UNDERSTANDING THE LOW TEMPERATURE PROPERTIES OF RUBBER SEALS

Property determination for the use in transport and storage casks for radioactive waste

Matthias Jaunich*[a], Kerstin von der Ehe[a], Dietmar Wolff[a], Holger Völzke[a], Wolfgang Stark[b]

[a]BAM III.4 Safety of storage containers
[b]BAM VI.3 Durability of polymers

Outline

- Introduction / Motivation
- Seals
  - Elastomers
  - Function / Influencing factors
- Behaviour at low temperature
- Methods and Results
  - classical Thermal Analysis:
    - DSC
    - DMA
  - Compression Set
- Things to do
  - Component Tests

Motivation

Qualification / selection criteria
Judgement of production irregularities

MATERIAL

physical / chemical properties

- Density
- Stiffness
- Glass Transition Region
- Decomposition temperature
- Permeability Coefficient

?

- CSR
- CS

COMPONENT

function

- Leckage Rate
- Boundary Conditions:
  - Groove Geometry
  - Temperature
  - Time
  - Media / Radiation

finding the correlation between physical properties and component behaviour

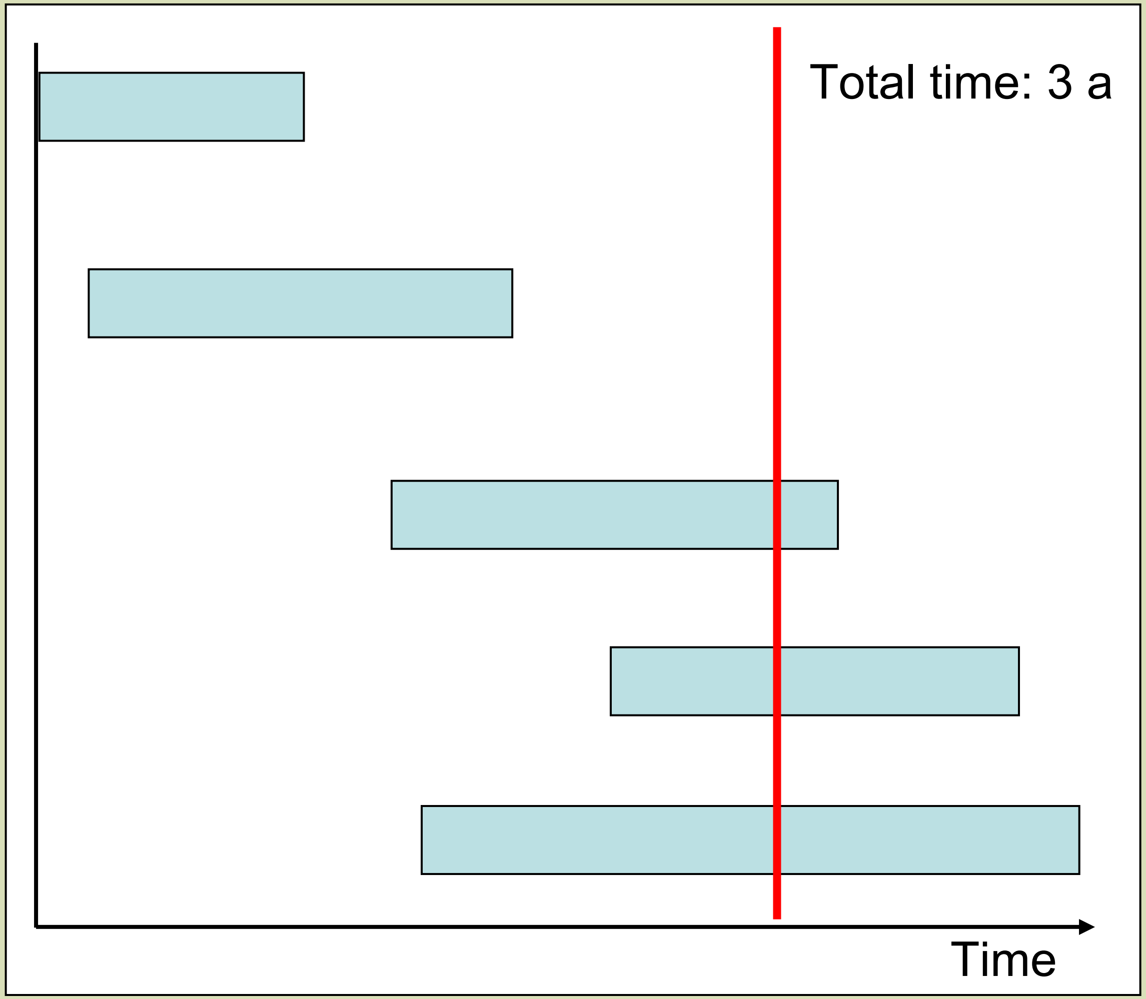
Material selection

Determine physical / chemical properties

CS

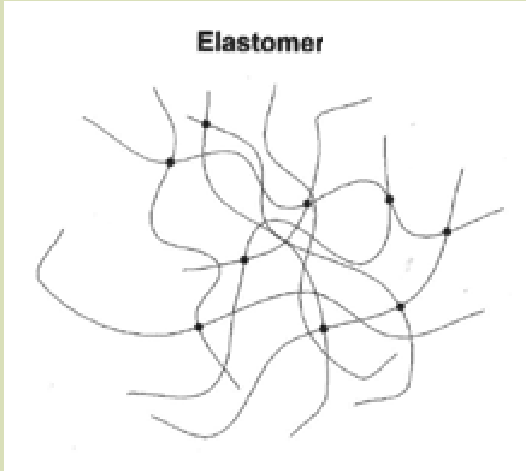
Component Tests

