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CIGRE A3.24 WG

Overview

TOOLS FOR THE SIMULATION OF INTERNAL ARC EFFECTS IN MV AND HV SWITCHGEAR

Nenad Uzelac, A3.24 convener

2012 IEEE switchgear meeting

Agenda

1. Working Group Background
2. Effects of Internal Arc
   - Pressure Rise
     - Air vs SF6 comparison
3. Mechanical stress on the switch enclosure
4. Conclusion

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Background

- WG started in 2009
- 20 members -international experts in Internal Arc testing and computational modeling from manufacturers, users, labs and universities.
- Had nine 2-days working group meetings
- Last meeting scheduled for January 2013
- Deliverable: Technical Brochure Q1/2013, Tutorial Q2/2013

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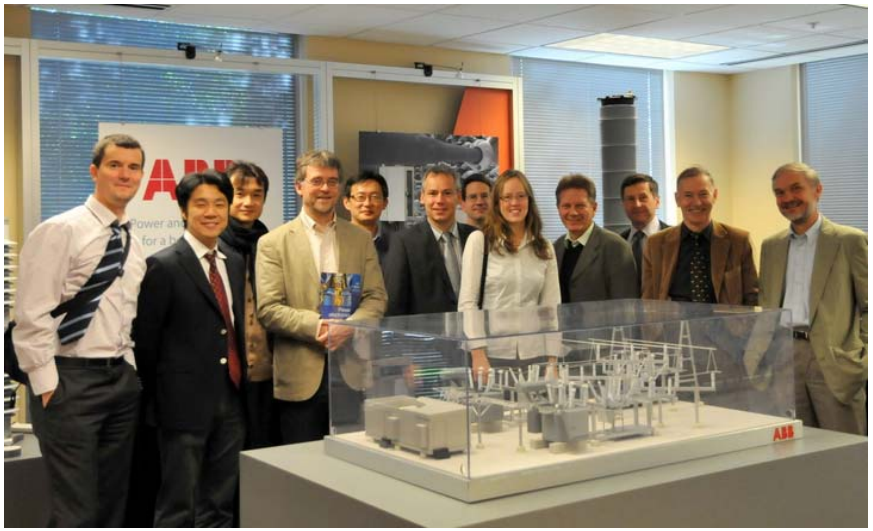
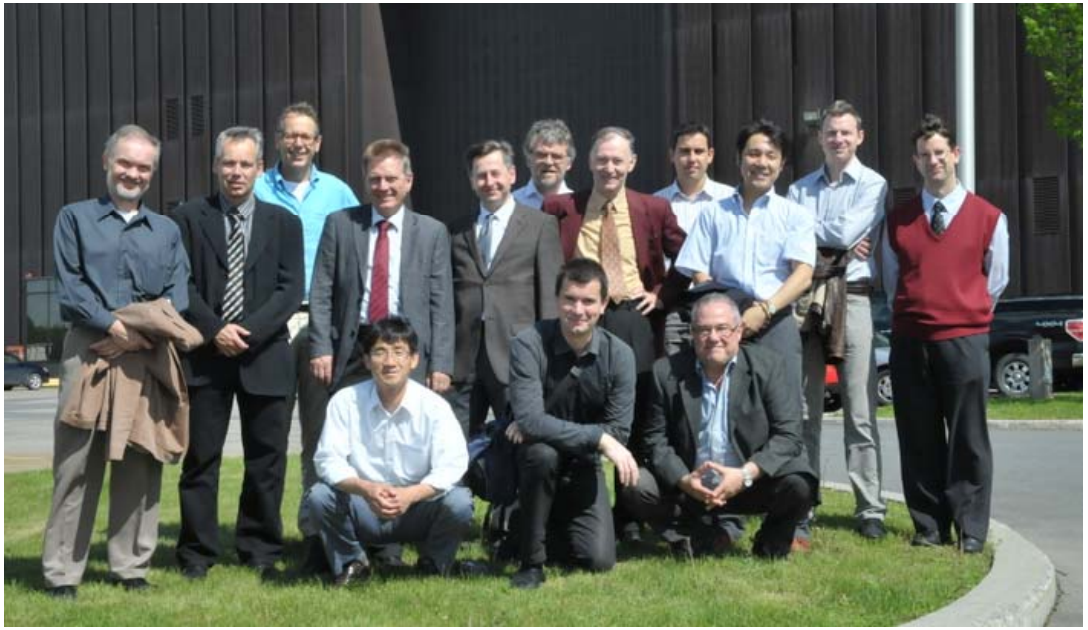
WG Meetings





