



Development of IM Design Methodology against Liquid Fuel Fire Threat

**Investigation of Boundary Conditions and Time to Reaction for the Thermal Analysis
of fast-cook off test by means of Numerical and Experimental Approach**

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- IM Awareness has been increased step by step in last 15 years.
- Became a requirement by the MoD for fast cook-off and bullet impact for the new projects after 2005.
- Requirements seemingly to be increased in near future.
- On the other hand TÜBİTAK SAGE had significant effort to increase its capabilities for designing FCO, SCO, FI, SCI, BI and SR since 2005.

Scope

- Modeling the FCO Threat:

- Determination of Boundary Conditions (BC's)
- Time to Reaction (TtR) Analyses
- Thermal Paths and Possible Precautions
- Validation Tests

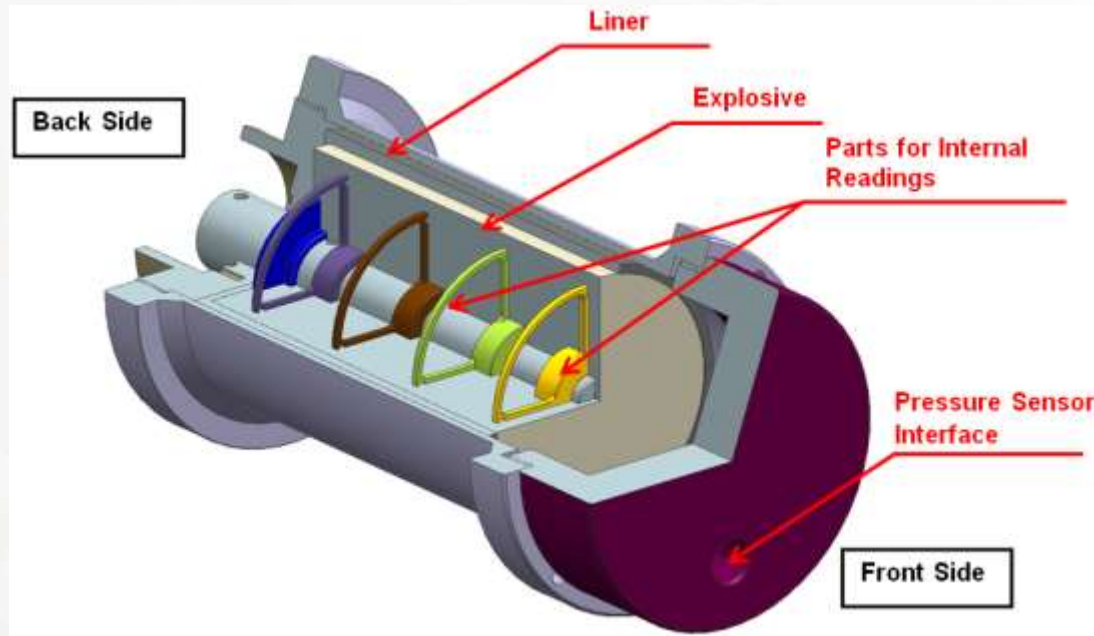
→ ANSYS

- Ventilation Characteristics:

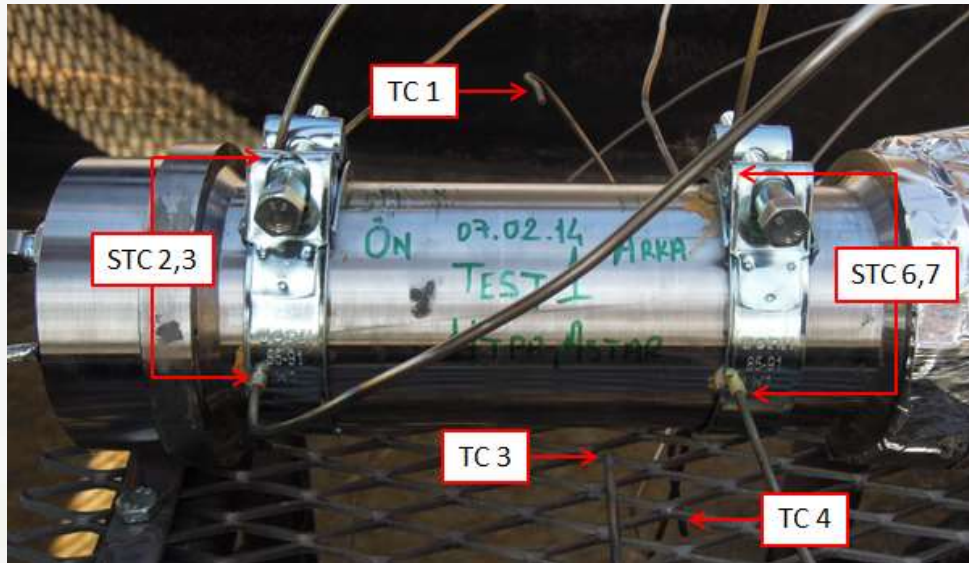
- Conservation of Energy and Mass Model
- Coupled Mass, Momentum and Energy Solver
- Validation Tests

