LIGHTNING ELIMINATORS
WWW.LIGHTNINGPROTECTION.COM

RETRACTABLE GROUNDING ASSEMBLY (RGA™)

RISK MANAGEMENT FOR FLOATING ROOF STORAGE TANKS

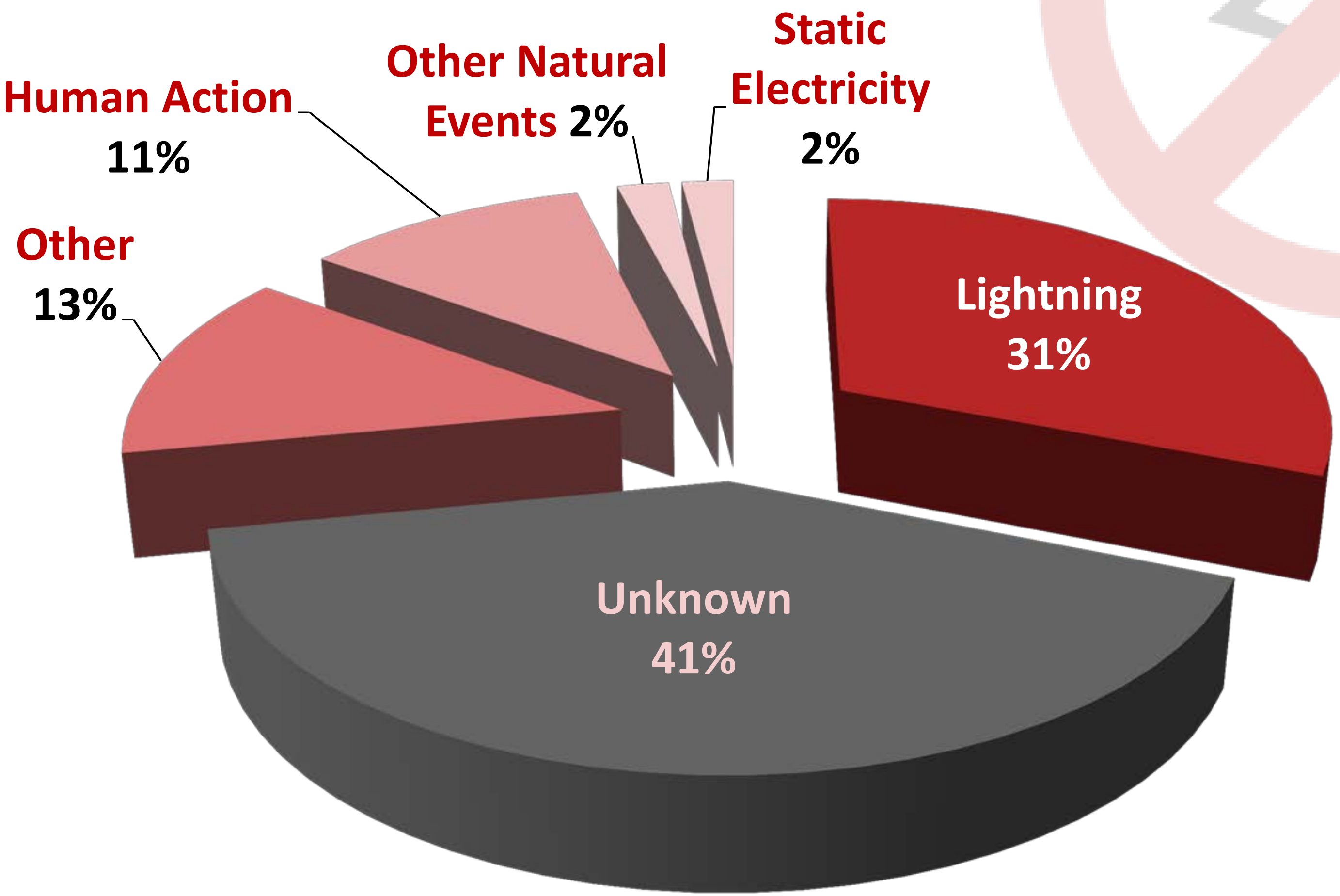
Agenda

- Lightning Statistics
- Lightning Discharge Process
- Bonding: The Roof-Shell Interface
- American Petroleum Institute

Storage Tank Lightning Facts

- **15 to 20 tank fires per year worldwide**
- **One-third attributed to lightning**
- **Lightning accounts for 61% of all accidents in storage and processing activities, where natural events are identified as the root cause of the incidents.**
- **In North America, 16 out of 20 accidents involving petroleum products storage tanks were as a result of lightning strikes -** *Liverpool John Moores University (W. Atherton & J. W. Ash), 2006*
- **15% increase in lightning-related losses from 2009 to 2010 –** *Lloyds & Insurance Information Institute, 2011*

Causes of Tank Fires



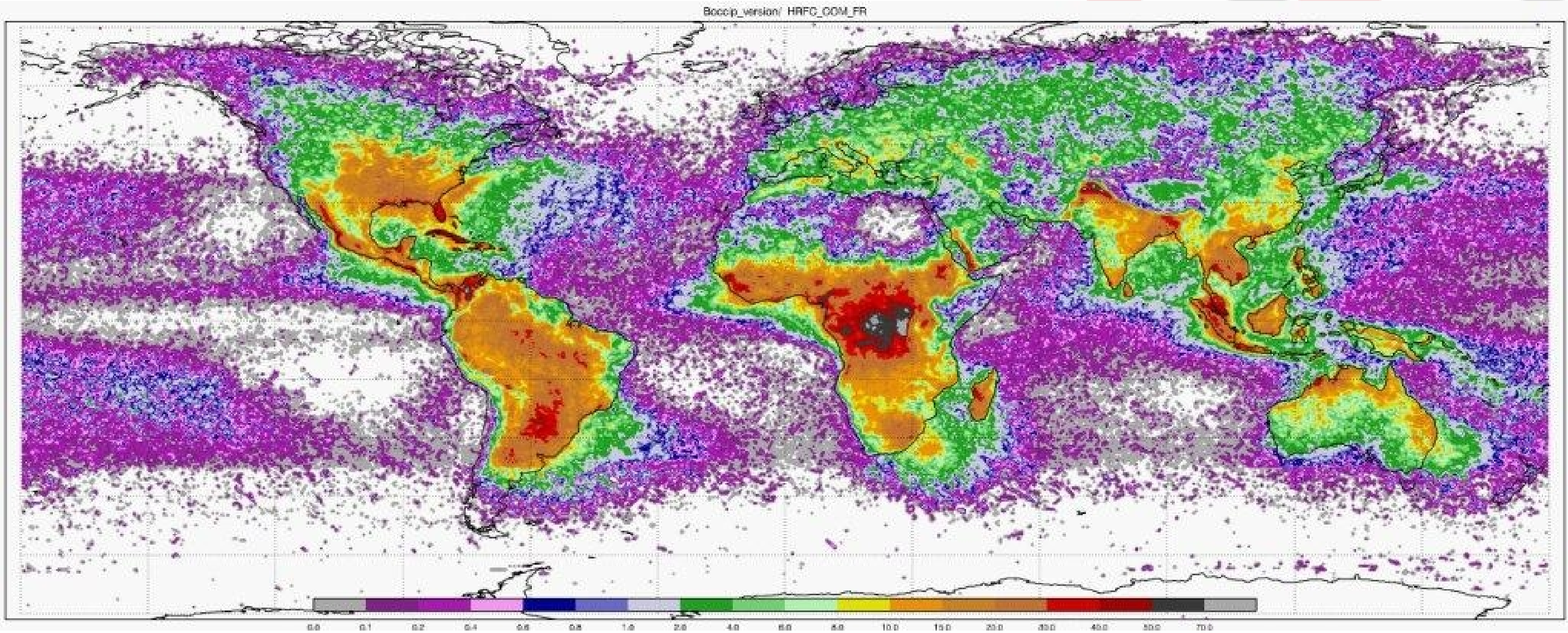
Tank Fires

1. PDVSA Bajo Grande Refinery, Venezuela – 2012
2. Mitsui Chemicals Iwakuni Otake Petrochemical Complex, Japan – 2012
3. MagRe Tech Refining, Bellevue, Ohio, USA – 2012
4. China Petrochemical, Heshan City, China – 2012
5. Sabine Disposal, Liberty, TX, USA – 2011
6. Green Tide Water Disposal, TX USA -2011
7. Kingman County, Kansas, USA- 2011
8. Colonial Pipeline Company, North Carolina, USA – 2010
9. McCook TX, USA- 2010
10. St. Mary Parish, LA, USA – 2010
11. Teppco at the Seaway Crude Oil facility, Texas, USA – 2009
12. Magellan Midstream Partners, Kansas, USA – 2008
13. Wynnewood Refinery Co. Oklahoma, USA – 2007

Tank Fires

14. The Engen Refinery, South Africa- 2007
15. Sunoco's Eagle Point Refinery, New Jersey, USA – 2007
16. Brisbane Oil Refinery, Australia – 2003
17. Escravos Tank Farm Fire, Nigeria, Africa - 2002
18. Trzebinia Refinery Malopolsak Region, Poland – 2002
19. Orion Refinery, Norco, LA, USA – 2001
20. Shell Oil, Woodbridge, New Jersey, USA – 1996
21. Sunoco Refinery, Sarnia, Ontario, Canada – 1996
22. Amoco Refinery, Texas City, USA – 1996
23. Pertamina Refinery, Cilacap, Indonesia – 1995
24. Newport, Ohio, USA – 1987
25. Newport, Ohio, USA – 1986
26. Chemischen Werke Huls, Herne, Germany – 1984

World Flash Density - NASA



Units are flashes per km^2 per year

LIS data has been updated through 2010 (the LIS data began in 1998). The LIS (Lightning Imaging Sensor) data observes the tropics between about 38S to 38N. Data for latitudes outside the tropics – pole-ward of 38 degrees) are from OTD (Optical Transient Detector) data obtained from 1995-2001.

Stroke Data

Peak Current	2 – 510 kA
99%	≅ 200 kA
50%	≅ 30 kA
Negative Polarity	> 90%
Time Between	> 10 Seconds
Duration (99%)	30 to 200 μs
RFI Range (95%)	200 kHz – 20 mHz

Cost Examples: Losses and Damages

Mitsui Chemicals Iwakuni Otake Petrochemical Complex, Japan April 21, 2012

Facility summary: stored uranium for nuclear fuel and radioactive waste The plant included 3379 units of radioactive waste (200L in each unit) and Uranium for nuclear fuel

Cause: Lightning strike

Damages:

- Killed 1/ Injured 25
- 100 houses near the plant were destroyed
- Close to one 1000 homes were damaged and
- 18 plants shut down due to the blast for months

Minimum Cost: > $40 Million – only includes loss of sales. This does not cover liability, regulatory fines or reparations

Environmental Damage: Increase in Radioactivity in the area

Additional Loss Examples:

- **2011 - Green Tide Salt Water Disposal Facility, Imperial Oil and Gas, Equipment Losses - $530,000.00**
- **2008 - Magellan, Kansas– > $ 10 Million as of 3 months after the accident**
- **2007 - Wynnewood Oil Refinery, Oklahoma USA –$15 Million (approx.) - including 50000 bbl naptha, 30,000 bbl diesel, 50,000 bbl gasoline per day (shut down for 3 days); Equipment damage costs not included**
- **1995 Cilacap, Indonesia – > $292 Million including 10 Tanks containing Oil, Petrol, Kerosene - shut down for ½ year; Plant produced $400,000 of product per day. 400 employees lost jobs for 1.5 years; Equipment damage unknown.**

Tank Fire Considerations:

- **Size of tanks has increased**
  - more severe hazard in the event of a fire
- **Tank fires extremely costly**
  - property damage, lost product, business interruption, environmental damage, and public opinion
- **Controlling tank fires**
  - large commitment of fire fighting resources

Lightning Cost & Statistics:

- **Lightning-related losses exceeded $5 billion in 2008 –** ***National Lightning Safety Institute, 2009***
- **By 2040s-2060s, weather damage in the UK during a "normal" year, is likely to be double that of current years –** ***Association of British Insurers, 2007***
- **Increased sea surface temperatures have been linked to increased cloud-to-ground lightning activity –** ***De Pablo & Soriano, 2002***
- **5-6% increase in global lightning activity can be expected for each 1°C change in global surface temperature –** ***NASA researchers Price and Rind, 1994***

