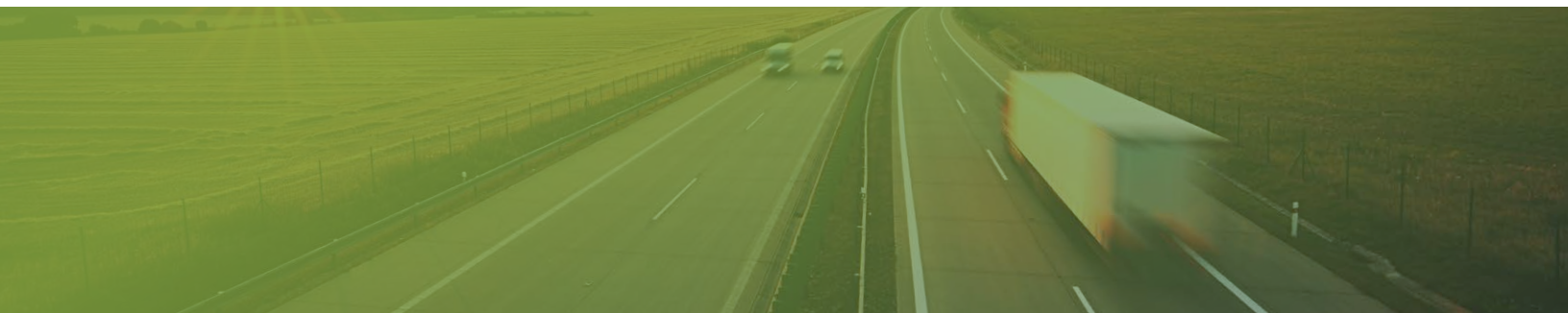
Fuels Institute

DFQC DIESEL FUEL QUALITY COUNCIL

Diesel Storage Tanks

INDUSTRY PRACTICES TO MINIMIZE DEGRADATION AND IMPROVE FUEL QUALITY



Introduction

New diesel engines are required to meet higher emissions and efficiency standards while also having a longer useful life. Therefore, modern diesel engines are consuming more diesel fuel in the engine's lifetime than before. This interplay between modern engine design and fuel consumption highlights the importance for improved diesel fuel quality.

Contaminated fuel can impact engine performance and fuel economy. Besides the negative impact on a fuel retailer's reputation, fuel storage and equipment owners also risk equipment degradation and replacement costs. Because liabilities and risks associated with fuel quality issues are often considered the responsibility of the owner/operator marketing the fuel to the consumer, it is vital that fuel quality be monitored and any issues be mitigated in a timely fashion.

Fuel contamination can occur at many points along the supply chain and each segment of the supply chain is responsible for implementing best practices with regard to maintaining fuel quality. This document is geared specifically toward tank owners and operators and provides guidance on best practices to minimize costly damage to fuel equipment and end users. It reviews the potential points where fuel-quality issues can occur (i.e., when fuel is delivered, inside the tank, and at the dispenser), discusses what to be aware of and why, and gives recommendations to mitigate potential problems. Most recommendations come in two forms: the minimum practices to ensure fuel quality and additional best practices to utilize for more preventative measures. If you need assistance implementing these best practices, contact your service provider to determine your options.

These best practices were curated from reviewing existing recommended practices for underground storage tank (UST) and aboveground storage tank (AST) installation and maintenance, as well as from interviews with leading industry experts regularly using these practices. By following these practices, along with periodic fuel-quality sampling, the operator may reduce costs associated with tank system repair or premature replacement and improve the quality of fuel delivered to customers.

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STRUCTURE AND NOTATION

AT A MINIMUM: Watch for this symbol and heading for minimum actions required.

ADDITIONAL BEST PRACTICES: Watch for this symbol and heading for further actions to take to ensure the best results.

Fuel Delivery

Prior to ordering fuel, contact the local or state division of Weights and Measures and request a copy of their fuel quality regulations. Incorporate these regulations into purchase orders for fuel as a minimum requirement for acceptance. After taking this proactive step, the first real opportunity to promote good fuel quality is related to your method of distribution.

1. SWITCH LOADING— This refers to when a delivery vehicle's compartments are used to transport different fuels. Issues may arise when compartments are not thoroughly drained and cleaned according to best practices, so residual product (of a different nature) contaminates subsequently loaded diesel fuel.

AT A MINIMUM:

- To ensure receipt of a non-contaminated product, negotiate a strong agreement with the fuel supplier and third-party hauler ensuring they have strict fuel handling and sequencing guidelines. Fuel supply and transport agreements should reference ASTM D975, Section 6, which states that diesel fuel should be free of undissolved water and sediment and should not be otherwise adulterated.
- Request that diesel deliveries be completed after a previous non-ethanol blend fuel or other distillate delivery. This same messaging may be applied at any bulk rack location with proper signage on fuel hauling sequencing.
- Good communication between fuel hauler and tank owner regarding expectations may significantly improve delivered fuel quality at zero costs.

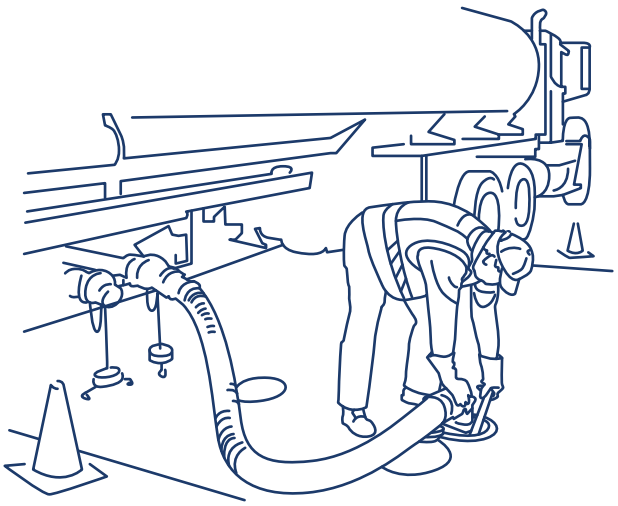
ADDITIONAL BEST PRACTICES:

- The use of dedicated delivery transports or dedicated compartments on a delivery transport will significantly reduce the potential for contamination of the fuel during loading and transportation.