→ MATLAB

→ ANSYS

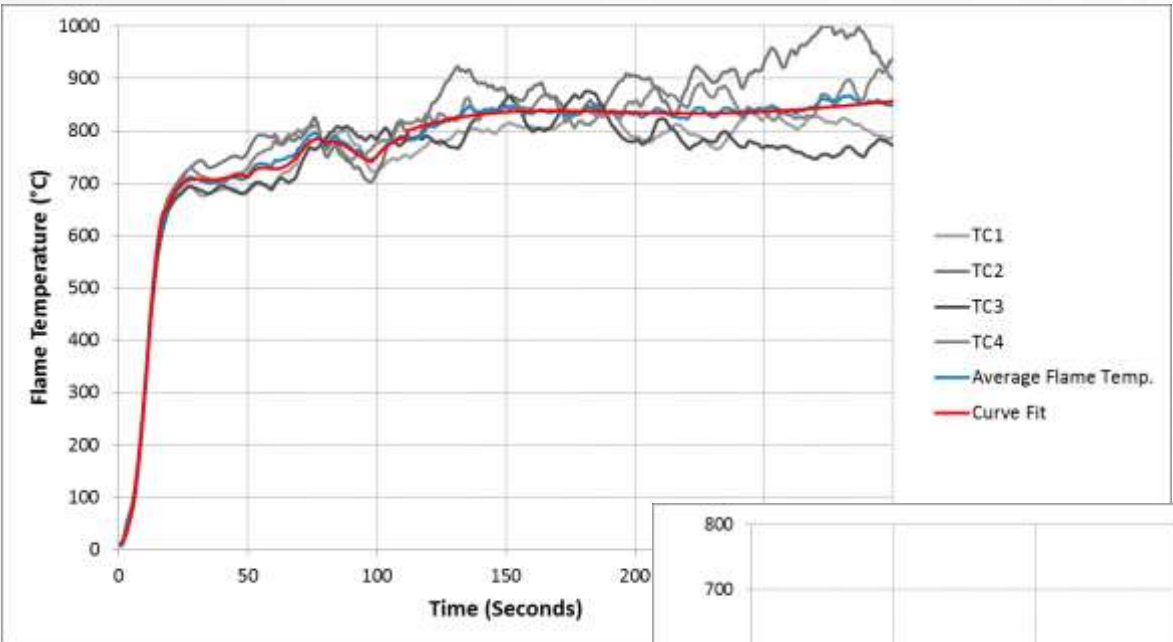


- Designed for the Purpose of:
 - TtR Determination and BC Measurements
 - Critical Ventilation Measurements (Chamber Pressure Measurements)
 - Internal Measurements (Burn Rate, Inner Temp, etc)



