Chapter 1

Liquid Heating Fuel

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Liquid Heating Fuel & its Properties

American Society for Testing & Materials (ASTM)

ASTM publishes industry specifications for many different materials including petroleum products. The specification for Fuel Oils is ASTM D396. This standard sets the minimum specifications for the fuel.

Flash point

The *flash point* of a fuel is the maximum temperature at which it can be safely stored and handled without serious fire hazard. For #2 fuel, the flash point is 100°F minimum. Biodiesel has a much higher flash point, over 200°F. The flash point of a blended fuel is that of the fuel in the blend with the lowest flash point, always treat biodiesel blends as if the flash point is the same as #2 fuel.

Fire point (also called ignition point)

The *fire point* is the lowest temperature where the vapor of a liquid will initiate and sustain a combustion reaction. For #2 fuel, the fire point is approximately 500°F.

Pour point

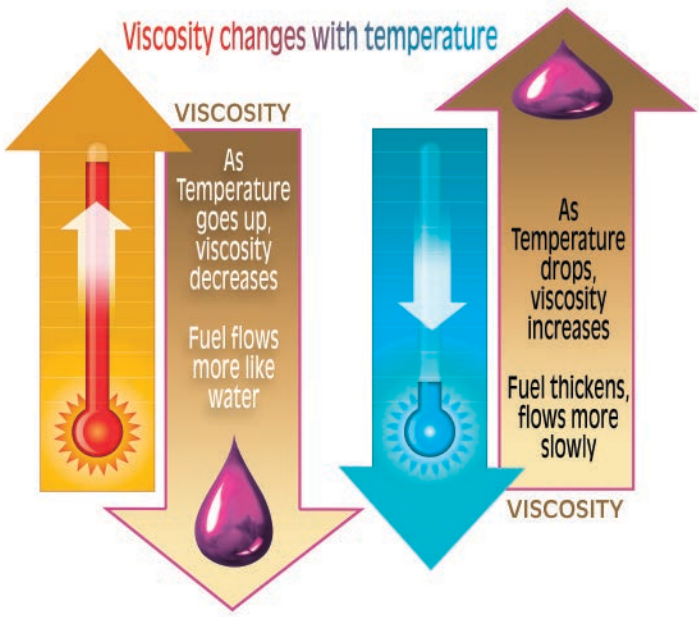
The *pour point* is the lowest temperature at which fuel will flow. Below this, it turns to a waxy gel. The ASTM maximum pour point for untreated #2 fuel is 21°F. Additives or kerosene can be added to the fuel during the winter to lower the pour point and ensure that it flows.

Cloud point

The *cloud point* is the temperature at which wax crystals begin to form in the fuel. ASTM does not list a cloud point specification for #2 fuel, but it is typically 10° to 20° above the pour point. The crystals that form can clog fuel lines, filters and strainers restricting fuel flow. Raising the temperature causes the crystals to go back into solution. Both pour point and cloud point affect winter performance and fuels that do not meet these specifications could cause problems if they are not properly treated.

Viscosity

The *viscosity* is the thickness of a fuel and its resistance to flow. Grease has a high viscosity, it does not flow easily—gasoline has a low viscosity, it flows easily. Heating fuel's viscosity changes dramatically with temperature. As the temperature decreases, viscosity increases. Cold fuel causes poor atomization, delayed ignition, noisy flames, pulsation, and possible sooting.



Physical Properties of #2 Heating Fuel

ASTM Specification:	D 396
Flashpoint:	100°F minimum (37.8°C)
Fire Point:	>500°F (260°C)
Pour Point:	17°F (8.3°C)
Cloud Point:	Pour point temp. plus 10-20° (F)
Viscosity:	Varies: increases as temp. drops
Water/Sediment:	ASTM allowable amount of H_2O: 0.1% (Water content is usually much lower in practice)
Sulfur Content:	Ranges from 0.5% to 0.05% (5000 to 500 parts per million); ASTM maximum allowable amount is 0.5%.
Color:	Colorless, but the fuel is dyed red for tax compliance reasons. Color resembles cranberry juice.
BTU Content:	139,000 (approx.)

Suppose the temperature of fuel in a basement tank is 60°F in the winter, and a delivery of 5°F fuel is made. The colder fuel will have a higher viscosity and burner performance will be affected until it warms.

Water and sediment

Accumulation of water in tank bottoms is undesirable as it leads to the formation of sludge and ice. Water and fuel usually do not mix, but if organic sediment is present in the fuel, it acts as a binder to stabilize the mix forming sludge. This forms a white milky substance that will not burn. Unfortunately, water can get into the system from condensation, leaks in lines, or missing vent and fill caps.

