



Minimum Burning Pressure as a Basis of Safety for Explosives Operations

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Outline

- What is minimum burning pressure?
- How can it be used as a basis of safety?
- How is it measured?
- How does it change from product to product?
- Potential as a standard test
- Take-home messages



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What is Minimum Burning Pressure?

- When ignited by a localized heat source, water-based explosives (emulsions and watergels) won't burn sustainably unless the pressure is above a threshold value: the MBP.
- Above the MBP, the rate of burning increases with pressure.
- In a closed environment, localized burning increases the pressure, accelerating the burning, increasing the pressure, etc.
- Can lead to detonation



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MBP as a basis of safety

- If the product can't sustain burning, acceleration to detonation is not possible
- Ensuring that operation cannot exceed MBP can be one basis of safety
- Canadian pumping guidelines: “using pumping pressures well below the laboratory measured minimum burning pressure (MBP) of the corresponding emulsions or watergels is a good safety practice”



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Why so interested in MBP?

- Water-based explosives are used extensively in large quantities
- Pumping is one of the most hazardous operations for water-based explosives
- Even though these materials are considered to be relatively safe, accidents do happen...



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Why so interested in MBP?



Despite relative insensitivity under normal operating conditions, the potential for loss of life and damage from an accidental initiation of large quantities is considerable.



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Why so interested in MBP?

- Two relevant Canadian accidents demonstrated that emulsions and watergels were still hazardous:
- 1975, CIL Beloeil Works, EGMN-sensitized watergel, 8 dead, 19 injured
 - Deadhead pumping of a progressive cavity pump
- 1988, CIL Explosives Technical Centre, McMasterville, 4 dead, two injured
 - Vapour-phase ignition in a piston pump making experimental emulsion



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Background

- Lots of tests to look at thermal hazards – heating the whole sample: DSC, ARC, Dewar...
- Very few designed to look at the effect of local ignitions
- Closest test used regularly is the Internal Ignition/DDT test in the UN TDG Manual
 - Black powder charge used to ignite and pressurise a 2.5-kg sample in a steel pipe
 - No quantitative information on pressure
 - Needs specialized facilities



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Development of the experimental technique

- Technique developed for watergels in the 1970s by CIL in Canada
- Based on strand-burner technique used for propellants
- Simple in principle: put explosive in vessel, pressurize, ignite with hot wire and observe
 - If it all burns, we are above MBP
 - If it doesn't, we are not
- However, there are some pitfalls that only took a decade to sort out...



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Development of the experimental technique

- We now (finally) have a very reliable methodology
- Quantitative
- 20 g of sample per test – no special facilities
- Easy to do and simple to interpret
- One person can carry out a MBP determination in two days, or a go/no-go at a single pressure in one day



