ULTRA LOW SULFUR DIESEL STORAGE AND DISPENSING SYSTEMS –
WHAT THE RAILROAD INDUSTRY NEEDS TO KNOW ABOUT CORROSION

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ABSTRACT

EPA mandated use of ultra low sulfur diesel fuel (ULSD) will soon take effect for non-road diesel fuel, including locomotives. This standard has been implemented for several years for highway ULSD and many railroads already use ULSD due to its availability. Information has surfaced regarding a possible connection between ULSD and equipment issues in storage and dispensing systems. Issues included accelerated and excessive corrosion and equipment failure.

In early 2010, a group of interested parties distributed a survey to investigate these issues. While the survey did not reveal any obvious patterns, it identified many issues. Forty-two percent of respondents reported ULSD-related equipment corrosion. To determine the scope and nature of the issues, the Clean Diesel Fuel Alliance (CDFA) formed a committee, which also includes the Association of American Railroads. A consultant was hired to conduct sampling and further research. Results of this study should become available by late 2011.

The implications to the railroad industry are great. Some railroads have already identified problems with possible connections to ULSD. Corrosion can affect any piece of equipment that stores, conveys or dispenses diesel fuel. This includes the fuel tank and diesel engine on the locomotive itself. It is critical for the railroad industry to understand the issues and gain access to current information. This paper addresses the history, specific issues, possible mechanisms of corrosion, items to watch for, solutions and new information.
INTRODUCTION

ULSD Transition

The U.S. Environmental Protection Agency's ultra low sulfur diesel (ULSD) program was developed to help reduce emissions from diesel engines. This is being accomplished in part by a stepped approach to reducing the sulfur content in diesel fuel available in the U.S. to various transportation sectors to 15 ppm (1). All highway diesel fuel has been required to be ULSD compliant since December 1, 2010. California has required ULSD compliance since September 1, 2006. The ULSD fuel standard of 15 ppm sulfur has applied to non-road diesel fuel production since June 2010 (2). This standard is required for locomotive and marine diesel fuel by the beginning of 2012. However, since California has been under this rule since 2006, and refiners and importers have been required to produce 100% ULSD since 2010, availability of low sulfur diesel (500 ppm) has steadily declined. Many railroads have already begun using ULSD in locomotives ahead of the deadline.

Typical Railroad Facilities and Equipment

Everyday, railroads receive, store, and dispense millions of gallons of diesel fuel (3). Locomotive service facilities receive diesel fuel via pipeline, tank car, and/or tanker trucks. Fuel is metered upon receipt prior to delivery to storage. The fuel is generally stored in API 650 or UL142 compliant aboveground vertical or horizontal storage tanks. The fuel is then metered and filtered and pumped to a fixed fuel dispensing system or loaded into tanker trucks for direct to locomotive (DTL) fueling operations. See Figure 1. Typical railroad fueling facility equipment includes valves, basket strainers, loading arms and hoses, swivel joints, meters, control valves, pressure relief valves, filters, and fueling nozzles (See Figures 2 through 5). Materials of construction generally include carbon steel, which is externally coated. Most diesel fuel piping and storage tanks are not internally coated. All of these types of facilities, including the
tanker truck tanks and equipment, tank cars, and locomotive fuel tanks have, or will soon be, used exclusively with ULSD.

**The Beginning of ULSD Related Corrosion Issues**

In late 2007, ULSD users began reporting excessive corrosion and excessive corrosion rates in systems that had been switched to ULSD. These comments were shared on the Petroleum Equipment Institute’s (PEI) online forum. The corrosion initially reported to PEI was mainly on equipment found in fiberglass underground storage tanks and the associated dispensing systems. Since then, similar issues have surfaced in steel tanks. Damage reported included clogged filters, broken down seals, excessive corrosion on internal piping in both the liquid and head spaces, probe cable deterioration, meter failures, line leak detector damage, automatic nozzle shutoff failures, storage and vehicle tank leaks, valves not seating, swivel joints failing, and pipe failures. The cause of the corrosion was not immediately evident as deterioration and corrosion did not resemble the damage associated with other well know corrosion mechanisms, such as microbes or galvanic corrosion. Additionally, there was no apparent pattern as to the geographical location, refiner, or system type to pinpoint a localized problem. Corrosion was found in all regions of the country, in new and old equipment, and in high and low use facilities. Since materials and systems have not changed but the fuel has, the assumption points toward ULSD contributing to the new corrosion problems (4).

