Lightning Risk and Storage Tank Protection

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1. Lightning risk for petroleum storage tanks
2. Risk quantification and analysis
3. The physics of the lightning risk
4. API recommendations to reduce risk
5. Case Study: Takreer and the Abu Dhabi National Oil Company
Tank Fires are Common

- 15 to 20 tank fires per year worldwide
- One-third attributed to lightning
Lightning is leading known cause of tank fires

- Lightning: 31%
- Unknown: 41%
- Other: 13%
- Human Action: 11%
- Other Natural Events: 2%
- Static Electricity: 2%
NASA Lightning Flash Density Map

Units are flashes/square kilometer/year
NASA Lightning Flash Density Map – Europe only

Units are flashes/square kilometer/year
Lightning Cost/Risk Trends – past/present

- Lightning-related losses exceeded $5 billion in 2008 (National Lightning Safety Institute, 2009)

- Lightning accounts for 61% of all accidents in storage and processing activities, where natural events are identified as the root cause of the incidents. (Liverpool John Moores University, Atherton and Ash, 2006)

- 15% increase in lightning-related losses from 2009 to 2010 (Lloyds Insurance Institute, 2011)
Lightning Cost/Risk Trends – future

- 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)

- 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)

- 10-20% increase in lightning frequency for each 1°C increase in temperature (National Institute of Space Research, Brazil, 2013)
Tank Fires Caused by Lightning (sample)

1. China Petrochemical, Heshan City, China – 2012
2. Wynnewood Refinery Co. Oklahoma, USA – 2007
3. Engen Refinery, South Africa – 2007
4. Sunoco’s Eagle Point Refinery, New Jersey, USA – 2007
5. Brisbane Oil Refinery, Australia – 2003
6. Escravos Tank Farm Fire, Nigeria, Africa - 2002
7. Trzebinia Refinery Malopolsak Region, Poland – 2002
8. Orion Refinery, Norco, Louisiana, USA – 2001
11. Newport, Ohio, USA – 1987
Cost Examples – Tank fires caused by lightning

• Magellan, Kansas, 2008 – “$10M [€7.5M] and still counting”

• Wynnewood Oil Refinery, Oklahoma USA, 2007 - approximate loss $15 Million [€11M], including 50000 bbl naptha, 30,000 bbl diesel, 50,000 bbl gasoline per day (shut down for 3 days); Equipment damage costs not included.

• Cilacap, Indonesia, 1995 – 10 Tanks containing Oil, Petrol Kerosene - shut down for ½ year; Plant produced $400,000 of product per day = Loss of $73 Million [€55M]; 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.
1. IEC 62305: Protection Against Lightning
   Part 2: Risk Management
   • very detailed, very complex
   • numerous inputs, such as structure geometry, location, contents, construction materials, etc.
   • quantifies risk vs. cost
2. NFPA 780: Standard for Installation of Lightning Protection Systems
Annex L: Risk Assessment
• detailed, somewhat complex
• numerous inputs
• compares lightning risk with tolerable risk
API RP 545

Recommendations apply to all external floating roof tanks

- Exceptions for tanks in very low lightning areas (future)
- Exceptions for tanks with high flash point (less volatile) contents (future)
Wynnewood Tank Fire

Internal Floating Roof Tank
ignited by lightning June 2007

http://www.youtube.com/watch?v=KGlwLC_lqOI
Wynnewood Tank Fire

20k bbl gasoline + 50k bbl diesel
Burned for ~36 hours
Glenpool, OK, Tank Fire

External floating roof tank
125,000 bbl, ignited by lightning June ‘06
Tank Ignition Physics

How does lightning cause ignition of tank contents?

What are the physics?
## Lightning Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Current, negative first strokes (50(^{th}) %)</td>
<td>30 kA</td>
</tr>
<tr>
<td>Peak Current, negative first strokes (95(^{th}) %)</td>
<td>80 kA</td>
</tr>
<tr>
<td>Flash Duration, negative flashes (50(^{th}) %)</td>
<td>13 millisec</td>
</tr>
<tr>
<td>Flash Duration, negative flashes (95(^{th}) %)</td>
<td>1.1 sec</td>
</tr>
<tr>
<td>Range of Strokes per Flash</td>
<td>1 to 30</td>
</tr>
<tr>
<td>Average Number of Strokes per Flash</td>
<td>4</td>
</tr>
<tr>
<td>Peak Temperature (&gt;50,000(^{o}) F)</td>
<td>&gt; 28,000(^{o}) C</td>
</tr>
</tbody>
</table>
Current Flows from Direct Strike

CURRENT FLOW

LIGHTNING STRIKE
Current Flows from Nearby Strike
Lightning Current Flows

When does lightning current flow across the roof/shell interface?

