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Maintenance and Storage Of Fuel Oil for Residential Heating Systems

A Guide for Residential Heating System Maintenance Personnel

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1. INTRODUCTION

The quality of No. 2 fuel affects the performance of the heating system and is an important parameter in the proper and efficient operation of an oil-burning system. The physical and chemical characteristics of the fuel can affect the flow, atomization and combustion processes, all of which help to define and limit the overall performance of the heating system.

The use of chemical additives by fuel oil marketers has become more common as a method of improving the quality of the fuel, especially for handling and storage. Numerous types of additives are available, but reliable information on their effectiveness and proper use is limited. This makes selecting an additive difficult in many situations.

Common types of problems that contribute to poor fuel quality and how they affect residential heating equipment are identified in Chapter 2 of this booklet. Chapter 3 covers the key items that are needed in an effective fuel quality monitoring program, such as what to look for when evaluating the quality of fuel as it is received from a supplier, or how to assess fuel problems associated with poor storage conditions. References to standard procedures and brief descriptions of the procedures also are given. Chapters 4 and 5 discuss approaches for correcting a fuel-related problem, including the potential uses of chemical additives. Different types of additives are described to help users understand the functions and limitations of chemical treatment. Tips on how to select and effectively use additives also are included. Finally, Chapter 6 emphasizes the importance of preventative maintenance in any fuel monitoring program.

2. IDENTIFYING THE PROBLEM

What is sludge?

Sludge is a very broad term which describes the material that has accumulated at the bottom of a tank and contains gum, dirt and other debris. Gum is formed when fuels degrade over time and involves a complex process, which is not well understood. This process involves different types of chemical changes and is affected by many constituents found in the fuel. Other contaminants, such as water, rust, dirt, and microbiological growth, contribute to the spoilage of heating fuels. Table 1 lists the components that have been identified in distillate fuels. These types of contaminants can plug filters, nozzles, and fuel lines, clog screens, and cause wear in pumps and other parts with close tolerances. In addition, dissolved metals can catalyze fuel degradation; water can promote microbial growth and the buildup of sludge.

Type or Category	Examples
Inorganic compounds	Dirt, dust, sand
Fuel filter particles	Paper, cotton
Metals	Fuel pump wear particles, fuel tank corrosion debris, corrosion debris from filler pipe screens, walls, and caps
Biological growth	Fungus, yeast, bacteria
Organic compounds	Fuel-derived sediment and/or gum, wax

Source: U.S. Army Belvoir Research, Development & Engineering Center [1]

Table 1. Particulates (or debris) in fuels

3. MONITORING PROGRAM

Monitoring the fuel during prolonged storage is an essential part of maintaining good fuel quality. Guidelines have been established for maintenance for fuels used by the military, utilities, and the automotive industry. Although most fuels used for home heating have a relatively rapid turnover rate for usage, usually a certain amount of fuel remains in the tank and becomes mixed with new fuels. Contaminants in the old fuel, such as sludge and water at the bottom of the tank, can degrade the quality of the new fuel. Therefore, it is important to monitor the condition of the fuel within the tank, the transfer system, and the incoming fuel.

3.1 Requirements for Accepting a Fuel Supply

Refer to Appendix B for the requirements specified in the American Society for Testing and Materials (ASTM) for distillate fuels used for home heating and diesel engines. For most of the properties, the limits for both fuels are nearly identical. Traditionally, diesel fuels are sold for use interchangeably as either heating oil or engine oil. In 1993, however, there will be a major change in the quality of diesel fuel used for motor vehicles; the sulfur content of fuel will be reduced to 0.05 wt%. Consequently, the two products can be segregated to some extent.

A fuel surveillance program should contain components of quality control. Fuel specifications should become an integral part of the contractual agreements between the fuel supplier and the purchaser. In other words, a bulk sample of fresh fuel oil, used for heating, should at least meet all of the limits in specification ASTM D 396. The buyer is then responsible for periodically sampling and checking on the quality of the fuel as it is received. Many of these tests can be performed by private testing laboratories that analyze petroleum samples. Typical costs for each analysis are included in Appendix B. These costs are current estimates and were provided for planning purposes. The actual costs may be slightly lower for several samples.

Not all of the ASTM tests need to be done for every batch of fuel. With the rapid turnover of fuel supply between the time of purchase by an oil marketer and delivery to the homeowner, there is a need for quick diagnosis of the quality of fuel on some basic minimum requirements. Table 2 gives guidelines that the fuel marketer can use when accepting a batch of fresh fuel from a supplier that might indicate an off-spec fuel or contamination. A visual inspection for haze and floating particles is the easiest and one of the most important tests to do. These tests are simple to do with the appropriate equipment and training. Refer to Figures 2 to 5 in Section 3.4 for illustrations and descriptions of some of these sampling and analysis devices. Most of these tests overlap the requirements under ASTM D 396.

3.2 Sampling

Sampling is the key to any fuel monitoring program. Procedures that are improperly followed can give misleading information or detect a problem that does not exist. Standard methods for sampling can be found in ASTM D 4057, "Practice for Manual Sampling of Petroleum and Petroleum Products". In brief, the following guidelines should always be noted:

- Always use clean sampling devices and new sample containers. There are two types of samples: (1) bottom sample and (2) bulk sample (mid to upper region), which should not be contaminated with bottom samples.
- Check to make sure of the amount of sample necessary for conducting the tests. Two liters should be sufficient.
- There are several devices for pulling bottom samples; the Bacon Bomb Thief or Fuel Thief (Figure 2) are simple devices that can be used for taking both bottom samples or all level samples. Devices should be cleaned after each sample has been taken to prevent contaminating each successive sample.

Test	Property Going Off-Spec or Contaminant	Type of sample
1. Visual [1] (clarity and color)	Water (haze), dirt and other solids	Bulk
2. Visual, appearance	Water, sediment, sludge	Bottom
3. Field test kits for fuel microbes [2]	Fuel microbes	Bottom
4. Flash point [3]	Other petroleum products (gasoline, jet fuel)	Bulk
5. Cloud or pour point [3]	Cloud or pour point (critical during cold weather operation)	Bulk

[1] Visual appearance should be bright and clear. Methods ASTM D 4176, D 1500
[2] No ASTM methods are available. Manufacturers of biocides often market these test kits for field use. Some kits can provide some measure of the degree of contamination (i.e. no contamination, moderate or severe).
[3] ASTM D 93, D 2500, D 97 respectively; results should conform to ASTM D 396, D 975 fuel specifications. Refer to Appendix B.

