Influence of ageing on the properties of IHE

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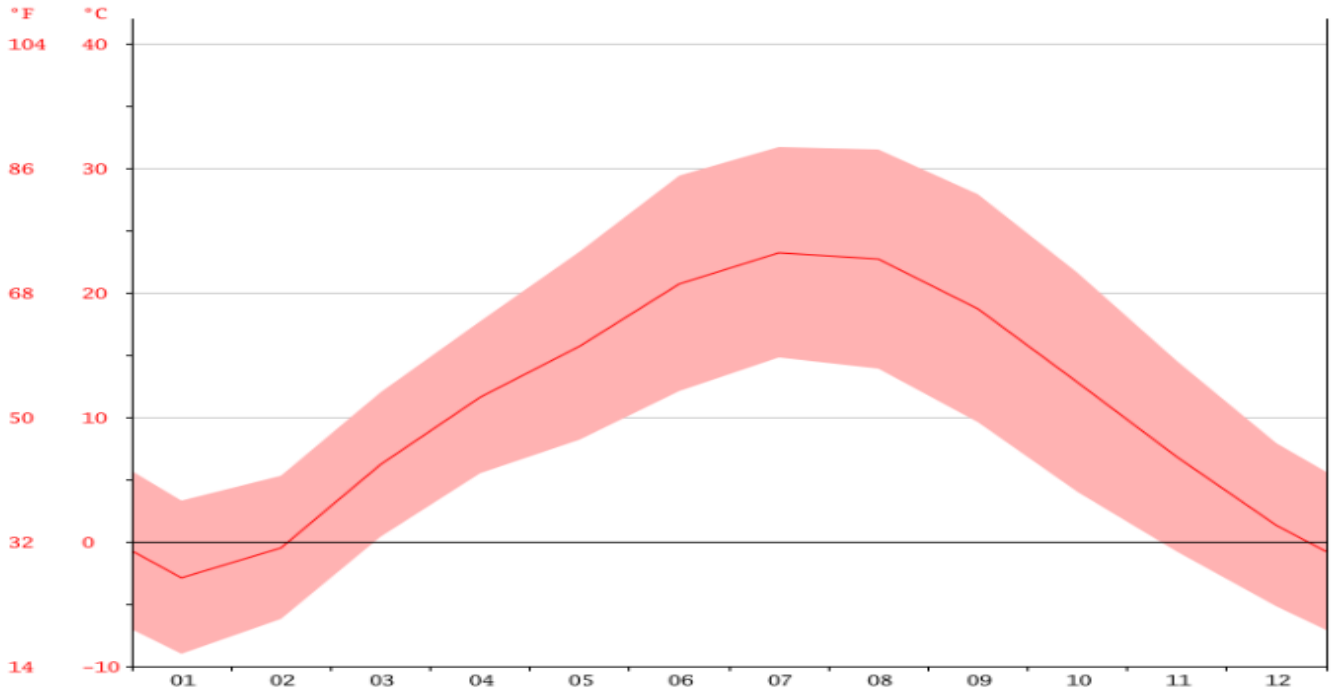
Motivation

- Modern scenario in NATO countries might be in very hot and also very cold regions
- The storage for ammunition in conflict area is under non-ideal conditions

Camp in Kabul



Temperature diagram Kabul

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Motivation

- Handling of ammunition in battle zones is different to normal training
- In duty the unprotected vehicles with all their ammunition might be outside in the sun for some days or weeks

Practice shooting in Afganistan

Fully loaded vehicles

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Motivation

- To minimize risks of the handling of munitions, investigations concerning properties of aged high explosives were done

- Different explosives were prepared, aged and investigated

- The investigations were planned in different steps

1. Determination of the properties of unaged explosives
2. Ageing of explosive samples
3. Determination of the properties of aged explosives
4. Comparison with unaged samples

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Status

- High explosives e.g. the binder system of PBX is subject to an aging process during life time
- Sublimation rate in TNT based explosives is also a part of the ageing process
- Different experiences conc. ageing of high explosives exists
- Different methods are written in literature

Goals

- Gain experience conc. ageing of PBX and additionally melt cast explosive
- Find a successful method for investigation of aged samples

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Tested explosives

Three different explosive charges were tested

- Plastic bonded explosive
  - PBX-1 (RDX, Me, HTPB-binder)
  - PBX-2 (RDX, HTPB-binder), investigations partly still in progress
- Melt cast explosive
  - MC-1 (TNT based), investigations partly still in progress

Geometry of samples

- Cylinder 40x40mm, machined
- Janaf samples
- Miscellaneous

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Ageing of samples and realized tests

Ageing

Storage at

- +21°C, 12 months (reference)
- +63°C, up to 12 months
- +71°C, up to 6 months

  to simulate ≈ 25 years under depot conditions

Because of safety reasons no storage at higher temperatures!

