DKT 2012

TPE Forum

TPE versus Gummi:
Freundlicher oder feindlicher Wettbewerb?

TPE versus Rubber:
Friendly or unfriendly competition?

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Introduction

- History of TPE
- Uniqueness of TPE
  - TPE Family Tree
  - Basic Properties of TPE
  - Morphology – Property dependency
- Positioning of TPE
  - Property Map
  - Stress Relaxation
- TPE Versus Rubber
  - Compounds / Compounding
  - Forming
  - Property Description
- Summary

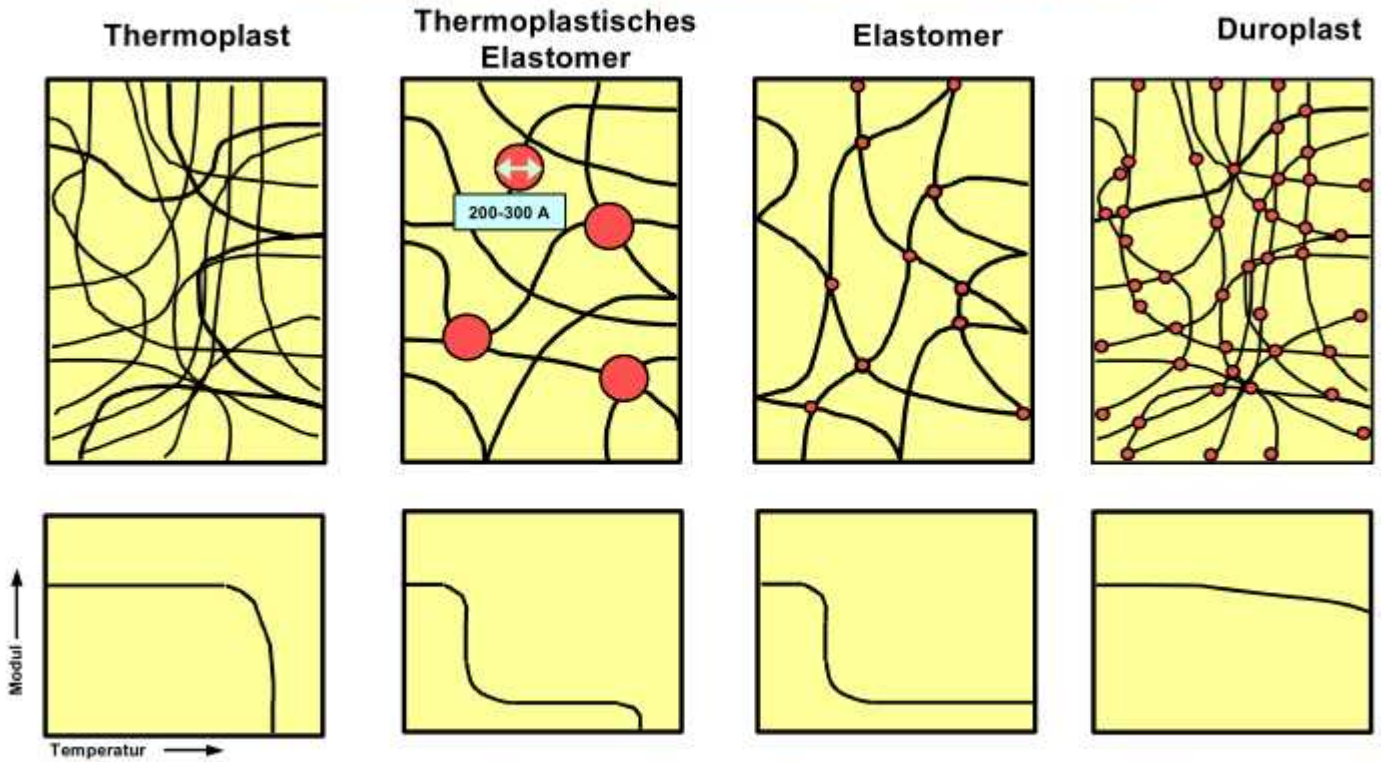
History of TPV
Patent History

- US 4,594,390 A is the Patent Base of Monsanto / AES on TPV
- Title: Process for the preparation of thermoplastic elastomers
  - Published 02.05.84
- US 4,803,244 Union Carbide on Silane crosslinked TPV
  - Published Nov. 16, 1987
  - Since then, the price has moved sligthly downward, because of Korean Competitors, but not much.
  - But a lot of compounders are established today
  - Example: Allod – based on SEBS.

Uniqueness of TPE

Source: E. Osen, KHK 04

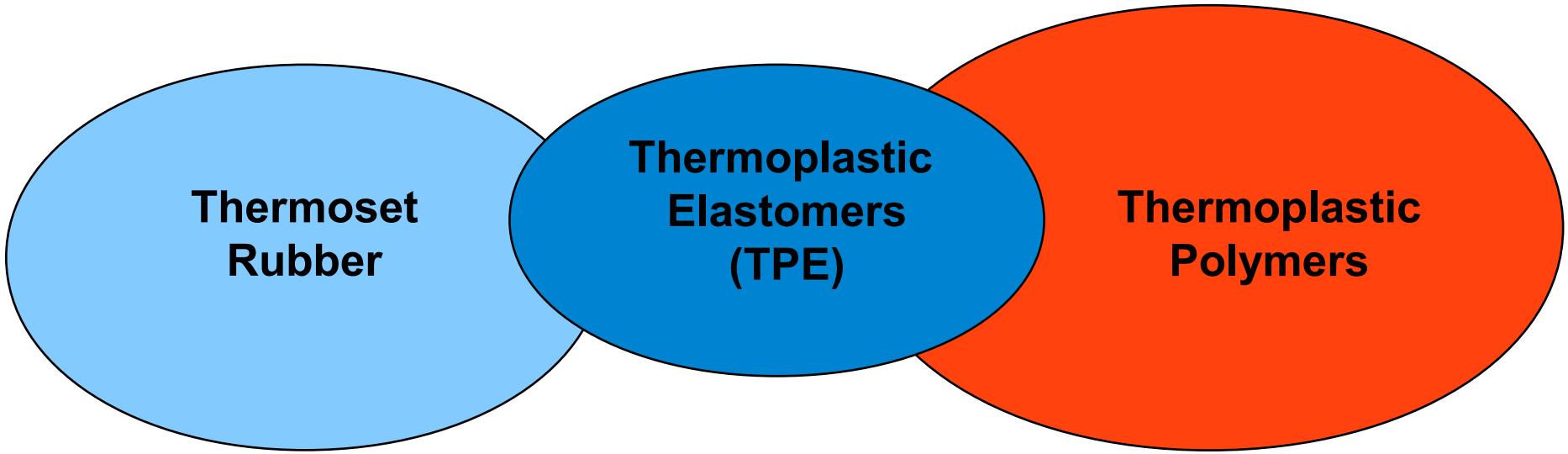
Structure of TPE



Die Vernetzung makromolekularer Werkstoffe bestimmt u. a. den Modulverlauf.
Thermoplastische Elastomere haben vernetzte Domänen.

Crosslinks of polymer materials determines their modulus
Thermoplastic elastomers have crosslinked domains only

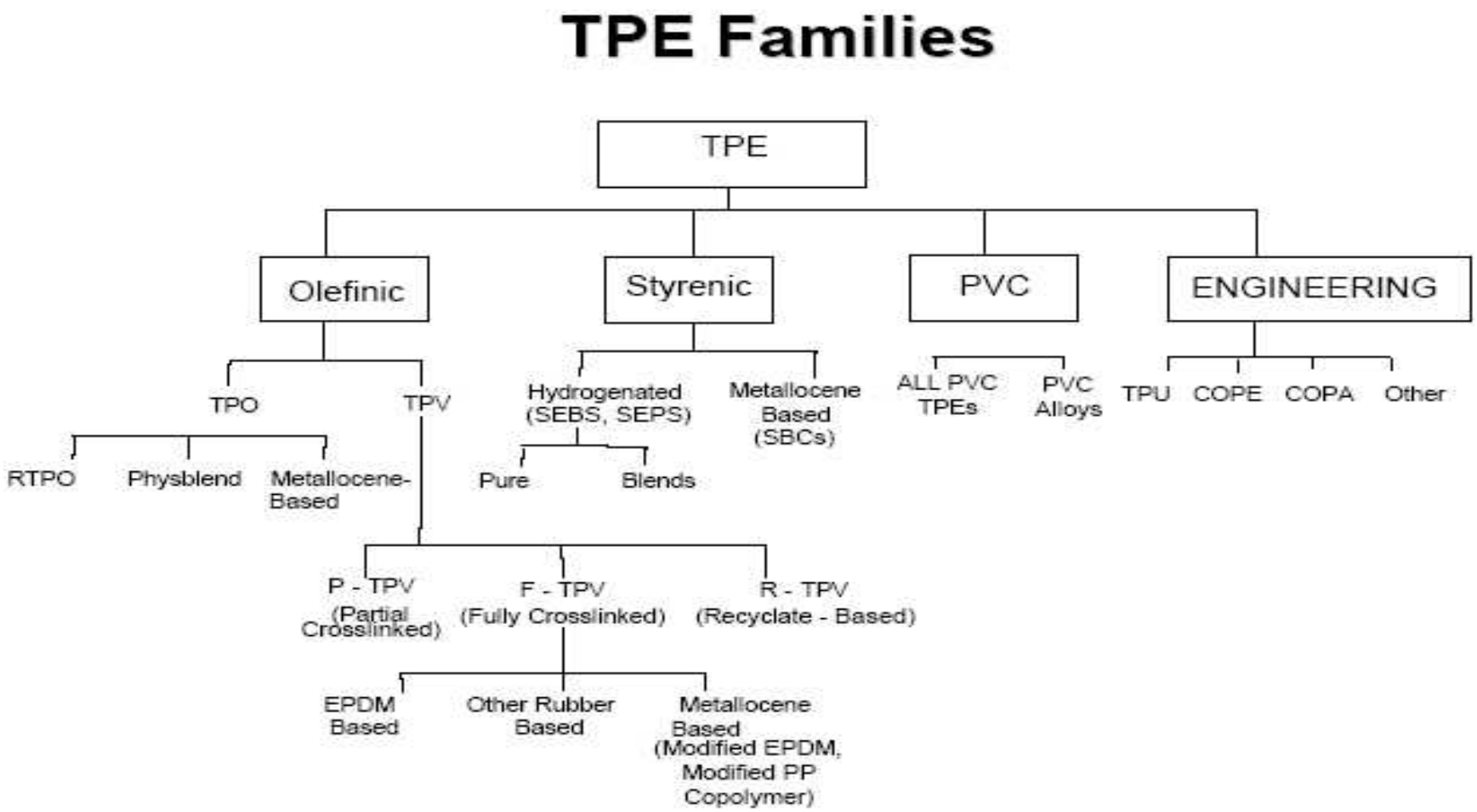
Uniqueness of TPE



Between Rubber and Thermoplastic:
TPE is a "Dual Phase" material, which contains a thermoplastic continuous phase surrounding rubber droplets

Uniqueness of TPE
TPE Family Tree

Source:R. Eller, TX, Feb. 2000

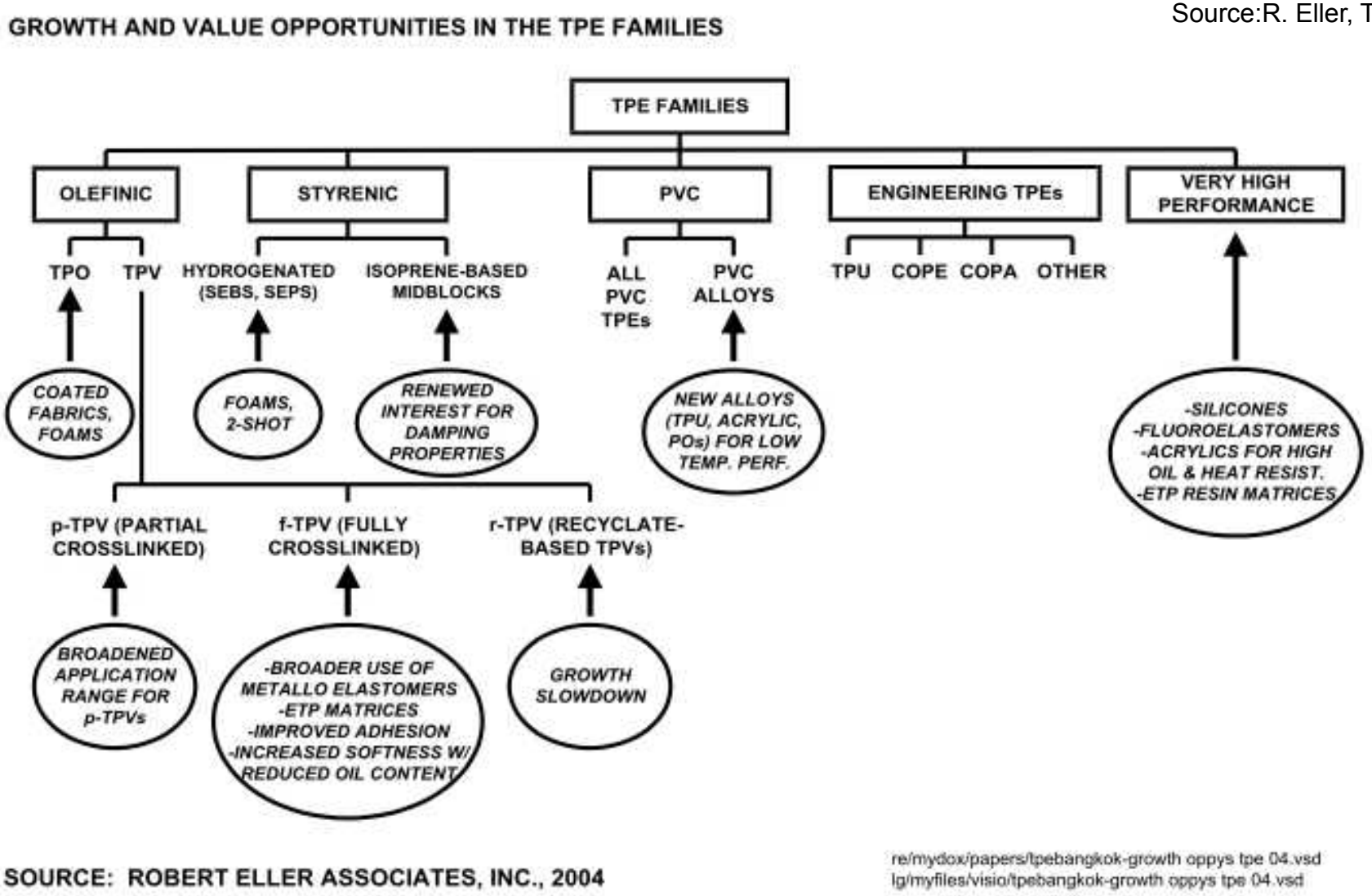


From: Rober Eller, "SPE Polyolefins 2000", Houston, TX, Feb 2000.