Table 2. Quick and easy tests to determine off-spec fuel.

- Bottom samples should be pulled from the low end of a tank, if possible. Figure 1 shows the potential problems associated with underground tanks. Underground tanks are sometimes installed with a slight tilt to allow for water to collect in the sump. If the fill tube is used as the sampling port and it is not located at the low end of the tank, sludge or water may not be detected. If a tank has been static for a prolonged period, to increase the chances of detecting contaminants, you may want to take samples from different levels or from more than one location, if possible.
- If there is no ready access to the tank, a sample may be obtained through the fuel line. This sample will give some information on the bulk fuel going through the fuel lines. If

samples are taken from a line, make sure that the line has been flushed to get a representative sample.

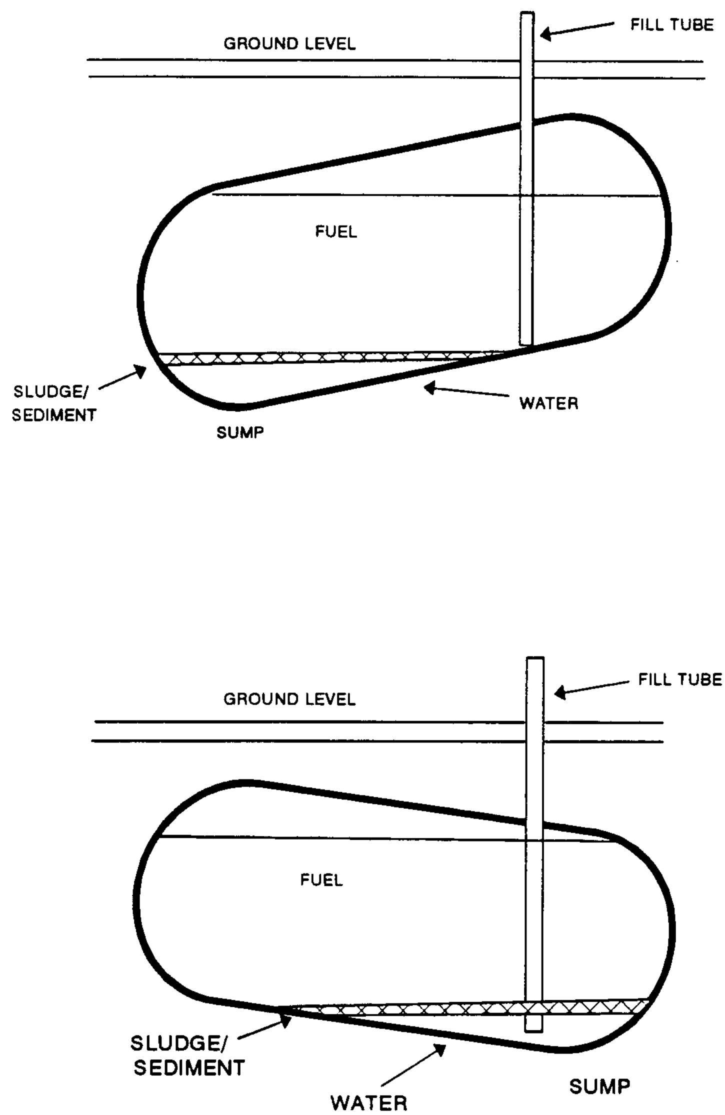


Figure 1. Potential Problems with Monitoring Underground Storage Tanks.

Source: Electric Power Research Institute [2]

3.3 Assessing Fuel Quality in Storage

Sampling of fuel from a storage facility, such as a tank, will help to assess the specific condition of that fuel. These samples will be different from those obtained for fresh fuels or from any other tank. Contaminated fuel in a tank will degrade the quality of a fresh fuel supply after fill-up.

A visual inspection of a bulk sample will generally show if the fuel has clarity or contains free water. Color is not a measure of a fuel's quality. During long-term storage, if the color appears to have changed, it may indicate that the fuel has deteriorated or changed. Look for floating particles or haziness. Haziness usually indicates water, or in cold weather, wax. The fuel can then be analyzed and compared to the specifications of ASTM D 396 or D 975.

Additional tests also can be run on the bulk samples, such as particulate contamination (ASTM D 2276), accelerated stability (ASTM D 2274), and biological growth (not an established ASTM test). Although these tests are not listed under ASTM D 396 or D 975 as requirements, they are used to establish diesel fuel quality for military purposes (military specification VV-F-800D). The particulate contamination test gives an accurate measure of the existing cleanliness of the fuel. However, the accelerated stability test, in general, is not very accurate. It is a predictive test that is done at elevated temperatures to accelerate aging of the fuel. While this test may give a good indication of the performance of a stabilizer additive in the fuel and its resistance to oxidation, it is not necessarily a good test for predicting how a fuel will respond to the tank's environment under normal field conditions.

Bottom samples may either be tested by a laboratory or the fuel user for biological activity. There are several field test kits that fuel users can use to determine whether or not a fuel is contaminated with biological growth. These kits usually contain sample bottles, the nutrient, and an indicator (dye or chart). Positive or negative results can be obtained in several days. These kits are much less expensive than laboratory analyses. While laboratory testing for biological growth can give plate count results, they can be misleading at times, because of the time difference between taking the sample and the time it takes to get the sample to the lab.

There is no need to test bottom samples of the tank for stability or cleanliness, because the tank will have water and sediment on the bottom. This does not mean that all of the fuel is bad, but that there is debris that should be removed.

The following is a recommended time schedule for sampling and analysis:

- In a static tank commonly used for bulk storage, both bottom and bulk sampling should be conducted at least twice a year. Check for water accumulation in the tank every 90 days.
- In a tank that has a relatively consistent turnover, such as in a homeowner's tank, a bottom sample should be taken annually. Check water accumulation monthly. Because the fuel is constantly changing during turnover, a bulk sample will be of little value.
- Samples of the incoming fuel supply should be taken randomly to ensure that the supplier is in compliance with your specifications.

3.4 Analyzing Fuel Samples

A brief description of what is needed to conduct some simple analyses is given below.

Manual Sampling

(ASTM D 4057 - Standard Practice for Manual Sampling of Petroleum and Petroleum Products)

The basic principle of this procedure is to obtain a sample or a composite of several samples that represent the material in a tank car or storage tank. Many different types of devices can be used to collect a fuel sample. One of the simplest and most versatile samplers is the fuel thief which is shown in Figure 2. The fuel thief is typically 1" in diameter or larger, and varies in length. A check valve or a ball valve at the bottom of the thief remains open as the sampler is lowered. When the sampler is held stationary near the bottom of the tank, the check valve closes, effectively containing a column of fuel. Water and sludge, if present, also will be collected in the column.

