PRESLHY

Electrostatic Measurements

KIT, 19th April 2018

Pre-normative REsearch for Safe use of Liquid HYdrogen

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Introduction

- Some data were generated for LH2 electrostatic behaviour in 1970s
  - Currently being reviewed
- Aspects of interest:
  - Charge generation during transfer (charge density in liquid; earthing of tankers, vehicles etc)
  - Electrostatic fields / space potential of “mist” in vicinity of accidental releases
    - Hydrogen can be ignited by low energy corona discharges
  - Electrostatic fields / space potential of liquid / “slush” resulting from accidental releases

Basic Electrostatics

For most hazardous situations need :

- Source of charging
- Accumulation of electrostatic charge
- A sudden discharge of the stored charge

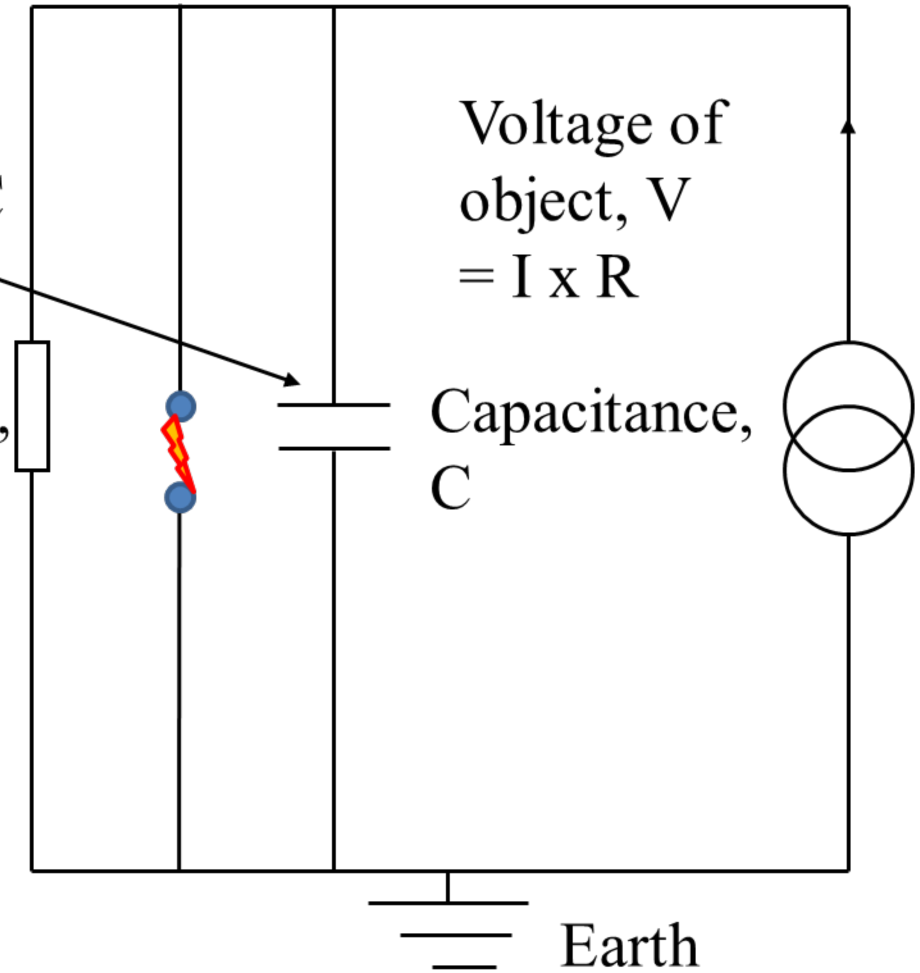
Note: hydrogen can also be ignited by a gradual release of charge (corona discharge)

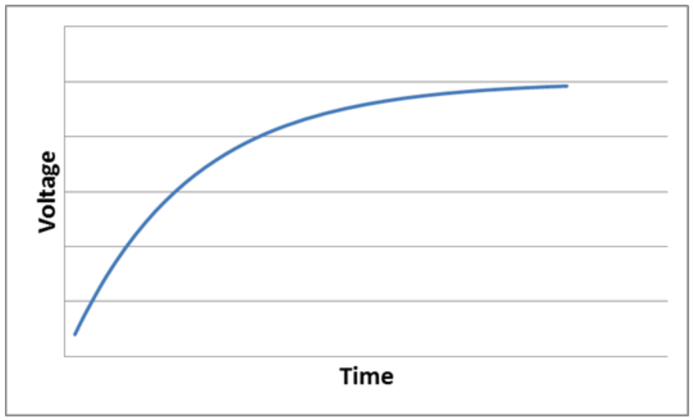
Basic Electrostatics

- Charging commonly occurs where materials are in contact and then separate
  - Or, charging can occur from other sources (e.g. by induction or corona)