Wynnewood Tank Fire

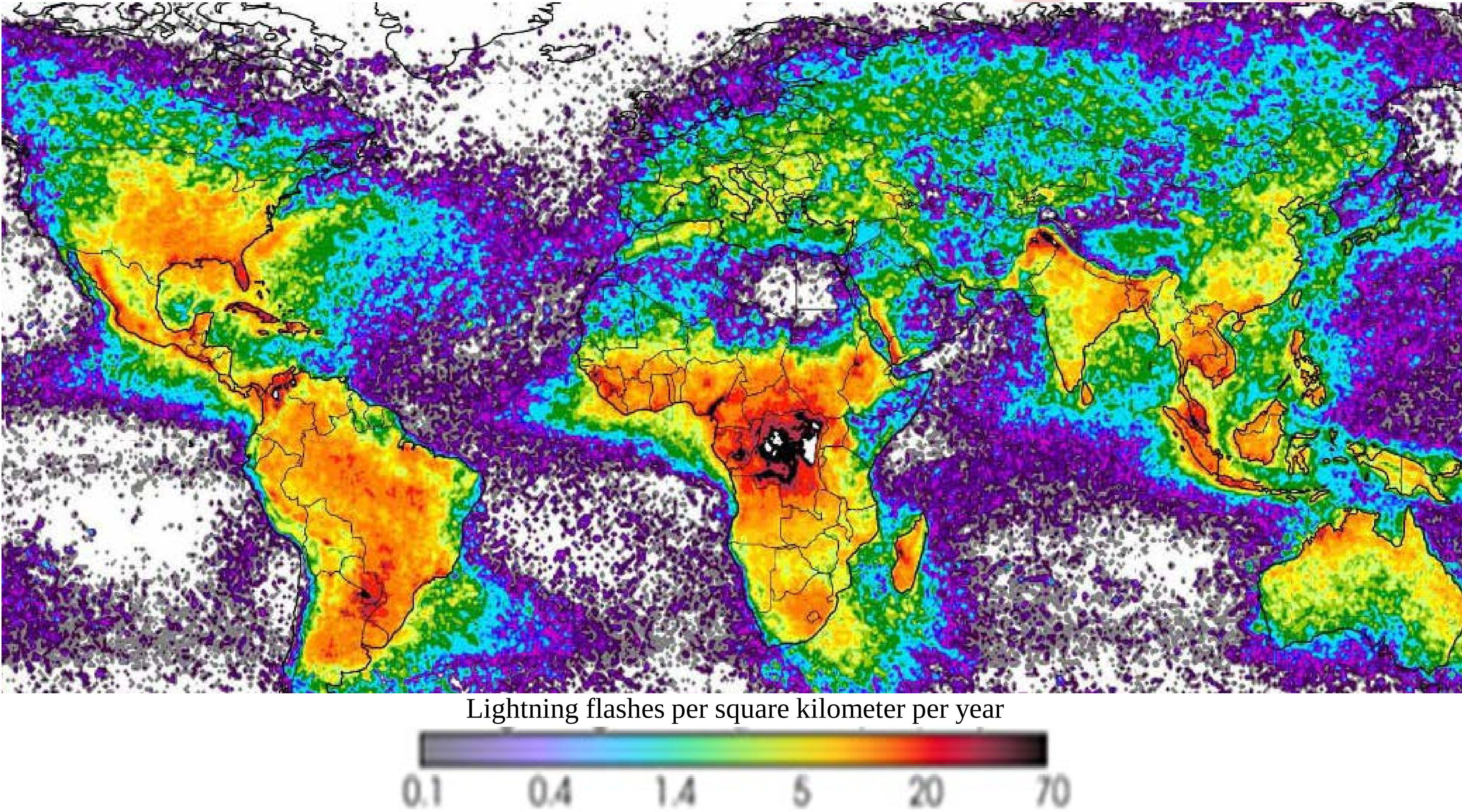
Internal Floating Roof Tank, Ignited by lightning, June 2007 - http://www.youtube.com/watch?v=KGlwLC_1qOI

How?

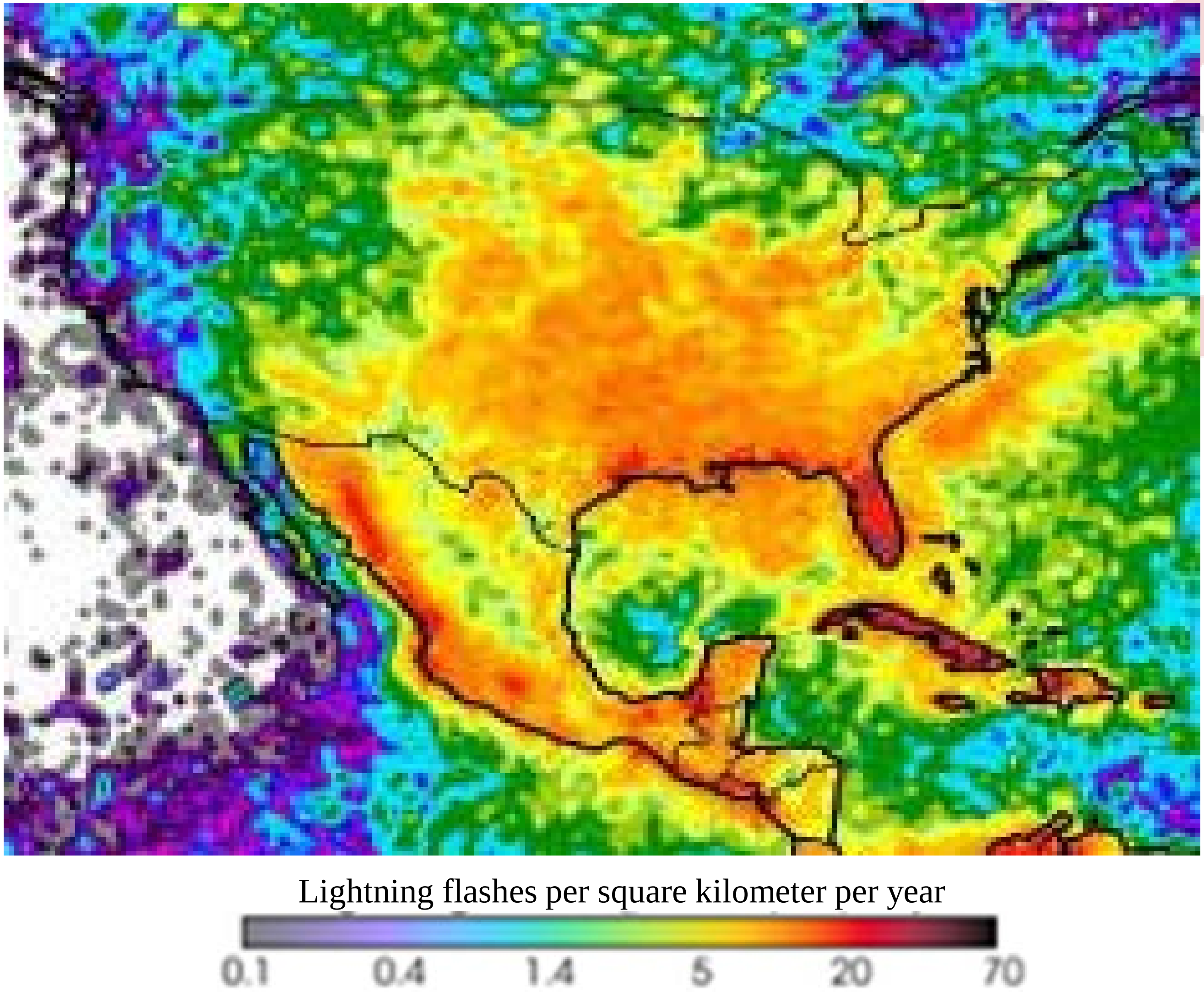
How does lightning cause ignition of tank contents?

What are the physics?

