Full Surface Tank Fire

Emergency Planning and Preparedness

- All photos are from the open source

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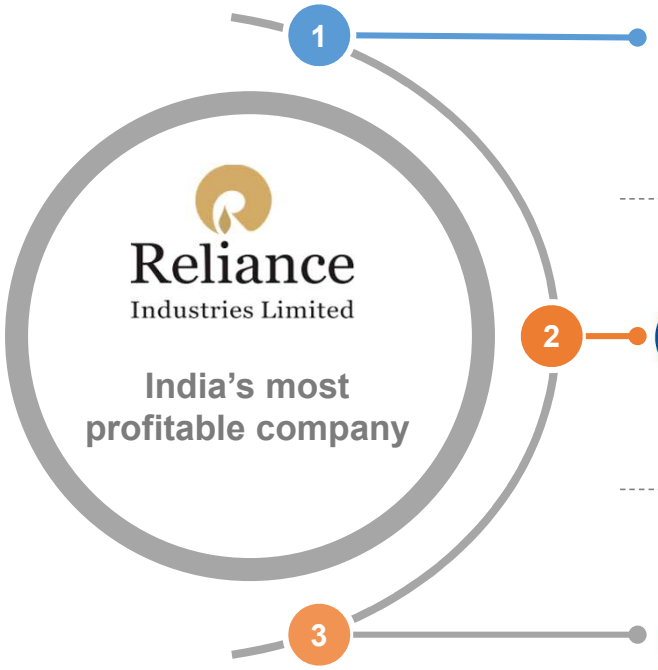
New Reliance for a New India



Reliance O2C

Largest and most complex single site refinery at Jamnagar with 1.4 MMBPD crude refining capacity; **vertically integrated** portfolio across O2C value chain, among **lowest cost positions** and **global top 10 rankings in key products**

Jio-bp 51:49 fuel retail JV

A **global leader** and one of the **long-term winners**

Jio DIGITAL LIFE

Largest digital services provider in **India – 419.9 mn subscribers** (Jun'22)

1st operator[1] to **cross** 400mn subscribers in a **single country market**

Strategic investment by **Facebook & Google** and investments by **marquee financial investors** totaling to **$20bn for ~33% stake** in Jio Platforms Limited

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Reliance RETAIL

Largest Organized Retailer in India

208 mn registered customer base with a **diversified product portfolio** of groceries, fashion & lifestyle, consumer electronics and connectivity across **15,866 stores across 45.5 mm sq. feet** (Jun'22)

Investments from Silver Lake Partners, KKR, GA, TPG, Mubadala, GIC, PIF and ADIA totaling **~$6bn for ~10% stake** in Reliance Retail Ventures Limited

Three mega growth engines and a strong liquid balance sheet

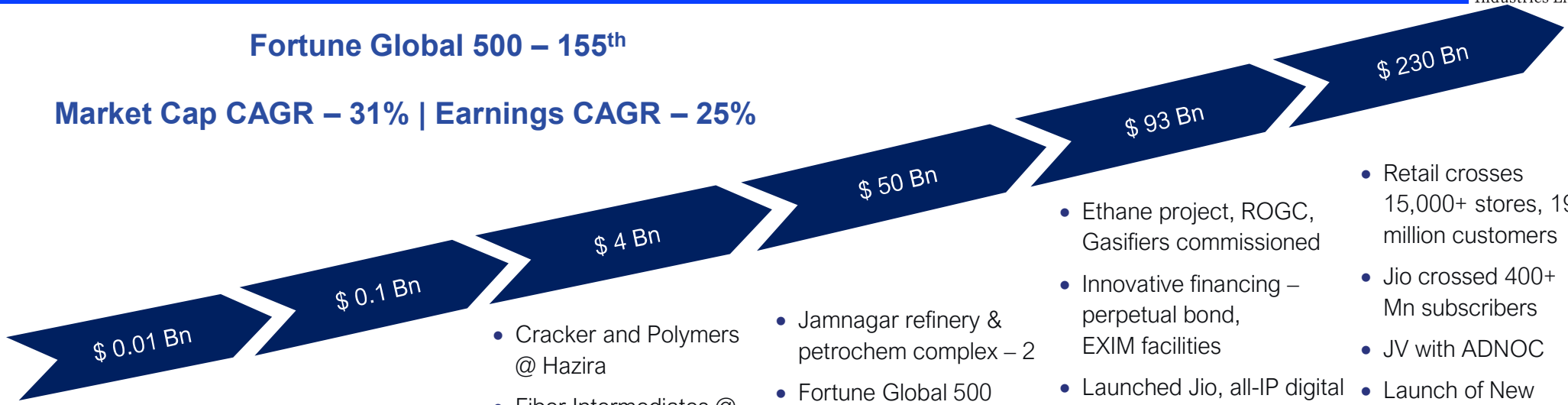
- Note: Exchange rate used: US$1 – INR 78.9725; [1] Outside China; [2]

Phenomenal Growth Journey – Now A Top 100 Global Company

Reliance Industries Limited

Fortune Global 500 – 155th

Market Cap CAGR – 31% | Earnings CAGR – 25%



1977-80

- IPO

1981-90

- Patalganga Complex
  - PFY
  - PSF
  - PTA
  - PX

1991-2000

- Cracker and Polymers @ Hazira
- Fiber Intermediates @ Hazira
- Jamnagar supersite - Integrated refinery & petrochem complex
- GDR Issue
- 50/100 Years Yankee Bond
- Upstream – PMT

2001-2010

- Jamnagar refinery & petrochem complex – 2
- Fortune Global 500
- IPCL acquisition
- Acquired broadband spectrum
- Launch of Reliance Retail
- KG-D6 discovery & commencement of production
- Recron Malaysia