During strike to shell? Yes
During strike to roof? Yes
During strike near tank? Yes
Lightning current flows across the roof/shell interface in ALL situations.

This is an official API finding.
Relative Risk

Tank is MOST at-risk when roof is high.
Relative Risk

Tank is LEAST at-risk when roof is low.
Risk Reduction Recommendations from American Petroleum Institute (API)
Risk Reduction

API RP 545
Lightning Protection for Hydrocarbon Storage Tanks

Project Start = 1999
Document released as RP in 2009
RP will become standard
Other standards (NFPA 780) have copied
Risk Reduction

Sample Cutaway of FRT Shell-Roof Interface

- Tank Shell
- Shunt
- Secondary Seal
- Seal Fabric
- Top of Floating Roof
- Floating Roof Rim
- Metallic Shoe
- Hanger Assembly
Risk Reduction

Potential Arc Locations at Shell-Roof Interface

Potential Arc Points

Submerged arcing may be OK
Methods to Bond Roof-Shell

1. Shunt – short conductor connected to roof and contacting the shell
2. Bypass conductor – cable providing direct connection between roof and shell
Problems with Conventional, Above-the-Roof Shunts
Risk Reduction

Shunts to Rust
Risk Reduction

Painted Tank Walls
Risk Reduction

Shunt not making contact with out-of-round Tank
API testing proved that shunts will arc under all conditions, whether they are clean, dirty, rusty, new, old, well-maintained, etc.
Risk Reduction

Conventional Bypass Conductor, when roof is high
Risk Reduction

API RP 545: 3 Primary Recommendations

1. Install submerged shunts every 3m/10ft around roof.
   a) On existing tanks relocate shunts to under liquid.
   b) 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.
   a) Insulation level should be 1kV or more.

3. Install bypass conductors no more than every 30 m/100ft around tank circumference.
   a) Bypass conductors should be short as possible.
Evaluation of API RP Recommendations

1 of 3

1. Install submerged shunts every 3m/10ft around roof perimeter.
   a) On new tanks, requires substantial change from standard designs. $$
   b) On existing tanks, requires major overhaul. $$
Risk Reduction

Submerged Shunt

- Tank Shell
- Secondary Seal
- Seal Fabric
- Top of Floating Roof
- Floating Roof Rim
- Metallic Shoe
- Hanger Assembly

Submerged Shunt
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. $$$
   b) On existing tanks, requires major overhaul. $$$
Risk Reduction

Insulating Seal Assembly

- Tank Shell
- Secondary Seal
- Insulator (2)
- Seal Fabric
- Top of Floating Roof
- Floating Roof Rim
- Metallic Shoe
- Hanger Assembly
Evaluation of API RP Recommendations

3 of 3

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

Bypass Conductors Every 30m/100ft
Risk Reduction

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.
Risk Reduction

Bypass Conductors: Conventional vs Retractable
Risk Reduction

Case Study:

TAKREER and the Abu Dhabi National Oil Company
TAKREER and the Abu Dhabi National Oil Company

Takreer (Abu Dhabi Oil Refining Company)
• State owned oil refining company with ADNOC group, Abu Dhabi, UAE
• Largest in the UAE, Involved in refining and supply of petroleum products.

Ruwais Refinery
• 91 Storage Tanks in Phase-1
• 120 tanks being added as a part of expansion plan.
Background

• Takreer’s position on Environment, Health & Safety

• Increased Lightning Activity in the region

• A shut down, even partial, on account of major or minor fire incident is not acceptable.
Takreer Safety commitments

• Safety conscious

• Huge investments in fire protection and safety systems

• Proactive approach to fire prevention measures.