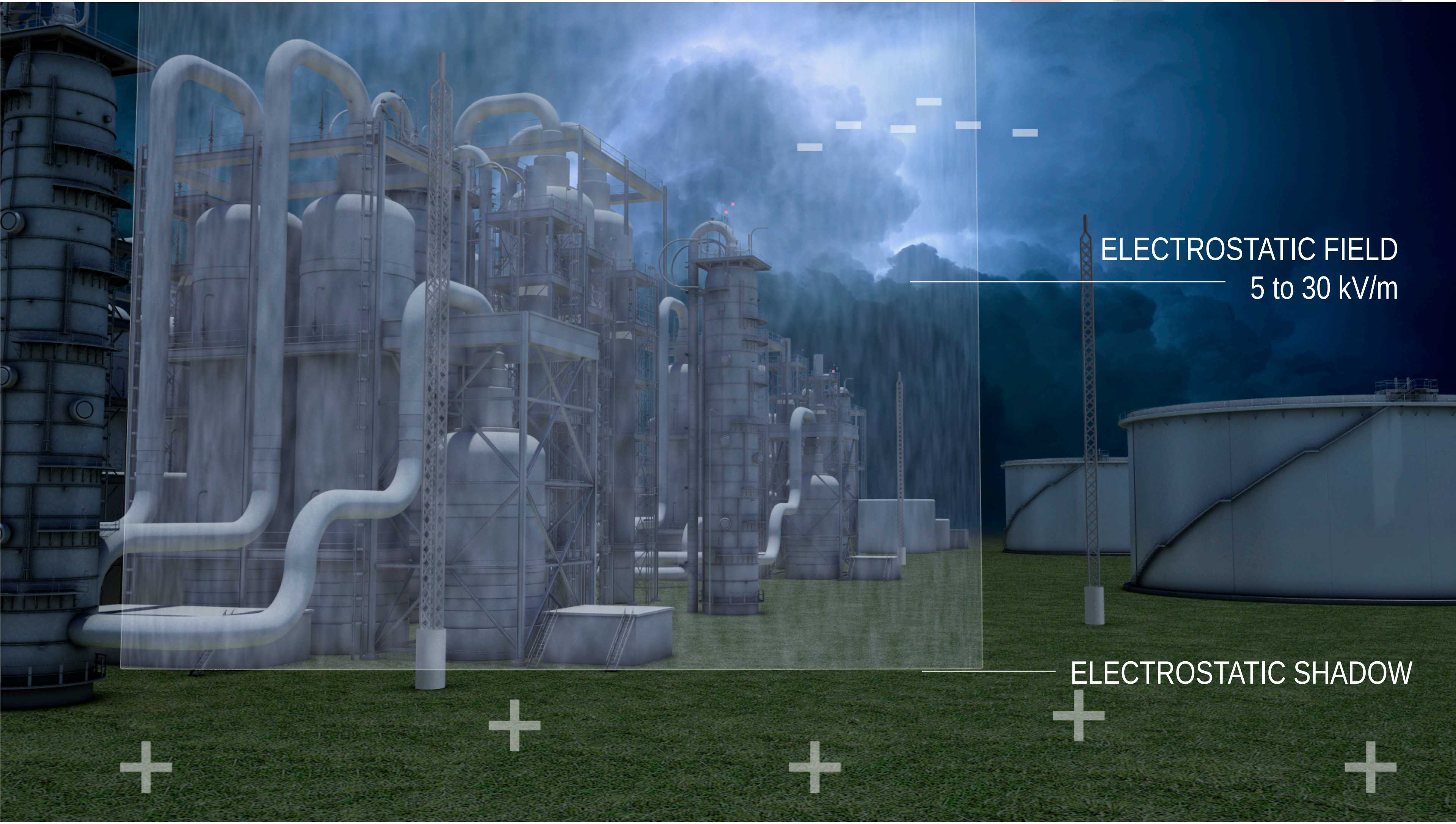
Lightning Strike Density



Lightning Strike Density – N. America



Electrostatic Field

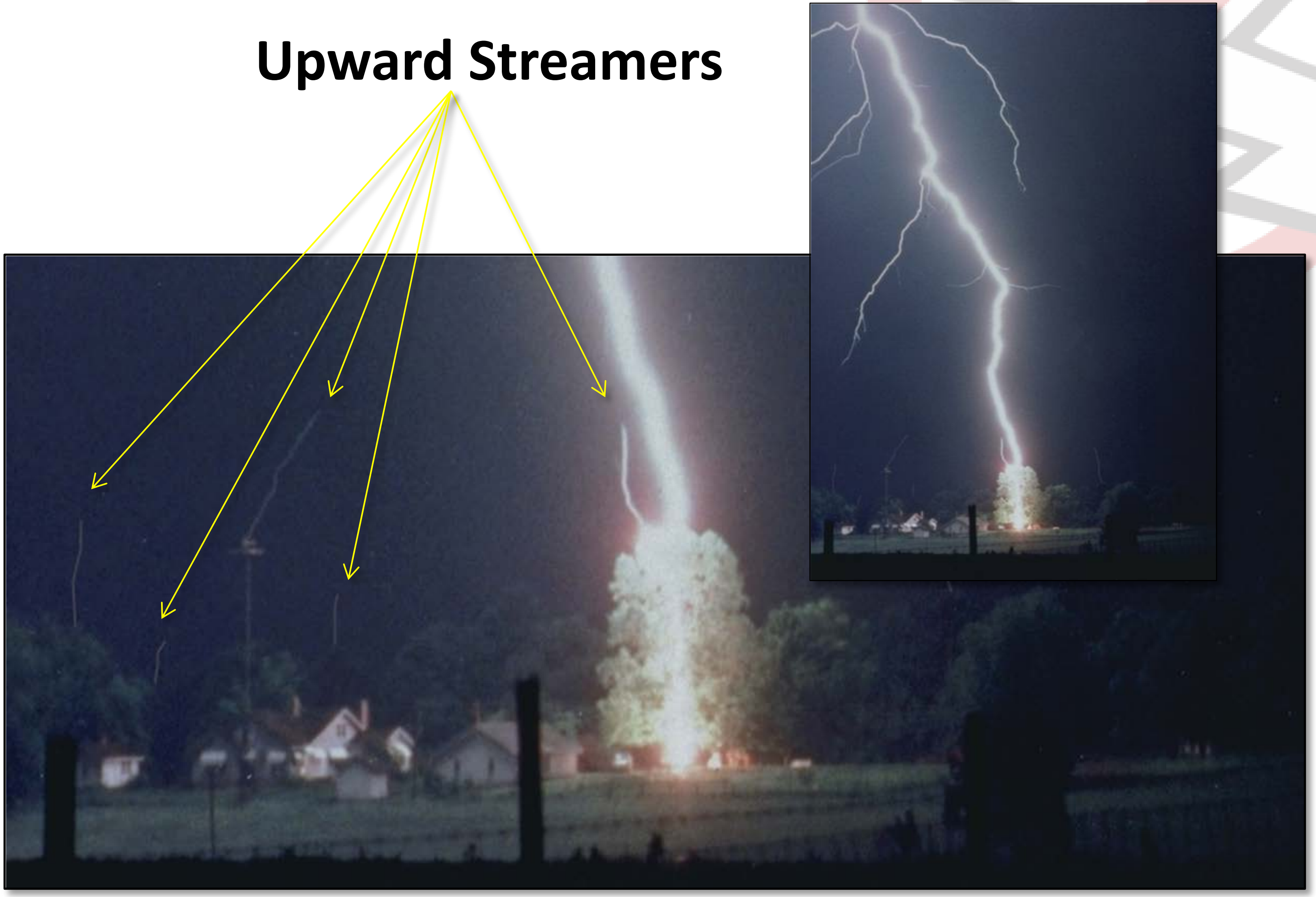


10^8 V ± 10%

Rising Streamers

Striking Distance

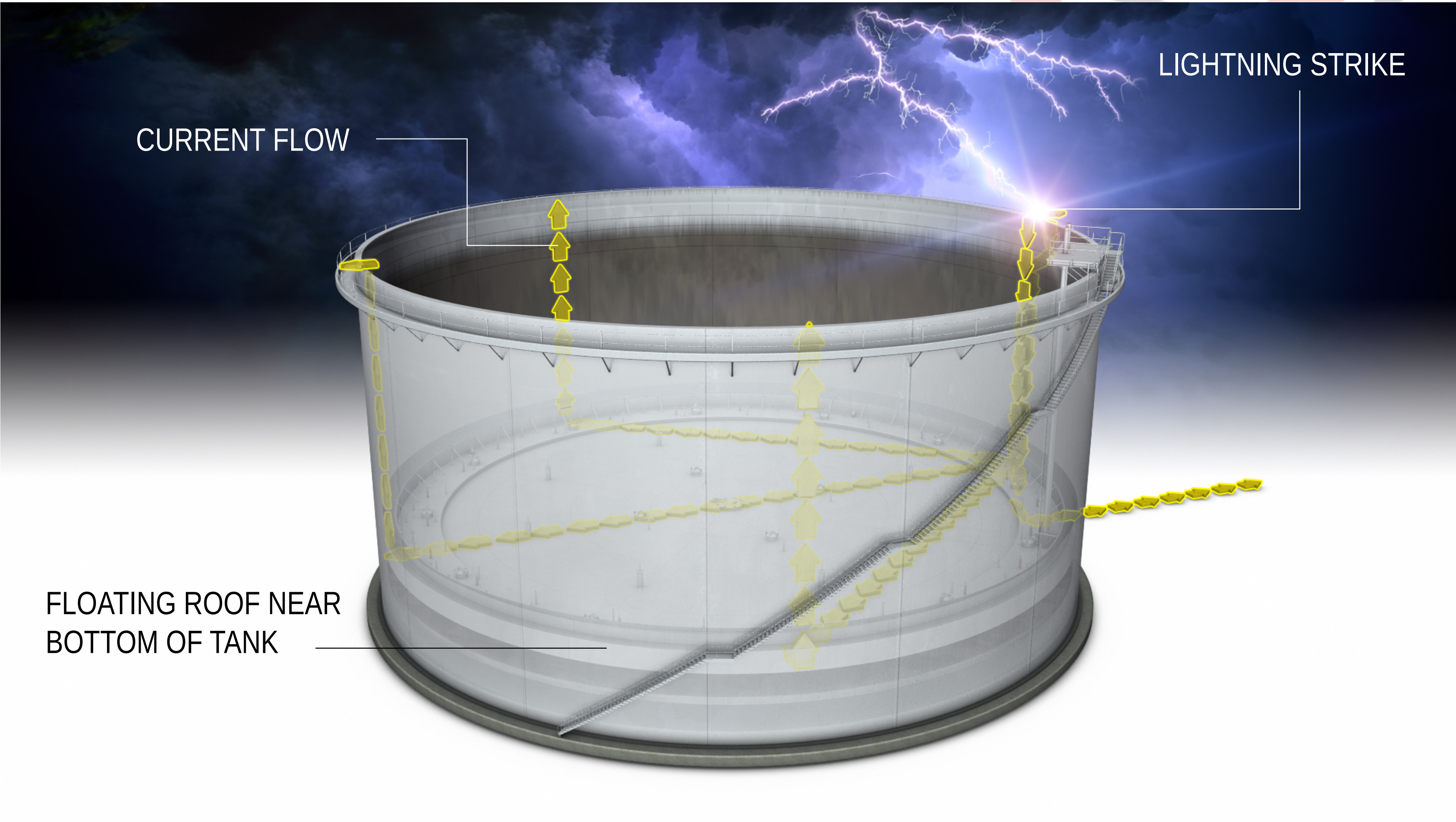
Storm Generated Upward Streamers



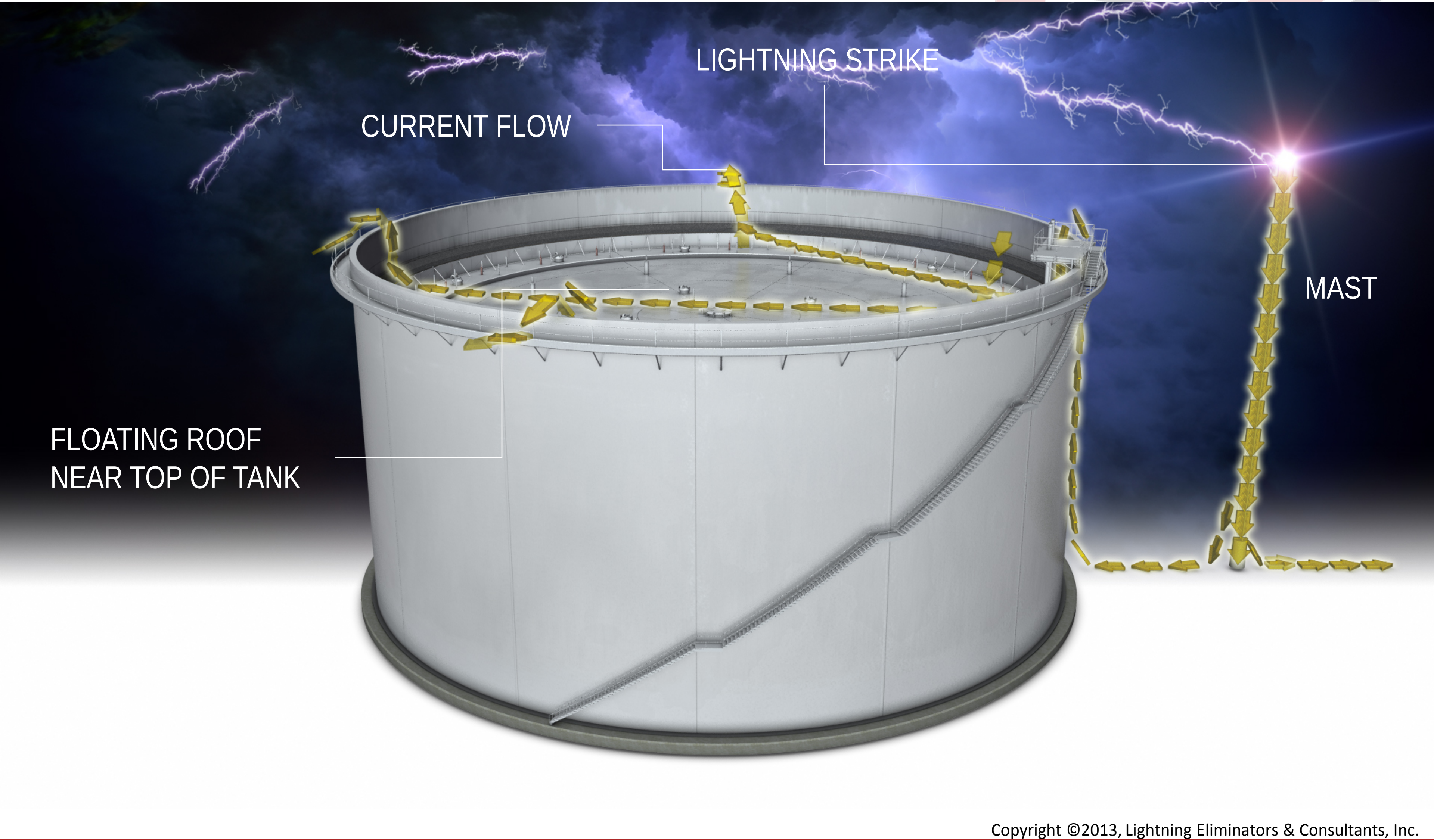
Key Lightning Parameters

Peak Current, negative first strokes (50^{th} %)	30 kA
Peak Current, negative first strokes (95^{th} %)	80 kA
Flash Duration, negative flashes (50^{th} %)	13 millisec
Flash Duration, negative flashes (95^{th} %)	1.1 sec
Range of Strokes per Flash	1 to 30
Average Number of Strokes per Flash	4
Peak Temperature (>50,000 F)	> 28,000 C