Uniqueness of TPE

TPE Family Tree

Source:R. Eller, TX, Feb. 2000



Uniqueness of TPE

Basic Properties of TPE

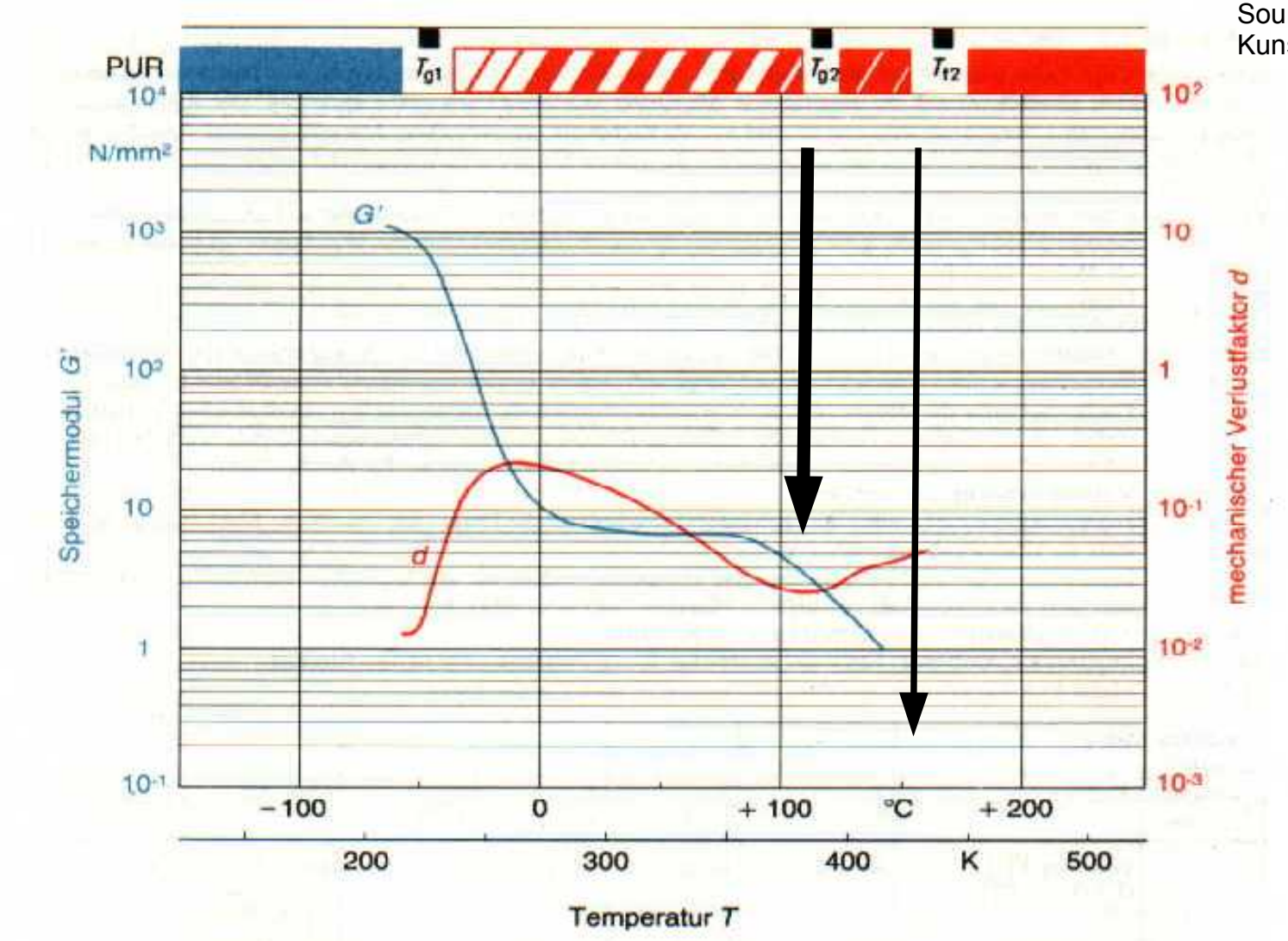
Source:Franck/Biederbick,
Kunststoff-Kompendium 88

- Hard-elastic, brittle
- Hard elastic, tough
- Tough, still to hard for application as Elastomer
- Soft-elastic, area of application
- Very soft, not applicable for service
- Viscous melt, forming area
- Chemical aging and decomposition

Uniqueness of TPE
Basic Properties of TPE

Source:Franck/Biederbick,
Kunststoff-Kompendium 88

Storage Modulus G'

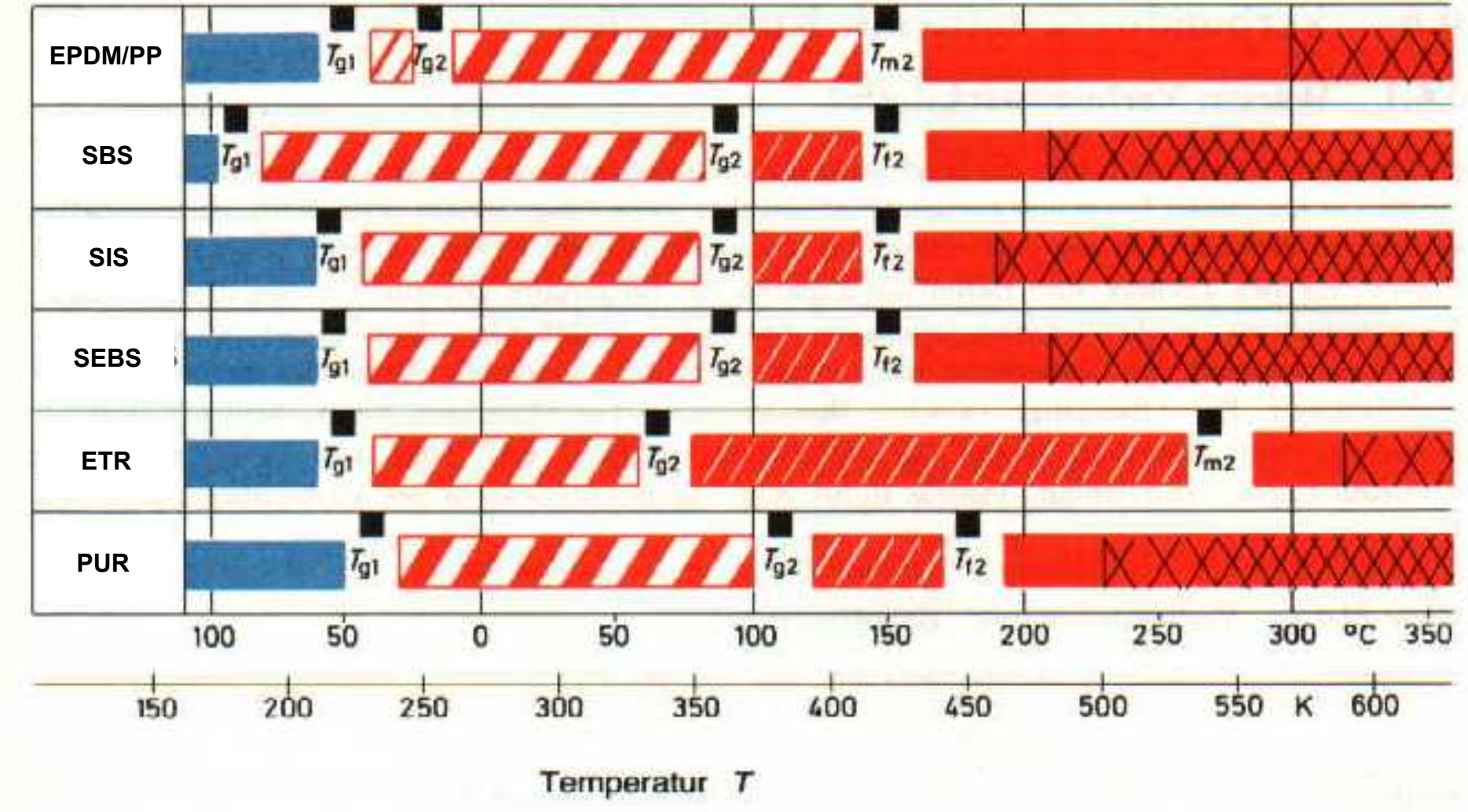


Mechanical loss Modulus d

Uniqueness of TPE

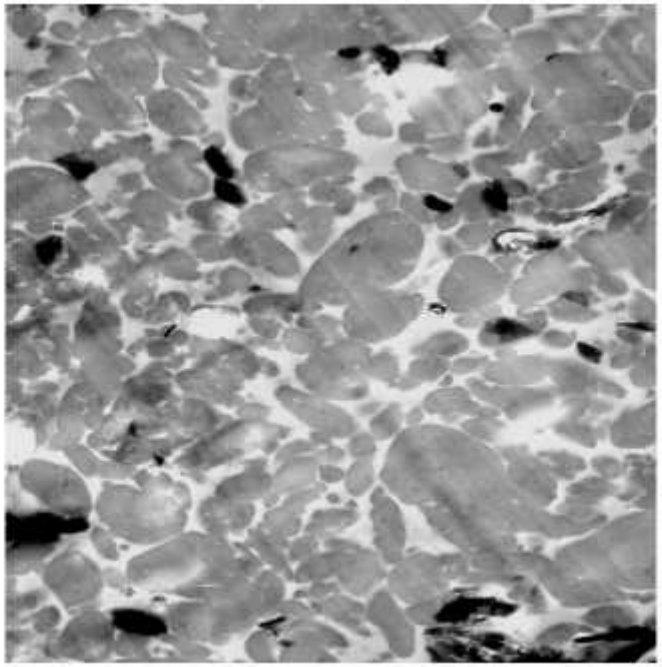
Basic Properties of TPE

Source:Franck/Biederbick,
Kunststoff-Kompendium 88



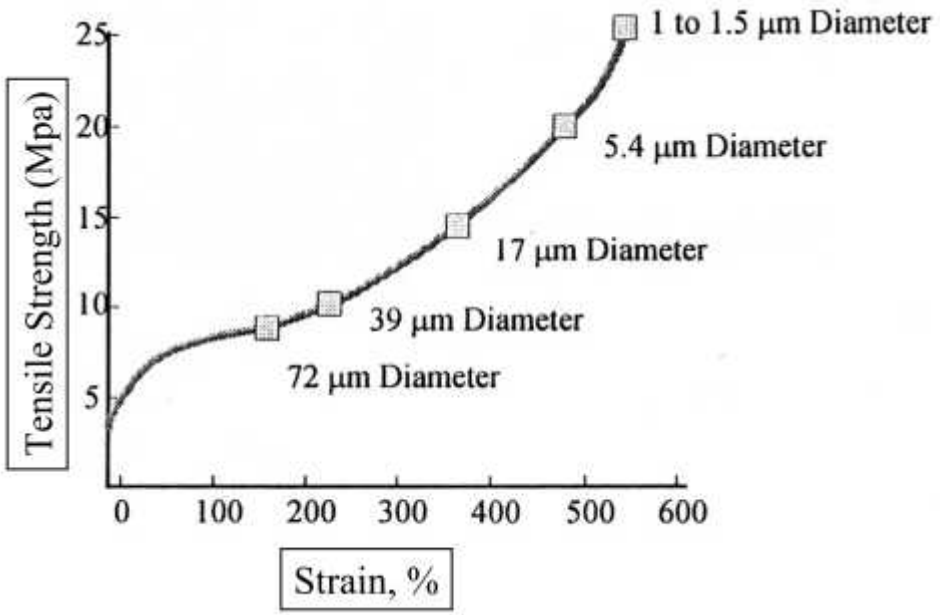
Uniqueness of TPE
Morphology - Property Dependency

