Biodiesel Blends

What's "Green" About Biodiesel? Part II

Research Experiences for Teachers Participant, 2008
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Biodiesel Background information

Alternative energy sources have become more and more important as our sources of nonrenewable energy (mainly petroleum) have become increasingly rare and costly. Those of you who have your driver's licenses know that the cost of gas has been rising steadily. What if there was a less expensive fuel available that produced significantly less pollution and was produced from a renewable resource? There is such a fuel, and it is called Biodiesel. Biodiesel is fuel made from plant oils or animal grease, so it is relatively inexpensive, very abundant and a renewable resource. Biodiesel seems to be one of several very promising answers to our current energy crisis.

In the following pages you will learn how to Biodiesel is made, what some of the benefits and drawbacks are, and some of the current issues surrounding the use of this fuel.

The following curriculum was produced for high school teachers and students. This material is intended to provide a variety of information and activities for high school students to develop a broad understanding of the issues surrounding Biodiesel as an alternative fuel.

Table of Contents

Biodiesel vs. Standard Diesel: Research Report

1) Brief description of lesson	Students conduct research on biodiesel and produce a short research paper regarding alternative energy.
2) Learning Objectives:	The student will research an alternative fuel and compare it to standard diesel. The student will analyze the ecological, financial, personal, etc. implications of alternative energy usage. The student will utilize an affective skill set when responding the prompts.
3) Kansas State Standards:	Standard 1: Science as Inquiry (1.1.3a, 1.1.5c, 1.1.5d) Standard 2: Chemistry (2A.2.1a, 2A.2.3e, 2A.3.1a) Standard 3: Life Science (3.4.5) Standard 4: Earth and Space Science (4.1.2e, 4.1.3b) Standard 5: Science and Technology (5.1.1d, 5.1.2, 5.1.3b) Standard 6: Science in Personal and Environmental Perspectives (6.1.1, 6.3.1a, 6.3.1b, 6.3.2a, 6.5.1) Standard 7: History and Nature of Science (7.1.5, 7.2.2a)
4) Skills used:	Writing in science.
5) Students prior knowledge on this topic:	Students have most likely heard of diesel fuel. Many may be aware of biodiesel or ethanol fuels as alternative energies. All students should be moderately to highly aware of the fossil fuel crisis and the need for renewable energy sources.
6) Relevance: Where does this knowledge apply in everyday life?	In coming months or years, students will need to be making decisions about alternative energy options. Due to this research, they will be better informed to make a decision.
7)Planned formal assessment	The final product will be a research report. A rubric is provided.

Instructions: Please choose one of the prompts on the following page. You will use the prompt to provide the basis for a research report. Your report should be 300-500 words long and should describe the problem and its implications. You must compare and contrast Biodiesel (FAME) and Standard Diesel #2 fuel in your report.

RESEARCH/BIBLIOGRAHY:

* You will need to use of 5-10 sources information.
* You MUST include one of each of the following types of sources:
  - -one book
  - -one journal or magazine article
  - -one primary source (an interview with a real person)
* Please use Annotated MLA format for your citations.
  (Annotated means you must include 2-3 sentences about the information you found in that source.)
* Please include footnotes within your text for all information you found in one of your sources.

RESEARCH PAPER:

* Please choose a topic from the topics list. Conduct research on your topic and then write a paper to discuss and compare/contrast the properties of standard #2 diesel fuel to Biodiesel fuel.
* Please use standard MLA format (1"margins, single-spaced, 12 pt font, Times New Roman, etc.)
* You must use 5-10 sources of which one must be a book, one must be a journal article and one must be a primary source (an interview with a real person).
* Please include a cover sheet with your name, hour, date and title of your essay.
* The paper must be 300-500 words in length.
* Your paper must address your chosen research topic in depth.
* Your writing should be high quality and display good syntax (correct spelling and grammar). Remember to proof read!!
* In addition to providing depth of information, you should also include your own thoughts and reactions to the prompt.

Biodiesel Research Topics

1.) Discuss the similarities and differences in cold weather properties for standard diesel fuel and biodiesel. How would those properties affect a vehicle's performance in the summer? How about the winter? (Address gelling, cloud point data, cold flow properties of fuel, etc.)

2.) How does the viscosity of the two fuels compare? Give specific details about how this affects engine performance?

3.) What are some of the maintenance issues associated with using biodiesel in a diesel engine?