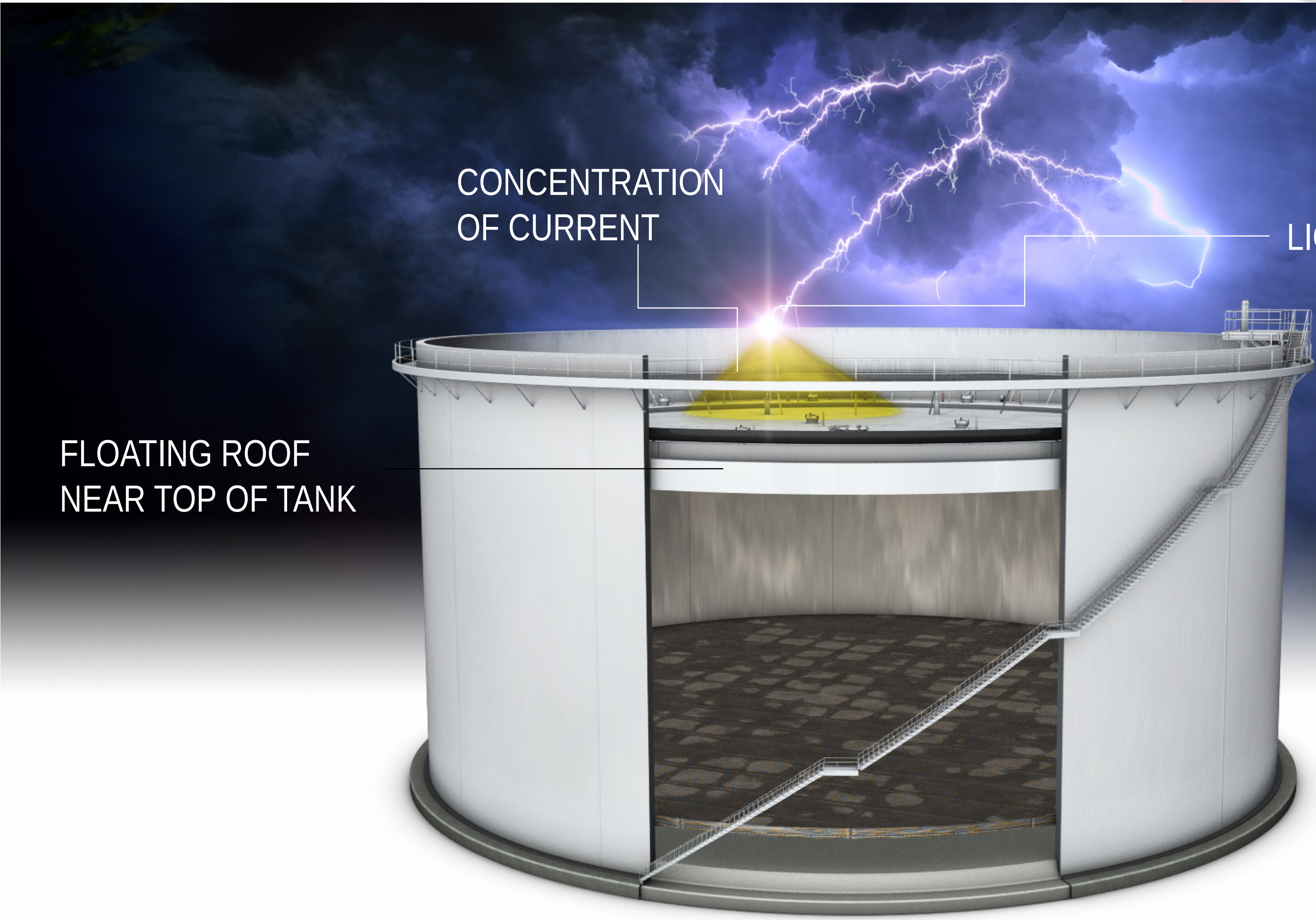
Current Flows from Direct Strike



Current Flows from Nearby Strike

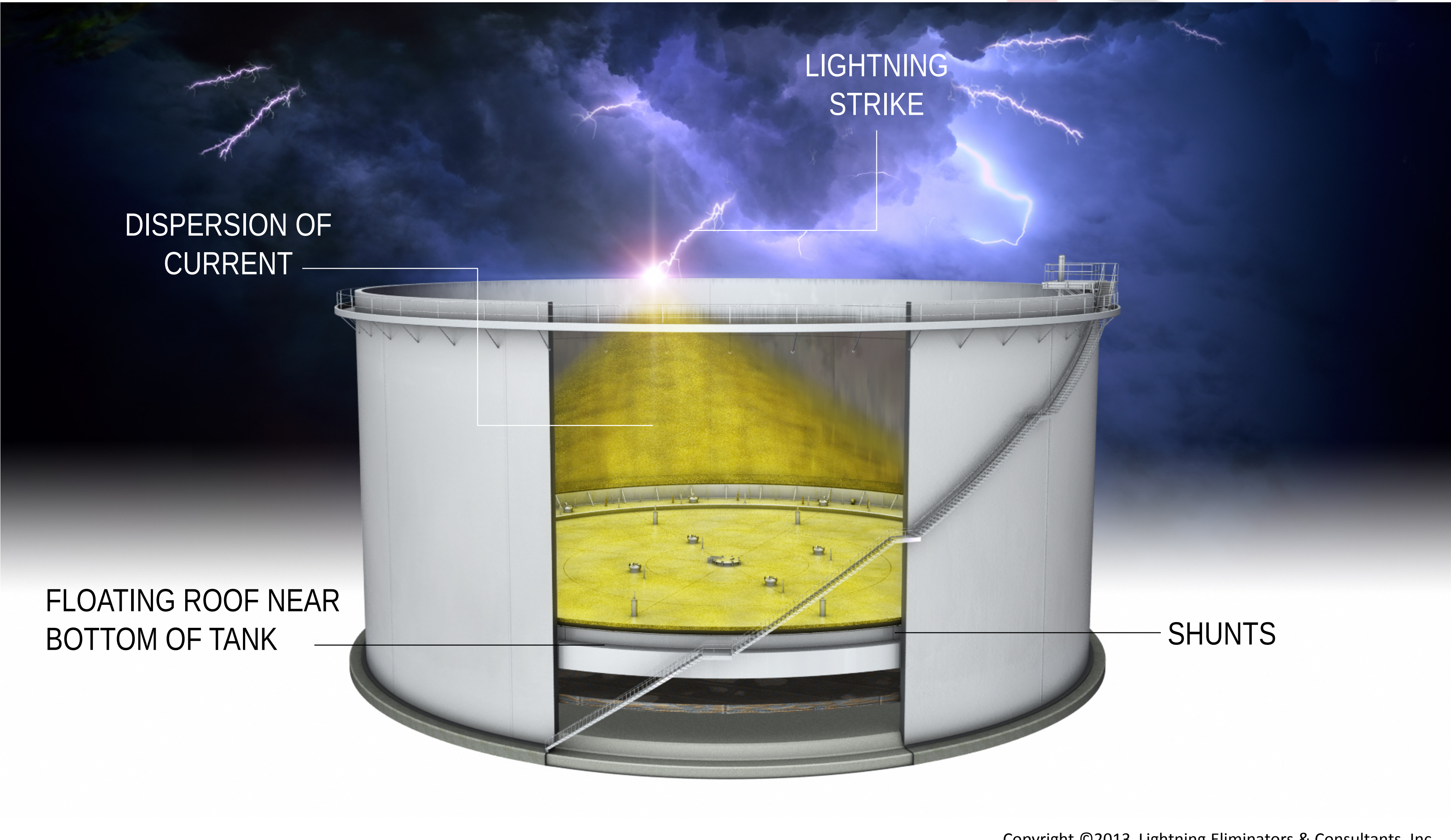


Tank is MOST at-risk when roof is high



80% of all tank fires occur when tank is more than half full

Tank is LEAST at-risk when roof is low



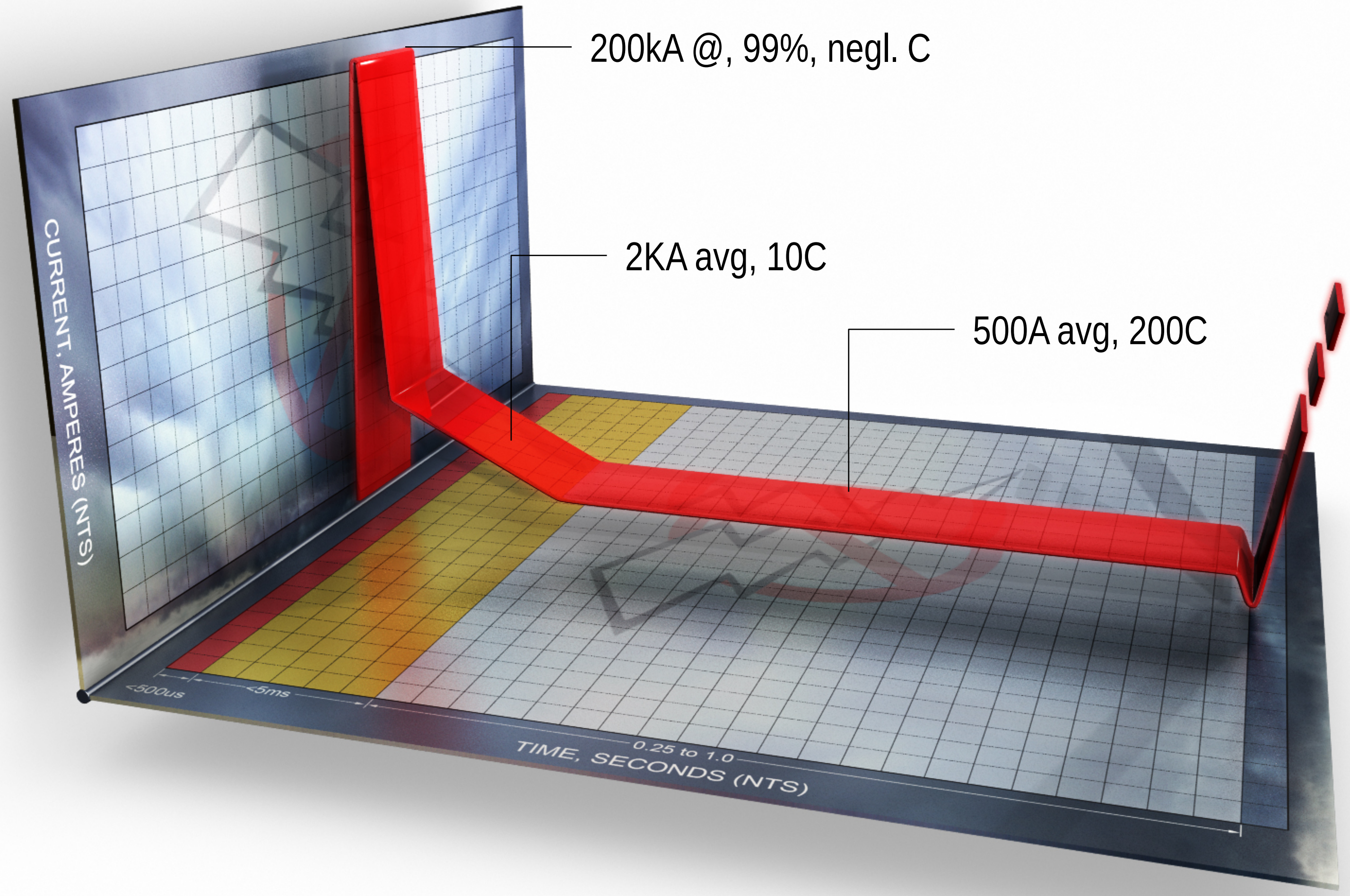
Impact on Grounding on Lightning Protection for Tanks

1. A tank is well grounded if resting on earth or foundation.
2. Occurrence of sparks, rim fires, etc., not dependent on grounding resistance.
3. Presence of membrane has no impact on lightning-related currents.
4. Lightning safety for tanks is not dependent on tank grounding.