2. WATER — Water is the most critical factor contributing to product and tank system degradation and fuel quality. When fuel is being delivered, it is common for water inside the tank to get stirred up and/or for water to be introduced into the tank. If possible, allow tanks to settle one hour per foot of fuel depth in the tank prior to pumping fuel out so water can settle to the floor of the tank.

AT A MINIMUM:

- Be aware of pooling water at or near the fill-port.
- Ensure proper site drainage away from the tank pads and tank openings, especially in low lying areas.
- Check and maintain manway gaskets, bolts, and covers as well as fill ports and spill buckets.
- Do not drain the spill bucket back into the UST.
- Any liquids captured in the containment system should be removed and disposed of properly.
- Sticking your tank weekly with water indicating paste can yield important trends for water accumulation.[1]
- Stick tank with water indicating paste anytime a delivery is completed both pre- and post-delivery.



- If you are unsure of your UST tilt, stick both ends of tank when possible.

ADDITIONAL BEST PRACTICES:

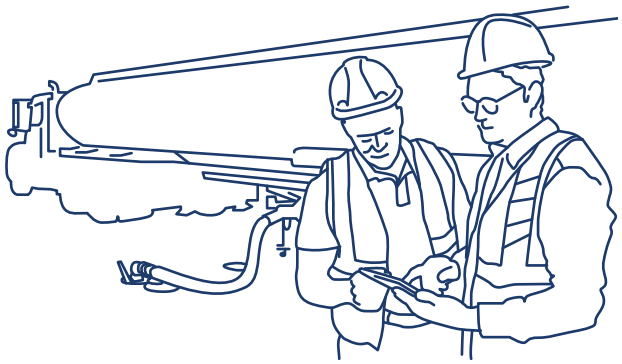
- Use an in-tank water-level monitoring system and record water-level measurements before and after each delivery to identify potential water influx during delivery.
- Because in-tank systems may not detect all levels of water, additional weekly tank sticking may help determine the potential sources of water infiltration (e.g., rain, hauler, product source, etc.).
- Ensure the appropriate water-detecting paste is used and left in the fuel long enough to affect the paste or gel, per the paste's instructions — not all water-sensing paste changes color in biodiesel blends. If fuel is being delivered during heavy rainfall, use an umbrella or canopy to prevent rainwater–fuel contamination.
- The tank owner should adopt a "zero tolerance" attitude towards free phase water in the tank and remove as much water as physically possible. Standards provide an allowable water limit, but ongoing studies indicate that any level of water in the fuel system has the ability to promote microbial growth and impact fuel quality.
- Contact your tank service provider or utilize a portable fuel polisher when water is detected to remove excessive water.

1 Note: If any equipment is ever removed (i.e., a riser tube) from the tank to perform an activity such as tank "sticking" and that piece of equipment has both wetted (in contact with fuel) and non-wetted (not in contact with fuel) surfaces, it is to the advantage of the tank owner to inspect the equipment as it is being removed from the tank to determine if the non-wetted areas of the equipment has corrosion. If the non-wetted equipment does have corrosion this is an indication of a corrodant type of material with a vapor pressure great enough to escape the liquid phase and enter the ullage (head space). This is very typical in riser tubes on the tubing that is considered a non-wetted area.

3. CLARITY — The appearance of diesel fuel can provide a valuable first detection of potential problems. Fuel should be clear and free of debris. This requires visibly checking for haze and sediment upon delivery.

AT A MINIMUM:

- Visual surveys are a zero-cost method for maintaining fuel quality.
- A "white bucket test[2]" (five gallon) can be completed prior to dropping the fuel into the UST. This will require coordinating with your fuel distributor and on-site staff and should be completed more frequently when entering the colder months where haze may indicate dissolved phase water that can impact the fuel's cold-flow properties.
- Collecting in-tank samples following a delivery will not provide a representative test of the fuel being delivered as it has mixed with existing fuel. In-tank sample collection will require on-site staff to remove manway lids under hazardous conditions. However, reducing sampling hazards may be possible by working with the fuel hauler to grab samples prior to dropping the fuel into the UST.



ADDITIONAL BEST PRACTICES:

- Collect a sample from the transport as the fuel is being delivered and store it in a clear quart jar.
- Label the jar appropriately and inspect it for clarity using the methodology in ASTM's Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (ASTM D4176-04 and Adjunct to D4176 Distillate Fuel Bar Chart).
- Samples should be kept for a period of time relative to the time it takes for the tank to turn over. In the event a customer complaint or other fuel quality issue arises, the sample may be sent to a lab for analysis. When you are done with the sample, dispose of it by adding it back to the tank.
- Observe the stored samples for precipitous fallout of paraffins (waxes), glycerin, sediment, and water. If cold flow properties are of concern, subject the samples to cold (outdoor ambient) temperatures to determine impacts on the fuel.[3]
- Following manufacturer's or supplier's guidance, adjust cold flow improvers if necessary.

For more information on visual spot-checking fuels, see STI R111[4] or API RP 1640[5].

2 Jim Gammon, "Manual of Aviation Fuel Quality Control Procedures," 5th Edition, ASTM; Note: this test should never be performed with gasoline, only diesel.

3 Note: With the exception of extreme geographies, buried USTS have a constant temperature in a range between 50F 60F. Outdoor ambient temperature is not a good indicator of tank temperature conditions.

4 STI R111, https://www.steeltank.com/Publications/STISPFAStore/ProductDetail/tabid/502/rvdsfpid/storage-tank-maintenance-standard-r111-308/Default.aspx

5 API RP 1640, https://www.api.org/~/media/files/publications/whats%20new/1640%20e1%20pa.pdf

4. LAB TESTING FUEL— Various triggers (such as cloudiness and change in seasons) warrant submitting a fuel sample to a lab for a full or partial-spec analysis (ASTM standard D975 ULSD, D7467 B6-B20, and D6751 B100). Tank owners should be familiar with current ASTM testing standards and review potential fuel testing based on the product in the tank as well as equipment type and customer responses to that fuel. Often, a limited critical spec analysis is desirable and can save significant testing costs. A fuel testing lab can provide sample containers, shipping materials, and proper documents for submitting samples, when and if necessary.