Storage for PBX-1 partly unpacked and partly packed; for PBX-2 and MC-1 only packed

Tests

Change of geometry

Mass lost (loss of plasticizer)

Density

Shore A hardness

Thermal analysis (DSC)

Vacuum stability

IM-Properties

- Impact and Friction sensitivity
- GAP-Test

Mechanical properties

- Tensile testing and compressive testing

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Change of geometry

Tested on cylinder (PBX packed and unpacked)

- Diameter
  - Biggest change ≈2.4%
- Length
  - Biggest change ≈2.1%
- Weight loss
  - Biggest weight loss ≈ 4%
- Density
  - Biggest change 1.66->1.71g/cm^3

Storage temperature	Storage time	Weight loss		Geometry change			
				Diameter		High	
		unpacked	packed	unpacked	packed	unpacked	packed
[°C]	[months]	[%]	[%]	[%]	[%]	[%]	[%]
+21°C	0	0	0	0	0	0	0
	12	-0,03	0,04	-0,05	0,16	0,04	0,12
+63°C	3	0,55	--	-0,49	--	0,18	--
	4	--	0,02	--	0,05	--	0,28
	6	0,79	--	0,53	--	0,38	--
	9	2,08	--	1,18	--	0,96	--
	12	2,5	--	1,14	--	1,17	--
+71°C	3	3,79	--	1,67	--	2,21	--
	4	--	0,02	--	-0,02	--	0,39
	6	3,88	--	2,35	--	2,13	--

Obvious change of geometry and weight in unpacked PBX samples, no influence on packed PBX and melt cast cylinders!

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Shore A hardness

- Because of the high Shore A level of MC-1 investigations were only done with PBX

- The Shore A of the PBX sample increased with storage time
  - The changes of the shore A of the packed samples in a range of 15-20 Shore A
  - The Shore A values of the unpacked PBX samples increases so extremely that the values are outside of the measuring range (maximum 100 Shore A, start value 65 Shore A)

Obvious differences between unpacked and packed samples

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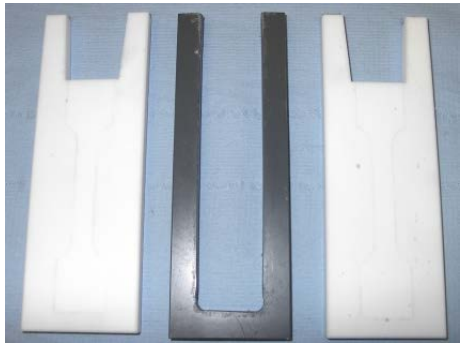
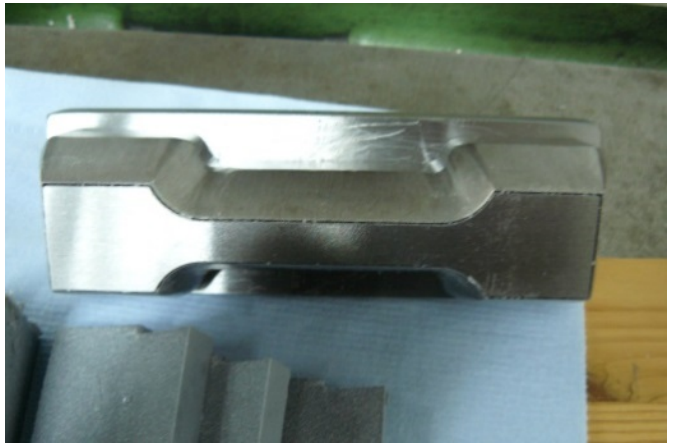
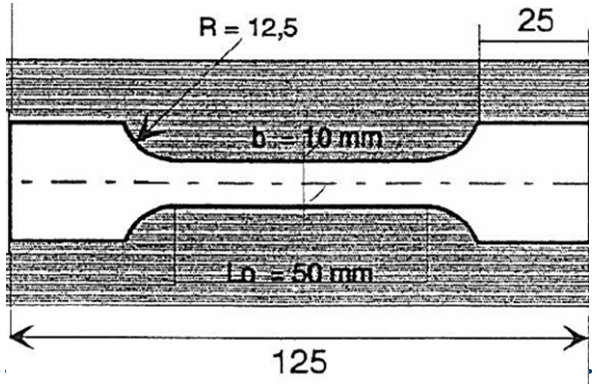
Tensile Tests on PBX

