January 30, 2007

**JF-1A FUEL CONDUCTIVITY SENSOR**
**Technical Application Note 07-004**

# Wide-Spread Use of USLD and its Effects on Safe Truck Loading

## Background

Changeover to reduced sulfur fuels is now mandated by the United States Environmental Protection Agency. This results in widespread distribution of Ultra Low Sulfur Diesel, (USLD), throughout the United States[1]. ULSD exhibits electrical conductivity similar to Aviation Turbine Fuel, in many instances as its electrical conductivity is also less than 5 pS/M. High-speed transfer of low conductivity fuels greatly increases the danger of static discharge associated with truck loading operations, particularly in switch loading situations. In response to this situation API recently revised it Recommended Practice, (RP) 2003, which more clearly defines conductivity levels in fuel, the maximum rates at which each level should be transferred. Unlike Aviation Turbine Fuel, ULSD is more likely not to be delivered in dedicated transports increasing the probability that switch compartment loading will occur at your facility. This application note aims to help you fully understand "safe" low conductivity fuel loading. Readers of this application note are also directed to read D-2 Application Note 06-003 on Fuel Stability for additional background information on fuel conductivity measurements, and, automated conductivity injection systems.

D-2, Incorporated manufacturers the JF-1A in-line conductivity sensor which is designed to provide high-accuracy continuous measurement of conductivity of distillate fuels in both flowing and non-flowing applications.

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1. [1] US EPA, SR15 Rule, Issued 1 August 2006, requires :

| *On-Highway Diesel Fuel Sulfur Content* | |
|---|---|
| Refinery | ≤ 15ppm by June 1, 2006 |
| Terminal | ≤ 15ppm by September 1, 2006 |
| Retail | ≤ 15ppm by October 15, 2006 |

Note similar regulation is being implemented in other countries, such as the European Economic Region.

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**API Recommended Practices**

In June 2006 API modified RP 2003 for safe loading of low conductivity fuels. The revised RP changes the definition of conductivity levels as:

> **High Conductivity -** measured conductivity above 50 pS/m.
> **Low Conductivity -** measured conductivity between 5 pS/m and 50 pS/m.
> **Ultra-Low Conductivity** - measured conductivity less than 5 pS/m.

The API RP 2003 recommends that if conductivity is maintained in the High Conductivity range, issues related to controlling flow speed and relaxation intervals are not as high a concern for the fuel transfer system. Below 50 pS/m the distributor must be concerned that the RP for velocity and relaxation time are "always" observed under all operating conditions of the loading system. When handling fuels below 50 pS/m the operator is always at risk, as any subtle change in the system operating conditions could result in operations that are outside API RP 2003, leaving the operator liable in the event that an incident occurs. The operator can avoid such a situation if they can "demonstrate" that safe loading "always" occurs as all fuel loaded have a "documented" conductivity > 50 pS/m. This is echoed in the API RP 2003 Appendix A, which states:

> "Introducing the anti-static additive at the final distribution point (such as at a loading rack) alleviates the dilution/absorption concerns. However, the presence of additive in the final product is less certain due to the potential for additive injection **system failure** or variability in conformance to local procedures.
>
> Regardless of where in the distribution system the additive is introduced, if this is considered part of the static protection system, it is incumbent on the operator to verify that an adequate amount of additive is present in the final product. Hence, the **operator must have systems in place** (instrumentation, analyzers, testing, etc.) at all the critical points in the system **to ensure that an adequate increased conductivity is achieved[2]."**

Clearly the case has been made for the use of "automated & monitored" conductivity additive injection systems to alleviate any questions that the operator was working within the RP of the API. A complete Conductivity additive system built by D-2 which uses the JF-1A sensor tied into the operators DCS can provide both the protection and

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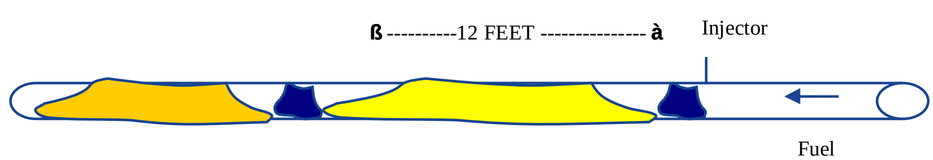
[2] API Recommended Practice 2003 has been updated and revised by a Safety & Fire Protection Subcommittee team with Doug Jeffries as Champion and Ken Crawford providing support. RP 2003 is now presented for ballot. The revisions to RP 2003 from the Seventh (1998) to the Eighth (2006) edition have focused on updates, technical accuracy, readability and addressing the issues associated with a continuing pattern of incidents with low conductivity fuels. This includes concerns associated with Ultra Low Sulfur Diesel (ULSD) fuels to be introduced in the USA in 2006

“documentation” that a safe fuel loading practice was in place.

**Safe Fuel Injection Systems**

Safe fuel additive injection systems can be obtained if they supply fuel that has near “constant’ conductivity at all times during the loading process. Although this sounds straightforward, careful engineering and automated control loop design must be implemented to handle the “dynamic” requirements of the system. The system must take into account, highly varying fuel transfer rates, fuel sensitivity to additive, fuel temperature, and, variability in compartment load sizes. The most common misconception we find in speaking with customers is that all that is required is the loaded compartment has the correct “average” conductivity, when actually what is required is that “all” fuel entering the compartment has the “correct conductivity”. “Correct Conductivity” has a conductivity value in excess of 50 pS/m due to SDA treatment and total sulfur content less than EPA SR15 requirements (including sulfur contained in the SDA additive). We anticipate that each vendor may/will establish what constitutes a “correct value”.

