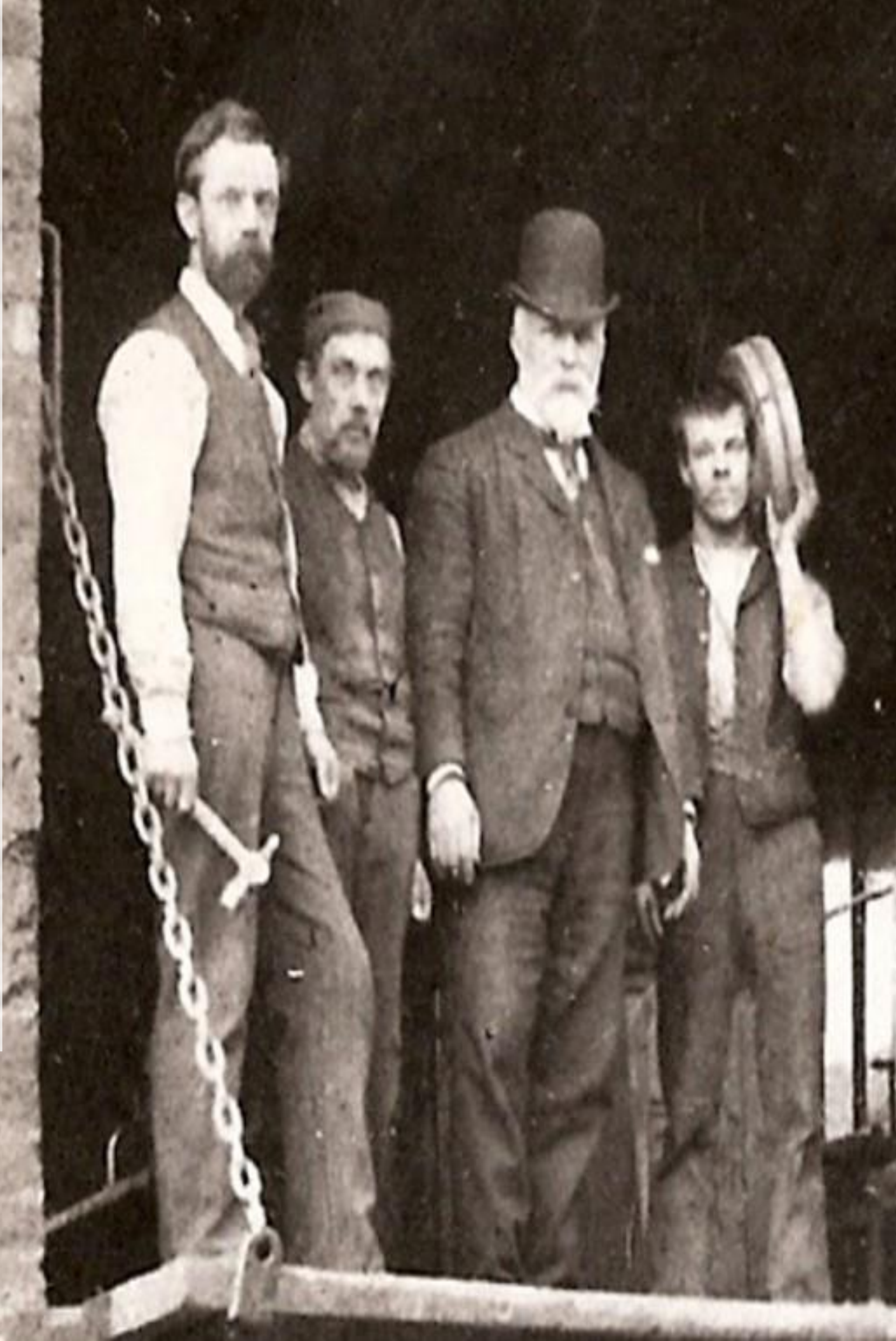
James Walker

Compounding and Manufacturing Elastomers for Nuclear Applications

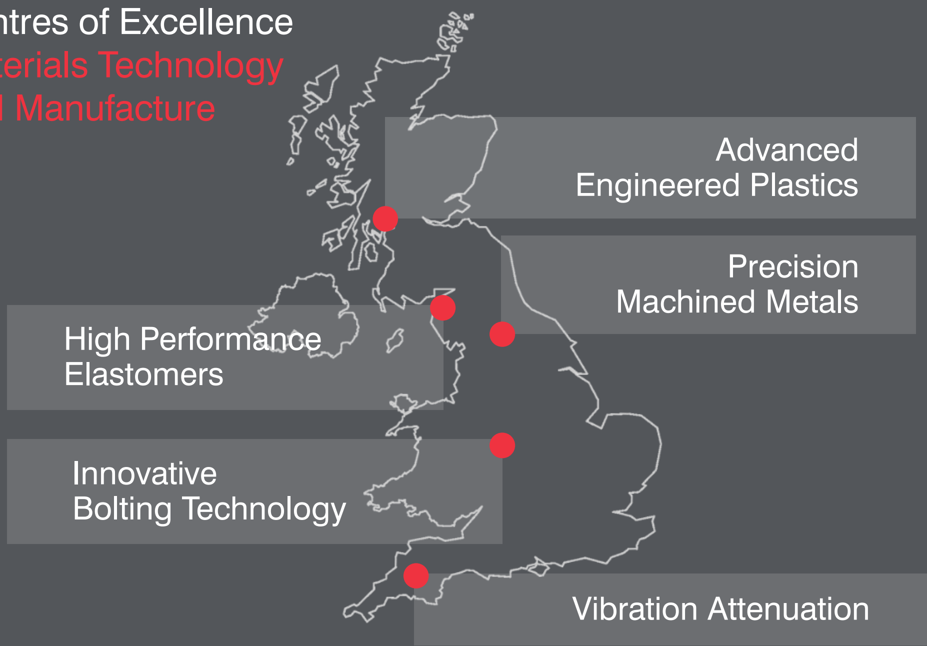
Polymers in nuclear applications 2019

Andrew Douglas FIMMM



James Walker Overview

