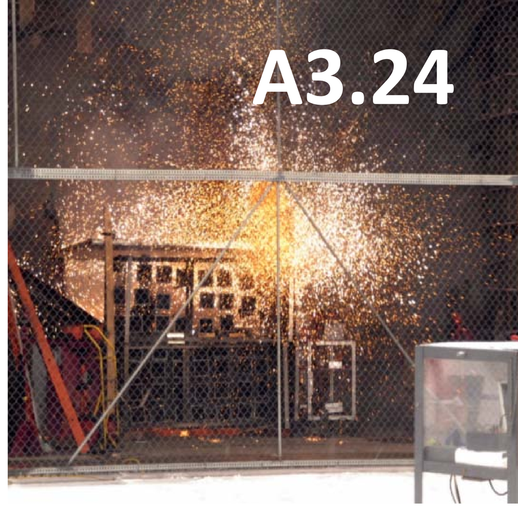


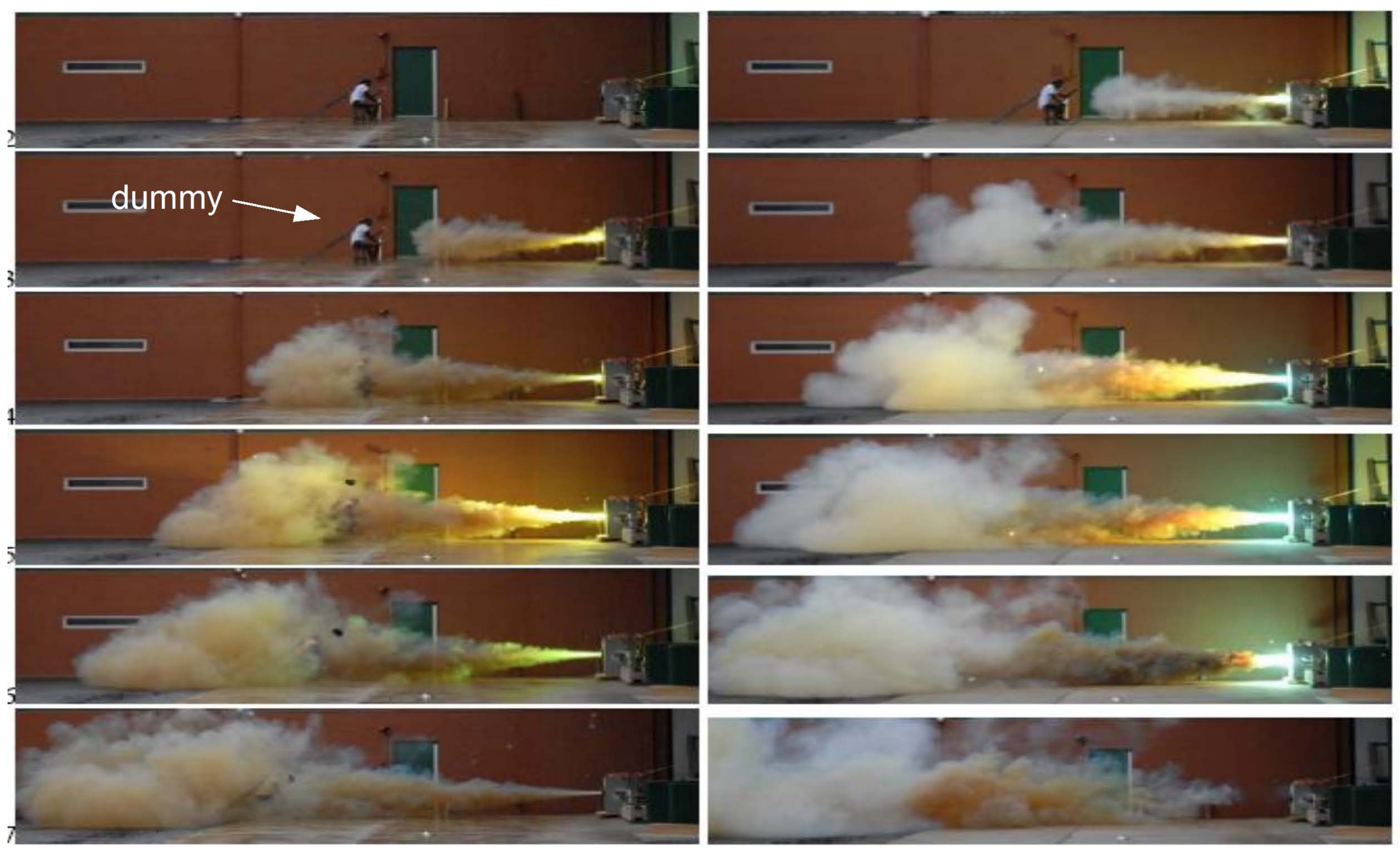
Study Committee A3
High Voltage Equipment