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Motivation of Work

- To provide methods for pressure rise calculations, allow benchmarking
- To reduce internal arc tests for environmental reasons by improving the hit rate of the design
- To verify design modifications by simulations
- To replace SF_6 in GIS for testing by air with proper consideration of the differences

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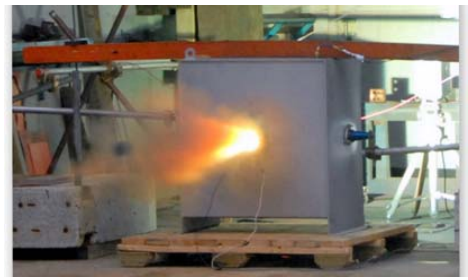
2 Effects of Internal Arc fault:

A. Pressure rise inside switch

B. Mechanical Stress on switch enclosure

C. Burn through

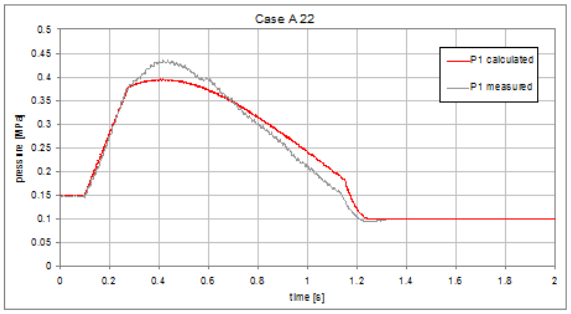
D. Mechanical stress on the installation room

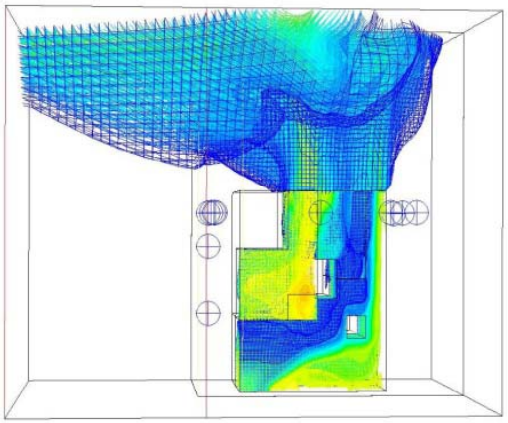


This presentation focuses on #1 & #2

2 A: Pressure rise calculations:

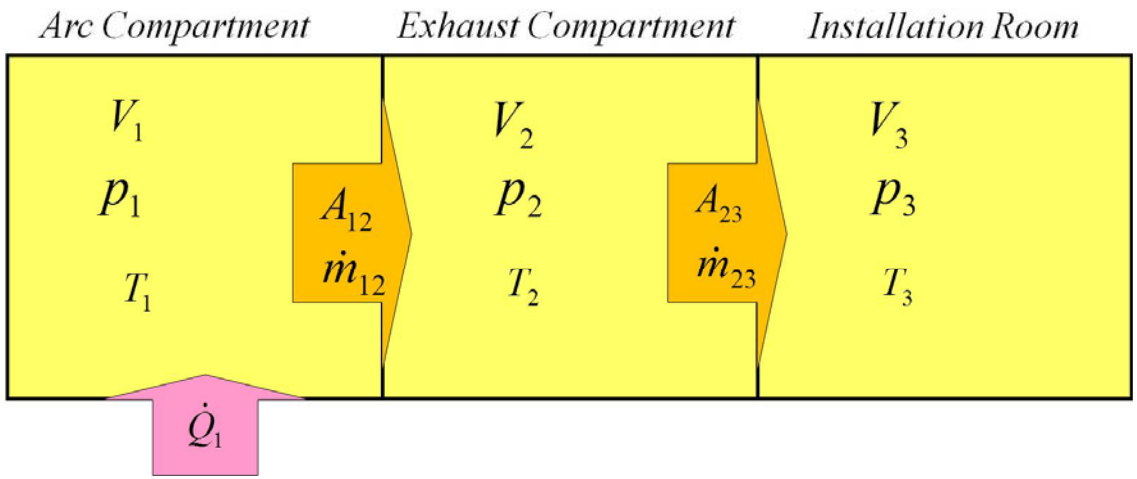
- Developed methods for pressure rise calculations, showed evidence for reliability range and allowed benchmarking
- **Simplified Analytical Model:**
  calculation results of pressure rise in arcing compartment within 10% from measured.
- **Enhanced Analytical Model**
  Simplified + additional approximations
- **CFD Model:**
  calculate pressure distribution and gas flow in odd shapes geometry and very large rooms
- This presentation focuses on Simplified Analytical model