2011-20

- Ethane project, ROGC, Gasifiers commissioned
- Innovative financing – perpetual bond, EXIM facilities
- Launched Jio, all-IP digital network
- India's largest Rights Issue
- Largest capital raise through asset monetization across Jio, Retail and fuel retailing
- KG D6 new production system

2021-22

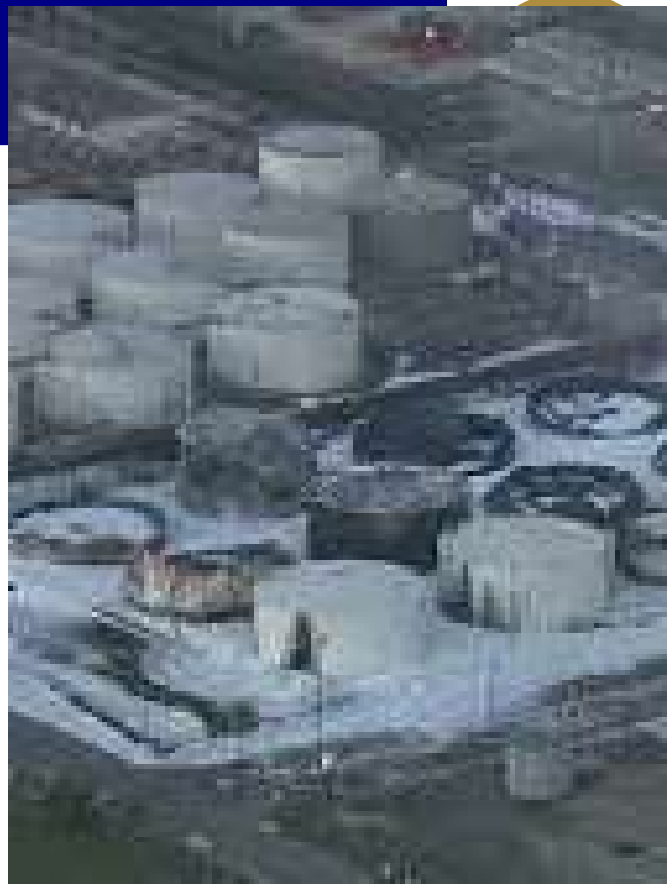
- Retail crosses 15,000+ stores, 193 million customers
- Jio crossed 400+ Mn subscribers
- JV with ADNOC
- Launch of New Energy & New Materials
- Acquired REC Solar
- First ever jumbo US$ Notes issuance from India

Note: CAGR since IPO

Full Surface Tank Fire

Is it a Real Threat ?
Or Speculation ?

What History says ?
What Statistics says?



ITC Deer Park - Texas

- All photos are from the open source

Cuba Oil Tank Fire and Boilover

- All photos are from the open source

Milford Heaven Refinery

- All photos are from the open source

Thailand Refinery

- All photos are from the open source

Caribbean Petroleum

All photos are from the open source

Jaipur Tank Depo

- All photos are from the open source

Buncefield Tank Depo

- All photos are from the open source

Chevron UK Tank Fire

- All photos are from the open source

Many More in the History

- All photos are from the open source

Where are we –Industry Perspective

Are we prepared ?

Do we have a Strategy and Plan?

Do we have Infrastructure?

Do we have Resources?

Do we have Competency?

Do we have Trained Responders?

Do we conduct mock exercise?

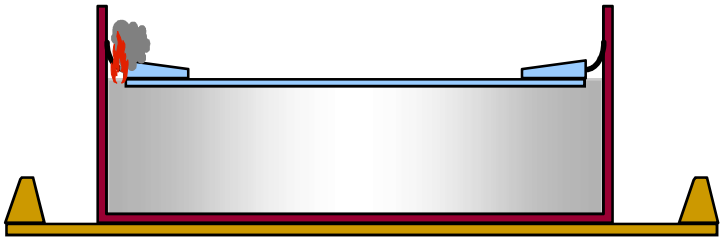
Trigger – Full Surface Tank Fire Scenario

Few most common initiating event

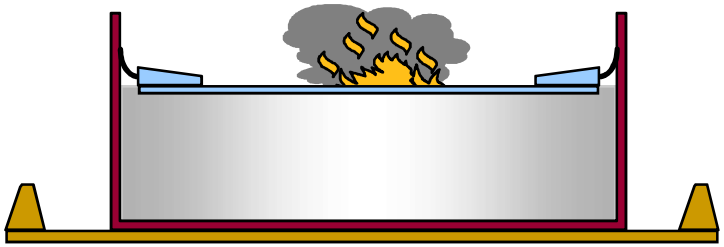
- ✓ Rim Seal Fire
- ✓ Vent Fire
- ✓ Pontoon fire and explosion
- ✓ Spill on Roof and Fire
- ✓ Overpressure resulting in tank failure and Fire
- ✓ Overfilling resulting in LOPC and subsequent VCE
- ✓ Spill in dyke and fire

- ✓ Full surface tank fire
  - ✓ Unobstructed Sunken Roof tank fire
  - ✓ Partially Sunken / Obstructed Sunken Roof tank fire

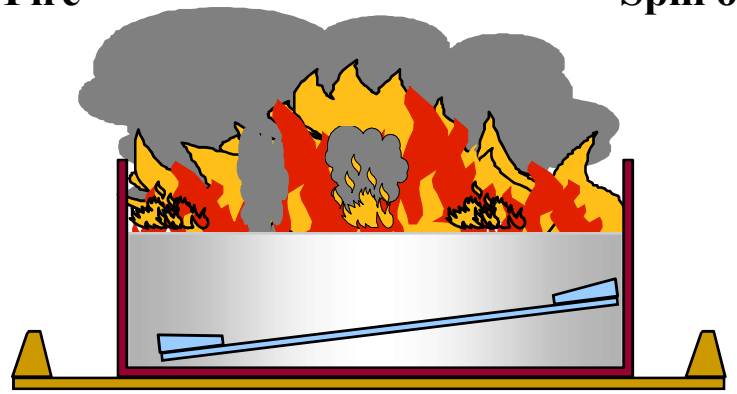
External Floating Roof Tank Fire Scenarios