Source: K. Walton, RCT 77



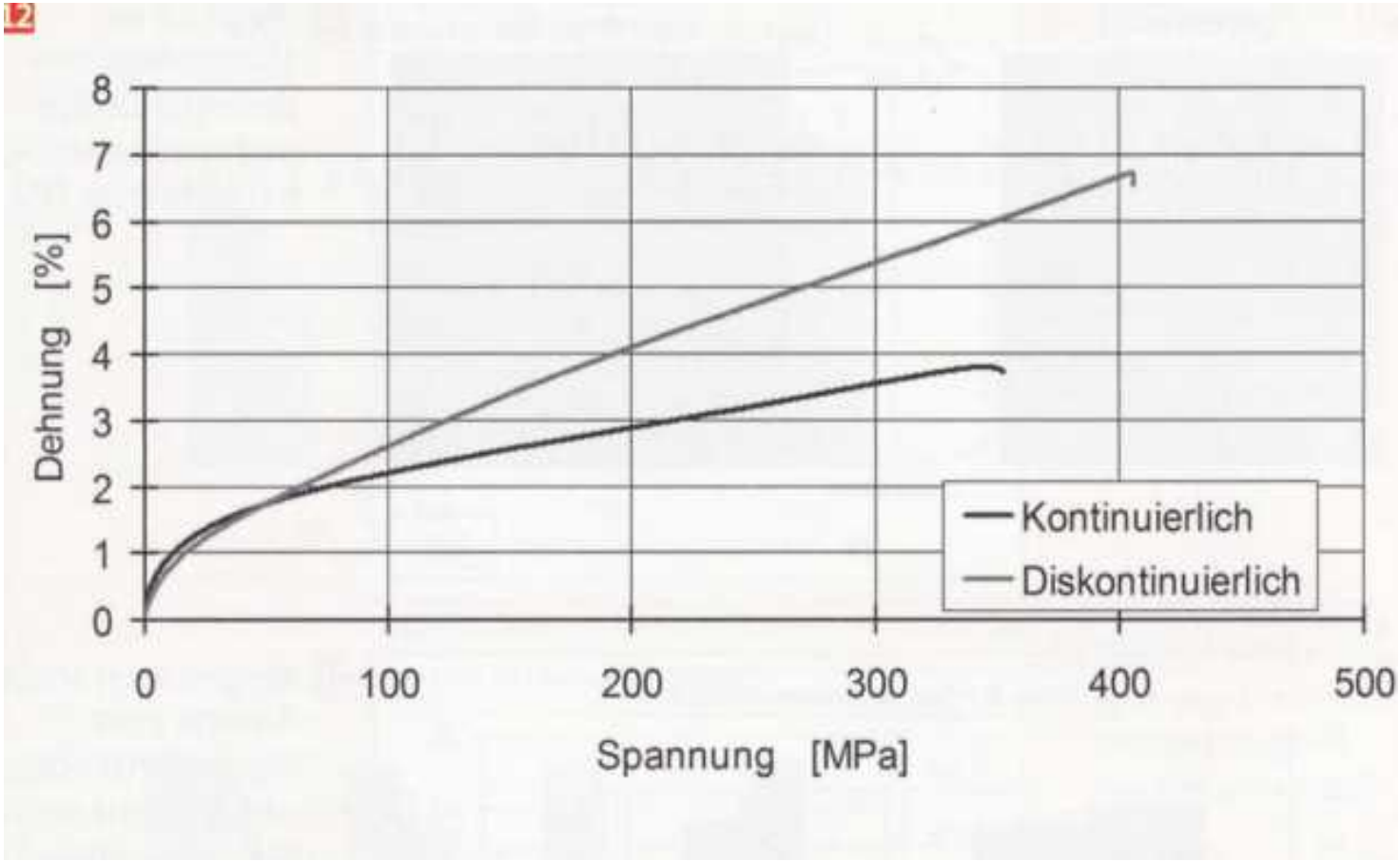
– Transmission electron microscopy (TEM) of PP/EPDM TPV. Dark areas are crosslinked rubber particles.

Source:A.Y.Coran, R.P.Patel
Thermoplastic Elastomers 96



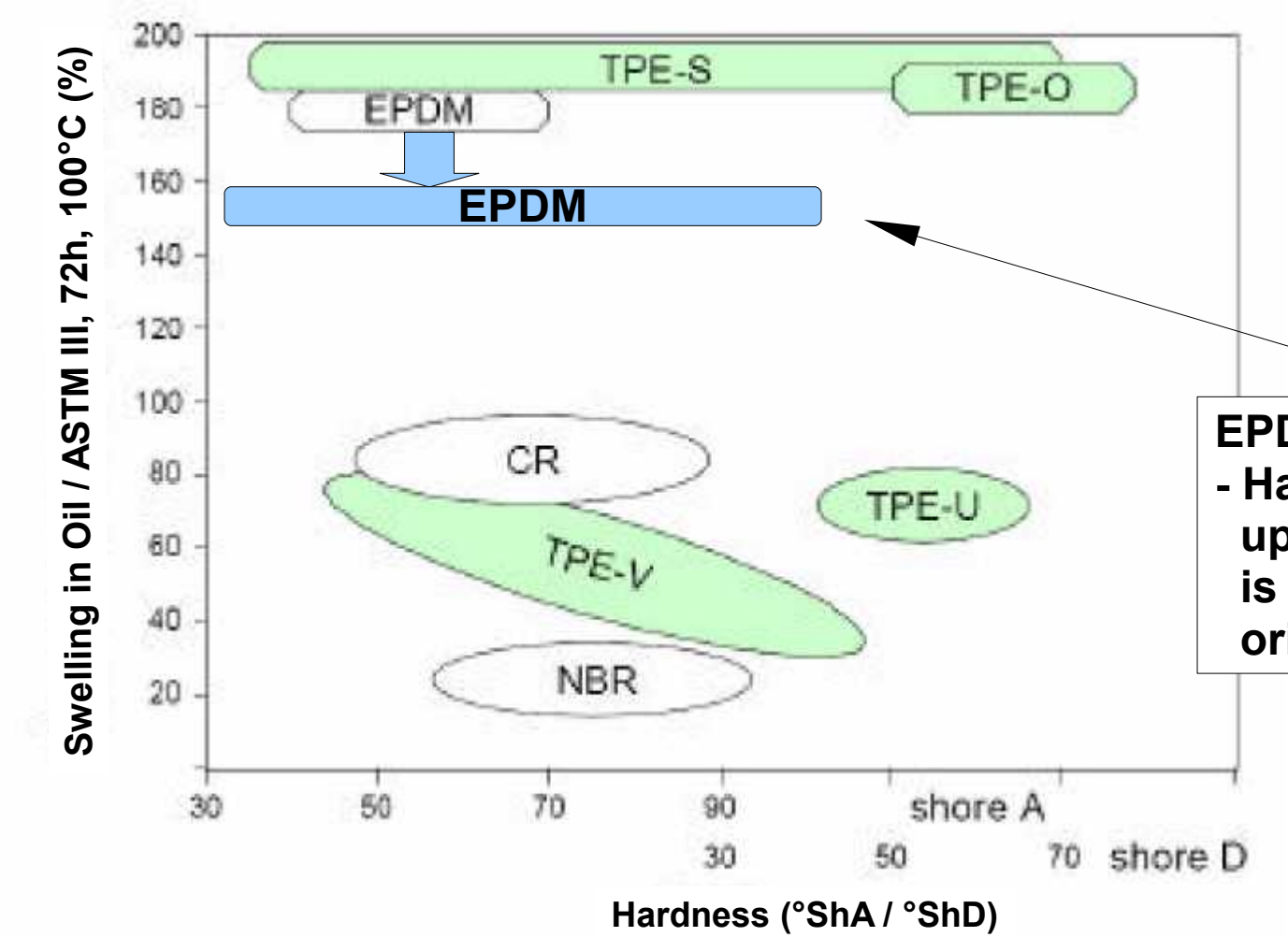
Uniqueness of TPE
Morphology - Property Dependency

Source: W. Michaeli et.al.
KHK Sept. 2011



Positioning of TPE
Property Map

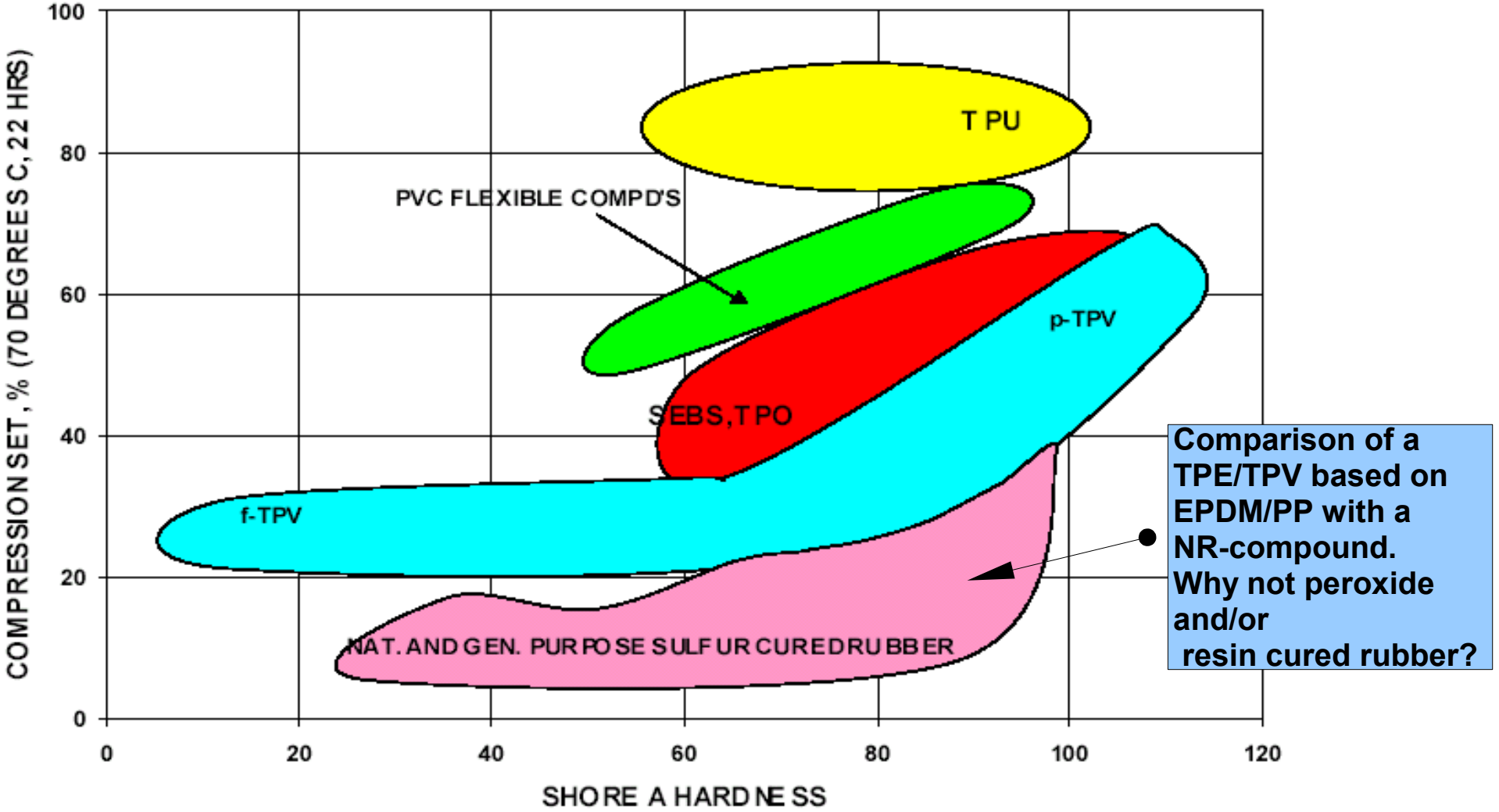
Source:Wittig, GAK 1997



EPDM Compounds:
- **Hardness from 20°ShA up to 95°ShA is possible, opposite to original slide**