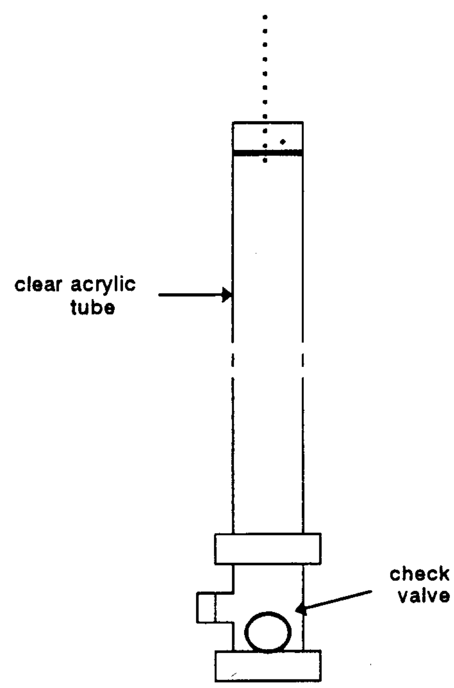


Figure 2. Diagram of a Fuel Thief Sampler

Visual Test

(ASTM D 4176 - Free Water and Particulate Contamination Pass/Fail Procedure)

This procedure can be used as a field test at ambient temperatures. This visual test quickly and qualitatively indicates whether a sample of fuel is contaminated with water or particulates. A sample of fuel is obtained and placed in a clean glass jar. The sample is swirled and examined for visual sediment or water drops (or haze). The results of the test are considered "pass," if the sample is found to be "clear and bright," or fail, if otherwise. At low ambient temperatures at or below the cloud point temperature of the fuel, cloudiness or haze may be caused by wax crystals forming.

Relative Density (API Gravity)

(ASTM D 287 and D 1250 - API Gravity of Petroleum Products, Hydrometer Method)

The API gravity is measured directly with an API hydrometer that is immersed into the fuel (Figure 3). The gravity of the liquid varies directly with the depth of immersion of the floating hydrometer. This measurement depends on the temperature of the fuel. For field testing, use a thermohydrometer, which is a combination of a hydrometer and a thermometer in one device.

Viscosity

(ASTM D 445, D 446 - Kinematic Viscosity of Transparent Liquids)

The kinematic viscosity of liquid petroleum products can be determined by measuring the time for a volume of liquid to flow under gravity through a calibrated viscometer (Figure 4). Because viscosity of the fuel is very sensitive to temperature, the test must be conducted at a closely controlled temperature.

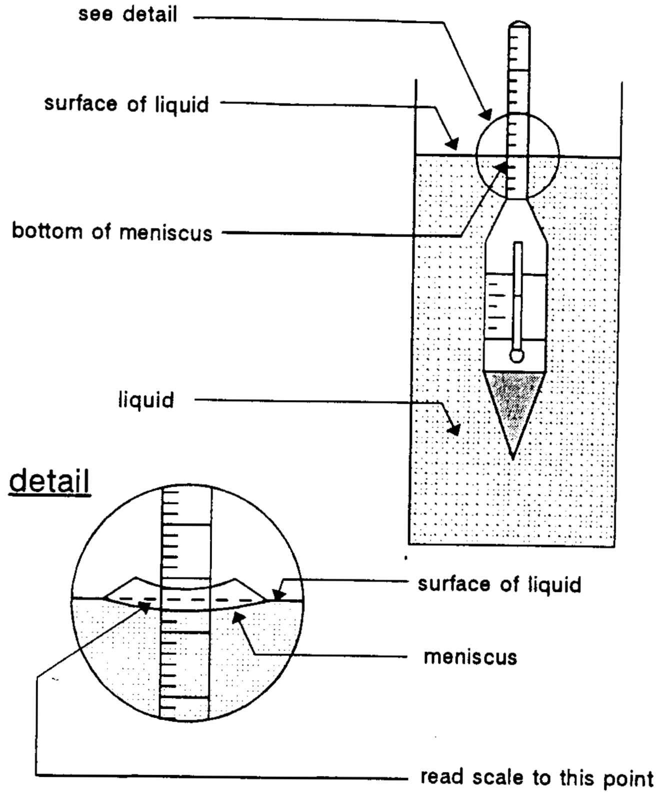


Figure 3. Hydrometer Scale Reading for Transparent Liquids

Source: ASTM D 1298

Cloud and Pour Points

(ASTM D 2500 - Cloud Point of Petroleum Oils)
(ASTM D 97 - Pour Point of Petroleum Oils)

The same equipment can be used for both tests (Figure 5). The test procedures, however, vary slightly.

To determine the cloud point, a sample of the fuel is put into a glass jar, cooled in a low temperature bath (methanol and dry ice), and examined periodically. The cloud point is that temperature at which a cloud or haze of wax crystals first appears

