This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Lightening Protection System in Tanks and Case study with Questions and Answers

Milind Nimje – DGM (Ops) HO, IOCL

Lightning strike in EFRVT in IOCL Terminal in Oct'22

12/10/2022 evening there was thunderstorm and the Tank 13 got struck with lightening.

RSFPS got actuated and fire brought under control within seconds.

Since last 20 years , the incident has happened thrice at the Location.

Presentation comprises -

a) Features of lightening strike, Role of Shunts in EFRVT. Role of Bypass Conductors in EFRVT.
b) Features of Mechanical Shoe assembly which connects roof to shell in EFRVT.
c) Challenges in Field.
d) Site photographs and observations.
e) Clauses on LPS in OISD GDN 180 , API RP 545 , IOCL communication and application in the Terminal.
f) Recommendations.
g) Questions and answers for better understanding.
d) Probable cause of damage to EFRVT 13

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Features of lightening strike-

It is very important to know the lightening behavior so that we can implement efficient protection system.

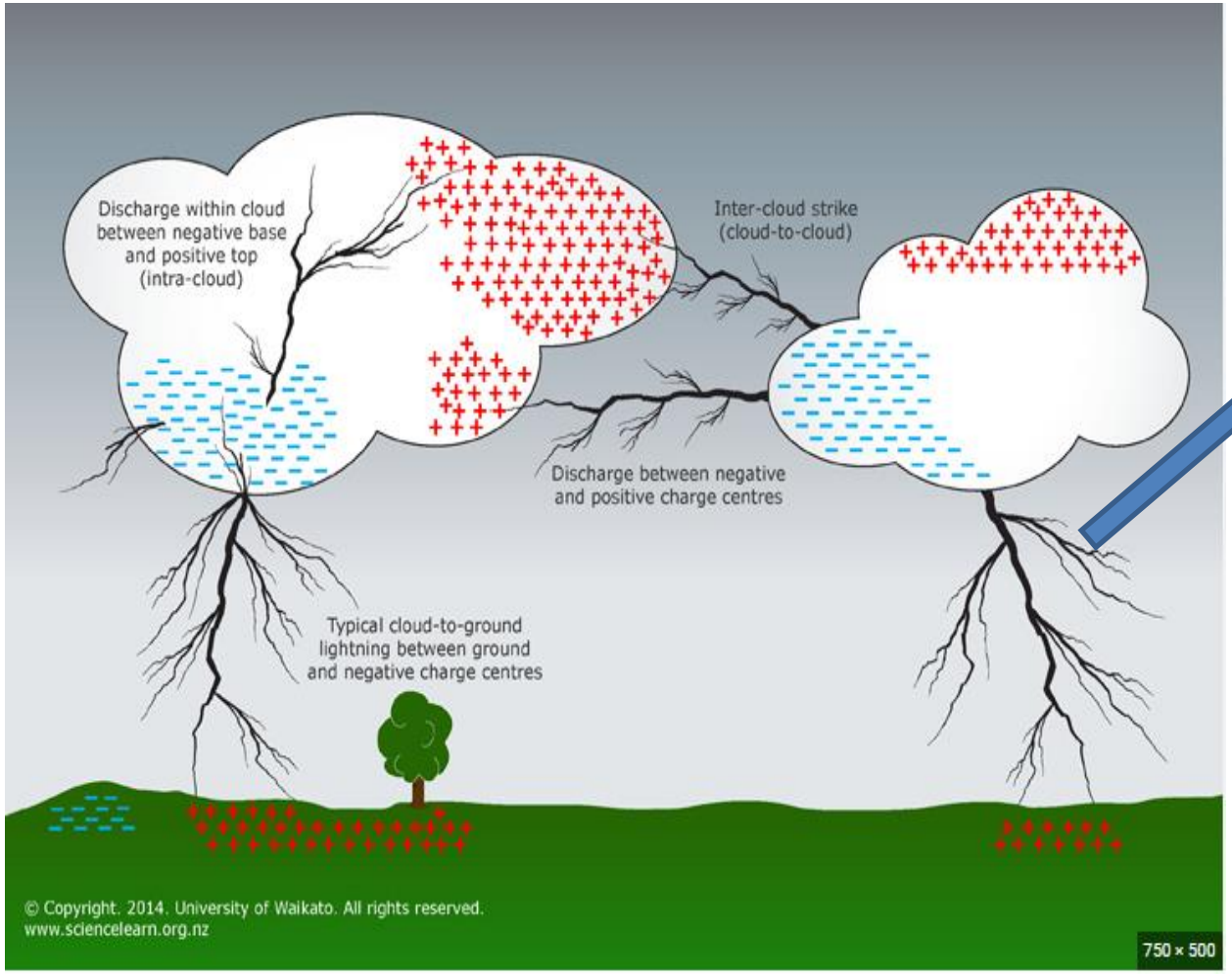
Note- Absolute lightening protection is difficult as the behaviour is random and unpredictable.

1) How lightening originates and attaches.
2) How lightening current flows.
3) How lightening current behaves.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

1) How lightening originates and attaches

There are particles of rain/snow inside clouds. They collide and hence charge is developed.



In relation our Earth, trees, structures become positively charged, creating an imbalance.

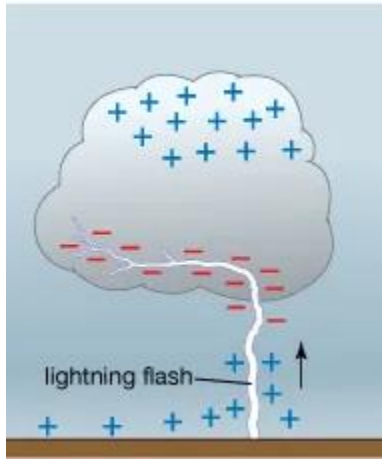
Nature tries to amend the imbalance by achieving stability by passing current between the 2 charges.

Some section of the earth are more +vely charged and attract the lightening. It is the prime reason for random behaviour of lightening.

Alternatively, this feature helps in designing the effective protection mechanism.