**BACKGROUND**

**Industry Survey**

In response to the reported issues, a task force formed and met in Washington, D.C. in January 2010 to discuss approaches to better understand and address possible issues associated with the introduction of
ULSD. The task force consisted of twelve organizations and government agencies, including PEI, Steel Tank Institute, Petroleum Marketers Association of America (PMAA), NATSO (association representing travel plaza and truckstop owners), NACS (The Association for Convenience and Petroleum Retailing), SIGMA (a national trade association representing independent motor fuel marketers and chain retailers), American Petroleum Institute, National Biodiesel Board, National Association of Fleet Administrators and American Trucking Association, EPA’s Office of Underground Storage Tanks (OUST) and the Office of Transportation and Air Quality (OTAQ). As a result, the task force developed a five-question survey to better understand the characteristics and impact of current ULSD corrosion (5). These questions were:

1. Which of these would best describe your role in the industry (tank owner, fuel supplier, service provider, equipment manufacturer, regulator/inspector, cargo tank motor vehicle owner, other)?
2. Are you receiving more reports within your organization regarding equipment operational problems related to ULSD than you did before ULSD was introduced in 2006?
3. Indicate those areas where you are receiving the reports identified in the previous question.
4. How many separate locations do you have first-hand knowledge of these problems?
5. If desired, please enter any comments or additional details that may help us better understand your experience.

There were approximately 1,200 respondents to the survey. The results of the survey were tabulated and discussed by the task force in April, 2010, and presented in Figure 2 (5). Some key findings were:

- Forty-two percent of respondents reported increased equipment-related issues after the introduction of ULSD.
- Nearly 5,000 locations were reported to have ULSD related issues.
- Widespread problems were reported across the United States and Canada, with no apparent pattern or concentrated areas.
- Sixty-nine percent of survey respondents with ULSD issues were tank owners.
In the summer of 2010, ASTM International held a conference titled *Workshop on Fuel Corrosivity and Material Compatibility of Petroleum and Alternative Liquid Fuels*. Many of the presentations focused upon ULSD issues, providing a current overview and presenting case studies and theories for the increased corrosion.

The conference began with the Steel Tank Institute and the Petroleum Equipment Institute giving a brief overview of the history and scope of the issues (6). Several photographs illustrated the typical type of corrosion recently found in ULSD systems. The results of the industry survey were also shared and need for further study was expressed.

Next, BP Global Fuels Technology discussed diesel soaps (7). Diesel soaps can form when corrosion inhibitors or lubricity improvers react with tank water bottoms. Conclusions indicated that the formation of diesel soaps use up some of the corrosion inhibitor, thereby making the fuel more corrosive. Innospec Fuel Specialties then presented a similar topic which drew the same conclusions as the BP presentation (8).

Ford Motor Company then highlighted issues with some vehicle fuels tanks (9). Corrosion appeared mainly in the vapor space of interior coated steel fuel tanks. After some research, acetic acid was found in the fuel and the associated fuel tank coatings. It was speculated that these acids are a residue of the desulfurization process used to process ULSD at the refinery, although it was acknowledged that not all refineries use this type of process. This issue should be investigated in locomotive fuel tanks as well as fuel tanks in other on-track service equipment.
CDFA Steering Committee

The Clean Diesel Fuel Alliance, a collection of 26 government, industry, marketing and trade associations, met again in late 2010, and hired a consultant to conduct a more scientific study to determine causes and distribution of problems that appear to be associated with ULSD. The study is supervised by a steering committee made up of members from API, PEI, The Steel Tank Institute, PMAA, NACS, NATSO, Ford and the Association of American Railroads (AAR). Phase I of the study, completed in early 2011, reviewed the results of the PEI survey and analyzed the consultant's own nationwide inspection database in order to develop a hypothesis of what may be causing the corrosion. Phase 2, which should be completed in late 2011, will include additional field research and inspections, as well as real-world testing of the hypothesis developed in Phase 1. To date, the study has collected data on problem sites, collaborated with individual companies conducting independent research, examined possible causes, developed a list of areas to research further and developed ideas of what specific testing can be done. It is hoped that the results of this study will give definitive answers of the causes of corrosion as well as methods to manage it.