- Charging typically involves small currents (ca. microAmps);
  - Large voltages required for hazardous discharges (ca. 1kV)

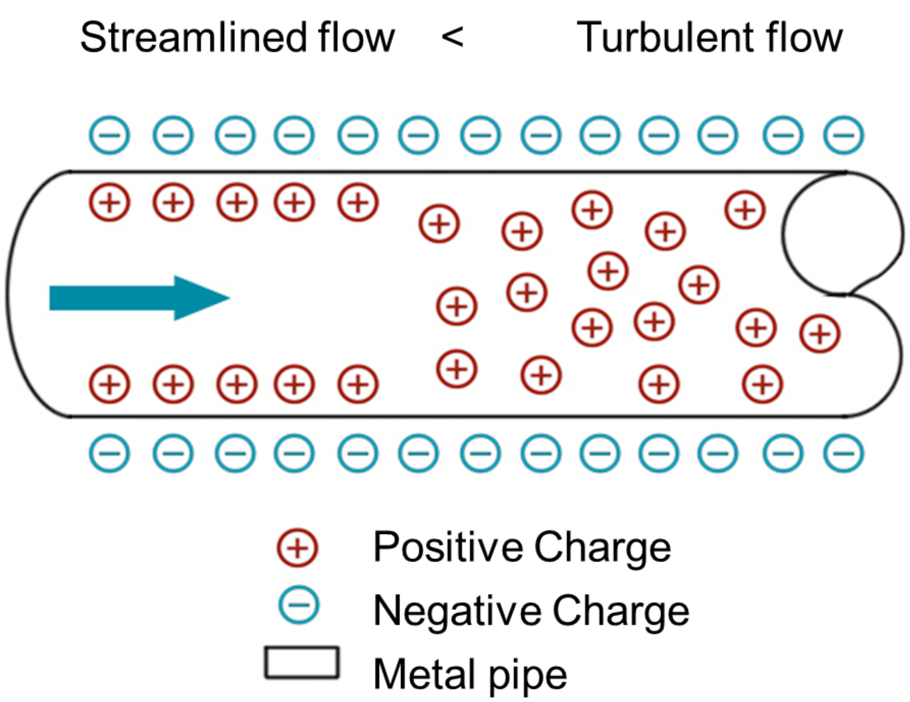
Basic Electrostatics





Basic Electrostatics

Charging of liquids due to flow in a pipe



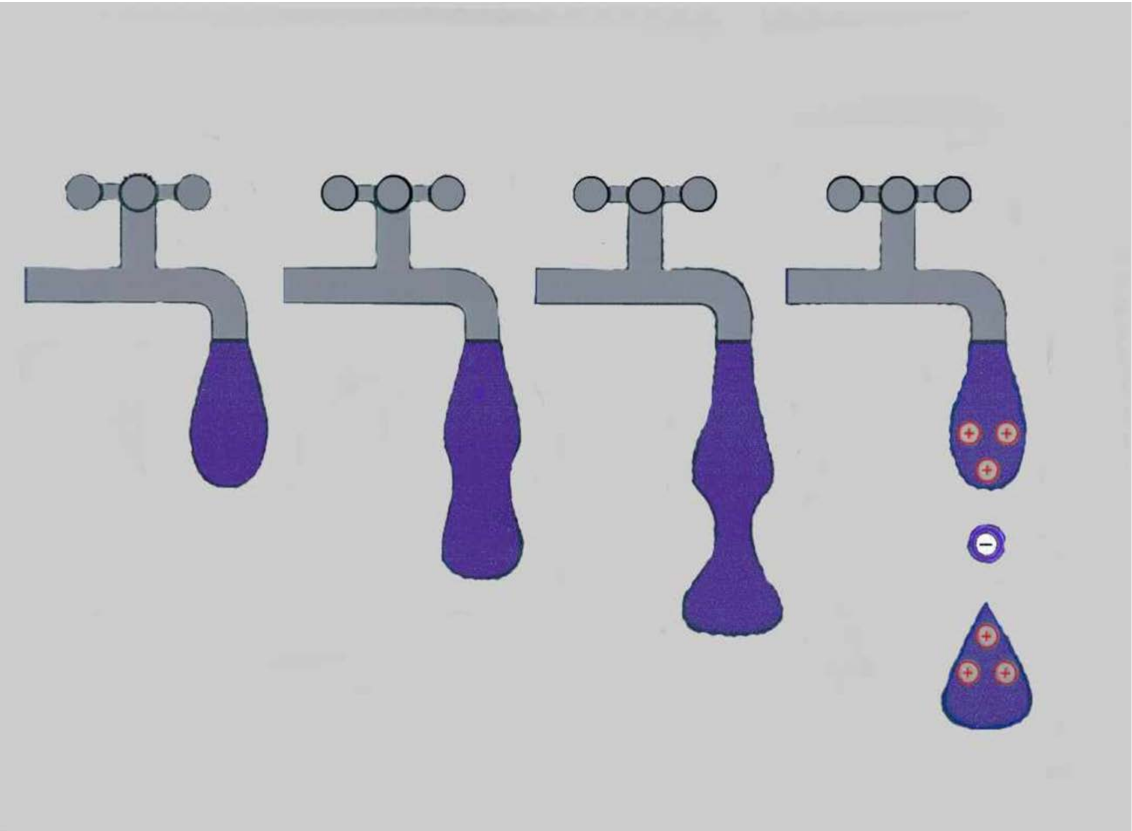
The level of charge in the liquid depends upon, amongst other things, the velocity of transfer, bore and the conductivity of the liquid