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Pressure vessels



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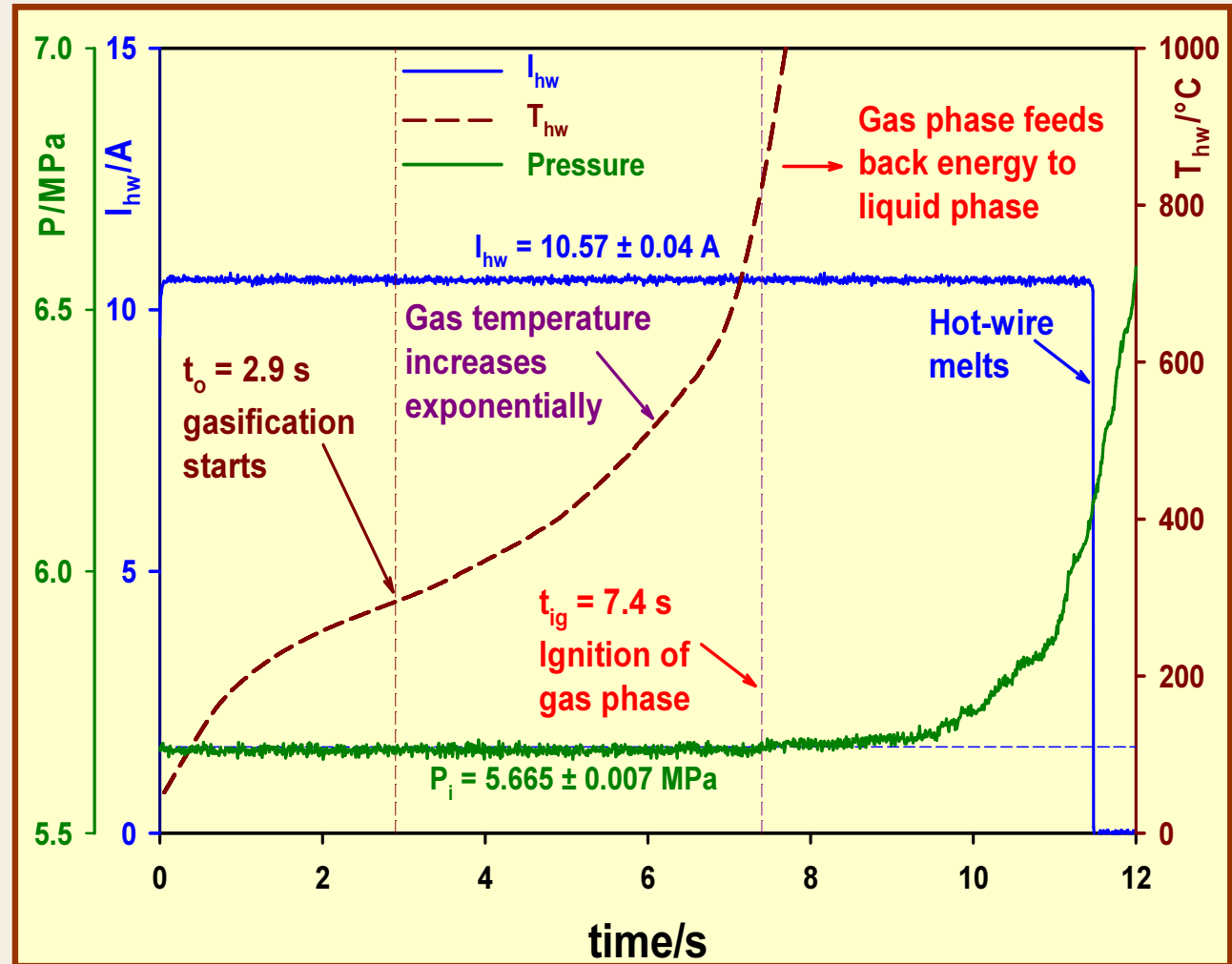
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Instrumentation

- Measure pressure and voltage through hot wire at constant current
- Derive hot wire temperature