Three Components of Lightning Strike

1. Fast component, up to about 100 microseconds
2. Intermediate component, up to about 5 milliseconds
3. Slow component, up to about 0.5 seconds

Three Components of Lightning Strike



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Peak Temperature	> 50,000 F

API RP 545

American Petroleum Institute (API) Technical Committee for Lightning Protection for Hydrocarbon Storage Tanks

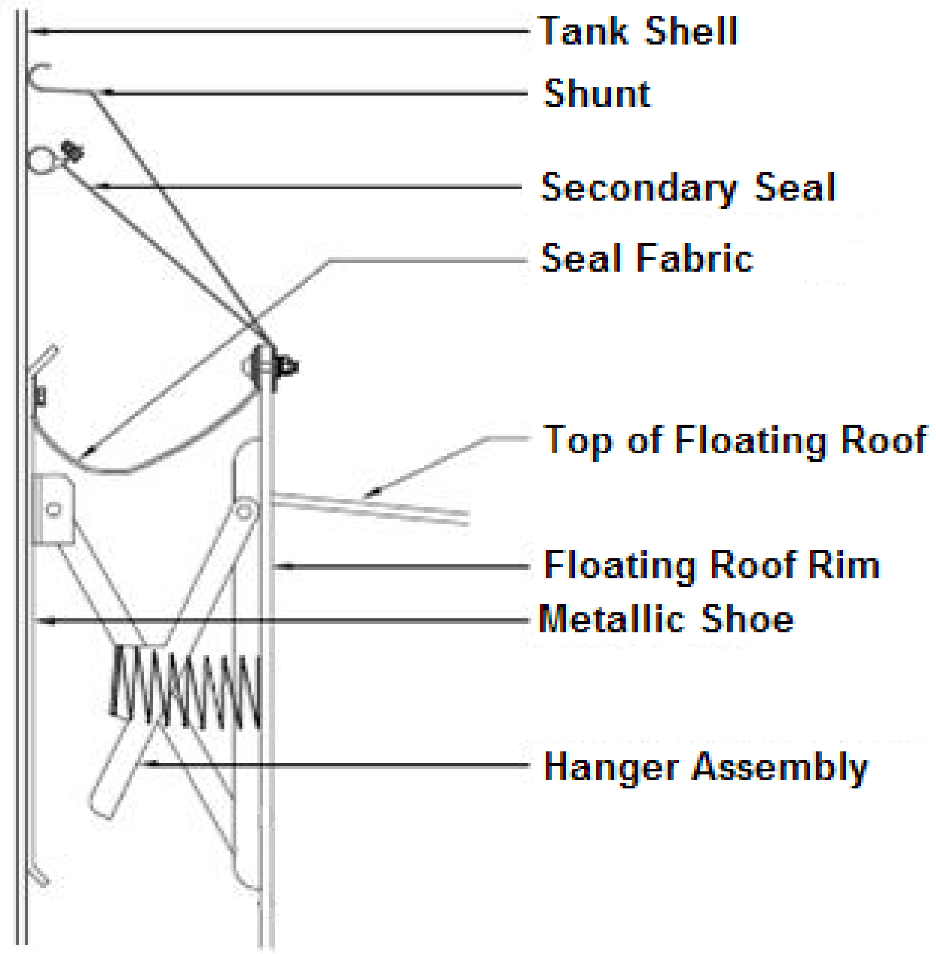
Project Start = 1999
Document released as RP in 2009
RP expected to become Standard

Committee Examined all Aspects of Lightning Effects on Storage Tanks

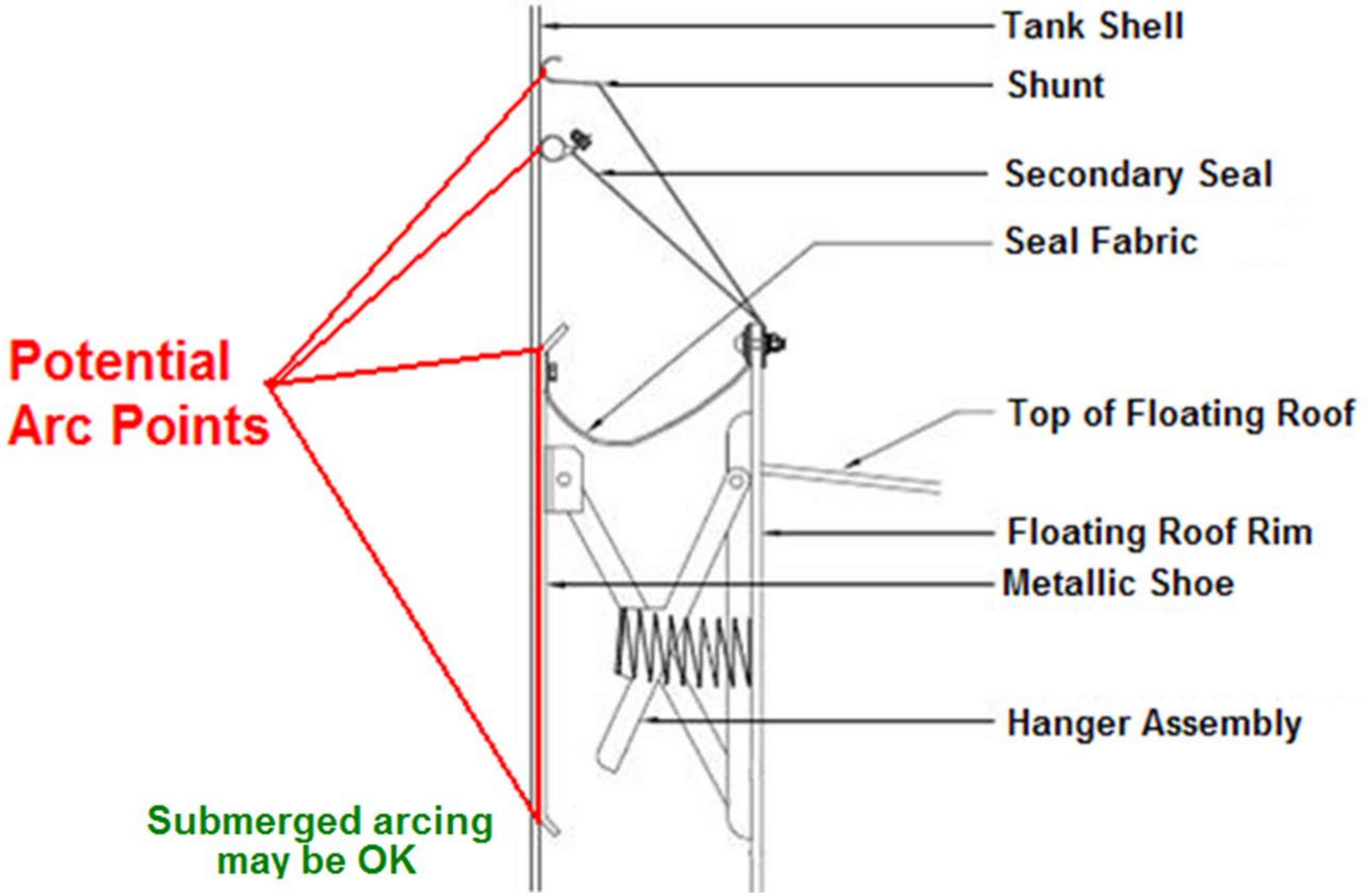
Focus on:

1. **Arcing in vapor spaces**
2. **Bonding**

Sample Cutaway of FRT Shell-Roof Interface



Potential Arc Locations at Shell-Roof Interface



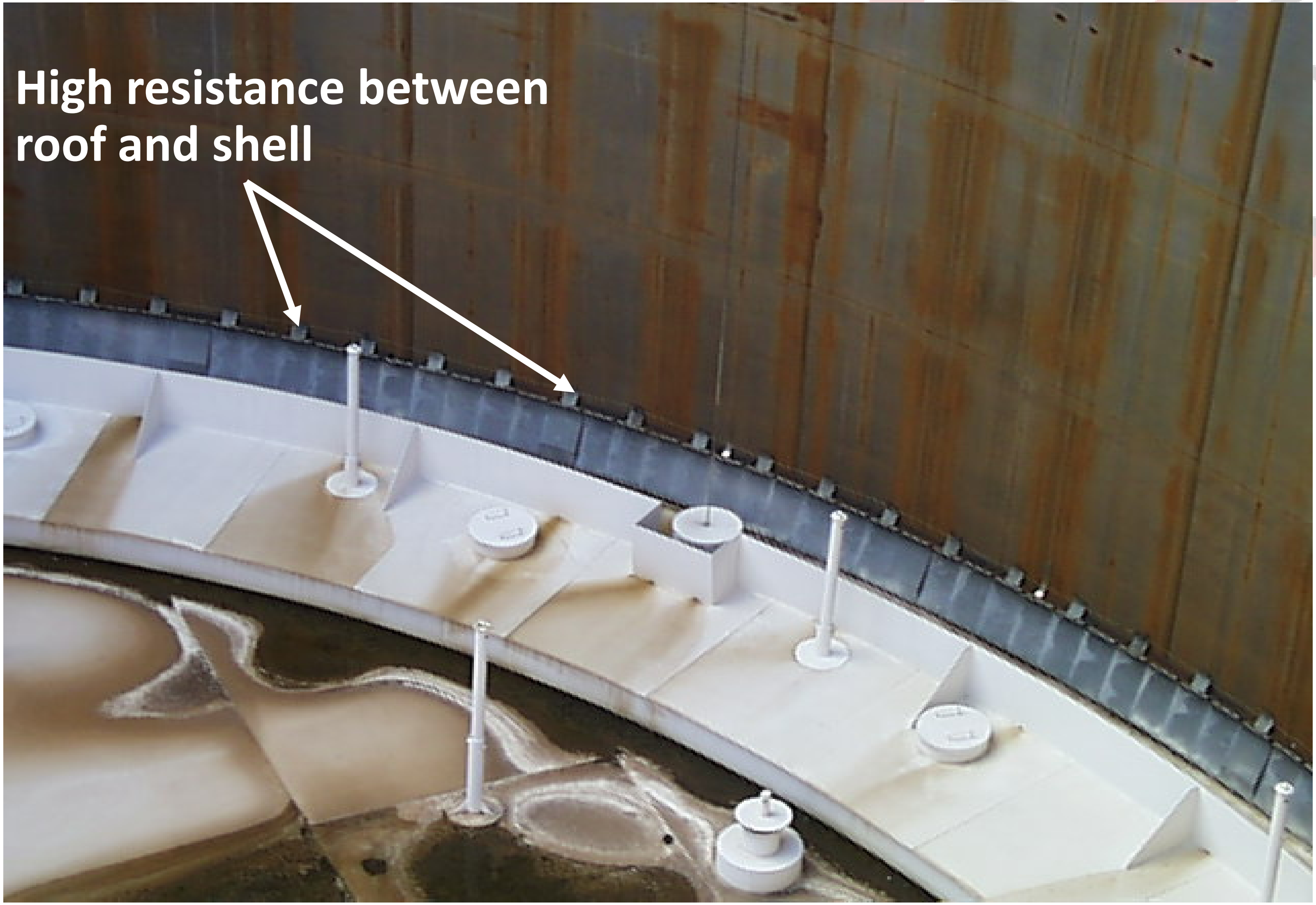
Methods to Bond Roof-Shell

1. **Shunt – short conductor connected to roof and contacting shell**
2. **Bypass conductor – cable providing direct connection between roof and shell**