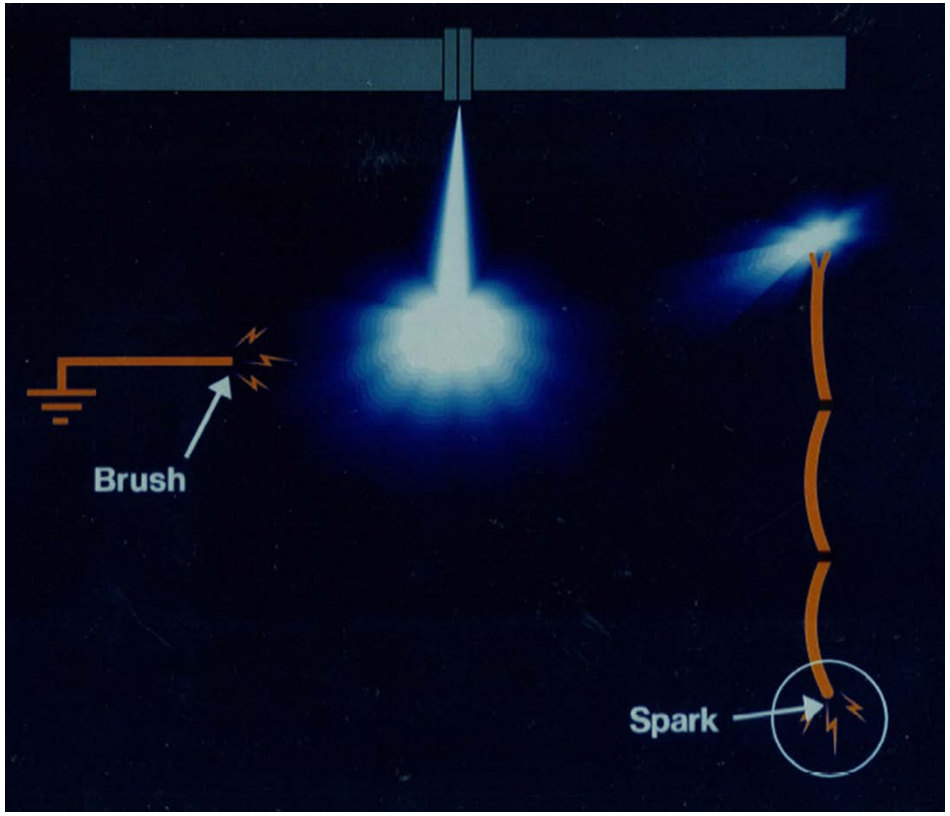
It is a balance between charge generation and charge relaxation (recombination)

The liquid needs to travel a certain distance down the pipe to become fully charged

