Safety in Electrical Systems thru Effective Design & Maintenance

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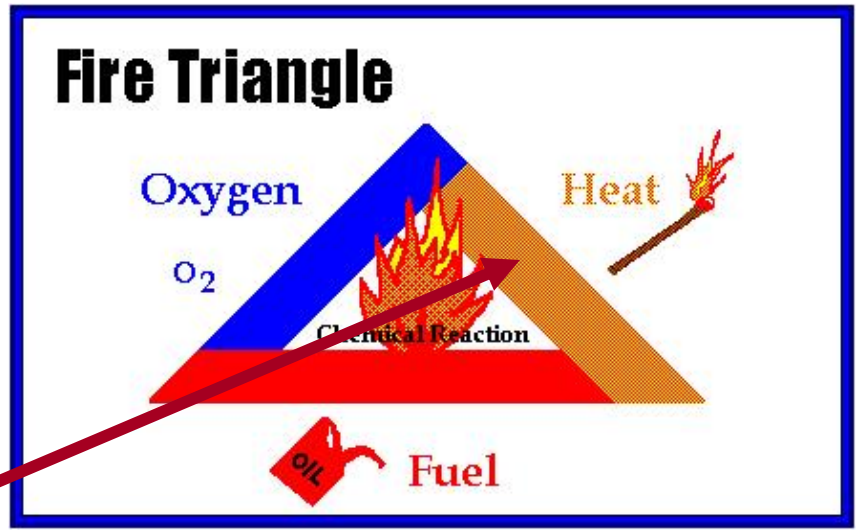
Working environment in Petroleum plants

- Working environment is hazardous
  - Can‘t avoid presence of vap/gas
- Air is present in abundance
  - Can‘t avoid Oxygen
- Only thing, we can control is “Ignition”



Electrical hazards and Consequences

Ignition Sources :

- Tank Trucks
- Electrical drives, controlling devices, cables.
- Lights and Switches
- Atmospheric discharges (lightning)
- Static charge
  - Generation
  - Uncontrolled Presence
- Stray current

Electrical Hazards :

- Electrocution
- Arc Flash
- Arc Blast

Consequences :

- Fall
- Burn
- Injury
- Damages
- Fire
- Fatality

Arc Flash / Blast Effect can be disastrous

- Arc produces a temperature of 19000 deg Celsius apprx

- Arc melts wires, expands air several times, creates blast pressure waves

Key parameters for Electrical System design

System design should be based on :

- Supply voltage rating, Current capacity, frequency.
- Hazardous Area Classification and Zones
- Equipment Spec Compatible to Zones of operation
- Mechanical strength, durability of equipments
- Cables Insulation , termination, gland packing
- Electrical Protections, Integrity of Interlocks / Relays
- Integration of safety features with the system

Distribution of Electrical Equipments

Electrical system includes a substation, stand-by power supply i.e. DG Sets, MCC panels, cable networks, motor drives, electrical controllers i.e. electrical fittings. Equipment/s are distributed according to hazardous area classifications.

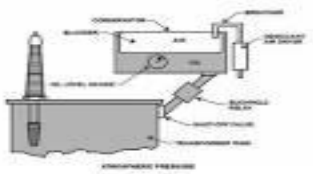
Non-Hazardous Area	Hazardous Area
Electrical power provided by Supply agency at the substation, in bare form. • Substation houses DP structure holding overhead HT electrical line, step down transformer. • For large substation, switch yard with bus bars are installed in addition. • Stand-by power supply i.e. DG Sets, MCC panels are housed in MCC room.	Remaining down end facilities. ▪ Motor drives ▪ Vast Cable networks ▪ Electrical controllers ▪ Protective Equipment/s

Substation Safety

- DP overhead bare power lines creates hazards at ground
  - Snapped charged line at ground dissipates potential in wide area
  - ‘Step potential‘ could be fatal
- In such case, Contact Supply Station immediately
- Good House keeping
  - No Tree
  - Clean grass & bushes
- Cover Substation under observation system

Transformer

- Hazards due to Faults
  - Internal (Core faults, winding failures, etc.)
  - External
    - Overloading
    - Over voltage
    - Bushing flash over
    - Faults at tap-changer equipment
- Risks
  - Fire,
  - Injury
  - loss of life