Positioning of TPE
Property Map

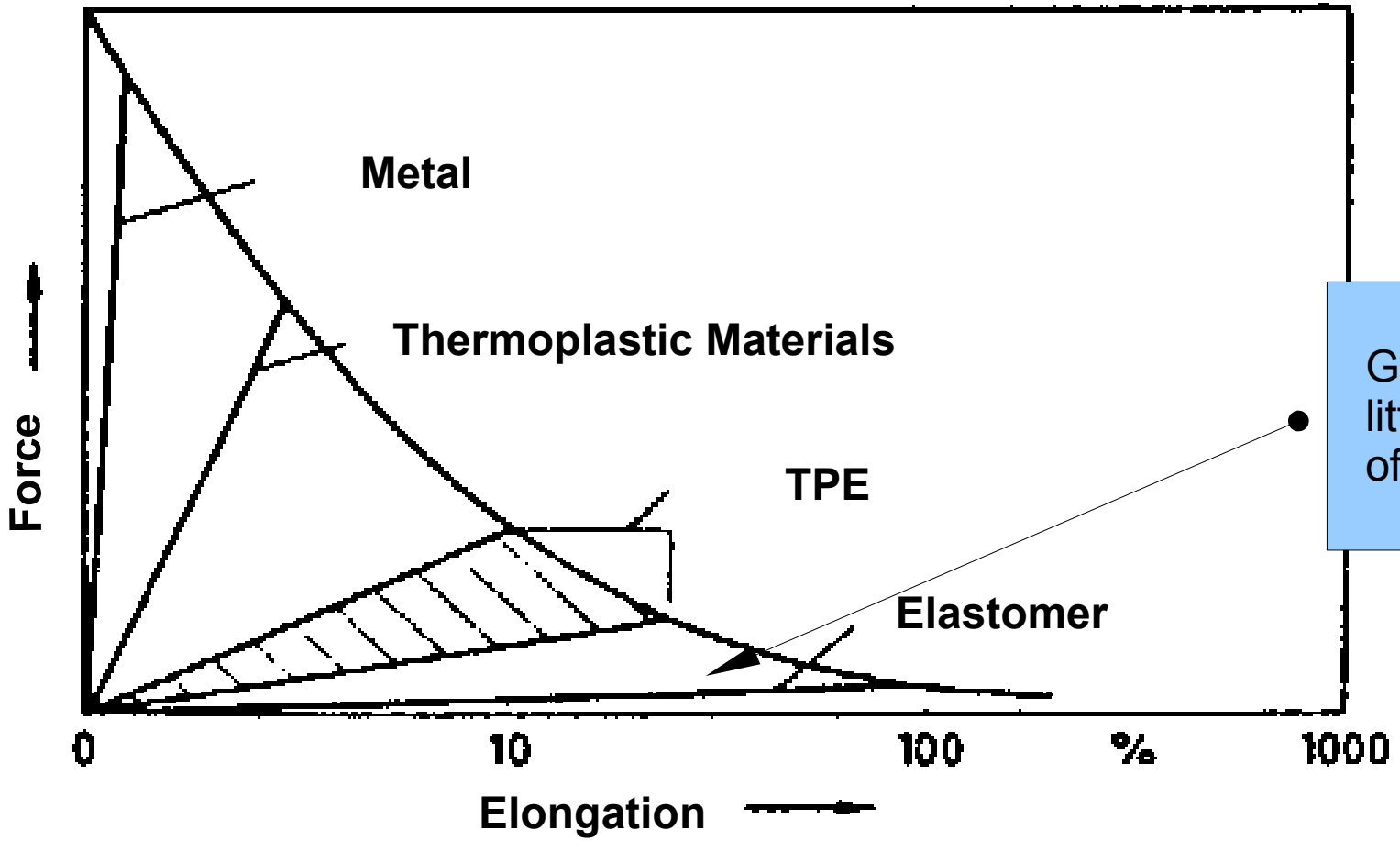
Source:R. Eller, W. Klingensmith
IISRP Annual Meeting 2001



Positioning of TPE

Stress relaxation behaviour

Source:H. Domininghaus
Plastverarbeiter 89



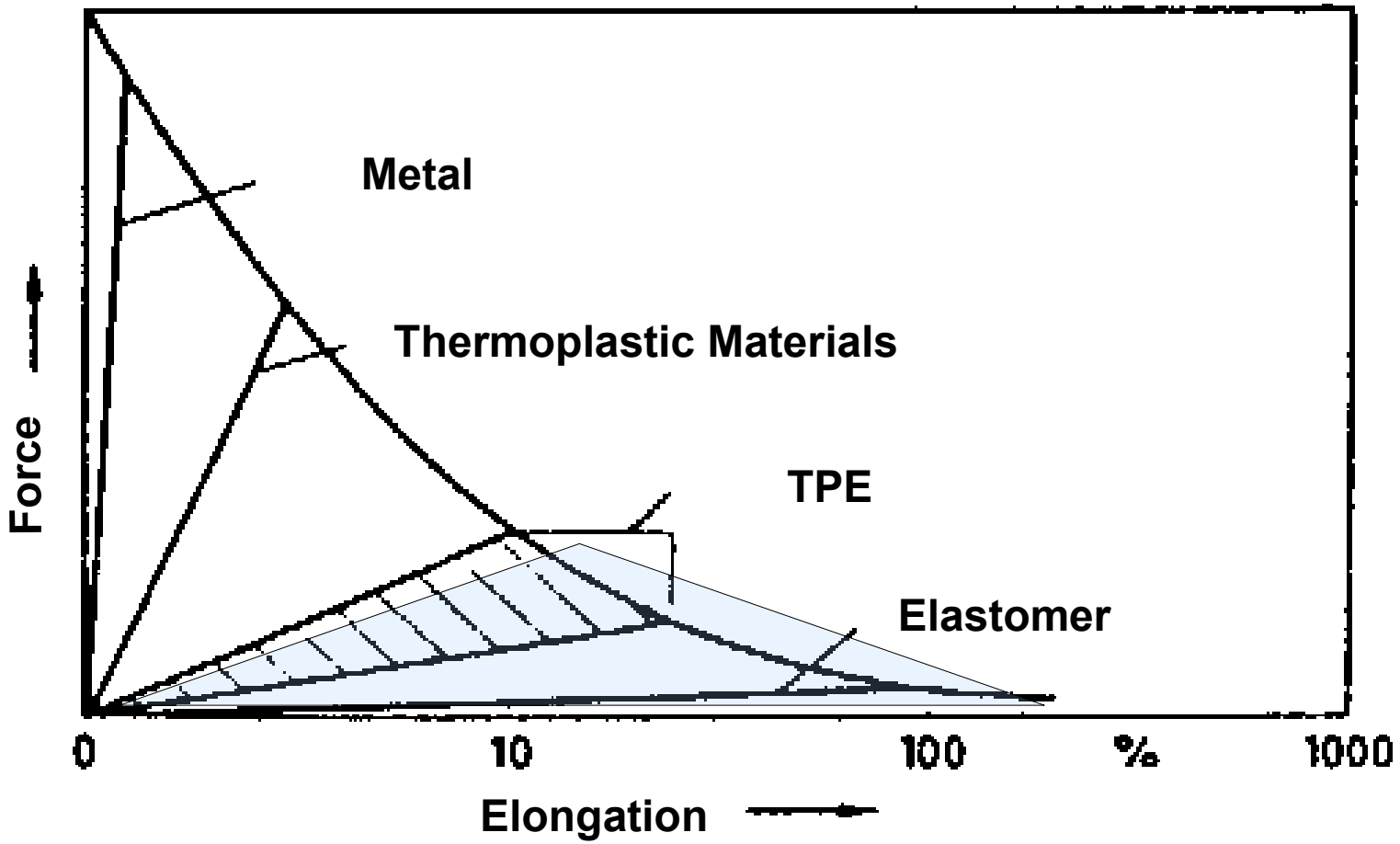
Graph suggests little performance of vulcanized rubber

Applicability of Stress/Strain on different Materials until elasticity limit, but with complete recovery after removing of the load

Positioning of TPE

Stress relaxation behaviour

Source:H. Domininghaus
Plastverarbeiter 89

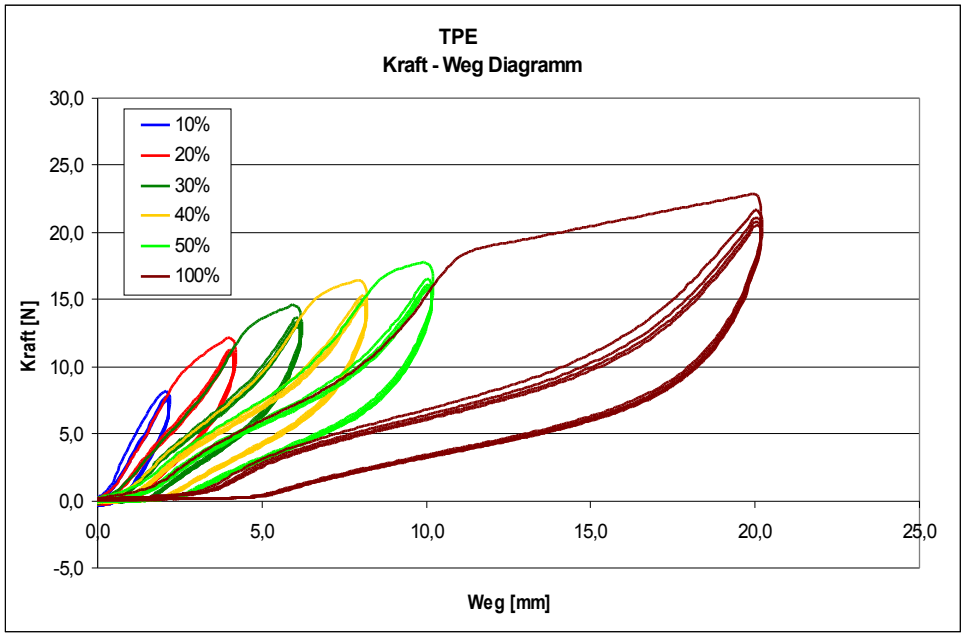


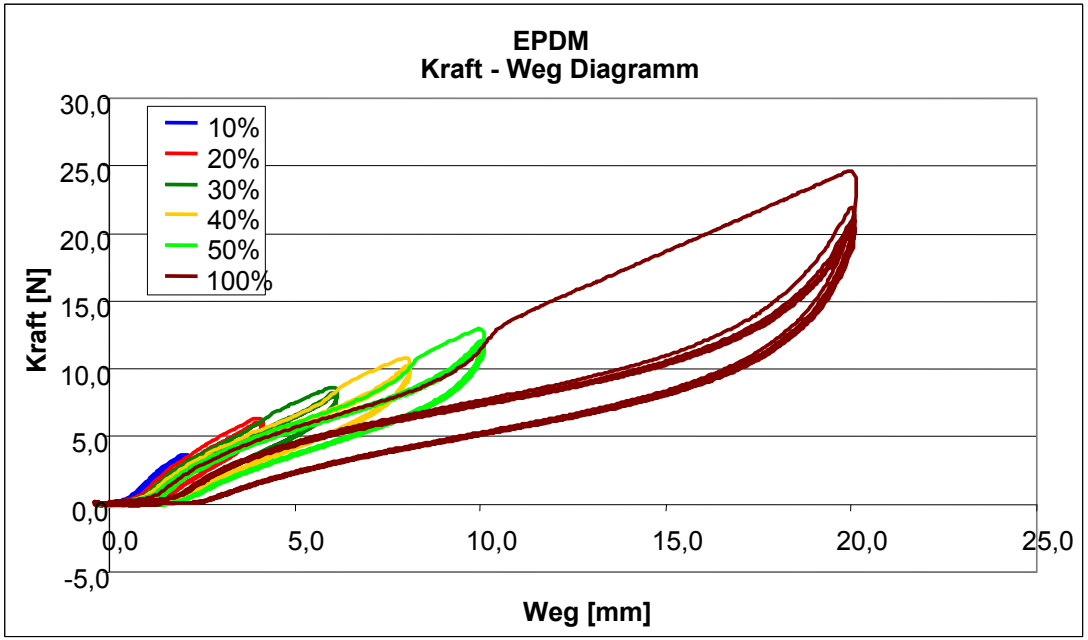
Applicability of Stress/Strain on different Materials until elasticity limit, but with complete recovery after removing of the load

Positioning of TPE

Stress relaxation behaviour

Source: C. Thomas
DIK TPE Seminar



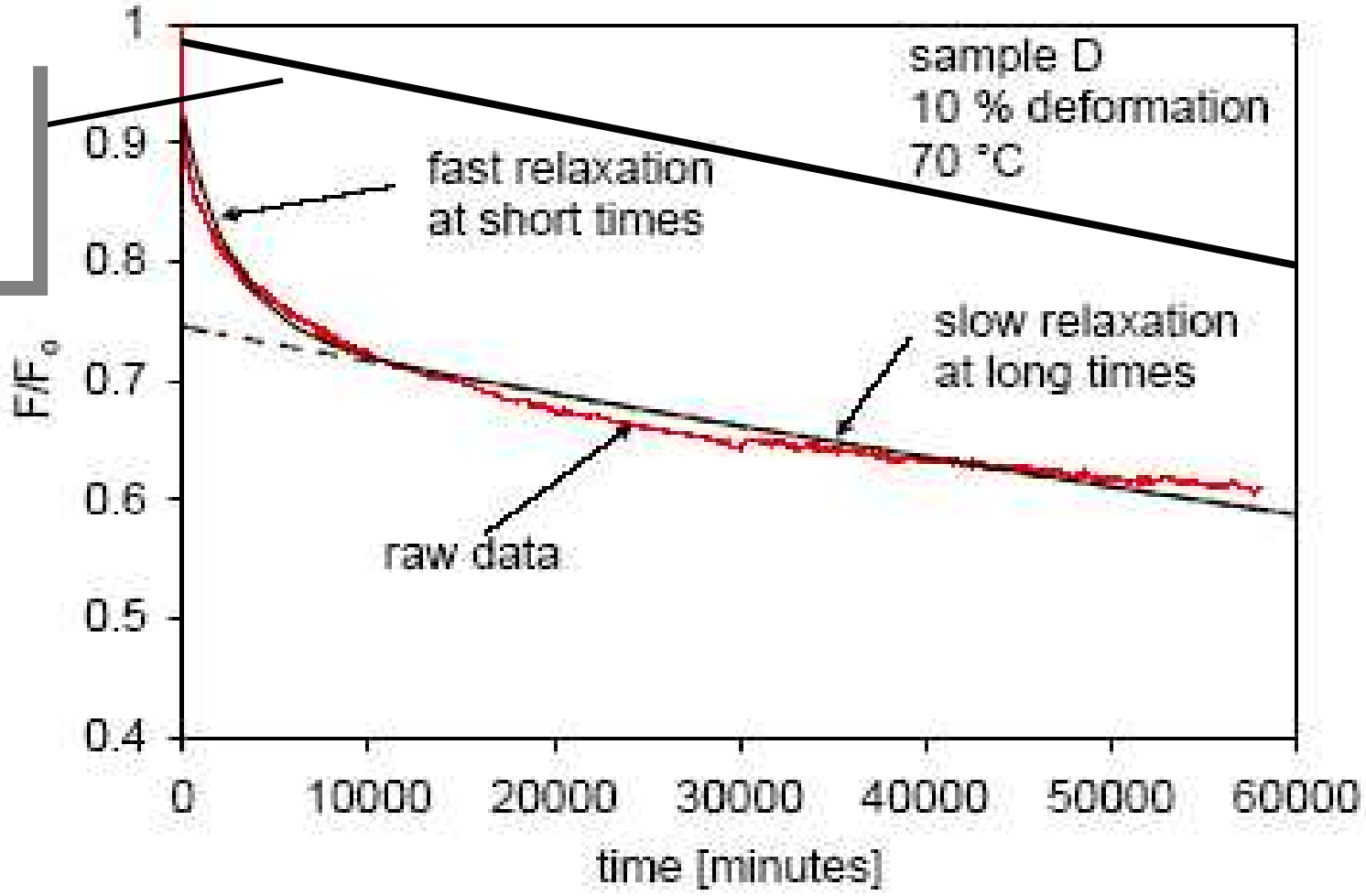


Positioning of TPE

Stress relaxation behaviour

Source: E. Jourdain,
Autom.Elast.Conf. 04, Detroit

Compression load relaxation for Elastomers (typical behavior)