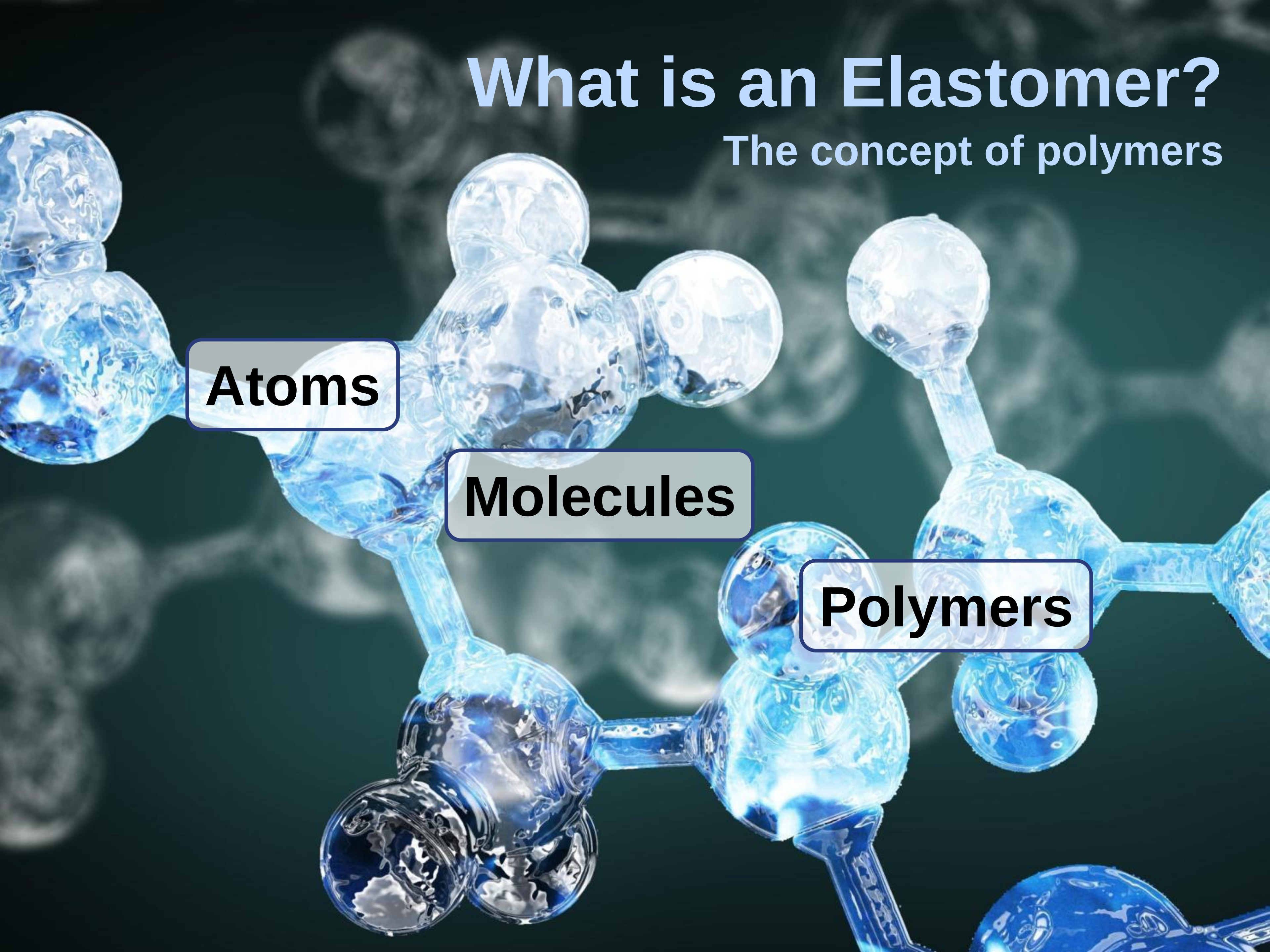
Centres of Excellence
Materials Technology and Manufacture

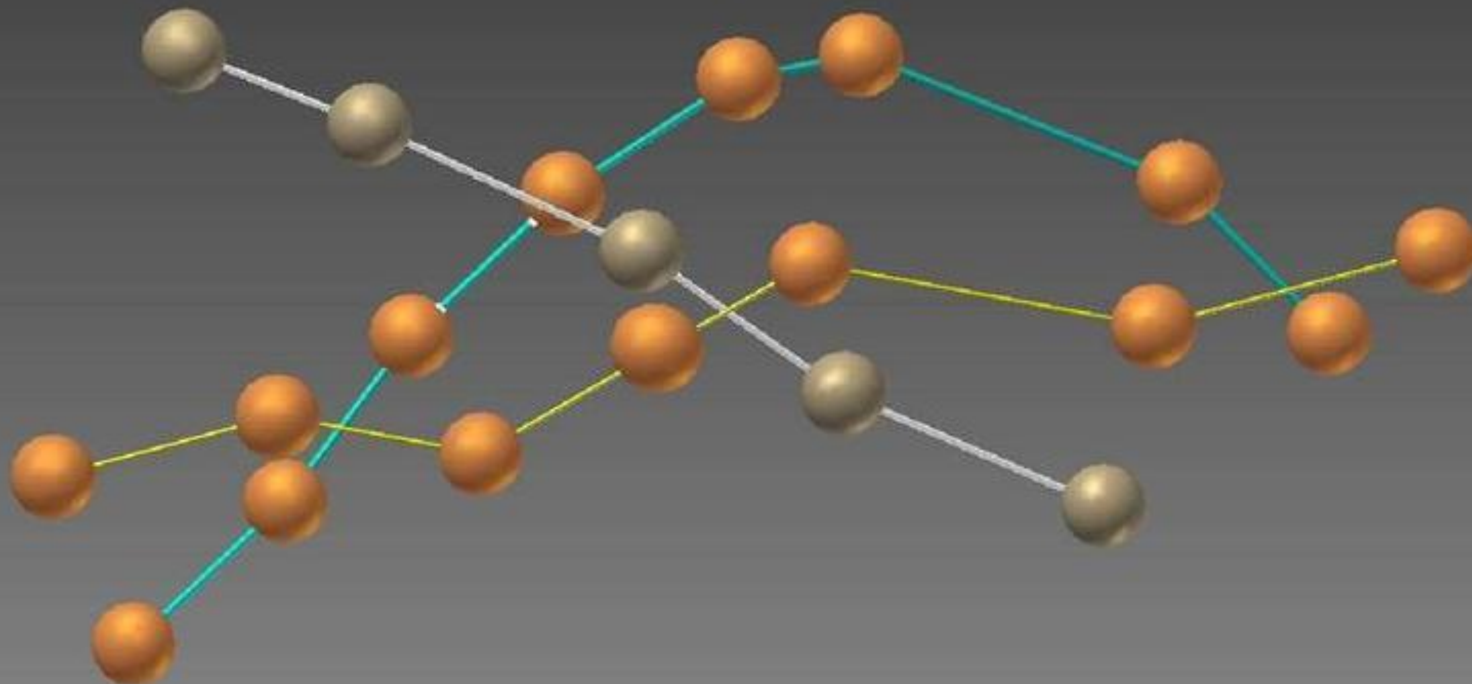


- 2000 employees / £200m turnover
- Established 1882
- 16 manufacturing sites
- 35 sales / support offices

What is an Elastomer?