TOOLS FOR THE SIMULATION OF PRESSURE RISE DUE TO INTERNAL ARC IN MV AND HV SWITCHGEAR

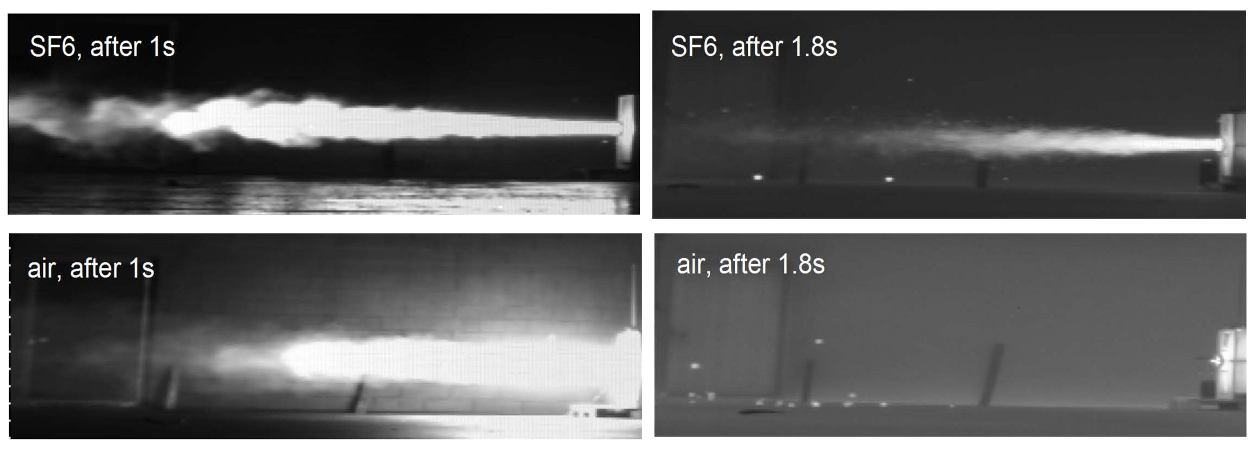
N. Uzelac, Convenor (US) M. Glinkowski, Secretary, (US), L. del Rio (ES), J. Douchin (FR), E. Dullni (DE), S. Feitoza Costa (BR), E. Fjeld (FI), M. Glinkovski (US), K. Hong-Kyu (KR), M. Kriegel (CH), J. Lopez-Roldan (AU), R. Pater (CA), G. Pietsch (DE), T. Reiher (DE), G. Schoonenberg (NL), S. Singh (FR), R. Smeets (NL), T. Uchii (JP), L. Van der Sluis (NL), P. Vinson (FR), Y. Daisuke (JP)