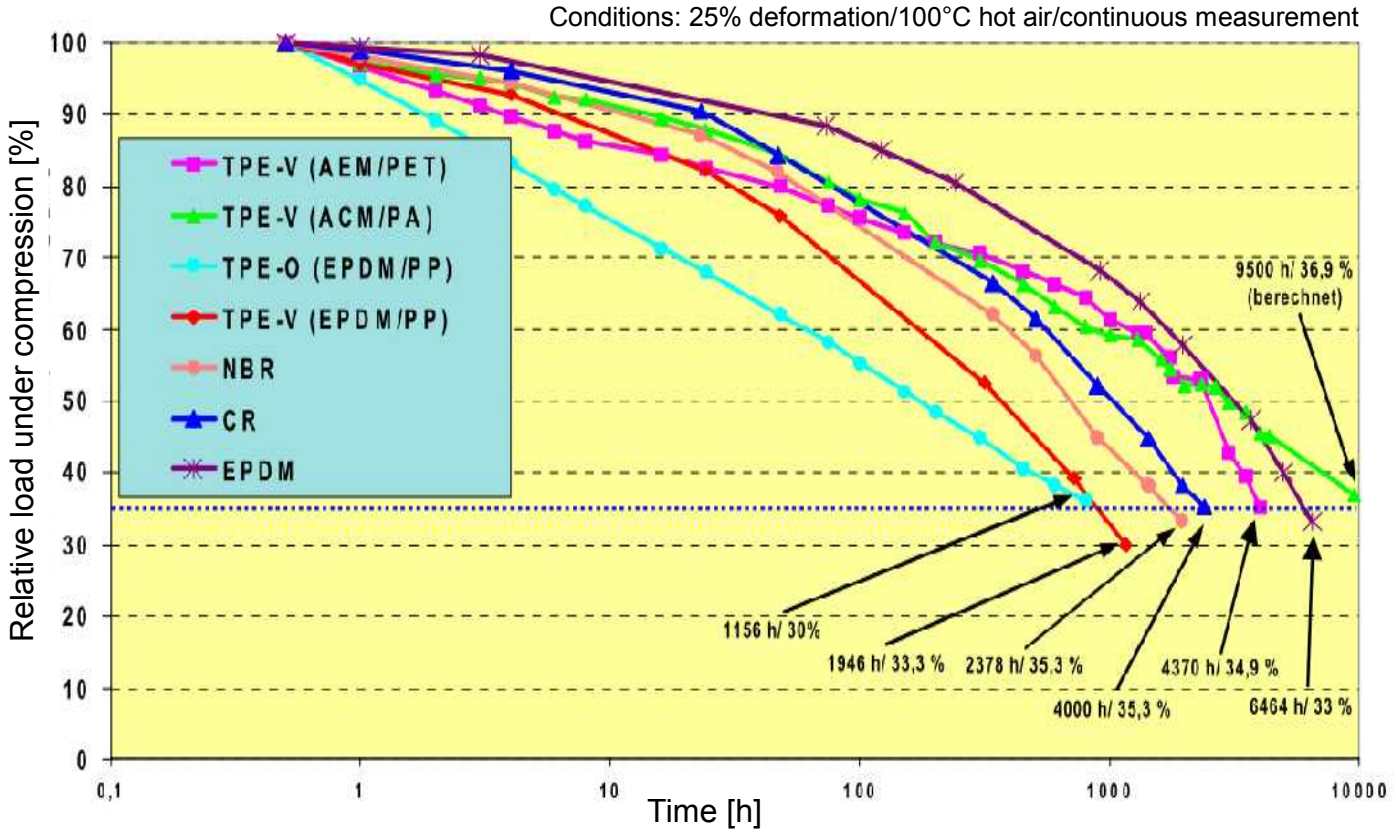


Positioning of TPE

Stress relaxation behaviour

Compression Stress Relaxation of different rubbers compared with Standard and high performance TPE.

Source: E. Osen
KHK 2006



TPE versus Rubber
Compounds / Compounding

- **TPE**
  - **Continuous Matrix**
    - **PP**
    - **PO**
    - **TP Polar Polymers**
    - **Developments mostly on Heat / Media resistant TPE**
  - **Suppliers**
    - **Since 2000 numerous suppliers established similar to the TP-Industry**

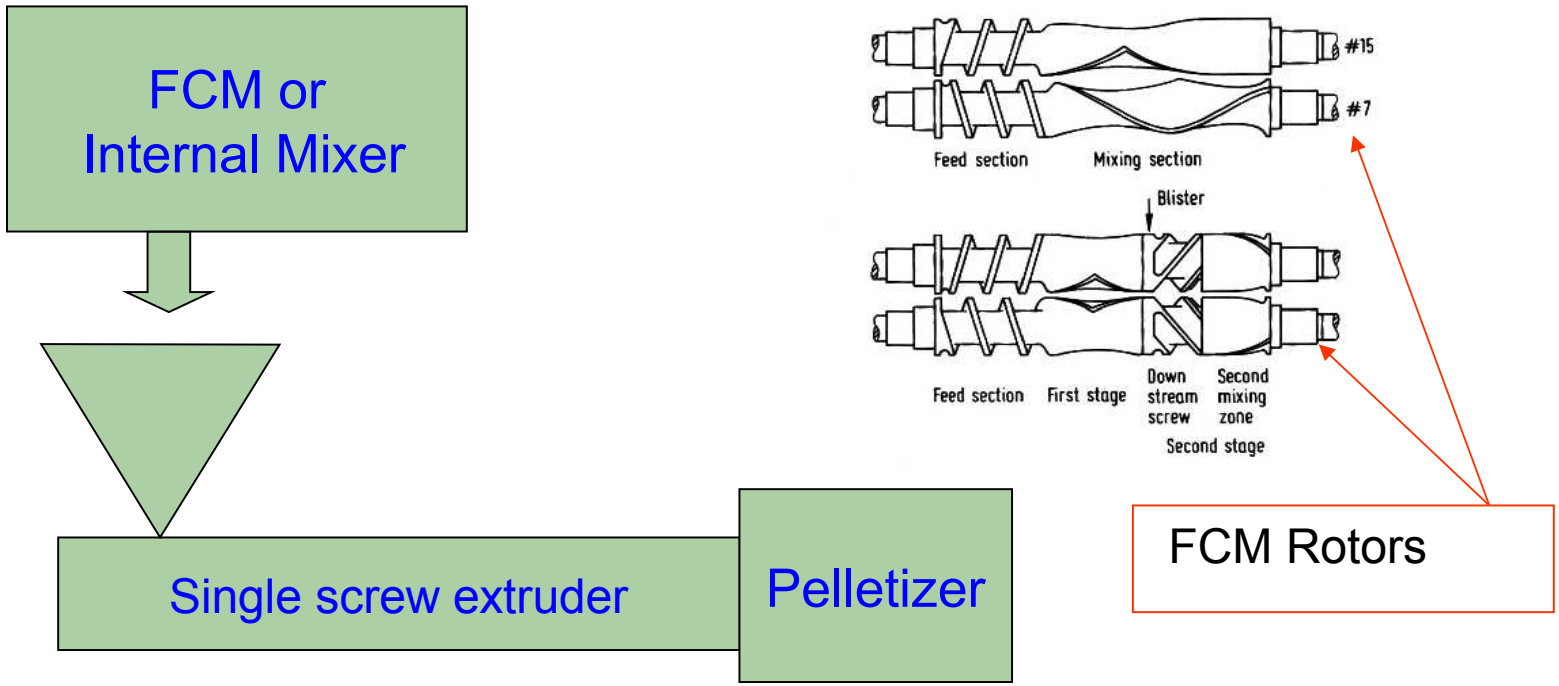
- **Rubber (TSR)**
  - **Material developments are seldom**
  - **Developments for improvement**
    - **Machines**
    - **Compounding to meet specifications**
  - **Material replacement during life cycle is difficult:**
    - **Expensive testing**
    - **Customer declines**
    - **Economical restrictions (Ownership of mixing equipment)**

TPE versus Rubber
Compounds / Compounding

Source: HF Mixing
Former Farrel

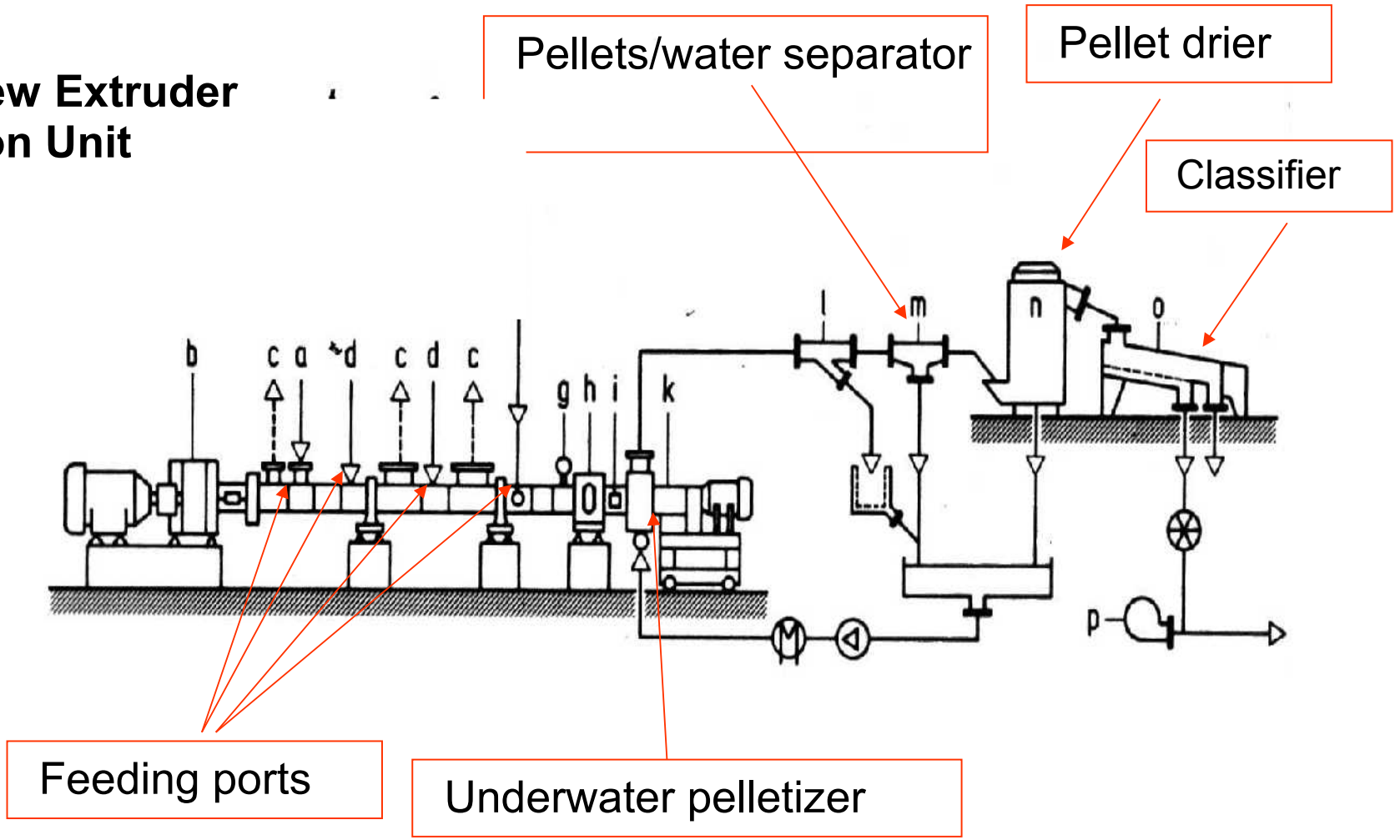
Two stage compounding

- FCM (Farrel Continuous Mixer)
- Internel mixer
- Discharged to single-screw extruder and then pelletized