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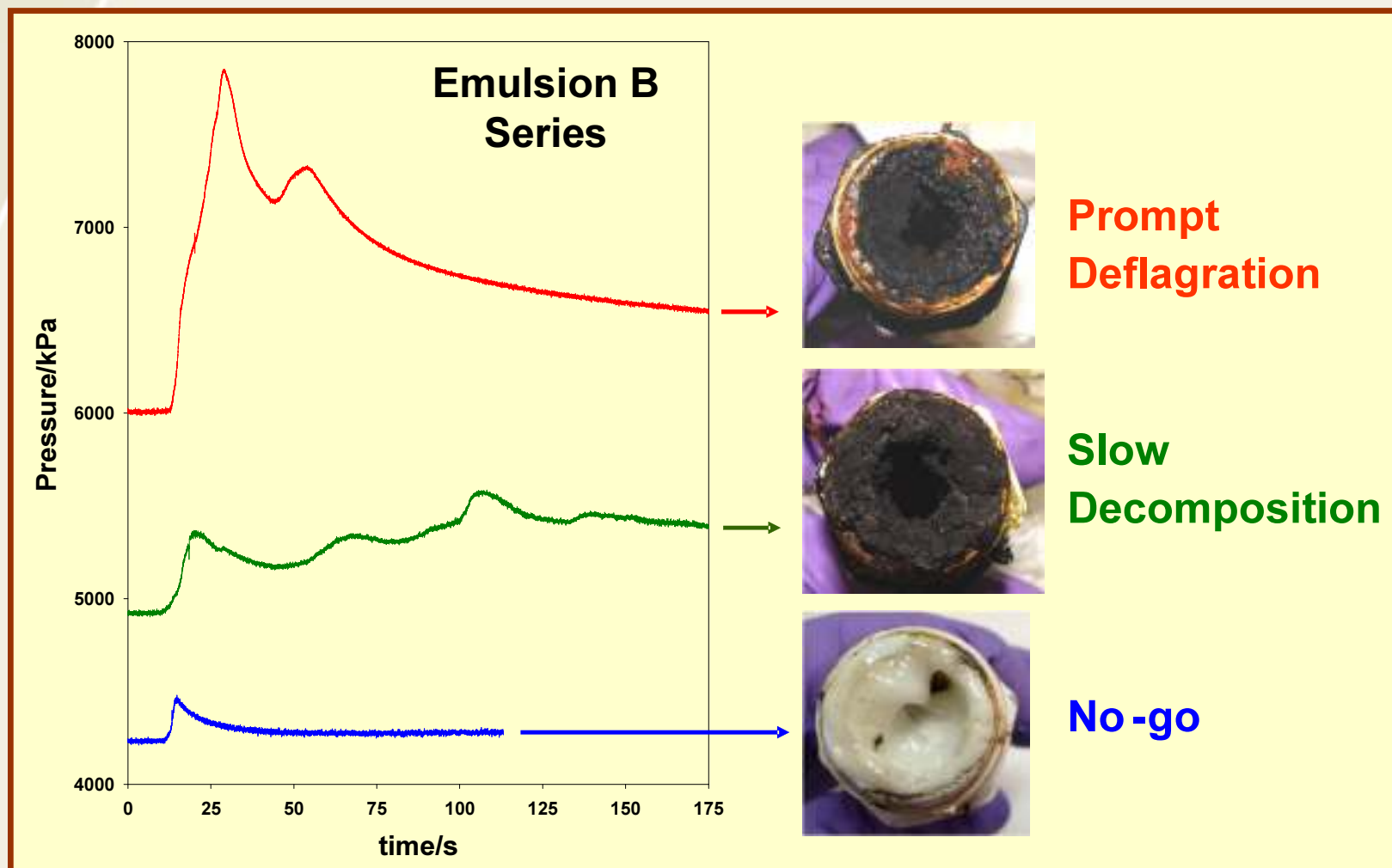


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Go/no-go



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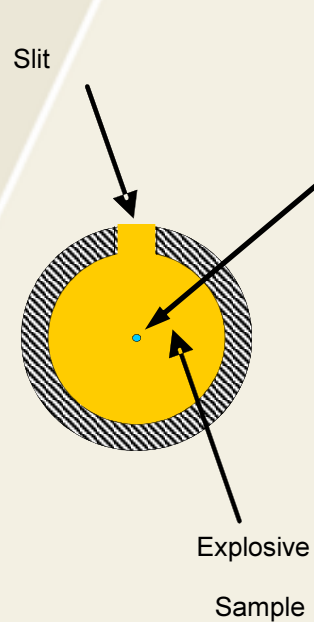
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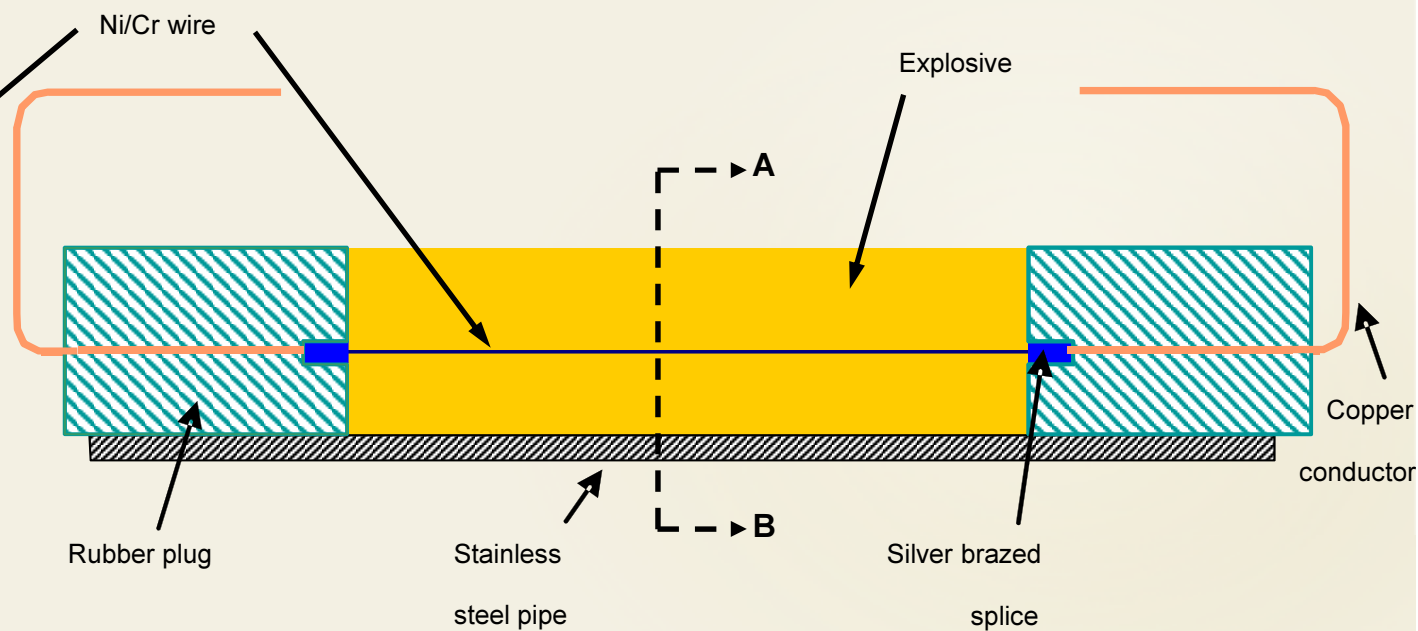