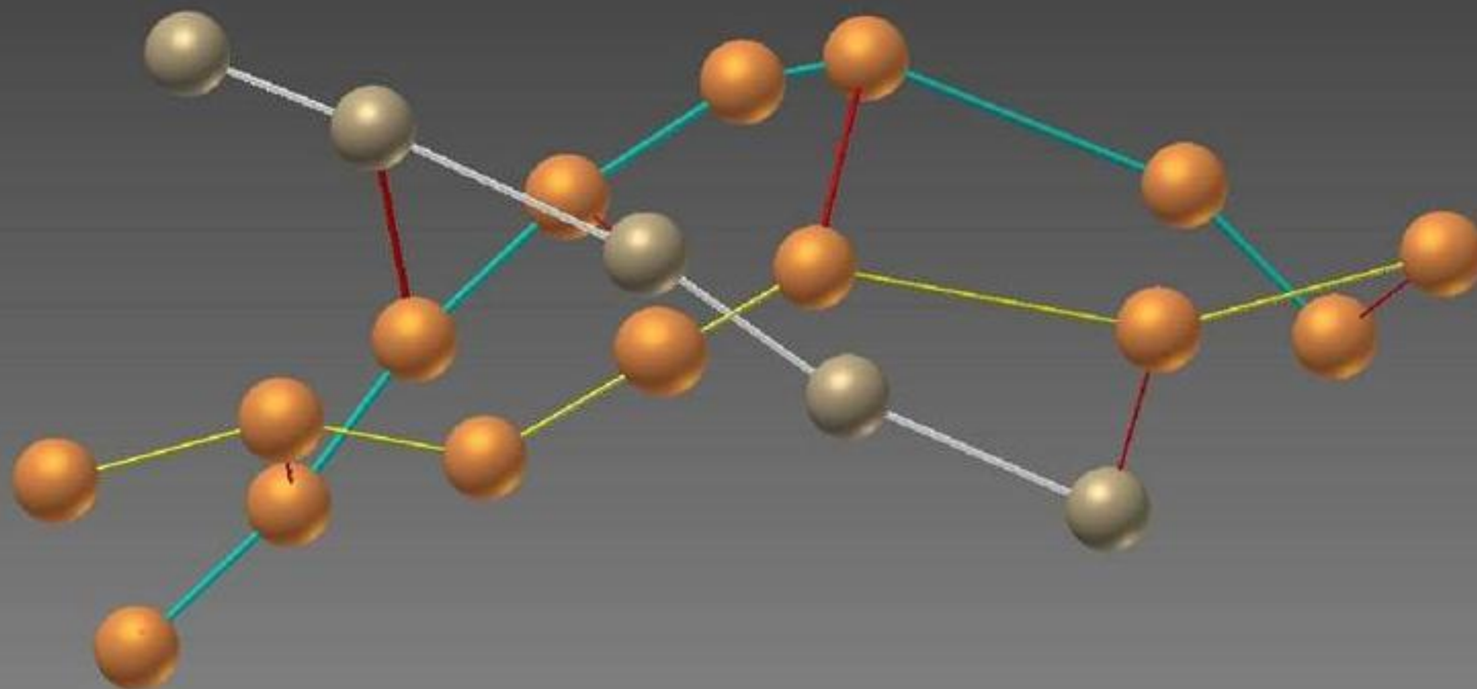
The concept of polymers



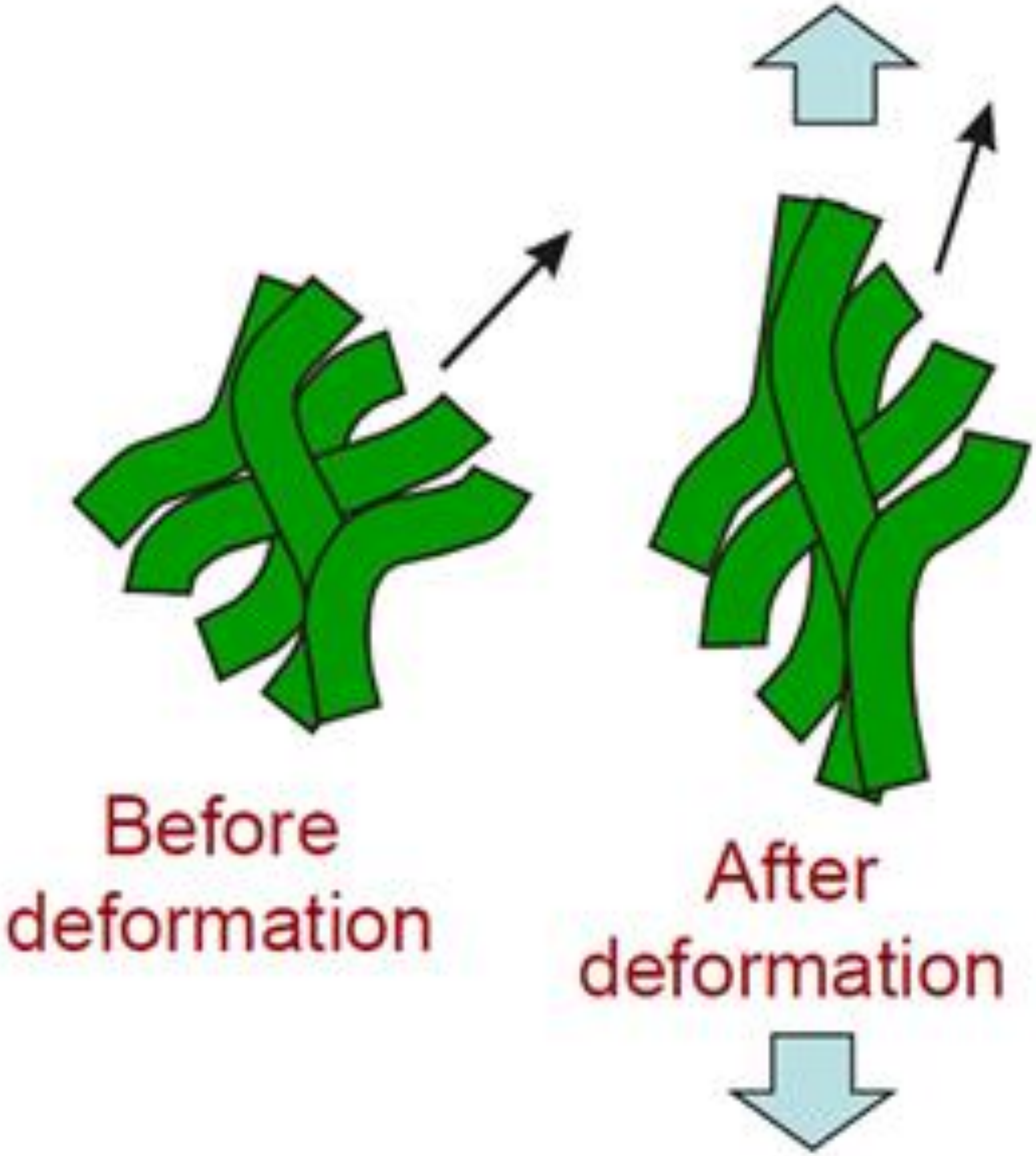


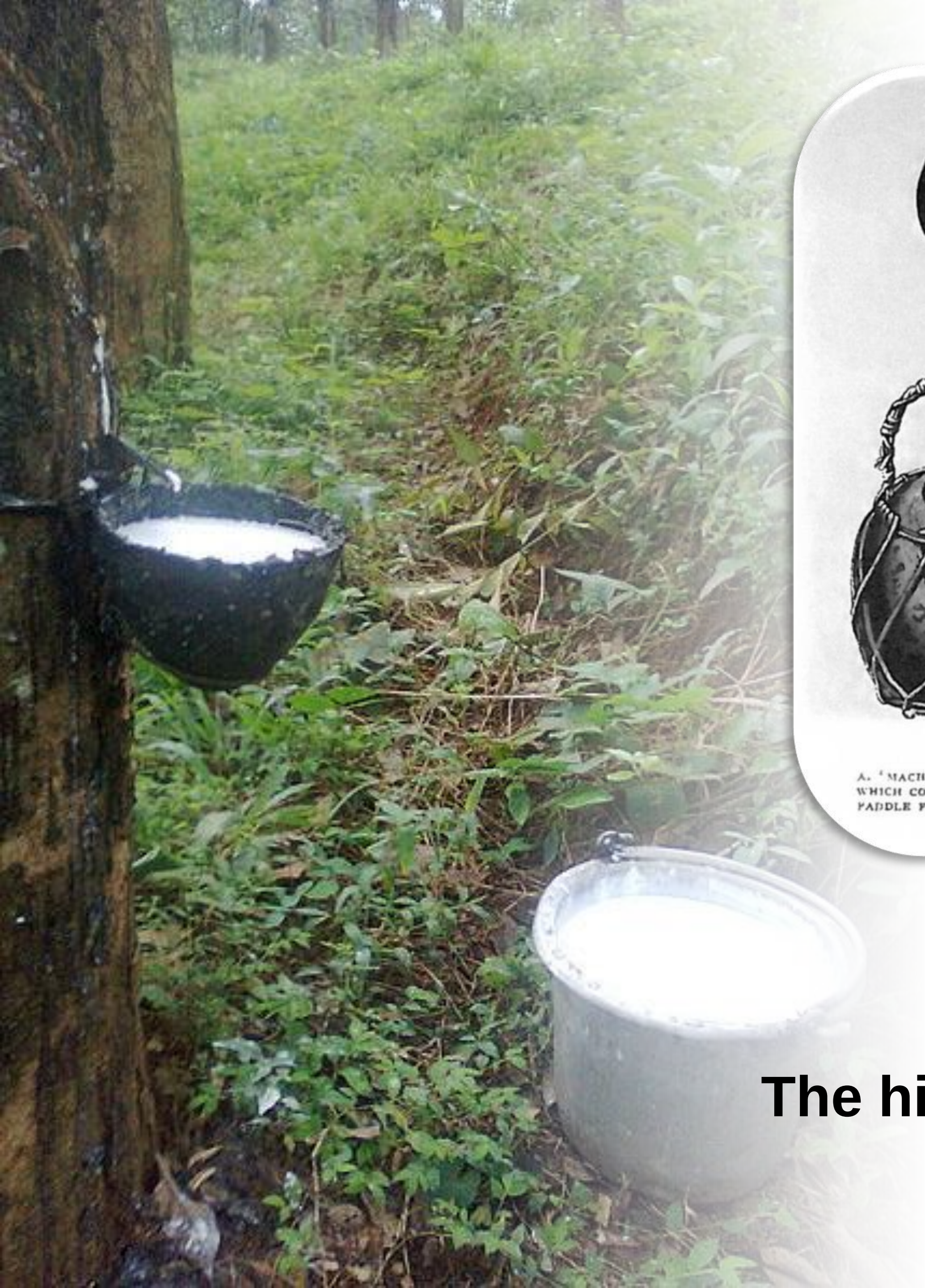
Polymer

structure



Polymer structure with
crosslinks

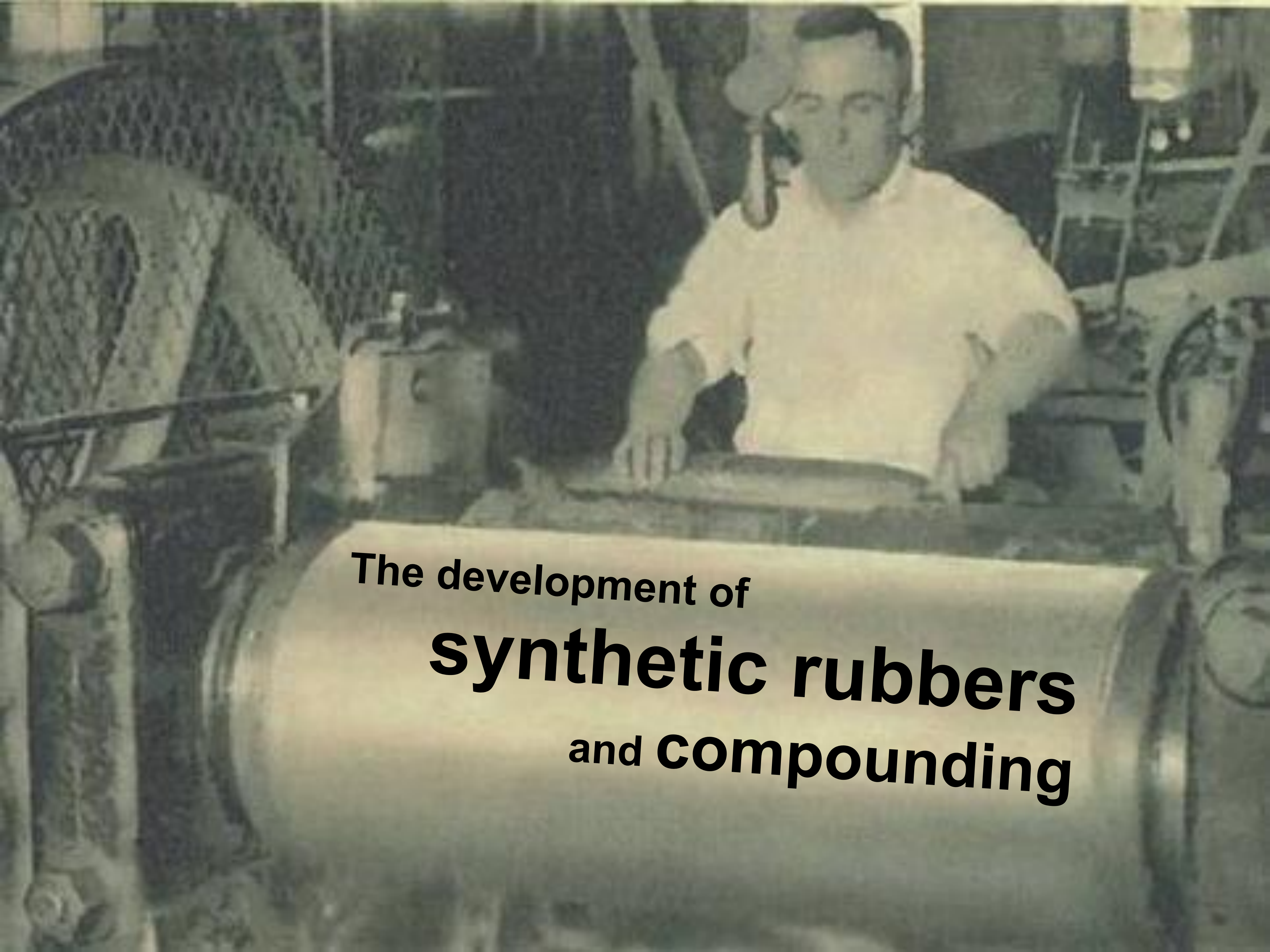

Before
deformation
After
deformation



IMPLEMENTS USED BY BRAZILIAN RUBBER COLLECTORS

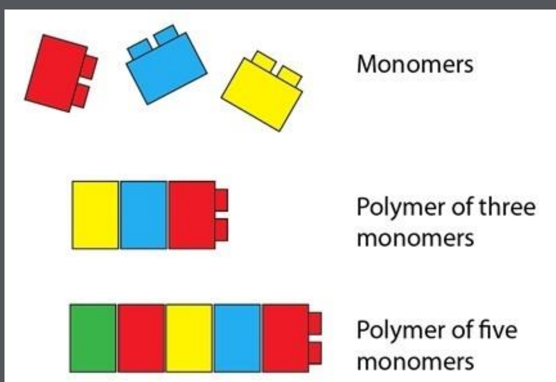
A. 'MACHADINHA' SMALL AXE) FOR TAPPING. B. COLLECTING CUP. C. COLLECTING VESSEL INTO WHICH CONTENTS OF CUPS ARE POURED. E. SAUCER BY MEANS OF WHICH LATEX IS POURED OVER PADDLE F DURING SMOKING PROCESS. THE PADDLE F (TO THE LEFT) IS SHOWN COVERED WITH A LAYER OF RUBBER