AT A MINIMUM:

- Test fuel whenever there is a change in fuels being stored.[6] This may include when modifying existing fuels (ULSD) with higher blends of biodiesel.
- Testing should also be done when equipment indicates a fuel issue. Restricted flow rate at the dispenser can indicate fuel-quality issues, especially when filters are needing to be changed more frequently as well. Fuel filters are commonly changed once per year.

ADDITIONAL BEST PRACTICES:

- Submit fuel for testing if visual checks (tank or dispenser visual check) reveal persistent cloudiness or sediment or if there are customer complaints or other fuel-quality issues, such as reduced flow rate.
- Discuss the visual sample (and filter, if impacted) with the lab to choose the best sampling regiment. A full D975 analysis is expensive and typically not necessary, but the lab consultation can determine the appropriate testing protocol for the sample in question.
- Test fuel during seasonal transitions to stay ahead of environmental changes such as additional moisture in the tank or cold weather fuel-quality concerns.
- Review any fuel abnormalities with your laboratory representative to decide which testing analysis should be performed. See Appendix for full ASTM Standards as well as less expensive partial spec analysis.

6 See suggested Partial-Spec Analyses in Appendix. For more information on biodiesel blends, see Alternative Fuels Council Biodiesel Fuel Quality plan, https://natsoaltfuels.com/resources.html

Equipment Maintenance: Tanks

After delivery, the next step in maintaining fuel quality is regular preventative maintenance to keep quality fuel from degrading on-site.

1. SUBMERSIBLE TURBINE PUMP (STP) SUMP— Because equipment in sumps can suffer from corrosion and degradation, all sump connections and joints should be designed with material that is impervious to the composition of fuel vapors to ensure system integrity. STP riser pipes, in contained and non-contained sumps, may allow water intrusion into the tank.

AT A MINIMUM:

- Visually inspect sump systems for signs of water entry and/or water entry/and or water damage, as well as equipment degradation and corrosion.
- Some sump systems may suffer from significant water intrusion from surface run-off or malfunctioning entry fittings for piping or conduits. Therefore, ensure all fittings are tight and intact and there is no leak in the system.
- Remove any water found inside the sump system.

ADDITIONAL BEST PRACTICES:

- Use desiccants to remove condensation.
- Check and replace desiccants frequently. In some cases, it may take a large amount of desiccant to keep the moisture level below the dew point.
- Because desiccants will only address moisture from the air, integrate sensors with the tank gauge to monitor for water inside the sump.[7]

7 "40 CFR Part 280—Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)," Legal Information Institute, Cornell Law School, accessed Aug. 21, 2020, https://www.law.cornell.edu/cfr/text/40/part-280.

2. SPILL BUCKET— Spill buckets require periodic maintenance, as outlined in the Petroleum Equipment Institute's (PEI) standard RP 1200. Before a delivery, inspect the spill bucket and remove any fluid that has accumulated inside. Spill bucket liquids should never be drained or pumped into the tank, as any water or other contaminants would also be released into the UST, contaminating product.

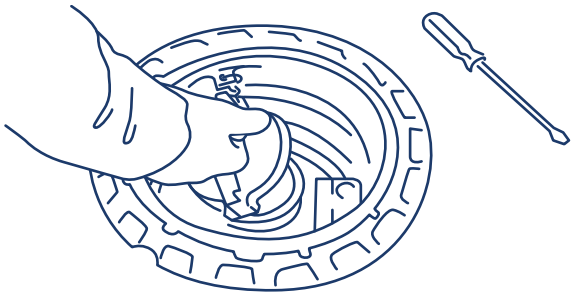
AT A MINIMUM:

- Inspect spill bucket regularly for liquid.[8] Safely remove accumulated liquid according to PEI recommendations.
- After a delivery, inspect, clean, close, and secure the spill bucket.
- Check the gasket and seals frequently to ensure rainwater does not collect in the bucket.
- A spill bucket that collects water regularly should be repaired and monitored to assure water is no longer collecting.

ADDITIONAL BEST PRACTICES:

Perform weekly inspections of the spill buckets. If water or other debris is observed in the spill bucket, remove the water and any debris in accordance with industry practices. If spill buckets take on water regularly, contact your service provider to determine cause and make repairs as needed. The following provides an approach that can be used:[9]

1. Put on safety glasses and gloves, place safety cones around the tank field, and remove the spill bucket's lid.
2. Remove liquid first by inserting the bilge pump's solid shaft into the bottom of the spill bucket.
4. Place a flexible hose into the bucket and hold the bilge pump steady with one hand while pumping the handle with the other until the bucket is filled halfway.
5. Place a lid on the bucket and discard its contents according to local regulations.
6. Remove foreign objects from the spill bucket using a reaching/grabbing tool and dispose in a plastic trash bag.
7. Clean remaining liquid with an absorbent towel on the end of a reaching/grabbing tool and dispose in a plastic trash bag.
8. Once cleaned, inspect fill port cap for proper seal and integrity. Note and communicate damage, missing tank tags, incorrect fuel type color code, or general integrity issues to company maintenance staff.



8 Petroleum Equipment Institute, "RP900: UST Inspection and Maintenance (2017 Edition)," accessed Aug. 21, 2020, https://www.pei.org/rp900.