Basic Electrostatics

Droplet and particle formation and break-up can also cause charging



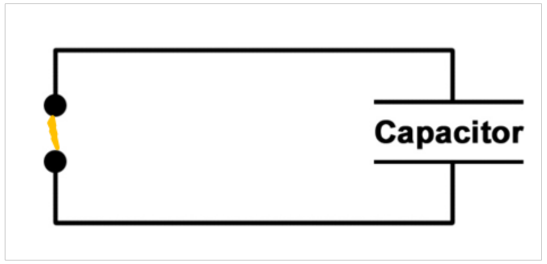


Droplets conveyed along a pipe in a gas stream also generate charge

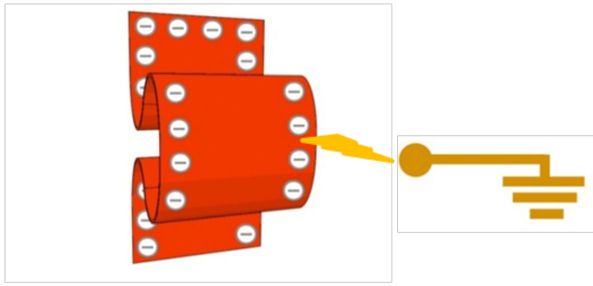
Basic Electrostatics

Types of discharge

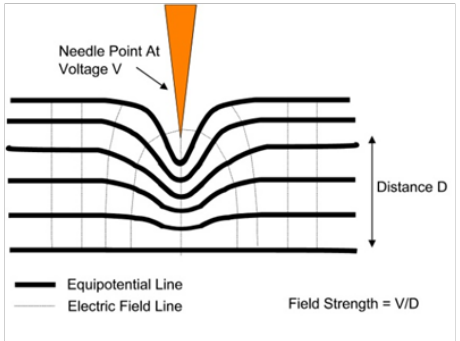
Accumulation of charge on an isolated conductor giving rise to a **spark** discharge



Accumulation of charge on the surface of an insulator giving rise to a **brush** discharge



Coronas can occur at sharp edges of highly charged conductors (a current rather than a spark)



Field strength for breakdown (discharge) in air ca. 3kV/mm; in hydrogen gas ca. 1.8kV/mm.

For ignition of hydrogen gas at room temp:

Minimum spark ignition energy, ca. 0.02 mJ

Minimum charge transfer for ignition, ca. 4nC

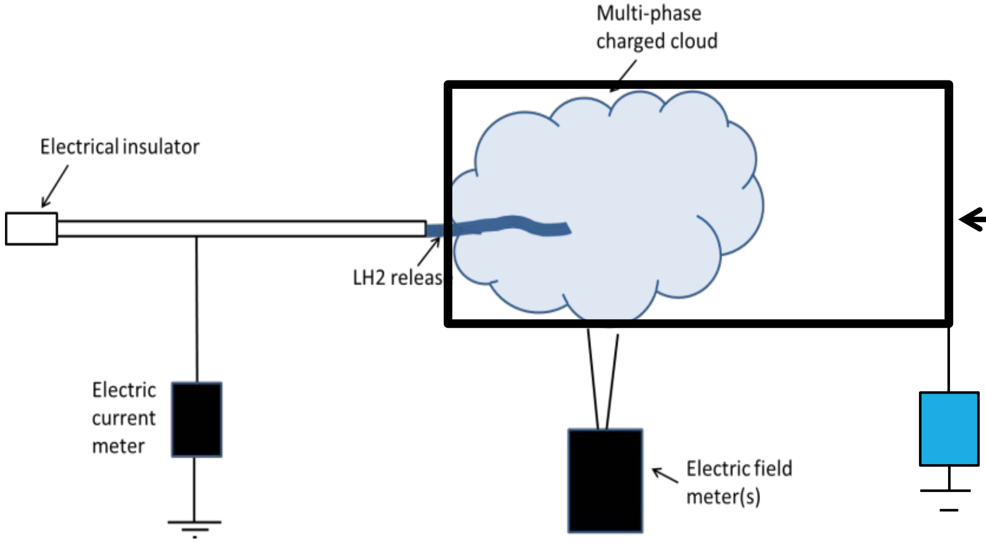
Minimum corona current for ignition, ca. +150µA (no ignition at -290µA)

Previous work

- Cassutt et al, 1962
  - Resistivity of LH2 ca. 10^{-17} ohm-cm
    - Ca. 3 orders of magnitude less conducting than typical insulating hydrocarbons
  - Charge accumulation on liquid during transfer
    - Measured space potential within tank
    - No direct measurement of charge density in the liquid
  - Space potential on plume from vent
    - Measured by Faraday cage at vent outlet
    - Indications of highest charging when two-phase flow occurred (beyond measurement capability)
- Waclaw Werner, 1925
  - Dielectric constant ca. 1.23 that of free space
    - Ca. half that of typical non-polar hydrocarbons
  - Relaxation time, τ ~1000 times x typical insulating hydrocarbons
- Literature search ongoing for other data

Proposed experiments at HSL

- Electrostatic measurements on a plume, to estimate the average charge density and maximum potential of the cloud