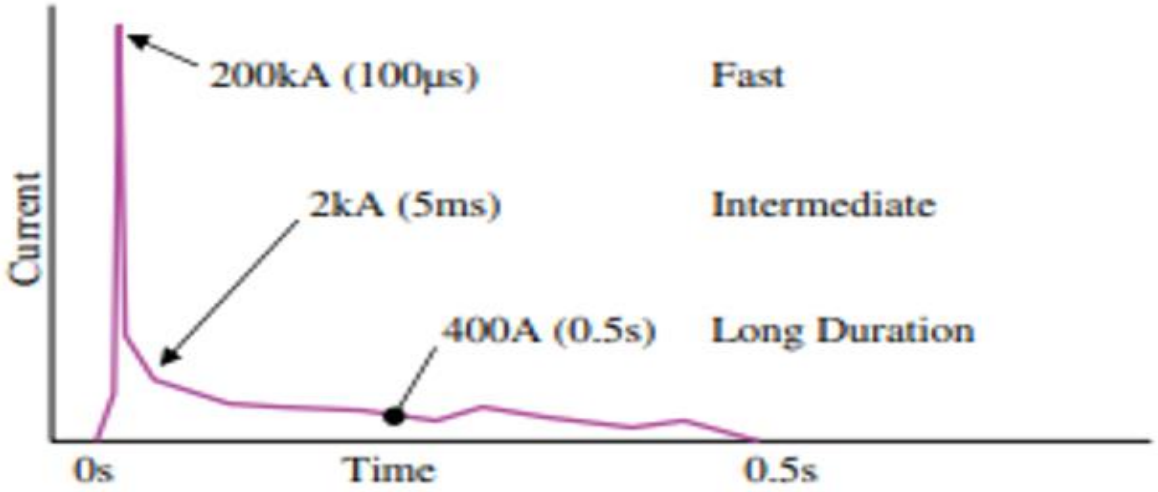
1) How lightening originates and attaches

- The “leader” strike creates a breakdown path through the air in a series of jumps 25 m to 100 m in length.
- Only when it is within a similar distance from the ground, or grounded structure, is the strike point determined, when it makes its final jump to the nearest point.
- This then completes the electrical connection between cloud and ground and the main lightning current can then begin to flow.
- It follows that even if there are tall structures nearby, they do not necessarily get struck, because the downward propagating leader does not see such a structure unless it comes to within perhaps 25 m to 100.



This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

2) How lightening current flows



What makes fast and safe discharge of lightening current difficult is the frequency with which it vibrates. (Below 1 Hz to near 300 MHz).
It creates more impedance and leads to inductance.

- There are 3 components in the lightening current-

i. The fast component contains very high peak current and most of the energy and lasts in micro seconds.

ii. Intermediate duration

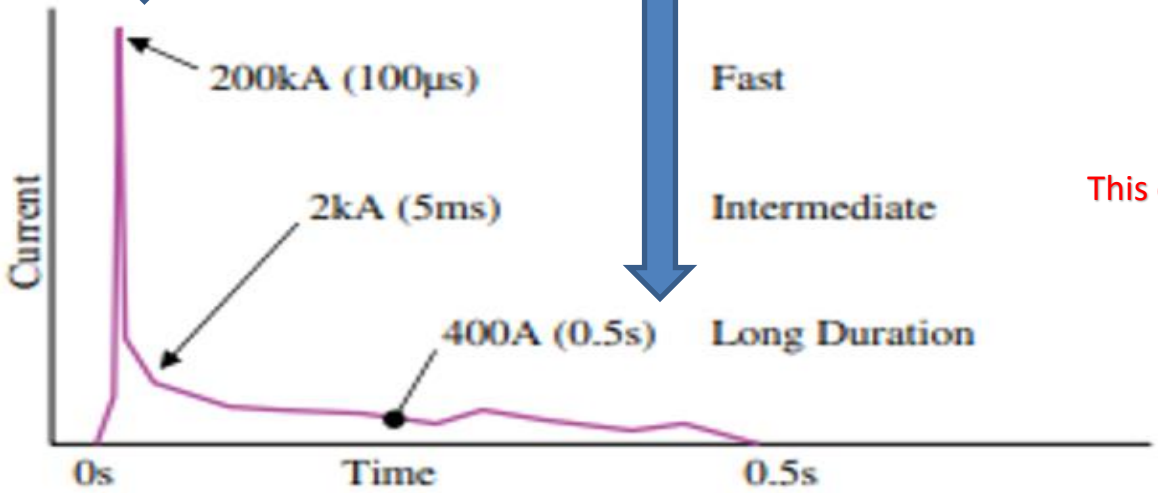
iii. Long duration current invites the risk of hot spots and sheet melting.

$$\text{Net resistance in Ohms} = \sqrt{(\text{Resistance})^2+(\text{Inductance})^2+(\text{Capacitance})^2}$$

3) How lightening current behaves.

API 545 Recommendations

4.2.1.1 Shunts for Conduction	4.2.1.2 Bypass Conductors
For fast and intermediate duration components of lightning stroke current	*For intermediate and long duration components of lightning stroke current*



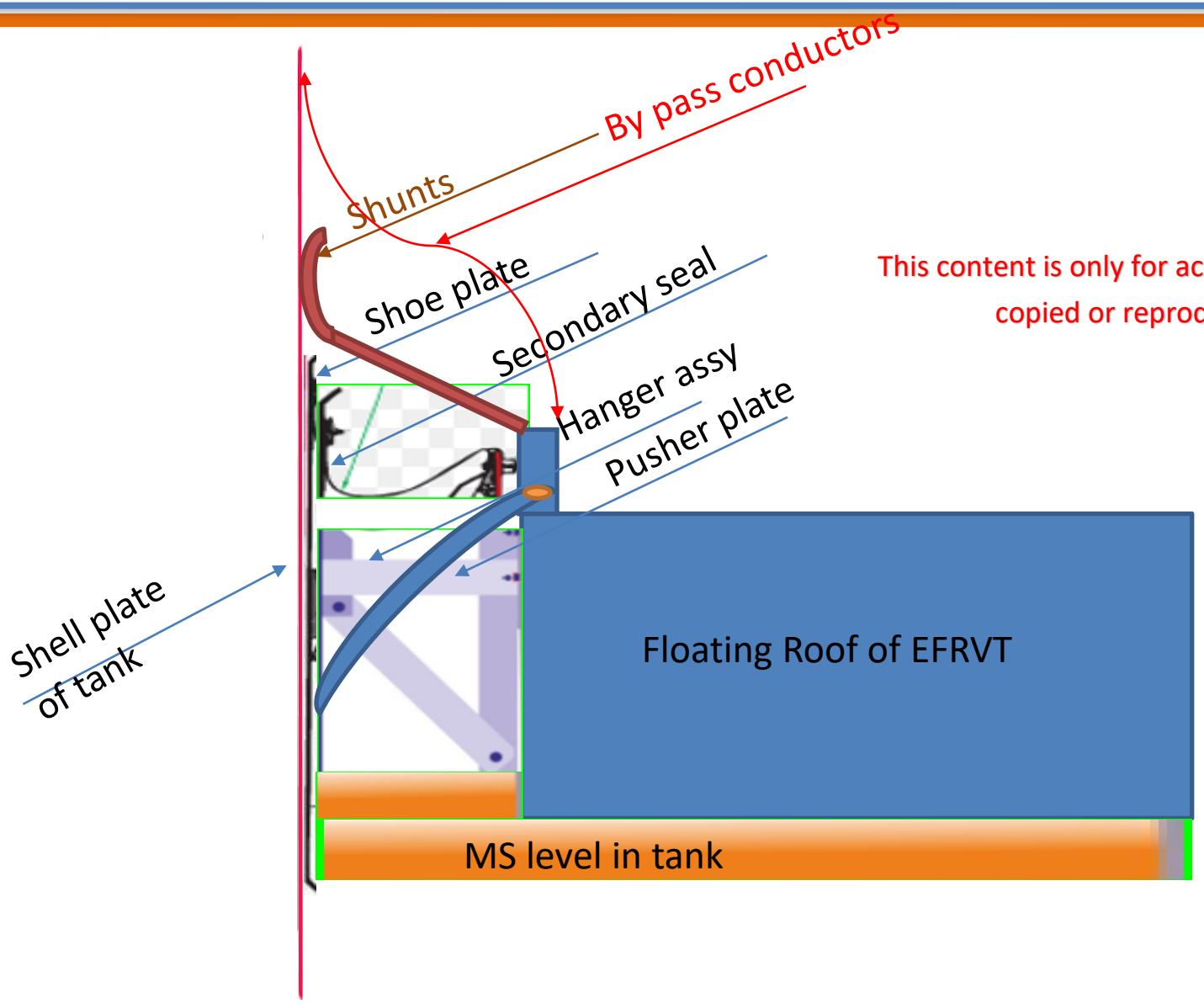
The fast current (200 kA, 100 ms duration) is actually 1000 times higher amplitude than the long duration currents, but the long duration currents last 10,000 times longer.

