Conductivity of Product → Challenges in handling Hydro Carbon

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Purpose of this presentation: →

1. **Building Awareness about Electrical Conductivity (or specific conductance)** of Hydro Carbon.
2. **Challenges in Handling BS VI** Hydro Carbon – Low Sulphur Content
3. **Recent Accidents** (National & International)
4. **Knowledge Sharing**

Definition of Conductivity: →

Conductivity (or specific conductance) of an electrolyte solution is a **measure** of its **ability to conduct electricity**.

Conductivity is measured by the international standard (SI), **unit of conductivity is Siemens per meter (S/m).**

In simple terms conductivity is nothing but the **capability of a substance to transmit electrostatic charges**, normally expressed in **picoSiemens per meter** (pS/m) or conductivity units.

Conductivity of Petroleum Products

For petroleum products, the following conductivities are defined for the liquid temperature during transfer operations :→

Conductivity Level	Measured Conductivity
High Conductivity	**> 50 pS/m**
Low Conductivity	**< 50 pS/m > 2 pS/m**
Ultra-low Conductivity	**2 pS/m**

(**Conductivity measurements** at **laboratory temperature** shall be **adjusted** to **represent transfer temperature** using rationale such as explained in Annex B.6. of **API Recommended practice 2003**)

Conductivity versus Temperature: →

The **conductivity of a solution increases with temperature**, as the mobility of the ions increases i.e., **Higher the temperature, higher shall be conductivity.**

Thermal conductivity describes the ability of a material or object to transfer heat through it.

The **higher the thermal conductivity value** of a material, the **more efficiently and quickly heat can pass through it**. The value for thermal conductivity is generally reported in W/(m/K).

Fuel Conductivity – It's Significance: →

Electrical conductivity of fuels is an important consideration in the safe handling characteristics of any fuel.

The risk associated with explosions due to static electrical discharge depends on the amount of hydrocarbon and oxygen in the vapor space and the energy and duration of a static discharge.

There are **many factors that can contribute to the high risk of explosion**.

- For **Ultra Low Sulphur Diesel (ULSD) fuels** in particular, **electrical conductivity is** likely be **very low** before the addition of static dissipater additive (SDA).

The intent of this requirement is to reduce the risk of electrostatic ignitions while filling tank trucks, barges, ship compartments, and rail cars, where flammable vapours from the past cargo can be present.

Generally, it does not apply at the retail level where flammable vapours are usually absent

Clause 3.1.22 of API 2003

Static accumulator

A static accumulator is a liquid with a **conductivity less than 50 pS/m.**

Static Dissipater Additive (SDA)

Materials added in low quantities to improve the ability of low viscosity fluids to dissipate (relax) a static charge through increased conductivity.

These are sometimes called "conductivity improvers."

Clause 3.1.26 of API 2003

Switch Loading

The **practice of loading** a **low conductivity, low vapor pressure product** into a **fixed or portable tank or truck which previously contained a high or intermediate vapor pressure product (such as gasoline or solvent)**, resulting in a **flammable atmosphere** while loading the **low vapor pressure product**.

Charge Accumulation and Relaxation →

Electrostatic charges continually leak away from a charged body.

→**Dissipation of the charge** starts as soon as a **charge is generated** and **can continue** after charge generation has stopped.

→ **Electrostatic charges accumulate when they are generated at a higher rate than they dissipate.**

The **ability of a charge to dissipate** from a liquid is a function of the following:→

a) **Conductivity of the PRODUCT** being handled **?**
b) **Conductivity of the CONTAINER**
c) **Ability of the container to BLEED a charge to ground. ?**

Charge Accumulation and Relaxation →

In a grounded conductive container, the **ability of a liquid to dissipate a charge is governed by the liquid's conductivity**. **The higher the conductivity, the faster the charge dissipates**. Generally, liquids with conductivity greater than 50 pS/m (50 C.U.) do not accumulate static charges provided the material is handled in a grounded conductive container. **Above 50 pS/m, charges tend to dissipate as fast as they are generated.**

For **liquids with conductivity greater than 2 pS/m, the charge relaxation follows an exponential decay proportional to the relaxation time constant**. **Liquids with lower conductivity follow a hyperbolic decay**. This may create dissipation times shorter than predicted by exponential decay.