2 Simplified analytical model

- Outlined in detail in Technical Brochure.
- Used to calculate uniform ΔP using ideal gas equation in V1, V2 and V3
- Some limitations exist. Both analytical models don't calculate spatial differences in pressure inside the volumes



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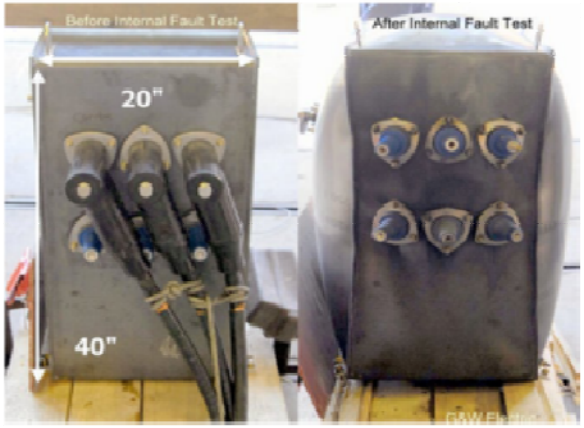
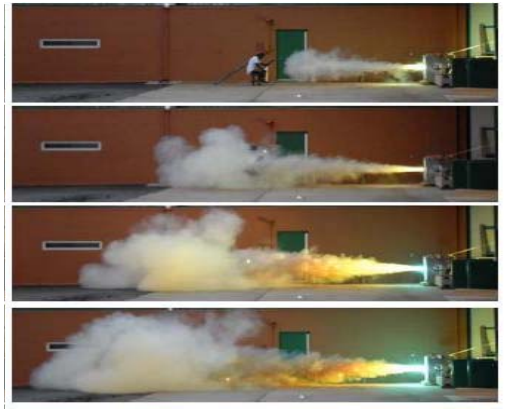
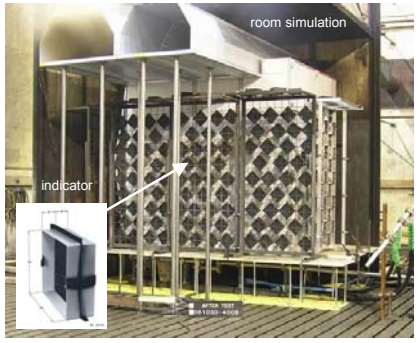
Analyzed 70+ Cases



- AIR, SF6, N2
- 5 ltr – 1200 ltr
- 12kA – 63kA
- 10ms – 1.2s





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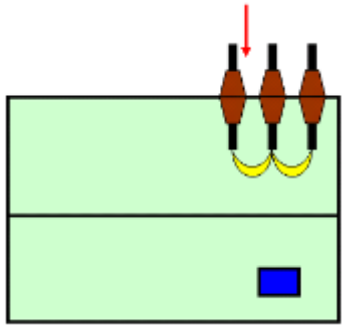
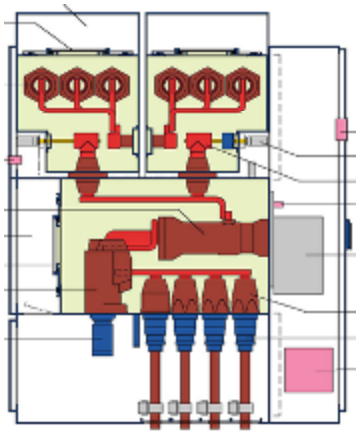
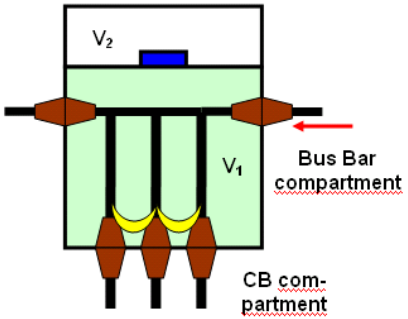
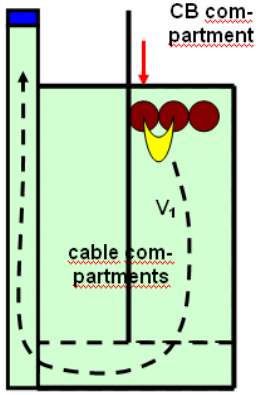
i. Simplify geometry