Because of this difference in scale the different current components behave differently, both in the way they flow and in the risk they pose.

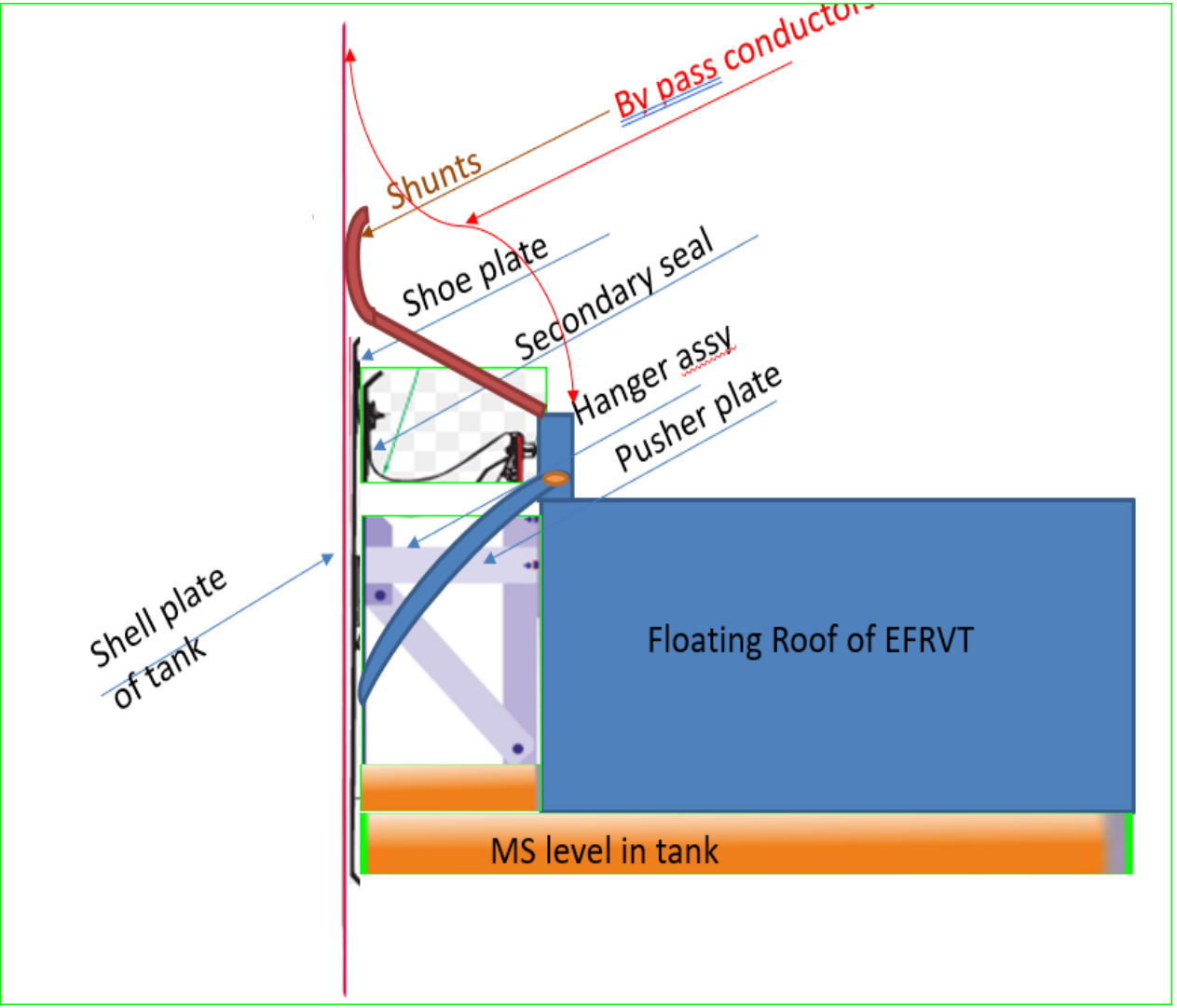
Accordingly different means are required to address the above.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Let us now understand the sealing of space between roof and shell through mechanical shoe assembly and then secondary seal in EFRVT.



This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.



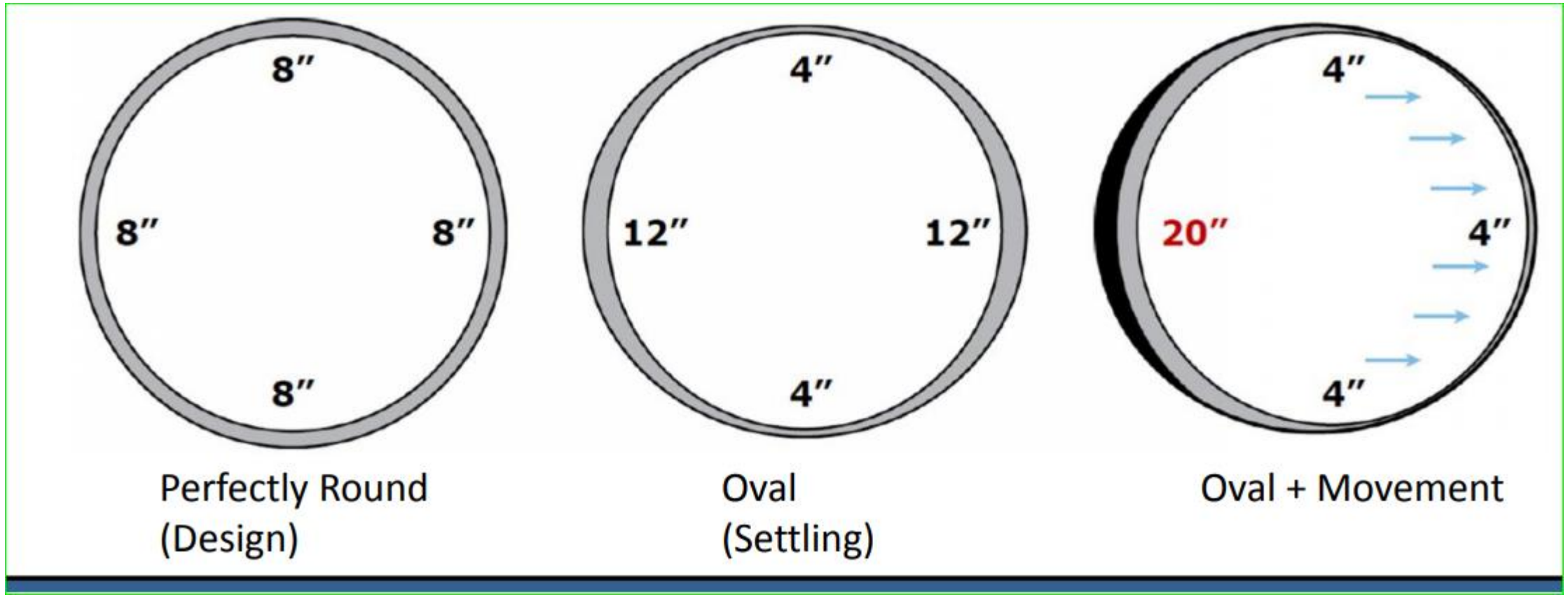
Shunts are not low resistance electrical connections. They provide short and direct path to the lightening current.