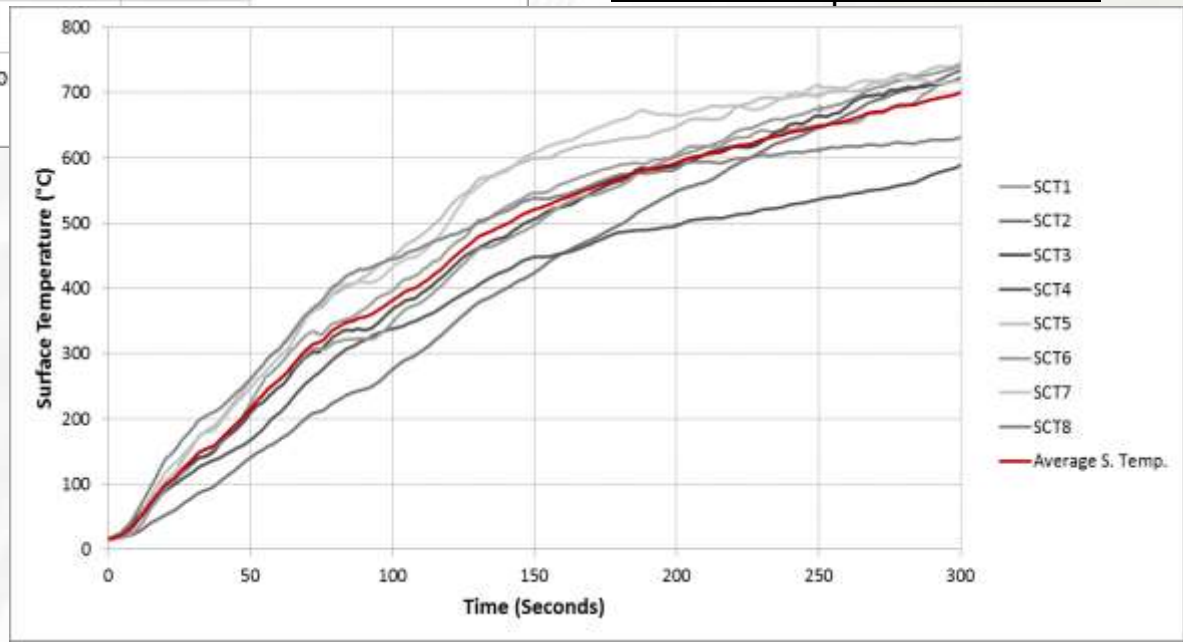
- Defining the BC for Thermal Analyses:
 - Gas Temperature Measurements
 - Use of Literature Defined Emissivity and Convection Coef. (Victor A.C, 1995)