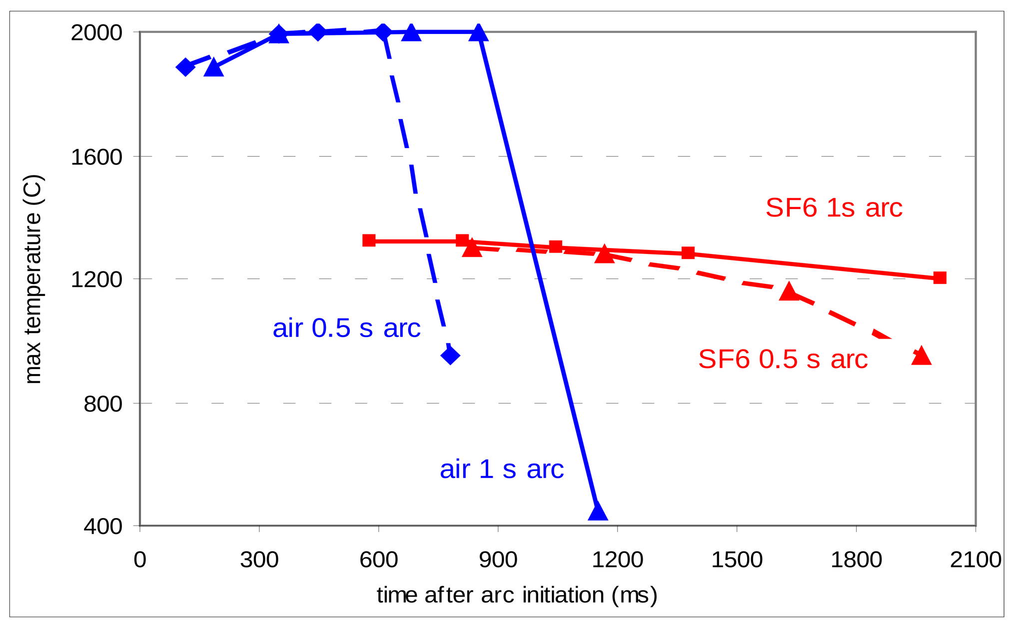
Motivation / targets of work:

- To provide methods for pressure rise calculations, show evidence for reliability range and 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