- Testing with unpacked samples
- Measurements in temperature range
- Sample preparation
  - Cast in special mould without machining
  - Cast in „U-Profile“, afterwards cutting
  - Cast as disc, afterwards cutting
  - Cast as bloc, afterwards shaping and cutting





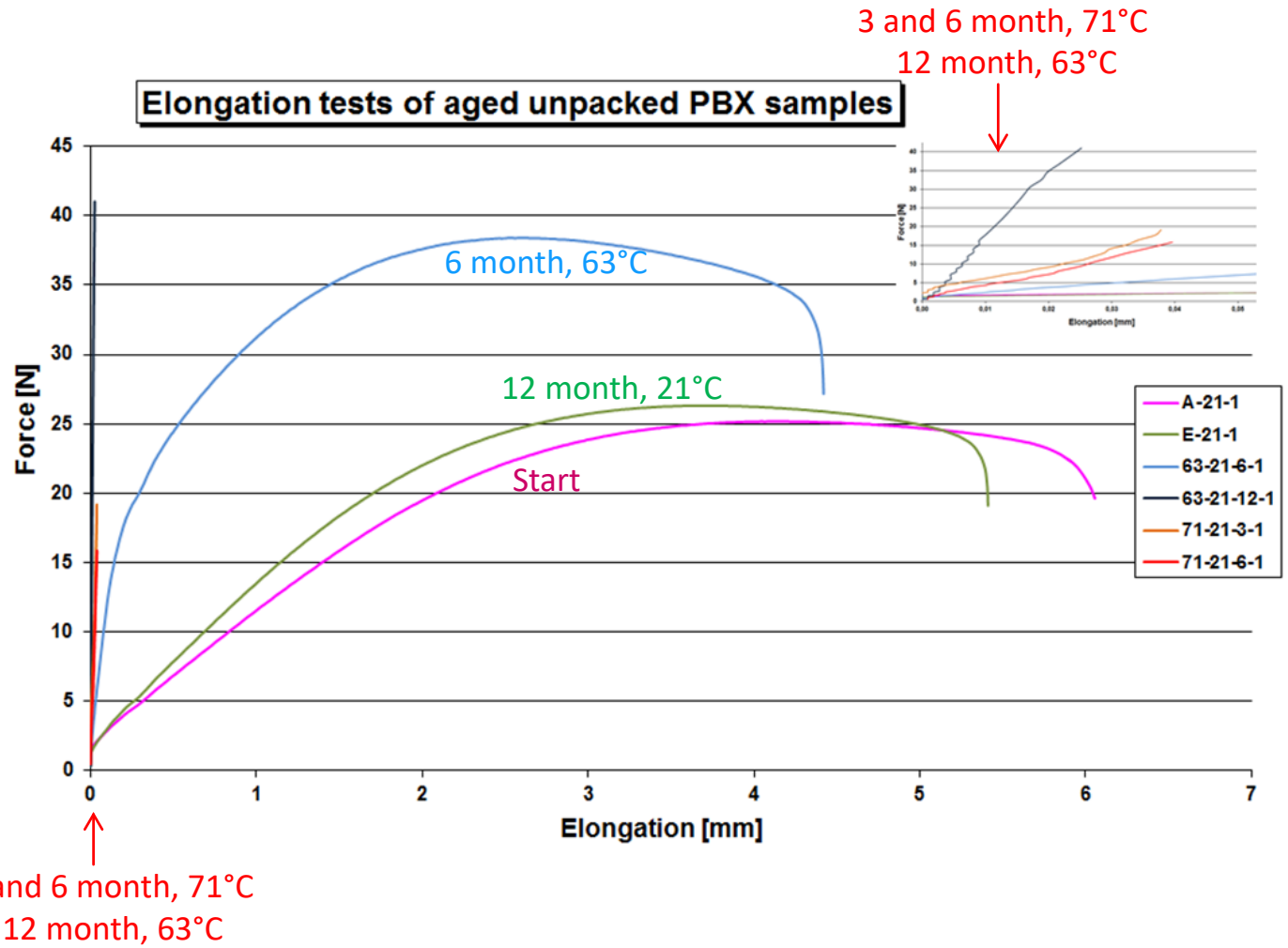