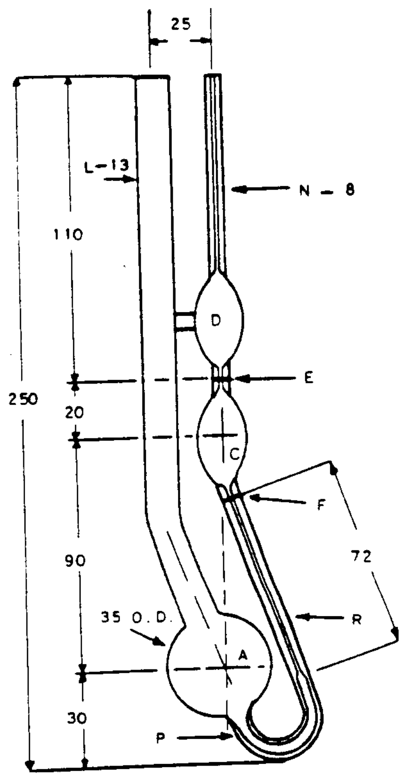
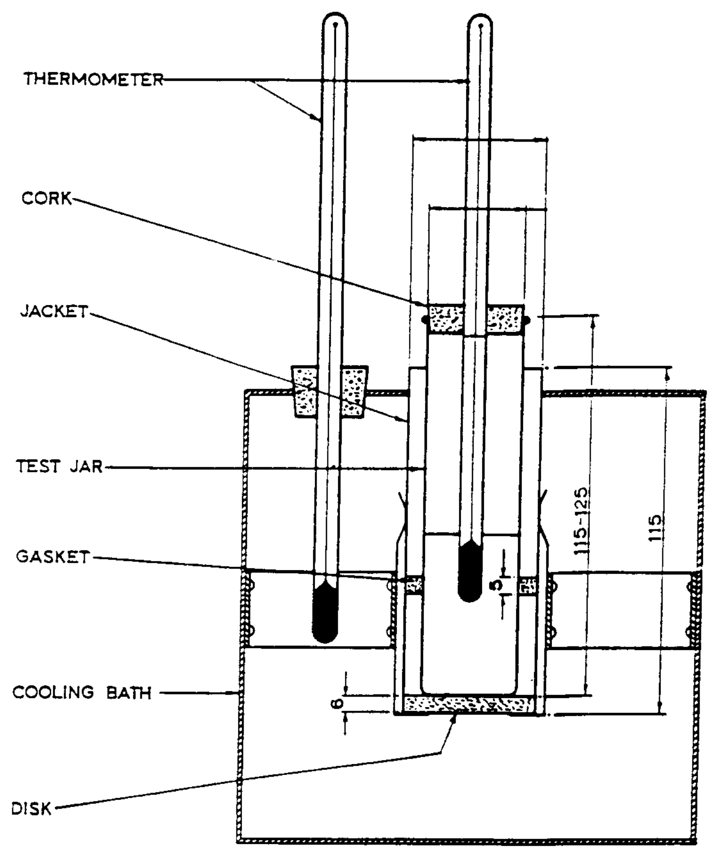


Figure 4. Cannon-Fenske Routine Viscometer

Source: ASTM D 446

at the bottom of the test jar. The temperature is measured by a thermometer immersed in the fuel and touching the bottom of the jar.

The pour point is the lowest temperature at which the fuel is observed to flow. The pour point is reached where the oil shows no movement when the jar is held horizontally. The temperature is measured by a thermometer whose bulb is located just below the surface of the fuel.



NOTE—Dimensions are in millimetres.

Figure 5. Apparatus for the Pour Point Test

4. CORRECTING THE PROBLEM

What happens when you encounter off-spec fuel?

Identifying the type and degree of contamination depends on many factors. The size and configuration of the tank can affect the type of sample you are able to retrieve. If possible, determine the configuration of the tank as part of the surveillance program. Refer to Section 3.3 for a description of sampling problems.

There are several ways to deal with off-spec fuel. If the problem is discovered in time with a fresh batch of fuel, then the fuel should not be accepted from the supplier. The alternatives are to bring the fuel back into specifications by the following:

Dilution/blending

In some cases when a fuel is found to be off-spec, dilution with another fresh fuel can effectively bring the entire batch to within acceptable limits. For example, blending can lower a high cloud point or raise the flash point [2]. Blending should always be done with small test samples and analyzed before attempting to blend the entire stock. Blending should not be done with fuels that are contaminated with microbes, debris, or water.

Fuel/Additive Treatment

A successful fuel treatment program requires knowledge of the quality of fuel that goes into the tank and the service history for specific problems. Refer to Chapter 3 for guidance on routine monitoring. A treatment program prevents or retards fuel deterioration.

A misconception that many of us have is that a single ingredient or chemical additive can effectively cure the problems associated with fuel degradation during storage. If the fuel has already deteriorated, i.e. sludge has formed, treatment with an additive will not restore the fuel's quality. A dispersant cannot effectively breakup large masses of materials. A treatment program is most effective when used with clean, fresh fuel in a clean storage system.

Additives respond differently to different fuels because of the inherent fuel properties. The results you obtain may not always be the same with a new fuel supply.

Tank Cleaning

The majority of the problems that lead to "no heat" calls, plugged lines, filters, and nozzles are caused by sediment or sludge that accumulate over a long time. If the material stays at the bottom, usually it is innocuous. However, when it is stirred up after a fill-up, the material can get re-suspended in the fuel and get carried into the fuel system, where it is transported and gets trapped in equipment that have close tolerances. Chemical treatment alone will not effectively cure these problems. With massive accumulations at the bottom and/or sides of the tank, mechanical cleaning with fuel filtration, use of chemical additives, and a preventative maintenance program are the only effective ways to remove and minimize future occurrences of such problems.

Some companies are now marketing portable tank cleaning and filtration systems that an oil service company can use to do their own cleaning. The effectiveness depends a great deal on the conditions of the tank, accessibility to the interior of the tank, and operator experience.

There are companies that offer tank cleaning as a service. A survey of some companies showed that, typically, for a 275-gallon tank, the cleaning costs range from $125 to $300, which covers sludge removal from the tank. In some cases, there is an added charge per gallon of sludge waste generated for hauling it away.

In accordance with state regulations, a reputable tank cleaning company is required to have a permit to hold and haul the sludge materials. For example, in New York State, this permit is called a Regulated Waste Transport License, which is issued by the NYS Department of Environmental Conservation (NYSDEC), and is marked on the truck as NYSDEC Lic # A1-___ (three digit number). Check to see that the transporter has a valid license. You also can verify the license by calling in that number to the NYSDEC. Check with the Department to see if they have a list of local reputable companies. To obtain this type of information in another state, call the state environmental regulatory agency.

Ask the following questions when inquiring about tank cleaning services:

- How is the tank cleaned? How is the sludge removed? Can the sides and bottom be mechanically cleaned or vacuumed and dried? (This may depend in large part on the accessibility to the tank.)
- What procedures do I need to follow beforehand? (Some specified volume of fuel may be needed in the tank before cleaning.)
- How much fuel can be reclaimed after the cleaning process? (Contaminated fuel may contain only an inch or two of sludge at the bottom. In some cases, the bulk volume of the fuel is placed into a temporary holding tank, filtered, and then pumped back into the tank. The less waste or sludge generated, the less it would cost to dispose of it, and the more fuel reclaimed.)
- Is there a guarantee on the cleaning? (Some companies will reclean the tank for no charge or at a reduced fee if this problem reoccurs.)
- How long does the process take? (This depends on the size of the tank, the extent of contamination, and the equipment capacity. Some companies claim that it can take one hour to one and a half hours to do the job.)

- How much fuel will I lose? (There are equipment and procedures that try to minimize the fuel lost and any downtime.)