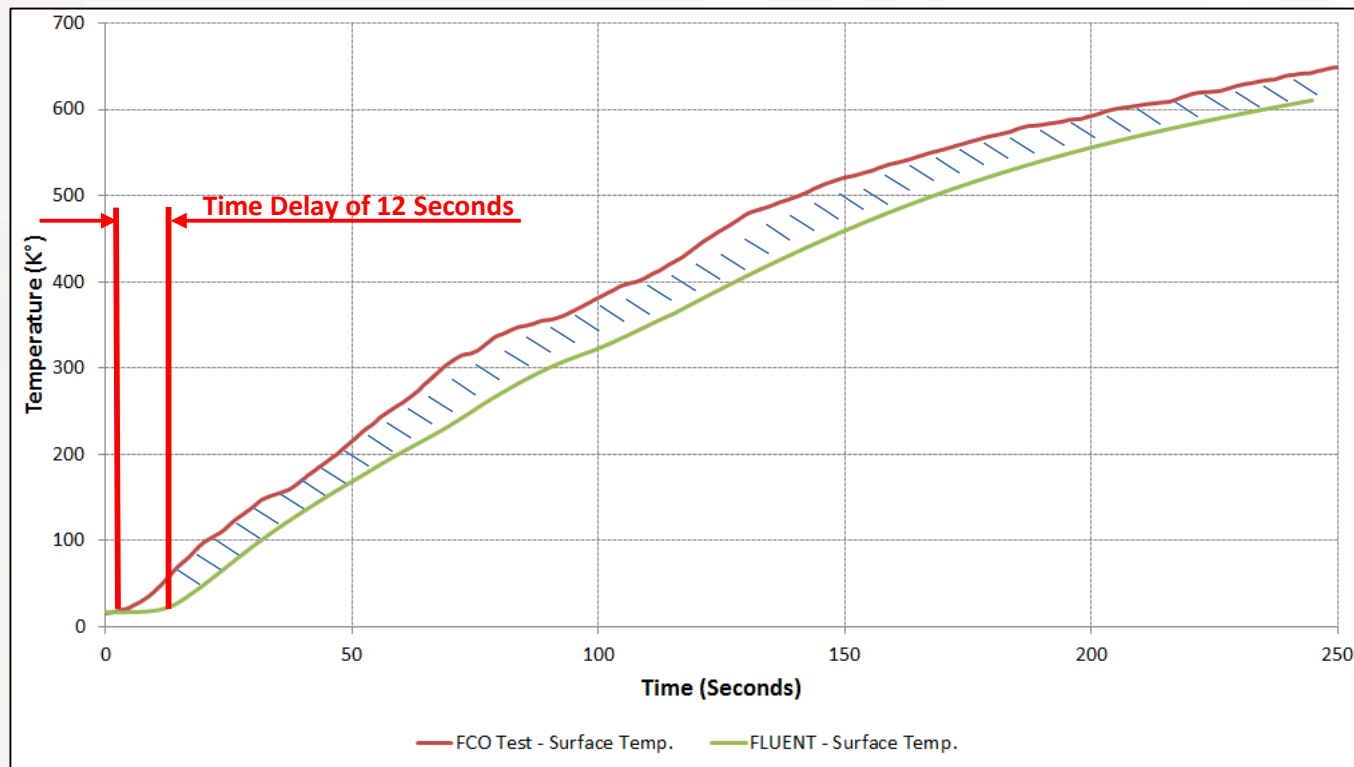
Observation of Test Data



Flame Temperature - Time

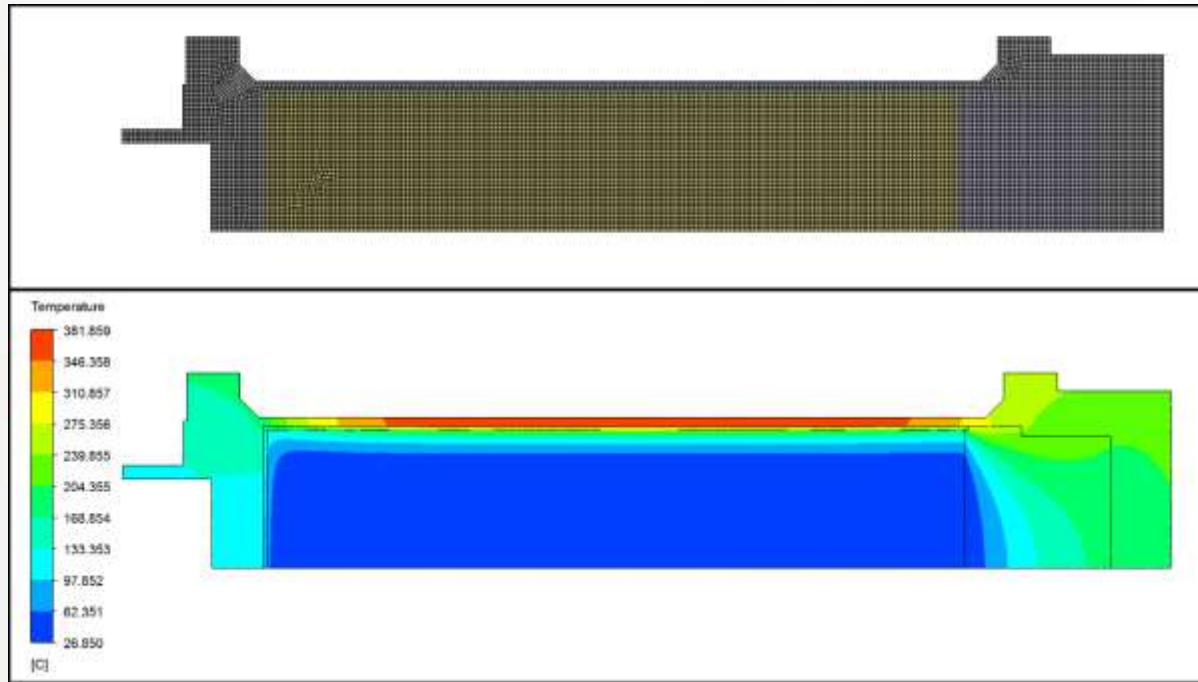
Surface Temperature - Time





Surface Temperature – Time Analyses and Test Comparison

- 12 seconds of “delay” observed between test and analyses average surface temperature.
 - Response time of thermocouple



- Thermal Analyses:
 - 2-D (axisymmetric) and 3-D (for buoyancy) analyses
 - %1 difference observed - Cont'd with 2-D approach
 - Complex geometries - buoyancy effect differ (3-D)