4.) What are some feedstocks that are being considered and/or used to produce biodiesel? Discuss the consequences of using these feedstocks from the perspective of farmers, consumers, oil companies, etc.

5.) Discuss the toxicity levels of diesel fuel versus biodiesel fuel. In other words, how hazardous are these substances to your health if you spill the fuel on yourself or breathe their vapors, etc.

6.) Discuss the use of ethanol versus biodiesel. Address the following factors: cost, energy output in engine, corrosion of engine parts, ratios allowed by law, etc.

7.) Discuss the factors in the debate about using a biodiesel versus standard diesel in automobiles. (Address the environment, savings at the pump, oil companies, farmers, fuel emissions, toxicity levels, carbon footprint, etc.)

8.) Discuss some of the factors one should consider when producing biodiesel at home. (Address cost of production, fuel taxes, federal fuel production amount limits, federal fuel standards (ASTM), on-road fuel vs. off-road fuel, dyeing off-road fuel red, fuel emissions, testing quality of your fuel, etc.)

9.) Discuss the reasons a manufacturer might impose restrictions on which ratios of biodiesel will qualify for the manufacturer's warranty and why.

10.) What are some of the ecological consequences associated with using alternative energy sources such as biodiesel? Give specific examples to support your argument.

11.) Describe the differences between a gasoline engine and a diesel engine. Discuss the effects of using these engines on our environment. (Include the environment, toxic fumes, air pollution, carcinogens, cost of production, political reasons, etc.)

12.) What is the CO_2 cycle and how does it relate to the ecological benefits of biodiesel?

13.) What is a carbon footprint? Explain how alternative fuels, such as biodiesel, can affect one's carbon footprint.

14.) How does the flashpoint of biodiesel compare to standard diesel? Explain how this affects the safety of transporting the fuels, storing the fuels, personally handling the fuels, accidental spilling of the fuels, etc.

15.) Discuss the connection between cost and energy output for Biodiesel versus #2 s standard Diesel fuel.

16.) Discuss the reasons Biodiesel and other alternative fuels are not widely used yet.

17.) What would some of the benefits be to blending various types of feedstock oils? Explain how it could be beneficial.

18.) Discuss what kinds of criteria you think would be important to create standards for bio-fuels and why you think they would be important.

19.) Discuss both sides of the fuel vs. food debate. Are you for or against using crops for fuel? Explain what your position.

20.) When is it illegal to make biodiesel? Discuss the reasons people are making Biodiesel illegally. Why is it illegal? What are some of the dangers of making it non-commercially?

21.) How does the chemistry of the Biodiesel production process compare to the production of hydrogen peroxide in the cells of your body. Explain the process for both, and compare and contrast.

22.) Discuss the issues associated with the demand for biodiesel fuel and how much supply would be readily available in the United States. Also consider the consequences for farmers, consumers, producers of biofuels, etc.

23.) Research the solvent properties of biodiesel and standard Diesel 2. What ramifications will this have in terms of engine parts? What questions would you need to address as an engine manufacturer? How do you think this would affect warranties on parts? What other issues might you need to consider?

24.) What is the typical shelf life for standard diesel and biodiesel fuel? What are some of the concerns consumers might have about shelf life? What are some concerns fuel companies might have? Describe some ideas for solving these problems.

25.) Come up with your own idea. Must be approved by instructor first.