9 Materials needed for this procedure include: Safety vest, shirt, or jacket; chemical resistant gloves; safety glasses; dedicated 5-gallon bucket; absorbent towels specifically designed for petroleum cleanup; plastic trash bags; trash compactor bag; fuel bilge pump; exterior safety cones; and reaching/grabbing tool

3. TANK VENTS— Vent stacks are required to allow for the movement of vapors between the tank and the atmosphere during fuel deliveries and dispensing to prevent damage to the tank by avoiding extreme pressures. However, they also allow humid air to enter the tank system, which can cause water to condense in the UST. Despite NFPA 30A prohibiting shared ventilation (for example, a diesel tank sharing a vent line with a gasoline tank),[10] it has been noted in the field.

AT A MINIMUM:

- Ensure that vent piping is not damaged by vehicle impacts by placing bollards to protect the vents.
- Ensure that vents are not restricted by pests or other debris.
- Verify that your gasoline and diesel tanks do not share a common vent stack. If they do, cease all operations until the issue is resolved. For fire safety, this situation must be avoided at all costs (NFPA 30A), including halting fuel deliveries until the tanks can be separated from the common vent. Aside from being a fire hazard, a common vent stack shared between a diesel tank and a gasoline tank can allow gasoline and/or ethanol vapors into the diesel tank during delivery or pull them into the tank during dispensing. These vapors may lower the diesel fuel flash point and may result in the formation of acetic acid in the tank.

ADDITIONAL BEST PRACTICES:

- Install a “rain cap” (open atmospheric vent cap) to prevent precipitation from entering the top of the vent pipe.
- Consider using desiccant systems in regions with high humidity or atmospheric moisture, seasonally or otherwise.
- Consult your service provider or desiccant manufacturer to determine if desiccants are widely used in the region and to determine the most effective placement, of the desiccant, in your equipment containment system.

10 National Fire Protection Association Code 30a (Flammable and Combustible Liquids Code) is typically adopted by state agencies having jurisdiction to regulate hazardous and flammable materials. See *NFPA 30A, Code for Motor Fuel Dispensing Facilities and Repair Garages* (Quincy, MA: National Fire Protection Association, 2021), available at https://catalog.nfpa.org/NFPA-30A-Code-for-Motor-Fuel-Dispensing-Facilities-and-Repair-Garages-P1165.aspx.

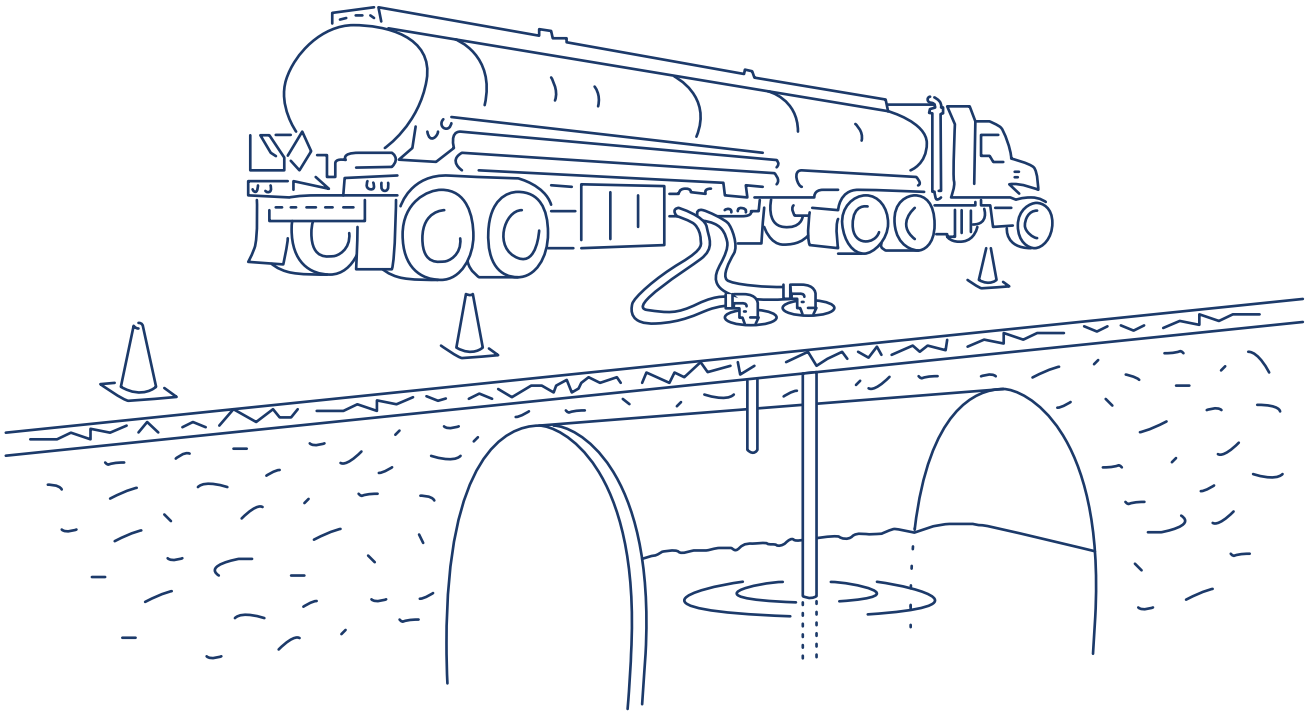
4. TANK MONITORING— Free water must be kept out of fuel storage tanks. Vigilantly monitor the tank to catch problems before they start.

