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Standard Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems¹

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INTRODUCTION

Every year a number of fires and explosions in petroleum product systems are attributed to spark ignition from accumulated static electricity. Such fires require a flammable hydrocarbon/air mixture and an ignition source. Safety practices can concentrate on the elimination of either factor, but this guide provides a general background on how electrostatic charges are formed and how they may be prevented or dissipated.

A subtle and often misunderstood feature of these incidents is the possible accumulation of hazardous electrostatic charges in systems which are properly bonded and grounded. This can occur because refined hydrocarbon fuels have low electrical conductivities and electrostatic charges may be retained within the fuel and on its surfaces.

1. Scope*

1.1 This guide describes how static electricity may be generated in petroleum fuel systems, the types of equipment conducive to charge generation, and methods for the safe dissipation of such charges. This guide is intended to increase awareness of potential operating problems and hazards resulting from electrostatic charge accumulation.

1.2 This guide is not intended to provide specific solutions but indicates available techniques the user may wish to investigate to alleviate electrostatic charges. This guide does not cover the effects of stray currents or of lightning, either of which can also produce sparks leading to fires or explosions.

1.3 This guide is not intended to address detailed safety practices associated with static electricity in petroleum product systems.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

¹ This guide is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.J0.04 on Additives and Electrical Properties.

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1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

- D56 Test Method for Flash Point by Tag Closed Cup Tester
- D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
- D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)
- D396 Specification for Fuel Oils
- D910 Specification for Leaded Aviation Gasolines
- D975 Specification for Diesel Fuel
- D1655 Specification for Aviation Turbine Fuels
- D2276 Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling
- D2624 Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
- D2880 Specification for Gas Turbine Fuel Oils
- D3699 Specification for Kerosine

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

D3948 Test Method for Determining Water Separation Characteristics of Aviation Turbine Fuels by Portable Separometer

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination

D4308 Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter

D5191 Test Method for Vapor Pressure of Petroleum Products and Liquid Fuels (Mini Method)

D5452 Test Method for Particulate Contamination in Aviation Fuels by Laboratory Filtration

D6615 Specification for Jet B Wide-Cut Aviation Turbine Fuel

2.2 *National Fire Protection Association (NFPA) Standards*.³

NFPA Standard No. 30 Flammable and Combustible Liquid Code

NFPA Standard No. 407 Standard on Aircraft Fuel Servicing

2.3 *Canadian General Standard Board (CGSB) Specification*.⁴

CAN/CGSB 3.517 Diesel fuel

CAN/CGSB 3.520 Diesel fuel containing low levels of biodiesel (B1–B5)

2.4 *British Standards Institute (BSI) Standard*:

BS 5958 (Part 2) Recommendations for Particular Industrial Situations⁵

3. Terminology

3.1 *Definitions*:

3.1.1 For definitions of terms used in this guide, refer to Terminology **D4175**.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *bonding, v*—the practice of providing electrical connections between conductive parts of a fuel system to preclude voltage differences between the parts.

3.2.2 *bottom loading, v*—the practice of filling transport compartments by pumping fuel through a bottom inlet.

3.2.3 *charge accumulation, n*—the increase of electrostatic charges in a tank, compartment, or liquid resulting from a rate dissipation slower than the rate of charge delivery by the incoming product.

3.2.4 *charge generation, v*—the creation of electrostatic charges in a liquid due to the separation of ionic species during liquid flow.

3.2.5 *charge relaxation, n*—the decrease of electrostatic charges with time.

3.2.6 *combustible liquid, n*—a liquid having a flash point at or above 38 °C (100 °F) (See Test Methods **D56** and **D93**).

3.2.6.1 *Discussion*—Subdivisions of this classification will be found in NFPA Standard No. 30.

3.2.7 *conductivity, n*—the reciprocal of electrical resistivity, the capability to transmit electrostatic charges normally expressed in picoSiemens per metre (pS/m) for petroleum products.