Tests and calculating pressure in Air and SF6

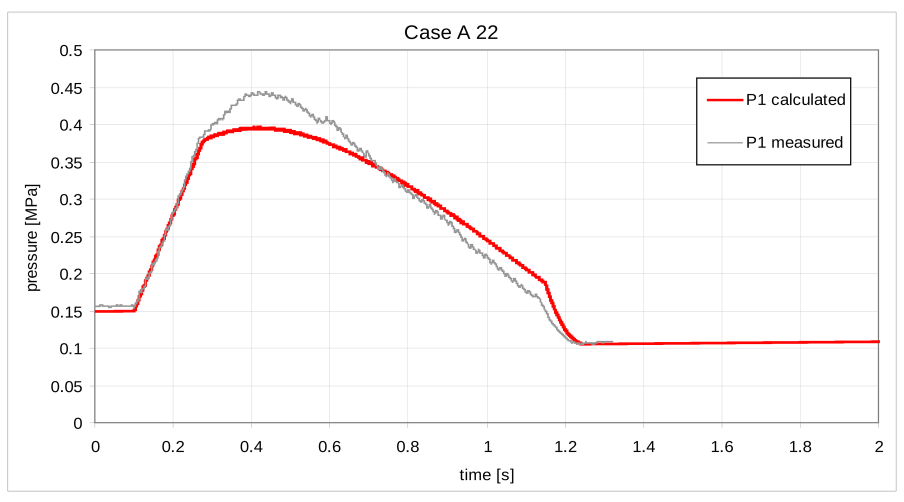


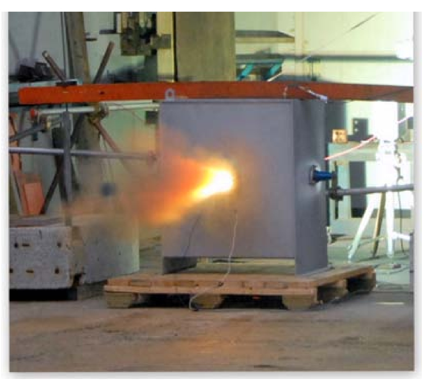


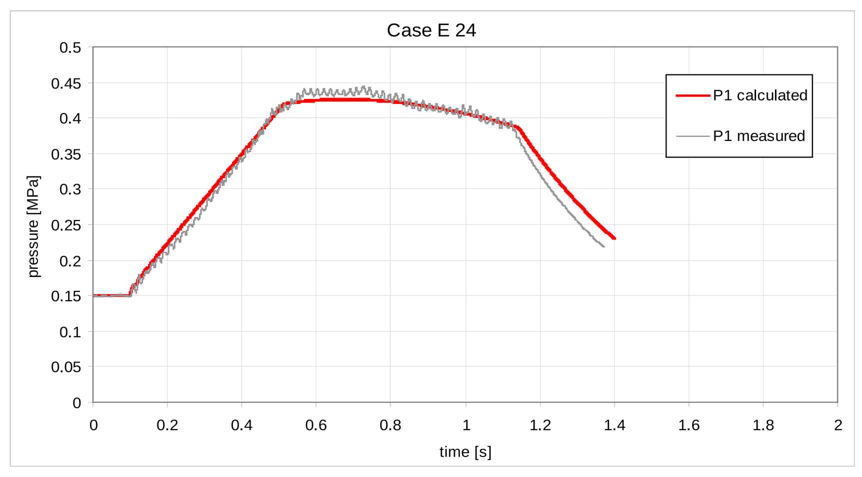
- **Arc compartment:**
  The mechanical stress of the fault arc compartment is higher when filled with air instead of SF6 due to the faster and higher pressure rise in air.
- **Intermediate compartment:**
  With air, the exhaust gas gives a lower peak pressure in the adjacent compartment than with SF6; 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.