ULSD Corrosion

Corrosion Characteristics

The main characteristic of the ULSD corrosion is excessive and accelerated corrosion which appears in both submerged and vapor space areas were corrosion has not previously been an issue. Photographs of various types of corrosion can be seen in Photos 1 through 9.

Photos 1 and 2 illustrate corrosion on piping that was submerged and piping in the tank vapor space. While these photographs depict equipment in underground storage tanks, railroads utilize aboveground horizontal tanks that have internal piping in the same conditions if built according to UL 142 standards.
Vertical aboveground storage tanks may also have internal piping and instrumentation, including floats and cables that may be affected.

Photos 3, 4 and 5 show corrosion associated with a strainer. Corrosion is seen on the screen and in the strainer housing itself. “Coffee ground” particles from a clogged strainer are shown in Photo 5. Strainers are utilized by railroads on fuel pumping systems. Sudden excessive strainer clogging can indicate a problem.

Photo 6 shows a spring type check valve that has failed due to internal corrosion. The spring is very badly damaged and the check valve has come apart. Railroads may utilize spring check valves in pressure relief loops. Pressure relief valves may also be affected.

Photos 7 and 8 show corrosion on a filter housing and filter housing threads. Railroads filter fuel in large wayside filters that contain the same filter elements found in locomotives. These filters should be checked frequently for increasing differential pressure, which indicates a need for a filter change.

Photo 9 shows a submerged pump that has been badly corroded in less than a year. This photograph reveals how serious and fast-acting the ULSD corrosion problems can be.

**Theories**

Many theories have been considered for the increased incidents of ULSD system corrosion (6) (10) (11) (12). These include:

- Decreased biocide-like sulfur content leads to increased microbes
- Decreased natural biocide-like aromatics lead to increased microbes
• Microbiological corrosion for unknown reasons
• Diesel fuel not properly processed
• Acid or other compounds remaining from new refining desulfurization process
• Fuel additive causing an unexpected reaction
• Galvanic reaction from dissimilar metals
• Reaction from increased biodiesel use
• Increased water bottoms due to decreased water holding capacity of ULSD
• Corrosion inhibitor depletion with reaction to water bottoms
• Corrosion inhibitor depletion during transportation
• Grounding issues
• Hydrogen sulfide present in fuel in extremely small quantities
• Caustic carryover when refining fuel
• Acetic acid has been shown to be present in fuel
• Diesel soaps formed from corrosion inhibitors

It can be seen that there are many theories and mechanisms that can lead to increased corrosion. Most of them fall into the following categories:

• Reaction with additives
• Reaction with tank system materials
• Microbial
• Water bottom interaction
• Refinery process carryover
Possible Causes

Although the CDFA study is not complete at the time of this writing, several most likely causes have been identified as contributors to ULSD corrosion issues. These include the following.

Microbiological activity is suspected for several reasons. Acetic acid has been found in fuel samples. Microbes, specifically Acetobacter, can produce acetic acid as a by-product of their metabolism. Antimicrobial additives have been reported to be used with some success after the coffee ground like substance has been found clogging filters (11).

Acetic acid may also be forming for currently unknown reasons. There have been reports that the unwetted portions of the tank and equipment in the vapor space are affected by corrosion before the submerged areas of the tank. This may be due to the fact that acetic acid has a very high vapor pressure. The acetic acid would be more likely to be highly concentrated in the vapor phase. The unwetted portions of tanks and components are exposed to this corrosive vapor. This was the cause of the corrosion found by Ford in its fuel tanks (11).

Some research indicates a possible chemical reaction may be occurring between fueling system components and the fuel, causing acetic acid formation. Little is known about this mechanism, and more information should be forthcoming (11).