Biodiesel Research Report Rubric

	A	B	C	F
Cover Sheet	All appropriate details are included: Name, Hour, Date, and Title of project. Student has gone the extra mile to make the cover sheet attractive and visually appealing.	All appropriate details are included: Name, Hour, Date, and Title of project. Student has provided a reasonably attractive cover sheet.	All appropriate details are included: Name, Hour, Date, and Title of project. Cover sheet has necessary information only. Appearance lacks style or creativity.	Cover sheet is not present or is missing required information.
Quality of Research	Student has exceeded the minimum research requirement of 5 sources. Student has demonstrated a high depth of knowledge of their subject. Annotations display depth of knowledge of source material.	Student has exceeded the minimum requirement of 5 sources. Student has demonstrated an acceptable level of knowledge of subject. Annotations display depth of knowledge of source material.	Student has met the minimum requirement of 5 resources. Student has demonstrated an acceptable level of knowledge of subject. Annotations display knowledge of source material.	Student has not met the minimum requirement of 5 resources, and/or Annotations are missing, and/or Annotations display a lack of knowledge of source material.
Appropriate Length	Student has written 450-500 words.	Student has written 400-450 words.	Student has written 300-400 words.	Student has written less than 300 words.
Quality of writing	Student has used strong writing techniques to illuminate their topic with depth and clarity.	Student has used good writing techniques to present their topic with clarity, but could have developed a couple thoughts more fully.	Student used adequate writing techniques to present their topic with clarity, but could have developed many or most thoughts more fully.	Student used less than adequate writing techniques. Student did not present their thoughts with depth or clarity.
Quality of thoughts presented	Student presented the scientific principles and discussed various ramifications of their prompt. They presented their thoughts and original solutions or ideas.	Student presented the scientific principles and discussed various ramifications of their prompt. They neglected to include their thoughts and original solutions/ideas.	Student presented a limited view of the scientific principles. Student discussed a small portion of the ramifications. Student shared briefly about their thoughts and solutions/ideas.	Student did not display depth of discussion. Concepts were covered on a surface level, or contained excessive personal conjecture.
Formatting (MLA format, syntax, grammar, spelling, etc.)	Student used MLA format and displayed correct syntax and formatting throughout.	Student used MLA format and made 1-2 small syntax or spelling errors.	Student used MLA format and made 3-4 small syntax or spelling errors.	Student did not use correct format and/or there were multiple syntax or spelling errors.
Bibliography	MLA Format used. 7-10 resources used. Annotations are complete and include thorough description.	MLA format used. 6-10 resources used. Annotations are complete and include thorough description.	MLA format used. 5-10 resources used. Annotations are present and descriptive.	MLA format is not used and/or annotations are not present or appropriate.

Story Time: Some drawbacks for using biodiesel

1) Brief description of lesson	Students will read about some of the effects biodiesel has on engines and write a creative story about their findings.
2) Learning Objectives:	Students will learn the negative effects of biodiesel on engines Students will respond affectively to the topic Students will enhance their understanding of cause and effect relationships Students will understand that not all solutions to the energy crisis are 100% effective.
3) Kansas State Standards:	Standard 1: Science as Inquiry (1.1.3a, 1.1.5c, 1.1.5d) Standard 2: Chemistry (2A.2.1a, 2A.2.3e, 2A.3.1a) Standard 3: Life Science (3.4.5) Standard 4: Earth and Space Science (4.1.2e, 4.1.3b) Standard 5: Science and Technology (5.1.1a, 5.1.1d, 5.1.2, 5.1.3b) Standard 6: Science in Personal and Environmental Perspectives (6.1.1, 6.3.1a, 6.3.1b, 6.3.2a, 6.5.1) Standard 7: History and Nature of Science (7.1.5, 7.2.2a)
4) Skills used:	Writing skills Data Table interpretation skills Technical reading skills
5) Students prior knowledge on this topic:	Students may have minimal to moderate knowledge of biodiesel as an alternative fuel. Because of their age ranges, they will also have knowledge about gas prices. Some students may be familiar with diesel engines from farm equipment or other diesel vehicles.
6) Relevance: Where does this knowledge apply in everyday life?	It is important for students to realize that solutions to social problems often have unintended consequences. It is also important for students to understand both the positive and negative effects of renewable energy options.

Background: Biodiesel is not a perfect fix to our energy crisis. Below, you will learn about some of the concerns for engine manufacturers. Biodiesel fuels that are made from Soybean oil or Rapeseed oil are called **Fatty Acid Methyl Esters** or **FAME** for short.

Story opening:

"Hey man, check out my new car!" you shout out to your best friend while leaning out the window of your brand-new, bright yellow Volkswagen bug . "I had racing stripes put on!! Isn't it awesome?!"

Your best friend gives a pleased whistle and exclaims, "Wow! Nobody could miss you in that!"

After bantering back and forth for a few minutes, your best friend's dad comes out to examine your new bug. "That sure is a nice paint job; you think I could take it for a spin?" He says wistfully. "I used to have a VW bug back when I was a kid."

After a few blocks, your best friend's dad says, "You know, I've been making my own biodiesel in the garage for a couple of years. You ought to try some in your bug. It'd save you some money on gas, and you'd be helping the environment too."