Problems with Shunts

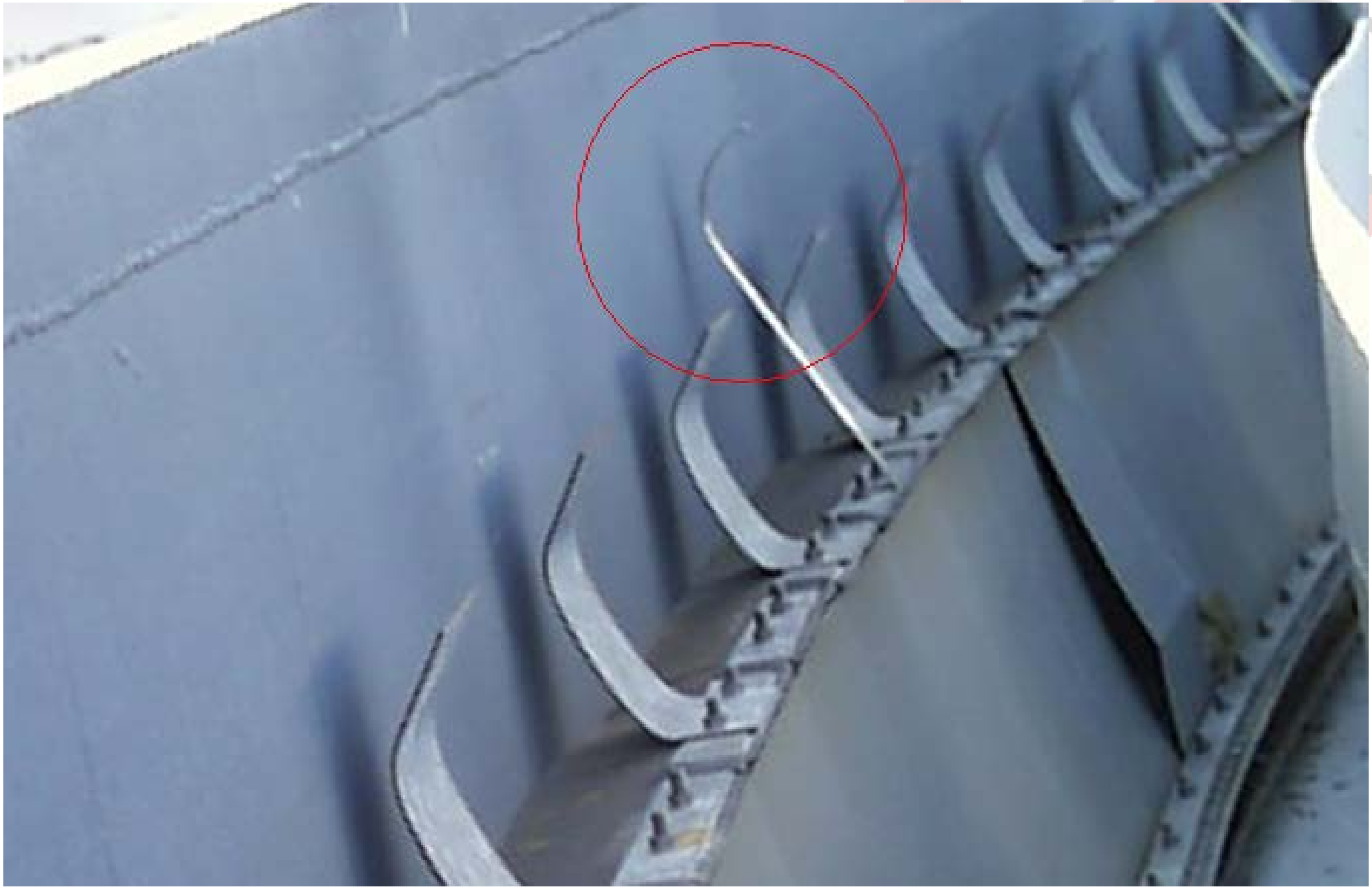
1. Dependent on spring tension for contact
2. Petroleum insulates tank inner surface
3. Floating roof is not always centered
4. Regular maintenance is required
5. Source of arcing

Shunts to Rust



Painted Walls

Shunt not making contact with Out-of–Round Tank



When Does Lightning Current Flow Across Roof/Shell Interface?

During strike to shell? Yes
During strike to roof? Yes
During strike near tank? Yes

Current flows across roof/shell interface in ALL situations.
(This is an official API finding!)

API Testing

API testing proved that shunts will arc under all conditions, whether they are clean, dirty, rusty, well-maintained, etc.

Shunt Warning

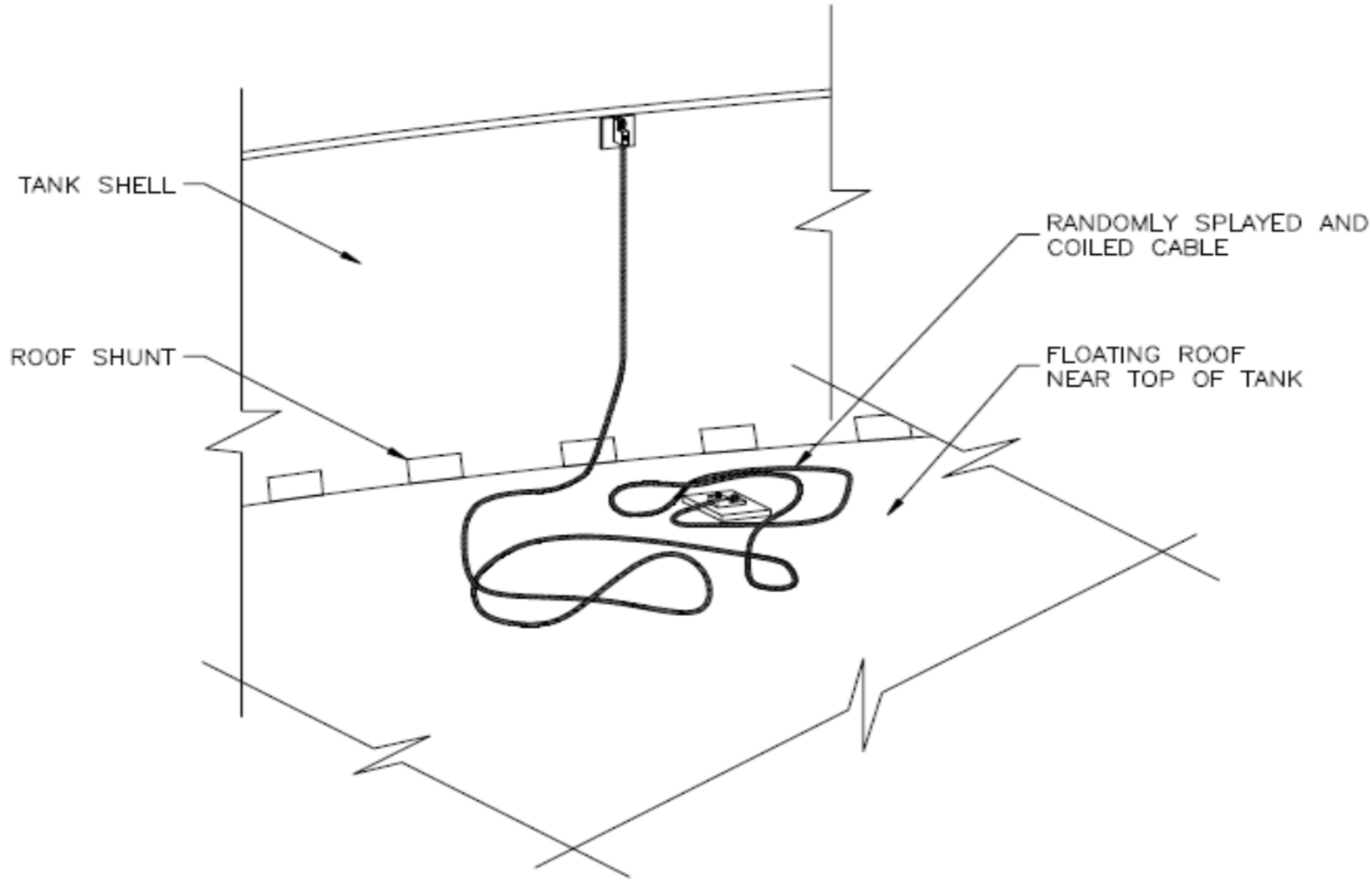
API FRT Shunt Warning from Summer 2006

Problems with Conventional Bypass Conductors

- Unnecessarily long
- High inductance
- Randomly coiled when roof is high*
- Rusty, painted connections
- Too few in number

*Tank is most at-risk when roof is high

Conventional Bypass Conductors, with High Roof



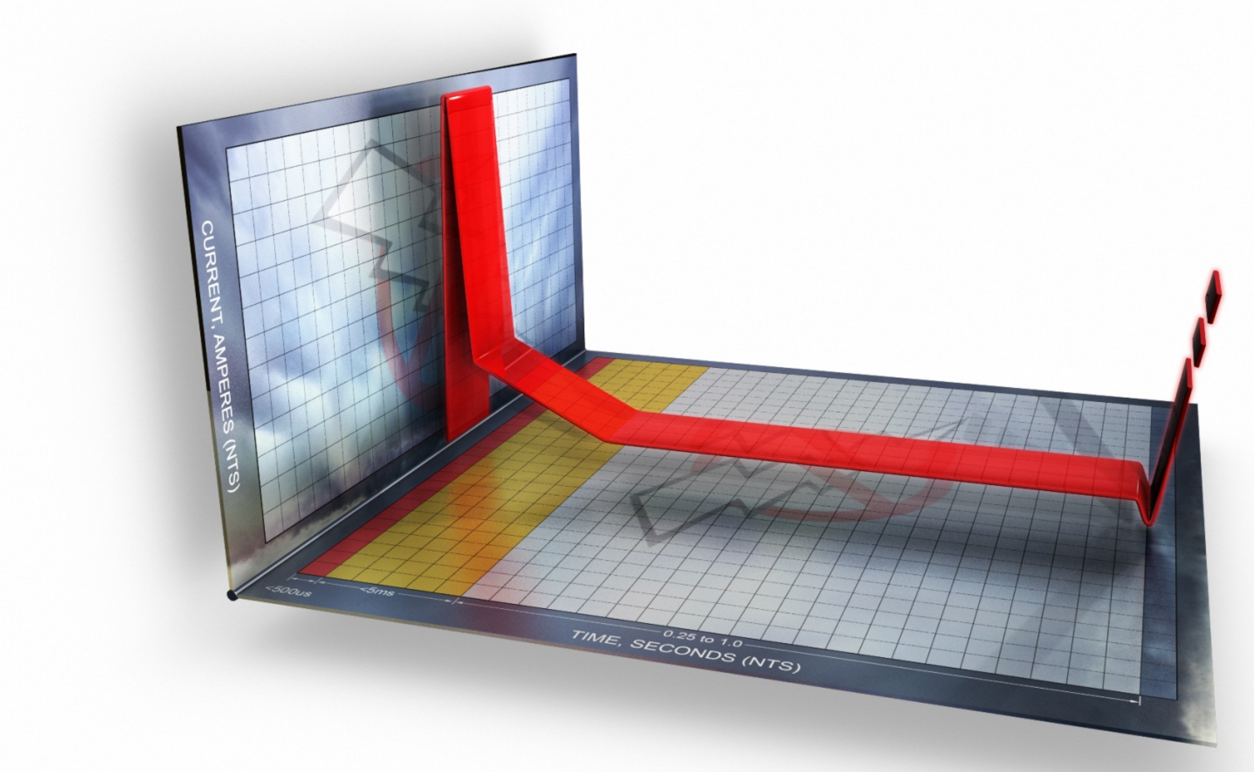
Walkway with Roof-Shell Bonding Cable

*Impedance is too high at lightning frequencies

Lightning Currents & Vapor Ignition

IGNITION OCCURS DURING COMPONENT C – ACCORDING TO API TESTING

BYPASS CONDUCTORS ARE NEEDED TO CONDUCT COMPONENT C – ACCORDING TO API



Lightning Current Paths

	Shunts	Bypass Cond.	Vapor Ignition
Fast	X		No
Intermed.	X	X	Yes
Slow		X	Yes

- The lower the inductance of the Bypass Conductors, the quicker the transition from the Shunts.
- Fast component is too brief to ignite vapors, per API testing.

RP 545: 3 Primary Recommendations

1. Install submerged shunts every 3m/10ft around roof.
   1. On existing tanks relocate shunts to under liquid.
   2. Submerge by one foot or more.