In some cases, if you are dealing with an underground tank with a small fill pipe, access to the interior of the tank for mechanical cleaning may be difficult and impractical. Replacing an underground tank with an aboveground tank located indoors may be a more feasible option, especially if it can be installed where it can be monitored and maintained more effectively. This is prudent, especially if you are dealing with an old tank. A limited study conducted on twenty residential tanks showed that the majority of tanks that were about 10 years or older have more problems with water and sludge than newer tanks [3]. If you are installing a new tank, be sure to check the local laws that apply and the latest technology available.

5. FUEL OIL ADDITIVES

The use of chemical additives by fuel oil marketers has become more common as a method of improving the quality of the fuel, especially for handling and storage. Nationwide, nearly half of the marketers use additives [4]. These additives are blended either at the bulk plant on trucks or right in the customer's tanks.

Numerous types of additives are available, but they are often difficult to select. The confusion begins with all the advertising claims and testimonials from a variety of sources accompanying the products. With this in mind, it is necessary to look closely at your needs and match them to the product. The key to effective additive treatment is to understand the following:

- what the additive is used for,
- treatment rate and effectiveness,
- the limitations,
- costs,
- hazards and safety precautions,
- regulations associated with additive usage, storage and disposal.

5.1 Types of Additives

The first priority is to define the problem and then to determine if an additive is really needed. To do this, sampling of the fuel is necessary. The procedures and references for sampling are explained in Section 3.2.

There are additives that perform various functions. Some of the more common types that oil marketers use include:

- Cold flow improver
- Dispersant
- Corrosion inhibitor
- Biocides

Other additives, which are used in No. 2 diesel fuel, include the following:

- Antioxidant
- Metal deactivator

Cold Flow Improver

Use of flow improver treatment to avoid waxing problems is an effective preventative measure. However, once wax is formed, using of an additive will not change the waxes already present, although, if the temperature falls lower, an additive will interact with and modify newly separating waxes. To help dissolve wax, a solvent, such as kerosene, must be used. Unfortunately, kerosene cuts can be more expensive, have a lower heat content, and reduced fuel lubricating properties. The improvement caused by an additive will depend on the characteristics of the fuel, as well as on the additive itself.

Dispersant

Middle distillate fuels will deteriorate over long periods to form gummy deposits. Dispersants are used to maintain insoluble residues suspended in the oil. Typically, dispersants are used in multifunctional packaged additives with other stabilizing and antioxidizing additives. Dispersants are most effective before the fuel degrades. Once the gummy deposits form and are amassed with dirt, biological organisms, and other debris to form sludge, it is much more difficult to disperse this accumulated sludge.

Corrosion Inhibitor, Antioxidant, and Metal Deactivator

Tank surfaces that come in contact with the fuel can rust as a result of water or acids that could be present in the fuel. Corrosion inhibitors can be used to prevent the formation of rust. Fuel degradation caused by oxidation or aging, which ultimately forms gum deposits, can be slowed down by using antioxidant additives. Dissolved metals, such as copper, can enhance degradation by accelerating aging. To minimize these effects, metal deactivators can be introduced into the fuel to combine with the metals to render them inactive.

Biocide

Biocides must be fuel soluble and must migrate to the water phase. Microbiological organisms present in the fuel are most commonly classified as bacteria, mold, or yeast.

Certain strains are commonly used to evaluate an additive for its effectiveness, such as Pseudomonas aeruginosa (bacteria), Cladosporium resinae (mold), and Candida tropicalis (yeast). For a biocide to be effective according to U.S. Military Specifications, MIL-S-53021, the additive must kill or inhibit the growth of these three organisms based on the effective biocidal concentration.

Fuel biocide additives are regulated under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), and the product must be registered with the federal Environmental Protection Agency (EPA). The product should contain a registration number, which is usually indicated on the container label as REG. NO. (6-digit number). This law requires that for a product to be marketed it must meet at least all of the following criteria:

- The product has to perform as claimed
- EPA has evaluated the risks of the product
- Labelling that contains information, including product use, treatment rate, human exposure, and hazards, must be provided

Table 3 lists the types of distillate fuel additives that may be used to ensure satisfactory fuel quality during storage [5].

Multifunctional Additive

Multifunctional additive packages are commonly used by the military. The specification for a stabilizer additive package for diesel fuel (MIL-S-53021) requires that the package contain petroleum-soluble compounds, which have the following functions:

Additive	Function
Dispersants	Keeps fuel oxidation products suspended
Metal Deactivators	Inhibit gum formation
Corrosion Inhibitors	Prevent rust in fuel systems
Flow Improver	Reduce pour point
Oxidation Inhibitors	Minimize deposits in filters
Biocides	Kill active growth and inhibit further growth of bacteria and microorganisms

Table 3. Distillate Fuel Additives

antioxidant, biocide, corrosion inhibitor, dispersant, metal deactivator. By comparison, multifunctional additives are generally more effective than individual additives (Figure 6).

5.2 Selection of Additives

The type of additives an oil marketer or a consumer will typically encounter are classified as aftermarket fuel additives. These are proprietary products being marketed commercially that are advertised to be used with fully formulated fuels (such as No. 2 and diesel). It is essential that additives be purchased from reliable sources to ensure that the products are effective in meeting the claimed benefits. The following are general guidelines and questions to keep in mind when selecting an additive:

1. Define the problem and the additive that is needed.
2. Make sure that the fuel sample you are having tested represents the fuel you want to treat.
3. Will the additive be used once or will it require continuous treatment?
4. Does the additive perform more than one function?