3.2.7.1 *Discussion*—Conductivity has also been expressed in conductivity units (C.U.) where I.C.U. = 1 pS/m = $1 \times 10^{-12} \Omega^{-1} \text{ m}^{-1}$.

3.2.8 *conductivity improver additive, n*—a material added to a fuel in very small amounts to increase its electrical conductivity and thereby reduce relaxation time.

3.2.8.1 *Discussion*—Conductivity improver additives are also known as static dissipator additives (SDAs) or antistatic additives.

3.2.9 *flammable liquid, n*—a liquid having a flash point below 38 °C (100 °F) (see Test Methods **D56** and **D93**) and having vapor pressure (Test Method **D323** or **D5191**) not exceeding 276 kPa (40 psia) (see NFPA Standard No. 30).

3.2.9.1 *Discussion*—The definition of flammable is currently under discussion by the UN Committee of Experts on the Transportation of Dangerous Goods.

3.2.10 *grounding, v*—the practice of providing electrical continuity between a fuel handling system and ground or earth.

3.2.11 *high vapor pressure product, n*—a product having a vapor pressure above 31 kPa (4.5 psia) **(1)**.⁶

3.2.12 *intermediate vapor pressure product, n*—a product with a vapor pressure below 31 kPa (4.5 psia) and a flash point below 38 °C (100 °F) **(1)**.

3.2.13 *low vapor pressure product, n*—a product with a flash point above 38 °C (100 °F) **(1)**.

3.2.14 *relaxation time, n*—the time required for a charge to dissipate to 36.8 % of the original value **(2)**.

3.2.15 *residence time, n*—the length of time after a charge is generated that a product remains in piping or a closed vessel.

3.2.16 *splash filling, v*—the practice of allowing fuel to free-fall or to impinge at high velocity on a tank wall while loading a compartment.

3.2.17 *static discharge, v*—the release of electrical energy in the form of a spark or corona discharge across a gap between surfaces of differing voltage.

3.2.18 *switch loading, v*—the practice of loading one type of product into a tank or compartment which previously contained a different type of product.

3.2.18.1 *Discussion*—When involving handling safety, switch loading often refers to loading a low vapor pressure product into a tank or compartment previously containing a high vapor pressure product. A flammable vapor in the ullage space is likely to result.

³ Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, <http://www.nfpa.org>.

⁴ Available from Canadian General Standards Board (CGSB), 11 Laurier St., Phase III, Place du Portage, Gatineau, Quebec K1A 0S5, Canada, <http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb>.

⁵ Part 2 of British Standard Code of Practice for Control of Undesirable Static Electricity, available from British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., <http://www.bsigroup.com>.

⁶ The boldface numbers in parentheses refer to the references at the end of this standard.

3.2.19 *top loading, v*—the practice of filling transport compartments through an open dome at the top of the transport.

3.2.20 *ullage (vapor) space, n*—the space between the liquid surface and the top of the tank or compartment containing the liquid.

3.2.21 *unbonded charge collector or accumulator, n*—unbonded, conductive objects which concentrate electrical charges.

3.2.21.1 *Discussion*—These unbonded charge collectors may be objects floating on the surface of the charged liquid or objects such as gaging tapes lowered toward the charged surface. The high conductivity of metallic charge collectors permits the rapid discharge of accumulated charges.

4. Significance and Use

4.1 Pumping, filtering, and tank filling of petroleum products, particularly refined distillates, can cause the generation and accumulation of electrostatic charges and can result in static discharges capable of causing fires and explosions. This guide provides an overview of the factors involved in the generation of such electrostatic charges. Methods are described for the alleviation of the problem, and cited authoritative references contain more details.

4.2 This guide is not intended to provide operating or safety rules for the handling of petroleum products to avoid electrostatic hazards.