Comparision of results

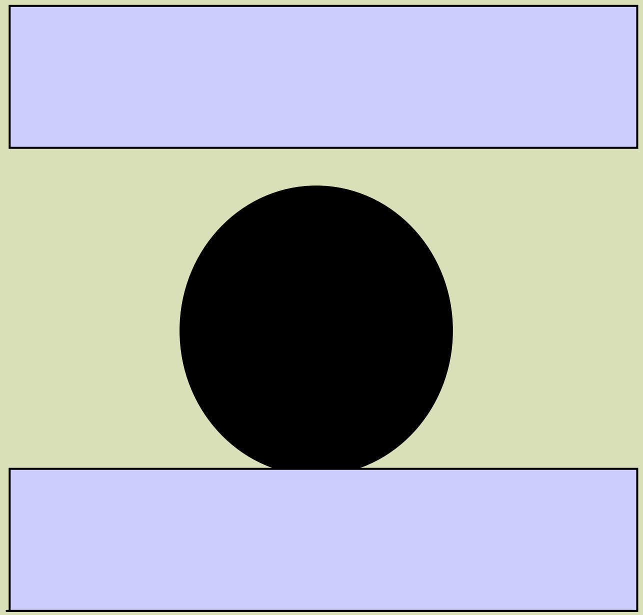


➢Elastomers: Keyfacts

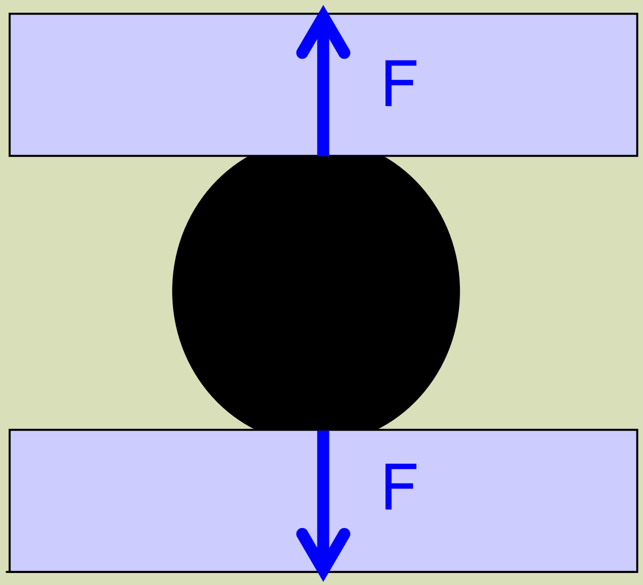
- long chainmolecules / Polymers
  - ❖ natural or synthetic rubber/caoutchoc
- mildly crosslinked
  - ❖ different crosslinking agents are used
    - Sulfur, Peroxides, Radiation, . . .
  - ❖ shape persistent / viscoelastic
  - ❖ elastic strains of up to 1000 % are possible
  - ❖ increased chemical durability



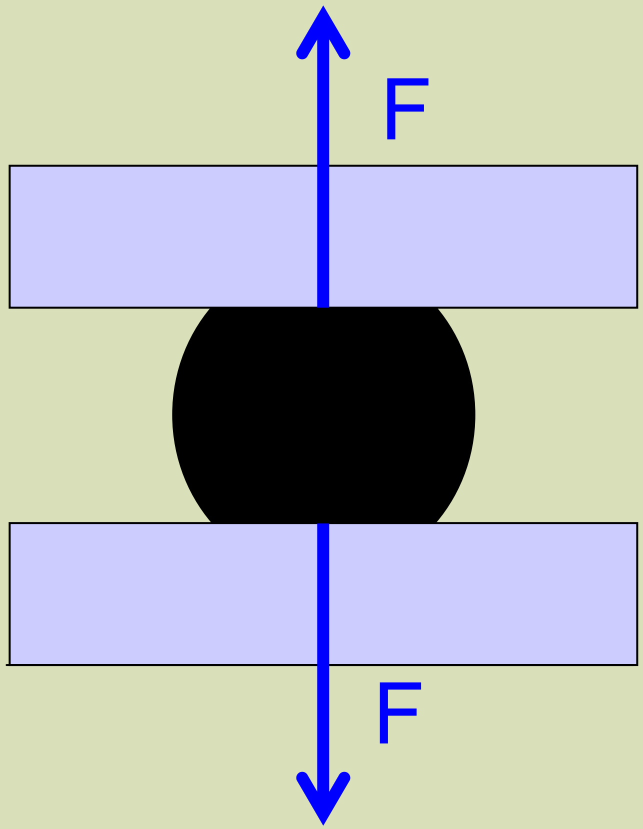
Function / Influencing factors



Function / Influencing factors



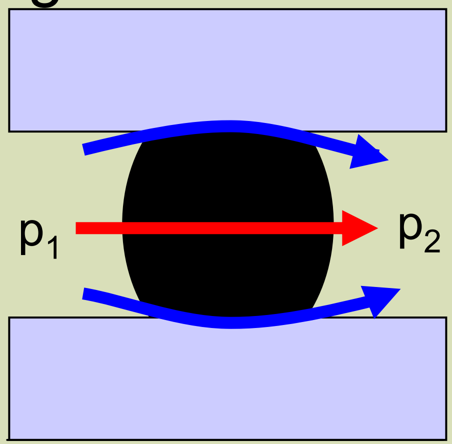
Function / Influencing factors



Function / Influencing factors

The Leakage rate Q consists of the following contributions:

$$Q = Q_{perm} + Q_{trans}$$



$$Q_{perm} = P * A/d * (p_1 - p_2)$$

with:

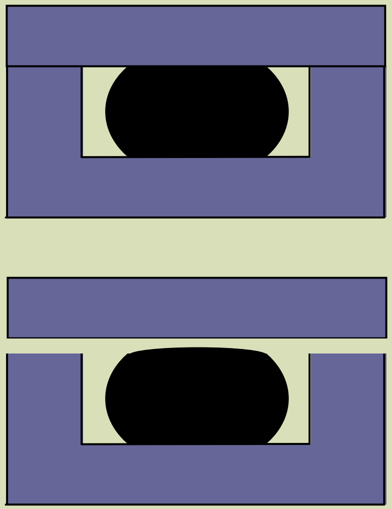
with:	P:	Permeability coefficient (Solubility * coefficient of diffusion)
	A:	Area
	d:	seal thickness
	p:	pressure

$$Q_{trans} = f(\text{material contact, pressure difference})$$

Behaviour at low temperatures

1. case:

A leakage appears under dynamic load:

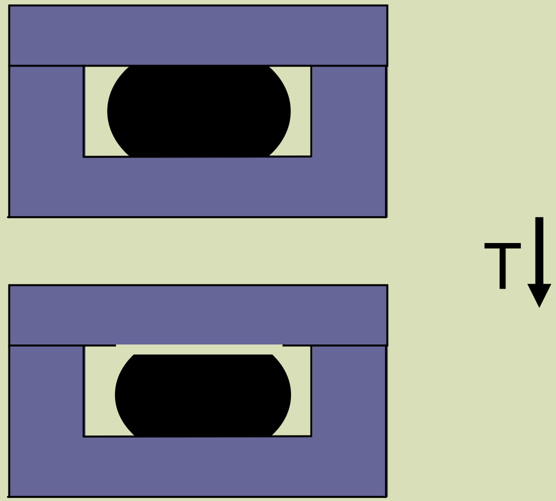


cause:
The velocity of the spontaneous elastic recovery is temperature dependent.