Charges can also accumulate regardless of the conductivity of the fluid if the container being filled is made of low conductivity (nonconductive) material (e.g. a plastic bucket), or if the container is conductive but is inadequately grounded. A metallic (conductive) fuel container resting on a plastic bed liner of a pick-up truck is an example.

For liquids with conductivity greater than 2 pS/m, the charge relaxation follows an exponential decay proportional to the

Static Discharge Mechanisms →

As electrostatic charge accumulates, the electric fields and voltages increase. **When the electric field exceeds the insulating properties of the atmosphere, a static discharge can occur.** **Two types of static discharges** are of primary concern in the petroleum industry: **spark and brush discharges.**

Spark Discharge

Spark discharges occur between conductive objects that are at different voltages. Usually, one of the objects is not adequately grounded. An example would be a **metal can floating on a static accumulator and the side of a tank-truck compartment.** Avoiding ungrounded and unbonded conductive objects through sound design, maintenance, and operating practices can prevent this type of spark.

Brush Discharge

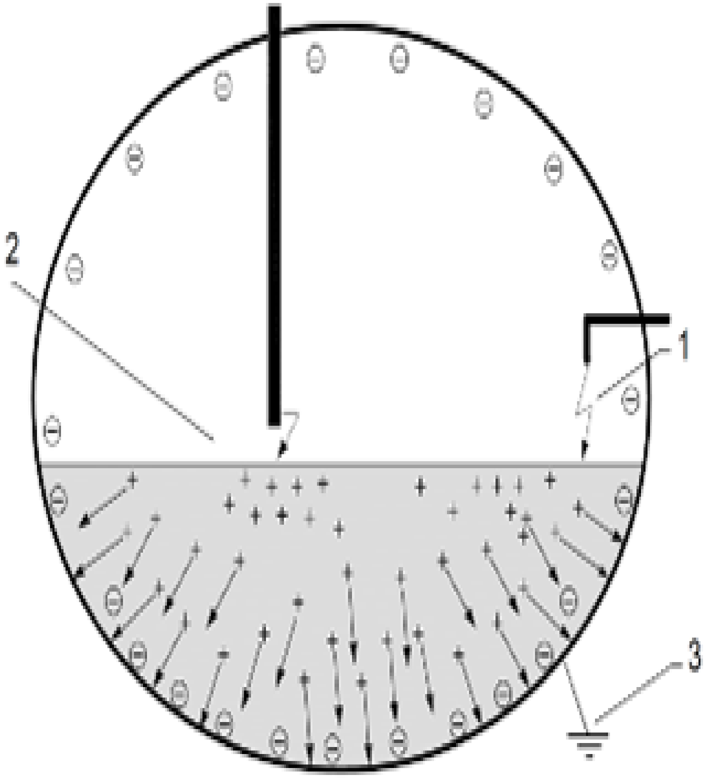
Brush discharges can **occur between a grounded conductive object and a charged low conductivity material.** An example would be a spark between the **bottom of a filling arm** and the **surface of the product** during splash loading.

Brush discharges can be eliminated by avoiding the charge build-up on the product through **adequate residence times, flow rate restrictions, etc., and by designing and operating equipment to avoid conductive objects protruding into the container.**

Static Discharge Mechanisms →

<u>Brush Discharge:</u>

It is an electrical <u>disruptive discharge</u> **(Effective Energy - 10 to 20 mJ)** similar to a <u>corona discharge</u> that can takes place at an <u>electrode</u> with a high <u>voltage</u> applied to it, embedded in a **nonconducting fluid.** The streamers spreads out in a fan shape, giving it the appearance of a "brush".



Switch Loading and Special Situations →

Experience shows that **many static related incidents** have occurred during switch loading. **Switch loading is the most frequently cited cause of static incidents when handling bulk hydrocarbons**.

Loading heating oil, diesel fuel or lubricating base oil with low electrical conductivity into a tank that previously contained gasoline is an example of switch loading.

Even when the compartment appears free from standing liquid from the previous load the tank or compartment can contain a flammable mixture. **Residual vapors from the previous high or intermediate vapor pressure cargo in an "empty" tank mixed with air can be in the flammable range. Static electricity can accumulate when loading a low conductivity, low vapor pressure product. For a given set of conditions there can be a static discharge and ignition.**

Ignition (Brush Discharge) Possibilities shall arise during Switch Loading →

Brush discharge due to

- **Low conductivity** / Low Sulphur content of BSVI HSD
- Product filling **velocity (higher)**

Inadequate dissipation of

- **Additional accumulated charge** on the product could be **due to**
  - **Higher velocity** and
  - **Continual / Residual charge** on the body of the Tank lorry, **due to single pole wiring** with **Master switch in ON** condition.