Test and Analysis Comparison

Configuration

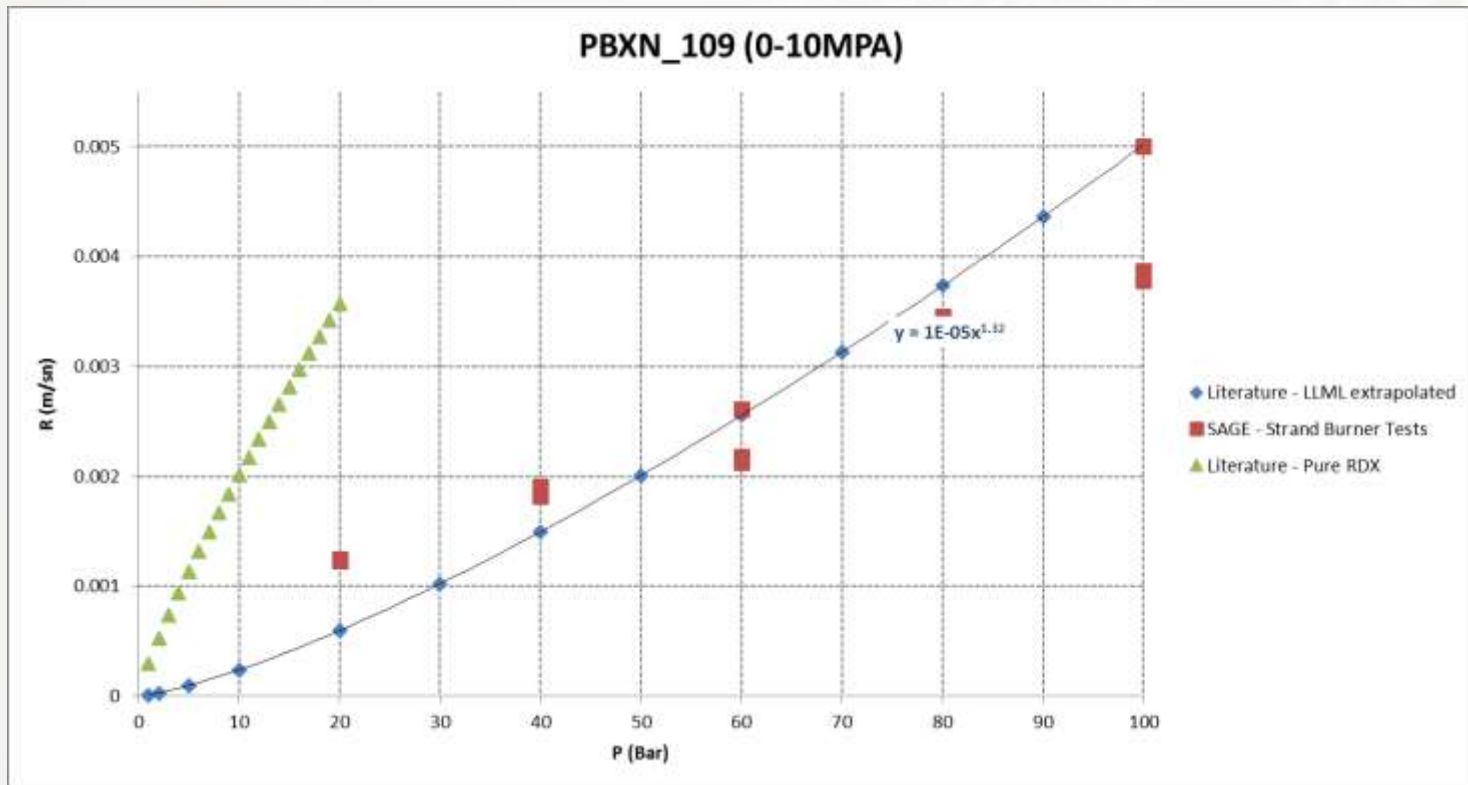
Results & Comparison

Test Item No	Explosive LD	Liner Thickness (mm)	Liner Type	Predicted TtR (sec.)	Predicted TtR* (sec)	Observed TtR (sec.)	Difference (sec.)	Error %
1	2.67	3.50	HTPB Based Thermoset	238	226	200	26	13.1
2	1.71	3.50	Thermoplastic Liner	229	217	200	17	8.6
3	1.71	3.50	Thermoplastic Liner	229	217	186	31	16.7
4	1.60	1.00	Thermoplastic Liner	129	117	120	-3	-2.8
5	1.60	1.00	Thermoplastic Liner	129	117	108	9	8.0
6	1.60	1.00	Thermoplastic Liner	129	117	120	-3	-2.8
7	1.60	1.00	HTPB Based Thermoset	133	121	107	14	13.0
8	1.60	1.00	HTPB Based Thermoset	133	121	118	3	2.5