Fuel additives have also been investigated as possible corrosion contributors. Overall, different additives are used in ULSD for lubricity, conductivity and corrosion inhibition that were not previously needed in low sulfur diesel. It has also been shown that overdosing of corrosion inhibitor can lead to diesel soap formation, therefore reducing the corrosion inhibitor in the fuel further (11).
Hydrogen sulfide is a product of the hydrotreating process, which is used by some refineries to reduce the sulfur content to the required 15 ppm. Although it is stripped from the fuel, some small amounts may still pass through to the customer (11).

Other corrosion mechanisms have been ruled out as being the cause of the ULSD specific issues. These include galvanic corrosion, grounding/shorting issues, fuel processing problems (ruled out because the problem is not localized), and the use of biodiesel (11).

**Concerns**

Concerns may include equipment failures and increased maintenance, but the most important consideration is a release of fuel. The following is by no means an exhaustive list of concerns and potential system failures.

Equipment may fail and be required to be replaced with minimal leakage. This may include meters and check valves. It may also include failure of equipment inside tanks that will not result in an immediate release, such as instrumentation cables and riser pipes. Equipment failures may also include something as catastrophic as a tank or pipe failure. Smaller leaks may also form, such as at threaded connections at drains, pressure gauges or pressure relief valves.

It has been seen that the excessive corrosion can cause filters and strainers to clog more frequently, requiring more frequent replacement. While the cost of increased maintenance activity is a concern, the cost of not responding to this type of problem may be higher. Clogged filters and strainers can lead to increased pressure drops in the system and lower flow rates. This can lead to pressures within the system below the required pressure for automatic nozzle shut off. This could lead to an overfill at the locomotive.
Another concern is failure of equipment associated with leak detection systems. This may include line leak detectors and tank probes. Previous experience that the cables leading to these instruments may also be affected. While premature failure of these items may not lead to an immediate spill, the secondary containment systems of tanks and pipes may be unknowingly compromised if the leak detection system is not functioning. Additionally, product releases may occur without being immediately detected by the leak detection systems. Malfunctioning tank level instrumentation may lead to a tank overfill or to pump damage due to the low level shut-off not working.

**PATH FORWARD**

The Clean Diesel Fuel Alliance (CDFA) has already determined to study the ULSD corrosion in more detail. Until some definitive results are found, there are some actions that can be done in the short term to help identify and minimize any ULSD related issues.

**System Inspection**

It is recommended that any systems having an increase in filter changes and unusual equipment and seal failures, and that are known or suspected to have used ULSD, be immediately inspected. This should include both internal and external inspections of tanks and associated equipment. These inspections should include a review of tank water bottom management. All submerged instrumentation and leak detection system components should be verified for functionality. Pressure relief valves, check valves and other components that rely on springs should be tested. Filters and basket strainers should be checked for differential pressure drops and filter change frequencies reviewed. Swivel joints and associated seals should be checked for leakage. Locomotive fueling nozzle malfunctions should be investigated. It is also recommended that locomotive fuel tanks and associated systems be inspected and checked for any signs
of increased filter plugging or engine maintenance. It may also be advisable to check tank cars, especially those that are top unloaded, as water bottoms may accumulate over time.

The items discussed above are not exclusive to fuel receipt, storage and dispensing systems. Used oil collection and storage systems, as well as industrial wastewater collection and storage systems associated with railroad fueling facilities may also be impacted by the presence of ULSD. It is beyond the scope of this paper to discuss the equipment and function of these systems, but they should also be considered.

**Sampling**

Sampling is key to determining the health of a system and investigation of system failures. Sampling should accompany the inspection programs discussed previously. Many aspects of the system should be sampled when investigating problems.

To assure quality of fuel received, stored and dispensed, a regular fuel inspection and sampling program should be implemented. One of the main theories of ULSD corrosion relates to the stability of corrosion inhibitors in the fuel. Typical fuel receipt quality control inspections include visual inspection and testing for water. For systems developing possible ULSD related issues, it may also be a good idea to test the corrosivity of the fuel received per NACE (13). This test can be performed to assure that received fuel is in compliance with specifications and testing can also be performed on stored product to help determine if corrosion inhibitors are depleted during storage. Fuel should also be sampled for microbial activity. Many railroad facilities may not have good locations to sample fuel. A typical inline sample port that can help with sampling activities is shown in Figure 3.