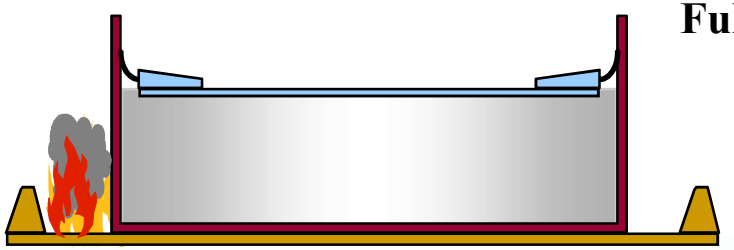
Rimseal Fire



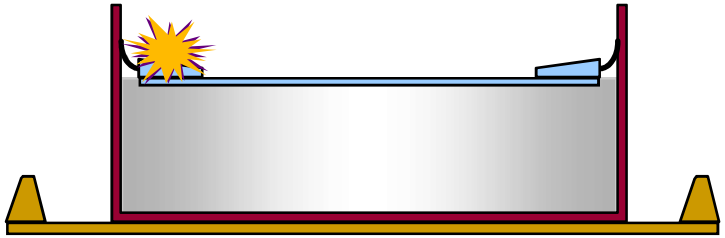
Spill on Roof Fire



Full Surface Fire



Bund Fire



Pontoon Explosion

- All photos are from the open source and WFHC

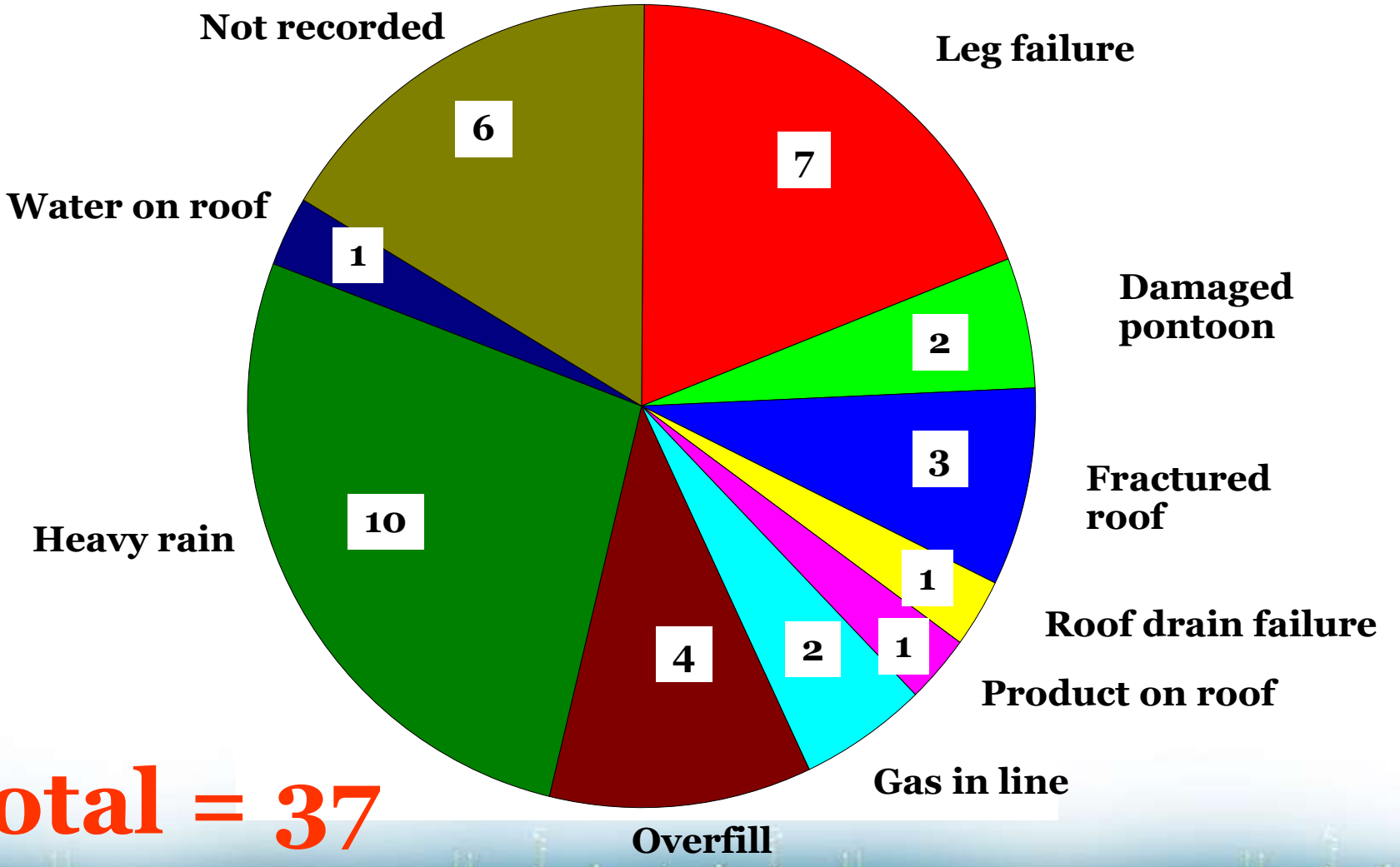
LASTFIRE Study Statistics

- ✓ Data Collected from 164 tank farm installations in 36 countries.
- ✓ Tank Population analysed : > 2400 tanks
- ✓ Tank years of operation : 34000 tank years
- ✓ Average age of the tank : > 27 years

