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SPECIFICATIONS FOR STATIC ELECTRICITY

(PROJECT STANDARDS AND SPECIFICATIONS)

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SCOPE

This Project Standards and Specification covers the minimum requirements to assist in reducing fire hazard from static electricity by presenting a discussion of the nature and origin of static charges, the general methods of mitigation and recommendations in certain specific operation for its dissipation. This application is specific to petroleum production, refining and marketing installations.

It is not possible always in a plant to prevent the formation of explosive mixture, so a possible source of ignition must be excluded from these areas. Sparks and arcs which result from switches, starters, relays and similar devices have been rendered harmless by explosion-proof installations. However, there exists an ever present fire hazard in the processing industries from ignition with may arise from static sparks.

REFERENCES

Throughout this Standard the following dated and undated standards and codes are referred to. These referenced documents shall, to the extent specified herein to form a part of this standard.

— API RP 2003 – Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents
— National Fire Protection Association - 1986

DEFINITION AND TERMINOLOGY

— Like Charge – Charges that repel each other due to having the same charge
— Unlike Charge – Charges that attract each other due to having different charge
— ATF – Aviation Turbine Fuel

GENERAL

What is Static Electricity?

Static Electricity is a phenomenon of electrification of materials through physical contact and separation and the various effects that result from the positive and

negative charges formed. In general, static electricity results from removal of electrons from the atoms of one material (leaving it with positive charge) and absorption of these electrons on the second material (negative charge) during physical separation of the two materials.

Both materials remain charged if they are well insulated electrically. The generation of static electricity cannot be prevented absolutely, because its intrinsic origins are present at every interface.

Conductivity

A charge on one body can induce a charge on a second body that is brought near it (See Appendix: A). Now, assume a charged insulated conductor is brought close to a second insulated conductor. Like charges are induced on the opposite end of the second conductor. Unlike charges are induced on the near end of the second conductor, bound to the original charges.

If the opposite end of the second conductor is momentarily grounded, the like charge disappears but the bound unlike charge remains. Then, if the original charge conductor is removed, the second conductor retains the unlike charge which is no longer bound. There is a voltage between the second conductor and ground.

Poor conductors behave similarly, but when the charge is in the body of the conductor, more time is required for the transfer. This is important in liquid hydrocarbons because the charge must move out of the liquid's body to the surface before it can transfer to the inside of the container.

Relaxation Time

Relaxation time is a measure of the time; it takes charge to leak away from a charged liquid when the liquid fills a metal container connected to ground. The time varies with the product. It is actually the time in seconds, to remove 63% of the charge.

Zero charge is only approached (but not reached) in four or five times the relaxation time, γ (tau). γ is approximately equal to 18 divided by the conductivity of the liquid hydrocarbon in picomhos per meter.

For example, if a product has a conductivity of 1 picomho per meter, γ is 18 seconds. Thus, no charge will be approached in 90 seconds. If the conductivity

were raised to 100 picomhos per meter, γ would be only 0.2 second. So practically zero charge condition would remain after 1 second.

THEORY OF STATIC ELECTRICITY

Generation

Generation of electric charge usually occurs whenever a liquid, for instance a hydrocarbon, flow past a solid or another liquid. The degree of charge generation in the case of oil products is determined not solely by the nature of such liquids or solids but also by the type and concentration of certain trace compounds which are nearly always present in solution in oil products.

Static electricity is generated by the separation of like or unlike bodies. Electrostatic charges, positive and negative, always occur in pair and are developed when any bodies that have been in contact are separated. The negative charges migrate to one body, leaving the other body with a positive charge. For sufficient charges to be developed, the bodies must become and remain insulated with respect to each other so that the electrons, which have passed over the boundary surface or interface, are trapped when separation occurs. Insulation may occur through complete physical separation of the bodies or because at least one of the bodies is an insulator. Petroleum products which have a low conductivity can serve as insulators.