⇒ the leackage can close with time.

2. case:

During cooling a leakage appears under static load:

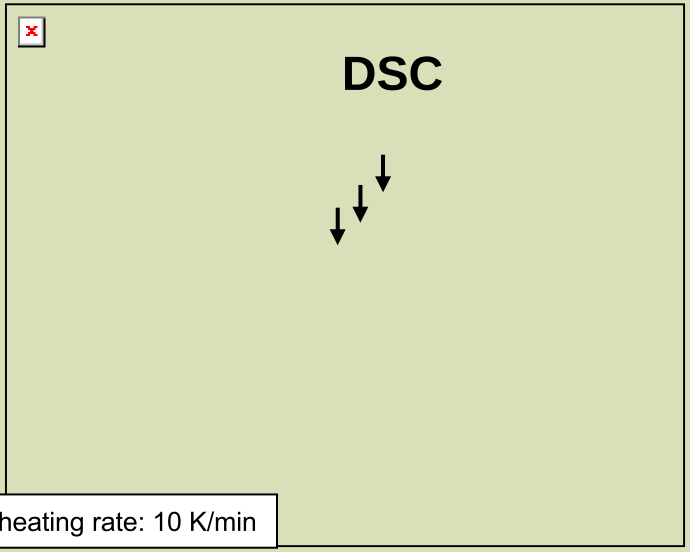


cause: $$\alpha_{Metall} \neq \alpha_{Elastomer}$$

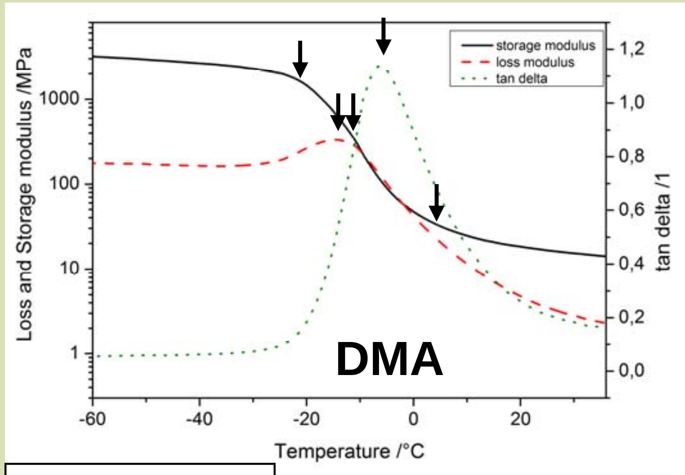
⇒ the seal contracts in the groove

⇒ below a critical temperature this can not be leveled out by relaxation.

Thermal Analysis: glass-rubber transition



heating rate: 10 K/min



single cantilever
1 Hz
1 K/min

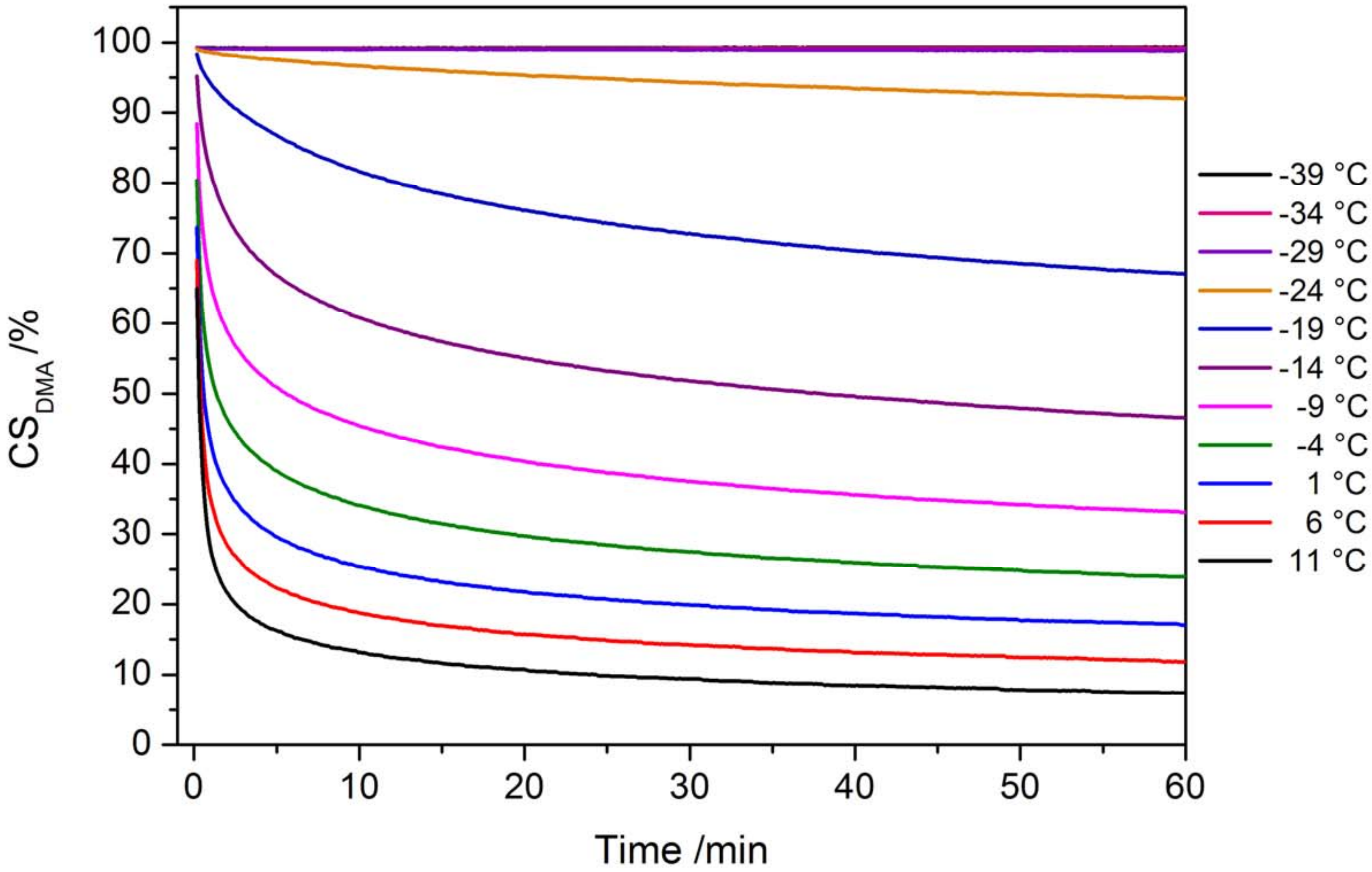
method	T_g
DSC: Heat flow-onset	-21 °C
DSC: Heat flow-inflection point	-17 °C
DSC: Heat flow-offset	-14 °C
DMA: E'-onset	-25 °C
DMA: E'-inflection point	-19 °C
DMA: E'-offset	-11 °C
DMA: tan δ -peak	-6 °C
DMA: E''-peak	-15 °C