LASTFIRE	Loss of containment			Initial Fire Event				
	Onto roof	Sunken roof	Into bund	Rimseal	Small bund	Large bund	Spill on roof	Full surface
Number of Incidents	55	37	96	55	3	2	1	1
(x 10^{-3} /tank year)	1.6	1.1	2.8	1.6	0.09	0.06	0.03	0.03

- All data from the open source and WFHC

SUNKEN ROOF FAILURE CAUSES



Total = 37

- All data from the open source and WFHC

Full Surface Fire Analysis

Total of 6 full surface fires

- 1 escalation in 55 rim seal fires
  (Roof pontoons contained vapours and/or liquid)
- 1 escalation in 2 bund fires impinging on tank shell
- 1 escalation from a spill fire on the roof
- 1 full surface fire in 37 sunken roofs incidents
- Escalation to 2 downwind tanks in full surface fire
  (Low boiling temperature fuel)
- 1 Boilover in 6 full surface fires

• All data from the open source and WFHC

Is it a speculation or real ?

Incident will strike when you are least prepared

Let’s appreciate and accept

Full Surface tank fire is a reality

Low Probability - High Consequences

Let’s get prepared

Success Stories – Good reason to be prepared

- **Union Carbide,** Taft, LA : Sept.1998 Sunken Roof on 234' Naphtha Tank
- **BP Alliance**, Belle Chase, LA : Sept.1998 Sunken Roof (200') Crude Oil Tank
- **Chevron**, Pascagoula, MS : Oct.1998 Sunken Roof (202') Crude Oil Tank
- **Amoco Refining**, Texas City : Oct.1998 Sunken Roof (345') Crude Oil Tank
- **Orion Narco Refinery**, Louisiana June 2001 Sunken Roof (270') Gasoline Tank
- Kuwait Oil Fields – Multiple tanks full surface
- Exxon Baton
- Turkey
- Buncefield UK

Many more success stories – How to achieve

Codes and Standards - Requirement

- Majority international codes and standards like NFPA, API, EN, IP19 recommends fixed system for most likely scenario for tank fire
  - ✓ Rim Seal fire @ External Floating Roof tanks
  - ✓ Full Surface @ Fixed roof tanks including IFR tanks

- Indian Standard OISD - Capability of one largest diameter tank full surface fire
- Austrian Federal Fire Fighting Association - Fixed system for full surface tank fire in floating roof
- No standard recommends for capability of multiple tank fire scenario which is very low probability scenario. Need different type of approach to address this situation if arise.

International Practice - Preparedness

- Majority of the International Refinery and Oil Companies seek assistance of Industrial Fire Response agencies. These agencies mobilise expertise with response equipment to the emergency site
- Some of the Refinery and Tank operators develop in-house capability. Self sufficient
- Few Refinery and Oil Company operate Hybrid model in collaboration with supplier + Mutual aid + manufacturer
- API 2021 Management of Storage Tanks – Pre Fire Plan for all tanks in site

- Every Industry should have their own strategy and plan in place.

  "Controlled Burnout Vs Capability to Fight Full Surface Fire"

Foam Solution at a Glance – Full Surface

Foam Concentrate Requirement				
Diameter of Tank	48	60	82	92
Surface Area	1808.64	2826	5278.34	6644.24
Foam Solution Application @ 8.1 LPM/M2	**14649.984**	**22890.6**	**42754.554**	**53818.344**
Foam Solution Application @ 10.4 LPM/M2	18809.856	29390.4	54894.736	69100.096
Foam Concentrate Required 3%(LPM)	**564.29568**	**881.712**	**1646.84208**	**2073.00288**
Total Foam Concentrate 3% Litres @ 65 Min	**36679.2192**	**57311.28**	**107044.7352**	**134745.1872**
Foam Concentrate Required 1%(LPM)	188.09856	293.904	548.94736	691.00096
Total Foam Concentrate 1% Litters @ 65 Min	**12226.4064**	**19103.76**	**35681.5784**	**44915.0624**

- To achieve a successful full surface tank fire fighting – Which are the options available with industry.

Options # 1 – Full Surface Fixed System

- ✓ Fixed foam system – Applicable for limited number of tanks on site. Foam application to full surface fire by fixed system
- ✓ OMV Refinery Austria - Upto 90 M diameter EFR tanks with capability of full surface application within 30 minutes
- ✓ Advantage of the systems

  - very safe operation
  - very fast activation
  - very efficient in terms of water-flow and amount of foam concentrate when compared with monitor over the top / aerial applications

- All photos are from the open source

Options # 2 – HVLR Dyke Monitors

- ✓ Minimum 4 monitors all four side of tank dyke with foam induction arrangement
- ✓ Limited success as aerial foam application from downwind and cross wind monitors is not effective
- ✓ Continuous foam supply is a challenge
- ✓ Distance of monitor from the tank center for effective foam landing is a challege – Monitor @ Dyke to Tank Center
- ✓ Large tank farm area – foam distrubution is a challenge

- All photos are from the open source

Options # 3 – Foam Tender Roof Monitors

- ✓ Required high volume monitors and pump mounted on foam tender. Number of vehicles based on tank diameter to maintain foam application rate
- ✓ Continuous foam supply is a challenge after foam tank empty
- ✓ Positioning of foam tender for effective foam discharge
- ✓ Foam loss due to high wind and flame updraft – Need to compensate with high application rate
- ✓ Limited success reported in real time scenario for large diameter tanks