You have heard a lot of really good things about biodiesel, so you think you might try it…

Writing your own story about biodiesel: Use the chart on the next page and choose 3 or more problems that could go wrong if you do decide to put biodiesel in your car. Write a 2-3 page short story about your adventures. Creativity is encouraged. You may use the story opening provided, or create your own.

Fatty Acid Methyl Ester Fuels as a Replacement or Extender for Diesel Fuels

FAME Fuel - Joint FIE Manufacturers Statement, issued June 2000

During extensive field trials conducted by the Fuel Injection Equipment (FIE) Manufacturers in collaboration with end-users, the following injection equipment and engine problems have been identified as being caused by the following fuel characteristics. The incidence of these effects is likely to be *increased* when the engine is in **irregular use**, in applications such as stand-by generator units, automatic plant and seasonally used vehicles.

Fuel injection equipment - potential problems with FAME (non exhaustive list)

Substances that form in FAME	**Problems caused in the engine**
Fatty acid methyl esters (general)	Causes natural rubbers to soften, swell, or harden and crack which causes Fuel Leakage
Free methanol in FAME	Corrodes aluminum & zinc in Fuel Injection Equipment Low flash point (catches on fire at low temperatures)
Potassium and sodium compounds in FAME	Solid particles cause blocked nozzles
Dissolved water in FAME	FAME reverts to fatty acids which causes filter plugging
Free water in mixtures	Corrosion of fuel injection equipment Allows bacteria to grow Sludging occurs Increases the electrical conductivity of fuel
Free glycerine	Corrodes metals that aren't made of iron Filter clogging Soaks cellulose filters Sediments on moving parts and Injector Coking and Lacquering
Free fatty acid	Provides an electrolyte and hastens the corrosion of zinc metal Corrosion of Fuel injection equipment
Salts of organic acids	Filter plugging Organic compounds forms Sediments on parts
Higher modulus of elasticity	Increases injection pressure Potential of reduced service life
High viscosity (becomes thick) in cold weather	Generates excessive heat locally Pump seizures in rotary distributor pumps Early life failures Higher stressed components Poor nozzle spray - atomization
Solid impurities	Potential lubricity problems Reduced service life
As Biodiesel gets *older*, these things occur	
Corrosive acids (formic & acetic)	Corrodes all metallic parts may form simple cell Corrosion of Fuel injection equipment
Polymerization products	Deposits especially from fuel mixes Filter plugging Lacquering formation in hot areas

Brrrrr… Cold Flow Properties for Biodiesel

1) Brief description of lesson	Students will analyze biodiesel "cold flow" fuel data and make conclusions based on their findings. In addition, Students will have to read scientific information presented in a data table format and be expected to interpret the information
2) Learning Objectives:	Students will understand Celsius and Fahrenheit conversion. Students will read and understand a data table which will prepare them for state testing. Students will know what FAME is Students will understand trends in data Students will understand positive consequences of using biodiesel blends
3) Kansas State Standards:	Standard 1: Science as Inquiry (1.1.3a, 1.1.5c, 1.1.5d) Standard 2: Chemistry (2A.2.1a, 2A.2.3e, 2A.3.1a) Standard 3: Life Science (3.4.5) Standard 4: Earth and Space Science (4.1.2e, 4.1.3b) Standard 5: Science and Technology (5.1.1d, 5.1.2, 5.1.3b) Standard 6: Science in Personal and Environmental Perspectives (6.1.1, 6.3.1a, 6.3.1b, 6.3.2a, 6.5.1) Standard 7: History and Nature of Science (7.1.5, 7.2.2a)
4) Skills used:	Technical reading skills Data analysis skills Temperature conversion skills
5) Students prior knowledge on this topic:	Some students may be aware that diesel fuels tend to have poor function in cooler temperatures. Students should also be familiar with biodiesel as an alternative fuel.
6) Relevance: Where does this knowledge apply in everyday life?	Students are at the age where they are starting to drive, so information about fuel is very relevant to them. Even students who drive gasoline powered vehicles will be better informed about the options.

Background Information:

If you have ever driven a diesel vehicle, you are likely well aware of the tendency of diesel fuel to solidify in the winter. This is a problem because when diesel fuels gel or crystallize at low temperatures, it causes the *engine to stop*!!