Sulfur content

Sulfur exists in varying degrees in all fossil fuels. The ASTM limits on sulfur content of #2 fuel ranges from 500 ppm (0.05%) to 5,000 ppm (0.5%). Most of the #2 fuel currently used is Ultra Low Sulfur Diesel (ULSD), which can have a maximum sulfur content of 15 ppm (0.0015%).

Using ULSD fuel all but eliminates scale and soot formation on heat exchanger surfaces, so the efficiency does not degrade during the heating season. ULSD leads to energy savings and decreased appliance service.

Color

#2 fuel used for heating and hot water purposes is dyed red to differentiate it from on-road diesel fuel for tax compliance reasons. Problems with the fuel are not indicated by the darkness of the color.

Fuel related service calls

The industry's top two service priorities are improved reliability and reduced heating equipment service costs. A significant number of unscheduled no-heat service calls are caused by inconsistent fuel quality, fuel degradation, and contamination.

The fuel may vary throughout the year. Wholesalers get their product from around the world, from Malaysia to Texas. Each of these products is slightly different and as a result, the fuel in the customer's tank may be a mixture of a variety of fuels. A great deal of the inventory is created by blending various fuels together to meet the rather loose definition for #2 fuel laid out in the ASTM D396 specification. Addition-

ally, fuel degrades over time—water may enter the system giving bacteria an opportunity to grow. Good housekeeping and an aggressive "problem-tank" replacement program can cut fuel related service calls dramatically.

Potential problems in the tank

The first problem is that the population of fuel tanks in the field is aging. As tanks age, rust and sediments build-up. Secondly, fuel has a finite shelf life and breaks down over time. The third problem is the size and speed of delivery. Filling a tank stirs up the sediments and rust in the bottom of the tank, and that leads to plugged lines, filters, and nozzles.

Fuel stability

All fuels, no matter the source, will eventually degrade in the presence of oxygen.

The stability of fuel depends a great deal on storage conditions. Fuels that are stored for long periods of time and subjected to temperature extremes may form excessive amounts of sediments and gummy substances that can plug filters, strainers, and nozzles.

Major factors in fuel degradation

1. **Chemistry of the fuel**
   - **Heat and air cause the oxidation of organics**
   - **The presence of sulfur and nitrogen hasten degradation**
   - **Corrosion creates iron oxides (rust)**
   - **Presence of gels caused by mercaptan sulfur**
   - **Incompatible fuels**
2. **Microbiological effects**
3. **The tank and its environment: moisture, direct exposure to sunlight**
4. **Improper tank installation & maintenance.**
5. **Presence of water.**

Water problems

Water in the fuel tank is a serious problem. Water enters the tank in the following ways:

1. Condensation
2. Broken tank gauge (outside tank)
3. Loose fill or vent fittings and missing caps
4. Directly from delivery trucks
5. Leaking vent, fill pipes or tank
6. Pumping fuel from a tank being replaced into a new tank
7. Fuel bound water and sediment

Sludge

Sludge is a combination of water, colonies of bacteria, degraded fuel, and other contaminants like sand, grit and rust. The ability of bacteria to grow almost anywhere and reproduce amazingly fast makes it an all too common problem. The bacteria typically live in between the water and fuel and eat the fuel. They break the fuel down into hydrogen, CO_2 and carbon rich residue. The bacteria also create sticky slime or gum (biofilm) to protect themselves. This deterioration of fuel is a natural occurrence that will appear in all tanks unless proper maintenance, including the removal of water accumulations, is performed. The sludge grows at the fuel-water line and when stirred up, can lead to serious and recurring service problems—most notably plugged fuel lines, filters, strainers and nozzles. Sludge is acidic and may eventually destroy the tank from the inside.

To reduce sludge formation:

- **Never pump fuel from a tank being replaced into a new tank.** Even with filtration, sludge and water are often transferred along with the fuel causing service problems and shortening the life of the new tank.
- **Routinely check the tank for water and remove it when found.** Then, if possible, clean the sludge from the tank and/or treat the tank with a fuel conditioning additive.
- **Whenever possible draw the fuel from the bottom of the tank**—as water will condense and collect in all tanks, it is best to draw off the water as it forms. It will collect in the filter and small amounts can burn off in the combustion process. Allowing water to accumulate will create conditions favorable for the formation of sludge. The exception to this rule is outdoor above ground tanks. In cold weather, water in the bottom suction line may freeze, causing a blockage and no heat. One solution to this problem is to run the suction line into one of the top tappings on the tank and regularly remove the water that condenses in the bottom of the tank.