- All photos are from the open source

Options # 4 – Mobile HVLR Foam Application

- ✓ Mobile Trailer high volume monitors, Water connections at required pressure and foam proportioning and foam feed for monitors.
- ✓ Widely used by majority Refinery and Oil Companies
- ✓ Positioning of Monitors and Continuous water + foam supply
- ✓ Foam loss due to wind – Need to compensate with high application rate
- ✓ Many success stories in this arrangement

- All photos are from the open source and WFHC

Mobile HVLR Foam Application

- All photos are from the open source and WFHC

Options # 4 – Discussion

- ✓ Mobile Trailer HVLR – Capacity govern by largest tank dia
  At present up to 12000 GPM (@ 45000 LPM) available
- ✓ Fire water delivery system to HVLR – As per HVLR capacity
  - ✓ Large diameter hoses and connections
  - ✓ Compatible fire water network connections for large dia hose (6/8/12”)
- ✓ Foam Supply arrangement – All quantity at site before start
  - ✓ Foam Concentrate – Type + Foam Proportioning arrangement (1%/3 %)
  - ✓ Foam Feed to Monitors – Continuous uninterrupted supply
- ✓ Mobilisation arrangement and Site Deployment in tank up-wind direction at a safe distance with foam discharge in tank
- ✓ Miscellaneous critical accessories like Drone, Rangefinder and Thermal Imaging Camera
- ✓ Manpower – Trained and Competent responders in sufficient numbers