Tensile Tests on PBX

Significant influence of storage conditions

- Storage +71°C => no failure up to force maximum

  Samples were very brittle

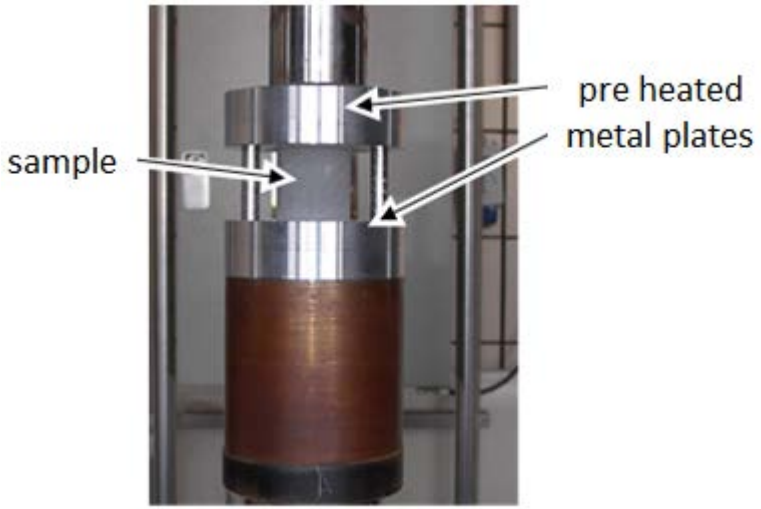


Compressive test

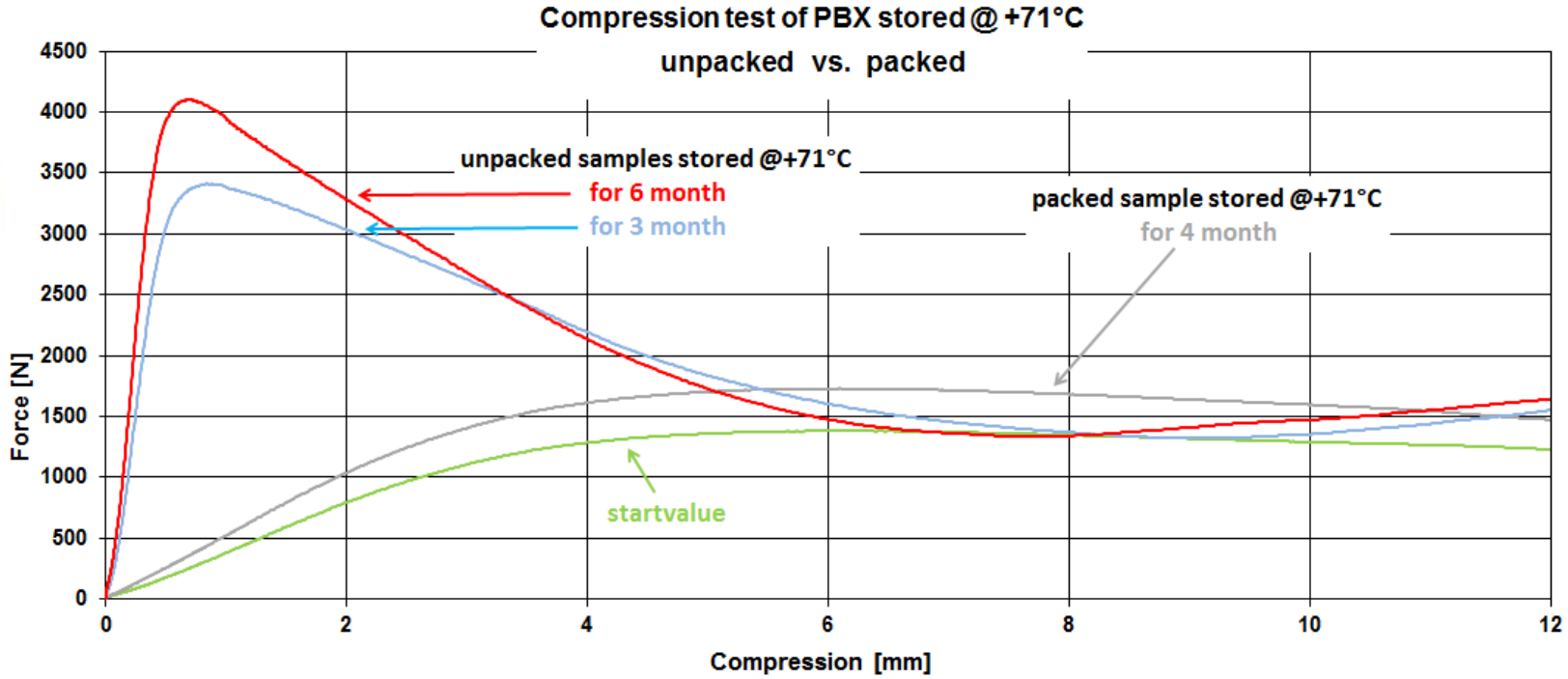
Measurements in temperature range (-46°C, +21°C and +63°C)