Testing configuration

Section A-B



Side Section



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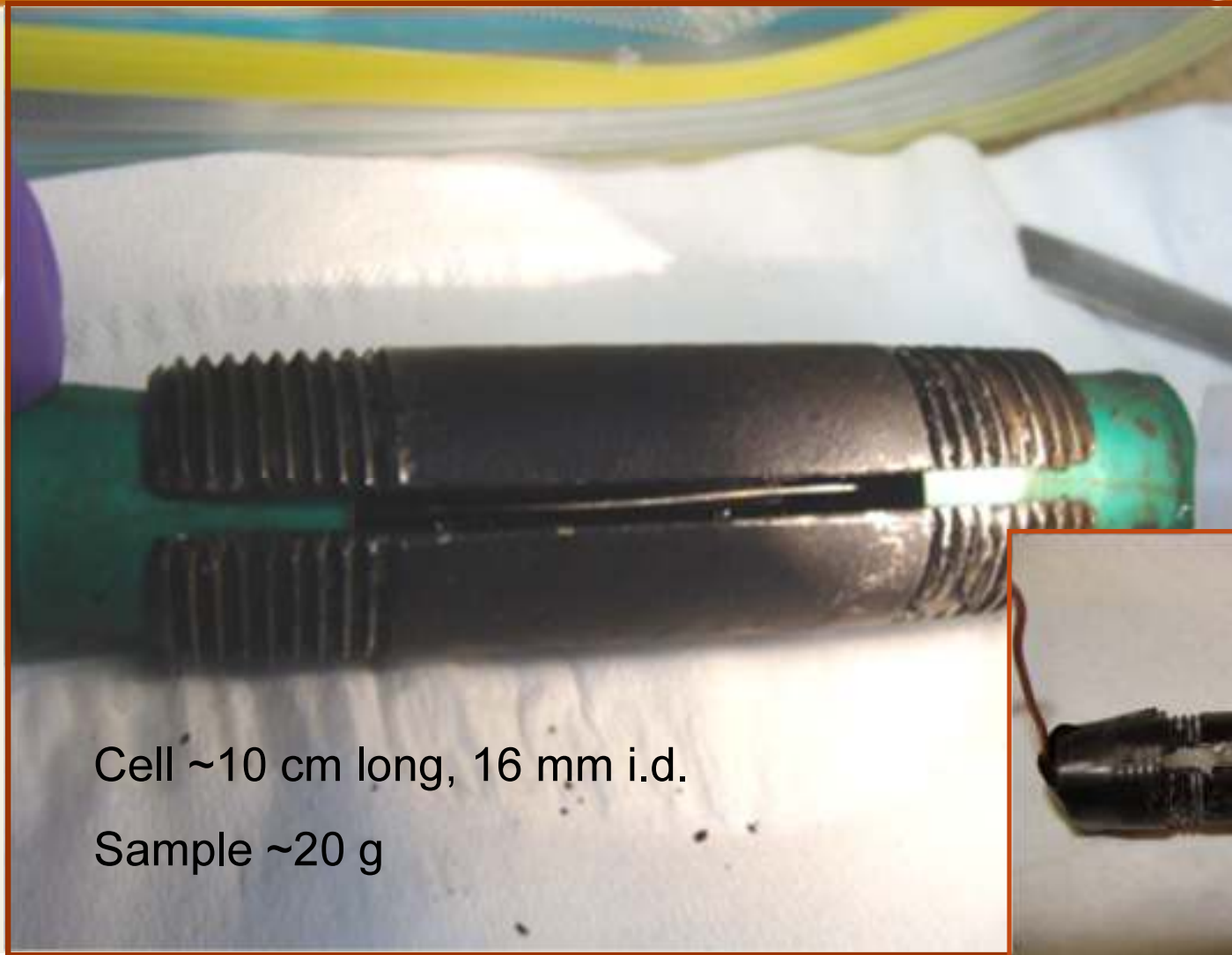


