2010 A2 Transformers Session

Transformer Fire Risk and Mitigation

Keynote address:

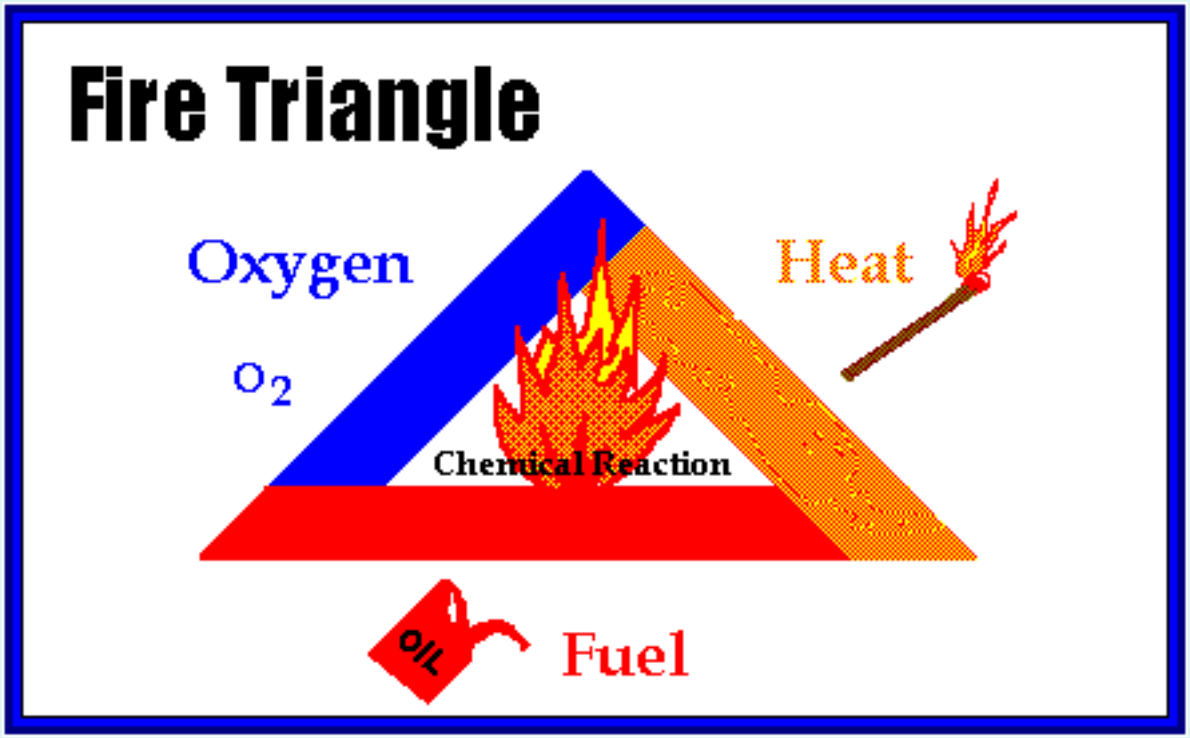
Marc Foata

Hydro-Québec - TransÉnergie
Canada

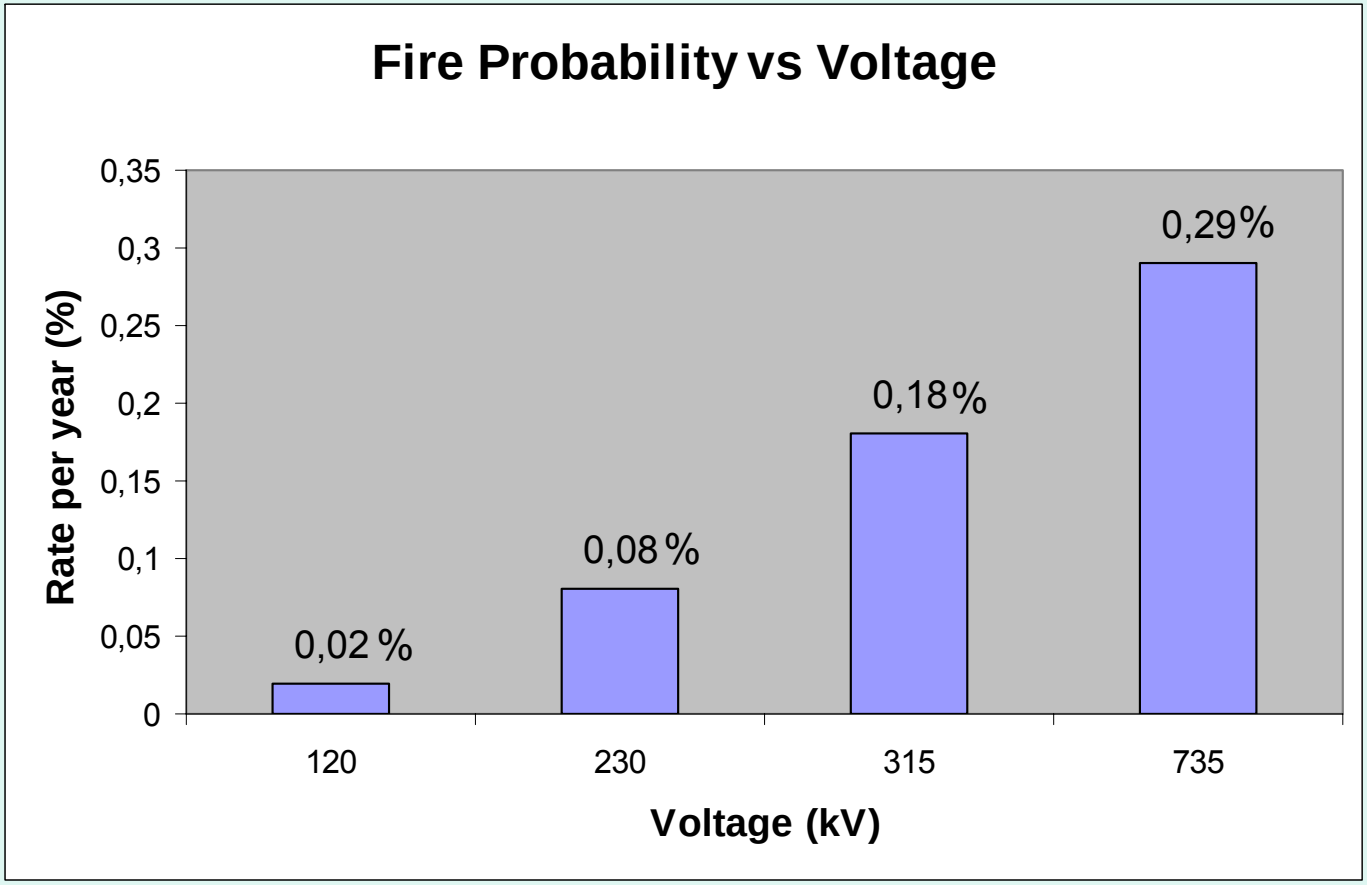
Transformer Fire Risk and Mitigation

1. Fire Basics
2. Statistics
3. Typical Fire Scenarios
4. Mitigation strategies
   - Pressure Relief
   - Energy Containment
5. Conclusions