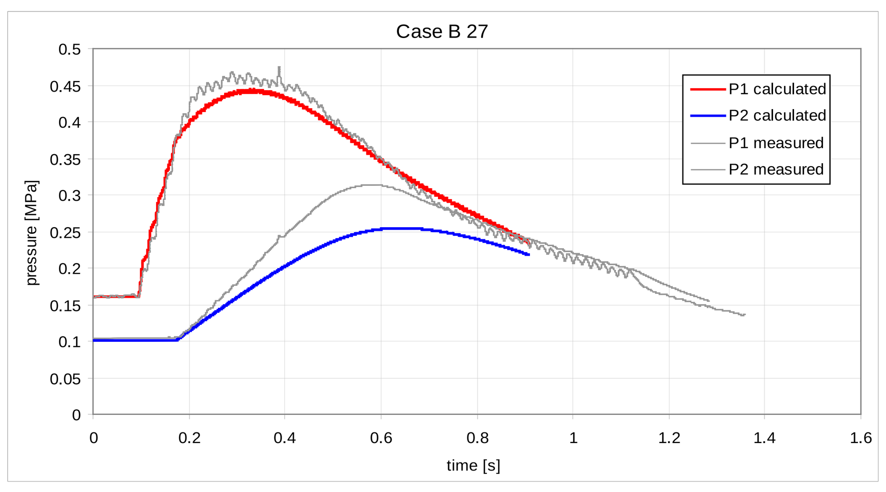
Air

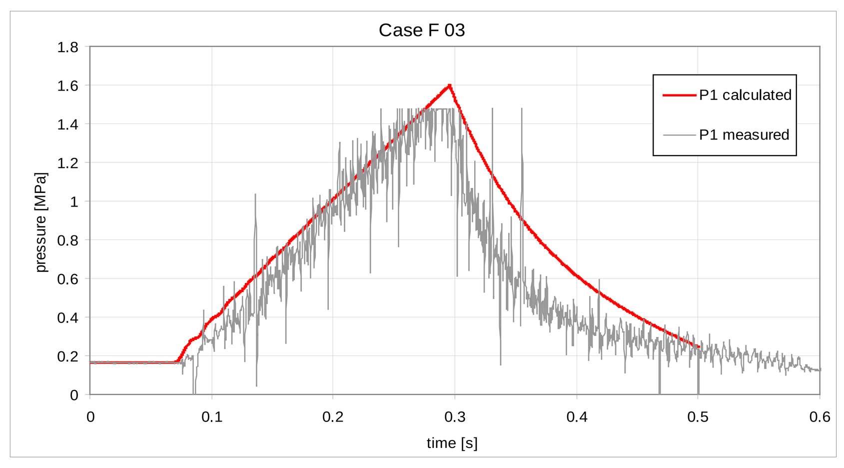
SF6

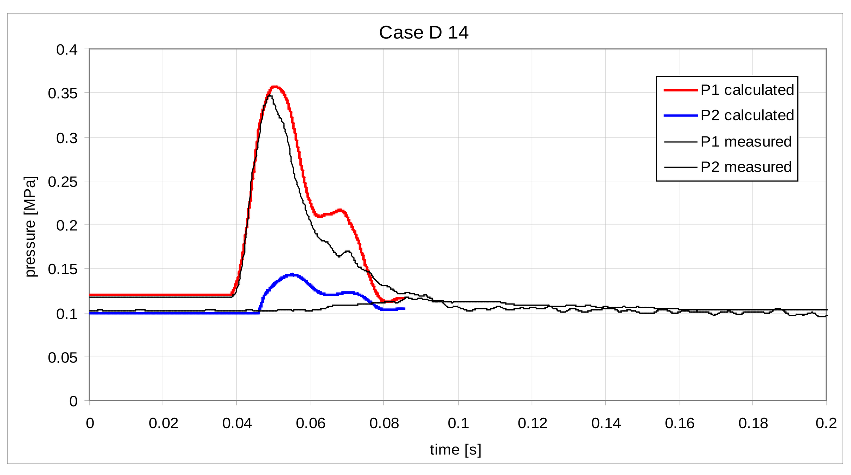


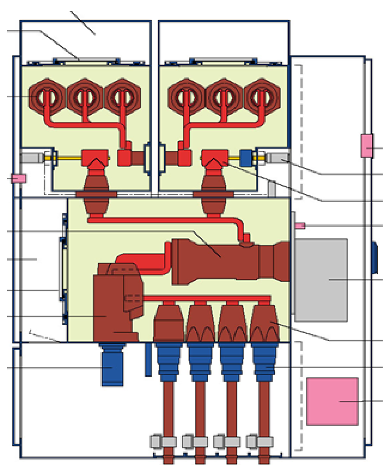


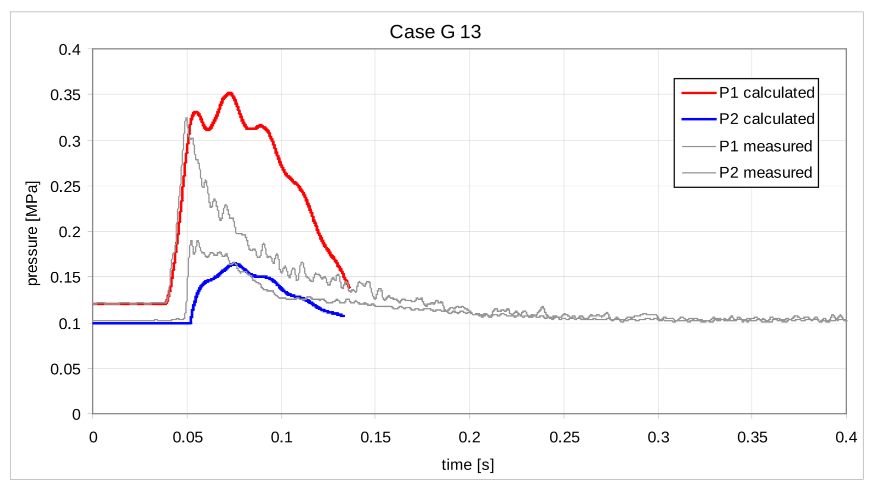