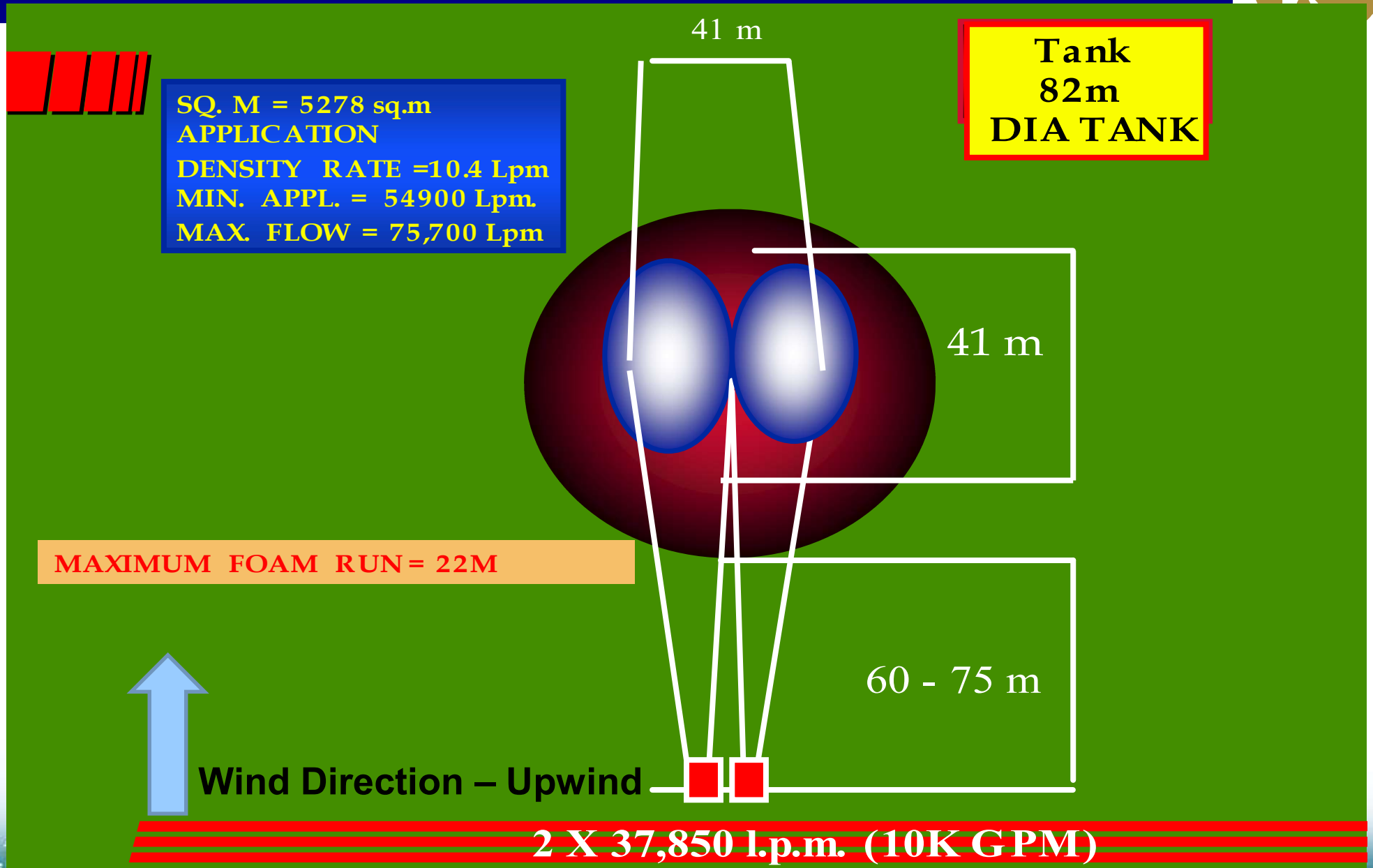
Resources – At a glance

- All photos are from the open source and WFHC

Final set up – Trailer Monitor in Action

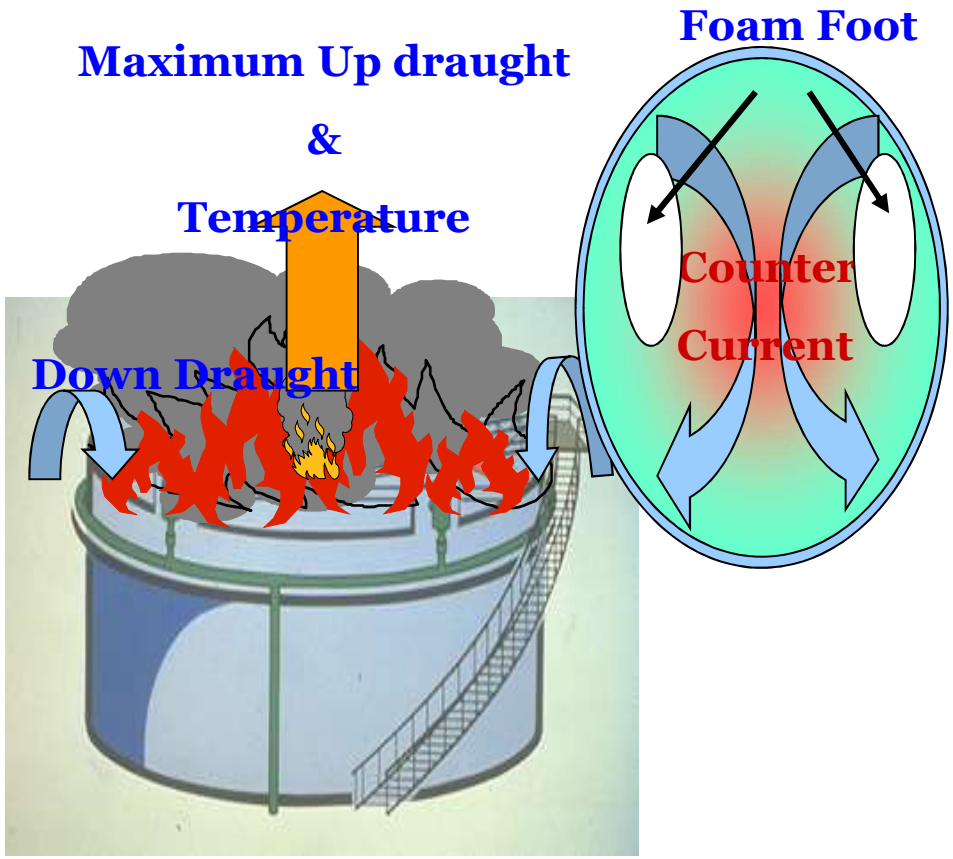
- All photos are from the open source

Full Surface Fire Attack Plan – Footprint Concept



- All Photos are from Williams Fire Hazard and Control

Full Surface Fire : Attack Plan



Fire Teasing: Before foam application on hot fire, recommended to tease the top burning surface with quick water sweeping across tank.

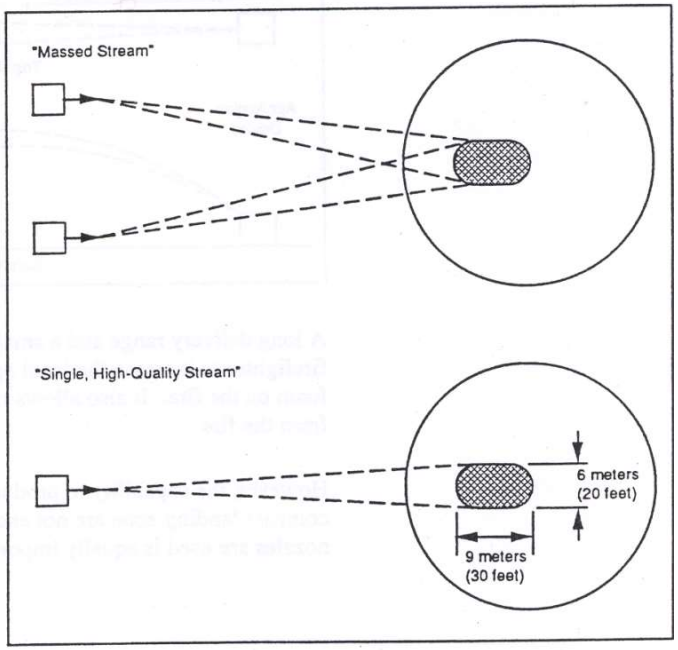
Foam Application

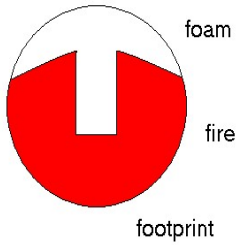
- The first stream of foam is completely destroyed as soon as it hits the surface.
- Due to thermal updraft foam will be lost in air and break up before landing
- This causes a delay before a continued blanket can be formed and the foam starts to spread.
- Foam should enter from tank fire breathing window

All Photos are from Williams Fire Hazard and Control

Full Surface Fire: Attack Plan

Foam Foot print





- After landing on the fuel surface, the foam is pushed to the back wall of the tank after which the foam spreads backwards towards the front side.
- Experimental observation show that the foam spreads more rapidly along the side walls because the foam jet on the central part of the tank opposes the spread
- 12'o' position is the last smily face of fire need to extinguish by cross side foam monitor / foam pourer / dyke monitor