A large amount of research has been done to estimate the lowest temperature at which a given fuel can be used. Some of the long chain hydrocarbons in #2 diesel fuel, known as waxes, will typically start to gel at about -9°C to -10°C. Biodiesel will generally start to gel at higher temperature than #2 diesel fuel. Soybean oil-based biodiesel will form crystals at about 0 °C and biodiesel from greases and animal fats can form crystals at 20°C or even higher.

ROOM TEMPERATURE: Keep in mind that room temperature is 20°C or 68°F.

FREEZING: Water freezes at 0°C, or 32°F.

Temperature Conversion:

This chart is provided so you can easily compare the Celsius temperature to the Fahrenheit temperature

To convert Fahrenheit to Celsius (Centigrade), subtract 32 and divide by 1.8.

To convert Celsius (Centigrade) to Fahrenheit, multiply by 1.8 and add 32.

°Celsius	-25	-20	-15	-10	-5	**0**	5	10	15	20	25	30	35	40
°Fahrenheit	-13	-4	5	14	23	**32**	41	50	59	68	77	86	95	104

Vocabulary Checkpoint:

* **Fatty Acid Methyl Ester (FAME)** is another name for **Biodiesel**

* **Feedstocks** are the starting materials we make the Biodiesel from. For example, some common feedstocks include: soybeans, canola oil and animal lard. Below, please find cold weather data on 3 different types of feedstocks used to make Biodiesel blends.

Cloud Points

Cloud Point - The cloud point is the temperature at which a cloud of wax crystals first appears in a fuel sample that is cooled under conditions described by ASTM D2500. The cloud point is determined by visually inspecting for a haze in the normally clear fuel.

Biodiesel concentration	Soy Methyl Ester	Canola Methyl Ester	Lard Methyl Ester
0%	-18	-18	-18
0.25%	-20	-18	-18
0.50%	-17	-18	-17
1.0%	-16	-18	-17
3.0%	-16	-17	-16
5.0%	-16	-17	-15
10.0%	-15	-17	-14
20.0%	-14	-15	-3
35.0%	-9	-12	-3
50.0%	-9	-10	-2
100.0%	2	-3	14

Pour Points

Pour Point - The pour point is the lowest temperature at which movement of the fuel sample can be determined when the sample container is tilted. The sample must be cooled following the procedure described in ASTM D97.

Biodiesel concentration	Soy Methyl Ester	Canola Methyl Ester	Lard Methyl Ester
0%	-27	-27	-27
0.25%	-27	-21	-24
0.50%	-27	-24	-24
1.0%	-24	-24	-24
3.0%	-24	-24	-21
5.0%	-21	-21	-18
10.0%	-18	-21	-15
20.0%	-18	-18	-9
35.0%	-15	-18	0
50.0%	-9	-15	3
100.0%	-1	-4	11

From: "Production of Biodiesel from Multiple Feedstocks and Properties of Biodiesels and Biodiesel/Diesel Blends," Final Report to National Renewable Energy Laboratory from Gas Technology Institute, Des Plaines, IL, Sept. 2001.
http://www.uidaho.edu/bioenergy/Bioshortcourse/Diesel_Fuel_Props.htm

Brrrrr... Cold Flow Properties Questions

Instructions: Based on the information on the previous pages, when answering the questions.

1.) Two methods are described for determining whether Biodiesel Blends could be used in colder temperatures: the Cloud Point method, and the Pour Point method. Based on their descriptions, which do you think would be more effective and why.

2.) What are some reasons scientists would want to blend standard #2 diesel fuel with Biodiesel?

3.) What are some negative consequences of using Biodiesel blends?

4.) What are some positive consequences of using Biodiesel blends?

5.) Looking at the data in the Cloud Point and/or Pour Point charts, what tends to happen as the percentage of Biodiesel is increased?

6.) Using the Cloud Point information, which percentage of Biodiesel made from soybeans would you use in your car and why?