Thermal Analysis

- DSC and DMA give an information about the glass-rubber transition process
- the glass-rubber transition temperature has to be defined: measurement method, -conditions and the analysis method
- the failure temperature can not be detected exactly by these methods
- so far no direct correlation between the glass-rubber transition temperature and seal failure is known

⇒ additional tests are required: Compression Set / Component Tests

"Compression Set" with DMA



M. Jaunich et.al. Polymer Testing 29 (2010) 815-823.

- Fit to homologous mechanical models (expanded Kelvin-Chain)

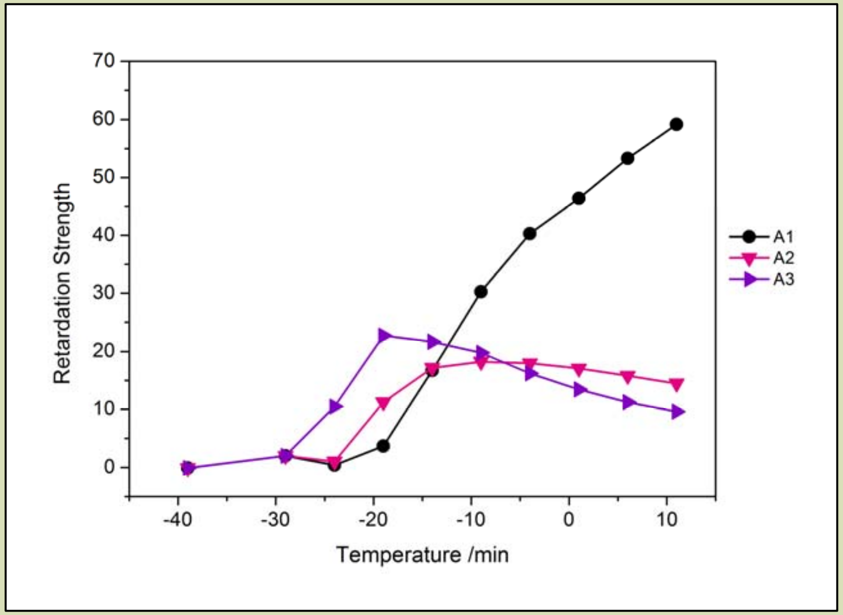
  $\Rightarrow$ complete description of the recovery over time

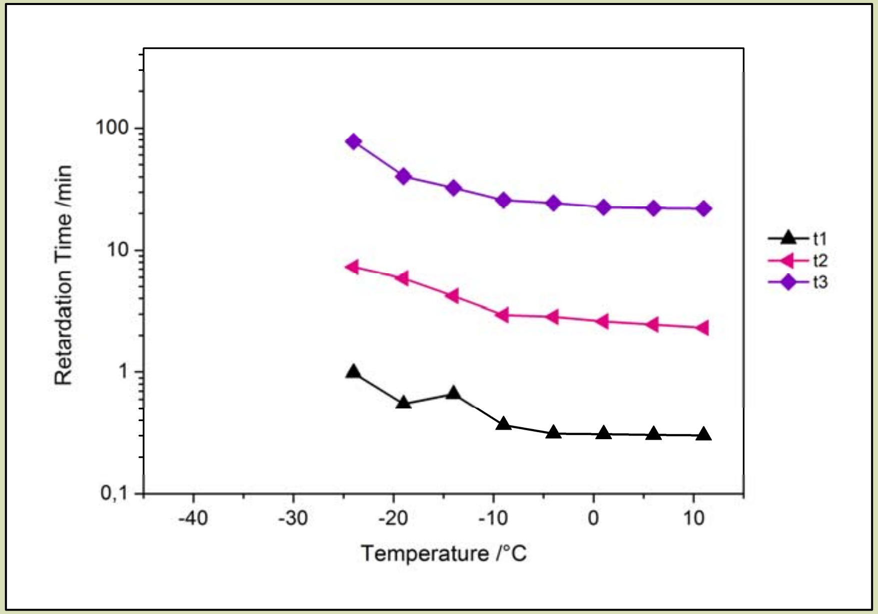
$$y = y_0 + \sum_i A_i e^{-\frac{x}{t_i}}$$