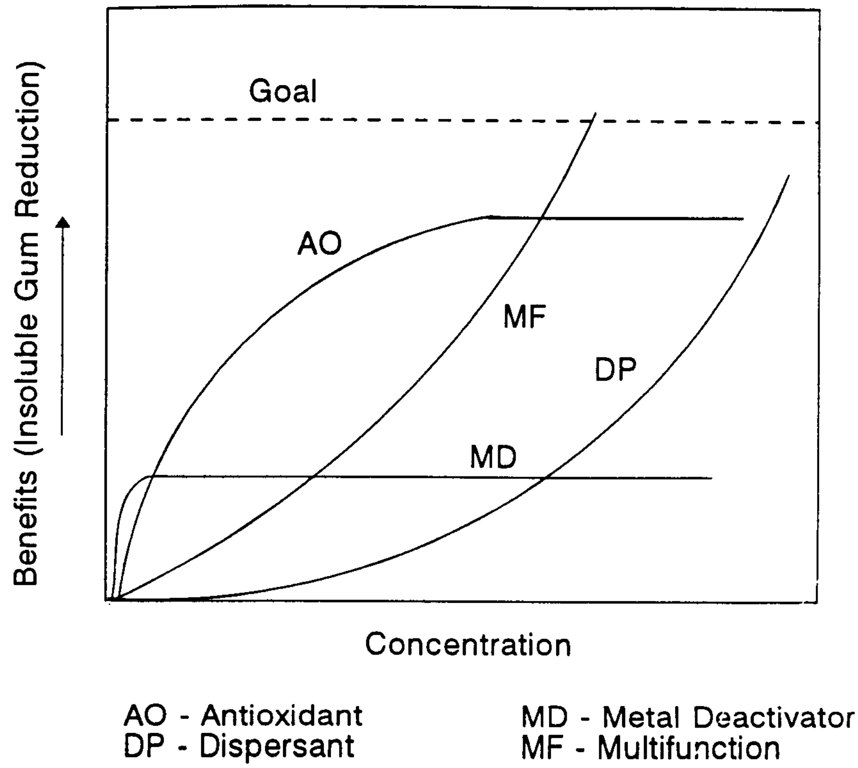


Figure 6. Additive Concentration Comparison to Obtain Desired Insoluble Gum Reduction

Source: C.P. Henry, E.I. duPont, Co. [2]

5. Does the additive have the correct usage approvals for your intended use?

6. Does the additive have a comprehensive data package supporting the efficacy of the product?

7. Does the additive or additive supplier have technical support that can assist you if you have questions or problems?

8. Follow all safety and handling instructions on labels. Material Safety Data Sheets (MSDS) also should accompany your order.

9. Check for the proper disposal of the additive containers. Know the local laws concerning disposal of sludge or water bottoms.

The Department of Defense (DOD) has very specific standards and specifications when purchasing diesel fuel additives used for tactical purposes or combat. The DOD, in cooperation with automotive and oil industries, developed a series of "screening test requirements" for aftermarket fuel additives. The requirements were derived from data obtained through standardized laboratory tests, which enable one to objectively assess whether the advertised claims of performance improvement can be partially or fully verified, and whether any adverse side effects will occur with the potential use of the additive due to its possible incompatibility with other additives already present in the formulated fuel [5]. All approved additives must meet such requirements as compatibility, stability, filterability, minimum handling temperature, and biocide activity to be qualified for use in diesel fuels. Many of these requirements can be applied to distillate fuel used for home heating.

To avoid unwarranted costs associated with reevaluating a fuel additive each time additives are purchased, a list of products has been prepared for use by the Government in procuring products that meet the requirements of the military specification, MIL-S-53021. The military qualified products list (QPL), QPL-53021, contains public information and is available upon request from the following organization [6]:

Standardization Documents Order Desk
Building 4D, 700 Robbins Avenue
Philadelphia, PA 19111-5094

The QPL provides information that individuals and industry organizations also can use such as brand names of approved additive packages, their effective treatment rates, and the additive suppliers.

6. PREVENTATIVE MAINTENANCE

A preventative maintenance program should be based on need, resources, and common sense. The key to a successful program includes: (1) specifications when purchasing fuels; (2) monitoring/sampling and record keeping; and (3) good housekeeping.

Establish a set of procedures and guidelines for the sampling and testing program and stick to it. This program should become a routine part of your maintenance, no different than changing oil or adding fuel. Set up documentation so that you can review your sampling, testing and remediation efforts at any time. You will find this information valuable and discover that in the long run you will have saved money and quickly solved problems.

Good housekeeping requires that you minimize dirt and water entering a tank. Water promotes the growth of microbes, which use the fuel as a food source, and accelerates internal corrosion of the tank. Water can enter a tank through fill pipes and vents, which have cracks or leaks, and therefore, these should be checked when water contamination is suspected as a problem. The change in air temperatures can cause condensation within the tank. Filters can be placed on vents to prevent particulates and water from entering the tank. Filters also contain desiccant which will absorb moisture inherent in the atmosphere of the tank. Dirt and debris are generally introduced into the fuel because of careless handling.

Be sure that those personnel who carry out the maintenance program are trained and motivated as to why they are doing the work. Sloppy procedures can be costly and ineffective. The system should be checked from the receipt of fuel, through delivery and storage. The following summarizes some of the major steps for a preventative maintenance program that should be followed:

- Sampling and analyses should be done according to the schedule listed in Section 3.3.

- Excessive sludge and water should be removed as soon as possible.
- Tank fill pipes and vents should be checked for cracks or leaks; they may be a source of water contamination.
- When additives are used, they should be added before filling, if possible, to facilitate mixing of the chemical.

There is little justification for cleaning tanks under ten years old on a preventative maintenance program, but there could be circumstances that would make cleaning necessary or desirable, such as a severe infestation of microbes [7].

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[6] "Stabilizer Additive, Diesel Fuel", Military Specification, MIL-S-53021A, August 1988.

[7] "Smart Service includes a Clean Tank," Fuel Oil and Oil Heat, January 1983.

[8] American Society for Testing and Materials, Annual Book of ASTM Standards, Section 5, Vols. 5.01, 5.02, and 5.03, on Petroleum Products, Lubricants, and Fossil Fuels, ASTM, 1916 Race St., Philadelphia, PA. 19103, 1988.

APPENDIX A

GLOSSARY OF TERMS

Ash is determined by igniting a sample of fuel in a vessel and allowing it to burn until only ash and carbon remain. This is done with a controlled laboratory setup and procedures. Ash in fuel oil is usually negligible (Method ASTM D 482).

Cetane number (typically used in diesel fuel specifications) is determined with a test engine and is a measure of ignition quality of the fuel (Method ASTM D 613). When a test engine is not available, cetane number is estimated by calculating the cetane index using a formula (Method ASTM D 976).

Cloud point is the temperature at which a cloud or haze of wax crystals first appears in the fuel. At or below this temperature, the wax crystals may clog filter systems. Satisfactory operation should be achieved in most cases if the cloud point is specified at 6°C above the tenth percentile minimum ambient temperature for the area in which the fuel will be used (Method ASTM D 2500).

Copper strip corrosion test is designed to assess the relative degree of corrosiveness of a petroleum product. Corrosion of various metals can occur, depending on the types of sulfur compounds present in the fuel. Corrosion is not necessarily directly related to sulfur content. Although most of the sulfur compounds in crude oil are removed during refining, some remain in the refined fuels. This test measures the possible difficulties with copper and brass or bronze parts of the fuel system (Method ASTM D 130).