Shunts are used for Conduction For fast and intermediate duration components of lightning stroke current Spaced no more than 3m apart Stainless steel, min 2 in wide, min 20mm2 cross-sectional area.

By-pass conductors are simply **conductors run between the perimeter of the floating roof and the tank shell at intervals not to exceed 30m**. These provide a low-resistance path between the floating roof and the tank shell.

Challenges in field

1) Tanks aren’t perfectly round. With age they wear, disengage and hence few shunts are not in contact with shell.



Challenges in field

2) There is hanger assembly and pusher assy which presses the shoe with the shell. Only at that point is there contact with shell while at other places there is possibility of gap as the force is not uniform,.

Various spring-like devices have proven unsuccessful, either because such devices become easily misaligned or dislocated with roof movement, or because such devices do not urge the shoe with the uniformity of pressure necessary to accommodate tank wall variations

3) The rubber seal should have insulation resistance of min 1kV. It is to have preferential path through shunts and bypass conductors. However with exposure to rain, light, diurnal cycle, the resistance of rubber seal changes.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

What went right?

1) As per OISD GDN 180 and Operations circular 101, Tk 13 was having provision of 4 Nos Bypass conductors of Copper wire having 50 mm dia for bonding between roof and tank shell.
2) Earth Pit resistance for the tank was within acceptable limits.
3) Fire fighting equipment's like Rim Seal Fire protection System and HVLR were in healthy condition and immediately put to use.
4) Officers, Staff and contact workmen all displayed adequate training to handle the emergency as all of them responded effectively.
5) Housekeeping in Tank Farm was in order.
6) Lightening strike is an act of God which is uncontrollable. Location handled the emergency in the best possible manner.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Various clauses and existing system in IOCL

S.N	Standard ref	Clause No	Description	System in IOCL	In Rajbandh Terminal
1	OISD GDN 180	7.2 c	Where a floating roof tank is equipped with both primary and secondary seal incompliance with environmental regulations shunts shall be installed so that they directly contact the shell above the secondary seal as in case of primary seal explained in a above.	In place	OK

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Various clauses and existing system in IOCL

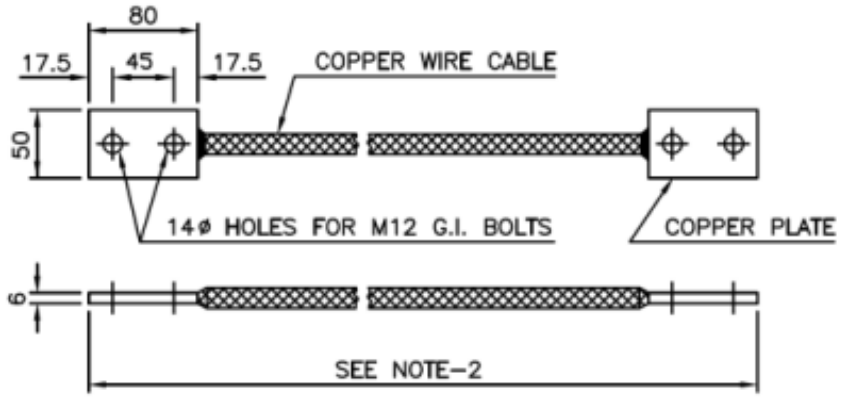
S.N	Standard ref	Clause No	Description	System in IOCL	In Rajbandh Terminal
2	API RP 545	4.2.1.1.2	The shunt to shell contact point shall be submerged atleast 0.3m (1 ft) below the surface of the liquid product.	Shunt is above secondary seal and as such the content of the clause is not applicable.	Not applicable

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

S.N	Standard ref	Clause No	Description	System in IOCL	In Rajbandh Terminal
3	OISD GDN 180	7.2 e	The tank floating roof shall be bonded to tank shell by direct electrical connection through bypass conductors in lin with API RP 545. The bypass conductors should be evenly spaced with a distance of not more than 30m around the tank circumference with a minimum of 2.	There is a communication that 1 additional bypass conductor shall be provided in addition to that mentioned in OISD GDN 180 / API RP 545.	In this case, as per reference (OISD/API RP 545) min 3 Bypass conductors are required to be installed for bonding between roof and shell, However, 4 bypass conductors (Each min 50 sqmm area) were installed and connected.
5	API RP 545	4.2.1.2.2	In addition to the above the following is mentioned- Each conductor including connections shall have maximum end to end electrical resistance of 0.03 Ohms.		

Various clauses and existing system in IOCL

S.N	Standard ref	Clause No	Description	System in IOCL	In Rajbandh Terminal
3	OISD GDN 180	7.2 Fig 9	As below	As per drawing.	In this case, the connections were bolted using single bolt . The connections were found to be loose.



DETAIL – K

Recommendations

1) The resistance of bypass conductors provided at all the EFR tanks should be checked and it is to be ensured that their resistance is less than 0.03 Ohms. The continuity test shall be conducted for the bypass conductors (Roof to shell) every quarter.

   How will one check the end to end resistance ?

   - ❖ Intrinsically safe Multimeter
   - ❖ Platform for standing and conducting checks.

2) The number of bypass conductors provided on EFR tanks (Roof to shell bonding should be with double bolts)

   - ❖ Such bolting arrangement should be with non corrodible fasteners. It should not be painted.
   - ❖ Visual inspection and physical inspection to be done to check tightness of fastening arrangement.

3) To avoid any PLT / TWD / Delivery operations during thunderstorm/lightening.

Recommendations

4) The scaffolding arrangement if any on the tank should be metallic and grounded. It should be removed on urgency , once the job is over.

5) Damage control system like Rim seal fire protection system, Foam pourer system to be maintained in healthy condition at all times.