Transformer Safety

Common Observation :

Inadequate maintenance or lack of it resulting in --

- Sweating of body
- Oil Leakage from bushing
- Oil leakage from bottom
- Low / nil oil in Conservator tank
- Change of color of Silica gel from white to brown i.e. symptom of water vapor ingress

Growing Trends to use --

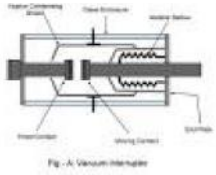
- Non-flammable Oil Transformer :

Silicone oil filled Transformer. Silicone oil is non-hydrocarbon, non fire-propagating oil.

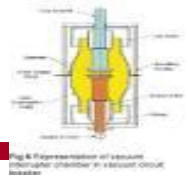
- Non-Inflammable Dry Type Transformer :

Fire resistant, non-inflammable insulation materials are used in the transformer. Air is the cooling media

- Effect of Oil drain
  "conducting parts i.e. core / coils carrying very high current" becoming exposed to tank body
- Effect of ingress of water vapor :
  Loss of dielectric strength of transformer Oil

Disconnecting Devises & Safety




Types --

Circuit breakers – Air, Oil, Vacuum, SF6

- OCB –

Flammability and high maintenance cost are two distinct disadvantages

- VCB

-The interrupters are ‘sealed ’ in which contacts are placed.

-Integrity test of the vacuum (leakage tests) when in needed, as per Manufacture’s manual.

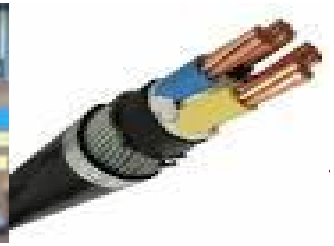
- SF6

Sulfur Hexafluoride Gas displaces Oxygen, nontoxic in pure state but after extinguishing arc toxic gases are formed. Purging is required.

In general, Circuit breakers malfunction due to :

- overheating due to loose connections.
- in operation in damp or cold environments.
- working in corrosive environments
- Rake-in or Rake-out without too much pressure

MCC Panel Safety



1. Integrity of Interlocks / Relays / Timers is vital. Any malfunction, will cause an adverse impact on breakers i.e. not to operate.

2. Armoured Cable termination, fixing cable gland and sealing so as not to allow ingress of any vap / gas.

3. Armour serves 2 purpose –

    a. Earthing continuity with Panel and motor drives / fittings.
    b. Protection of Cores against damage

4. At times, Rat / Lizard menace causes fire. Bottom plates should not be kept open.

Electrical fittings / Motor drives and Safety

2 different types of enclosures / equipments are used according to hazardous zones i.e Flameproof and Intrinsically safe.

Flameproof in Zone-1 /2

Design of A flameproof enclosure is such :

1. to withstand any explosion inside without damage , &
2. to prevent spread of flame beyond that enclosure to prevent external ignition.

Intrinsically Safe in Zone-0

Design of the equipment is such that:

• any spark that may occur inside the enclosure is incapable of igniting the gas / vapour.

- Design of circuitry is most important
- voltage not to exceed 25 volts

In both the cases, Safety is to be ensured by :

1. Manufacturers for design, &
2. Owners for :
   a. Installation carefully & without any harm to the fittings.
   b. Preventing opening during operation.
   c. Reclosing, after maintenance when needed, without leaving any gap between Cover & body.

Safety in Operating Practices

- SOP --- primarily for safety of employee
- Awareness about Static Charge generation, Control / Avoidance measures
- TLF Automation - Grounding Interlock mechanism (how effective ?)
- Presence of Stray Current in siding Rail Tracks i.e. Insulating Jointing (how effective ?)
- Strictly use Lock Out and Tag out as a policy
- Use and Care PPEs. PPEs may become ‘hazard‘ to user, consequences are skin contact with vap / liquid, injury.
- Training – there is no alternative.