Distillation range indicates the vaporizing tendencies of the fuel and generally characterizes liquid petroleum fuels. The 90% point is the temperature at which 90% of the liquid has evaporated in the specific test arrangement (Method ASTM D 86).

Flash point is the lowest temperature at which the vapor above the fuel can be ignited with a flame; this point can be measured with a test flame under controlled specified conditions. Flash point is used in shipping and safety regulations to define "flammable" and "combustible" materials. Contamination with gasoline (1% or 2%) can substantially lower the flash point of the fuel (Method ASTM D 93).

Heating value is a measure of the energy available from the fuel when it is burned. Usually it is expressed as Btu/gal.

Pour point is the temperature at which the fuel gels; below this temperature the oil stops flowing (Method ASTM D 97).

Ramsbottom carbon residue is the amount of carbon residue left after evaporating the oil under specified conditions. The value is intended to provide some indication of relative coke-forming tendency of the oil (Method ASTM D 524).

Relative density or specific gravity is the ratio of the mass of a given volume of liquid (fuel) to the mass of an equal volume of pure water, both at the same reference temperature (15°C or 60° F). API gravity is a different way of expressing specific gravity (sp gr at 60/60F reference temperature) and is calculated by:

$$\text{API gravity, deg} = (141.5/\ \text{sp gr}) - 131.5$$

A fuel with a lower API gravity generally has a higher heating value. For example, kerosene (No. 1 oil) has a higher API gravity than No. 2 oil, and therefore, a lower heating value (Method ASTM D 287).

Sulfur content of the fuel affects corrosion and the formation of deposits on boiler tubes. High sulfur fuels increase pollution effects and accelerate the formation of gum and sediment in the fuel during storage (Method ASTM D 129).

Viscosity determines the flow of the oil to the burner nozzle or atomizer. The fuel viscosity is very sensitive to temperature with higher viscosities at lower temperatures. The kinematic viscosity is expressed in units of centistoke (cSt) (Method ASTM D 445).

Water and Sediment in the fuel can cause corrosion of equipment and plugging of a system with tight spaces (such as burner nozzles and filters). A high content of water and sediment usually results from poor handling and storage of the fuel (Method ASTM D 1796).

APPENDIX B

ASTM SPECIFICATIONS FOR NO. 2 OIL USED FOR HOME HEATING AND NO. 2-D DIESEL FUEL USED FOR ENGINES

Appendix B. ASTM SPECIFICATIONS FOR NO. 2 OIL USED FOR HOME HEATING AND NO. 2-D DIESEL FUEL USED FOR ENGINES

TEST	METHOD		Heating Fuel Limits ASTM D-396	Diesel Fuel Limits ASTM D-975	COST [1]
1. Relative density, 60/60F or (API grav)	ASTM D 287		0.8762 (30 min)	NR	$15
2. Flash point	ASTM D 93		38 C (100 F) min	38 C (100 F) min	$35
3. Cloud point	ASTM D 2500		NR	Local [2]	$30
4. Pour point	ASTM D 97		-6 C (20 F) max	NR	$30
5. Kinematic viscosity, at 40 C	ASTM D 445		1.9 cSt min 3.4 cSt max	1.9 cSt min 4.1 cSt max	$35
6. Distillation range, 90 % point	ASTM D 86		282 C (540 F) min 338 C (640 F) max	282 C (540) min 338 C (640) max	$45
7. Sulfur content, % mass	ASTM D 129		0.5 max	0.5 max [3]	$75
8. Copper strip corrosion	ASTM D 130		3 max	3 max	$30
9. Ash, % mass	ASTM D 482		NR	0.01 max	$35
10. Ramsbottom carbon residue, % mass	ASTM D 524		0.35 max	0.35 max	$45
11. Water and sediment, % vol	ASTM D 1796		0.05 max	0.05 max	$25
12. Cetane number or Calculated cetane index	ASTM D 613 ASTM D 976		NR	40 min	$125 $ 10

NR - No requirements

[1] Typical estimated cost at current 1992 prices for each sample when sent to a contract laboratory; prices may be less for larger number of samples

[2] This temperature is not specified on a broad basis. Satisfactory operation should be achieved in most cases if the cloud point (or wax appearance point) is specified at 6 C above the tenth percentile minimum ambient temperature for the area in which the fuel will be used. For guidance, the tenth percentile minimum ambient temperatures for the U.S. during January and February are shown in the Appendix.