Fuel Standards Research Activity

1) Brief description of lesson	Students will choose a fuel standard to research with a partner. They will produce a PowerPoint explaining their findings.
2) Learning Objectives:	Students will understand the various types of diesel fuel standards Students will gain an affective appreciation for the need to standardize fuel production Students will conduct research and produce a product Students will work well in a team
3) Kansas State Standards:	Standard 1: Science as Inquiry (1.1.3a, 1.1.5c, 1.1.5d) Standard 2: Chemistry (2A.2.1a, 2A.2.3e, 2A.3.1a) Standard 3: Life Science (3.4.5) Standard 4: Earth and Space Science (4.1.2e, 4.1.3b) Standard 5: Science and Technology (5.1.1d, 5.1.2, 5.1.3b) Standard 6: Science in Personal and Environmental Perspectives (6.1.1, 6.3.1a, 6.3.1b, 6.3.2a, 6.5.1) Standard 7: History and Nature of Science (7.1.5, 7.2.2a)
4) Skills used:	Technical reading skill Technical writing skills Presentation skills Interpersonal skills Research skills
5) Students prior knowledge on this topic:	Students may have little to no knowledge about the standards required for diesel fuels.
6) Relevance: Where does this knowledge apply in everyday life?	It is important for high school students to understand and appreciate the significance of mandated standards for fuels.

Background information:

Because we want the chemicals we use for fueling our cars to be safe for ourselves, others and our environment, organizations, like the American Society for Testing and Materials (ASTM), create fuel standards. In the following pages, you will read about the standards required for Biodiesel and the tests that allow people to find out if their fuels are acceptable.

Instructions:

1.) Choose a partner who will help you be productive
2.) From the following list, choose a standard to research.
3.) Read the "Purpose" and "Significance and use of the recommended properties" in the EMA guidelines, as well as the "EMA Recommended Guideline on Diesel Fuel Properties"
4.) Use web resources or other resources to research your topic
5.) **Produce a PowerPoint of 5-10 slides to explain your topic to the class**
    a. Include a cover slide with your names, hour, date, Project Title
    b. Make attractive, visually pleasing slides
    c. Use pictures or graphics to support your research
    d. When presenting, make sure to only put short phrases on your slides, so you are NOT reading directly from the slides the whole time.

Research Topics:

Flash Point
Water and Sediment
Distillation
Kinematic Viscosity
Ash Content
Sulfur
Copper Corrosion
Cetane Number/Cetane Index
Ramsbottom Carbon Residue
API Gravity
Lubricity
Accelerated Stability
Detergency
Low Temperature Operability

Recommended Guideline on Diesel Fuel (EMA FQP-1A)

Engine Manufacturers Association

PURPOSE

This Recommended Guideline of the Engine Manufacturers Association is intended to define a diesel fuel that is superior in quality than the commercial fuel specification ASTM D 975.
The diesel fuel is considered to be "superior in quality" insofar as it may assist in improving the performance and durability of engines currently in use and those to be produced prior to 2004. It is not intended to enable diesel engines to meet 1998 Federal emission standards or, in general, to improve engine exhaust emissions. The most significant aspects of this Recommended Guideline are its requirements for a minimum fuel lubricity, increased cetane number and improved cold weather performance. These properties, described in detail below, should help address many current customer satisfaction and engine performance issues.

SIGNIFICANCE AND USE OF THE RECOMMENDED PROPERTIES

For the benefit of our customers and other interested parties, the following section summarizes the critical properties of diesel fuel and, where appropriate, the reason for EMA's selection of a particular quality level of that property.

Flash Point

The flash point temperature of diesel fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source under specified conditions. Flash point varies inversely with the fuel's volatility. Flash point minimum temperatures are required for proper safety and handling of diesel fuel. Due to its higher flash point temperature, diesel fuel is inherently safer than many other fuels such as gasoline.

Water and Sediment

Diesel fuel should be clear in appearance and free of water and sediment. The presence of these materials generally indicates poor fuel handling practices. Water and sediment can and will cause shortened filter life or plugged fuel filters which can in turn lead to fuel starvation in the engine. In addition, water can have negative impact on fuel corrosion and on microbial growth. It is for that reason we recommend separate analysis and maximum levels.

Distillation

This property provides a measure of the temperature range over which a fuel volatilize or turns to a vapor. Volatility is one of the primary factors, which distinguish #1 from #2 diesel fuel. No. 1 diesel typically has greater volatility than No. 2. The highest temperature recorded during distillation is called the end point. Ideally, one would specify an end point in the definition of fuel properties. However, because a fuel's end point is difficult to measure with good repeatability, the fuel's 90% or 95% distillation point is commonly used. EMA prefers the 95% distillation point since its reproducibility is acceptable and it is closer to the fuel's end point than the 90% point currently measured in D 975.