A_i: retardation strength

t_i: retardation time

y_0: value for $t \rightarrow \infty$





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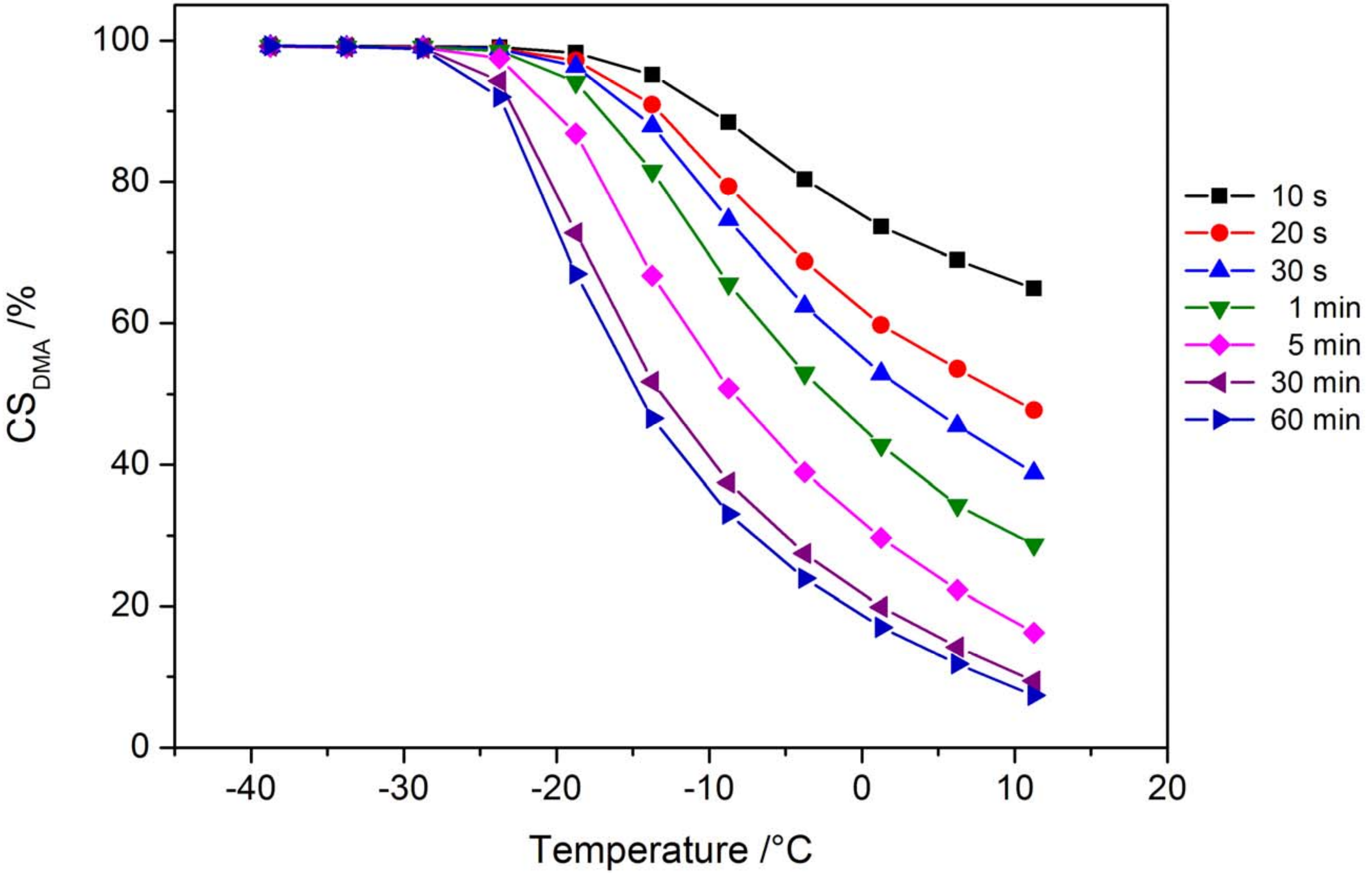