Fire Basics



Transformer Fire Rate



Statistics from Hydro-Québec - TransÉnergie

Main concern is on the larger power transformers

Causes of fire

~ 50%

Bushing Failure

<5%

External cause

~ 50%

Tank Rupture

<5%

Windings

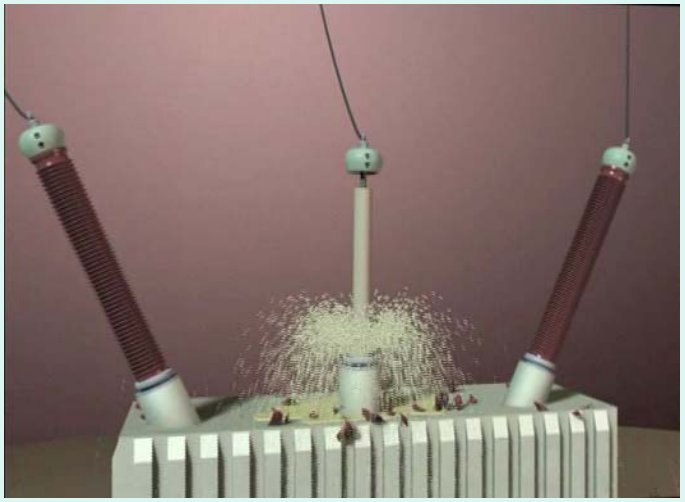
~ 70%

HV Leads and Connectors

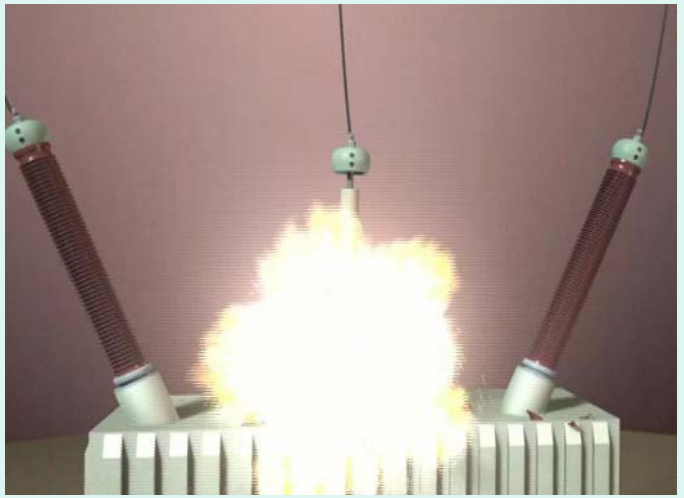
~ 30%

OLTC & Others

Typical Bushing Fire Scenario

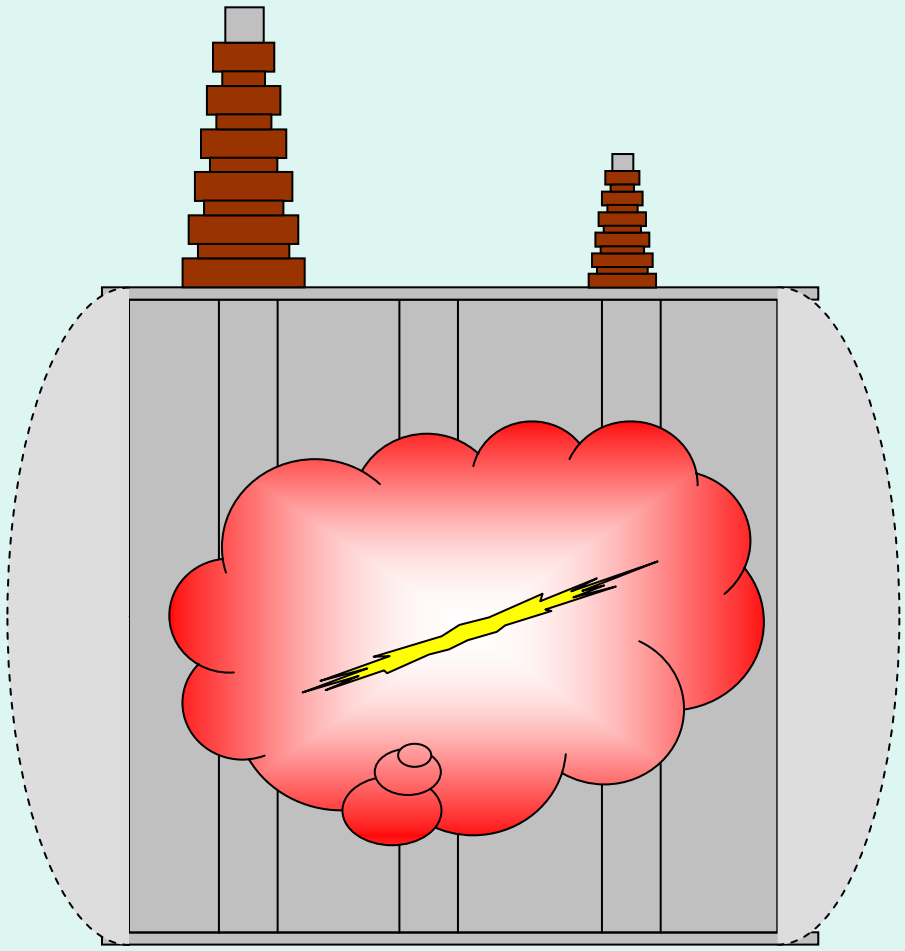


1. Porcelain explodes under internal arcing
2. Bushing collapses into the tank and oil outflow
3. Oil ignites – Fire is fed by the leak