6) Electrical audit of the Location to be conducted including provisions of OISD 180 for lightning protection system through competent party and their observations complied on priority.

7) Cameras shall be positioned covering Tank Farm area as much as possible with better resolution .

8) Test report on insulation characteristics of Bypass conductors to be available with rating as per OISD norms. The same to be tested at frequency as per OISD norms /annually.

9) Test report on insulation characteristics of secondary rubber seal to be available and checking done as per OEM norms. The same is recommended to be replaced with new one during tank cleaning operations (once in 5 years or as per OEM norms).

Questions for better comprehension

1) When lightening strikes, melting may happen. Is it because of long duration current or fast duration current?

Answer-

- Long duration current invites the risk of hot spots and sheet melting.
- The fast current (200 kA, 100 ms duration) is actually 1000 times higher amplitude than the long duration currents, but the long duration currents last 10,000 times longer.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Questions for better comprehension

2) When is CRVT is considered as self protecting against lightening strikes?

Answer-

- Minimum thickness of 4.8 mm.
- Safe and efficient discharge as there is no space/gap for charge to jump.
- PL comment on vapour space and level in tanks.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Questions for better comprehension

3) In EFRVT , what is the significance of :-

Insulation level rated as >1 kV for secondary rubber seal

Answer-

Current follows the path of least resistance. In this case, the high value of insulation, obstructs the flow of current and almost entire current flows through the shunt / Bypass conductors.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Questions for better comprehension

4) What is the highest level of protection Class I or Class IV?

Answer-

Class I

LPL	I	II	III	IV
Maximum current (kA)	200	150	100	100

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Questions for better comprehension

5) What is the lightening 3 seconds rule ?

Answer-

If you count the number of seconds between the flash of lightening and the sound of thunder and then divide by 3 you will get the distance in km.

3 seconds is 1km

15 seconds is 5 km

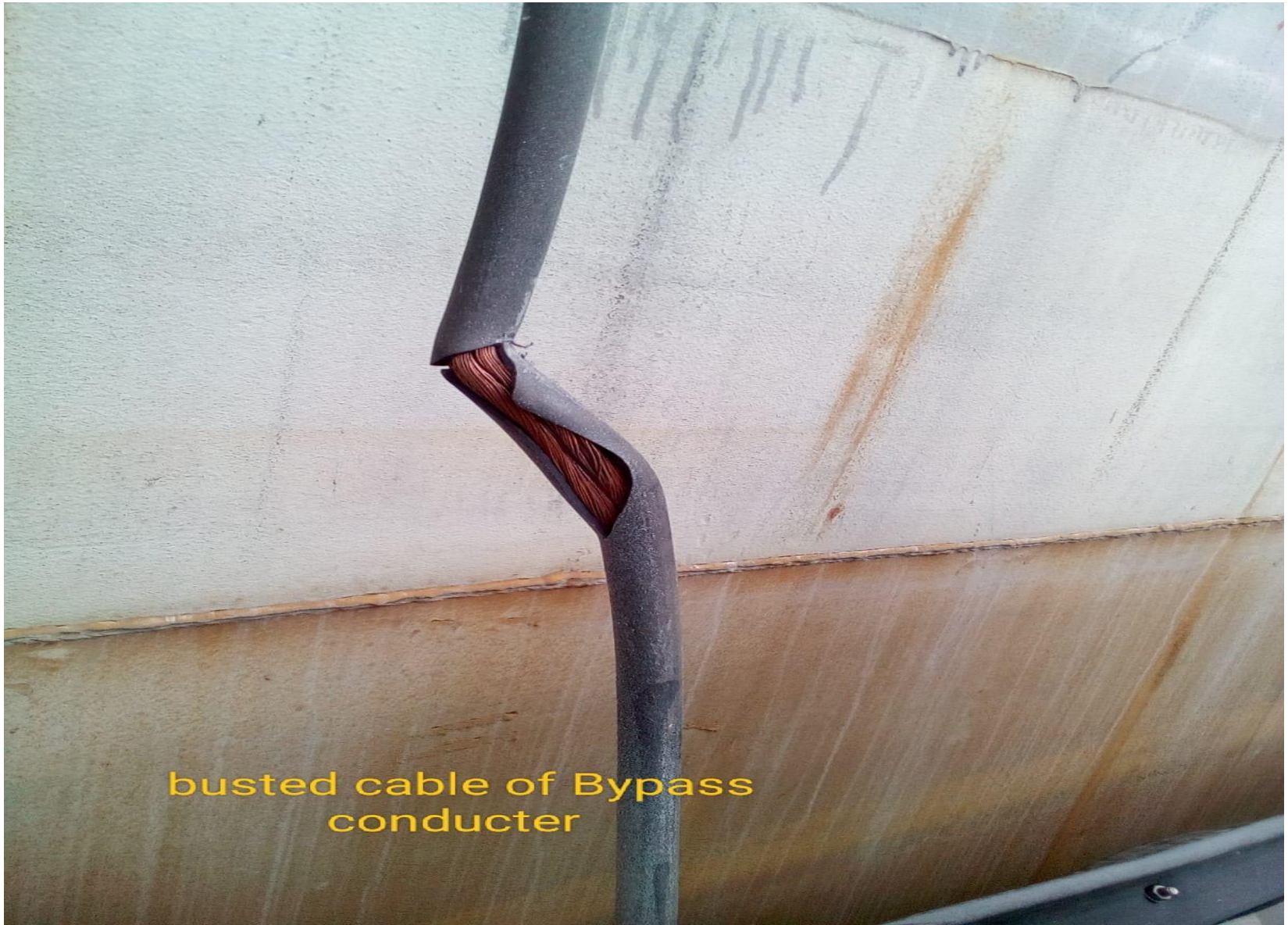
O seconds is done/ very close

damaged portion of rim
seal

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

another portion where
impact of flash is visible

hole through which
Bypass conducter
connected to roof


busted cable of Bypass
conducter

4 Protection of Specific Types of Tanks

4.1 Fixed-roof Tanks (Metallic) and Tanks with Internal Floating Roofs

For fixed roof tanks (metallic cone or dome) and internal floating-roof tanks (IFRTs), there is a possibility of flammable vapors being present at atmospheric vents. If present, flammable vapors can be ignited by a lightning flash.

Shunts or bypass conductors are not required for lightning protection. Bonding techniques to prevent static discharge between the floating roof and shell are addressed in API 650, Appendix H.

Tanks handling low vapor pressures or in-service with properly maintained floating roofs with tight-fitting seals are not likely to have flammable vapors at atmospheric vents unless it is being refilled from empty. In these cases, no further lightning protection is required (see Annex B).

4.2 External Floating Roof Tanks

4.2.1 Bonding Between Floating Roof and Shell

4.2.1.1 Shunts for Conduction

4.2.1.1.1 General

Shunts are used for conduction of fast and intermediate duration components of lightning-stroke current.