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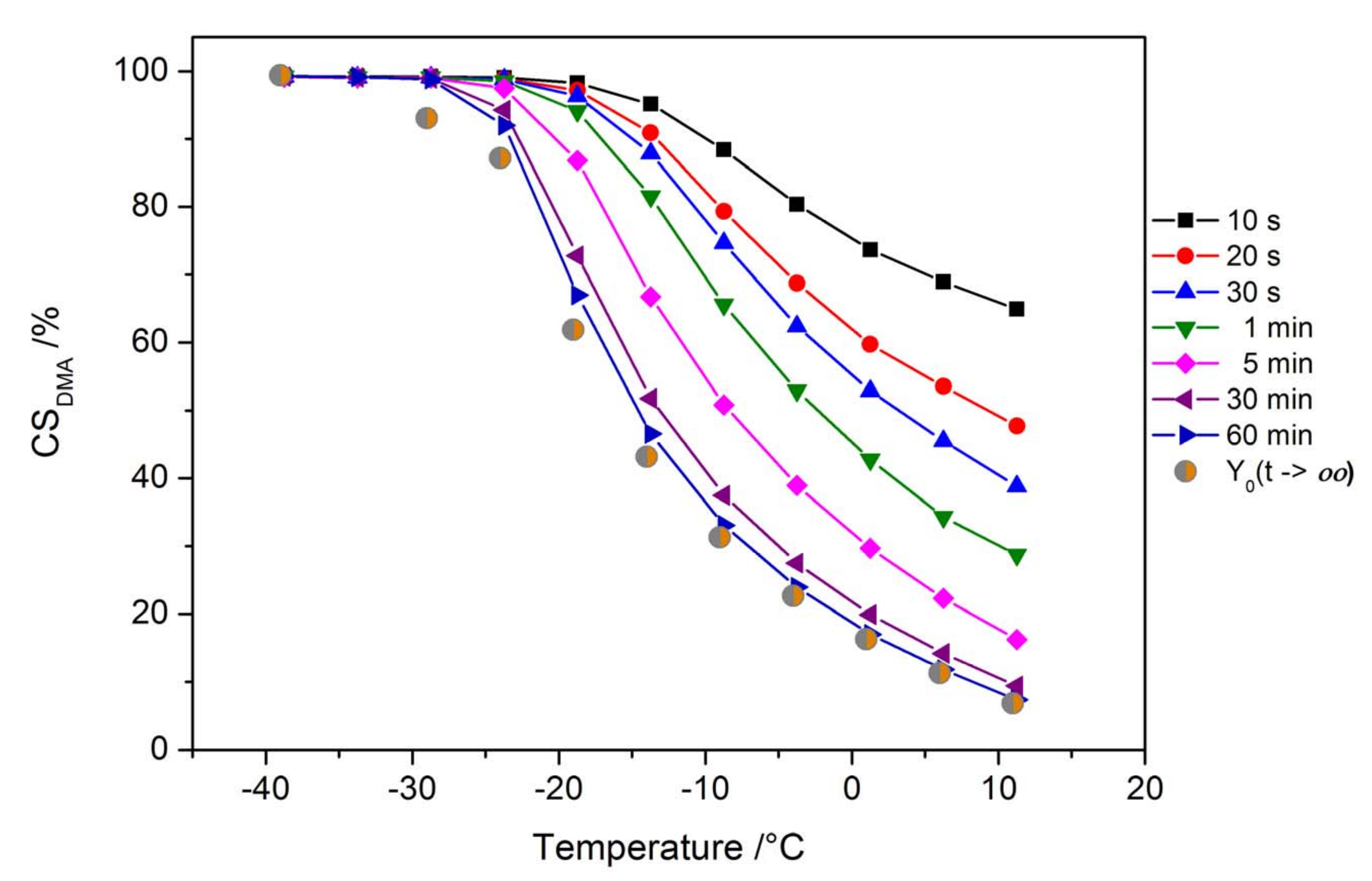
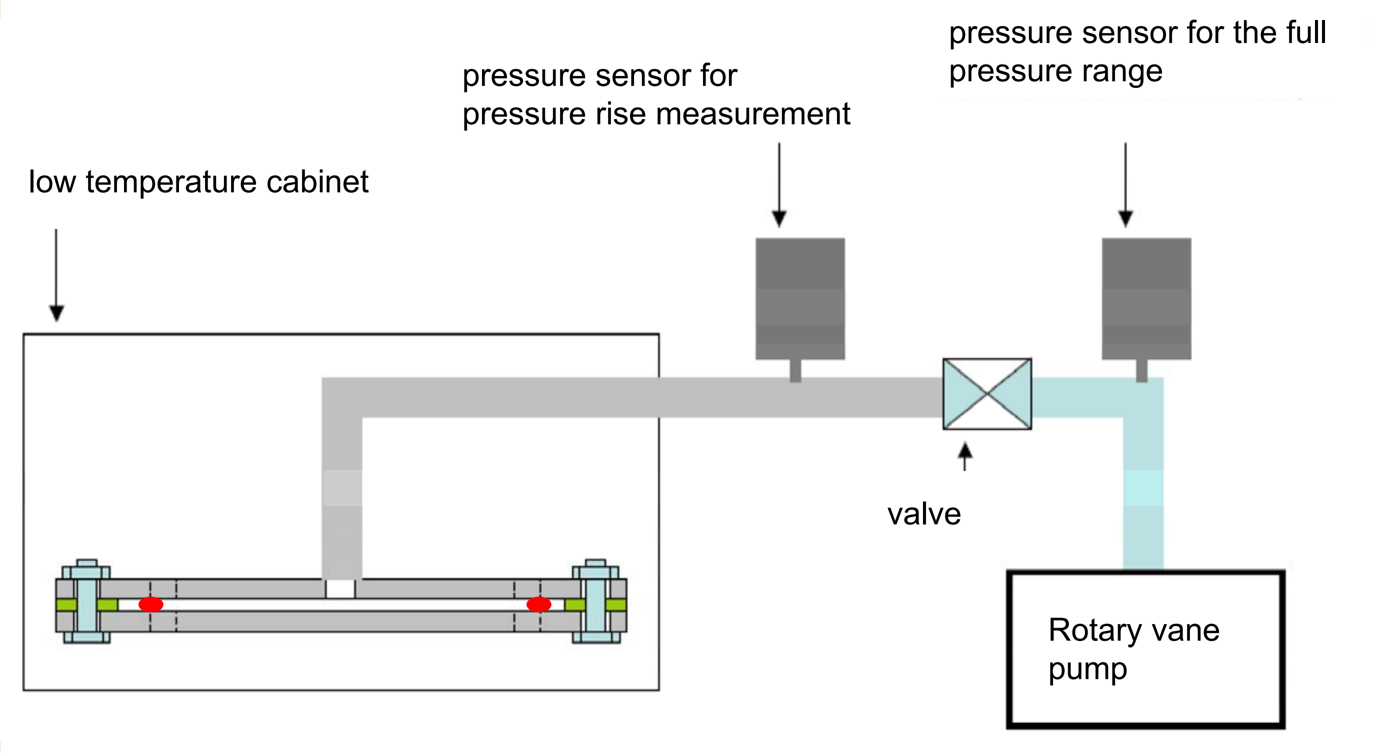


Component tests



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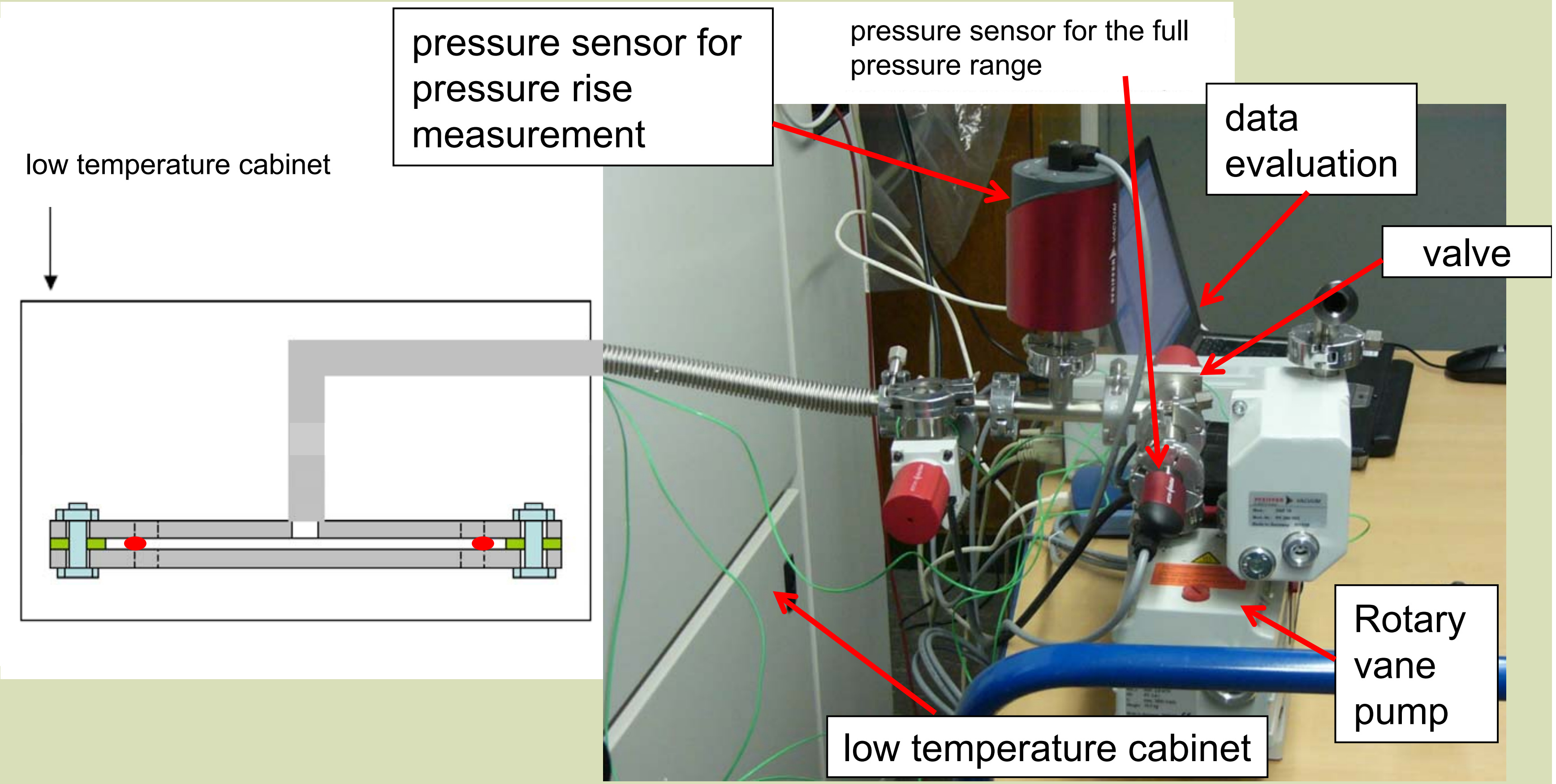