The most focus on ULSD issues is directed at tank water bottoms. Water bottoms in ULSD systems should be minimized and more about this will be discussed further. Water bottoms in all storage tanks should be sampled for compounds such as those associated with corrosion inhibitor depletion, diesel
soaps and microbial growth. Fuel deliveries entering the facility through truck, tank car and pipeline should be monitored for water content. Other tanks, such as locomotive fuel tanks that are normally topped off, should be checked for water content regularly since ULSD has a lower water holding capability. Automatic tank gauging systems with water detection capabilities are recommended in locations where water is an issue.

Filters and strainers should be carefully monitored for excessive differential pressures. If filter changes become more frequent, a problem within the system might be indicated. If this occurs, the filter media itself should be sampled and tested to determine if anything is out of place, such as microbial activity. It may also be beneficial to sample the filter or strainer debris to determine if its composition may be related to a problem with ULSD use.

If other components in the fueling system fail prematurely or by excessive numbers, they should also be tested to determine the cause of failure. This may include fueling nozzles and fueling crane components and seals, hoses, swivel joints and unloading arms.

**Tank Water Bottom Management**

One of the most important elements of fuel storage is proper removal of tank water bottoms. The CDFA states that less than 0.25 inches of water is more than sufficient to promote microbial growth (14). Many methods exist to collect, detect, and dispose of water found in fuel storage systems. These methods vary depending on the industry and the desired or required fuel quality. It is essential to keep water out of any fuel storage system to minimize microbial growth. Other issues associated with water in the system include accelerated fuel degradation, increased accumulation of sludge, and the introduction of other contaminants such as salts that can alter the chemical structure of fuel in ways that will damage various storage system components.
Two helpful documents which discuss tank water bottom management are as follows. The Clean Diesel Fuel Alliance has issued a document titled “Guidance for Underground Storage Tank Management at ULSD Dispensing Facilities” (14) and the Steel Tank Institute has issued a document titled “Keeping Water Out of Your Storage System” (15). The documents are available at the associated authoring agency's web sites. Although these documents were written with the retail service station industry in mind, they contain some very useful information that can be applied to the types of tanks commonly used by railroads for the storage of diesel fuel.

The dewatering of tanks is often accompanied by the wasteful removal of some product. This product is often disposed of by the same means as the water by draining to an industrial wastewater collection and treatment system on-site or hauled off-site for disposal. Much of this wasted fuel is a result of the volume of fuel that is displaced each time the drain pipe is opened to get to the water in the tank. Once the last of the water leaves the tank, the drain pipe is once again full of fuel. If the amount of fuel wasted by this operation is a concern and a driving factor in the frequency of dewatering performed on a tank, it is recommended that a product recovery tank or sump separator be installed and employed to recover this fuel. A typical sump separator can be seen in Figure 4. The purpose of this type of equipment is to capture the fuel, separate it from the water, and then return the fuel to storage. This simple procedure could save millions of gallons of diesel fuel each year that may be otherwise wasted through dewatering activities. The impact on industrial wastewater treatment systems and disposal costs would also be reduced.

How is Water Introduced?

Besides the need to address the removal of water, it is important to understand the many mechanisms by which undesired water may enter the system. It is important to identify and minimize these pathways. Some of these include:
• Condensation in tanks with vents open to the atmosphere. As tanks “breathe” in and out due to temperature changes and product removal and filling, condensation which can accumulate in humid conditions can be introduced into the fuel.

• Water can enter during transportation through pipelines, trucks and tank cars. Ways that it can enter include: through leaking vents, manways and other connections, from rainwater, runoff, and condensation.

• Rainwater can enter prior to delivery if the product is stored in open top floating roof tanks. Pipeline companies generally have means to mitigate the entry of water, and then to remove water from the tanks. However, if the tanks have poor water bottom management practices, then the water could potentially pass through to the customer.