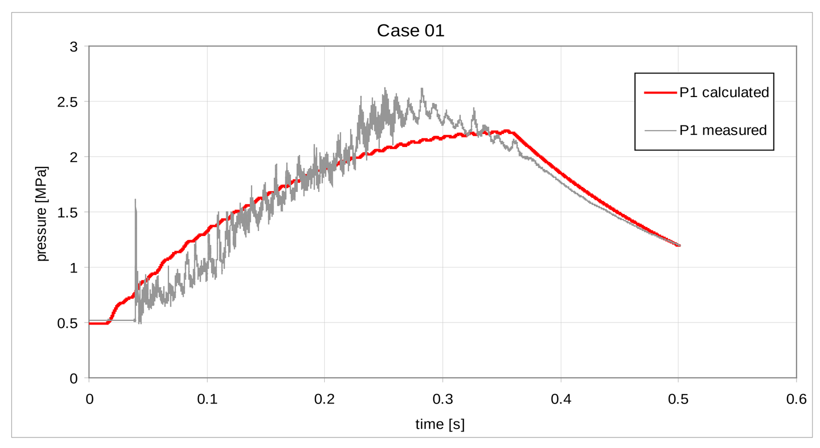


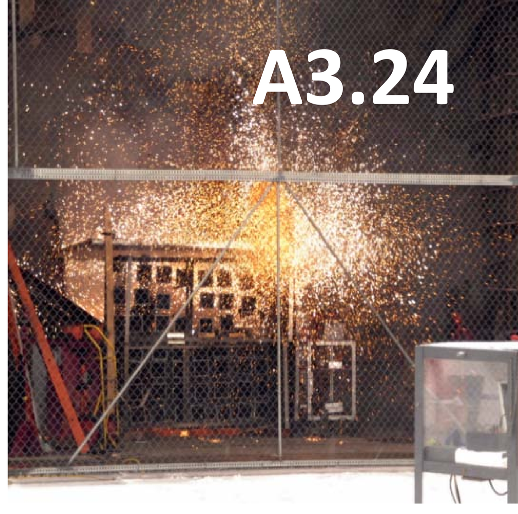












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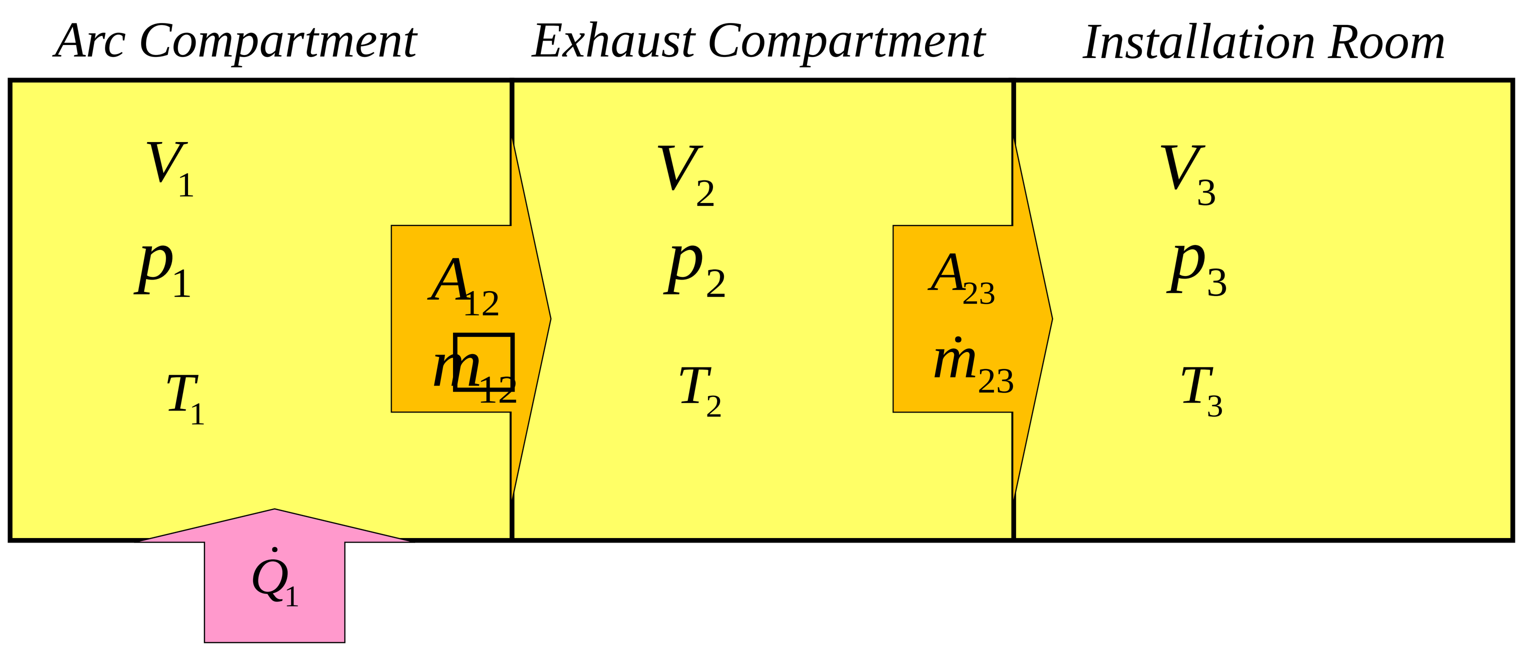