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ii. Calculate pressure rise for each case

Simplified model equations

$$Q_1 = k_p \cdot W_{el}$$

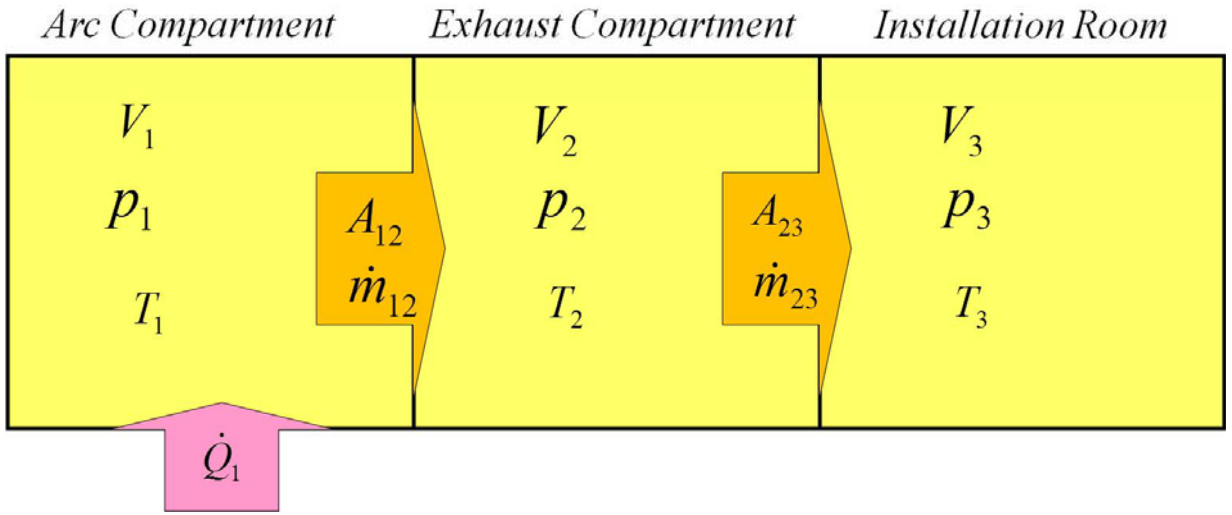
$$\Delta m_2 = \Delta m_{12} - \Delta m_{23}$$

$$\Delta m_{12} = \alpha_{12} \cdot A_{12} \cdot \rho_{12} \cdot w_{12} \cdot \Delta t$$

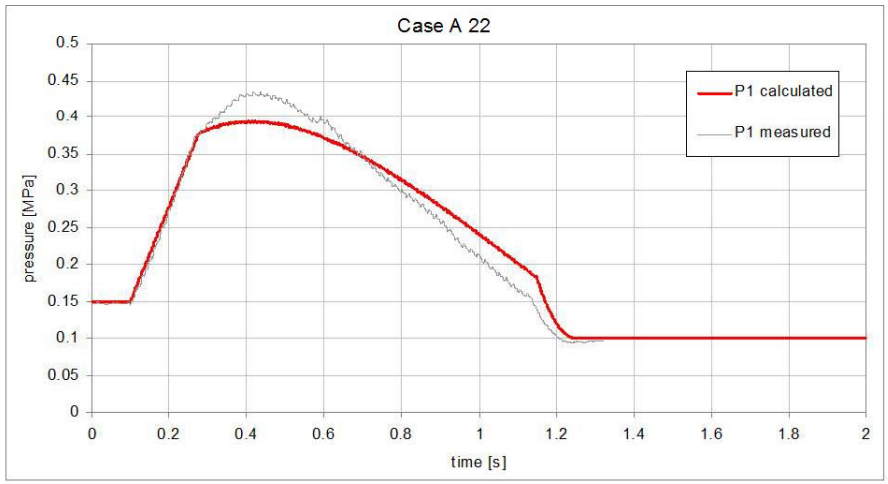
$$\Delta T_1 = \frac{\Delta Q_1 - \Delta m_{12}(c_{p1} - c_{v1})T_1}{m_1 c_{v1}}$$