AT A MINIMUM:

- Stick the tank with a product-appropriate water-detecting paste regardless of other methods used.
- Always ensure the gauging stick is pasted correctly and left in the fuel long enough to affect the paste or gel, per the paste's instructions.
- A negative tank stick does not mean there is absolutely no free water in the tank (tank design and tilt can lead to undetected pockets of free water in the fuel), but it is the most inexpensive way to test if water is in the storage tank. If possible, stick the tank at both ends to account for any possible tilt in the tank.
- Perform the test weekly, particularly if not using an electronic means of monitoring like an ATG. For a more aggressive approach perform the test before and after every delivery.
- Water sensors, whether as part of an automatic tank gauge or other sensors or test kits, are labor efficient in identifying the presence of water.
- Note any trends or water-level occurrences and compare against site activities, including recent rain, snow, or other precipitation.
- Sensors can also help pinpoint an issue with a delivery by taking readings before and after the fuel load is dropped. Water sensors can be inaccurate, however, if a UST was installed incorrectly or settled over time on the end where the sensor is not located. Therefore, if you stick the tank on the opposite side of the tank from where the ATG is located, you might get different readings that could be due to tank tilt.
- If water is detected when sticking the tank on the same side as the ATG, but it is not detected by the sensor, the tank gauge should be recalibrated, or the float adjusted by a service technician. Additionally, microbial growth and solids on the sensors can affect a sensor's ability to give accurate measurements.
- Make sure to inspect and service your water sensors regularly because significant quantities of water and sludge in diesel tanks can negatively impact the water sensor's accuracy.
- If fuel quality problems become apparent, contact your service provider to identify the point of entry and to remove water. Continue performing tank sticks daily until problem is resolved.

ADDITIONAL BEST PRACTICES:

- Collecting actual samples from the bottom of the tank is always the best determinant of free water.
- Sample collection may be completed by the owner/operator or a third party.
- Several tank sampling devices are available. Tank samplers that utilize a vacuum pump and tubing can obtain samples from multiple locations along the tank bottom. Tank bottom samplers open when they contact the bottom of the tank; then when raised, the plunger automatically falls tightly back into position, sealing the sampler



and preventing any contamination by liquid taken at a higher level. Some samplers will only sample to a depth of 14″ from the bottom, so a tank owner should ensure the model purchased will pick up sediment or water directly off the bottom.

- Collect bottom fuel samples at least once per month—weekly for best results, particularly at higher throughput sites where the tank's environment is constantly changing following each fuel delivery.
- Prior to pulling bottom fuel sample after delivery, allow fuel to settle for one hour per each foot of product depth. Visually inspect each sample for clarity and send to a testing lab once per month or as the visual inspection fails for clarity. The type of test should correspond with the nature of the observed issue or risk exposure at the time.[11]
- Where possible, tanks should be bottom sampled at both ends of the tank. If the tank has multiple compartments, each compartment needs to be sampled and monitored.
- The most critical time to sample is in the spring and autumn because temperature changes can result in additional condensation forming within the tank and impact the fuel's cold-flow properties.
- Tank owners should refer to ASTM D4057 and D7464 for up-to-date information on sampling methods.

11 For suggested tests, acceptable ranges, and detailed explanation of what test results could mean, please see Alternative Fuels Council, *Biodiesel Fuel Quality Plan: Biodiesel Blends 2018*, August 2018, https://www.natsoaltfuels.com/resources.html, especially Appendix A-1 Full Analysis Tables and A-2 Alternative Fuel Council Partial Panel Quality Check Tables.

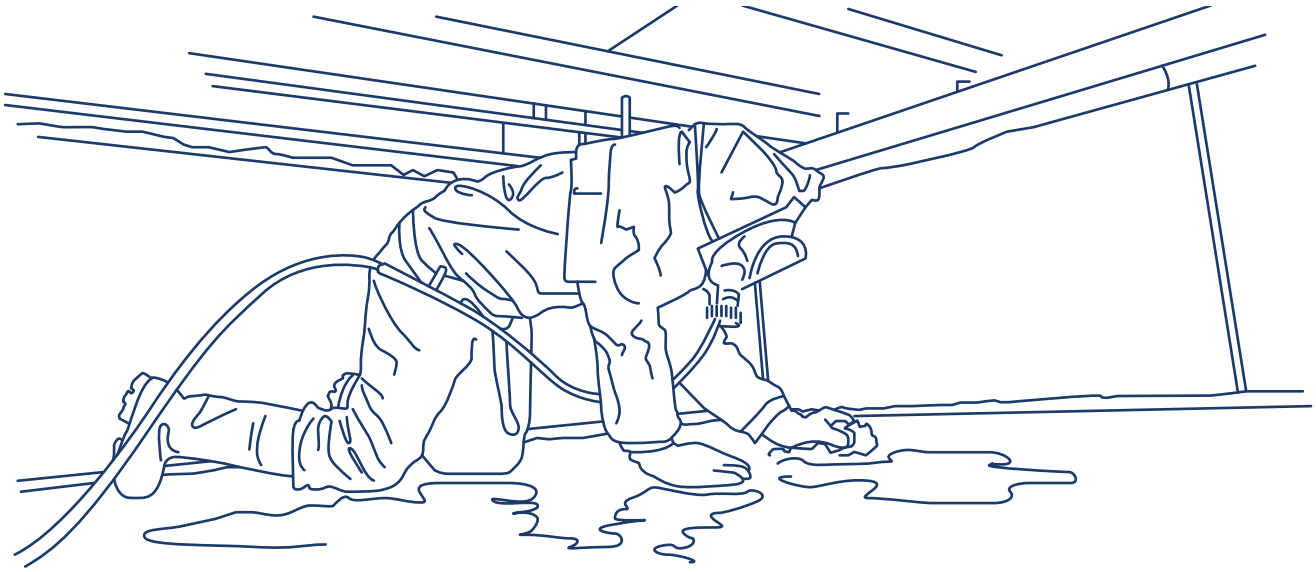
Tank and Fuel Remediation

If you are experiencing signs of fuel contamination or have confirmed contamination through lab testing, there are many options to restore fuel quality, along with the health of your tank and other equipment.

1. FUEL POLISHING, BIOCIDE TREATMENT, AND TANK CLEANING— If free phase water, sediment, or microbial growth contaminants are found during the monitoring practice, take remedial action immediately to address their presence via fuel polishing, biocide treatment, and tank cleaning.