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Testing configuration



Cell ~10 cm long, 16 mm i.d.

Sample ~20 g



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Work plan



Thirty four separate emulsions were prepared in-house at CERL. Systematically adjusted formulations:

- Varied oxidizer solutions – AN/SN/SP
- Water content
- Surfactants/oil mixtures/waxes
- Chemical additives – Urea
- Sensitizers – aluminum, AN prill
- Density modifiers/void sensitizers – thin walled/thick walled glass microspheres, plastic microspheres, polystyrene beads.



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Effect of formulation on MBP



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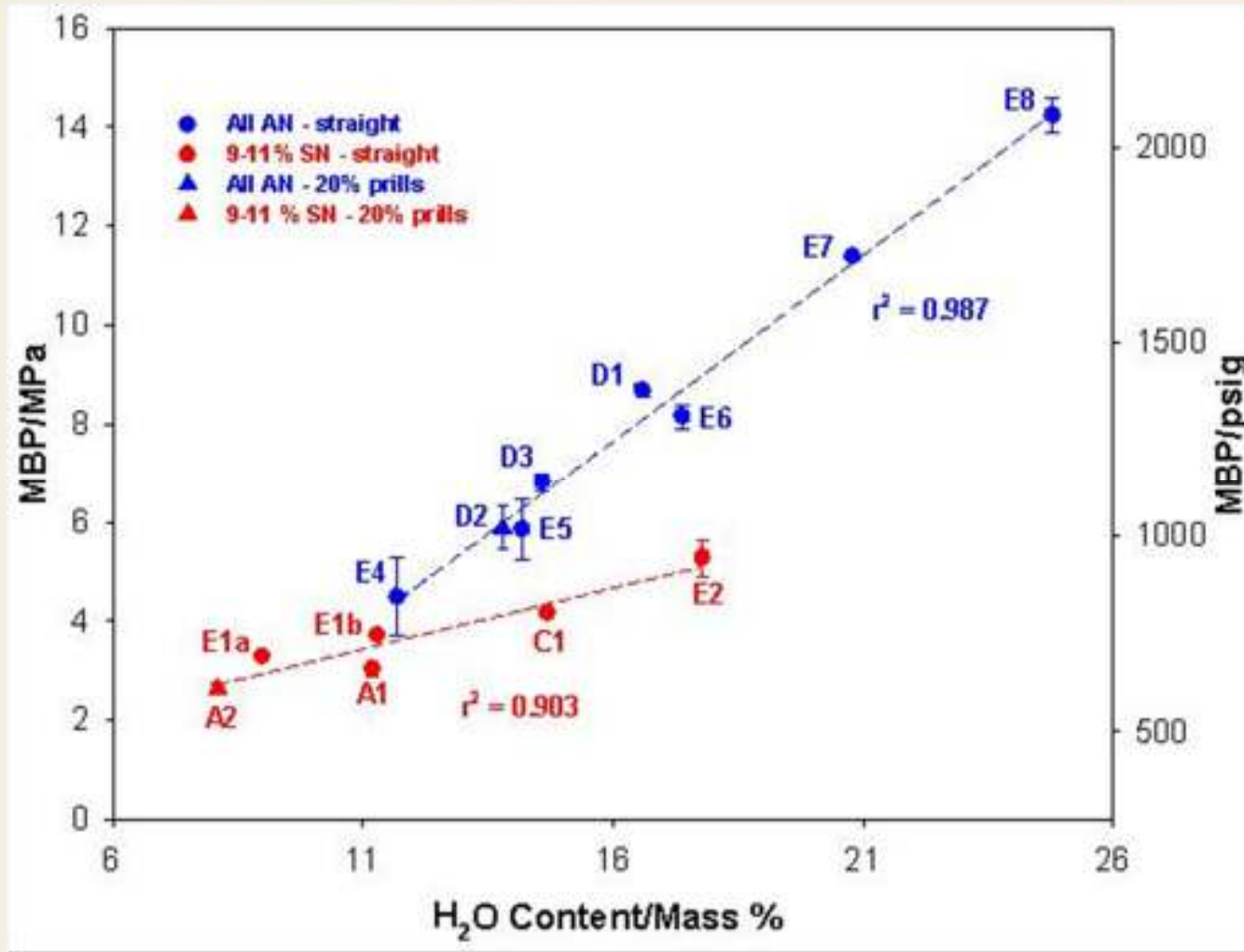
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Effect of water