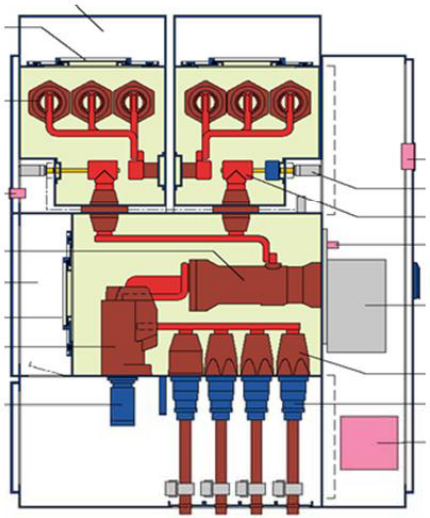
$$p_1 = \frac{(\kappa_1 - 1)}{V_1} \cdot m_1 \cdot c_{v1} \cdot T_1$$

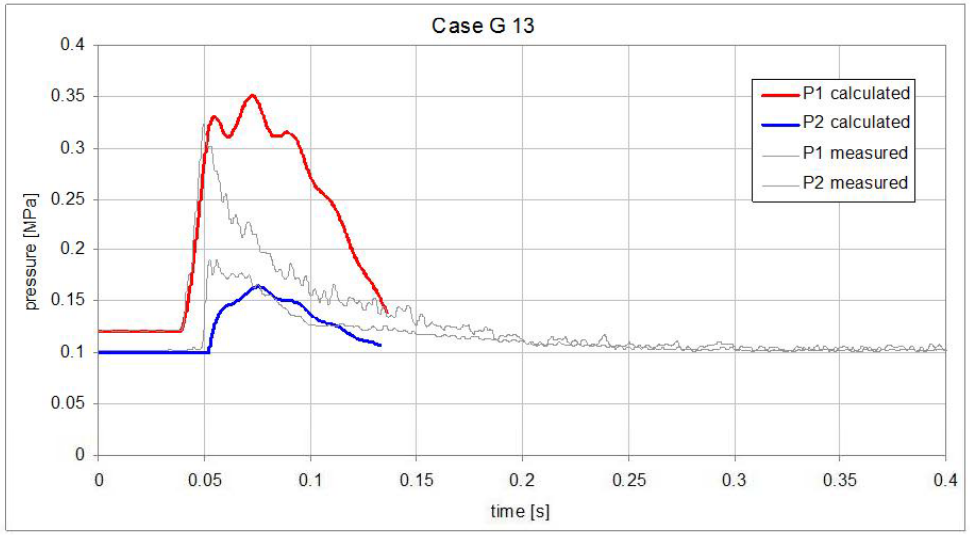
For better calculation prediction, Kp-factor and arc voltages need to be taken from the similar test