The history of natural rubber


The development of
synthetic rubbers
and compounding

Designing synthetic polymers…

Monomers & Polymers



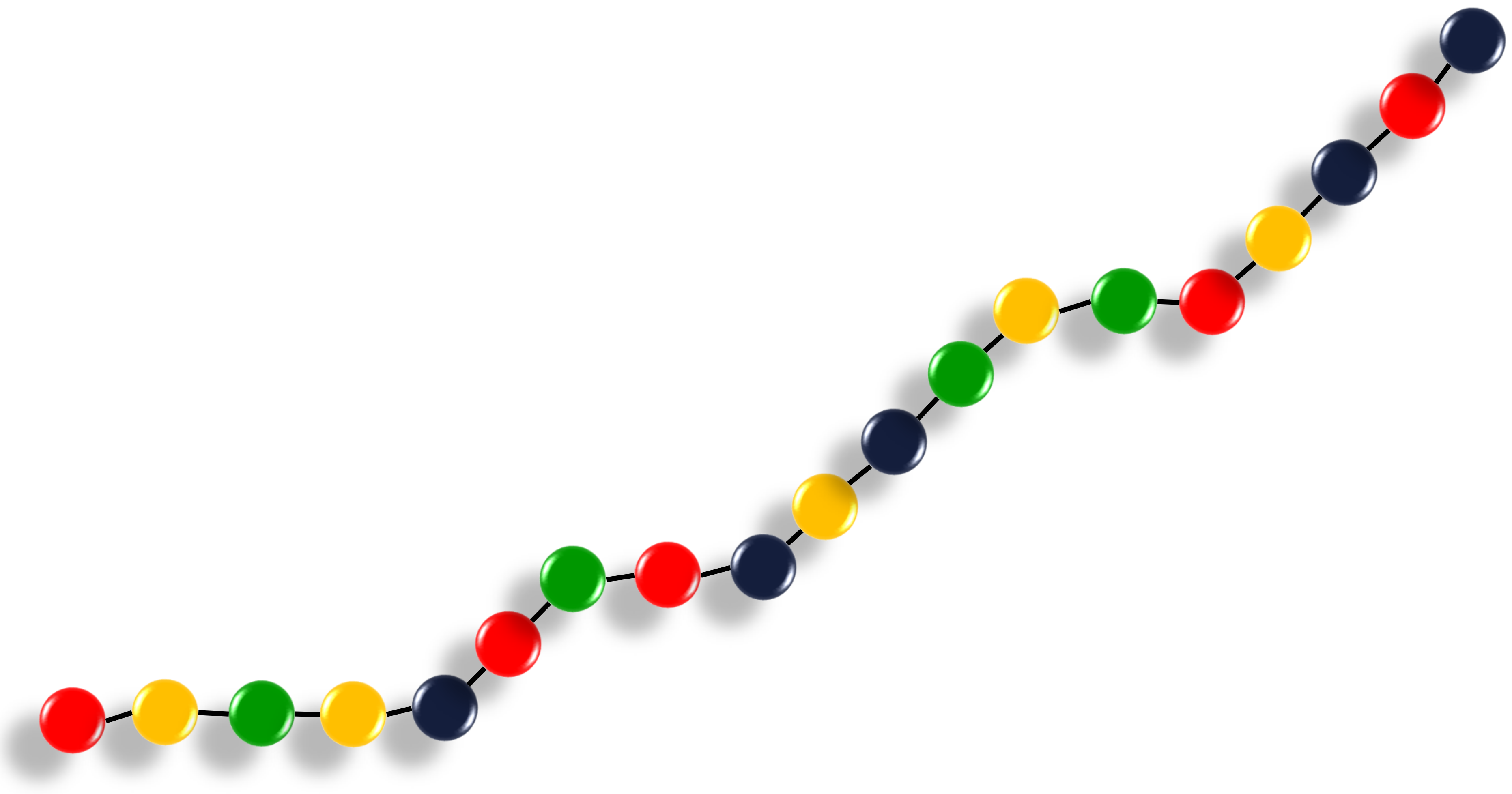
Attributes of monomer ‘building blocks’

Strength of bonds within molecules and between them

Highly polar gives resistance to swelling by oils/fuels

Flexibility at low temperatures

Synthetic Polymers



How long will it last?

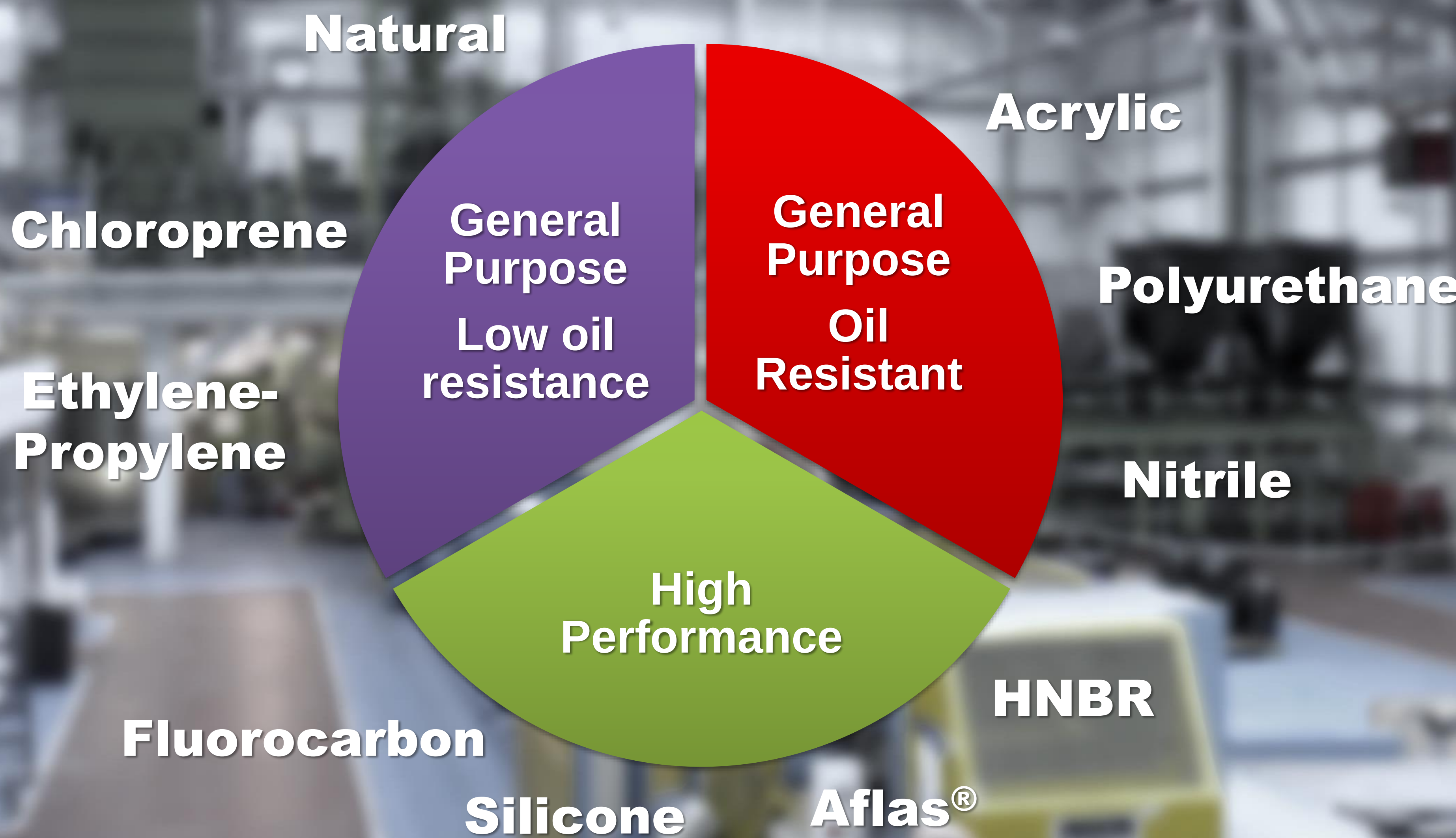
‘All of the disputed territories contain valuable minerals, and some of them yield important vegetable products such as rubber which in colder climates it is necessary to synthesize by comparatively expensive methods’