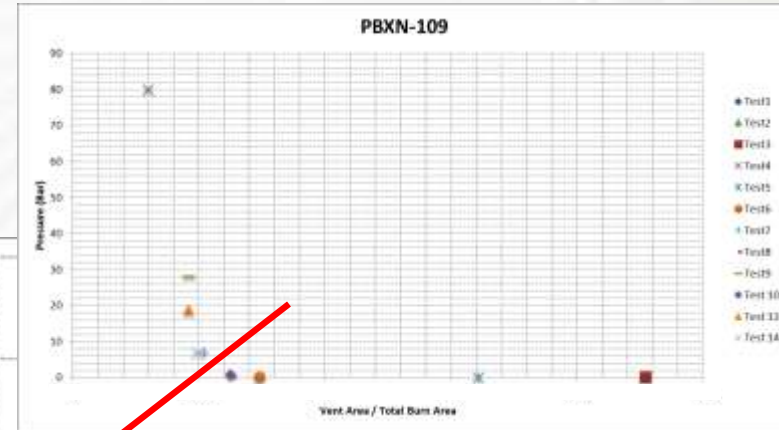
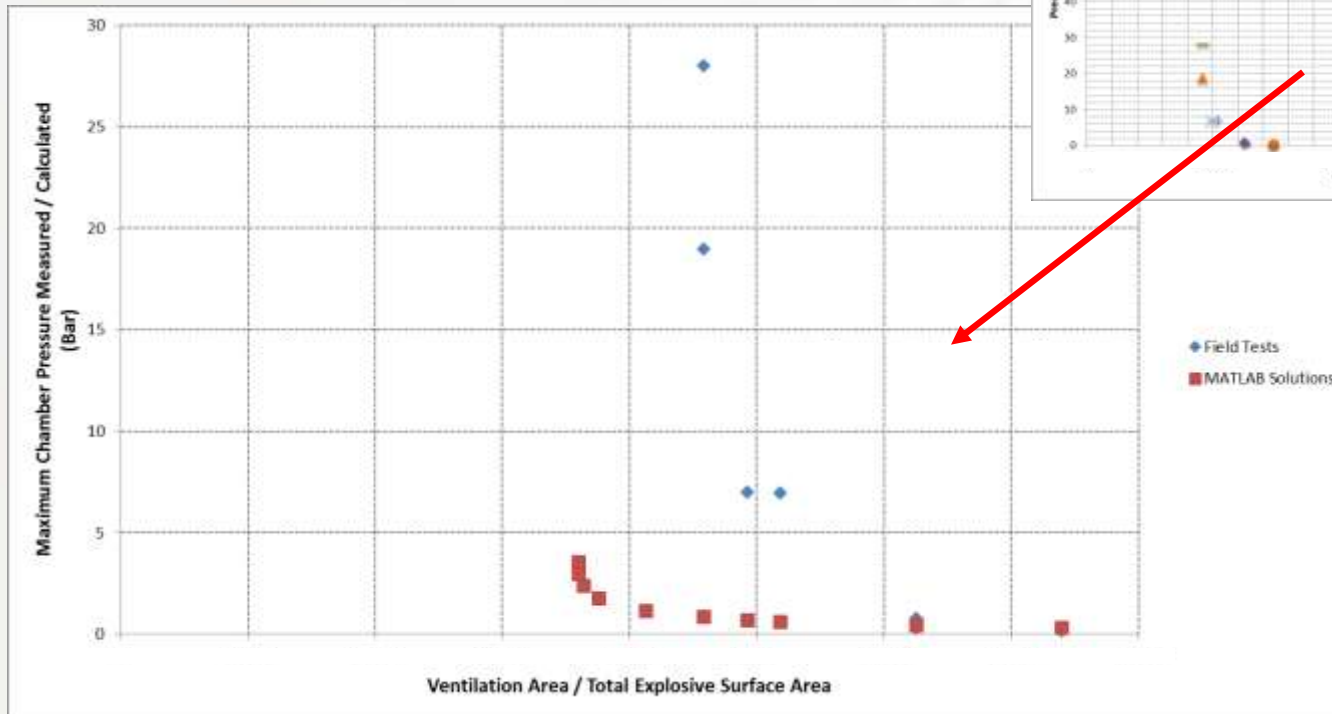
*: Predicted times to reactions are corrected according to the observed time delay

- Maximum difference of %16.7 between predicted and observed TtR.
 - Decomposition / melting of liner
 - Decomposition of explosive
 - Thermal expansion
 - Difference of flame temperature over the test item

- Study over ventilation characteristics:
 - PBXN-109 strand burner test (0-10 MPa)



- Study over ventilation characteristics:
 - Comparison of Test Results and Calculations



Thanks for Listening

Questions?