Samples: PBX-1 (unpacked and packed), PBX-2, MC-1

PBX-1 shows a significant influence of storage conditions

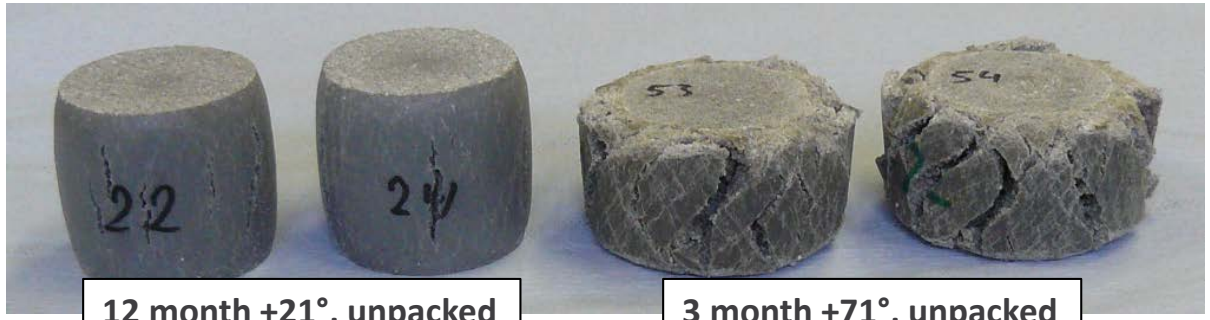


Set up compressive test



Compressive test

Unpacked, @71°C stored PBX cylinder showed significant optical differences after compressive tests



12 month +21°, unpacked

3 month +71°, unpacked

6 month +71°, unpacked

In comparison, packed PBX cylinders were more stable

All samples 4 month stored packed @ +71°C

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Compressive test

- Compressive tests of the melt cast explosive shows a significantly different fracture to PBX but no influence of ageing

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Vacuum stability

Testing of unpacked and packed stored PBX samples

- Hardly any change on vacuum stability

Storage		Vacuum Stability	
Temperature	Storage Time	unpacked	packed
[°C]	[month]	[cm³/2,5g]	[cm³/2,5g]
Start RT	0	0,12	0,08
+21°C	12	0,15	0,11
+63°C	3	0,27	0,11
	6	0,11	--
	9	0,26	--
	12	0,19	--
+71°C	3	0,24	--
	4	--	0,16
	6	0,19	--

Currently no measurements of the melt cast explosive are possible

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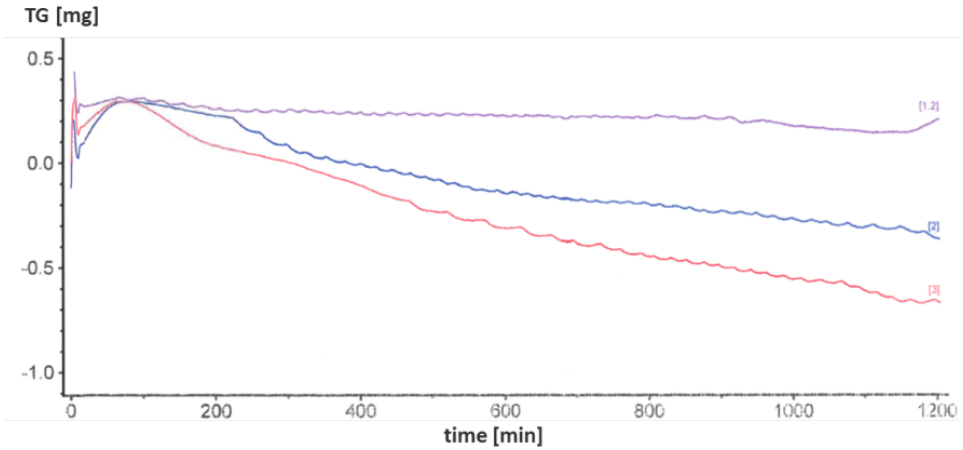
Thermal analysis