(!) AT A MINIMUM:

- While fuel polishing will not achieve a 100% UST cleaning, it is an inexpensive remediation technique for a contaminated tank. Fuel polishing is generally done via multistage filtration using various configurations, but it typically involves pushing a flexible suction hose into two tank accesses. Product is removed via one hose, a filter system removes water and sediment, and then the fuel is returned to the tank via the second hose.
- Because fuel polishing does not use high pressure, little to no affixed contamination is removed. The remaining dead microbes, water, fiberglass resins, corrosion of metal residuals, dirt from upstream, etc., will continue to degrade the fuel and tank and, in some cases, will allow freshly introduced microbes to thrive.
- Adding biocide treatment to kill live microbes on top of fuel polishing can address microbial contamination.
- A fuel biocide expert should be consulted because each class of fuel biocide has its own active ingredient(s), fuel solubility, mode of action, and speed of kill that will determine its suitability for a given application.
- Biocide treatments alone are not a total solution since they may leave some microbes still alive, leave dead microbes in the tank (adding to sediment issues), and potentially spur new microbial growth. Following biocide applications, tank cleaning and filter changes may be necessary.



- Filters on the outlet of the tank can help remove dead microbes, but they may need to be changed multiple times after using biocide to prevent clogging. Additionally, if sources of water intrusion are not corrected, microbial infestations will return. Therefore, biocide treatments are most effective in addition to fuel polishing and/or other methods of tank and product remediation.
- There are many fuel and tank cleaning methodologies. Consult a fuel cleaning contractor to choose the best and most cost-effective method for the problem at hand.

⊕ ADDITIONAL BEST PRACTICES:

- Perform tank cleanings annually for preventative maintenance and in response to acute problems that arise. The tank cleaning process involves cleaning contaminants and sediment from the walls and bottom of the UST. Tanks can be cleaned with fuel still in the tank or after fuel has been removed from the tank.
- Do a tank cleaning before introducing higher levels of biodiesel because biodiesel will have a scouring effect and push solids into your filter.
- During tank cleaning where the fuel is removed, a crew will either enter the tank to manually clean it or clean it remotely from the outside. The process entails hydro-cleaning and vacuuming out all solids and liquids until the tank is clean and dry. The removed fuel is filtered before reentering the tank. This process can take two to four hours, or more, to complete, depending on the methodology.
- In tank cleaning where the fuel is not removed, the fuel itself is used to pressure-wash the interior of the tank while simultaneously being filtered to remove contaminants.

Equipment Maintenance: Dispensers

The dispenser is the last piece of equipment used before the product reaches the end user and requires specific attention.

1. FILTERS — The National Conference on Weights and Measures, which sets standards states may choose to adopt, allows a minimum of a 30-micron filter at the dispenser. Some fleet operators who operate their own fueling systems find fuel-related damage to vehicles from hard particles as small as 4-micron in size, suggesting that a 30-micron filter adds little protection to a modern diesel engine. This is likely due to the fact that Tier 3 and Tier 4 engines are typically equipped with 10-micron pre-filters and 2-micron fuel filters, so diesel fuel with particulates that exceed the ISO rating dispensed through a 30 micron-filter places the burden of fuel clean up squarely on the engine's fuel filters. However, overly restrictive filters can come with challenges that need to be evaluated by each tank operator.

Using a more restrictive filter can increase the filter change-out interval because the increased level of particulate capture reduces the flow rate to the nozzle. Also, because fuel viscosity changes with the season, a more restrictive filter may work across the continental U.S. in the summer but fueling locations in colder climates might experience filters with slow flow when cold temperatures decrease fuel viscosity.

Depending on the material, fuel filters may remove just particulates or remove particulates and water. If water in fuel is a common issue, use a water-detecting-and-removal filter. If offering biodiesel blends, consult your filter manufacturer or supplier. Note that even when free-phase water is not present, water may be held in solution especially when ULSD is blended with biodiesel. If the site has proper water removal procedures at the UST,

the need to remove water at the dispenser will not likely be necessary. Another thing to consider is filter efficacy, which is dictated by the beta rating of the filter. For example, a 30-micron filter with a beta rating of 10 will still allow one out of 10 particles that are 30-microns or larger in size to pass through. As more Tier 3 and Tier 4 diesel engines come into the U.S. fleet market, filters will need stronger beta ratings to meet those operational engine demands.

Diesel fuel retailing falls into two distinct categories: ***Auto diesel*** refers to light-duty vehicles (LDV) where the consumer pumps fuel at a rate of around 10 gallons per minute (gpm); ***truck diesel*** refers to heavy-duty vehicles (HDV) where dispensers are rated up to 50 gpm.

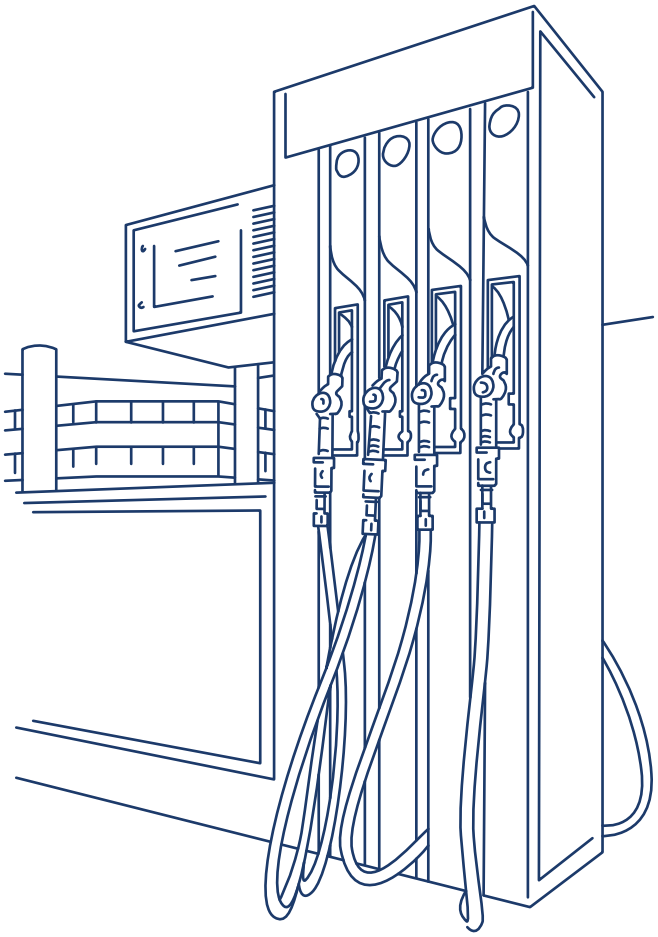
Note: During industry interviews for crafting this document, many high-volume travel centers reported very few fuel-quality complaints. Anecdotally, this suggests that the longer the fuel sits in the UST, the more likely microbial growth and sediment collection will be an issue. USTs that completely turn over quickly often do not have time to accumulate water, microbial growth, and sediment fall-out.