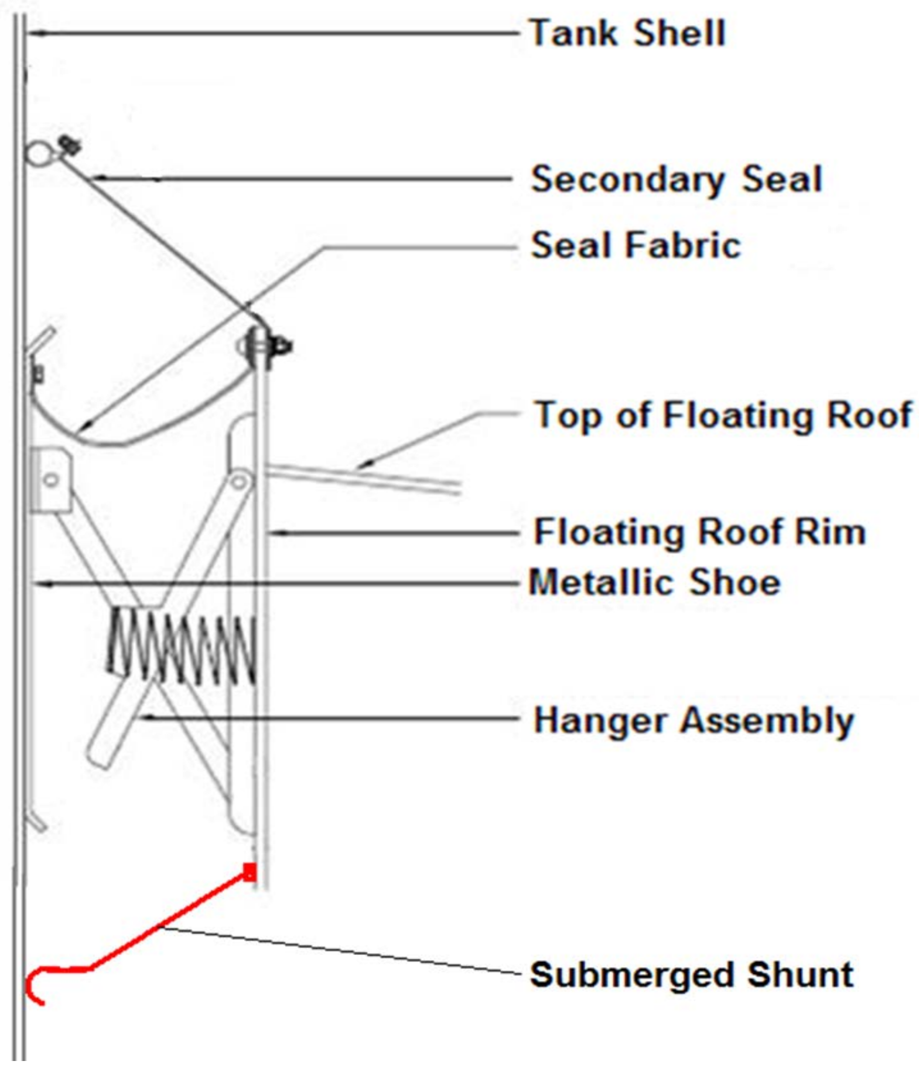
2. Insulate all seal assembly components and gauge pole from tank roof, to encourage lightning currents to travel through shunts and bypass conductors.
   1. Insulation level should be 1kV or more.

3. Install bypass conductors no more than every 30 m/100ft around tank circumference.
   1. Bypass conductors should be short as possible.

Evaluation of API RP 545 Recommendations (1 of 3)

1. Install submerged shunts every 10ft around roof perimeter.
   a) On new tanks, requires substantial change from std designs. $$$
   b) On existing tanks, requires major overhaul. $$$

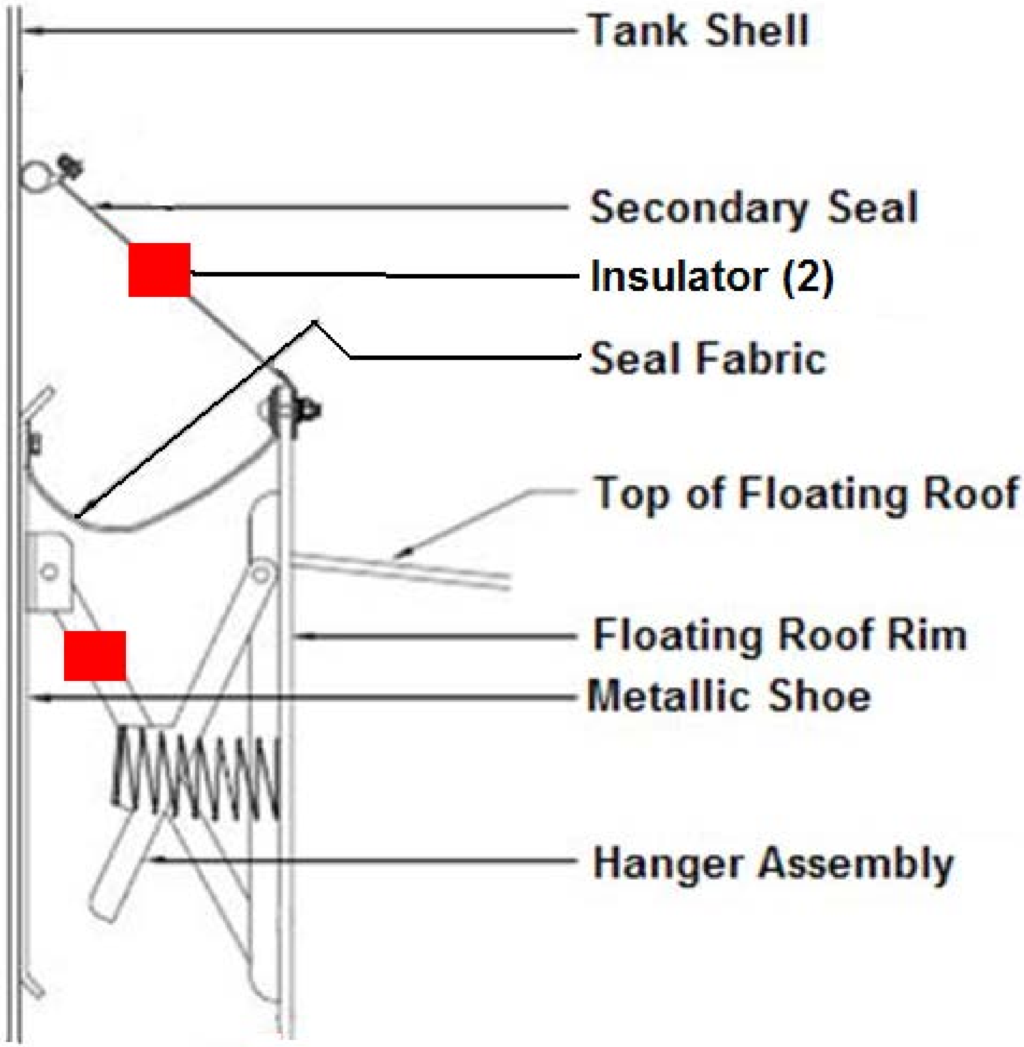
Submerged Shunt



Evaluation of API RP 545 Recommendations (2 of 3)

2. Insulate all seal assembly components and gauge pole from tank roof, to encourage lightning currents to travel through shunts and bypass conductors.
   a) On new tanks, requires substantial change from standard designs. $$$
   b) On existing tanks, requires major overhaul. $$$

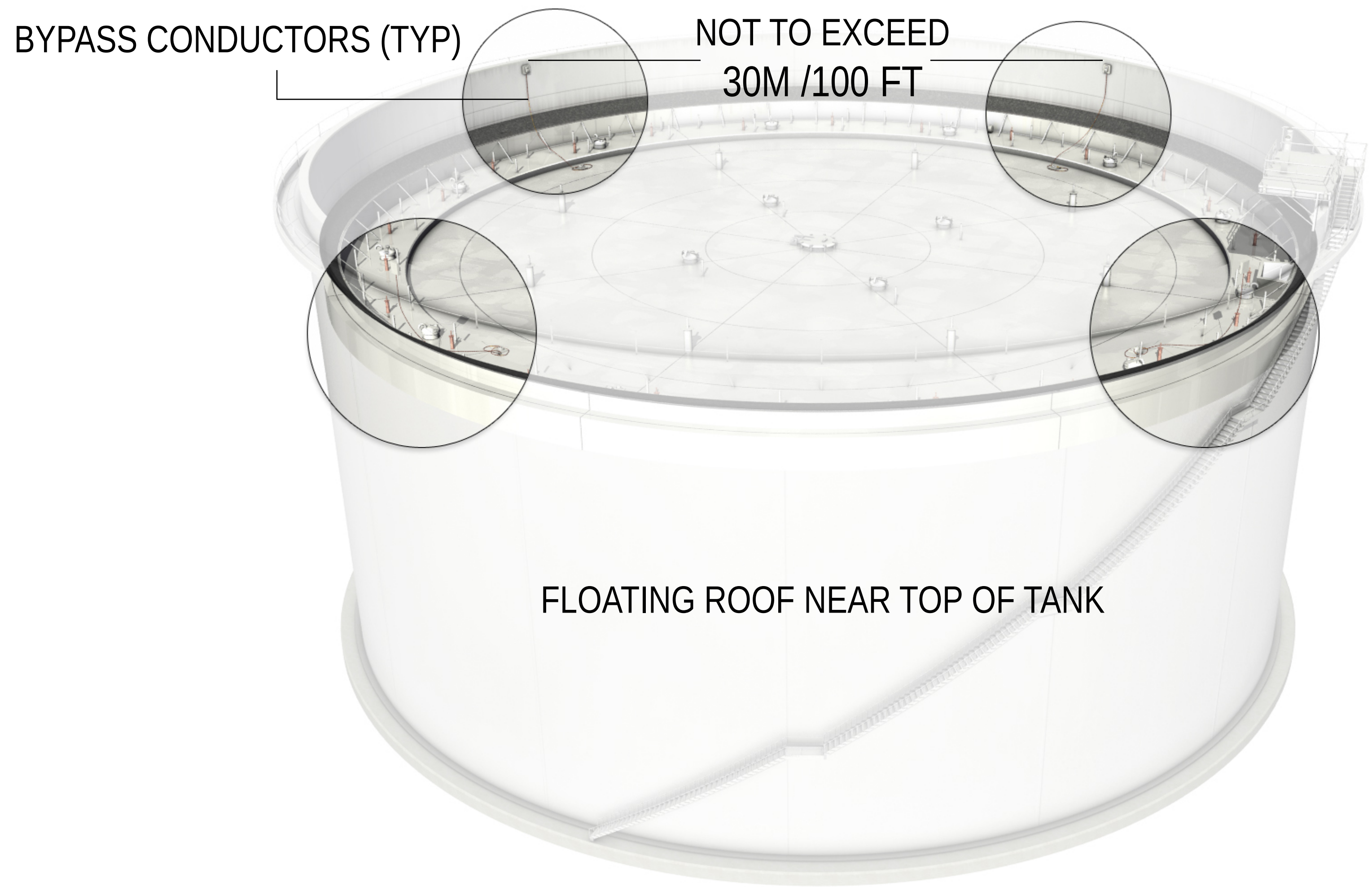
Insulating Seal Assembly



Evaluation of API RP 545 Recommendations (3 of 3)

3. Install bypass conductors no more than every 30m/100ft around tank circumference (at least 2).
   a) Easy and inexpensive to install on both new and existing tanks
   b) A retractable conductor is shortest possible bypass conductor.