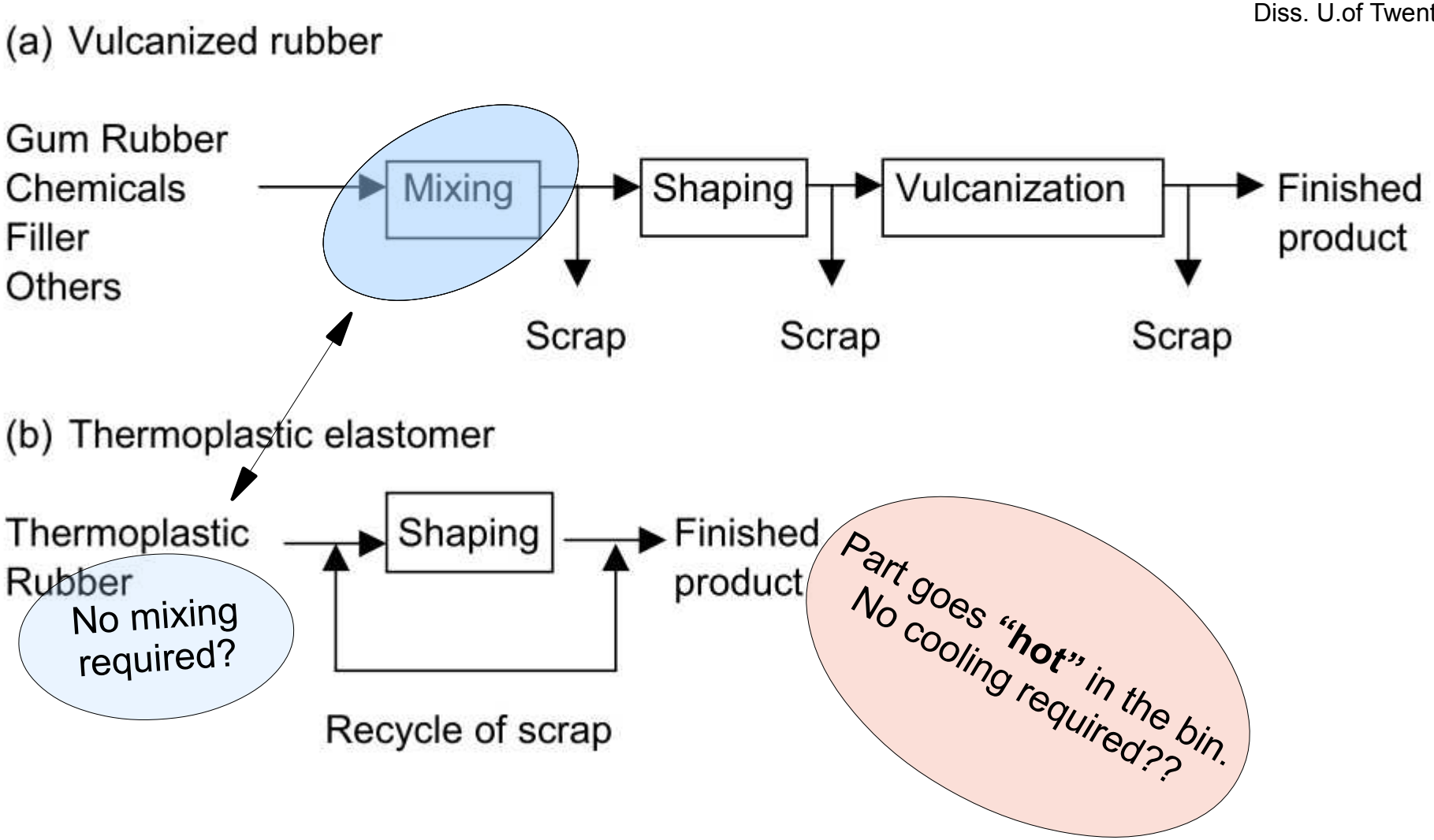
TPE versus Rubber
Compounds / Compounding

Twin Screw Extruder Production Unit



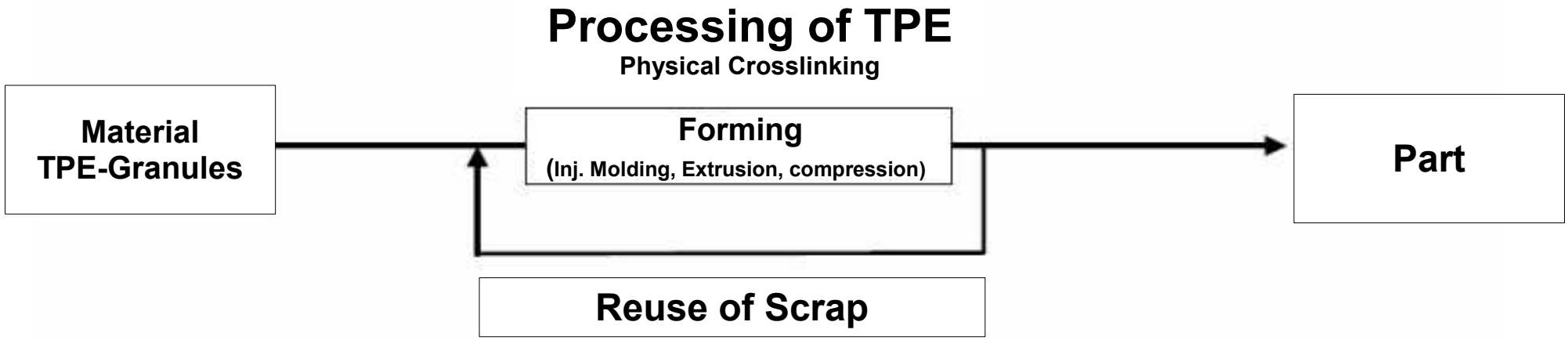
TPE versus Rubber
Forming

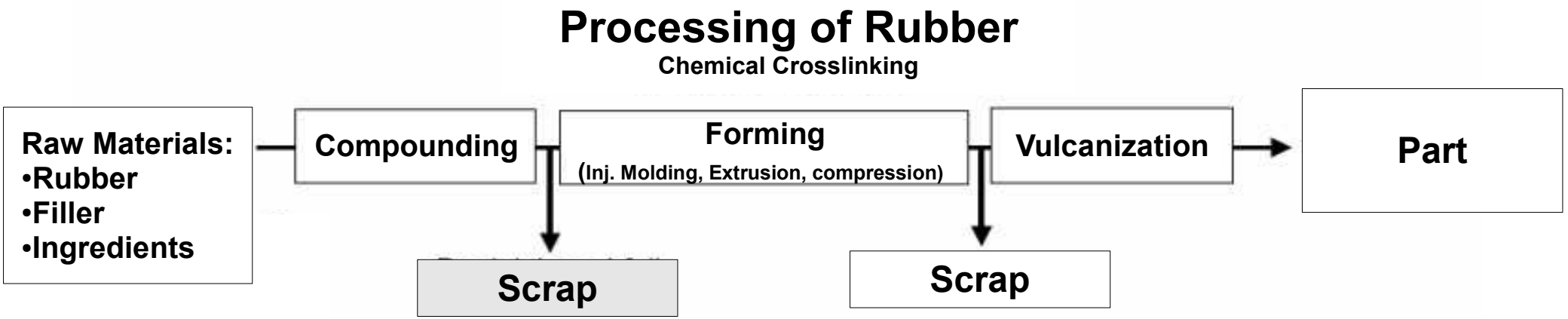
Source:K Naskar
Diss. U.of Twente 2004



TPE versus Rubber
Forming

Source:J. Stemper
Plastverarbeiter 84





TPE versus Rubber
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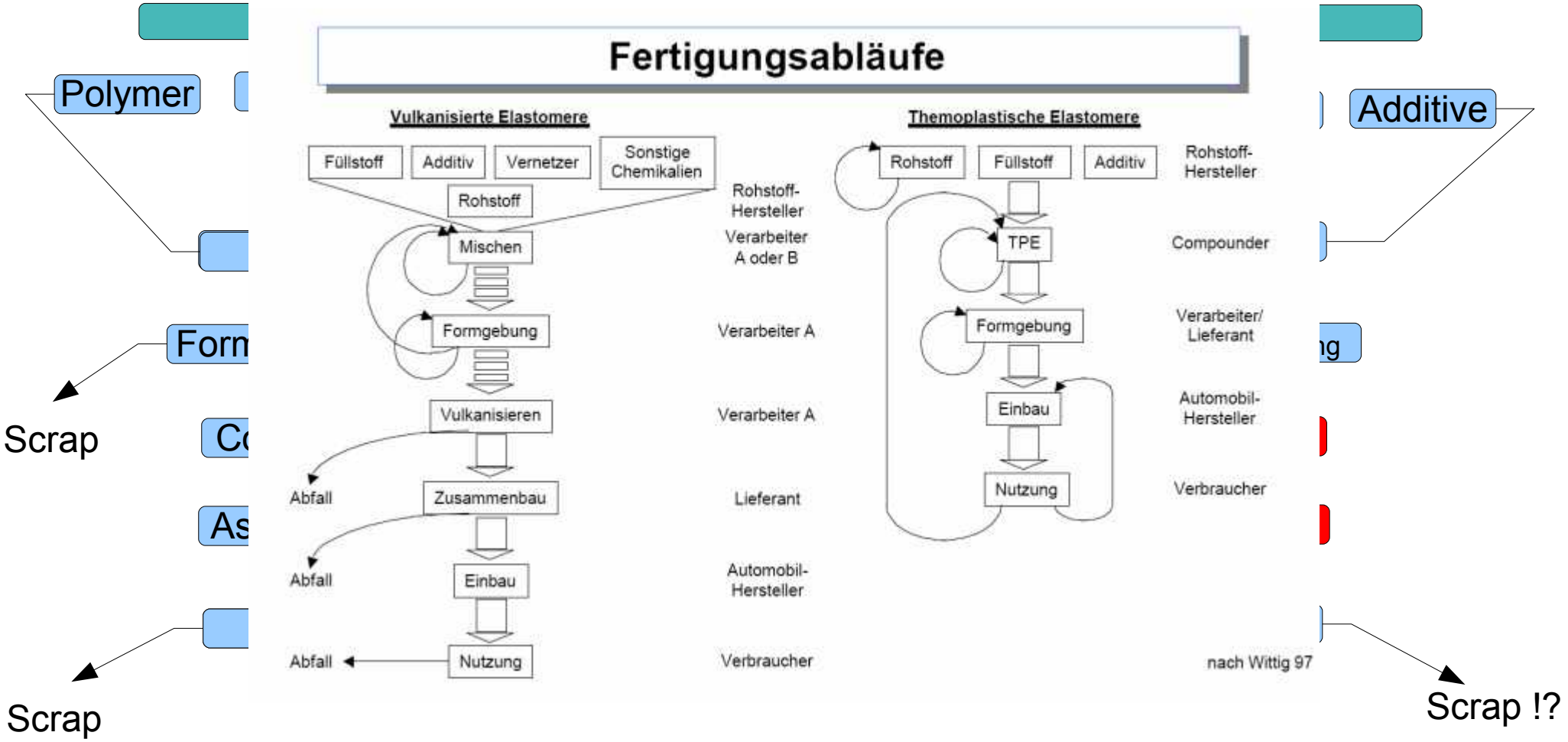
Source:Wittig, GAK 1997



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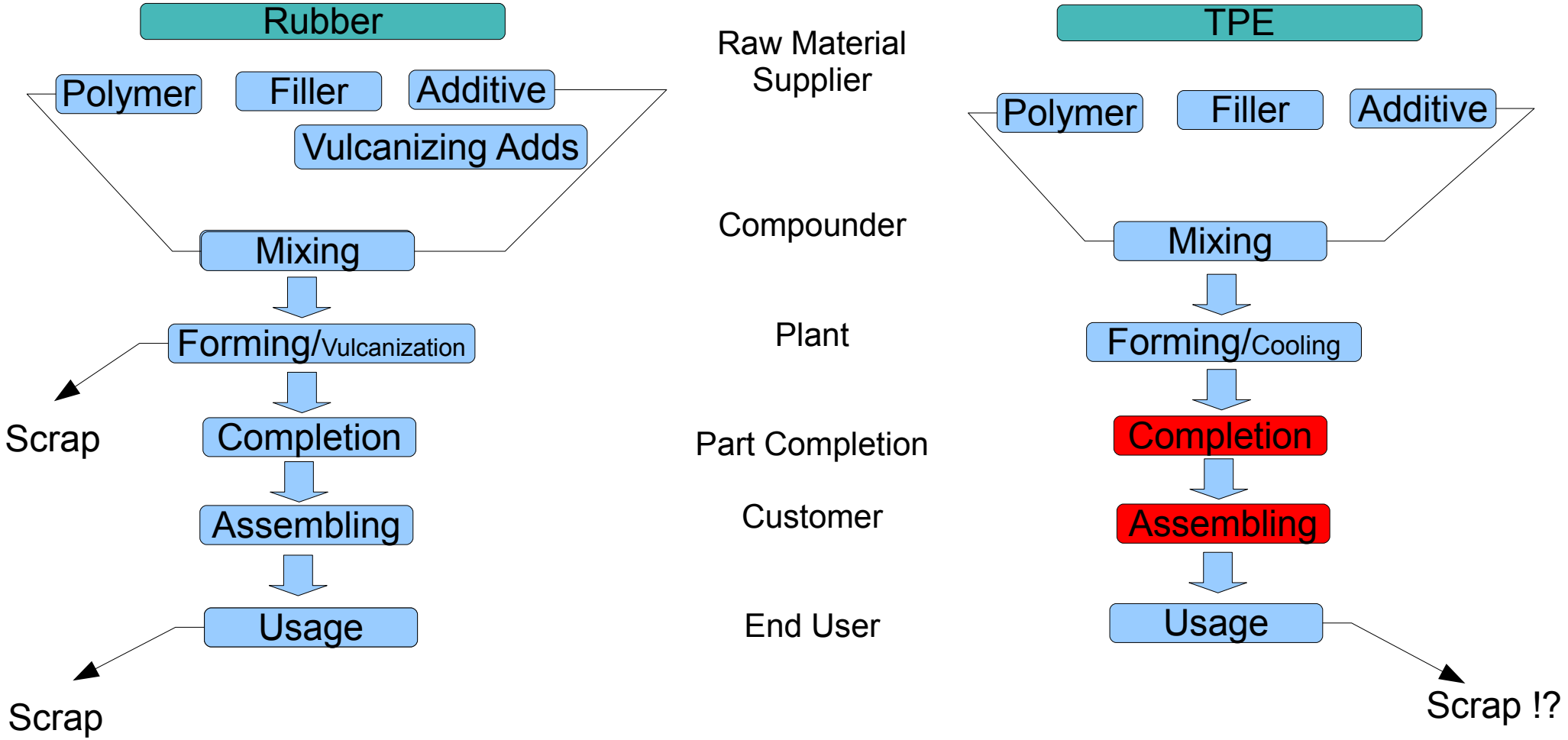

