. The plankton on this page and the next are single-celled algae called diatoms.

Dalhousie University oceanographer John Cullen, however, does not think that a low phytoplankton level necessarily indicates less carbon sequestration. A "successful" fertilization, he explains, will sink phytoplankton biomass—along with the nutrients it absorbs—to deeper waters, depleting the surface of chlorophyll (phytoplankton) and iron. Such declines might therefore be a signature of carbon being sequestered.

In any case, most investigators doubt that adding iron will shift the carbon load to the oceans. A dozen experiments have indeed shown that extra iron results in phytoplankton blooms, but whether carbon becomes trapped in the deep ocean over the long run remains unknown. In one such experiment, "less than 10 percent of the extra carbon that was fixed was actually making it to even 120 meters" of depth, says oceanographer Philip Boyd of the National Institute of Water and Atmospheric Research in New Zealand. And strong upwellings in the equatorial Pacific would probably release the trapped carbon back into the atmosphere in a few years anyway, says University of Southern California oceanographer Anthony Michaels.

Other data also counter Planktos's position that less

NORMAN KURING MODIS/NASA (map); STEVE GSCHMEISSNER Photo Researchers, Inc. (diatom)