• Lightning – acknowledged as one of the major source of fire incidents
Initiation

• Lightning prevention measures
• Interaction with major national and international companies
• Discussions with LEC / Consilium
• API RP 545 recommendations

Result

• Decision to protect all their floating roof tanks with retractable bypass conductors (LEC’s RGA)
1st Phase: Protection of 84 Floating roof tanks

• Challenge: Tanks in Operation, shut downs not viable

• Installation needed to be done on live tanks adhering to stringent safety standards in place by Takreer

• LEC’s methodology for installation on live tanks proposed, documented and reviewed.
Installation

Before Starting

• Adhere to all standard and site specific safety procedures for working on in-service floating roof petroleum storage tanks.

• For Example:
  – Personal Protection Equipment (PPE)
  – Work Permits
  – General, Safe Working Practices
Installation

RGA Mounting Holes

Installation Procedures

• Create 2 mounting holes for RGA on rim angle at top of tank wall.
• Create 2 mounting holes for RGA cable on foam dam of tank roof.

Risk/Safety Precautions

• Use of tooling can create sparks that may ignite flammable vapors.
• Use hand-operated punch tool to eliminate the possibility of creating a spark.
Installation

Hole Locations
• A) 2 holes required at the top of the wall on rim angle.
• B) 2 holes required on roof at the foam dam.

Risk/Safety Precautions
• Use of tooling can create sparks that may ignite flammable vapors.
  → Use hand-operated punch tool to eliminate the possibility of creating a spark.
Installation

**Recommended Tool to Avoid Sparks: Hand Punch**

- The mounting holes necessary for proper RGA installation are 7/16” diameter.
- With a 7/16” punch and die, the hand punch can deliver enough pressure to punch a hole in mild steel up to ½” thick.
- Easy to use: Operator can punch a single hole in less than 5 minutes.
- The blank, discarded metal piece generated by the punch is warm to the touch but cool enough to handle with bare hands.
Installation

Hand Operated Punch Tool
Installation

Prepare Surfaces (Electrical Path)

Installation Procedures

• Clean paint and debris from tank/RGA mating surfaces. The RGA bracket and cable must be in contact with bare metal on the tank shell and roof.

• Apply spray-on corrosion inhibitor

Risk/Safety Precautions

• Sparks can be generated if power tools are used to clean the metal surfaces.
  – Use hand tools only
  – Follow spray-on corrosion inhibitor manufacturer’s application instructions (standard aerosol can applicator).
Installation

Fasten RGA Bracket

Installation Procedures

• Align RGA horizontal mounting bracket with mounting rim angle holes.
• Fasten bracket to tank wall with supplied hardware.
• Apply corrosion inhibitor to hardware and bracket/tank interface.

Risk/Safety Precautions

• Bracket or hand tools may be dropped.
  – Use care when handling all materials and use tie-off safety lines when required.
Installation

Install RGA

Installation Procedures

• Lift RGA unit and place in bracket.
• Fasten lock bars over RGA shaft using supplied hardware

Risk/Safety Precautions

• Drop RGA unit or hand tools
  – Use care when handling all materials and use tie-off safety lines when required
Installation

Pretension Internal Spring Motor

Installation Procedures

• Manually rotate the RGA the in the direction to dispense the cable, but do not allow the cable to dispense. Refer to the installation manual to determine required number of pretension revolutions.

• Extend cable to the tank roof.

Risk/Safety Precautions

• Spring may recoil in an uncontrolled fashion resulting in possible damage to the unit.
  – Use care to manually maintain control of RGA rotation until cable is secured to tank roof.
  – Do not remove RGA unit from bracket.
Installation

Installation was completed in two months.

Validation and tests:

• Mechanical rotation and free movement
• Inspection at extreme roof positions
• Measurement of resistance between tank wall and RGA bracket
• Measurement of resistance from foam dam to ground strap
• Validation of results
Subsequent RGA installations

Takreer has now standardized provision of RGA’s for all existing and new projects

• Remaining existing tanks in Ruwais
• Being implemented on the new RRE (Ruwais Refinery expansion) project for 38 EFR tanks
• Installed in Mussaffah terminal as part of the IRP 2 Package 1 Project
• Under implementation in other terminals as part of IRP 2 Package 2 project
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.
5. Retractable bypass conductors can be safely installed on in-service tanks.
Lightning Risk and Storage Tank Protection

For more information:

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