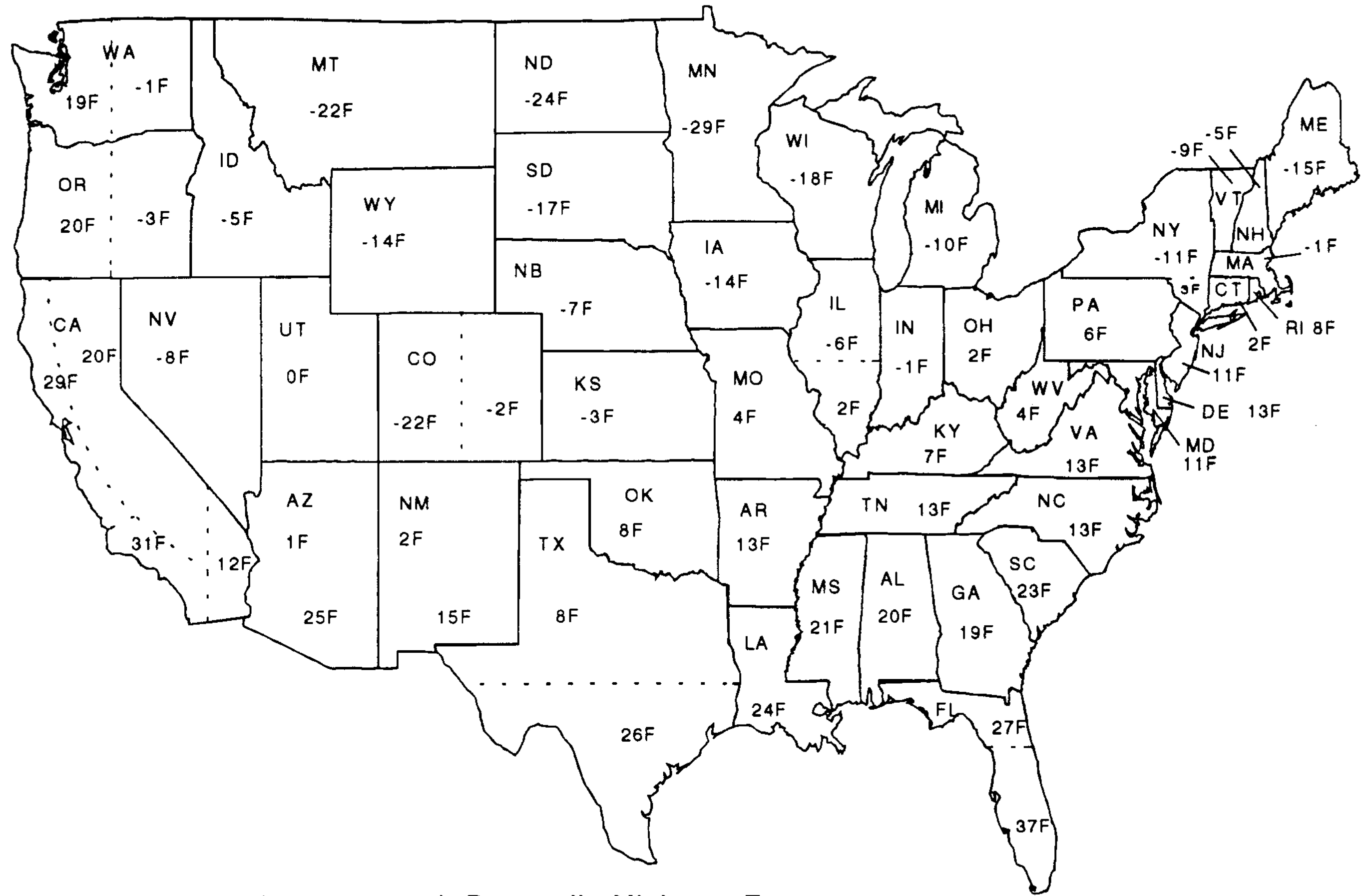
[3] EPA regulations will require a maximum value of 0.05% to become effective October 1, 1993.

The American Society for Testing and Materials (ASTM) methods and procedures referenced are contained in Volumes 5.01 and 5.03. Requests for these documents should be sent to the following address:

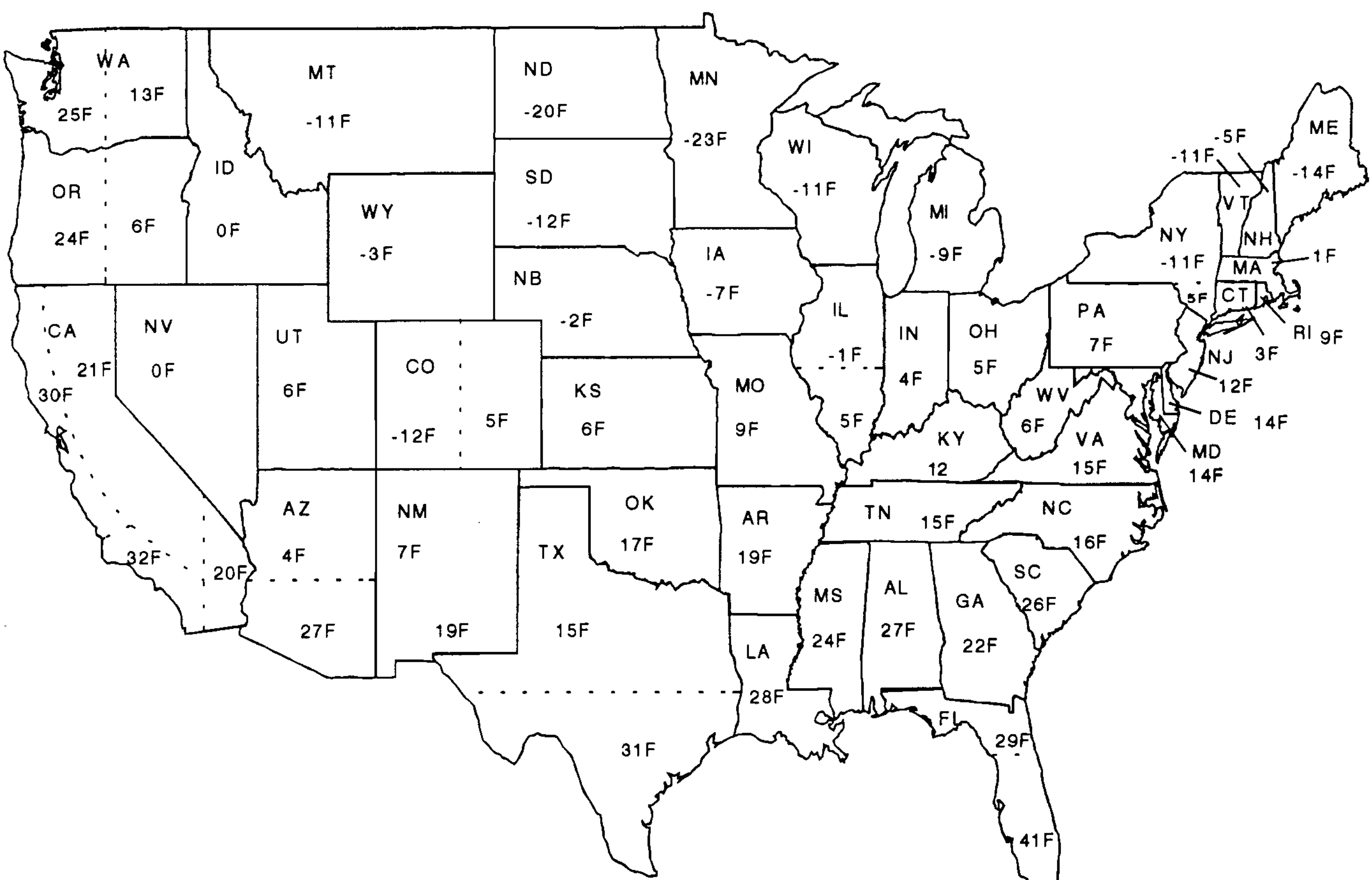
American Society for Testing and Materials
Publications Department
1916 Race Street
Philadelphia, PA 19103

APPENDIX C

TENTH PERCENTILE MINIMUM TEMPERATURES FOR JANUARY AND FEBRUARY. Refer to ASTM D 975 for additional maps.



January - 10th Percentile Minimum Temperatures



February - 10th Percentile Minimum Temperatures