Ref. L. Jonsson , ABB, CIGRÉ Australia 2008

Tank Rupture Mode

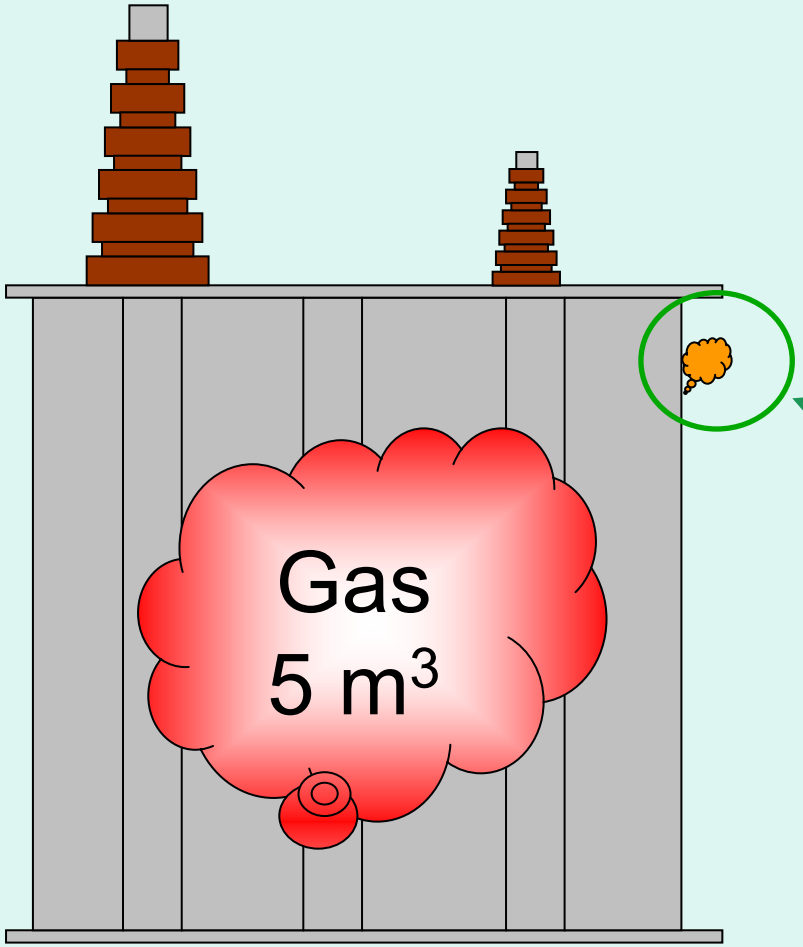


1. Insulation failure – Formation of an arc
2. Energy released decomposes the oil – Formation of a gas volume
3. Internal pressure increases – Tank deforms
4. Pressure exceeds tank strength – Rupture
5. Gas-Oxygen mixture ignites – Fire starts

Mitigation - Pressure relief

Case example:

- 100 MVA typical transformer
- 25 cm diameter PRD
- Arc is away from PRD
- 10MJ arc energy in 3 cycles