TPE versus Rubber
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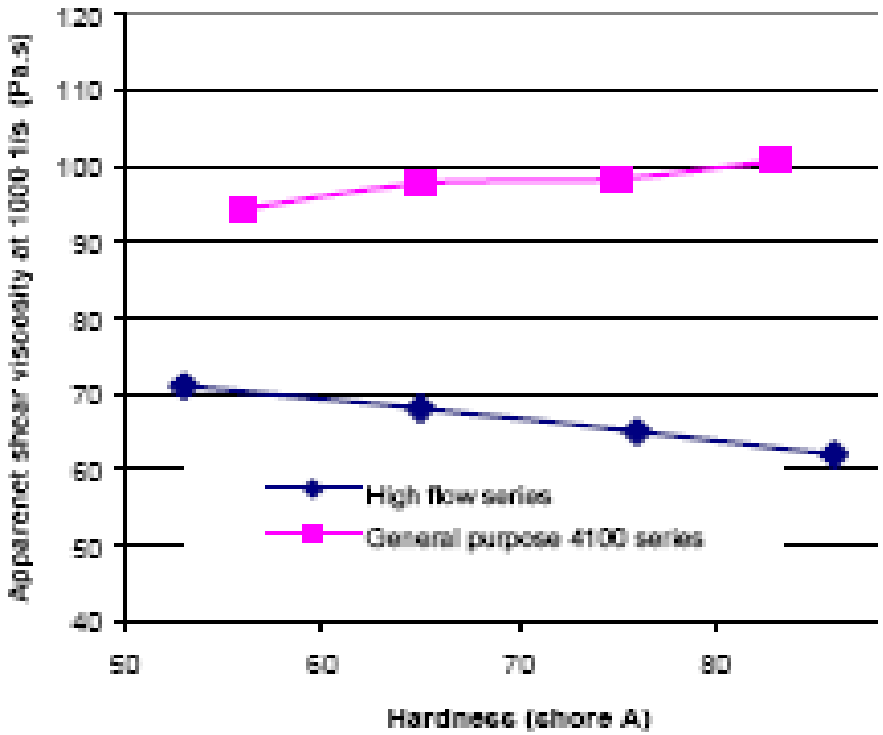
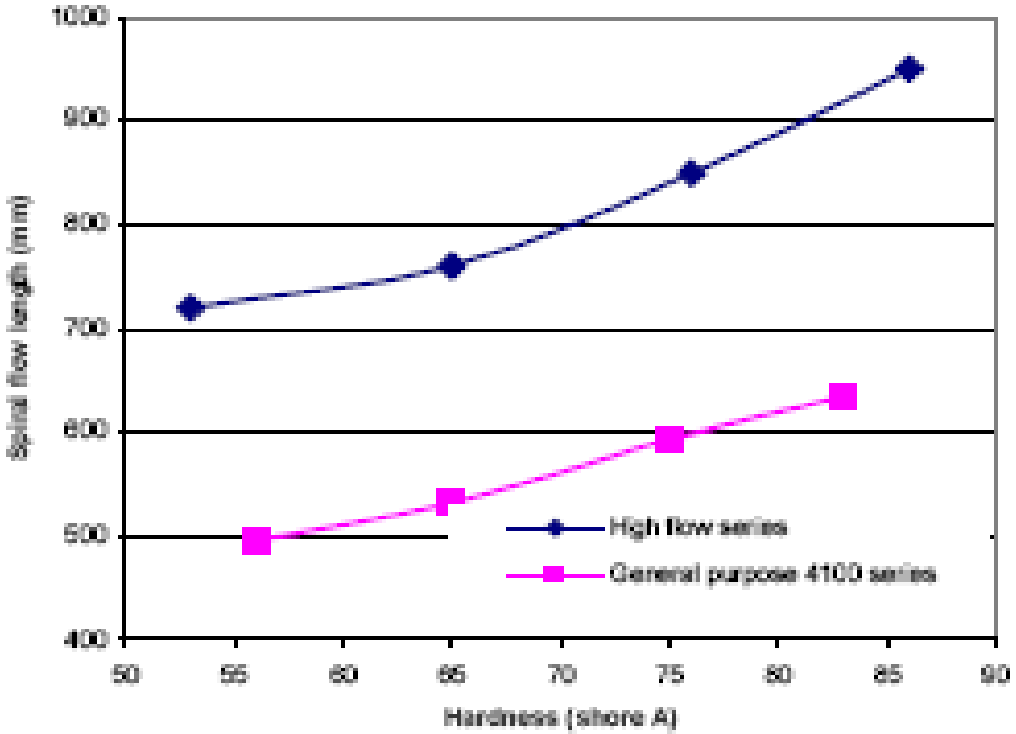




PP content is increased to achieve hardness, which improves flow.

TPE versus Rubber
Forming

Source:S.Z. Yu, H.-J. Graf
Standard Products priv. Comm.

- Calculation of TPE glass run channel solution versus EPDM
- Cost estimation

	EPDM	TPE
Extrusion	0.110 $/ft	0.130 $/ft
Flocking	0.020 $/ft	N/A
Slipcoat	N/A	0.020 $/ft
Molding	1.350 $/unit	0.270 $/unit
Total	1.480 $/unit	0.420 $/unit

Source:Internet

TPE versus Rubber
Property Description

Source:G. Williams
Autom. Elastomer Conf. 03

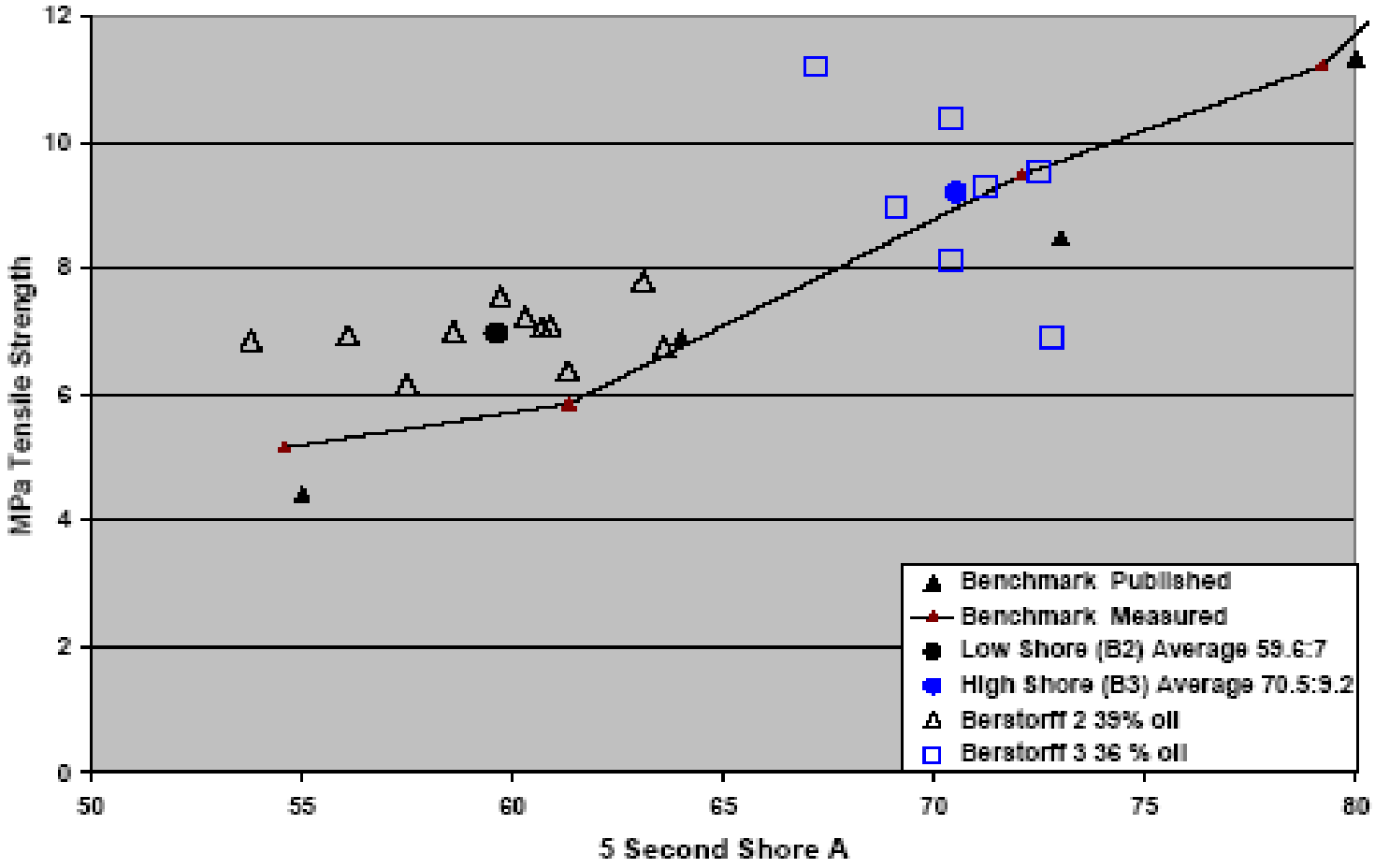
In an experiment with a production scale twin screw extruder to study the manufacturing process of TPE the following fomulation was used (Note the large amount of oil in this formulation):

65 SHORE A FORMULATION

	phr	Wt%
EPDM	100	30.42
Carbon Black	30	9.13
Polypropylene	50	15.21
Oil	130	39.55
SP 1045	10	3.04
Stannous Chloride (dihydrate)	1.7	0.52
Processing aid	5	1.52
ZnO	2	0.61
Totals	328.7	100.00

TPE versus Rubber
Property Description

Source:G. Williams
Autom. Elastomer Conf. 03



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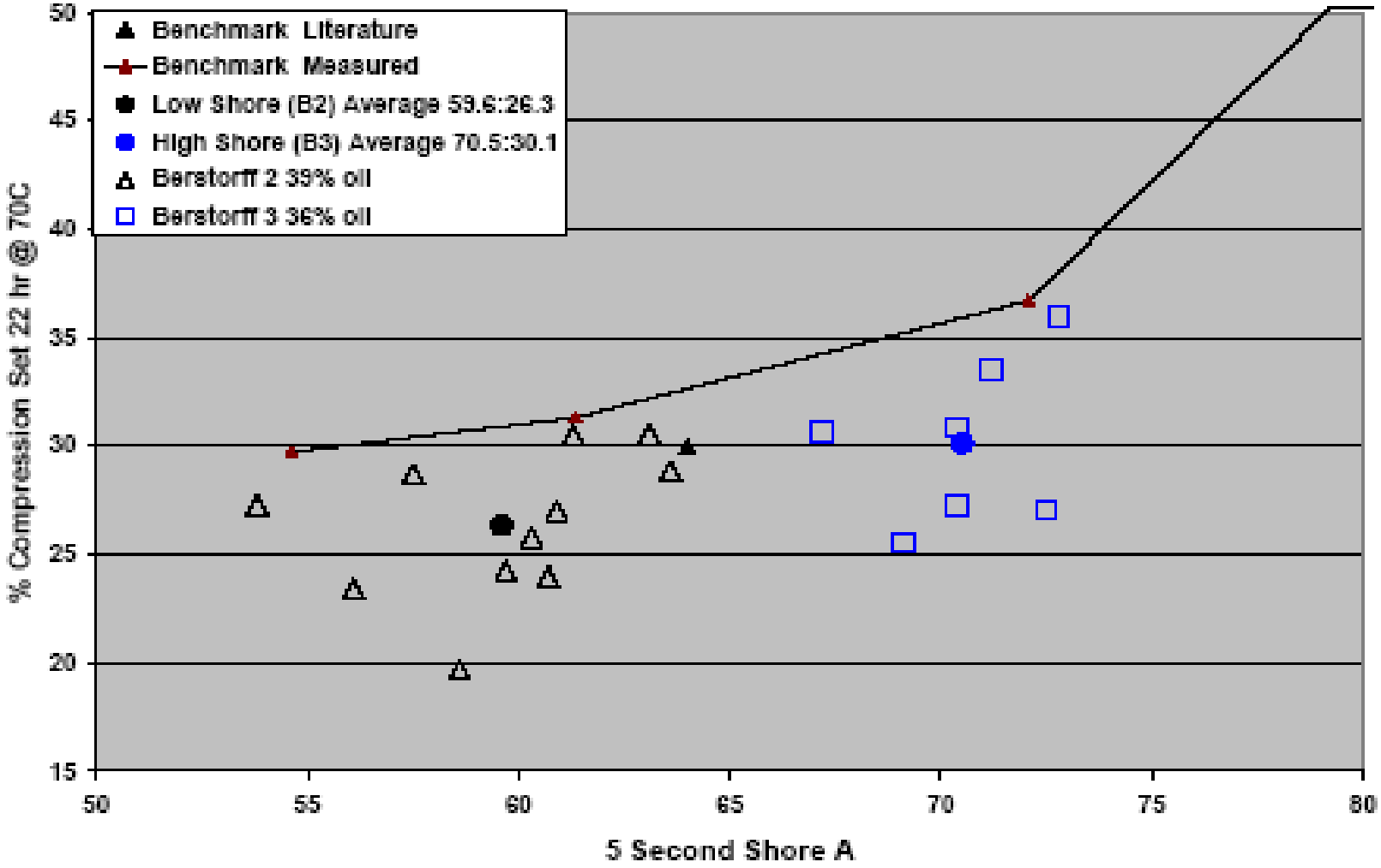