Safety in Maintenance practices

Requirements are :

- Maintenance personnel's technical expertise
- Safety measures taken during maintenance
- Work Permit
- RLA for Equipments & their parts

Inadequacy of maintenance or lack of it brings catastrophic disasters –

- Only experienced should be authorised to undertake maintenance on electrical system / equipment
- In case of outsourcing, track records, nature of works carried out, years of experience, particularly experience in Oil & Gas --- should be considered.
- Electrical 'Work Permit' to be issued before taking up work. Inspection must be made by Issuer before re-energisation.
- Residual Life Assessment (RLA) is an important tool to track failing parts and time of replacement of parts or equipment itself.

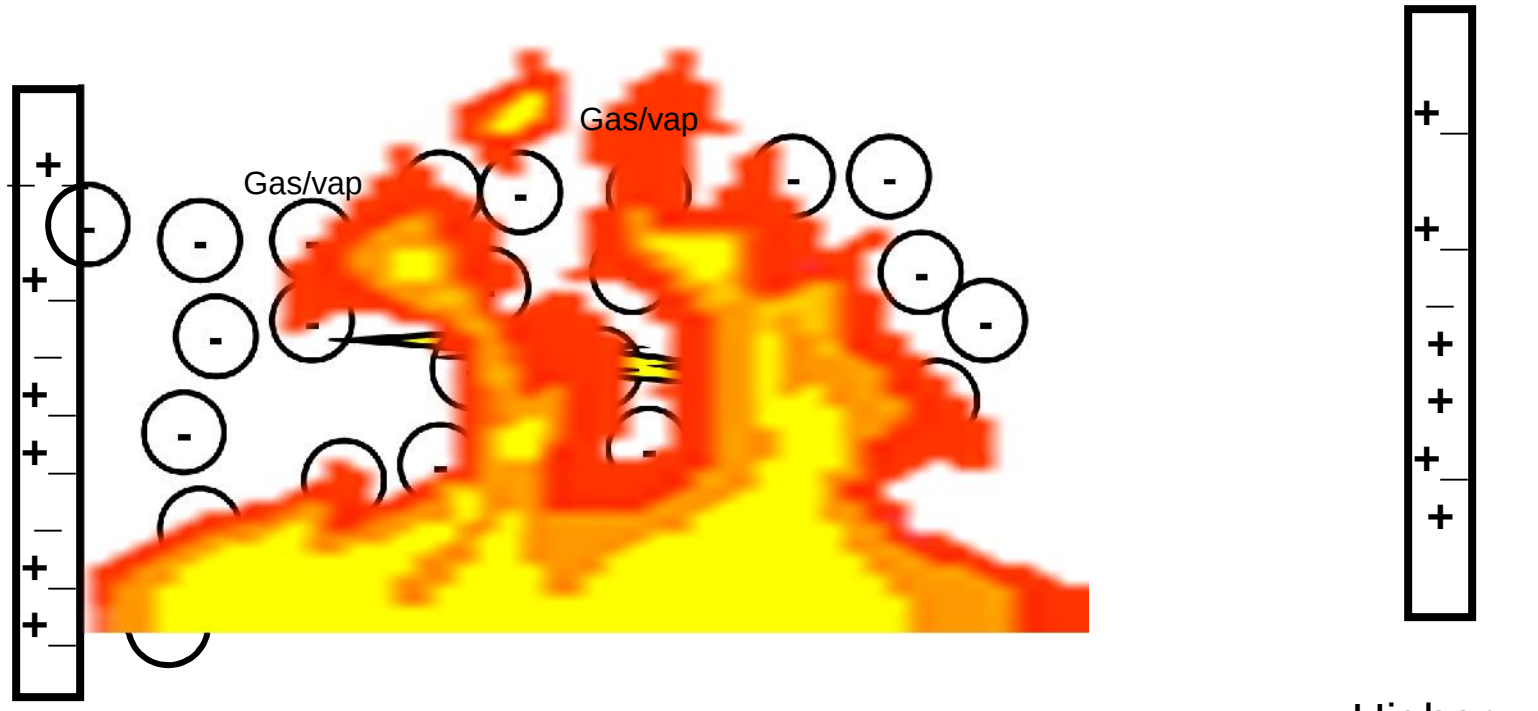
Spark

• It is a discharge channel / path transferring high density current from a charged body to another body of lower charge or earth.

• It is characterized by ionization of gas molecules present in the channel and luminous form.