Nineteen Eighty-Four, George Orwell, first published June 1949

Synthetic elastomers haven’t actually been around for that long so

100 year life predictions come with caveats…

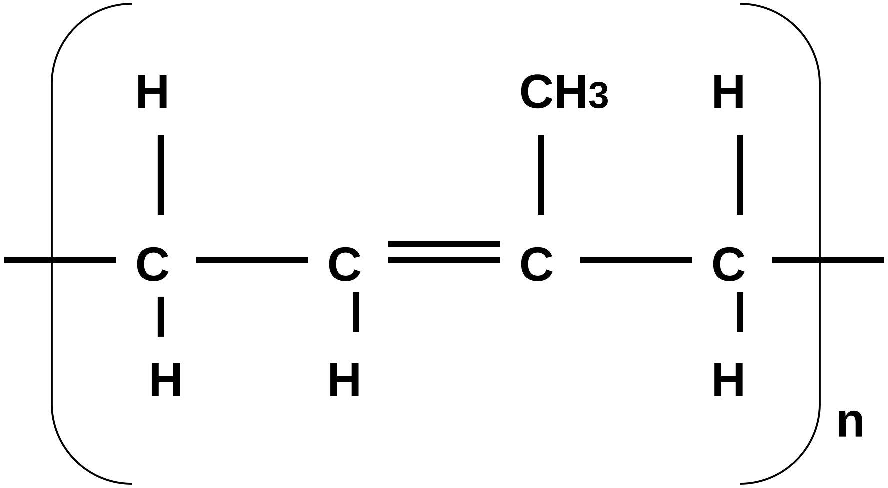
GENERAL ELASTOMER CLASSIFICATION



James Walker

Natural Rubber (NR)

Cis- 1,4- polyisoprene



Advantages: High resilience; high tensile/tear; good abrasion resistance; low cost.

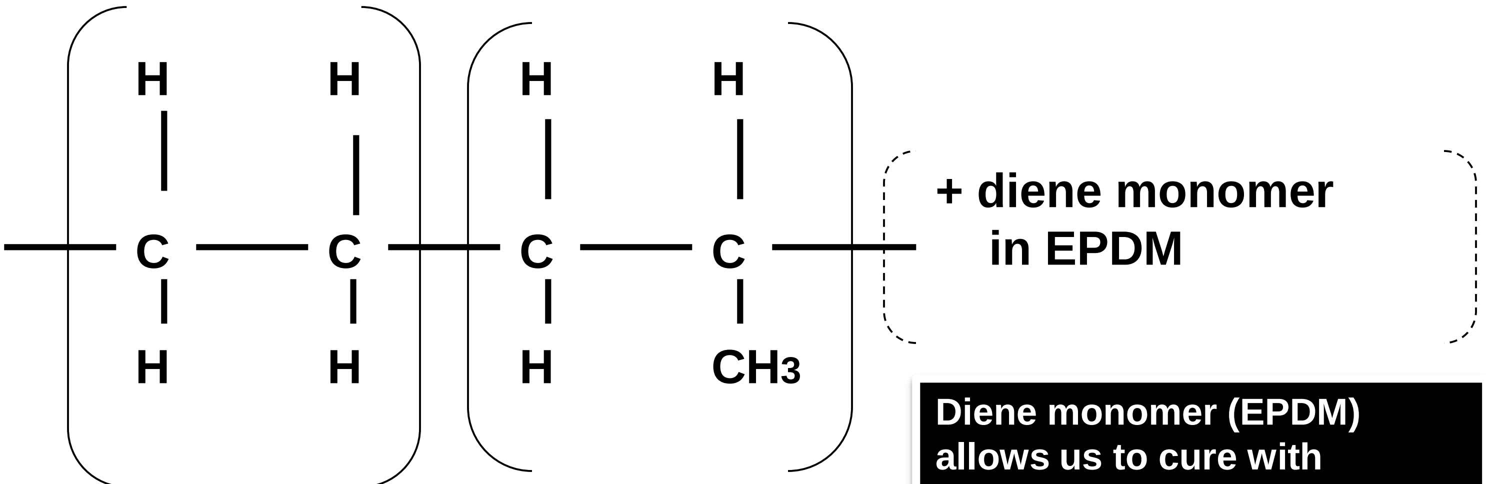
Disadvantages: Poor oil resistance; poor weathering resistance. Reversion.

Typical temperature range: -50°C to +100°C

James Walker

Ethylene-Propylene Rubber (EPM, EPDM)

Dipolymer of ethylene and propylene (EPM), or
Termonomer of ethylene-propylene with a diene monomer



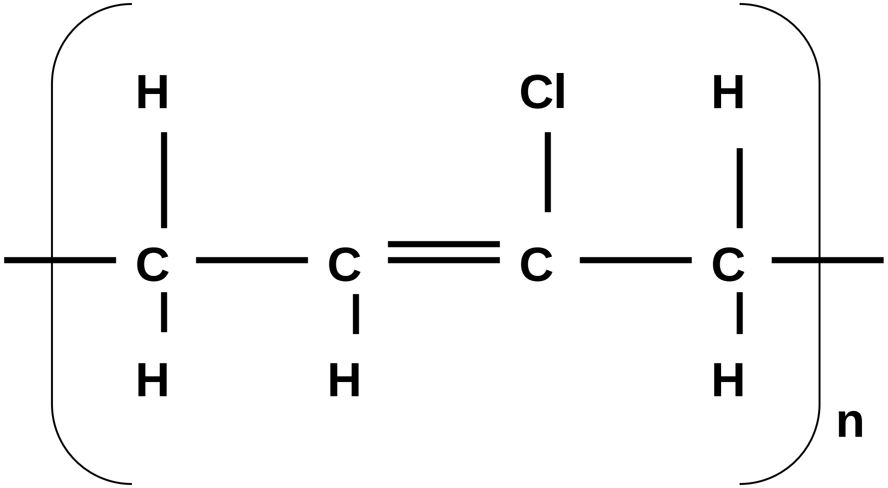
Diene monomer (EPDM) allows us to cure with sulphur as well as peroxides

Advantages: Excellent ozone/weathering resistance. Excellent radiation, hot water and steam resistance (peroxide grades); good resistance to inorganic and polar organic chemicals.
Disadvantages: Low resistance to hydrocarbons.
Typical temperature range: -45°C to +150°C (-49°F to +300°F) .