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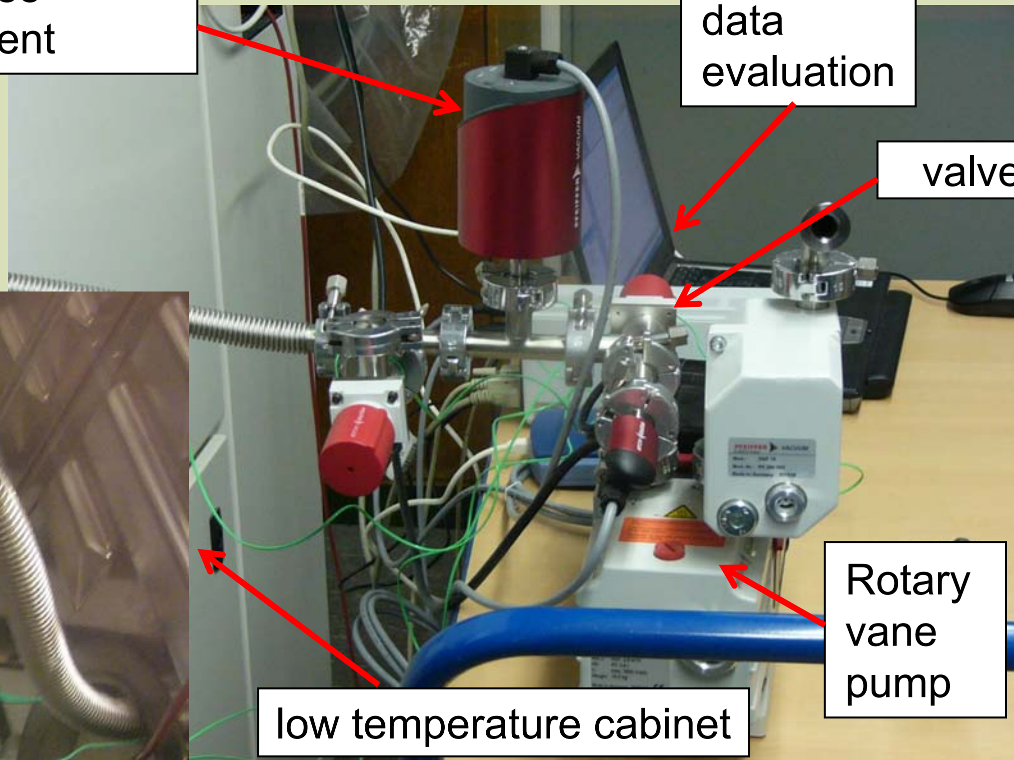