• Leakage into facility piping through poorly placed leak detection ports or other instrumentation connections.

• High throughput in the fuel distribution and delivery infrastructure, allowing less time for water to settle out of the product before it is delivered.

• Low throughput systems. The lower the throughput at storage and dispensing sites, the more likely water is to accumulate in the system.

**Information Sharing**

It may be time for a railroad industry survey similar to the one that was conducted by PEI. If such a survey was forthcoming, it is hoped that the appropriate personnel would be responsive in sharing any information relevant to ULSD issues. Results may be helpful to the CDFA study currently underway.

Additionally, an online forum could be created within the AREMA website to discuss issues and concerns. This forum could update concerned railroad personnel regarding the CDFA study and other
findings within industry relative to the ULSD corrosion. The more information is shared, the quicker all ULSD users can converge on answers and solutions.

CONCLUSIONS

ULSD is thought to be a cause of accelerated corrosion in storage and dispensing systems. Since EPA mandated use of ULSD will soon take effect for locomotives, and since ULSD is already being used by railroads in some areas, it is advised that the railroad industry watch for similar symptoms of corrosion found in other ULSD systems. Any excessive corrosion or other symptoms such as frequently clogged filters or equipment failures should be investigated by inspection and sampling. Water should be actively removed from any fuel storage system. Sharing of any relevant information with the Clean Diesel Fuel Alliance and other railroads will assist in the investigation for causes of ULSD related corrosion.
REFERENCES

5. *ULSD: From Talk to Action*, PEI Journal, Second Quarter 2010, 47-50
11. *Corrosion Issues with ULSD*, Lorri Grainawi, Steel Tank Institute, June 8, 2011

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Figure 1 – Typical Railroad Fueling Facilities
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Figure 3 – Typical Locomotive Fueling Nozzle

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Figure 4 – Typical Meter, Air Eliminator and Strainer

Figure 5 – Typical Wayside Fueling Filter
ULSD Survey Results (March-April 2010)

1. Which of these best describes your company's role in the industry?

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<th>Response Total</th>
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<td>Tank Owner</td>
<td>293</td>
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<td>Fuel Supplier (may also own tanks)</td>
<td>536</td>
<td>45%</td>
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<td>124</td>
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<td>Equipment Manufacturer</td>
<td>33</td>
<td>3%</td>
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<td>Tank or Equipment Inspector/Regulator</td>
<td>69</td>
<td>6%</td>
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<td>Cargo Tank Motor Vehicle Owner</td>
<td>45</td>
<td>4%</td>
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<tr>
<td>Other</td>
<td>92</td>
<td>8%</td>
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Total Respondents 1,192

2. Are you receiving more reports regarding equipment operational problems, premature failures, accelerated corrosion, rust, gasket or seal problems, and/or warranty issues related to ULSD than you did before ULSD was introduced in 2006?

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Total Respondents 1,192

3. At how many separate locations do you have firsthand knowledge of these problems?

Total Respondents 464
Average Response 10.49

4. Indicate those areas where you are receiving the reports identified in question two.

5. If desired, please enter any comments or additional details that may help us better understand your experience.

6. Would you be willing to participate in a follow-up survey?

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<td>115</td>
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Total Respondents 423

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42% reported increased equipment-related issues

Questions have been re-ordered and simplified for presentation purposes.

Figure 6 – PEI Survey Results (used with permission from PEI)
Figure 7 – Typical Inline Product Sample Port
Figure 8 – Typical Fuel Recovery Sump Separators
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Photo 12 – Steel Coupon from Tank Bottom
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Introduction
## ULSD Transition

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- **December 1, 2012**
Railroad Facilities

Storage Tanks
- Vertical and Horizontal
- Above and Below Ground
Railroad Facilities

- Pumping Systems
  - Pumps
  - Strainers
  - Flow Switches
  - Pressure Gauges
  - Pressure Relief Valves
  - Control Valves
  - Check Valves
Railroad Facilities

- Pumping Systems
  - Meters
  - Filters
Railroad Facilities

- Dispensing/Unloading>Loading Systems
  - Fueling Cranes and Nozzles
  - Tank Car Load/Unload
  - Truck Load/Unload
Railroad Facilities