In applications which operate at low loads and frequent idle periods, like bus engines, lower end point is desirable to reduce smoke and combustion deposits. Hence EMA recommends distillation temperature specifications lower than the current D 975 specification to cover those applications.

Kinematic Viscosity

Viscosity affects injector lubrication and fuel atomization. Fuels with low viscosity may not provide sufficient lubrication for the precision fit of fuel injection pumps or injector plungers resulting in leakage or increased wear. Fuels which do not meet viscosity requirements can lead to performance complaints. Fuel atomization is also affected by fuel viscosity. Diesel fuels with high viscosity tend to form larger droplets on injection which can cause poor combustion and increased exhaust smoke and emissions.

Ash Content

Ash is a measure of the amount of metals contained in the fuel. High concentrations of these materials can cause injector tip plugging, combustion deposits and injection system wear. Soluble metallic materials cause deposits while abrasive solids will cause fuel injection equipment wear and filter plugging.

Sulfur

To assist diesel engine manufacturers in meeting mandated limits for particulate matter in diesel engine exhaust, sulfur content is limited by law to 0.05% for diesel fuel used in on-road applications.

Copper Corrosion

The copper strip corrosion test indicates potential compatibility problems with fuel system components made of copper, brass or bronze. The limit requires that the fuel not darken these parts under the test conditions.

Cetane Number/Cetane Index

Cetane number is a relative measure of the interval between the beginning of injection and autoignition of the fuel. The higher the number, the shorter the delay interval. Fuels with low Cetane Numbers will cause hard starting, rough operation, noise and exhaust smoke. Current commercial fuel cetane requirements may not adequately address these customer satisfaction issues. Generally, diesel engines will operate better on fuels with cetane numbers above 50 compared to fuels with cetane numbers of the national average of approximately 45. Cetane number may be increased through the refining process or the blending of combustion ignition improving additives by fuel suppliers. Cetane index is an approximation of fuel ignition quality through measurement of distillation range and specific gravity. It is not affected by the use of combustion improver additives; therefore it produces an indication of the base cetane number of the fuel.

Ramsbottom Carbon Residue

The Ramsbottom Carbon residue test is intended to provide some indication of the extent of carbon residue that results from the combustion of a fuel. The limit is a maximum percentage of deposits by weight.

API Gravity

This is a measure of fuel's specific gravity or density. While specific gravity has no units, density is defined as mass per unit volume and both are temperature dependent. API gravity is defined as follows. API gravity of diesel fuel has a profound effect on engine power. As a general rule, there is a 3-5% decrease in the thermal energy content of fuel for every 10 degree increase in API gravity. This decrease in energy content will result in roughly the same percentage decrease in engine power. Use of fuels with higher API gravity will also result in higher fuel consumption (lower mpg). EMA's recommendation to include a maximum API gravity is based on our understanding of customer needs to maintain engine power, while minimizing fuel consumption

Lubricity

Lubricity describes the ability of a fluid to minimize friction between, and damage to, surfaces in relative motion under loaded conditions. Diesel fuel injection equipment relies somewhat on the lubricating properties of the fuel. Shortened life of engine components such as fuel injection pumps and unit injectors usually can be ascribed to a lack of fuel lubricity and hence is a concern to engine manufacturers. This property is not addressed adequately by ASTM D 975. ASTM has issued two tests to measure lubricity: the High Frequency Reciprocating Rig (HFRR) and the Scuffing Load Wear (SBOCLE) test. Current acceptability guidelines for both tests are provided in our chart. Aftermarket additives for improving diesel fuel lubricity should not be necessary and are not covered by this recommended guideline since they may react chemically with other additives causing them to lose their effectiveness, drop out of solution or even plug filters.

Accelerated Oxidation Stability (Rancimat)

Diesel fuel should be stable under normal storage and use conditions. Unstable fuel will darken and form black particulate materials which will cloud fuels and create gum residues in the fuel system. Although the accelerated stability test is intended to predict primarily storage stability, it can provide indication of overall fuel stability.

Detergency

All diesel fuels, which do not contain detergents, have a tendency to form carbon deposits on fuel injectors. It has generally been found that low sulfur fuels and thermally unstable fuels have a greater tendency to form these deposits. Detergent additives will prevent carbon deposits, which interfere with fueling and fuel spray patterns, from forming. Dirty injectors will invariability give rise to higher smoke levels in all equipment and in some equipment can limit power by restricting fuel flow. Diesel fuel detergency can be measured using the L10 Injector Depositing test. Passing limits for the test are provided in the attached table. These limits are expressed in terms of a CRC rating for injector cleanliness and a flow loss criterion.