- AN and AN/SN emulsions



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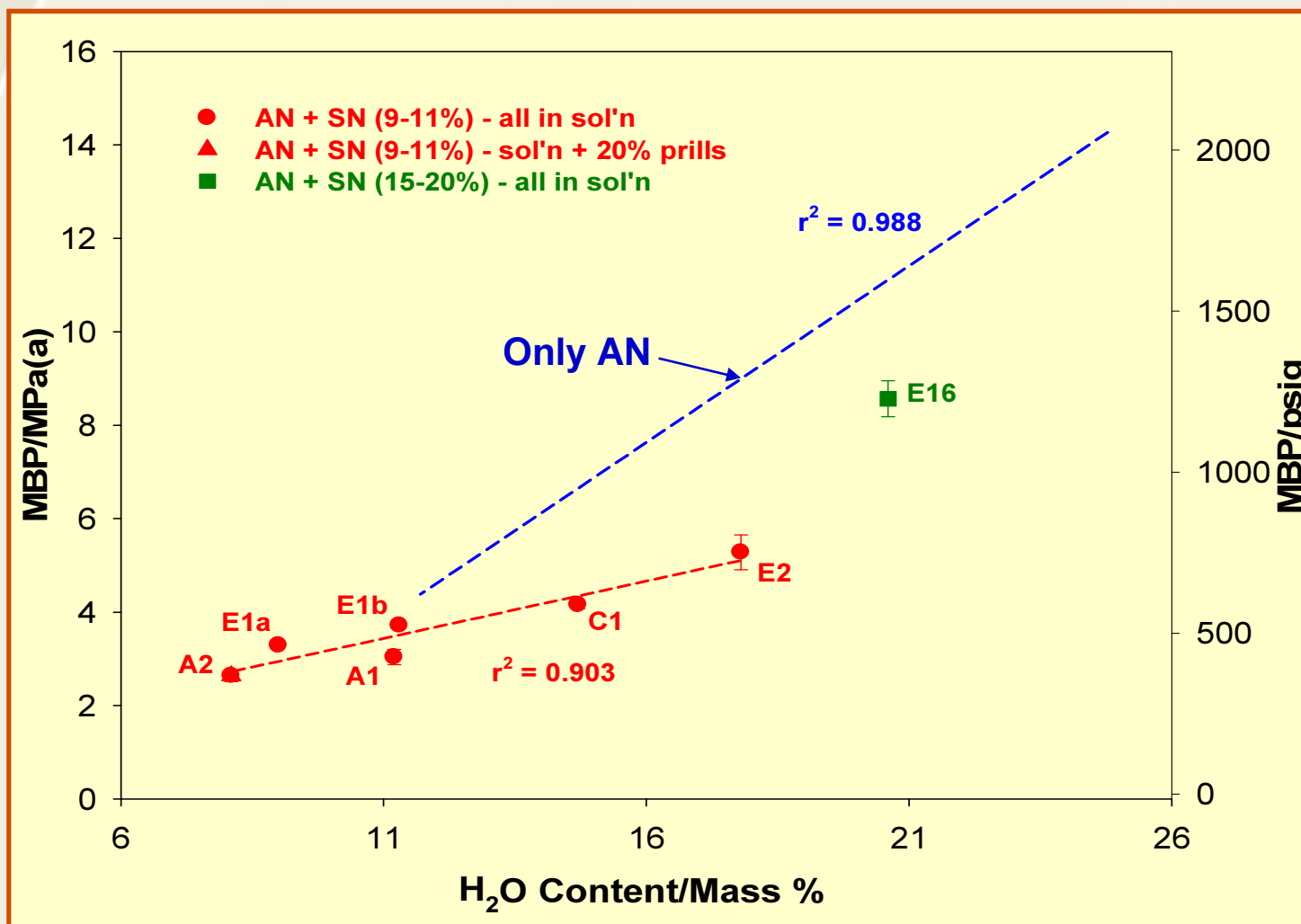