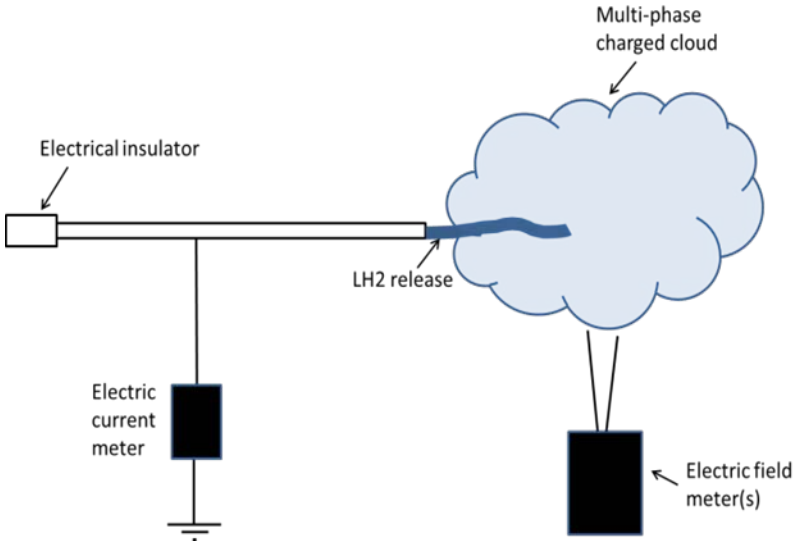


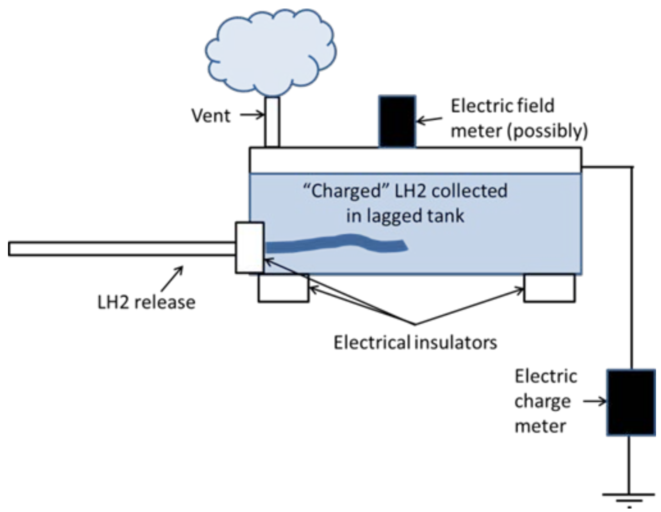
Alternatively use Faraday cage arrangement, like Cassutt

- To provide base level electrostatic measurements to draw practical implications from – i.e. comparison of propensity to ignite vs organics
- May also try elicit corona discharges from the cloud
- Possible variables:
  - Controlled: velocity, flow rate, change with time as pipe / surroundings cool
  - Uncontrolled: humidity

Proposed experiments at HSL

- Electrostatic measurements on pipeline, to estimate the charging current / charge density in bulk liquid flow





- To provide base level electrostatic measurements to draw practical implications from – i.e. comparison of propensity to ignite vs organics
- Direct wall current measurements & charge density in Faraday pail
- Possible variables:
  - Controlled: velocity, flow rate, pipe length

Proposed experiments at HSL

- Electrostatic charging measurements could be based on:
  - Direct current measurement
  - Charge accumulation on capacitor
    - Use virtual earth method, Q=CV, V~few volts

Potential issues (no pun intended!)

- Charge density in cloud too small to measure
  - Use virtual earth method using small values of low leakage capacitance
    - Q=CV, V~few volts
- Charge accumulation on LH2 small due to possible pipe lengths
  - $I_L = I_\infty(1-e^{-L/v\tau})$; needs further consideration
  - Use a variety of pipe lengths to understand relationship?
  - Use of Faraday pail to collect charged LH2
    - Q=CV, V~few volts

Potential issues (no pun intended!)

- Water vapour condensation compromises electrical insulation
  - Careful design of support structures
- Low charging rates may require:
  - very good electrical insulation (low resistance to earth) and / or
  - good screening of current measurement from external noise (suitable current range; robustness of measurement in field?)
- Mechanical strength of electrical isolators for isolated pipework sections at cryogenic temperatures
  - Searching for suitable plastics/composites

Conclusions

- Initial experimental design considered
- Assessment of existing literature / Standards ongoing
- Possible measurement methods identified
- Potential issues being considered