2 iii. Compare with test results and determine Kp factor







2 iv. Use tools to predict results

Must test similar object

1. Different switch / compartment size
2. Different fault currents
3. Different rupture disc openings
4. Different gas

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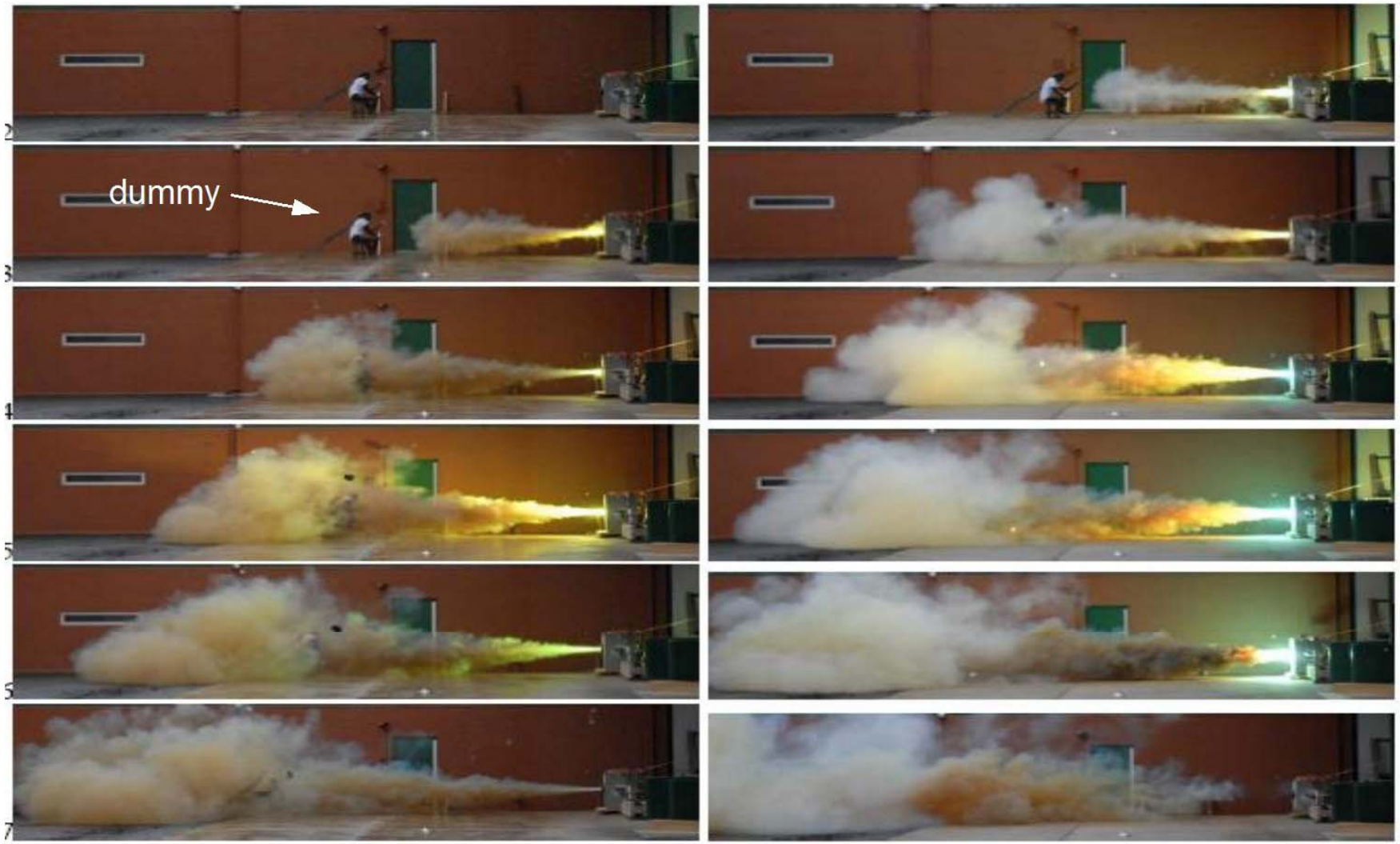
Air vs SF6



SF6

Air

3

SF6 vs Air

- **Arc compartment**:

  The mechanical stress of the fault arc compartment is higher when filled with air instead of SF6 due to the faster and higher pressure rise in air.

- **Intermediate compartment:**

  With air, the exhaust gas gives a lower peak pressure in the adjacent compartment than with SF6;
  hence the mechanical stress is also smaller.

- **Indicators:**

  Air and SF6 give the same direction and flow distribution of the gas exhaust in the installation room. The probability of indicator ignition might be comparable