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Effect of water AN/SN emulsions



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Effect of formulation on MBP

- Biggest effect is water content
 - MBP increases significantly with % water
- Oxidizers have an effect:
 - Sodium nitrate and sodium perchlorate reduce MBP
 - Substituting AN prills for AN solution has little effect
- Effect of fuels:
 - Aluminum reduces MBP,
 - Oil phase has little effect
 - Urea increases MBP



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Effect of formulation on MBP

- Effect of density modifiers is complex:
 - Plastic microballoons increase MBP slightly – heat sinks
 - Glass microballoons can significantly lower MBP, or increase it slightly – not well understood
 - Polystyrene beads increase MBP – low-temperature melting absorbs heat



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Effect of formulation on MBP

Decrease MBP	Minor effect	Increase MBP
Sodium Nitrate	Plastic microballoons	Water
Sodium Perchlorate	AN prills instead of AN in solution	Urea
Aluminum	Refinement	Polystyrene
	Oil phase	
Glass microballoons	Glass microballoons	



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Effect of formulation on MBP

- Extremes:
- AN-only emulsion, 24.8% water, unsensitized
 - MBP 14,240 kPa (2070 psia)
 - Easy to operate below the MBP
- AN/SN/SP emulsion, 6.7% water, doped with Al, AN prill and thin-walled glass microballoons
 - MBP 940 kPa (135 psia)
 - Not so easy to operate below the MBP



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MBP as a Standard Test

- Good potential as a standard test to quantify hazards of local ignition
 - Methodology straightforward and interpretation simple
 - Lab-based, fairly small samples
- MBP facilities of similar design now in place in Spain, South Africa and China
 - Interlaboratory testing underway
 - We would be happy to help other organizations set up the test



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MBP as a Standard Test

- Canadian standard for authorization of blasting explosives (2010):
 - MBP for bulk explosives must be at least 20% above the maximum pressure that the pumping system can develop
- Potential application of MBP to transportation
 - UN Series 8 tests not well liked
 - MBP test can differentiate among “bulk” and “packaged” emulsions
 - Could be used as an alternative to the UN 8(d) test



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Next steps

- Continue work on effect of formulation
 - Calcium nitrate
 - Effect of glass microballoons
 - Effect of surfactant
- Extend work to watergels
- Effect of elevated temperature – how might the MBP be changed in an accident (fire) scenario?



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Take-home messages

- MBP is a key safety parameter that can be used as a basis of safety for explosives operations
- A validated MBP measurement methodology is available
- Measurements are relatively easy to make and interpret
- MBP already incorporated into the Canadian authorisation process
- MBP can be used to differentiate between “bulk” and “packaged” products for transport classification



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Take-home messages

- Water content is a key parameter for AN-based emulsions: MBP increases with water content
- Effect of other ingredients is complex, but becoming much better understood
- Biggest cause for concern is underground bulk?
 - High pumping pressures, relatively low water content



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- The work program is developed jointly, costs are shared and the results are made public
- The program is currently in its fifth year and represents a great model for co-operation between industry and government



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Thank You!

Any Questions?



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