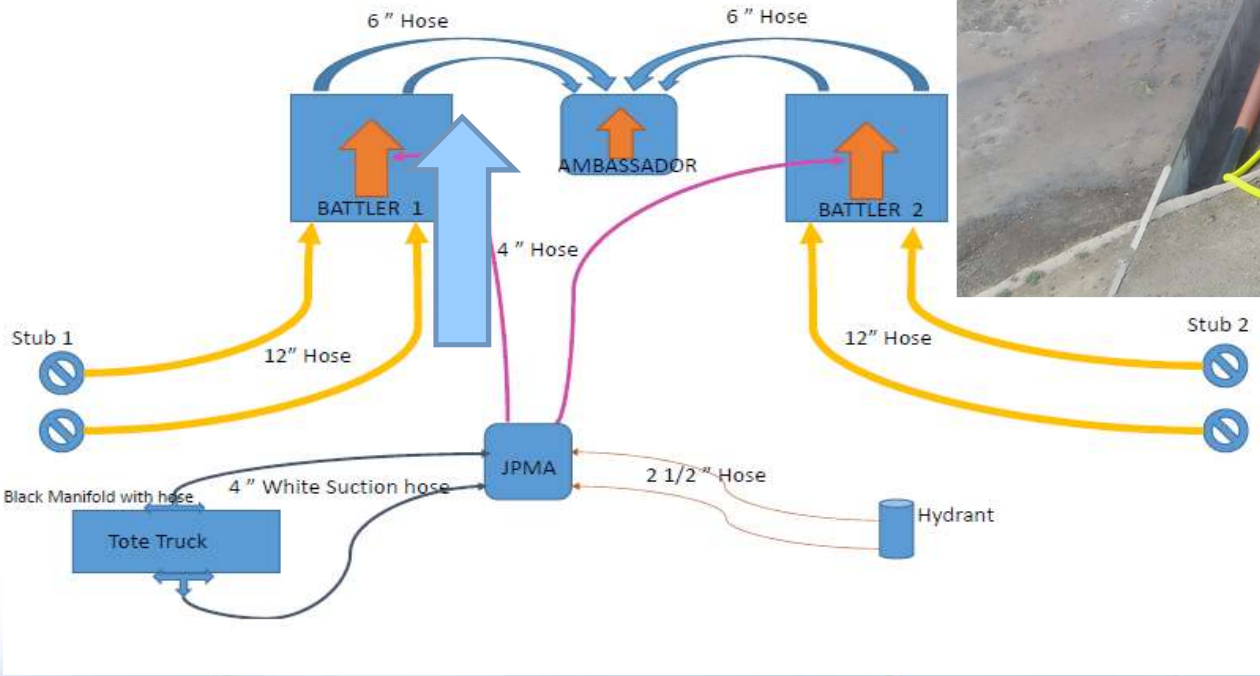
• All Photos are from Williams Fire Hazard and Control

Full Surface Fire – Final cut off

Foam Application

- All Photos are from Williams Fire Hazard and Control

Attack Strategy – Ground Deployment



Wind Direction – Upwind

- All Photos are from Williams Fire Hazard and Control

Actions Plan

On demand, Resources mobilisation

- ✓ 6/8/12” Storz flanged adaptors @ 6 nos. to be mobilised and fixed
- ✓ Trailer monitors to be mobilised
- ✓ JRC to be mobilised – Foam Proportioning system
- ✓ Foam Tote tanks to be mobilised
- ✓ Additional manpower
- ✓ Rangefinder, Drone and Thermal imaging camera in kit for fixing the attack location

Deployment and Foam Attack Plan – Foam from the tank breathing position during fire

Actions required at site – for affected tank

- ✓ Initial assessment of favourable monitor placement preferably best available 12 'o' clock ± in between 9 'o' or 3 'o' clock based on wind direction. Success rate depends on right placement of main attack monitors.
- ✓ Hose connections to the monitors
- ✓ Placement of foam tote trailers @ 50 - 100 mtrs away from the attack monitors on free motorable road trailer movement
- ✓ Foam concentrate hose connections to attack monitors
- ✓ Once all connections are ready – Uninterrupted foam Attack for at least 60 minutes and ready for 30 minutes extended foam supply
- ✓ Positioning of trailer monitor / dyke monitor for final finish at 12 'o' clock in case of smiling fire

Deployment and Foam Attack Plan

Actions required – for non-affected tank in same dyke

- ✓ Immediate foam dam filling with available foam tender and water spray of this tank only. Continuous cooling with Water spray to be considered in case of 32kw/m2 radiation flux on the tank shell.
- ✓ Maintain periodic foam dam filling of the tank
- ✓ Monitor the skin temperature of the affected and non-affected tank as well.
- ✓ **If possible monitor the heat wave travel in case of affected tank to know the Boil over if any ?**
- ✓ No water cooling for the affected tank recommended to avoid tank buckling outside uneven cooling scenario
- ✓ Fire water flow and pressure to be maintained for main foam attack monitors

Objective – Full Surface Tank Fire

- ✓ Minimise the losses and consequences of an accidental event
- ✓ Provide appropriate fire protection facilities to rapidly bring fire under control and achieve extinguishment.
- ✓ Judicious utilisation of resources

Full Surface Fire : Consideration

- ✓ Reduce inventory and allow to burn down
- ✓ Protect adjacent tanks
- ✓ Prepare for foam attack (Calculation, foam application position, distance from tank etc.)
- ✓ Do not cool burning tank except prior to foam attack to help foam to seal against shell
- ✓ Estimate boil-over time and prepare to evacuate
- ✓ Avoid working in bund