Simplified model equations

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

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

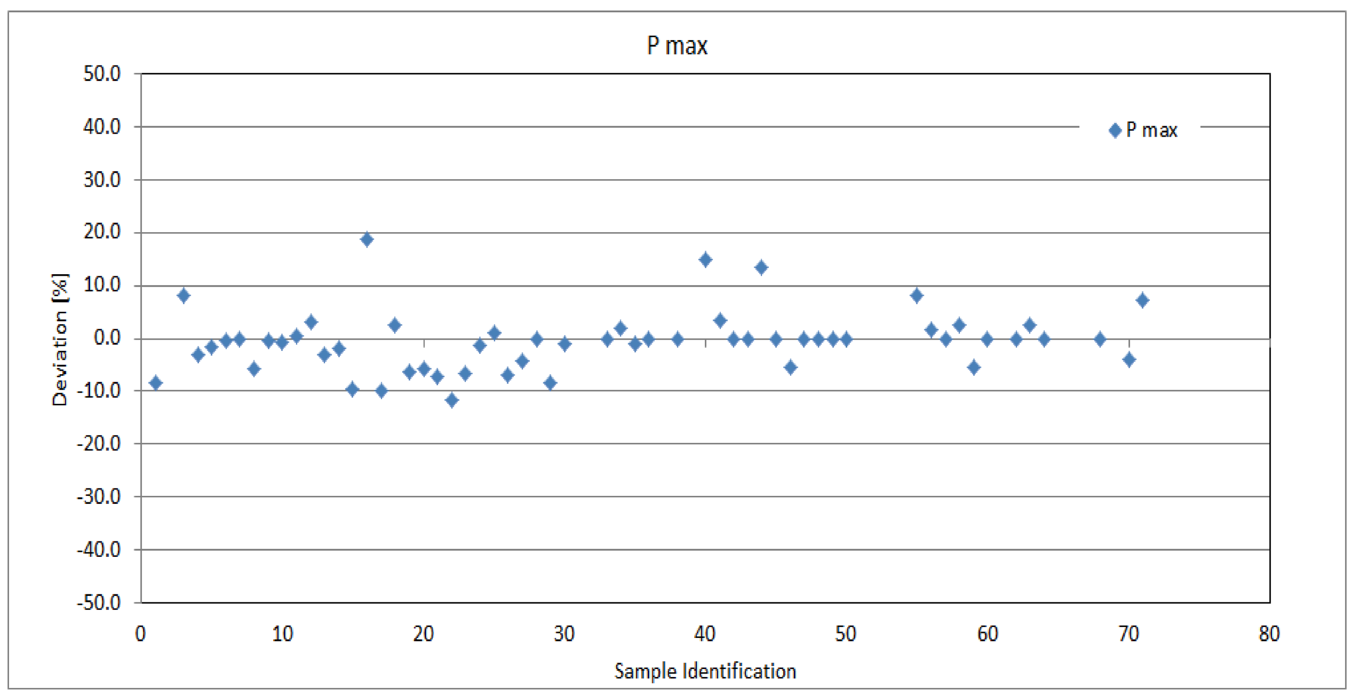
$$\Delta m_{12} = \alpha_{12} \cdot A_{12} \cdot \rho_{12} \cdot w_{12} \cdot \Delta t$$

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

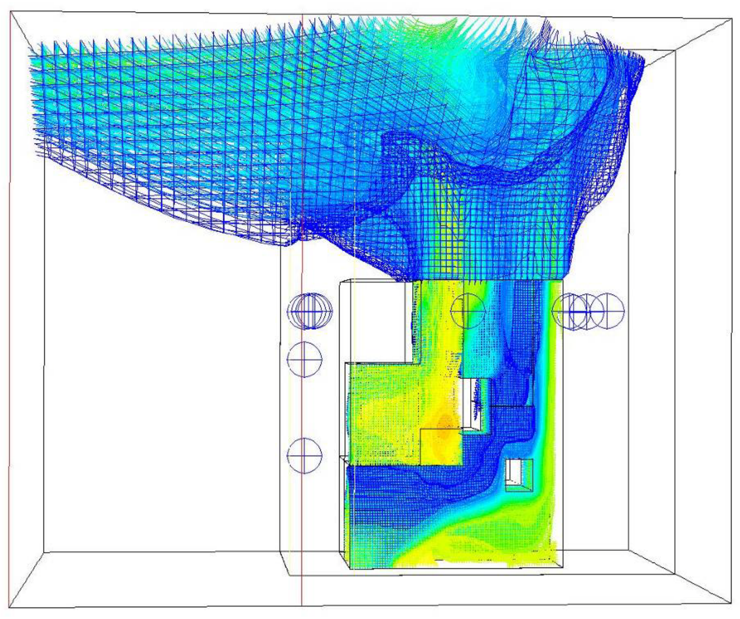
$$p_1 = \frac{(\kappa_1 - 1)}{V_1} \cdot m_1 \cdot c_{v1} \cdot T_1$$