1. Generation due to fluid flow:
   Of most importance in our operations is the contact and separation which takes place in flowing liquids. The liquid, prior to flow, contains equal quantities of ions, positively and negatively charged, and is electrically neutral. However, ions of one sign are preferentially absorbed by the surface of the container or pipe, leaving a surplus of ions of the opposite sign in the liquid at the interface. Upon liquid flow, charging of the liquid occurs because the absorbed icons are separated from the free ions by turbulence. The opposite charge is usually conducted throughout the metallic pipe wall, in the same direction because of the natural attraction between opposite charges. Ionizable impurities, such as water, metal oxide, or chemicals, increase the static generation characteristics.

   The flow of electricity caused by the entertainment of charged particles in the flowing fluid is known as the streaming current. If this charged stream enters a container or tank, an equal but opposite charge will be induced on the inside surfaces of the tank, Also, a charge of the same sign as the incoming stream

will be induced on the outside of the tank. These induced charges arise from charge separation within the tank wall following exposure to the electrostatic field created by the incoming charged liquid stream.

2. Generation due to settling:
   Strong electrostatic fields may also be generated by droplets of particles settling in a medium of low conductivity, or by agitation of such particles within the medium. If a liquid in a tank containing ionizable impurities is subjected to turbulence, the separation of ions can result in electrostatic charging within the body. Such charging may cause significant variations in voltage within the liquid or on the liquid surface. There is no change in the neutrality of total charge within the tank as long as no charged fluid flows into or out of the tank.

Rate of Generation

The generating mechanism is related primarily to rate of flow, ionic content, materials turbulence, and surface area of the interface. The rate of electrostatic generation in a pipeline or hose increases with increasing length of pipe or hose to a maximum liming value. The maximum limiting value is related to liquid velocity and conductivity and will be greater for high velocities of liquid flow than for low velocities. The large surface area of filters causes them to be prolific generators of static electricity.

Accumulation

Hazardous electrostatic charges can accumulate only on bodies which are relatively well insulated from each other and from ground. Otherwise, charges leak away and recombine with their counterparts as fast as they are formed. Electrostatic charges can accumulate on the surface of petroleum products which have a sufficiently high resistivity. Humidity has little effect on the migration of charges across hydrocarbon liquid surfaces. The amount of electrostatic charge which may accumulate on an insulated body depends upon:

Conductivity

The ability of liquid to retain an electrostatic charge is a function of its conductivity. This characteristic may be expressed in terms of conductivity (1 conductivity unit = 1 picomho per meter (or) picosiemens per meter = 10^{-14} Ω^{-1} or in the inverse from as resistivity (1 resistivity unit = 10^{14} Ωcm). Metals have very high conductivity and oils have low conductivity.

Electrostatic generation is not significant when the conductivity of the liquid exceeds 50 picomhos per meter. Above this value, the charges recombine as fast as they are separated. Thus, a conductivity of 50 picomhos per meter is the recommended minimum for the adequate removal of charge from a liquid. However, there is an overall lower limit of connectivity of 10 picomhos per meter below, which static charges may not be dissipated easily by earthing and bonding.

An important characteristic in connection with electrostatic hazards is the half value time of the liquid. This is the time taken for the charge in a liquid, completely filling a closed metal container, to decrease to half its original value. The half value time is inversely proportional to the conductivity and directly proportional to the dielectric constant of the liquid. A residence time (relaxation time) of 3 to 4 times the half value time may be assumed to be adequate for charges to "relax". The Table-I shows the relationship between conductivity's and half value times of various liquids.