Low temperature performance

As fuel gets cold, several bad things can happen. First, water in the fuel can freeze plugging lines and filters. Second, the viscosity of the fuel begins to increase, potentially leading to burner problems. Third, wax crystals begin to form in the fuel. This wax or paraffin is a natural component of #2 fuel. These wax crystals can eventually plug the fuel filter. Temperature is the main factor in changing fuel viscosity. As the temperature of the fuel goes down, the viscosity goes up and the fuel gets thicker which can cause operational problems.

Water detection paste

Water detection paste will indicate the depth of water at the bottom of the storage tank, but it will NOT detect a fuel-water emulsion. With the burner turned off, apply the paste in a thin coating on a gauge stick from zero up to four inches. Carefully lower the stick into the tank until it lightly touches bottom. Hold it in this position for the time recommended by the manufacturer, typically 30 seconds to a minute. Remove the stick— the water level will be indicated by a color change where water contacts the paste. If the water level shows on all of the paste, re-apply paste to a higher level and remeasure to determine the actual level of water in the tank.

Customers' tanks should be checked for water at least once a year and if detected, it should be drained from the tank ASAP. The technician should attempt to determine the source of the water.

Fuel additive treatment

There are numerous additives on the market that are designed to prevent or treat fuel related problems.

A successful fuel treatment program for individual tank problems requires knowledge of the quality of the fuel in the tank and the specific service issues being encountered. Using an additive off the shelf without testing may be ineffective and costly unless the challenges that need to be addressed are known. Always communicate with an additive professional before randomly treating.

Selection of additives: The multifunctional aftermarket additives available for heating fuel are proprietary products that offer a range of properties. Field tested additives could be beneficial if these guidelines are followed:

Guidelines:

- Define the problem and determine the additive that is needed to resolve it.
- Make sure the fuel sample being tested represents the fuel to be treated.
- Determine if the additive is to be used once, or if continuous treatment will be required.
- Determine if the additive performs more than one function.
- Make sure the additive supplier has technical support if there are questions or problems.
- Determine if the supplier can provide a way to measure effectiveness in specific cases. For example, a reduction in unscheduled service calls that include fuel unit, filter, strainer and nozzle replacements.
- Follow all safety and handling instructions on the labels and Safety Data Sheets (SDS) that should accompany the package. Always request a product data sheet with manufacturer recommendations on treatment ratio as well a SDS sheet declaring the handling guidelines.
- Follow the recommended treatment rates. Adding more than recommended is not any more effective than treating as designed by the manufacturer, and in some situations, it can make things worse.
- Properly dispose of the additive containers. Know and follow the local laws concerning disposal of sludge and water bottoms.

Types of additives:

Pour point depressants are designed to lower the pour point of the fuel and to avoid wax plugging of the filters. Once wax has formed in the fuel, which starts when the fuel meets the ambient temperatures, the additive will not perform as designed. It is important to introduce the additive into the fuel before the temperature reaches the fuel's pour point. An additive will not change the waxes present. To dissolve wax, a solvent such as kerosene must be used.

Dispersants separate the particulates that form preventing them from clustering into large enough masses to plug the fuel filters, strainers or nozzles. Dispersants were designed to keep these contaminants in suspension and stop them from settling to the bottom of the tank where they create sludge which can be drawn back into the fuel when a delivery agitates the tank.

Antioxidants and metal deactivators: Fuel degradation caused by oxidation or aging leads to gum deposits. Antioxidant additives can slow this process. Dissolved metals, such as copper, can speed aging and degradation, and produce mercaptide (sulfur containing) gels. To minimize these effects, metal deactivators combine with the metals and render them inactive. Periodic monitoring of fuel stability is recommended if these additives are being used.

Biocides: Serious problems can arise from microbial proliferation including sludge formation, acid and surfactant formation leading to operational problems. (Translation: Critters can grow in the tank creating a sludgy mess that will cause no heat calls.) Biocides kill or prevent the growth of bacteria and other microorganisms. They must be fuel-soluble and must be able to sink to the water in the bottom of the tank where all the microbes live.

Microbiological organisms in fuel are bacteria, molds and yeast. Since biocides are poisons, care must be taken when handling them. Read the label to determine product use, treatment rate and human exposure hazards warnings.