Air gap between two bodies breaks down due to high potential

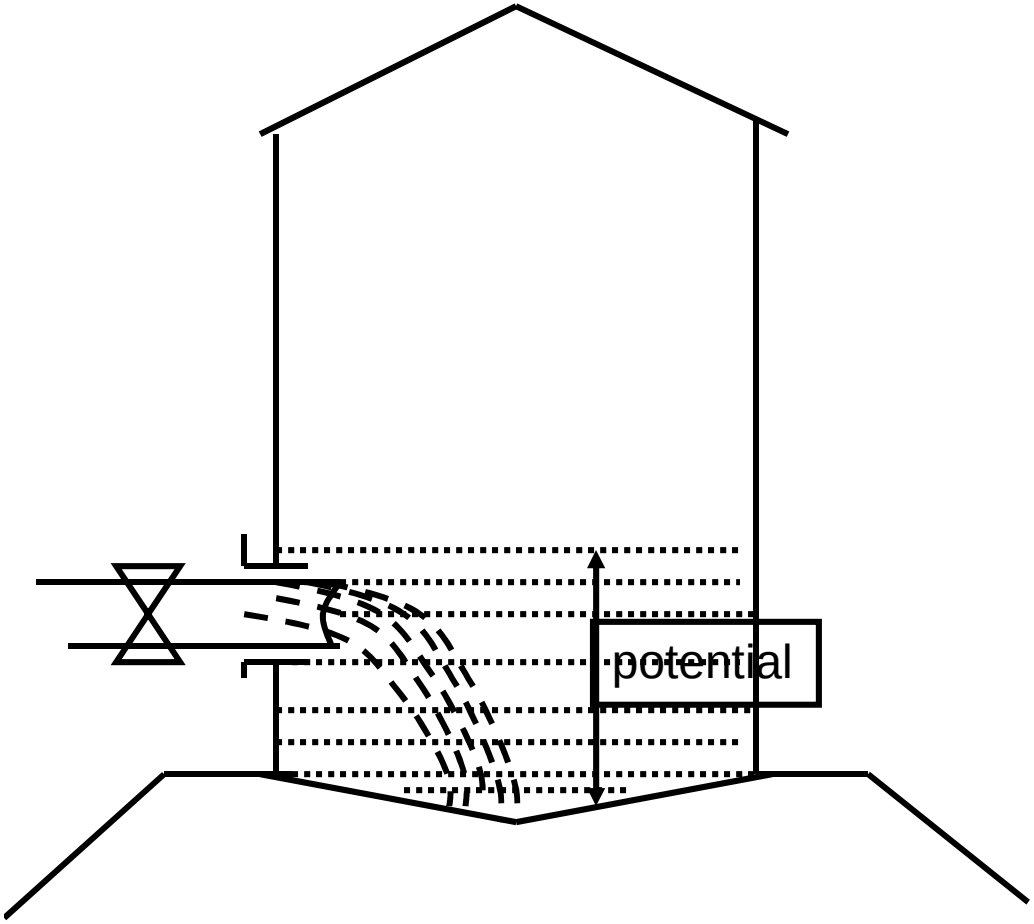
Air Break down potential is 75 KV across 1 inch gap i.e 3 KV across 1mm.
It requires only micro energy to ignite a fire



Zero or lower potential

Higher potential

During any kind of disturbance i.e. product filling / evacuation / churning, Static Charge is generated



Pressurized liquid, gas / vapour leave nozzle with a high force and in the form of tiny droplets.

• Droplets are charged ones. The more is the conductivity of liquids and velocity of discharge , the more is the charge.

• Entire vessel becomes charged due to potential developed

Charge Potential

Where generated charge does not find a leakage path or where rate of generation is much higher than rate of leakage, There will be potential development.

$$V = IR\left(1 - e^{-t/RC}\right)$$

V= potential of conductor in volts
R in ohm
C in F
I in A
t= time for charging, sec

Example :

Charge Potential

Consider -- An unearthed 200 ltr drum is being filled with MS in 5 min .

Assumption – Current density = 0.1 μ C/kg ,
leakage resistance = 10^{12} ohm,
drum capacitance = 50 pf .
Wt. of the product = 200 * density kg.
Filling rate = 200 / 5x60 kg/sec
C is Coulomb = Amp – Sec.