Ignition (Brush Discharge) Possibilities shall arise during Switch Loading →

The **ability of the low volatility material** being loaded to **accumulate an electrostatic charge** because of **low conductivity**, and **Operating conditions during loading**, **which encourage charge generation and reduce charge relaxation**—especially the velocity of the loading stream.

Switch loading also refers to the reverse situation when light product (for example, gasoline) is loaded into a container that previously held middle distillate fuel (for example, diesel), although this mode of switch loading is generally not considered a static ignition hazard (but may be a product contamination concern).

Low conductivity / Low Sulphur content of BSVI HSD →

Influence of the Sulphur content on middle distillate vd limits for TL

Product class/	Conductivity pS/m		
	> 50	> 10	< 10 or unknown
Diesel or gas oil with > 50 ppm Sulphur and all other middle distillate fuels	vd ≤ 0,5 m2/s	vd ≤ 0,5 m2/s	vd ≤ 0,38 m2/s
Diesel or gasoil with ≤ 50 ppm sulphur	vd ≤ 0,5 m2/s	vd ≤ 0,38 m2/s	vd ≤ 0,25 m2/s

Influence of Product Filling Velocity →

As per **API 2003 2015:**
The **regulatory** requirements for **reducing the static charge** for loading tank trucks is based on
1) Linear Velocity of Product and
2) Diameter of loading arm

Requirement as per API 2003 2015 →
1. **vd < 0.5 m2/s (‘v’** is velocity in m/s and **‘d’** is inside diameter of the downspout in meters)
2. **Linear flow velocity** should **never exceed 7 m/s.**

IF Sulphur content of the HSD was < 50 PPM **Conductivity** was < 10 pS/m. **Thus, vd has to be ≤ 0,25 m^2/s**

The product velocity has to be restricted to 4M/s **considering Max flow rate of 740 LPM.**

In Most of the cases the flow rate is > 740 LPM & linear velocity of product would be > 0.4 m^2/s(considering Low Conductivity factor)

Test Results Speak→

Lab conducted conductivity study on HSD and with addition of ASA. The conductivity of HSD is zero. The study was conducted in Refineries.

With addition of

- **@1 ppm of stadis additive the conductivity of HSD observed was 258pS/m @ 28 degc)**
- **@3 ppm of stadis additive the conductivity of HSD observed was 856pS/m @ 28 degc**

As per **ASTMD 975-22** accumulation of **static charge** occurs when a hydrocarbon **liquid flows** with respect to another surface.

The **electrical conductivity requirement of 25 pS/m minimum at temperature** of delivery shall apply when the transfer conditions in Table exist for the delivery into a mobile transport container (for example, tanker trucks, railcars, and barges)

Maximum Pipe Diameter (for a distance of 30 s upstream of delivery nozzle)	When Filling Tank Truck Compartments	When Filling Undivided Rail Car Compartments	When Filling Marine Vessels
0.1023 m	fuel velocity > 4.9 m/s	fuel velocity > 7.0 m/s	fuel velocity > 7.0 m/s
0.1541	fuel velocity >3.24 m/s	fuel velocity > 5.20 m/s	fuel velocity > 7.0 m/s
0.2027	fuel velocity > 2.47 m/s	fuel velocity >3.90 m/s	fuel velocity > 7.0 m/s
0.2545	fuel velocity>1.96 m/s	fuel velocity > 3.14 m/s	fuel velocity > 7.0 m/s

Managing the Conductivity →

Due to the **normal depletion of fuel conductivity** during commingling, storage, distribution, or a combination thereof, at low temperatures, the **fuel should be sufficiently treated**, if needed with **conductivity improver additives** {also called **Static Dissipater Additives** (SDA)} to ensure that the electrical conductivity requirement is met.

The method of fuel distribution and temperature at the point of delivery into mobile transport can **require a substantially greater conductivity level than 25 pS/m** at the point of additive treatment.

If a Static Dissipater Additive (SDA) is needed to meet the minimum conductivity requirement, then initial additive treatment should allow for temperature, commingling, distribution, and adequate mixing effects to ensure the minimum conductivity is attained at the point of delivery into mobile transport.