Vehicle Tanks

- Locomotive Fuel Tanks
- DTL Truck Tanks
- On Track Equipment Fuel Tanks
Timeline

- **2006**: ULSD Released
- **2007 – 2008**: Equipment Failures Increase
- **2009**: STI Gives Presentations to ASTM
- **2010 (March/April)**: PEI Survey
- **2010 (July)**: ASTM Workshop
- **2010 (Fall)**: CDFA Forms Committee
- **2011**: CDFA Study Begins
### PEI Survey Results

**Which of these would best describe your role in the industry?**

<table>
<thead>
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<th>Role</th>
<th>Count</th>
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<tr>
<td>Tank Owner</td>
<td>293</td>
<td>25%</td>
</tr>
<tr>
<td>Fuel Supplier (may also own tanks)</td>
<td>536</td>
<td></td>
</tr>
<tr>
<td>Service Provider</td>
<td>124</td>
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</tr>
<tr>
<td>Equipment Manufacturer</td>
<td>33</td>
<td>3%</td>
</tr>
<tr>
<td>Tank or Equipment...</td>
<td>69</td>
<td>6%</td>
</tr>
<tr>
<td>Cargo Tank Motor Vehicle Owner</td>
<td>45</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>92</td>
<td>8%</td>
</tr>
</tbody>
</table>
Are you receiving more reports within your organization regarding equipment operational problems related to ULSD than you did before ULSD was introduced in 2006?

- Yes: 42% (496 responses)
- No: 58% (696 responses)
How many separate locations do you have first-hand knowledge of these problems?

- Highest reported amount in survey: 250
- Lowest reported amount in survey: 1
- Average amount reported in survey: 10.49
- Total responses: 460
Indicate those areas where you are receiving the reports identified in the previous question.

<table>
<thead>
<tr>
<th>Canada</th>
<th>10%</th>
<th>12%</th>
<th>11%</th>
<th>22%</th>
<th>23%</th>
<th>14%</th>
<th>10%</th>
<th>11%</th>
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<td>30</td>
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<td>58</td>
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</tbody>
</table>
Problems reported from all regions of the country:
- Not one refinery
- Not one pipeline
- Not one brand of fuel

Data concluded:
- Problem not related to age of equipment
- Corrosion appears same in liquid and vapor areas
PEI Survey Results

- Filters clogging/requiring more frequent replacement
- Seal/Gasket/O-ring deterioration
- STP replacement/Column pipe wear/Motor problems
- Tanks rusting/leaking (includes tanks of vehicles)
- Meter Failure
- Line leak detectors damaged or broken
- Automatic nozzle shutoff failure/shorter lifespan
- Tank probes malfunctioning
- Check valves not seating
- Shear valves not sealing/failing tests
- Swivels failing/shorter lifespan
- Dispenser leaks/failures/premature replacement
- Solenoid valves clogged/failing
- Corrosion on the riser pipe
- Pipe failure
ASTM Conference

Workshop on Fuel Corrosivity and Material Compatibility of Petroleum and Alternative Liquid Fuels

“Problems with Petroleum Equipment in ULSD Service”
– PEI and STI

“Diesel Soap – Formation and Related Problems”
– BP Global Fuels

“Behavior of Corrosion Inhibitor Acids in Fuel/Water Blends”
– Innospec

“Diesel Fuel Tank Coating Delamination/Corrosion”
– Ford Motor Company
CDFA Study

ULSD Committee Members:
- API, PEI, STI, PMAA, NACS, NATSO, Ford, AAR

Consultant Hired Fall 2010

Two Phase Study
CDFA Study

- Evaluate 2010 PEI Survey data
- Consult historical site inspection data
- Develop hypothesis
- Follow-on survey
- Characterize corrosion
  - Up to 5 site visits
  - Up to 30 fuel and corrosion scraping samples
  - Component inspection (in place or at lab)
- Analyze results and develop conclusions
Corrosion Photos