4.2.1.1.2 Number and Placement

The shunt to shell contact point shall be submerged at least 0.3 m (1 ft) below the surface of the liquid product. The shunt shall have as short and direct a path as possible from the conductive floating roof to the tank shell. The shunts shall be spaced at intervals no greater than 3 m (10 ft) around the perimeter of the floating roof. When retrofitting existing tanks with submerged shunts, the abovedeck shunts shall be removed.

4.2.1.1.3 Cross-sectional Area—Minimum Width and Material

The shunts shall consist of an austenitic stainless steel conductor of at least 20 mm^2 (0.031 $in.^2$) cross-sectional area, or of other material conductors of equivalent current-carrying capacity and corrosion resistance. The minimum width of the shunt shall be 51 mm (2 in.). The shunts shall be of the minimum length necessary to permit the function of the floating-roof seal assembly. The shunts shall be of the minimum length necessary to remain in contact with the shell during the full horizontal and vertical design movement of the floating roof.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

4.2.1.2 Bypass Conductors

4.2.1.2.1 General

Bypass conductors are used for conduction of the intermediate and long duration component of lightning-stroke current.

4.2.1.2.2 Number, Length and Electrical Resistance

The tank floating roof shall be bonded to the tank shell by direct electrical connection through an appropriate number of bypass conductors. Each conductor, including connections, shall have a maximum end-to-end electrical resistance of 0.03 Ω. The bypass conductors shall be of the minimum length necessary to permit full movement of the floating roof. Bypass conductors should be evenly spaced not more than every 30 m (100 ft) around the tank circumference with a minimum of two.

4.2.1.2.3 Durability

The bypass conductors and termination connections shall be positioned and of sufficient flexibility, cross-sectional area, and corrosion resistance to have a minimum service life of 30 years.

Sample calculation of resistance of copper cable

Given :-

- Length = 20m(Assumed – Maxm)
- Cross sectional area = 50 sq mm = 50x 10-6 sqm
- Specific resistivity of Copper = 1.7 x 10-8 Ohm-m.
- To find Resistance of copper cable = Spec resistance x Length

$$= \frac{\text{Area}}{\text{1.7x 10-8 Ohm –m x 20m}}$$

$$\frac{}{\text{50 x 10-6 sq m}}$$

= 0.007 Ohms.

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.

Floating Roof Tanks:

In addition to the concepts followed in case of fixed roof type tanks, following measures are essential in case of floating roof type tanks used for storage of flammable liquids:

a) Metallic straps (Shunts) at intervals of not over 3 meter length on the circumference of the roof between the floating roof and the metallic shoe that slides on the inside of the shell will permit the charge to drain off without igniting vapour under the seal (Fig. 9) Refer API-RP-545 for cross-sectional area - minimum width and material of the Shunts, During M&I of storage tanks, the above deck shunts (if any) should be replaced with submerged shunts.

b) Tanks without a vapour space at the seal or with non-conductive seals do not generally require shunts at the seal. However, if shunts are not provided a tight seal must be maintained to prevent accumulation of vapours. Where metallic weather shields cover the seals they shall maintain contact with the shell.

c) Where a floating roof tank is equipped with both primary and secondary seals in compliance with environmental regulations, shunts shall be installed so that they directly contact the tank shell above the secondary seal as in case of primary seals explained in “a” above.

d) All conductive parts of internal floating covers or the floating portions of covered floating roof tanks, ladders should be electrically interconnected and bonded to the tank roof/shell.

e) The tank floating roof shall be bonded to the tank shell by direct electrical connection through bypass conductors in line with API-RP-545. The bypass conductors shall be of the minimum length necessary to permit full movement of the floating roof. Bypass conductors should be evenly spaced not more than every 30 m (100 ft) around the tank circumference with a minimum of two.

f) All gauge & guide pole assemblies, pertaining to floating roof should be electrically insulated from floating roof. This is to prevent jumping of lightning current across it. The insulation level should be rated greater than 1 KV.

Kusam Meco KM-822s-EX Intrinsically Safe Digital Multimeter

Home / Digital Multimeter
(Click to check other models)

Product Details

Brand: Kusam Meco

Kusam Meco KM-822s-EX - Intrinsically Safe True RMS Digital Multimeter with PC Interface.

KM-822s-EX complies to IEC SANS 600790:2000 & IEC SANS 60079-11:1999, which is an electrical apparatus for explosive gas atmospheres. Part 0 (general requirements) & part 1 (intrinsic). The approved explosive protection rating of this equipment is suitable for use in Zone 1 hazardous area, Group I (coal mines) underground & Group II (surface).

28II EX

ROBUST AND INTRINSICALLY SAFE

ecom
A PEPPERL+FUCHS BRAND

CERTIFICATION	
ATEX	ⓔ II 2 G Ex ia IIC T4 Gb ⓔ I M1 Ex ia I Ma
IECEX	Ex ia IIC T4 Gb Ex ia I Ma
NEC/CEC	Class I, Division 1, Groups A,B,C,D Class I Zone 1 AEx ia IIC T4 Ex ia IIC T4
EAC	PO Ex ia I Ma X 1Ex ia IIC T4 Gb X IP6X

CERTIFICATION	
PCEC	Ex ia IIC T4 Gb
INMETRO	Ex ia IIC T4 Gb
ANZEX	Ex ia I Ma

WATER AND DUSTPROOF

The 28 II EX carries the most important Ex-certifications and is also tested for drops of up to 3 meters. Additionally it is waterproof and dustproofed (IP67). Therefore, the 28 II EX DMM can survive the roughest treatment in the harshest environments.

CAT III 1000V
CAT IV 600V

True RMS

Multimeter **FLUKE 28II EX**

FOR ZONE 1

FEATURES & FUNCTIONS

- CAT III 1000 V/CAT IV 600 V
- Dustproof, waterproof (IP67)
- Measures up to 1000V / 10A (outside of the Ex-hazardous area)
- Min/Max/Avg and Peak capture

APPROVALS

The Fluke 28 II EX is available with different approvals - from ATEX to IECEx to NEC, so that the corresponding versions enable worldwide use on different continents in potentially explosive environments.