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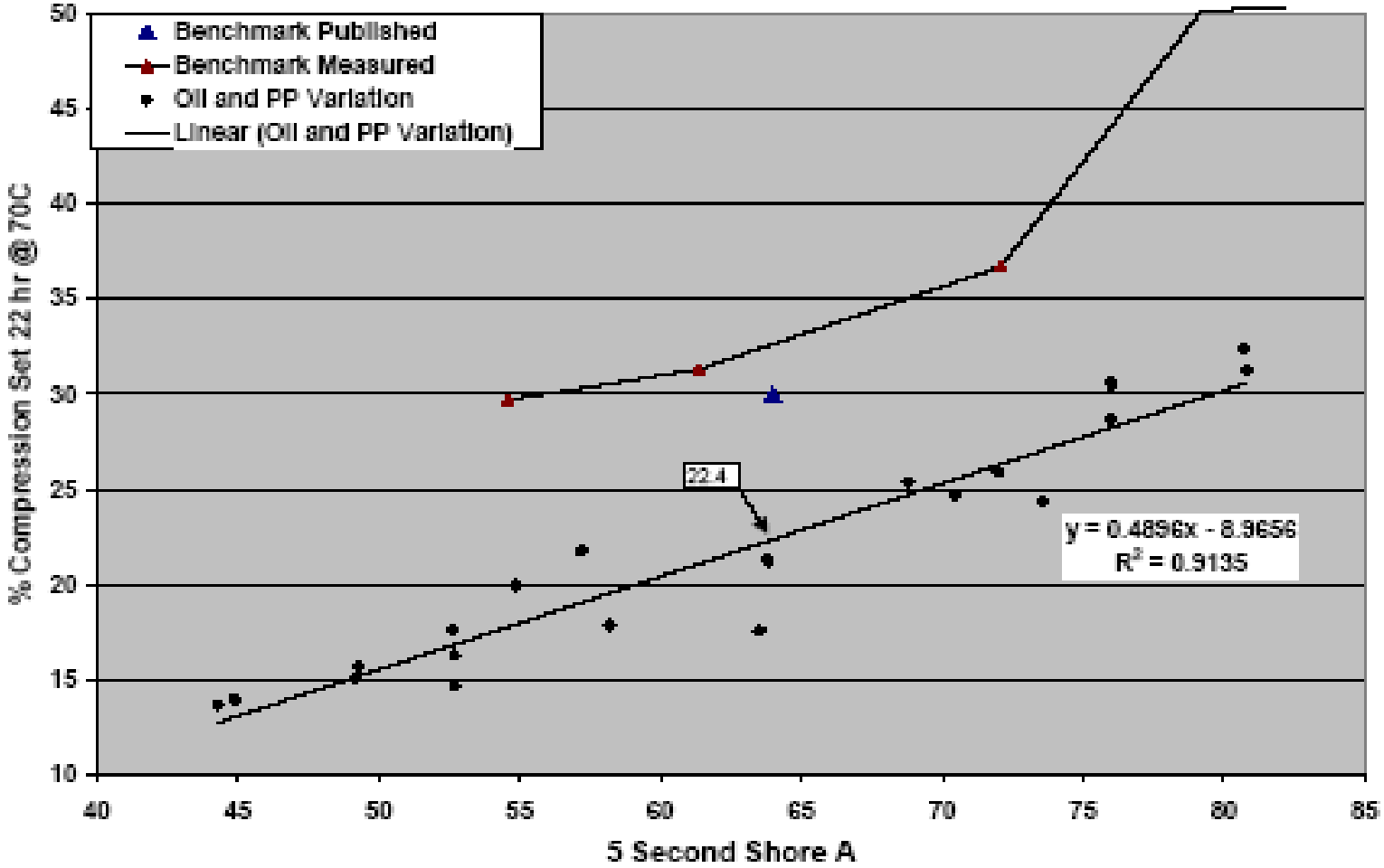


Reason, why most OEM suppliers not satisfied with TPE-V today

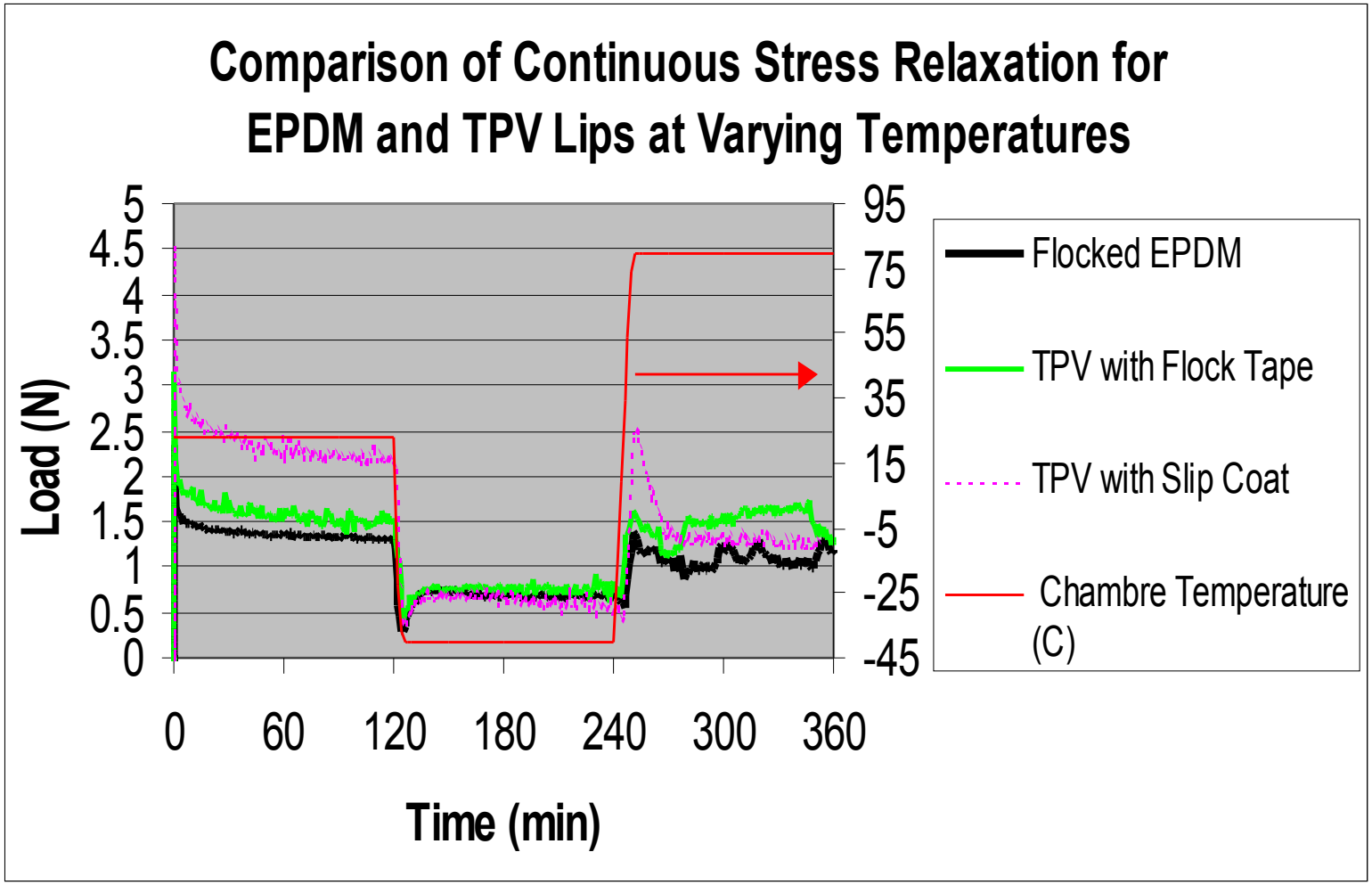
TPE versus Rubber
Property Description

Material	Hardness - °ShA	Tensile – Mpa			
		Confirmation		Supplier data sheet	
		longitudinal	perpendicular	longitudinal	perpendicular
TPE 1	55	3.8	7.5	3.3	8.6
TPE 2	60	5.4	5.5	5.4	7.4
TPE 3	60	4.5	5.5	5.4	6.4
TPE 4	60	3.8	5.4	5.8	

Reason, why most customers not pleased with suppliers today

TPE versus Rubber
Property Description

Source: S.Z. Yu
Cooperstandard Automotive



TPE versus Rubber
Property Description

Source:J.E.Pfeiffer
RDoACS Oct. 2002 No.8

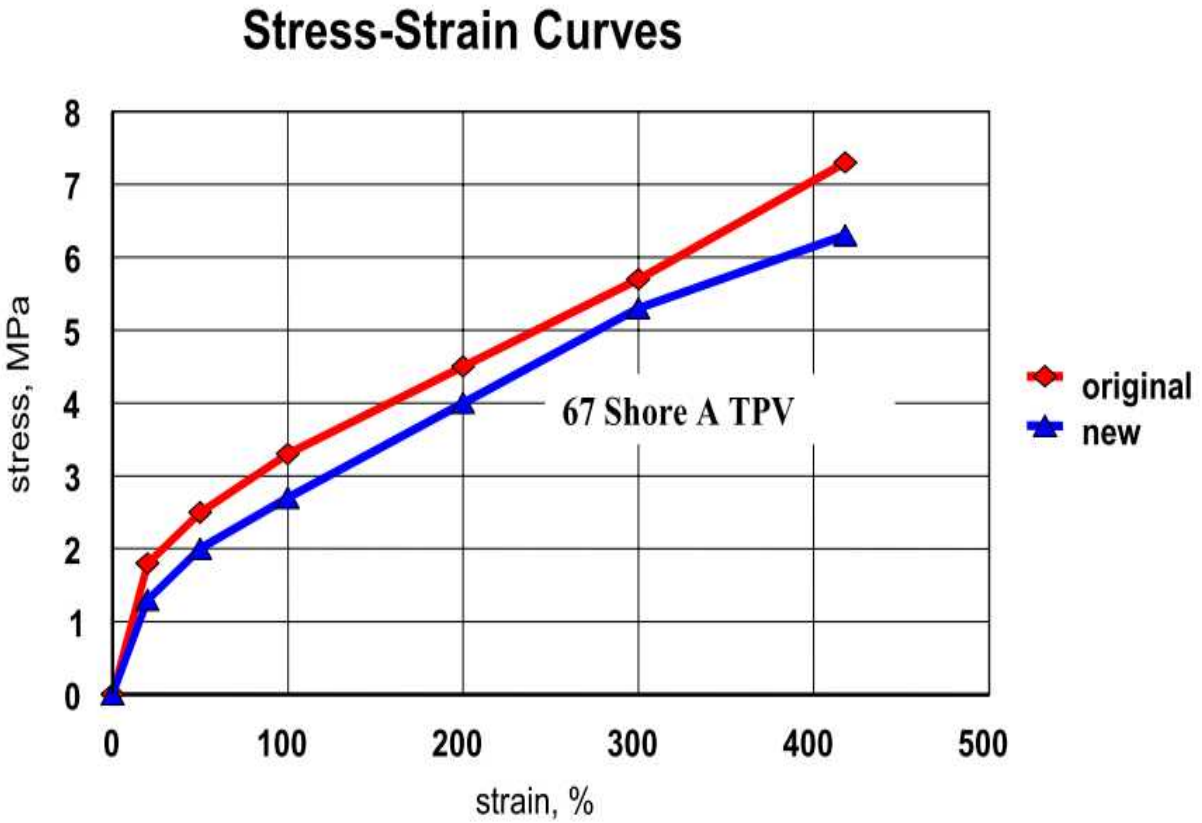


Figure 12: view of profile cross section in A pillar, (old profile)

Summary

Disadvantages of TPE compared to Rubber

- Resistance against Temperature falls short. Even a short period at a temperature beyond softening changes the shape irreversibly.
- Limited usage, because of high creep under load, if exposed to higher temperatures.
- Limited resistivity against media compared to special rubbers
- Process adjustments not possible
- High material costs
- Little to none protection of know how for development engineers

Summary

Processing of thermoplastic elastomers

- Opposite to Rubber processing, which is a cold/hot process, TPE are manufactured in a hot/cold process.
- Most TPE materials need a smaller flight depth than rubber compounds in case of injection molding, which requires machine investment.
  - For TPE Screws with longer L/D of 15 and a flat flight screw are preferred like similar used for PVC processing
- TPE parts can be manufactured in all processes typical for TP, like extrusion, blow molding, injection molding and thermo forming.

Conclusion

- **Competition is not always friendly**
  TPE should be offered with more reliable data to support the manufacturer, who is responsible for the part.
  To achieve this, we should have more
  - **Round robin tests**
    not only for more reliable data, but also to benefit from the standards in rubber manufacturers laboratory practice.
  - **Possibly define better test standards**
- **Manufacturers Material departments have to increase their attention at TPE.**
  It is insufficient to leave it in the hands of the development engineers.
- **More intense cooperation between material specialist at manufacturer and supplier will be beneficial for further developments and market penetration of TPE.**