Test Results – Product Conductivity and Filling Velocity →

This low conductivity in HSDBSVI is corroborated with study conducted in four regions covering Retail locations. Please find attached the data.

There are Possible operational risks while handling HSDBSVI which could be

- Top Loading of HSDBSVI into a tank truck where it falls free with high velocity
- Pumping through pipeline at higher flow rate

Possible routes to avoid and dissipate the Static electricity

- Bonding and earthing are the common ways to dissipate charge build up if any.
- Flow rates has to be limited.
- In case of **HSDBSVI** with electrical conductivity is observed in most of the cases below 10 pS/m, **bonding and earthing are not adequate** for charge dissipation and **use of anti-static additives may be required.**

Testing and communications 21st Sep' 2020

Sr. No.	Location	Date	Electrical conductivity, pS/m	Temperature °C
1	Bijwasan	08.09.2020	16	27.6
2	Bijwasan	09.09.2020	17	26.0
3	Bijwasan	10.09.2020	15	27.6
4	Bijwasan	11.09.2020	16	27.0
5	Bijwasan	12.09.2020	11	27.0
6	Bijwasan	14.09.2020	5	27.0
7	Bijwasan	15.09.2020	4	27.0
8	Bijwasan	16.09.2020	3	27.0
9	Bijwasan	17.09.2020	4	27.0
10	Budge Budge	10.09.2020	5	31.0
11	Budge Budge	12.09.2020	6	35.0
12	Budge Budge	14.09.2020	51	33.0
13	Budge Budge	15.09.2020	9	31.0
14	Budge Budge	16.09.2020	17	32.5
15	Budge Budge	17.09.2020	14	34.0
16	Devangonthi	08.09.2020	3	26.0
17	Devangonthi	09.09.2020	2	25.0
18	Devangonthi	10.09.2020	3	26.0
19	Devangonthi	11.09.2020	3	26.0
20	Devangonthi	12.09.2020	3	26.0
21	Devangonthi	14.09.2020	3	26.0
22	Devangonthi	15.09.2020	2	25.0
23	Devangonthi	16.09.2020	2	25.0
24	Devangonthi	17.09.2020	2	25.0
25	Sewree	08.9.2020	2	26.0
26	Sewree	09.09.2020	3	25.0
27	Sewree	10.09.2020	8	26.0
28	Sewree	11.9.2020	9	25.0
29	Sewree	12.9.2020	4	26.0
30	Sewree	14.9.2020	6	29.0
31	Sewree	15.9.2020	7	30.0

Test Results – Product Conductivity and Filling Velocity →

Bijwasan			
Date	Time	Electrical Conductivity in pS/m	
		MS	HSD
04-01-2023	12:08Hrs	140 at 16°C	001 at 16°C
04-01-2023	14:14Hrs	138 at 18°C	001 at 18°C
04-01-2023	15:52Hrs	145 at 18°C	000 at 18°C
04-01-2023	16:45Hrs	138 at 17°C	000 at 17°C
05-01-2023	10:00Hrs	118 at 13°C	001 at 14°C

Ennore			
Date	Time	Electrical Conductivity in pS/m	
		MS	HSD
04-01-2023	12:10 hrs	720 at 25°C	0 at 28°C
04-01-2023	14:14Hrs	20 at 24°C	0 at 28°C
04-01-2023	16:00Hrs	455 at 28°C	0 at 28°C
04-01-2023	17:00Hrs	23 at 28°C	0 at 29°C
05-01-2023	10:00Hrs	85 at 25°C	0 at 28°C