James Walker

Polychloroprene (Neoprene) Rubber (CR)

2-chlorobutadiene



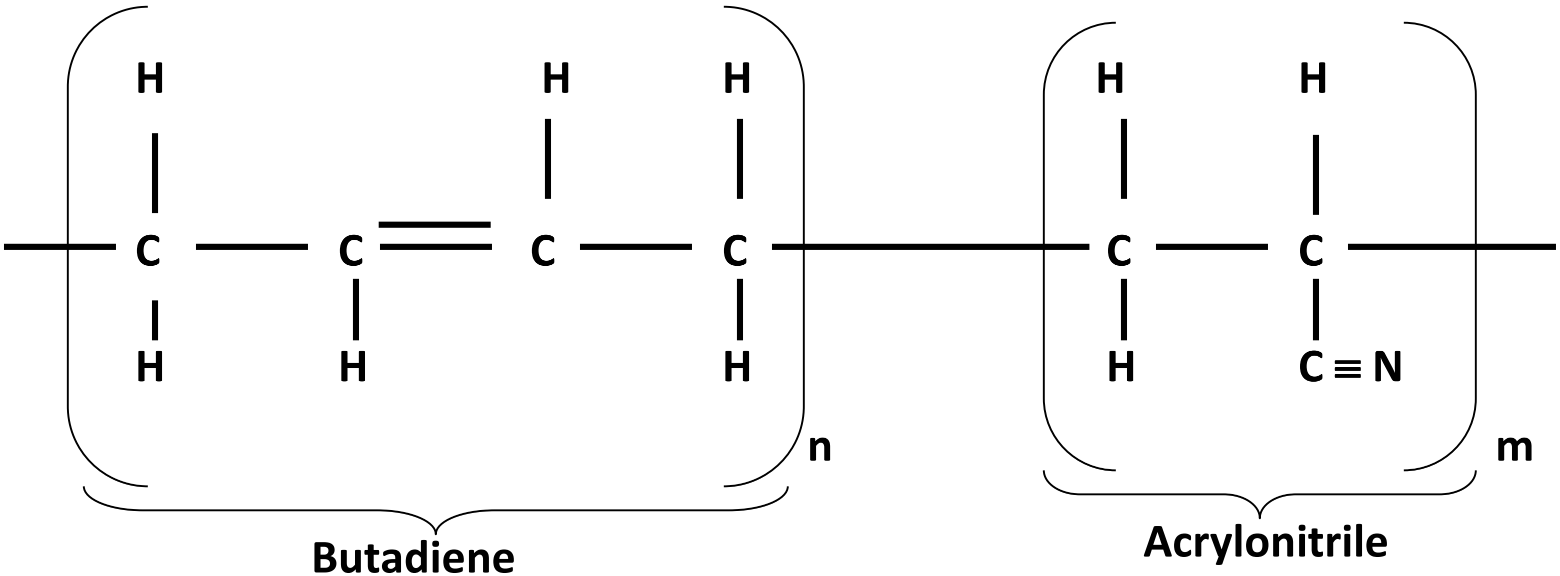
<u>Advantages</u>: Good weather and ozone resistance; good mechanicals; resistance to many Freons; some oil resistance; low cost.

<u>Disadvantages</u>: Only moderate oil resistance; limited temperature resistance.

<u>Typical temperature range:</u> -40°C to +120°C (-40°F to +250°F)

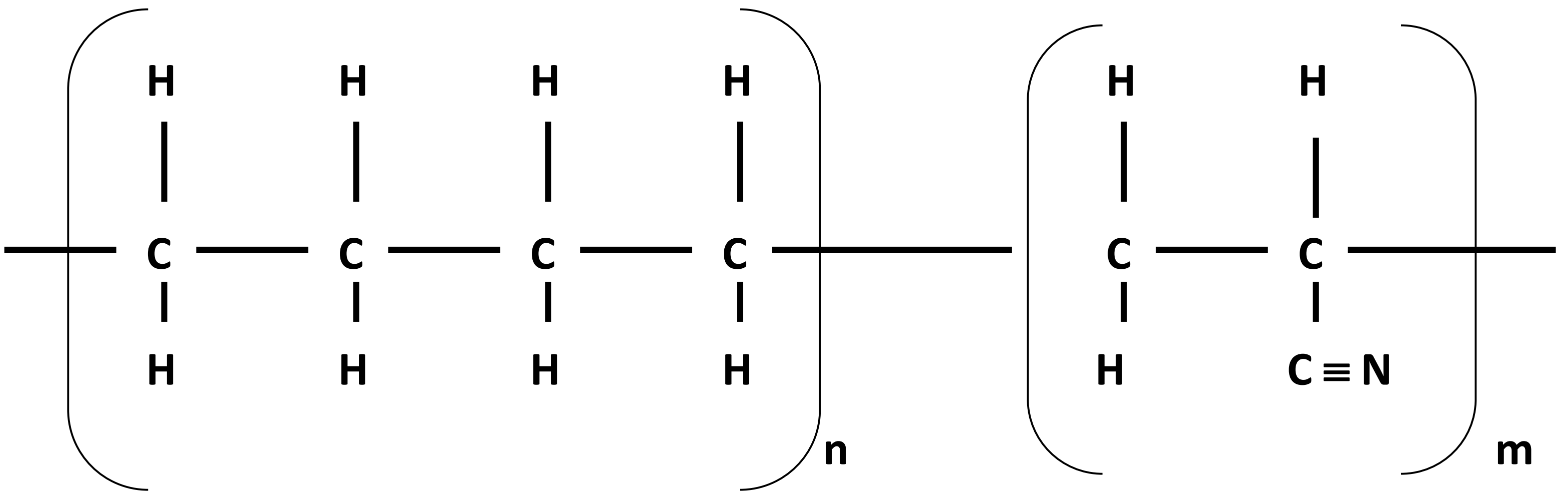
Nitrile Rubber (NBR)

Acrylonitrile-butadiene



<u>Typical temperature range:</u> -50°C to +120°C (dependent on ACN content!)

Hydrogenated Nitrile Rubber (HNBR/HSN)



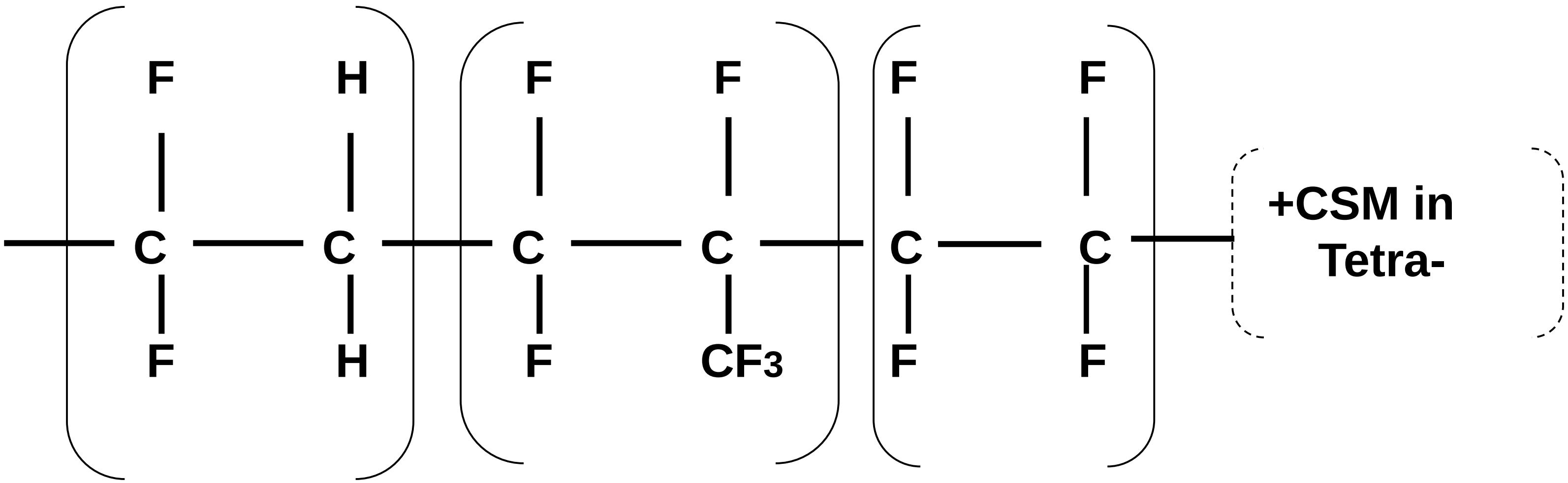
Made from NBR by hydrogenation reaction

Typical temperature range: -40°C to +160°C (dependent on ACN content!)