Typical Microbial Corrosion
Corrosion Photos

Strainers
Corrosion Photos

Filters
Corrosion Photos

Check Valves
Corrosion Photos

Submerged pump that has been in service less than one year.
Theories

- Decreased biocide-like sulfur content leads to increased microbes
- Decreased natural biocide-like aromatics lead to increased microbes
- Microbiological corrosion for unknown reasons
- Diesel fuel not properly processed
- Acid or other compounds remaining from new refining desulfurization process
- Fuel additive causing an unexpected reaction
- Galvanic reaction from dissimilar metals
- Reaction from increased biodiesel use
Increased water bottoms due to decreased water holding capacity of ULSD
Corrosion inhibitor depletion with reaction to water bottoms
Corrosion inhibitor depletion during transportation
Grounding issues
Hydrogen sulfide present in fuel in extremely small quantities
Caustic carryover when refining fuel
Acetic acid has been shown to be present in fuel
Diesel soaps formed from corrosion inhibitors
Possible Causes

- Reaction with additives
  - Diesel Soaps
- Reaction with tank system materials
  - Acetic Acid
- Microbial
  - Acetic Acid
- Water bottom interaction
  - Corrosion Inhibitor Depletion
- Refinery process carryover
  - Hydrogen Sulfide, Acetic Acid
Possible Causes

Unlikely Causes
- Galvanic Corrosion
- Electrical Short
- Fuel Processing Problem
- Biodiesel
Concerns

- Equipment Failure
  - Replacement Costs
  - Leakage
  - Pipe Rupture
  - Threaded Connection Failure
  - Swivel Joint Failure
  - Gasket Breakdown
  - Nozzle Failure
Concerns

**System Clogging**
- Increased Filter and Strainer Maintenance
- Increased Pressure Drops
  - Insufficient pressure to shut off automatic nozzles

**Leak Detection Systems and Level Gauging**
- Failure of Components and Cables
- Line Leak Detectors
- Tank Probes
- Tank Overfills
- Pump Damage
What Can Be Done Now?

- Education
- System Inspection
- Sampling
- Tank Water Bottom Management
- Communication
System Inspection

Symptoms

- ULSD in use or suspected
- Increased filter changes
- Unusual equipment and seal failures
- Fuel nozzle shutoff failures
System Inspection

- Internal and external tank inspection
- Equipment inspection
- Review water bottom management
- Verify instrumentation and leak detection
- Verify pressure relief and check valves
- Check differential pressures
- Review filter/strainer maintenance
- Industrial Wastewater Treatment Systems
Sampling

Received, Stored and Dispensed Fuel

- Visual
- Water content
- Corrosivity (NACE TM1072)
- Microbes
Sampling

- Water Bottoms
  - Soaps
  - Microbes
  - Additives

- Filters and Strainers
  - Differential pressure
  - Filter media
  - Debris
  - Microbes
ULSD has lower water holding capacity
<0.25” of water is sufficient for microbes
Required by NFPA 30
Issues
- Microbial growth
- Accelerated fuel degradation
- Increased accumulation of sludge
- Introduction of other contaminants (salts)
How does water get in the system?

- **Condensation** – Tank breathing
- **Transportation** – Leaking vents, manways...
- **Storage** – Open top floating roof tanks
- **Connections** – Leakage
- **High Throughput** – No settling time
- **Low Throughput** – Excessive settling time
Tank Water Bottom Management
Communication

Share Information
- Railroad Specific Survey
- Online Forum – AREMA Website
- CDFA through the AAR
Conclusions

- The deadline for ULSD use in locomotives is December 1, 2012
- ULSD has been in use since 2006
- ULSD is causing excessive accelerated corrosion in some systems
- A study is currently underway by the CDFA to understand the mechanisms
- Manage ULSD systems through inspections, sampling, and water management
- Share information
Acknowledgements

- Lorri Grainawi, Director of Technical Services, Steel Tank Institute
- Robert Renkes, Executive Vice President, Petroleum Equipment Institute
- Prentiss Searles, Marketing Issues Manager, American Petroleum Institute
- Robert Fronczak, Assistant Vice President Environment and Hazmat, Association of American Railroads
- James Richter, Deputy Chief Engineer Structures, Amtrak
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Questions?