5. Background

5.1 Ignition Principles:

5.1.1 For ignition to occur, it is necessary to have an ignition source of sufficient energy and a mixture of fuel and air in the flammable range. The boundaries of the flammable range are defined by the lean and rich limits. Below the lean limit there is not enough hydrocarbon vapor to sustain combustion, whereas above the rich limit there is not enough oxygen. The mixture temperature and pressure and the fuel characteristics, including boiling range and vapor pressure, determine the amount of a given fuel which is vaporized and therefore establish the flammability of the mixture. Normally these limits are measured under equilibrium conditions with the fuel partially or completely vaporized. However, ignitions have occurred below the lean ignition limit when the fuel was in the form of a foam or spray. Also, systems are not normally in equilibrium when there is sufficient fuel flow to generate electrostatic charges. Turbulence in the vapor space can lead to unexpected flammable air-vapor mixtures in localized areas. Equilibrium flammability limits can therefore be used only as rough guidelines of flammability.

5.1.2 The second requirement for ignition is a static discharge of sufficient energy and duration. Discharges occur when the voltage across a gap exceeds the breakdown strength of the fluid or air in the gap. Minimum energy requirements vary widely depending on the nature of the spark, the configuration of the spark gap and electrodes, nature of materials, and other factors. There is no doubt that sparks due to static electricity in petroleum systems can have sufficient energy to

ignite flammable mixtures when they occur in the vapor space. Discharges from highly charged fluids are known to penetrate plastic tubing.

5.2 *Charge Generation*—Whenever a hydrocarbon liquid flows with respect to another surface, a charge is generated in the liquid and an equal but opposite charge is imposed on that surface. This charge is attributed to ionic impurities present in parts per million or parts per billion quantities. At rest the impurities are adsorbed at the interface between the fuel and the container walls, with one part of the ionic material having a strong attachment for the fuel or the container. Under these conditions, there is no net charge on the fuel. However, when the fuel flows, one set of charges is swept along with the fuel while the opposite charges which accumulate along the wall surfaces usually leak to ground. This charge separation results in a rise in voltage in the moving fuel.

5.3 *Charge Relaxation*—When charged fuel enters a tank, a substantial voltage difference may be produced between the surface of the liquid and the tank walls and this may result in a static discharge. The voltage difference is limited by charge dissipation/relaxation processes which occur both in the pipe-work downstream of strong charge generating elements and in the tank itself. Relaxation in the pipework reduces the amount of charge that reaches the tank while relaxation in the tank reduces the voltage produced by a given amount of inlet charge. Under most practical loading conditions, the voltage generated by a given inlet charge density is proportional to the relaxation time of the fuel. This relaxation time is inversely proportional to the conductivity and is approximately 20 s when the conductivity is 1 pS/m. The conductivity of hydrocarbon fuels is highly variable as a result of natural product differences, commingling, or the use of additives. Products not containing additives, including diesel fuels, may have conductivities of less than 1 pS/m but many modern additive packages (not just static dissipator additives) provide considerably increased conductivity, possibly up to several hundred pS/m or more. The relaxation time can therefore be anything from a fraction of a second to a number of minutes. It has been found that the reduced relaxation time produced by increasing the conductivity more than compensates for any increase in charge generation that may occur. The highest voltages and electrostatic ignition risks are therefore associated with low conductivities. Unless conductivities are controlled, the possibility of encountering low conductivity product should be allowed for when defining safe loading procedures (3, 4).

6. Practical Problems

6.1 Certain switch loading operations, such as loading of diesel fuel into a truck which previously carried gasoline and still contains vapors or liquid gasoline, are especially dangerous. The combination of a flammable vapor space and charged diesel fuel presents a potential explosion hazard if an electrostatic discharge occurs. Analyses (5) of past tank truck accidents reveal that switch loading or splash filling, or both, account for 80 % of static-initiated explosions. More information on the hazards of flammable atmospheres formed during switch loading will be found in 7.6.