Low Temperature Operability

Several tests are commonly used to characterize the low temperature operability of diesel fuel. These are Cloud Point, Cold Filter Plugging Point (CFPP), and Low Temperature Flow Test (LTFT). Among these, the LTFT is preferred by EMA as providing the best overall correlation with field performance. However, for non-additized fuel, cloud point and LTFT correlate very well. Since Cloud Point is more practical as a refinery quality control test, it is listed as our primary recommendation. Low temperature operability of bulk diesel fuel can be negotiated by the customer and fuel supplier. However, in the retail fuel market, low temperature operability is the responsibility of the fuel supplier. It is adjusted on a monthly basis during the winter, or sometimes sooner depending on expected ambient temperatures at the point of sale. Low temperature flow requirements usually vary depending upon fuel filter media and the presence of fuel heaters. However, to avoid operational problems the selection of a fuel's low temperature properties should be made based on the lowest ambient conditions expected during operation. Unless specifically recommended by the engine manufacturer or discussed with the fuel supplier in advance, modification of the waxing properties of fuels using aftermarket fuel additives is not recommended as an option for meeting the low temperature operability requirement, because of possible incompatibility with other additives already contained in the fuel.

EMA Recommended Guideline on Diesel Fuel Properties

Test	ASTM Method	FQP-1A EMA #1 Diesel Fuel (See #1 Below)	FQP-1A EMA #2 Diesel Fuel (See #1 Below)
Flash Point, °C min.	D 93	38	52
Water, ppm max	D1744	200	200
Sediment, ppm max	D2276 or D5452	10	10
% Vol. Recovery, °C	D 86	90%, max. 272 332	95%, max. 288 355
Kinematic Viscosity, 40 °C	D 445	1.3 - 2.4	1.9 - 4.1
Ash, % max.	D 482	0.01	0.01
Sulfur, % max.	D 2622	0.05	0.05
Copper Corrosion, max.	D 130	3b	3b
Cetane Number, min.	D 613	50	50
Cetane Index, min.	D 4737	45	45
Rams Carbon, 10% residue max.	D 524	0.15	0.15
API Gravity, max	D 287	43	39
Lubricity, g. min.	D6078(2)	3100	3100
Accelerated Stability, mg/L max.	D 2274	15	15
Detergency - L10 Injector	CRC Rating	<10	<10
Depositing Test	% Flow Loss	<6	<6
Low Temperature Flow, °C	D2500 or D4539	(see #3 below)	(see #3 below)
Microbial Growth		(see #4 below)	(see #4 below)

1) #1 Diesel Fuel and #2 Diesel Fuel are intended for use in the same applications described in the definitions of Grade No. 1-D and Grade No. 2-D respectively in ASTM D 975.

2) EMA recommends that lubricity levels be determined by ASTM D6078 ,Scuffing Load Wear Test (SBOCLE). Alternatively, lubricity may be measured using the High Frequency Reciprocating Rig (HFRR), ASTM D6079. Using this test, a wear scar of 0.45 mm at 60°C is equivalent to a SBOCLE result of 3100 g.

3) Diesel fuels must pass the Cloud Point (D2500) 0r Low Temperature Flow Test (D4539) at the use temperature. Low temperature flow capability is the responsibility of the fuel supplier for retail fuels. It is adjusted monthly during the winter, depending on local climate. Unless specifically recommended by the engine manufacturer or discussed with the fuel supplier in advance, modification of the waxing properties of fuels using aftermarket fuel additives is not recommended as an option for meeting the low temperature operability requirement.

4) While EMA has not included any recommendation with respect to Microbial Growth, it should be noted that microbial growth can cause operational problems, corrosion and sediment build-up in diesel engine fuel systems. The growth of microbes in fuel storage tanks and vehicle/equipment fuel tanks is believed to be related to pipeline and storage techniques and times and cannot be sufficiently addressed in a fuel specification.

Information is from the Engine Manufacturers Association EMA FQP-1A
Recommended Guideline on Diesel Fuel
http://www.tdiclub.com/articles/Diesel_Fuel_Guidlines/
If you have questions about this association position, contact EMA headquarters at:
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