TABLE - I

LIST OF CONDUCTIVITIES & HALF VALUE TIME OF VARIOUS LIQUIDS

Liquid	Conductivity (Conductivity units	Conductivity (ohm-1 m-1)	Half Value Time (Sec.)
Highly purified Hydrocarbons	0.001	10 (-15)	12,0000
Light Distillates from refinery operation	0.01 to 10	10(-14) to 10 (-11)	1200 to 12
Shell Jet A-1 with ASA-3	150 to 300	15 X 10 (-11) to 30 X 10 (-1)	0.08 to 0.04
Crude Oil	1000 to 100,000	10 (-9) to 10 (-7)	0.012 to 0.00012
Distilled water	1 X 10 (8)	10 (-4)	12 X 10 (-8)

Source : Fire & Safety Manual – Refineries & Petrochemical Panel – National Safety Council

Static Discharge

In actual practice, electrostatic charges constantly leak from a charged body because they are always under the attraction of an equal but opposite charge. This leakage characteristic is called relaxation; and, because of this, most static sparks are produced while the generating mechanism is active. It is possible, however, for charges generated in moving some refined petroleum products to remain for a time after the fluid has stopped because of the insulation qualities of the fluid.

Sparks and Arcs

A spark is essentially a transient phenomenon and can be described as the passage of an electric charge across a gap between two points not previously in contact. An arc is defined as the flow of electric current that occurs at the instant separation of two points previously in contact. Electrostatic discharges are usually sparks.

Sparking Potential

For static electricity to discharge as a spark, the voltage across the spark gap must be above a certain magnitude. In air, at sea level, the minimum sparking voltage is approximately 350 volts for the shortest measurable length of gap. Increased gaps require proportionately higher voltages with the actual voltage dependent upon the dielectric strength of the material (or gas) which fills the space in the gap. For air, the dielectric strength is approximately 30,000 volts per cm. Therefore, the voltage across a 1 inch air gap would have to be over 75,000 volts in order for spark discharge to occur.

In the petroleum industry, these spark gaps will assume many forms and appear at various locations. For example, a spark gap may be formed between a tank vehicle and the overhead filling downspout if they are not bonded together or in metallic contact. In this case, a static potential difference is developed between the tank vehicle and the downspout due to the static charges generated during the flow of product into the compartment.

The potential developed is related to the amount of charge on a body and to the capacitance of this body with respect to its surroundings. Since the capacitance of a body with respect to its surroundings depends upon its size and position, it follows that the same charge will not always result in the same voltage and, hence, sparking may or may not occur.

Under the continuous influence of a charge generating mechanism, the voltage of an insulated body continues to grow. As the voltage becomes greater, the rate at which charge will leak through the insulation will grow since no insulation is perfect. At some voltage, the leakage of charge will be equal to the rate at which the charge is being placed upon the insulated body and a stabilized condition will be reached.

If this stabilized voltage is below the required sparking potential, no sparking will occur. If the stabilized voltage is above sparking potential, then sparking will occur before stabilization is reached.

Ignition Energy

The mere fact that a spark results from high voltage does not mean that ignition of a flammable mixture will occur. In order to initiate combustion, sufficient energy must be transferred from the spark to the surrounding flammable mixture.

Experiments under the most favourable conditions have ignited petroleum vapour air mixtures at approximately 0.25 millijoules. The energy requirement increases as the mixture composition approaches the lean or rich sides of the flammable range; ignite at a minimum where a slightly richer than ideal mixture composition is attained.

The energy requirement is also increased by a variety of other factors which tend to decrease the availability of the stored energy to flammable mixture:

1. A portion of the energy will be dissipated in a resistive portion of the discharge circuit and not be available at the spark gap.
2. The electrodes, across which the sparking occurs, will be of a shape and material so that a portion of the energy in the spark will be used to heat the electrodes and will be available in it's entirely to heat the material in the gap. This is more pronounced with short gaps and is known as its quenching effect.
3. The spark gap may be so long that the energy is distributed over too great a path length. The energy is not concentrated sufficiently to heat the mixture to ignition temperature.

The typical values of Minimum Ignition Energy (mj), along with the Minimum Experimental Safe Gap (mm) and the quenching distance (mm) for some hazardous materials are presented in Table-II. Also, the effect of fuel concentration on Minimum Spark Ignition Energy is presented in Appendix 'B'.