Calculation methods:

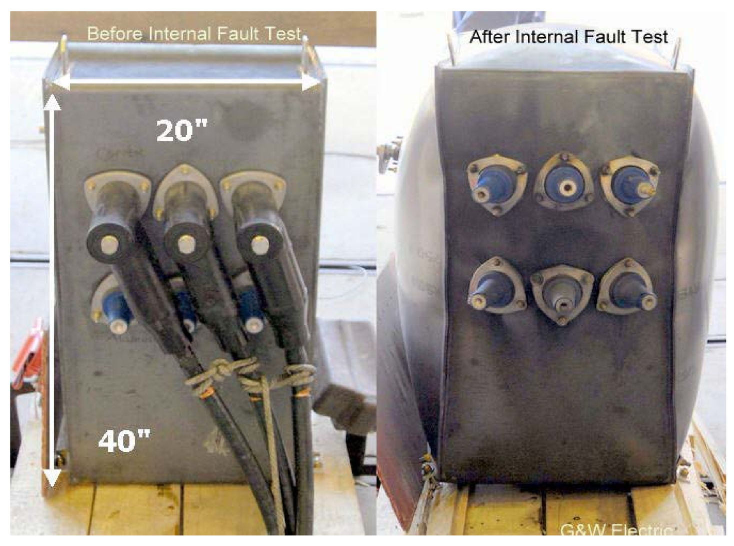
- **Simplified analytical model:**
  - Used to calculate unifom **ΔP** using ideal gas equation in $\mathbf{V_1}$, $\mathbf{V_2}$ and $\mathbf{V_3}$
  - The agreement between test results and calculation for the arc compartment is within ± 10 % (when Kp taken from the test)
  - Some limitations exist. Both analytical models don't calculate spatial differences in pressure inside the volumes

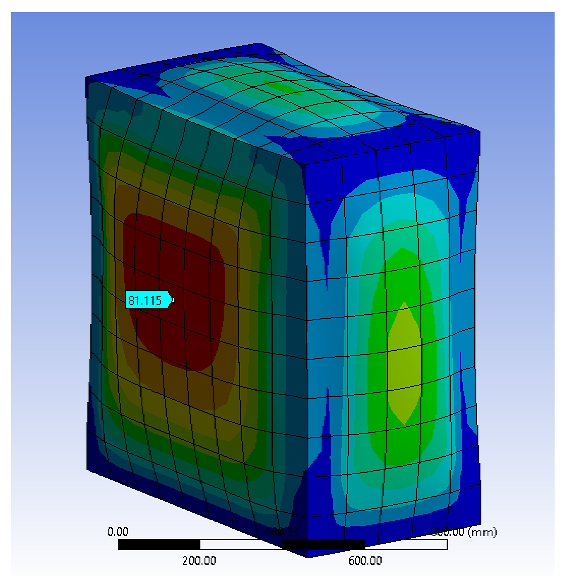


- **Enhanced analytical model:**
  - Used to calculate uniform **ΔP** inside volumes, with some added approximations to improve the simplified model.
  - Heat transfer factor kp decreasing with gas density
  - Air, SF6 and metal vapour mixtures included
  - Temperature dependent gas properties included



- **CFD models:**
  - Used to calculate pressure distribution and gas flow in odd shapes geometry and very large rooms
  - Requires expertise, computer power and time





- **FEA models:**
  - Allow to evaluate the mechanical stress on the enclosure
  - Calculation of deformation of enclosure by FEA stress analysis; for welded and bolted enclosures

- **Burnthrough of enclosures:**
  - Publication research
  - Calculation of burnthrough by FEM program