0,05 m^3
Maximum volume of oil expelled after 3 cycles

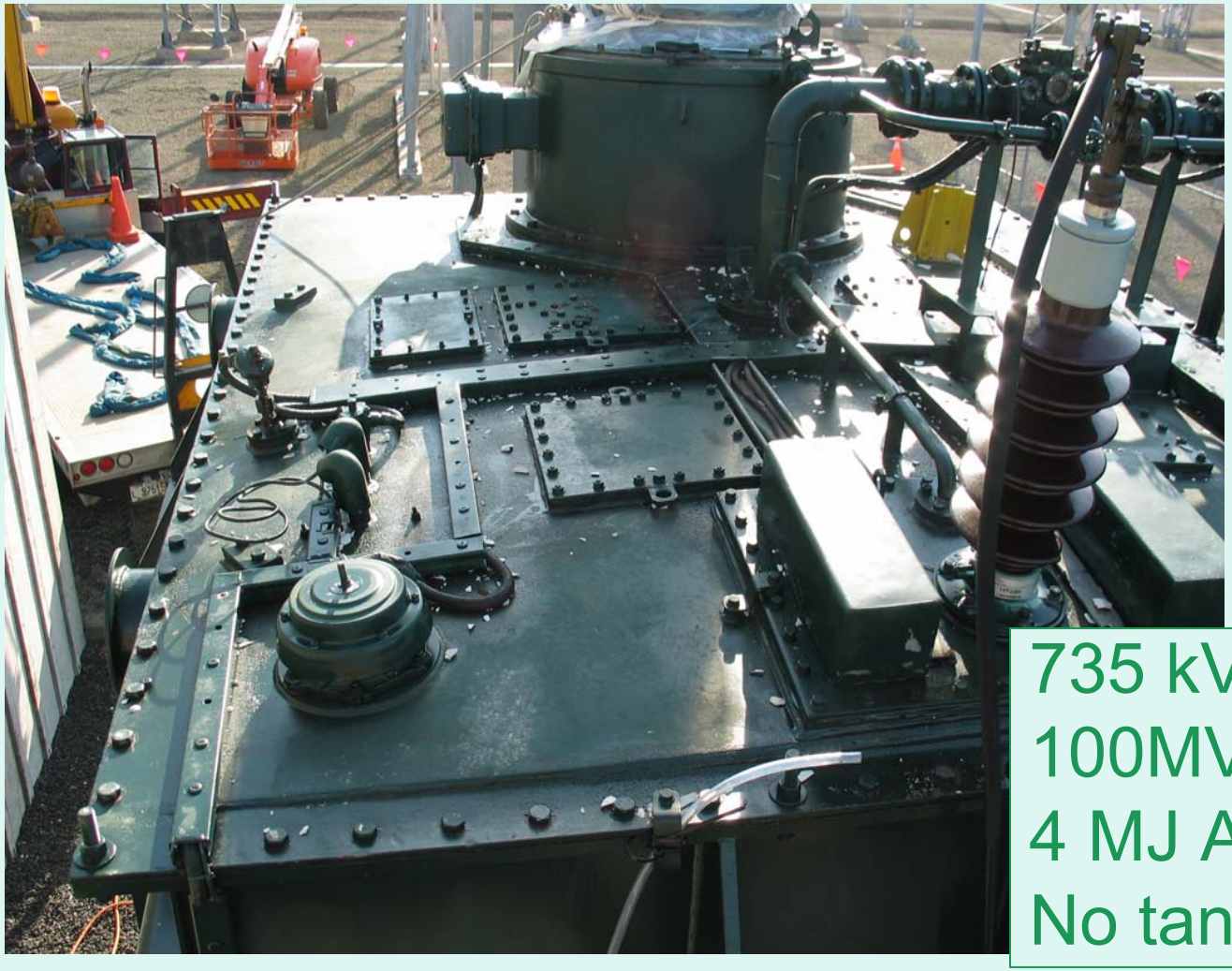
Mitigation - Pressure relief

Reference	Total Venting Area		Resulting % of peak pressure reduction
	m^2	Equivalent number of 25 cm diameter PRDs	
EPRI	1,0	20	10%
Kawamura et al	1,5	30	30%
Hydro-Québec (Paper A2-102, 2010)	1,5	30	< 40%

Mitigation - Pressure relief

Transformer with pressure venting system
Multiple rupture disks

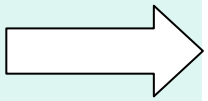
Mitigation - Energy containment



735 kV Reactor
100MVAR
4 MJ Arc
No tank rupture

Mitigation - Energy containment

Rupture occurs between 4 and 8 MJ



Arc energy vs consequences
(735 kV single phase units)