Potential developed at the end of 5 min filling , $V = IR (1 - e^{-t / RC})$
$= (.1 \times 10^{-6} \times 200xd / 5x60)$ amp x 10^{12} ohm x [1 – exp (- 5x60 sec / (10^{12} ohm x 50 x 10^{-12} F))]
≈ 33000 volts

Air breakdown potential is 75 kv per inch or 3kv per mm :

Thus for a potential of 33000v, spark will appear across a gap
= (33000 ÷ 3000) mm = 11 mm

Minimum Ignition Energy

Assumption – Capacitance for a 200ltr unearthed drum
= 50 pf.

Energy released = ½ x 50×10^{-12} x 33000^2 mj ≈ 27 mj

Data – Min ignition energy ---
Hydrocarbon --- 0.2 ~ 0.3 mj
Chemical Powder --- 10 ~ 30 mj.

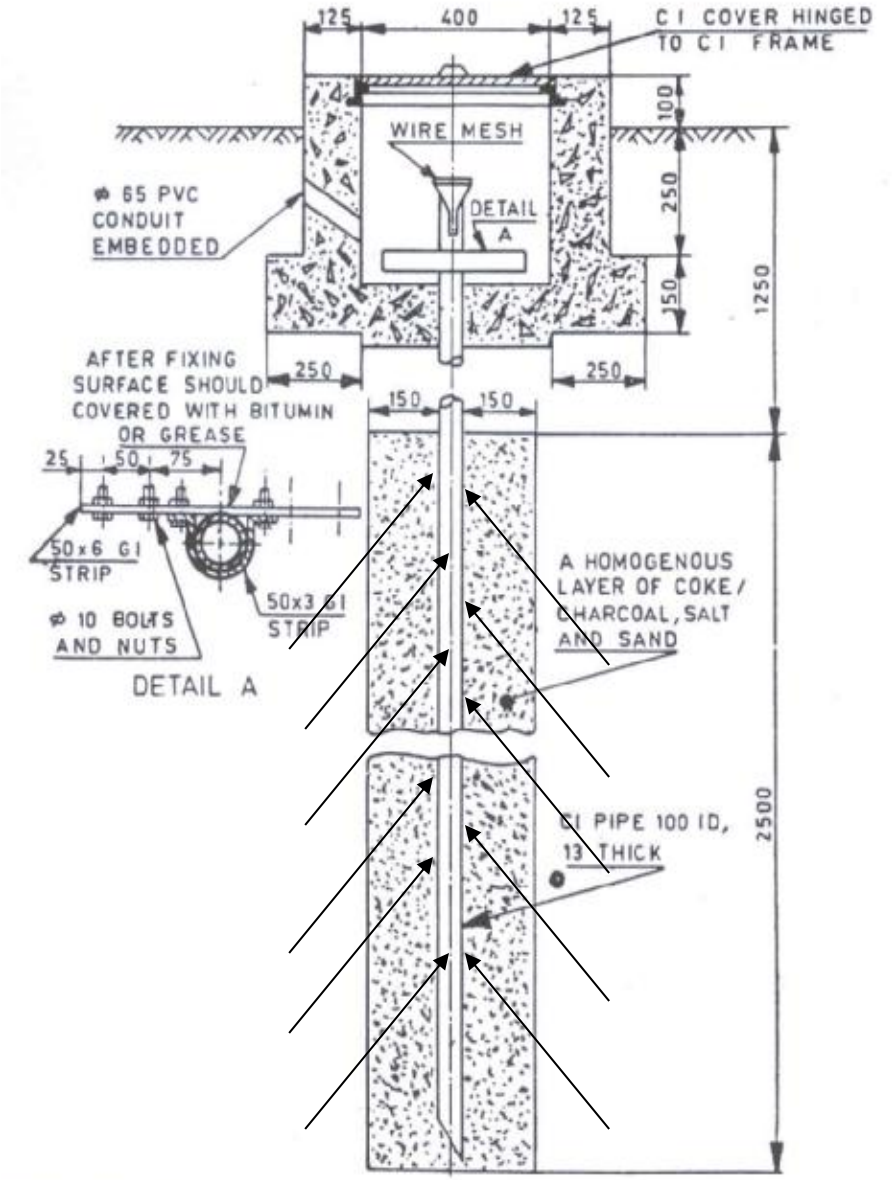
In practical situations a spark is caused at a potential of 10 kv.