DSC (heat rate 5K/min up to 360°C)

- With PBX samples hardly any influence on decomposition point / weight loss

Sublimation rate with MC-1

- Tests of MC-1 via DTA at isotherm temperatures (67°C, 71°C and 78°C) for determination of sublimation rates*
- Melted MC-1 in a cup with a diameter of 6.2mm ≈ 0.302cm² surface



Weight loss	Temperature	Sub Rate
[mg]	[°C]	[ng/cm²*sec]
0,16	67	8,8
0,6	71	33,1
0,9	78	49,7

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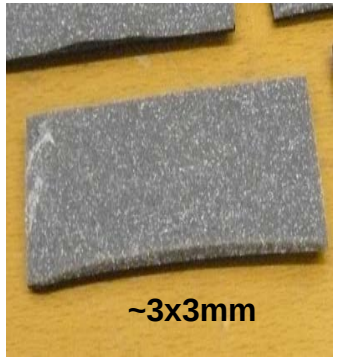
IM Properties of Explosive

Testing with unpacked PBX-1 samples

- No influence on friction sensitivity
- ***Important increase of impact sensitivity after storage at +71°C***

Storage		Tests	
Temperature	**Storage Time**	**Impact Sensitivity**	**Friction Sensitivity**
[°C]	**[month]**	**[J]**	**[N]**
Start RT	0	18	240
+21°C	12	18	240
+63°C	12	22	240
+71°C	6	8	240



Measurements of PBX-2 and MC-1 are still in progress

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GAP Test

Testing with packed PBX samples

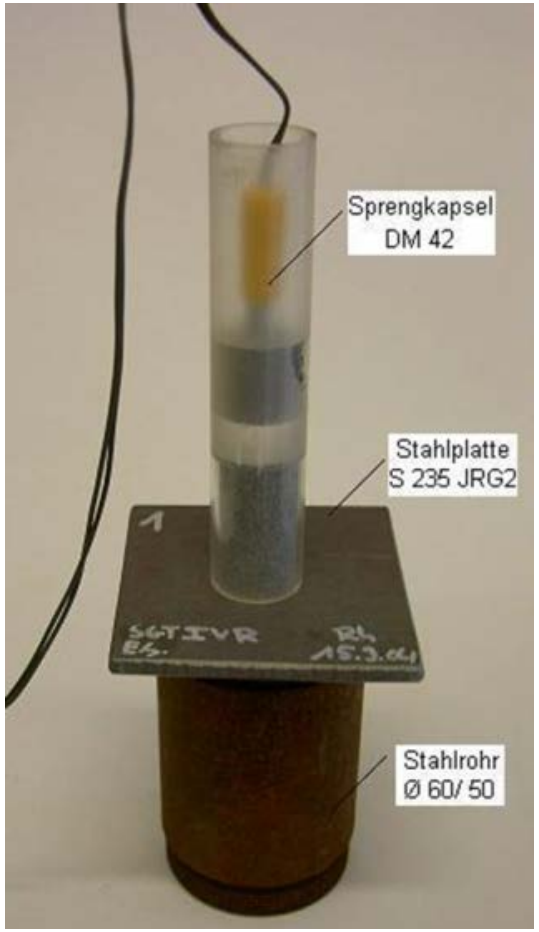
- 21mm GAP Test, GAP: PMMA
- Donor charge: HWC

Storage		GAP Test	
Temperature	Storage Time	Go	NoGo
[°C]	[month]	[mm PMMA]	[mm PMMA]
Start RT	0	7	8
+21°C	3	9	11
+63°C	3	10	11
+71°C	3	10	11

- Only small change during storage
- No influence of storage temperature

No tests with unpacked PBX

Measurements with MC-1 in progress



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Conclusion

Important parameters for the PBX:

- Sample conditions (packed and unpacked)
- Storing conditions (+71°C the biggest effects)

No / small change after storage:

- Vacuum stability, thermal analyses, friction sensitivity
- GAP test (packed)

Significant change after storage (unpacked samples)

- Impact sensitivity, tensile testing, compressive testing, Shore A hardness

Starting with 71°C significant sublimation can be detected

For testing of ageing phenomena of PBX the determination of mechanical properties (Shore A hardness (guide value) and tensile strength resp. compression tests) are favored

Because of the still running tests no final statement of the ageing of the melt cast can be given

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