AT A MINIMUM:

- The current NIST Handbook 130, which sets standards states may choose to adopt, requires 30-micron (or less) filters for diesel and biodiesel blends.
- For states that adopt the regulations within NIST Handbook 130, tank owners in those states must ensure free-phase water in the tank is below 0.25 inches for fuel blended with biodiesel. This will ensure filters do not prematurely enter slow-flow mode, particularly if they have a water separation component.
- Monitoring and recording flow rates and changes for each dispenser, can help indicate in-tank conditions. Change filters annually regardless of flow volume.
- If you see materials that are out of the ordinary on your fuel filter, such as sludge or slime, this could be an indication that significant degradation is occurring to the fuel or in the fuel system. If you see material that looks like coffee grounds in your fuel filter and the material responds to a magnet this may be an indication that significant corrosion is occurring in the fuel system. If you see this material on your fuel filters, begin checking your tank for water more frequently and review your entire system for points of potential water entry. Remove any free phase water that is found. If you notice material that looks like coffee grounds on your fuel filter, but the material does not respond to a magnet, this may due to microbial growth.

⊕ ADDITIONAL BEST PRACTICES:

- Because filters are the frontline defense, use 10-micron filters when possible to remove smaller particles and monitor the dispenser flow rate diligently.
- On-site staff should immediately investigate any slow dispenser complaints to avoid customer wait time.
- As part of preventative maintenance, change filters whenever the flow rate is not at optimal levels.
- As long as fuel tanks have less than one inch of water present, higher fuel turnover sites (travel centers) may consider using a high-flow 30-micron filter. For auto diesel dispensers, a 10-micron filter may be more suitable as fuel turnover is not as high, which could make the environment more suitable for impurities and water in the fuel to drop out and for microbes and sediment to accumulate.
- Replace filters proactively according to a predictive maintenance schedule depending on throughput. When replacing filters, inspect them: If they are slimy and smudgy, have the filter analyzed. This issue can be caused by a variety of sources, including the presence of drag-reducing agents (introduced in the pipeline), microbes, too many fuel additives, or other factors. It is important to understand the cause of the filter problem so that the issue can be addressed properly. “Coffee grounds” signals dead microbial residue or corroded metal (both show the same microbial issue).
- Consider installing desiccant water-management equipment.



Conclusion

While fuel quality can be impacted at any point along the distribution chain, the retailer is the last point before fuel is introduced into engines and potentially the point at which fuel sits the longest.

For these two reasons, it is paramount for tank owners to be proactive when it comes to monitoring fuel and storage equipment for fuel quality issues. A good fuel quality plan will reduce customer fuel complaints, as well as prevent equipment degradation and thereby minimize overall costs. To protect your brand, your customer base, and your own equipment, it is strongly suggested that you adopt a fuel quality plan. The purpose of this report is to give any tank owner resources to implement strategies for success. At the very least, understanding the problem and where to begin with respect to fuel quality is a free first step any operator can take.

APPENDIX: Full and Partial-Spec Analysis Options

TABLE 1: ULSD (UP TO 5% BIODIESEL)— ASTM STANDARD D975

PROPERTY	TEST METHOD
Flash Point (proc. A)	D93
Water and Sediment	D2709
Distillation at 90% recovery	D86
Kinematic Viscosity	D445
Ash	D482
Sulfur	D5453
Copper corrosion	D130
Cetane number	D613
Cetane index	D976
Cloud point	D2500
Ramsbottom carbon residue	D524
Lubricity	D6079
Conductivity	D2624
Visual Inspection	D4176

TABLE 2: ULSD (B6-B20)— ASTM STANDARD D7467

PROPERTY	TEST METHOD
Total Acid	D664
Flash Point (proc. A)	D93
Water and Sediment	D2709
Distillation at 90% recovery	D86
Kinematic Viscosity	D445
Ash	D482
Sulfur	D5453
Oxidation stability	EN 15751
Copper corrosion	D130
Cetane number	D613
Cloud point	D2500
Ramsbottom carbon residue	D524
Lubricity	D6079
Conductivity	D2624
Visual inspection	D4176

TABLE 3: BIOMASS-BASED DIESEL (B100)— ASTM STANDARD D6751

PROPERTY	TEST METHOD
Total Acid	D664
Flash Point (proc. C)	D93
Water and Sediment	D2709
Distillation at 90% recovery	D1160
Kinematic Viscosity	D445
Sulfated Ash	D874
Sulfur	D5453
Calcium and Magnesium	EN 14538
Sodium and Potassium	EN 14538
Oxidation stability	EN 15751
Copper corrosion	D130
Free and total glycerin	D6584
Cetane number	D613
Cloud point	D2500
Carbon residue	D4530
Visual inspection	D4176
Cold soak filterability	D7501
Phosphorus	D4951

TABLE 4: POTENTIAL CRITICAL PARTIAL SPEC ANALYSIS FOR ULSD

PROPERTY	TEST METHOD	REQUIREMENT	DESCRIPTION
KF Moisture, ppm	D6304	No U.S. specification. <100 ppm is typical	This method determines the proportion of water in a product like fuel additives and similar products to help predict a fuel's quality/ performance as well as premature corrosion of equipment.
Microbial Count	D6974	Determines amount and enumeration	This method detects the presence and enumeration of Heterotrophic bacteria and fungi in the fuel which indicates fuel contamination that causes slime accumulation on equipment and filters.
CFFP, °C, max or CFPP, °C, max	D2500 D6371	See B6-B20 Table	The cloud point for petroleum product is an index of the lowest temperature of their utility (for certain applications). Fuels must be transparent in layers of 40mm in thickness and have a cloud point below 49 °C.
Flash point, °C, min	D93	52	A fuel's flash point temperature is the measure of its flammability. The flash point test method is used in shipping and safety regulations in the range of 40 °C to 370 °C.
Sulfur content, ppm, max	D5453 (S15) D2622 (S500) D129 (S5000)	15 0.05 0.50	Feedstocks can contain sulfur-bearing materials. This method is used to determine sulfur in process feeds or in the finished product.
Visual	D4176	1-6 Clarity	Visual inspections will detect dissolved phase water (haze), free phase water, and impurities such as sediments.