Let’s address the misconception by example. We will examine a typical loading rack operating at 400 GPM through a standard 4” I.D. loading nozzle loading ultra-low conductivity fuel. The fuel has a velocity over 12 Feet/Second. We have found in the field standard gasoline additive injectors are used to inject a Static Dissipative Additive, (SDA), into this fuel stream[3]. These injectors have neither the speed nor the low volume required to inject SDA to maintain the required “correct” conductivity fuel. In this example if the injector injects 1 CC of SDA at a rate of 1 injection each second, each injection taking 1/20 of a second, then our 12 foot long section of fuel will have small “slugs” of very high conductivity fuel surrounded by longer ultra low conductivity fuel. This is illustrated below:




**The “Slug Effect” Created by Typical Gasoline Additive Injector**

[3] Typical Gasoline Additive Injectors examples are a Micro-PAC manufactured by ENRAF, US. ProPAC-3 Additive Injector Manufactured by Titan Industries.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It can be seen that 80% of the 12 foot section of fuel will not have sufficient conductivity to allow pumping at a rate above 3.5 ft/sec as limited (recommended) by API. The SDA slugs of fuel have conductivities in excess of >2000 pS/M, and, by chance spot sampled for a sulfur compliance would most likely fail. The average conductivity once well mixed in the truck could meet the high conductivity API Standard. We have heard the argument by some that a length of pipe between the injector and the loading rack will "spread" slug out, however, our direct measurements in the field indicate that even in systems with 200 ft or pipe (400 diameters) away from the injection point the "slug" of SDA has not changed "dramatically" in its distribution over time. It may be better distributed over the cross section; however, this does little to "protect" the truck from static discharge. In this scenario "slugs" of ultra low conductivity fuel could be entering a vapor filled compartment at a velocity sufficient to carry a static charge!

**Continuous flow SDA Additive Systems by D-2 Inc.**

D-2 has developed continuous flow SDA injection systems. These systems are designed to allow correct dosing of SDA at all flow rates during truck loading operations. Truck racks operate at a variety of flows, low speed start, high flow, multiple trucks, and multiple loading arms, all of these factors must be taken into account in an injection system. Systems built by D-2 are tailored to specific site requirements. In addition, our knowledge of SDA handling and storage are also designed into our systems, making sure your system delivers safe fuel under all environmental and site conditions that may prevail. The patent pending and recently ASTM approved JF-1A sensor is the heart of the system. JF-1A constantly adjusts additive rates and documents results without the need for hand measures or the exposure of employees to hazardous substances. Details of improved performance are illustrated in D-2 Application Note 06-003.

**Why Measure Conductivity?**

Normally one would not need to measure conductivity if the injection skid can verify that it is running, however, unlike other additives, SDA is additized at very low levels <1 PPM. At such rates only sophisticated mass flow sensors or other exotic flow measurement devices could reliably be used to detect a fault in the additive protection system. The use of a direct conductivity sensor can be used both to control the injection and also to document correct operation of the system. Final average load conductance can be printed directly on the BOL. (See also "cocktail" verification of mixed conductivity and lubricity additives).

**Why Use Conductivity to Control (stop) Fuel Loading Operations**

The ultimate goal of all fuel loading systems is to obtain “total” quality, speed of operations, and safety in their operation. If the Digital Control System, (DCS) detects conductivity below 50 pS/M the system can be programmed to optionally stop loading or slow fuel loading until the problem is recognized and corrected.

**Bill Of Lading Certification**

Most DCS loading systems have the ability to know input conductivity data from the D-2 system due to our experience in aviation fuel delivery. These systems can report conductivity values directly onto the BOL. This makes for a “documented” performance of the safety goal that each hauler can directly observe. Additionally when the fuel is transferred from the haulers to delivery vessel the hauler knows that the fuel is safe to transfer at any rate.

**Mixed Additive Cocktails**

The advent of ULSD has raised concerns for the lubricity of diesel fuel. In many instances a lubricity additive is required to obtain a fuel which meets lubricity specifications. Clearly there is an advantage for adding both SDA and Lubricity additives concurrently from a single additive system. Clearly slug injection of lubricity would not present a safety problem to the operator; however, SDA cannot be introduced in this manner, as we have shown above, since it could result in non-safe loading operations. On the other hand the JF-1A sensor can be used to detect the SDA portion of such a cocktail. As the ratio of SDA and Lubricity additive are certified by the additive manufacturer the conductivity of the fuel can be used as an “indicator” that the lubricity additive has been introduced (perhaps not its exact concentration) but an indicator that the cocktail has been dispensed in the fuel. We are continuing to work with additive suppliers to develop additional methods of detection for such “combined” additive packages.

**Conclusion**

The advent of wide-spread use of ULSD and its corresponding Ultra-Low Conductivity Fuel requires suppliers to review the safety of loading especially as more switch tank fuel loading will occur. D-2 Inc has developed effective real time sensors for the in-line measurement of fuel conductivity that has recently been ASTM adopted. This sensor combined with a “continuous stream” injection package form D-2 can ensure and document that “safe” fuel loading occurs at all times in your facility.