Bypass Conductors Every 30m / 100ft



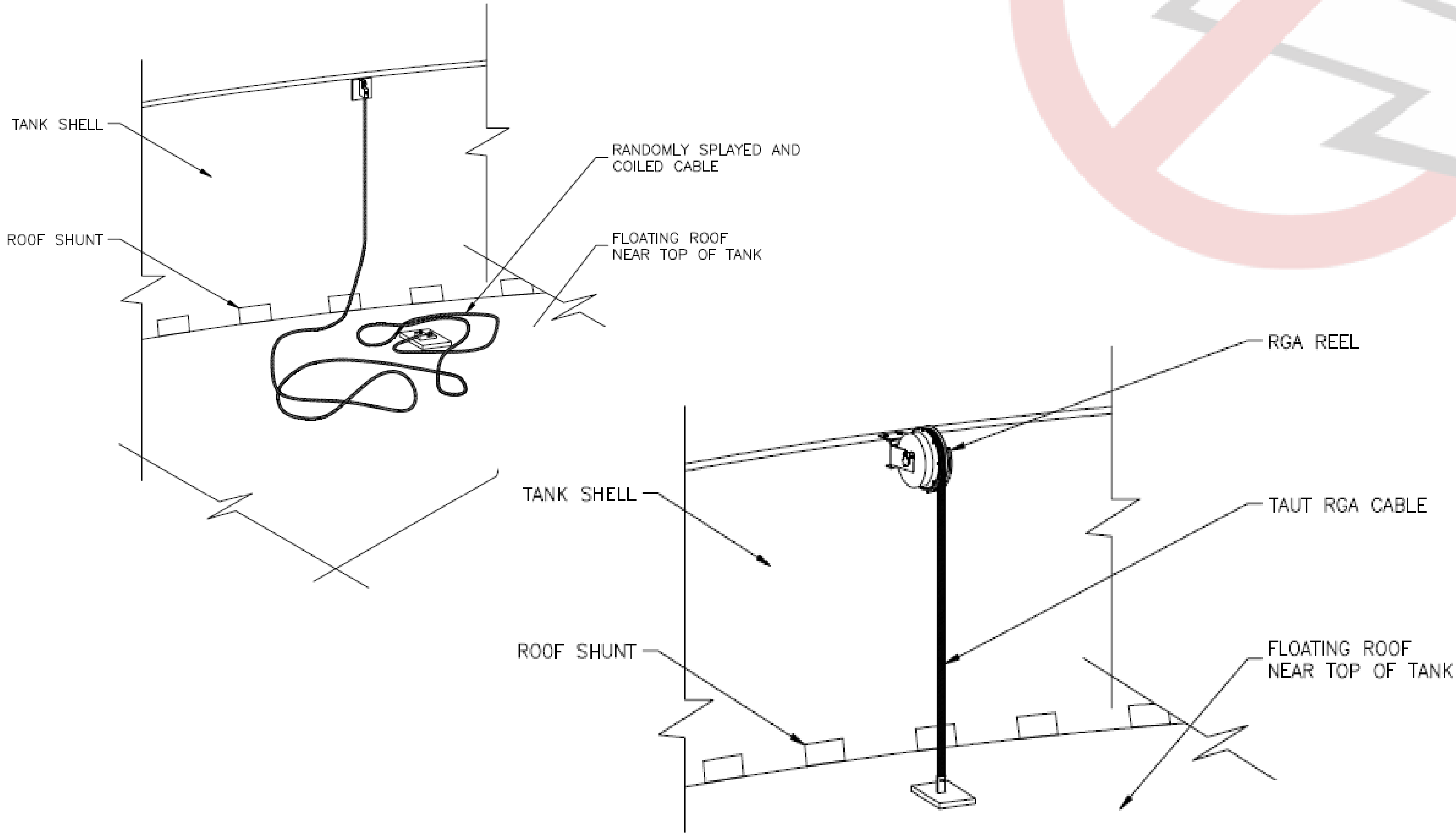
API RP 545: Summary of Recommendations

1. **Install submerged shunts every 3m/10ft around roof.**
   - **Major design change, major overhaul, expensive**
2. **Insulate all seal assembly components and gauge pole from tank roof.**
   - **Major design change, major overhaul, expensive**
3. **Install bypass conductors no more than every 30m/100ft around tank circumference.**
   - **Easy to install, immediate, inexpensive**

Types of Bypass Conductors

1. **Conventional – plain wire or cable.**
2. **Retractable – spring loaded reel.**

Bypass Conductors: Conventional vs Retractable



Bypass Conductors:

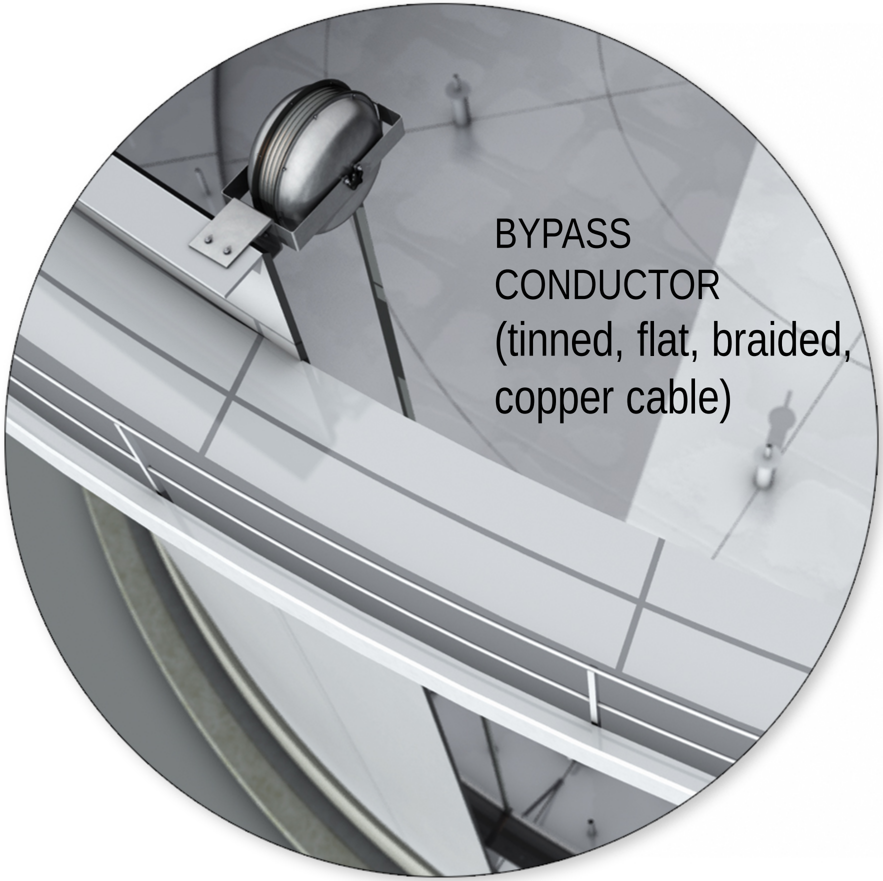
Example: 45m/150ft diameter tank, 15m/50ft high; roof is 12m/40ft high

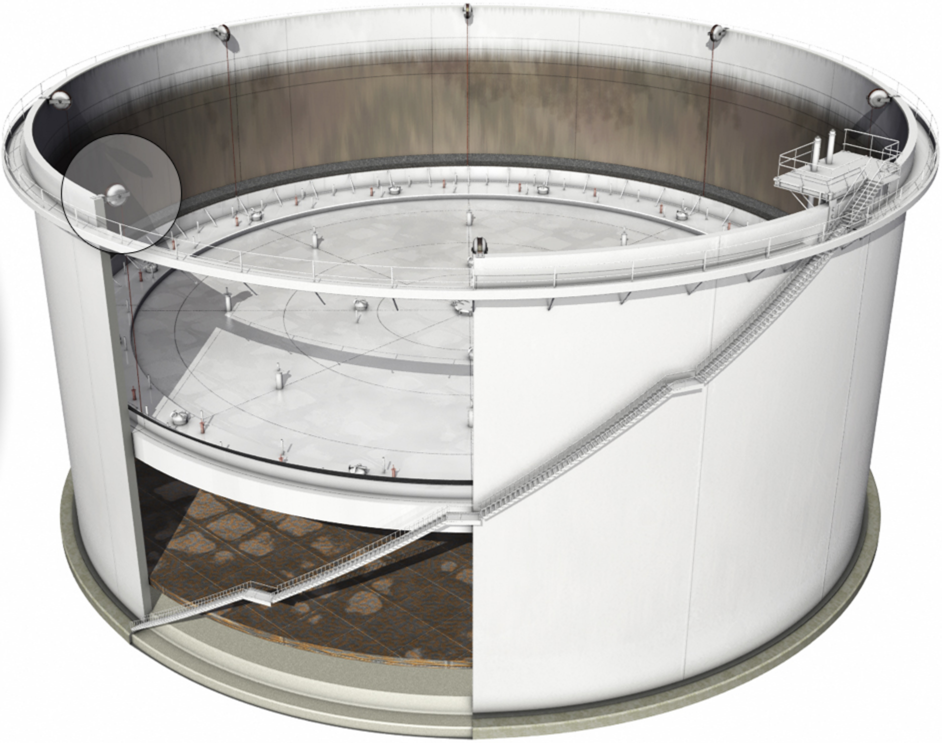
- Conventional cables are 15m/50ft long and randomly coiled
- RGA cable is 3m/10ft long and straight and tight
  - Has 15% of impedance of conventional 1/0 cable

The Retractable Grounding Assembly™ (RGA)

Creates a super low impedance bond between the roof and shell on FRT's

RGA Application





The Retractable Grounding

- **Most Effective Floating Roof Tank Grounding System on the Market**
- **Lowest Impedance Path of Any System**
- **Full-Time, Positive Connection**
- **Eliminates Risk of Sustained Arc**

Bonding Roof & Shell of FRT's

Bonding Method	Impedance at Lightning Frequencies	Likelihood Of Arcing at Seal	Easy to Inspect	Impaired By Condition Of Tank Wall
Shunts – Above the Seal	High	High	Yes	Yes
Shunts - Submerged	High	High	No	Yes
Walkway / Ladder	High	High	Yes	No
Roof-Shell Bonding Cable	High	High	Yes	No
Multiple RGA's	Low	Low	Yes	No

RGA - What You Get

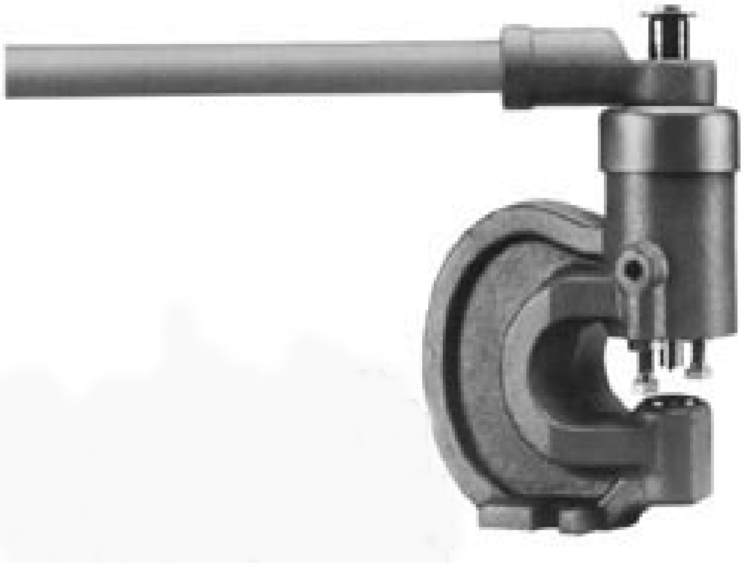
Plus Installation Manual – FREE!!!

RGA Accessories (1 of 2)

- **Replacement Strap Kit**
  - **Replacement end straps (2) and hardware kit**
- **Field Replaceable Cable for RGA-55**
- **Field Replaceable Cable for RGA-75**
- **Electrical Coating - Spray-on aerosol corrosion inhibitor**

RGA Accessories (2 of 2)

- **Cable Shortening Kit**
  - Cable fittings with 2 end straps and hardware
- **RGA Punch Assembly**
  - Used to create mounting and attachment holes without sparking.
  - Will punch $^{7}/_{16}$ inch diameter holes in mild steel up to ½ inch thick.



RGA Support Materials

1. Installation Manual and Pretension Chart
2. API RP 545 and 545A
3. ISO 9001-2008
4. CE ATEX Certificate
5. Patent owned by LEC
6. E and P award for engineering innovation
7. Technical papers and brochures in English, Spanish, Italian and Portuguese
8. Articles from various trade publications
9. RGA specifications for both -55 and -75

API RP 545 Notes (1 of 5)

Section 4.2.1.2.1 – Bypass conductors are used for conduction of the intermediate and long duration components….

These are the components that cause ignition. API testing found that the short duration component did not cause ignition

API RP 545 Notes (2 of 5)

Section 4.2.1.2.2 – The bypass conductors shall be of the minimum length necessary ….

A retractable conductor will always be the minimum length

API RP 545 Notes (3 of 5)

Section 4.2.1.2.2 – Bypass conductors should be evenly spaced not more than every 30m (100ft) around the tank circumference, with a minimum of two.

50m diameter tank example:

50π/30=5.24→6 RGA's

250ft diameter tank example:

250π/100=7.85→8 RGA's

API RP 545 Notes (4 of 5)

Section 1.2 - …this RP shall apply to new or reconstructed tanks.

API RP 545 Notes (5 of 5)

Section 4.1 – Internal Floating Roof Tanks

If present, flammable vapors can be ignited by a lightning flash. Shunts or bypass conductors are not required for lightning protection.

LEC's position is that bypass conductors should be installed on all types of floating roof tanks. Consider the Wynnewood tank with internal floating roof at http://www.youtube.com/watch?v=KGlwLC_1qOI

Summary

1. Tank fires are not uncommon, and lightning causes 1/3 of all tank fires.

2. Conventional roof-shell shunts and bypass conductors provide high impedance connections.

3. API RP 545 recommends the installation of bypass conductors.

4. Retractable bypass conductors provide a low impedance bond between the roof and shell.

The End

Retractable Grounding Assembly (RGA™)

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