When the Drum is earthed

(Assuming) leakage resistance is reduced to 10^6 ohms.

The potential developed will be = (33000 ÷ 10^{12})x 10^6
= 0.033 volts only

Effective Earthing comprises 3 Components



Earthing station -- Earth station i.e. electrode must be capable of dissipating into earth

Soil resistivity – It is the base line of the entire system. Soil resistance varies from location to location depending on soil characteristics , sub-soil water table, dissipation capability deep down, moisture content, salt content, capability to hold moistures, seasonal variations, etc.

Contact surface between Electrode and Soil –The contact area is the bridge for the dissipation of fault current / electric charge. The resistance developed between them adds to potential rise on the electrode. Same is true for no contact .

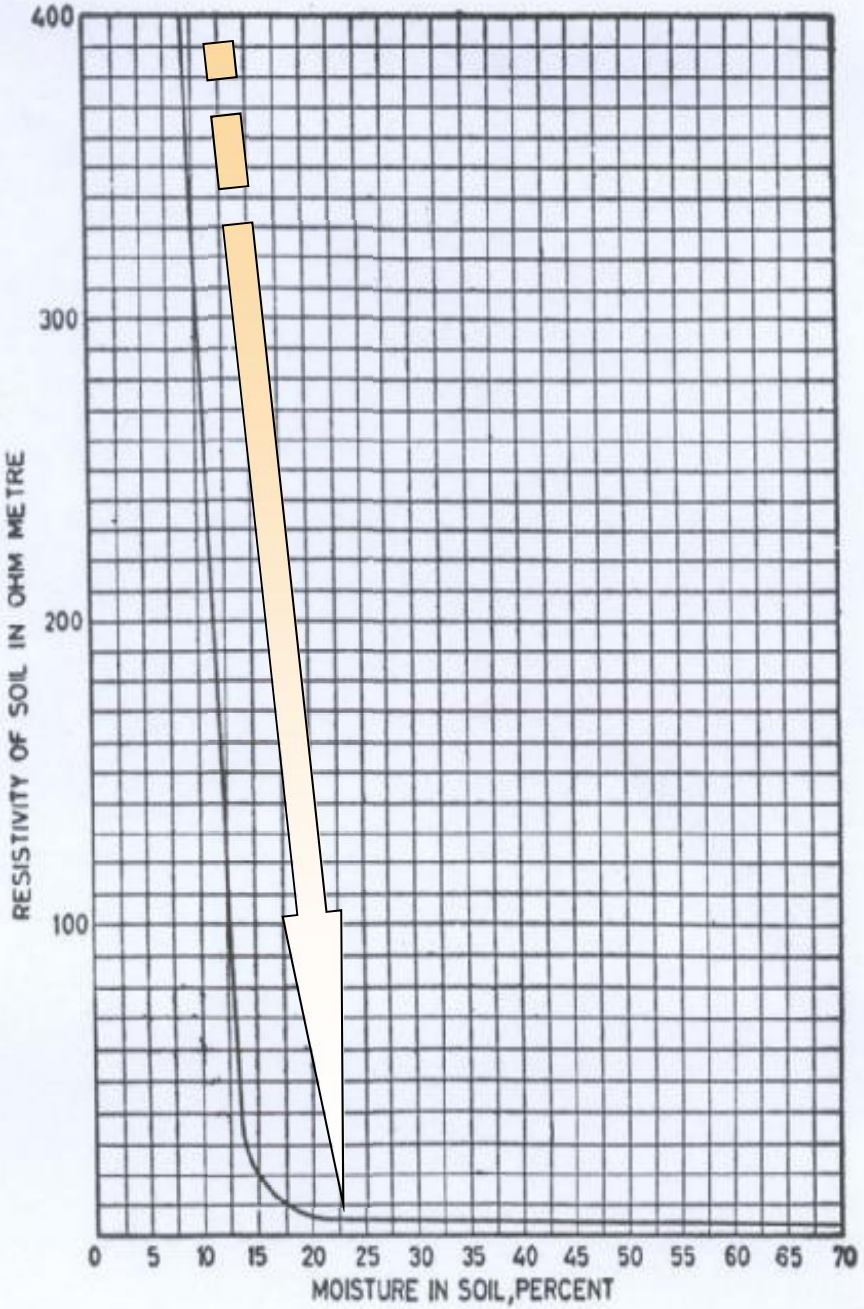


FIG. 9 VARIATION OF SOIL RESISTIVITY WITH MOISTURE CONTENT

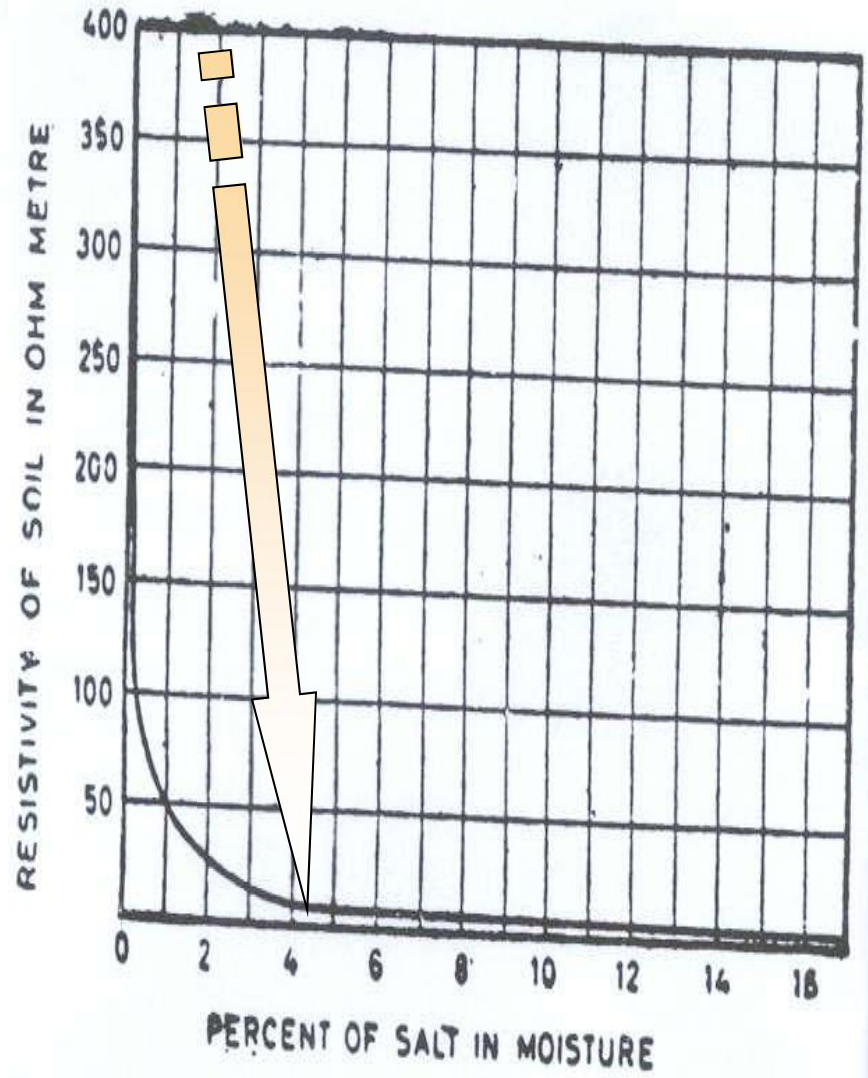


FIG. 10 VARIATION OF SOIL RESISTIVITY WITH SALT (Nacl) CONTENT, CLAY SOIL HAVING 3 PERCENT MOISTURE

Electrical Safety Objectives

In Conclusion, Electrical Safety is :

Primarily for Safety of :

- Working personnel
- Equipments / Plant
- Oil & Gas specific Areas of Concern e.g. static charge, lightning, stray current

Electrical Safety can be achieved thru –

- Safety considerations in Design of Electrical System and Installations
- Safety adopted in Operation practices
- Safety adopted in Maintenance practices
- Training
- PPEs

Thanks for your kind attention