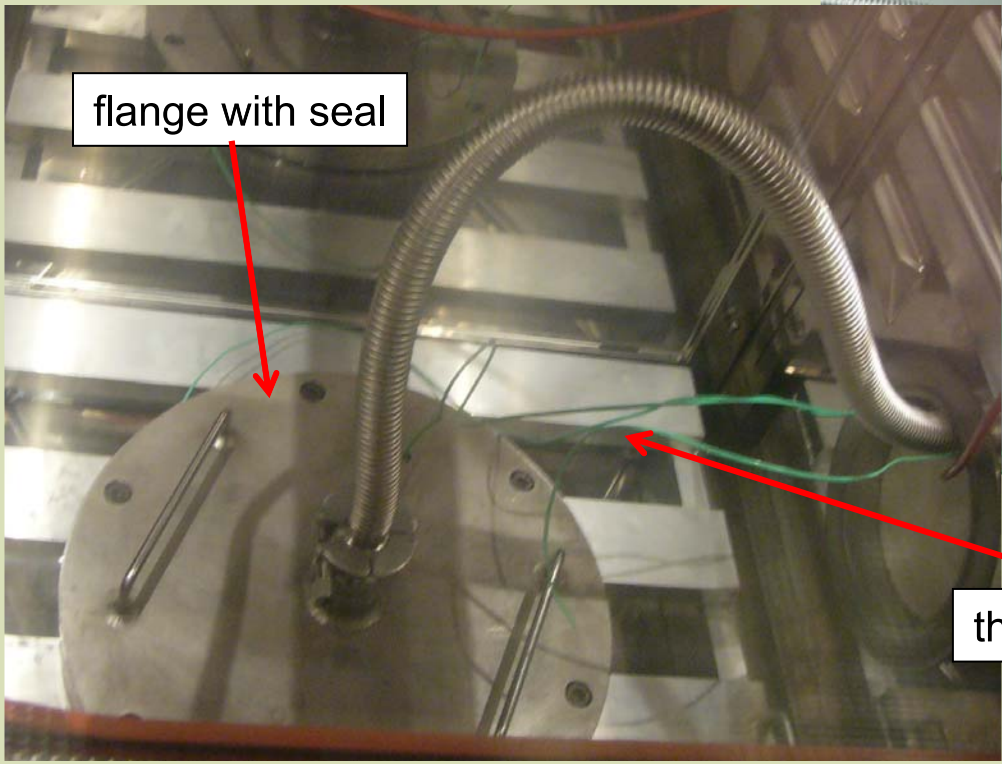

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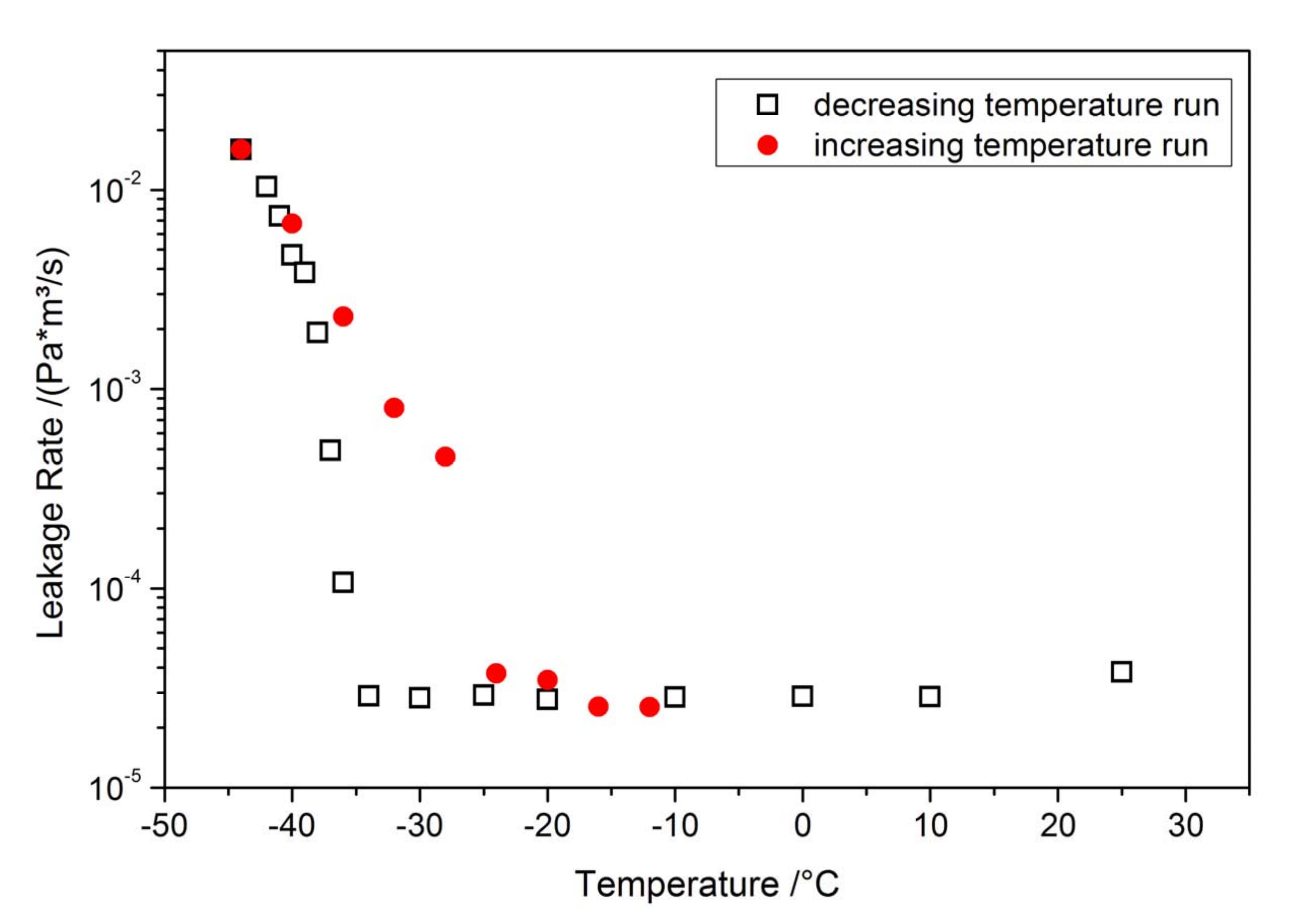


Summary

- ✓ Importance of material properties at low temperatures

  for seal function

- ✓ Failure mechanisms and how to investigate them

  Thermal Analysis allows to estimate the critical temperature region

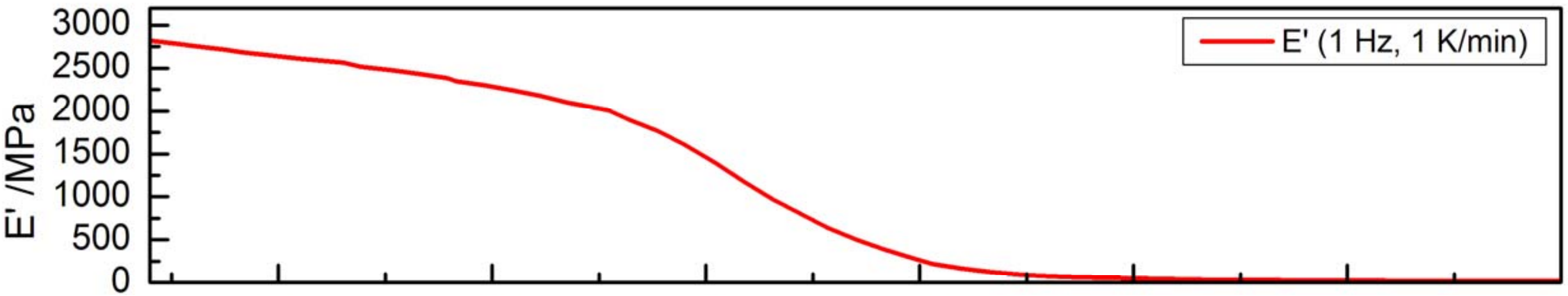
- ✓ Time and Temperature correlation of recovery behaviour and leackage rate

Possible Consequences

Space shuttle Challenger-disaster 1986

caused by neglection of the low temperature properties

Quelle:www.Wikipedia.org



THANK YOU
FOR YOUR ATTENTION!