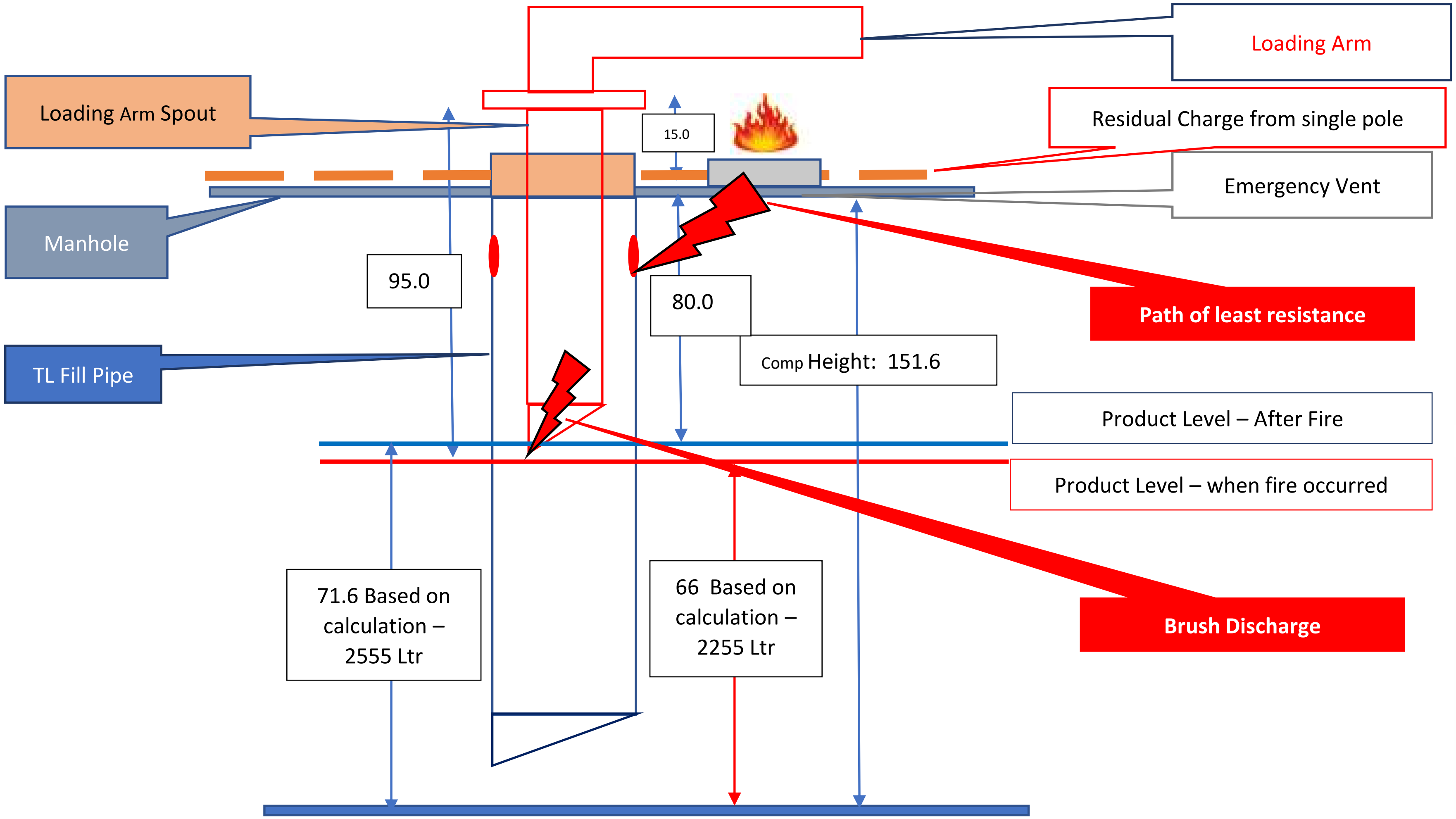
Seweree			
Date	Time	Electrical Conductivity in pS/m	
		MS	HSD
04-01-2023	13:45 hrs	30 at 28°C	2 at 28°C
04-01-2023	15:00Hrs	38 at 29°C	4 at 28°C
04-01-2023	16:00Hrs	32at 30°C	4 at 30°C
04-01-2023	17:00Hrs	40 at 28°C	5 at 29°C
05-01-2023	10:00Hrs	40 at 25°C	0 at 28°C

Budge Budge		
	Electrical Conductivity in pS/m	
	MS	HSD
Plain MS	20- 40 at 25°C	2- 5 at 25°C
EBMS	above 1000 @ 25 degc	

Factors that can aid – Brush Discharge

a. **Additional Electrostatic charge accumulation on the** surface of product in the compartment, during high velocity filling.

b. **Brush discharge can** propagate from **tip of loading arm** to filling level and subsequently can generate flame which shall traverse through emergency vent / TT manhole (path of least resistance) and may result in **flash fire** in the tank lorry filling gantry (TLFG) – **<u>if all the stated barriers align</u>**

