MARSH

SOLUTIONS...DEFINED, DESIGNED, AND DELIVERED.

COOLING OBJECTS AND CONSTRUCTIONS

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MARSH & McLENNAN COMPANIES

FLAME IMPINGEMENT

- Flames have momentum
  Cooling water on tank requires pressure between 4-7 bar
- Load bearing capacity and strength of Carbon steel (and Aluminum) is affected
- Cooling water flow depends on scenario – can vary between 2 – 10 l/min
- Heat exposure ≥10 kW/m^2, requires fixed cooling installation

RADIANT HEAT

- ≥10 kW/m^2 on adjacent tank in same bund – fixed cooling installation on tank
- ≥10 kW/m^2 on adjacent tank in adjacent bund – fixed cooling installation on tank preferred
- ≥10 kW/m^2 on tank in nearby bund:
  - Fixed cooling installation
  - Water screen with monitor (spray mode) between tank suffering from radiant heat and fire
  - Fixed hydroshield (more sensitive to wind)

APPLICATION RATES COOLING

	Application rate (l/min./m²) [Note 1]
Process areas (Application rates based on ground area)	
Process unit blocks	4
High density - stacked equipment	6 - 8
Cooling non-PFP or uninsulated vessels and equipment enveloped in flame [Notes 2 and 3]	
Process vessels, equipment, structural steel, pipe racks, fin-fan coolers etc.	10
Pumps handling flammable liquids in isolated areas [Note 4]	10
Pumps handling flammable liquids adjacent to cable runs, fin-fans, pressure equipment, pipe racks etc. [Note 5]	20
Compressors handling flammable gases	10
Electrical and instrument cable trays, transformers, switchgear etc.	10
Cooling equipment exposed to radiant heat	
Miscellaneous process equipment	2
Fixed [Note 6] and floating roof [Note 7] tanks containing Classes I, II and III liquids	2
Pressurised tanks (general)	10
LPG tanks	10
Buildings such as warehouses, offices and laboratories	2
Control of burning (application rate depends on product type)	
Water spray for control of fire	10 - 20

IP-19: Fire precautions at petroleum refineries and bulk storage installations

CARBON STEEL TANK ON FIRE

- Do not cool tanks unless uniform cooling of tank can be guaranteed
- Carbon steel tanks are generally designed to burn down with the liquid level – containment is not affected
- Roof (Aluminum & Carbon steel) can pose a problem

BUND FIRES

- Flame impingement affects welds in pipes and bolts in flanges, manhole covers
- Duration of exposure is important
- Short time exposure allows application of ≥2 l water/min/m^2 cooling of tanks
- Long time exposure requires ≥10 l water/min/m^2
- Material and design of bund and tank(s) in bund relevant for development of fire
- Effects of pool fires are worse than spill fires

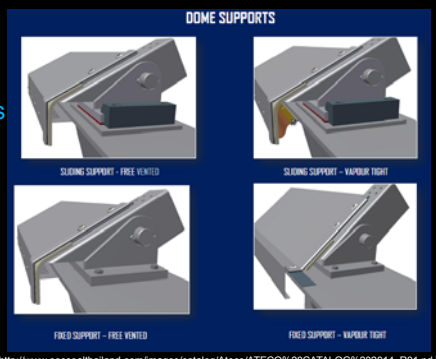
- Welds in pipes are affected
- Bolts in flanges are affected

Table Strength reduction factors for bolts and welds

Temperature θ	Reduction factor for bolts, $k_{b,\theta}$	Reduction factor for welds, $k_{w,\theta}$
20	1.000	1.000
100	0.968	1.000
150	0.952	1.000
200	0.935	1.000
300	0.903	1.000
400	0.775	0.876
500	0.550	0.627
600	0.220	0.778
700	0.100	0.130
800	0.067	0.074
900	0.033	0.018
1000	0.000	0.000

ALUMINUM GEODESIC DOME ROOFS (1)

- Newly built tanks
- Retrofitted tanks (next slide)
- Ventilated roofs
- Non-ventilated roof
- Felted roofs



http://www.ecosealthailand.com/images/catalog/Ateco/ATECO%20CATALOG%202014_R01.pd

shell buckling by outward pressures generated and compressive stresses generated by horizontal motion (in this case by earthquake)

Wide tank

Slender tank

https://eprints.usq.edu.au/8503/1/Kuan_2009_Main_Project.pdf

ALUMINUM GEODESIC DOME ROOFS (2)

No cooling

ALUMINUM GEODESIC DOME ROOFS (3)