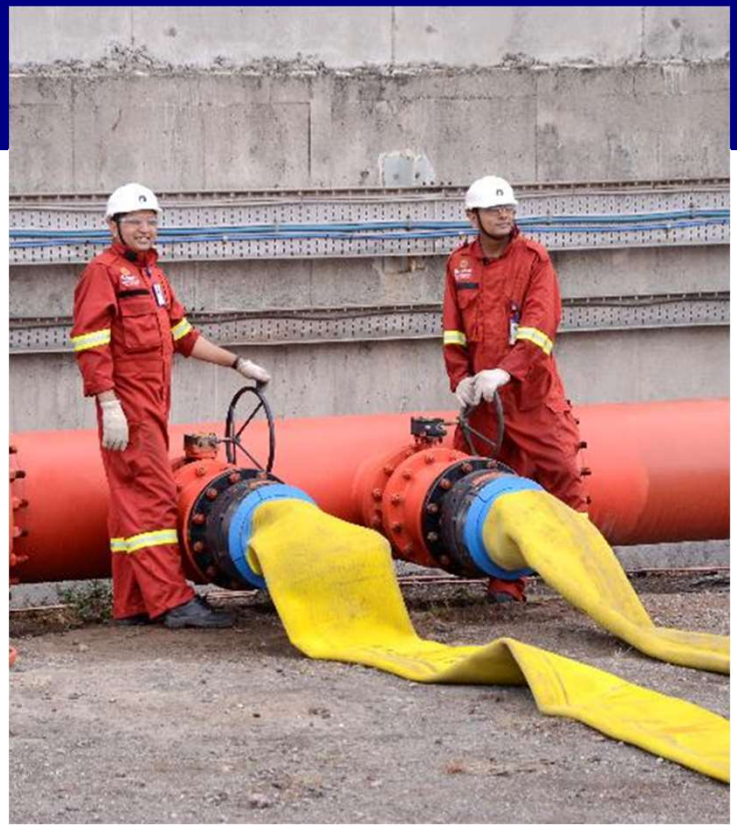
Full Surface Fire – May Fail

Potential Problems:

- Water and foam logistic problems
- Setting up foam attack in safe location upwind 12”o” clock breathing window
- Achieving the correct application rate
- No sufficient ullage for foam blanket
- Boil over and slop over

Options for Trailer HVLR 4 to 12 K GPM

- All photos are from the open source



Options for Network Connections

- All photos are from the open source

Options for Large dia hoses mobilisation

12” Hose storage and laying facility

Options for Foam Concentrate Tote

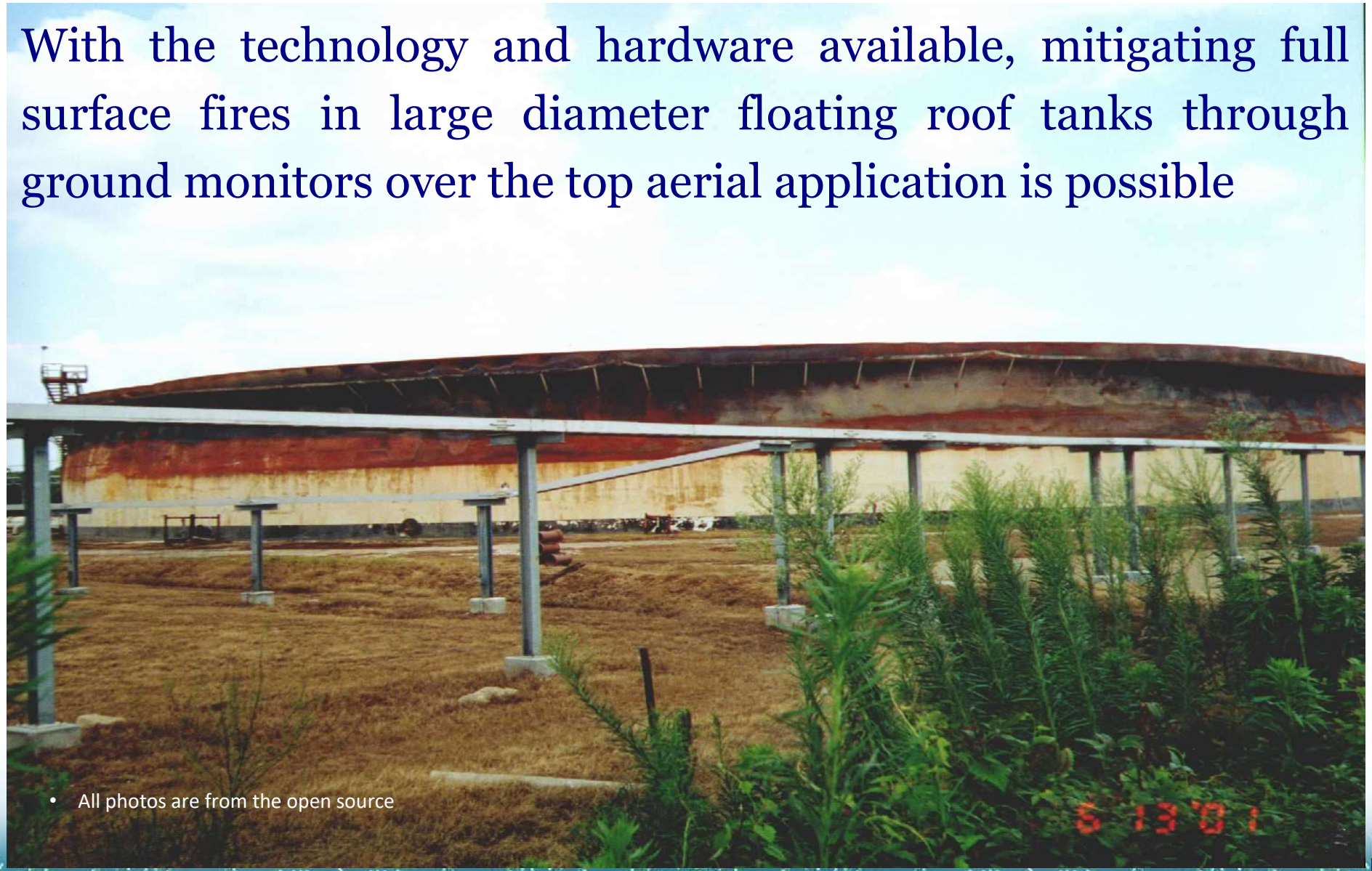
- All photos are from the open source

No Significant Success by this way

- All photos are from the open source

Conclusion

With the technology and hardware available, mitigating full surface fires in large diameter floating roof tanks through ground monitors over the top aerial application is possible



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Thanks