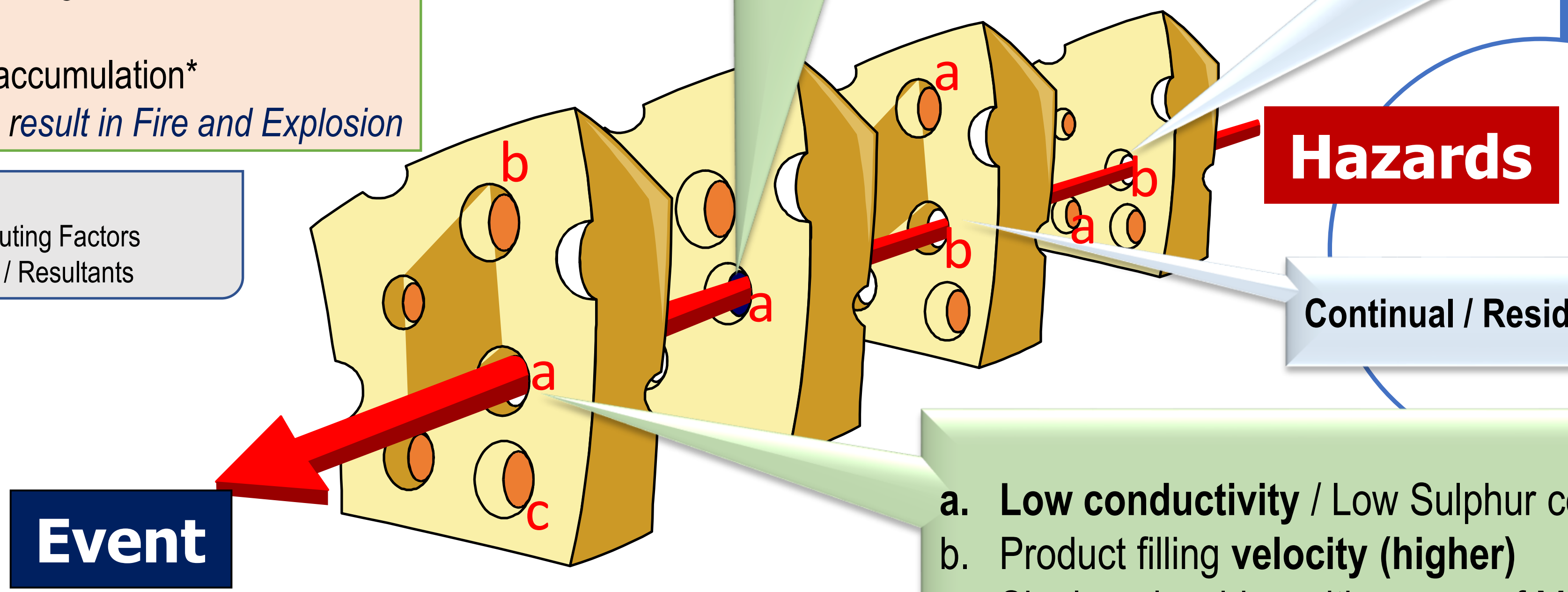


Swiss Cheese Model – Chances of Existing and Failed Barriers – Considering TL loading operations*

1. Brush Discharging*
   a. Low conductivity
   b. Higher filling velocity
2. Inadequate charge dissipation*
   a. Continual / Residual Charge on TL Body.
   b. Single pole wiring with case of Master switch ON
3. Flammable vapour accumulation*

** Can result in Fire and Explosion*

Legend:
a, b, ……… Contributing Factors
1, 2, 3…….. Events / Resultants



Switch Loading (MS to HSD)

TL loading with **Emergency vent in open** condition

Continual / Residual Charge on TL Body.

a. Low conductivity / Low Sulphur content of BSVI HSD
b. Product filling **velocity (higher)**
c. Single pole wiring with a case of Master switch ON

An incident can result:

If all barriers fail in a sequence.

Conclusion

Switch loading operation and the **turbulence** created due to **higher velocity loading,** can result in the **generation of increased static charge** and **combined** with **very low Electrical conductivity** (static accumulating) of low Sulphur HSD can create an **elevated risk for a static discharge in any receptacle.**

In addition, the receptacles pose inability to discharge static electricity **(inability in Static discharge inside the tank lorry leading to Flash / Fire / Explosion)**

Conclusion

*Higher probability - TL Loading

This can also occur during Tank Wagon Loading operations, Storage Tanks Filling and Handling through Pipelines