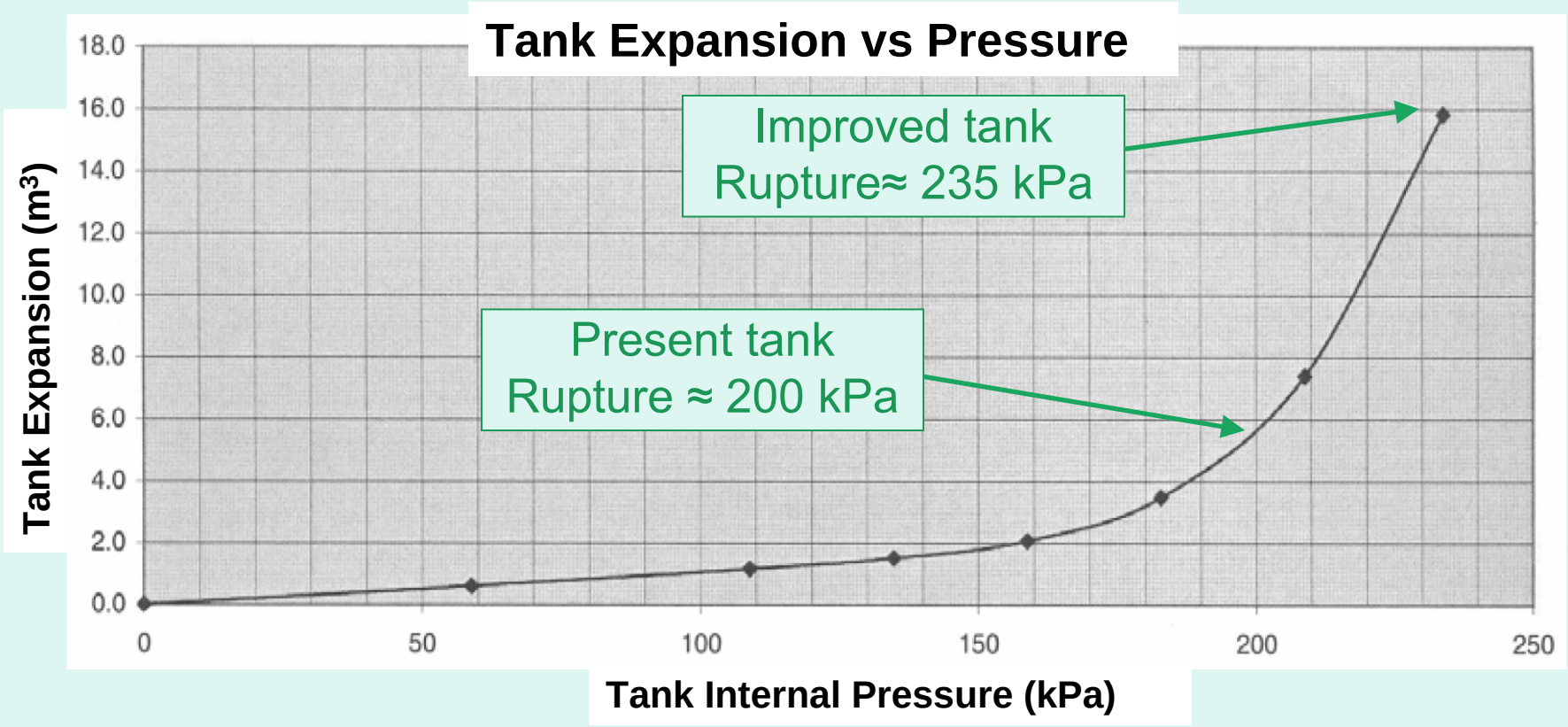
Arc energy (MJ)	Tank rupture	Resulted in a fire
1.0	No	No
2.5	No	No
4.0	No	No
8.0	Yes	No
8.5 – 13	Yes	No
14	Yes	Yes
19 – 23	Yes	Yes
20	Yes	No
26 – 67	Yes	Yes
94	Yes	Yes
147	Yes	No

All field cases from Hydro-Québec - TransÉnergie

Mitigation - Energy containment

Example 735 kV – 550 MVA Single phase

- Present tank (Rupture 200 kPa) - 5 MJ Arc energy containment
- Improved tank (Rupture 235 kPa) > ≈ 18 MJ Arc energy containment



Concluding remarks

For Oil-insulated Large Power Transformer:

- Bushing failures account for 50% or more of fires – Consider using RIP Bushings
- Appreciable increase in containment capability can be achieved with tank design enhancements
- Significant pressure venting can be achieved with large openings (>1m^2)
- In view of the limitations above, mitigation measures (Oil containment, fire barrier, etc.) should always be part of a sound fire protection strategy.