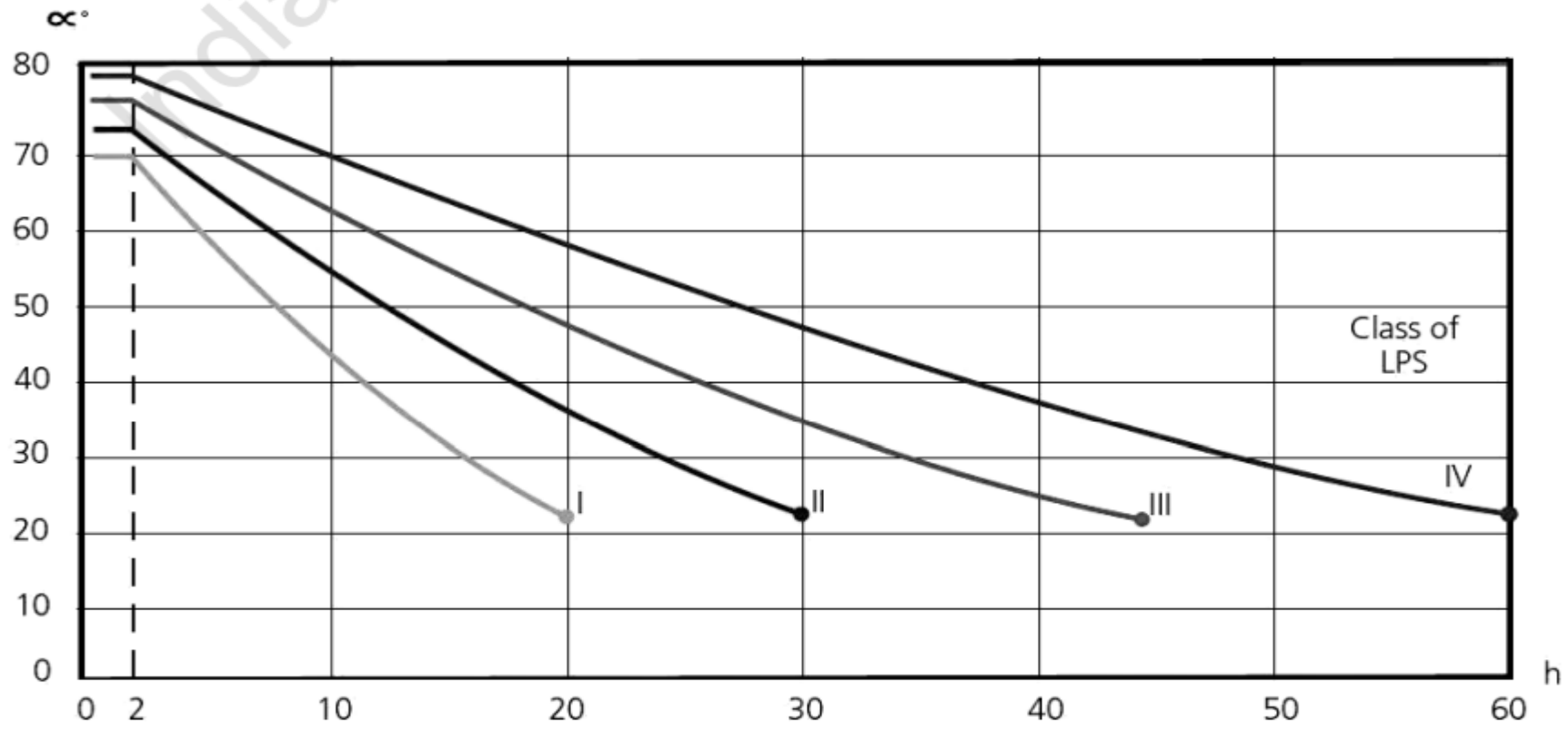
EASY TO USE

- Backlit keypad for extra visibility in poor lit areas
- Large display digits and 2-level backlight
- Long battery life: 400 hours typical (without backlight)

HANDLING BENEFITS

External Lightening Protection system.

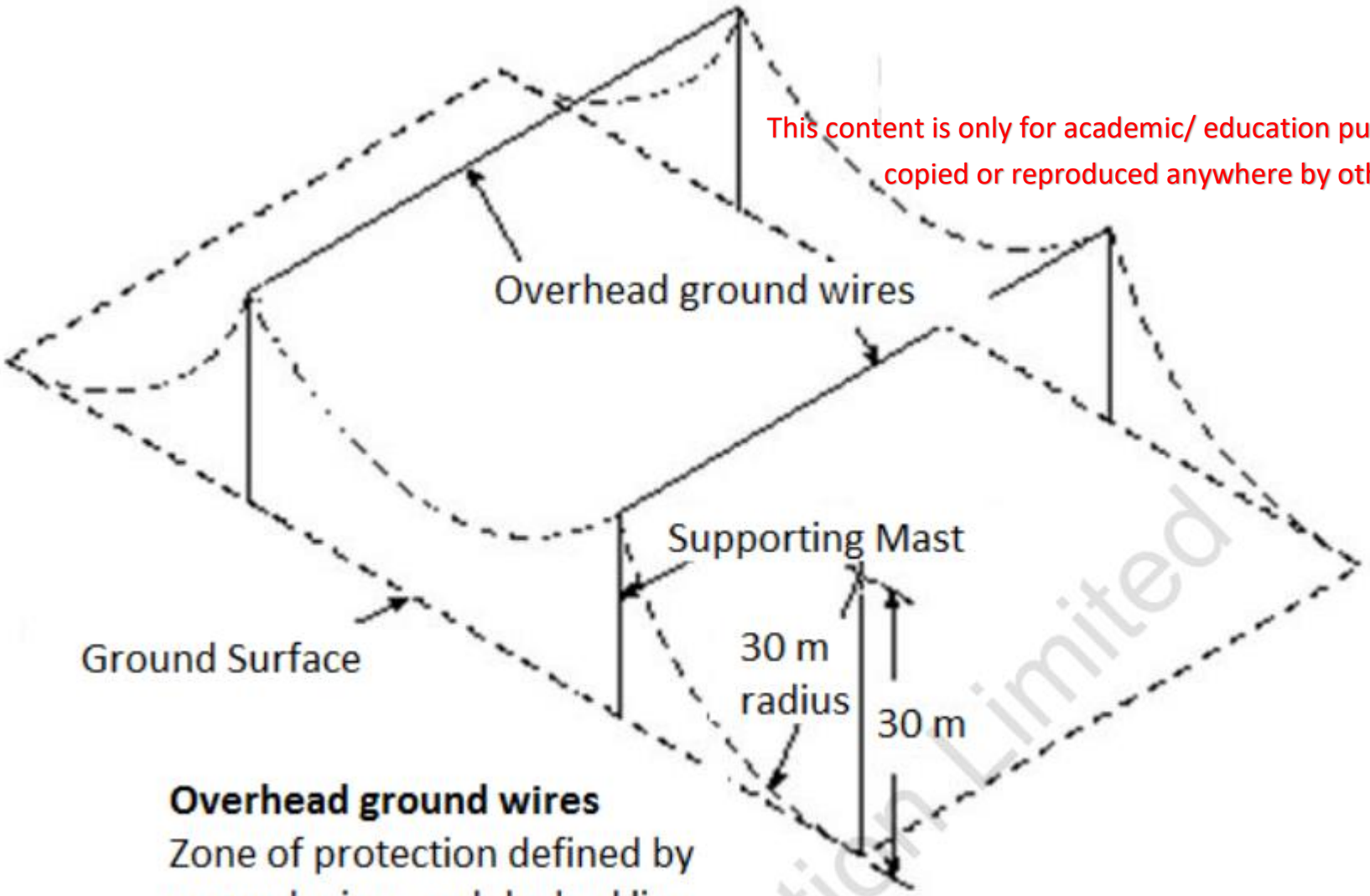
Relationship of protection angle corresponding to the class of LPS is mentioned below:



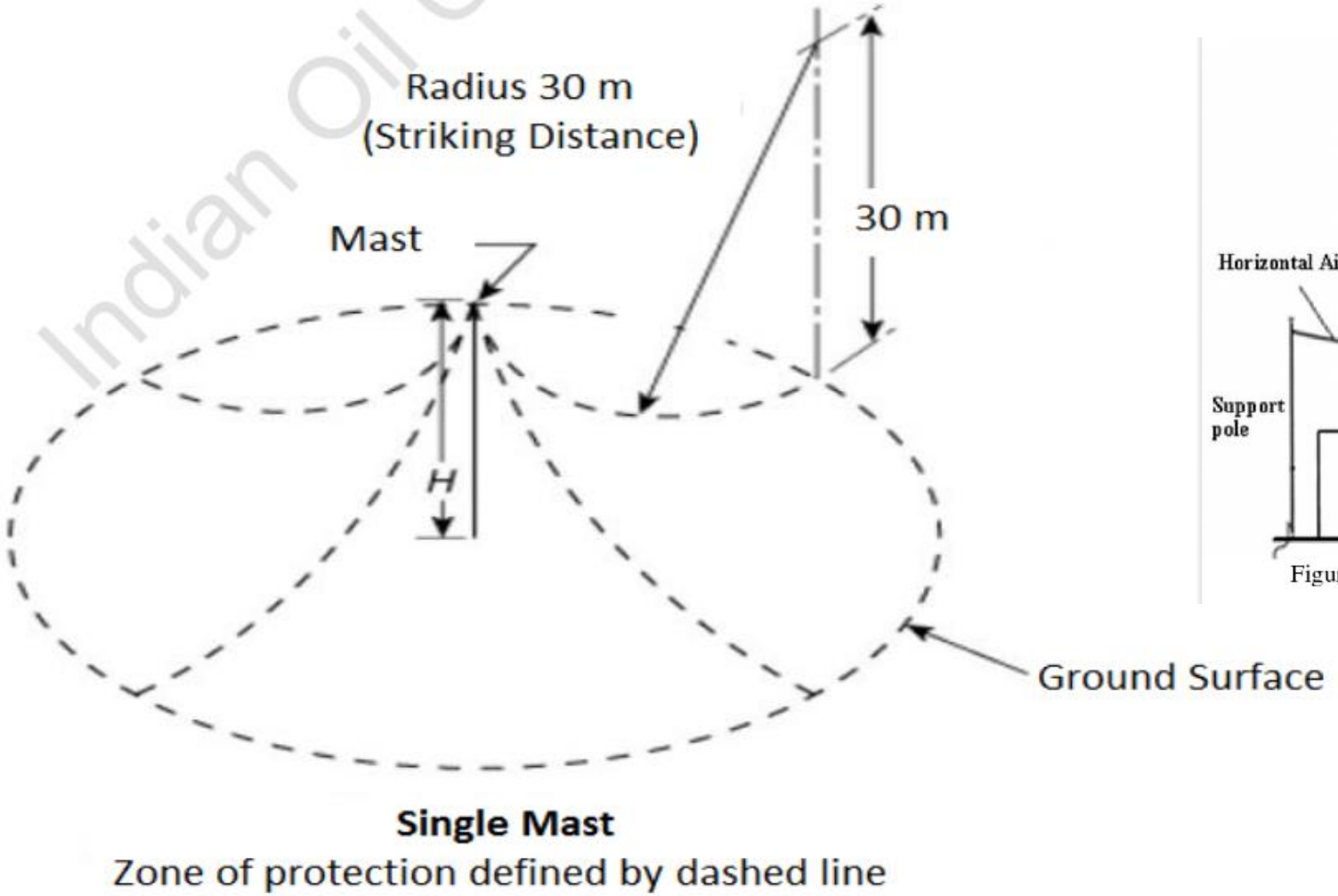
Protection angle graph.

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."

This content is only for academic/ education purpose. This should not be copied or reproduced anywhere by other than author.



Overhead ground wires
Zone of protection defined by ground wires and dashed line



Single Mast

Zone of protection defined by dashed line

Fig. 3

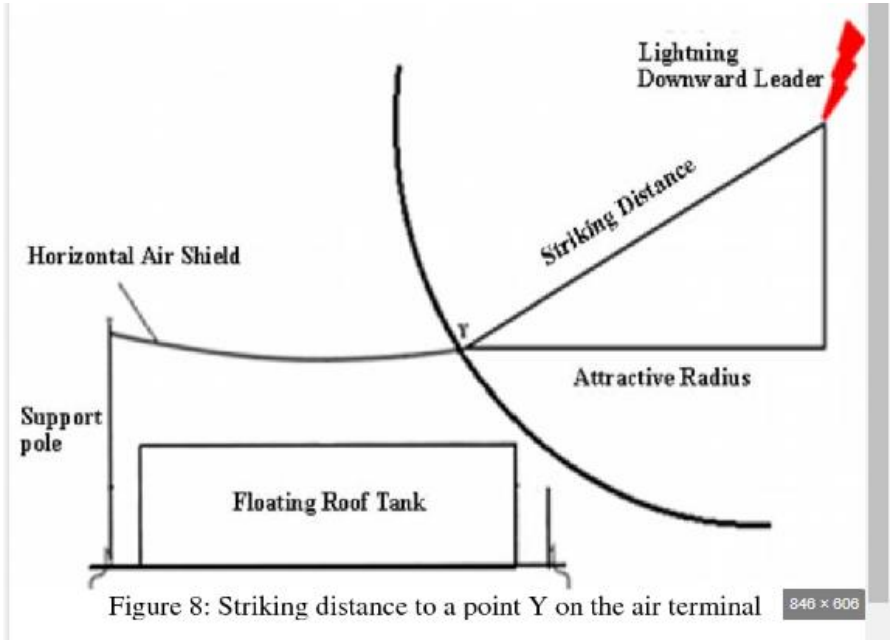


Figure 8: Striking distance to a point Y on the air terminal

4.0 LIGHTNING PROTECTION SYSTEM

4.1 Need for Protection

4.1.1 The necessity of providing lightning protection for structures located in non-hazardous areas shall be assessed by calculating overall risk factor. However, for hazardous areas lightning protection is essential considering the serious consequences of fire/damage due to lightning strokes and shall be provided irrespective of the value of risk factor. As mentioned in IS/IEC 62305-2, at least class II LPS should be adopted for the structure with a risk of explosion, though exception may be allowed when technically justified. Further, lightning protection level III may be adopted where the infrequency of lightning activity and/ or the insensitivity of the contents of the structure warrant it. Lightning protection shall be provided, as applicable, in

Class of LPS	Rolling Sphere radius (m)
I	20
II	30
III	45
IV	60

"OISD hereby expressly disclaims any liability or responsibility for loss or damage resulting from the use of OISD Standards/Guidelines."

line with the guidelines given in the subsequent sections of this Guideline. IS/IEC 62305-1 should be referred for general principles of LPS.

The size of earth mesh required is defined by the level of LPS determined/selected

LPS Class	Mesh Size (M)
I	5 x 5
II	10 x 10
III	15 x 15
IV	20 x 20