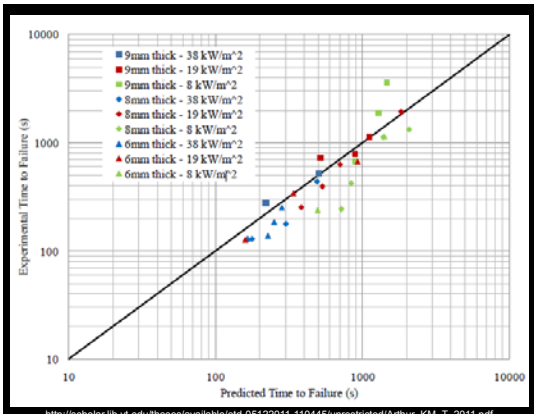
With cooling

SCENARIO & PURPOSE COOLING DOMES (1)

- Credible heat exposure scenarios:
  - Floating roof has sunk – full surface fire
  - Full surface fire adjacent tank
  - Fire in bund
- Linear temperature expansion coefficients of Aluminum is twice that of Carbon Steel
  This can cause severe tension at top of tank cylinder

SCENARIO & PURPOSE COOLING DOMES (2)

Structural strength of Aluminum fails within minutes when exposed to heat flux of ≥10 kW/m^2



Experimental vs. Predicted Times to Failure 4 Noded Aluminum (865 – 205 mm) shell

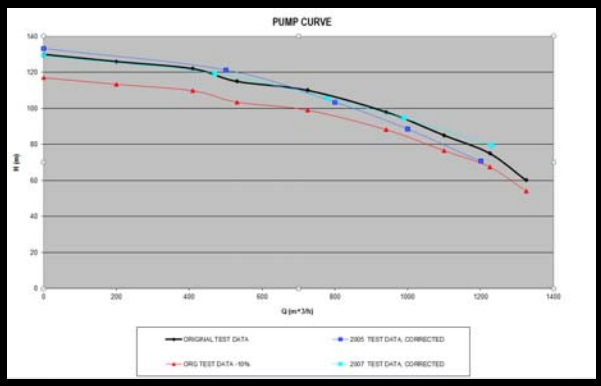
http://scholar.lib.vt.edu/theses/available/etd-05122011-110445/unrestricted/Arthur_KM_T_2011.pdf

SCENARIO & PURPOSE COOLING DOMES (3)

Roof failure scenarios:

- Roof collapses in cylinder – integrity containment
- Full surface tank fire: roof burns away gradually

SCENARIO BASED WATER MANAGEMENT



CONTAINMENT (1)

- Product(s), cooling water, fire fighting foam

References:

- Containment systems for the prevention of pollution *Secondary, tertiary and other measures for industrial and commercial premises* *http://www.ciria.org/Resources/Free_publications/c736.aspx*
- FM datasheet 7-83: Drainage and containment systems for ignitable liquids

CONTAINMENT (2)

- Primary containment = tank
- Secondary containment = bund
  - Product, cooling water, fire fighting water/foam
  - Fire proofing (fire water) pipe supports/cables
  - Provisions for drainage to tertiary containment
  - Seals in bund wall must be resistant against exposure to product and fire
  - Integrity bund floor and wall must be guaranteed for duration of incident – including after care

CONTAINMENT (3)

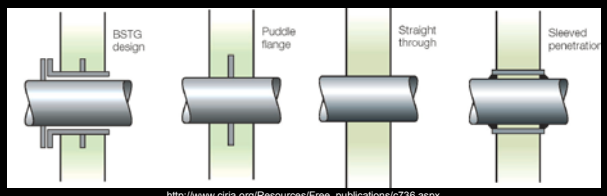
- Tertiary containment (tank, basin)
  - Transport product to tertiary containment in early stages of incident
- Design sewer – worst case scenario (storm water)
- Drainage & sewer system [capacity xx m^3/h]

CONTAINMENT (4)

- Flammable liquids
  - syphon or similar construction for non-water miscible hydrocarbons
  - flame arrestor water miscible liquids
  - open sewer system
  - closed sewers fully filled with vents / flame arresters

CONTAINMENT (5)

- All materials used in secondary/tertiary containment and drainage system shall be non-combustible
- Penetrations through bund walls shall be resistant to contact with product as well as the fire



http://www.ciria.org/Resources/Free_publications/c736.aspx

CONTAINMENT (6)

- Remotely operated valves in system or manually from safe location based on the scenario (toxic substances, heat flux)

QUESTIONS

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