Preventative maintenance

Good housekeeping means doing everything possible to prevent dirt and water from entering tanks. Water promotes the growth of microbes which use the fuel as a food source and accelerates the growth of sludge and internal corrosion of the tank. Water can enter the tank through cracked or leaking fill pipes and vents. They should be checked periodically and whenever water contamination is suspected. Varying air temperature and humidity can cause condensation within the tank. Dirt and debris are generally introduced into the fuel through careless handling.

Use of rags for cleaning components

The rags used for cleaning can be a source of contamination. Using a rag contaminated with sludge or microbes can introduce these contaminates to a clean system. Also, if they are of a loose weave or have frayed edges, strings or fibers, lint from these rags can get into the system and plug the nozzle.

Tank cleaning

With massive accumulations at the bottom and on the sides of the tank, mechanical cleaning, fuel filtration, the use of additives and a preventative maintenance program are the only ways to effectively remove the sludge. Portable tank cleaning/filtration machines are also available. Their effectiveness depends upon the condition of the tank, access to the interior and the operator's skill. Before attempting to clean the tank, let the burner draw the fuel down as low as possible to minimize the amount of fuel that will have to be disposed of. Be aware that cleaning a residential tank is usually expensive and difficult and a tank replacement may be more economical and effective.

Tank replacement

If tank contamination has gone too far, tank and fuel treatment remedies will only buy some time. A tank's surface contains microscopic pits and craters where bacteria can "hide." Once fresh fuel is added and a bit of water condenses, the bacteria can reproduce at an astounding rate and sludge formation begins. Often, the only solution is to replace the tank and fuel lines. Never pump the fuel from the old tank into the new one. The contaminants that caused the problem will be transferred to the new tank along with the fuel. It will take surprisingly little time to make the nice new tank as dirty as the old one.

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Figure 1-1

Keep the tank full

Topping-off tanks, especially outdoor above ground tanks in the spring, helps prevent condensation—the less air in tank, the less condensation.

Bioheat® fuel

Biodiesel is a renewable, biodegradable combustible liquid fuel. Biodiesel is manufactured by processing vegetable oils, such as soy and rapeseed (canola). It is also made from waste cooking oils and trap grease, tallow, and animal fats, such as fish oil. Biodiesel has an ASTM specification (D6751) for pure biodiesel (B100). Its heating value is approximately 128,000 BTUs per gallon and it has a slightly higher density and higher cloud and pour points than #2 fuel.

Bioheat® fuel is a blend of #2 fuel and B100 biodiesel. A blend of 5% biodiesel and 95% #2 fuel is referred to as B5, a blend of 20% biodiesel and 80% #2 fuel is referred to as B20, etc.

Bioheat® fuel can be used in burners with little or no modifications to the equipment or operating practices. The viscosity is higher, yet still within ASTM limits for #2 fuel. Flow rate and atomization are similar. Bioheat® fuel will create slightly less deposits on the heat exchanger due to the reduced sulfur levels. According to the #2 Fuel ASTM standard D396, a blend of B5 is considered the equivalent to normal #2 fuel without the presence of biodiesel.

While biodiesel has some different properties than #2 fuel, the use of biodiesel at higher blend levels will require little change to current equipment. Most customers today are already using a blend of B5 with their existing equipment. B20 (80% #2 fuel and 20% biodiesel) and higher blends are becoming more prevalent in the market. When working with biodiesel blends, the best practice is to use equipment and parts that are listed for the fuel in use. Service companies and fuel retailers should maintain records on the types of fuels delivered to each customer and the service histories of their customers.

Bioheat® fuel has strong public appeal as a renewable low-carbon fuel. It has good lubricity that will help with low sulfur fuels. It increases the country's fuel source diversity, reducing dependence on foreign crude and is a potentially huge market for American agriculture. With the implementation of carbon reduction standards in the states with the most heating fuel usage, biodiesel and Bioheat® are being adopted to prevent the reduction and potential elimination of the residential heating liquid fuel market.

Summary

Most fuel problems are created in the customer's tank and heating system long after delivery. Reliability is dependent on service technicians keeping customer's systems operating at peak safety, dependability, and efficiency.

Chapter 1: Additional Resources

NORA has compiled a library of additional technical resources for your continued education. Scan the QR code or go to the web address. Check back often, as NORA will continually add content as it becomes available.

https://Learning.NORAweb.org/liquid_heating_fuel

You will find:

- Videos
- Technical Bulletins
- Instructions
- and More