TABLE 5: POTENTIAL CRITICAL PARTIAL-SPEC ANALYSIS (B6-B20 AS EXAMPLE)

PROPERTY	TEST METHOD	REQUIREMENT	DESCRIPTION
KF Moisture	D6304	No U.S. standard to date, however, <200ppm is considered acceptable	Moisture may lead to premature corrosion, which can increase debris. This can cause filter plugging and reduce the effect of additives as well as increase bacterial growth.
Microbial Count	D6974	Results provide growth volume	Causes slime accumulations on system surfaces or at a fuel-water interface. Organisms indicate fuel-quality impacts and plug filters.
Cloud Point, °C, max CFFP, °C, max	D2500 D6371	Temperature at which the smallest observable crystals first occur	Wax content falls out of solution and crystals form as temperature drops. Cloud point is the measurement of the lowest temperature at which the fuel can maintain engine operability.
Oxidation Stability hours, min	EN15751	6 hours	Oxidation stability is a key parameter of biodiesel quality.
Biodiesel Content	D7371	6-20	As biodiesel content (%) in ULSD pulled at the terminal may be unknown, testing should be performed to determine final blend % being offered at the dispenser.
Visual	D4176	1-6 Clarity	Visual inspections will detect dissolved phase water (haze), free phase water, and impurities such as sediments.

TABLE 6: POTENTIAL CRITICAL PARTIAL-SPEC ANALYSIS (B100)

PROPERTY	TEST METHOD	GRADE NO. 1-B S15	GRADE NO. 1-B S500	GRADE NO. 2-B S15	GRADE NO. 2-B S500	DESCRIPTION
Sulfur, % mass (ppm), max	D5453	0.0015 (15)	0.05 (500)	0.0015 (15)	0.05 (500)	Feedstocks can contain sulfur-bearing materials. This method is used to determine sulfur in process feeds or in the finished product.
Cold soak filterability, s, max	D7501	200	200	360	360	Substances dissolved in the fuel can begin to drop out when the fuel reaches temperatures above cloud point, causing filter plugging and other issues. This method tests for a cloud point below 20° C to ensure low temperature operability
Acid number, mg KOH/g, max	D664	0.50	0.50	0.50	0.50	The acid number is used to determine the level of free fatty acids or processing acids that may be present in biodiesel.
Free glycerin, % mass, max	D6584	0.02	0.02	0.02	0.02 provide growth volume	Causes slime accumulations on system surfaces or at a fuel-water interface. Organisms indicate fuel-quality impacts and plug filters.
Total glycerin, % mass, max	D6584	0.24	0.24	0.24	0.24	The production of biodiesel through transesterification produces glycerin, an unwanted byproduct that must be removed. This measures the amount of unreacted percent of partially reacted feedstocks left in the biodiesel.
Oxidation Stability, hours, min	EN 15751	3	3	3	3	Oxidation stability is one of several methods to measure the stability of B100 biodiesel.
KF Moisture, mg/kg, range	D6304	500	500	500	500	Moisture may lead to premature corrosion which can increase filter plugging debris and bacteria. Excess moisture may also impact the effectiveness of fuel additives.
Visual	D4176	1-6 Clarity	1-6 Clarity	1-6 Clarity	1-6 Clarity	Visual inspections will detect dissolved phase water (haze), free phase water, and impurities such as sediments.

Fuels Institute

DFQC DIESEL FUEL QUALITY COUNCIL

About the Diesel Fuel Quality Council

The Diesel Fuel Quality Council is a non-advocacy organization comprised of a diverse range of stakeholders in the heavy-duty diesel industry. We got our start when in 2017, Mansfield Energy Corporation contacted the Fuels Institute to discuss a pervasive problem popping up amongst their customers. Many fleets were experiencing diesel engine problems and downtime presumably as a result of fuel quality. Perplexed as to why this was happening and looking for answers, Mansfield reached out to the Fuels Institute and asked us to start an industry-wide initiative to investigate the issue and see if we could come up with any mitigation strategies. Since then, we have been bringing stakeholders together to collaborate on research geared toward improving the relationship between diesel fuel quality and modern diesel engines. This report is the result of that initiative.

For more information on the Diesel Fuel Quality Council and a list of current members, please visit:
fuelsinstitute.org/councils/fuel-quality-council

About the Fuels Institute

The Fuels Institute, founded by NACS in 2013, is a 501(c)(4) non-profit research-oriented think tank dedicated to evaluating the market issues related to vehicles and the fuels that power them. By bringing together diverse stakeholders of the transportation and fuels markets, the Institute helps to identify opportunities and challenges associated with new technologies and to facilitate industry coordination to help ensure that consumers derive the greatest benefit.

The Fuels Institute commissions and publishes comprehensive, fact-based research projects that address the interests of the affected stakeholders. Such publications will help to inform both business owners considering long-term investment decisions and policymakers considering legislation and regulations affecting the market. Research is independent and unbiased, designed to answer questions, not advocate a specific outcome. Participants in the Fuels Institute are dedicated to promoting facts and providing decision makers with the most credible information possible so that the market can deliver the best in vehicle and fueling options to the consumer.

For more about the Fuels Institute, visit fuelsinstitute.org.

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