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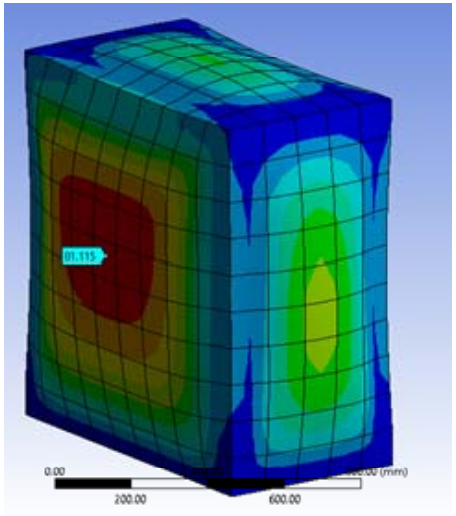
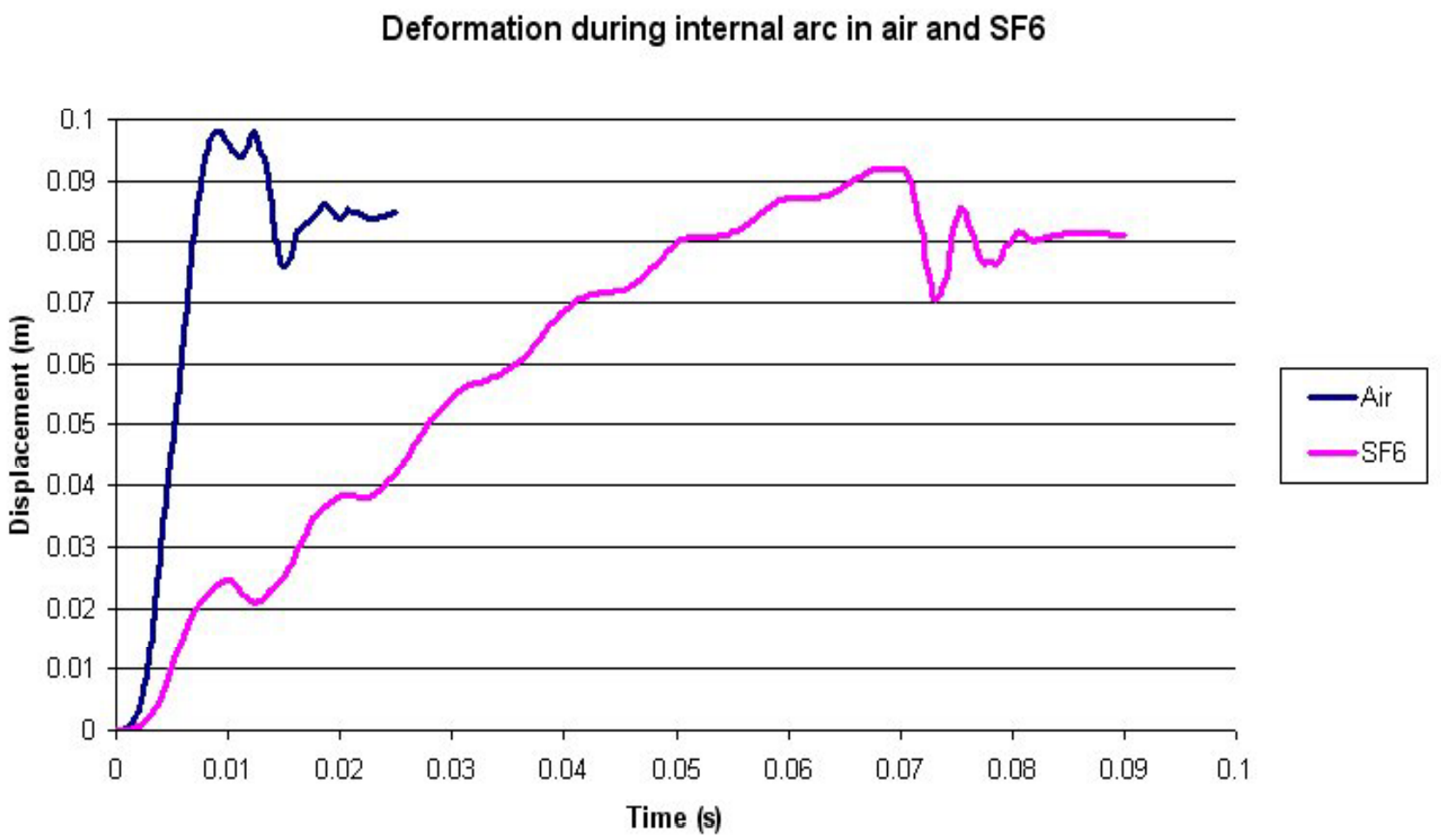
3 Mechanical stress on the switch

- First calculate the expected pressure rise inside the switch
- Then ese existing FEA to evaluate the mechanical stress on the enclosure
- Calculation of deformation of enclosure by FEA stress analysis can be done both for welded and bolted enclosures



3 Mechanical stress on the switch



Higher displacement for AIR filled then SF6 filed compartments

Conclusion

- A3.24 WG findings suggest that simulations can't replace type tests, but they could be used for interpolation between the known tests
- Run baseline test(s) and measure energy input (Kp, Varc)
- Use calculation tools to predict Pressure rise and mechanical stresses.

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Questions?