James Walker

Fluoroelastomers (FKM/FPM)

Eg., 'Viton®', 'Fluorel®', 'Tecnoflon®, DAI-El ™



Vinylidene fluoride, VDF (VF_2) Hexafluorpropylene, HFP Tetrafluoroethylene, TFE Cure site monomer, CSM

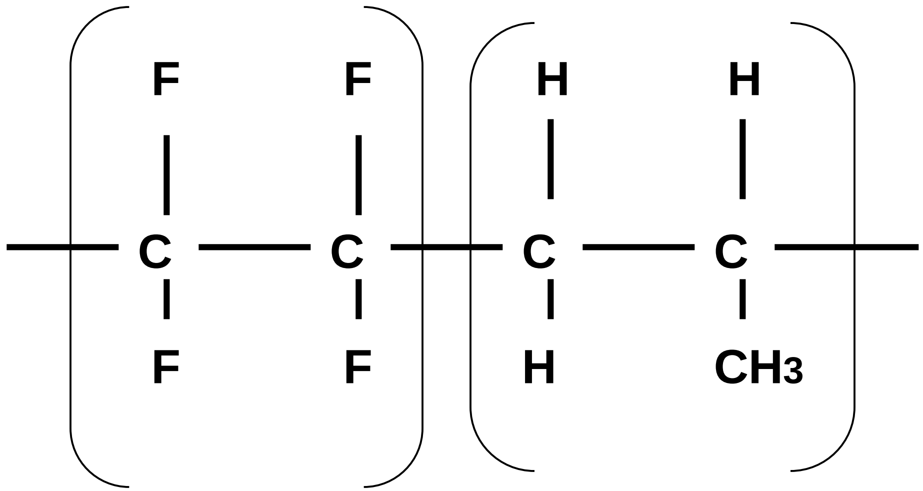
Dipolymers, VDF and HFP, ~66%F ('A' Types)

Terpolymers*, VDF, HFP, TFE (CSM) ~68%F to ~70%F FKM ('B' types at 68%F and 'F'types at 70%F).

<u>Typical temperature range:</u> -45°C to +200°C

Aflas® (TFE-P / FEPM)

Tetrafluoroethylene-propylene

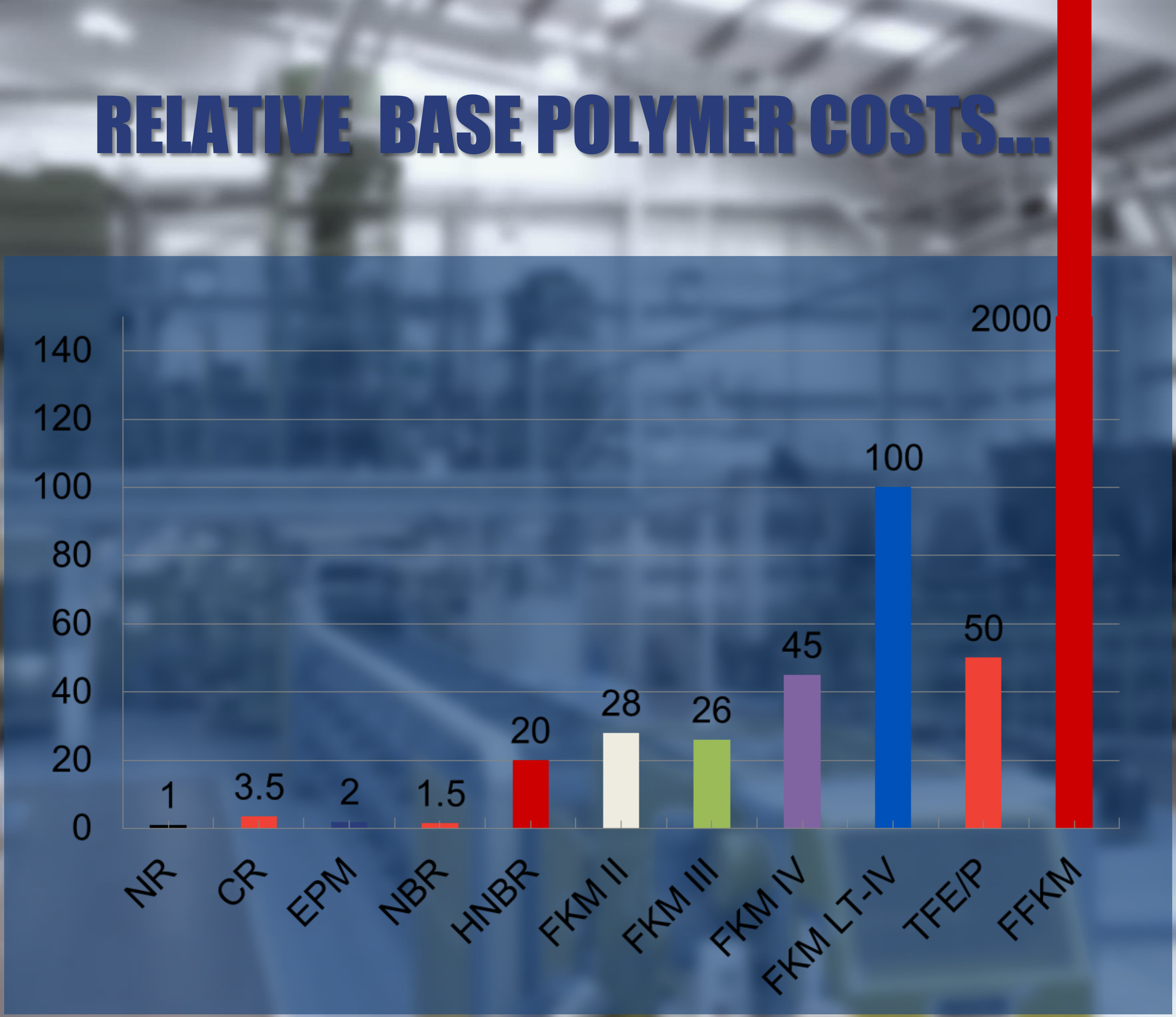


Tetrafluoroethylene Propylene

Speciality FKM

Advantages: Excellent ozone/weathering resistance; good heat resistance; excellent resistance to steam and radiation; good overall chemical resistance.
Disadvantages: High compression set; high Tg; poor resistance to aromatics
Typical temperature range: 0°C to +200°C

RELATIVE BASE POLYMER COSTS…



Protective system

Cure system

What **goes in** to an elastomer?

COMPOUND INGREDIENTS

1	POLYMERS	11	BONDING PROMOTERS
2	CURATIVES	12	PROCESS AIDS
3	ACCELERATORS	13	TACKIFIERS
4	ACTIVATORS	14	DESICCANTS
5	RETARDERS	15	PIGMENTS
6	CO-AGENTS	16	BLOWING AGENTS
7	FILLERS	17	PEPTISERS
8	PLASTICISERS	18	FLAME RETARDANTS
9	EXTENDERS	19	ODOURANTS
10	PROTECTANTS	20	COUPLING AGENTS

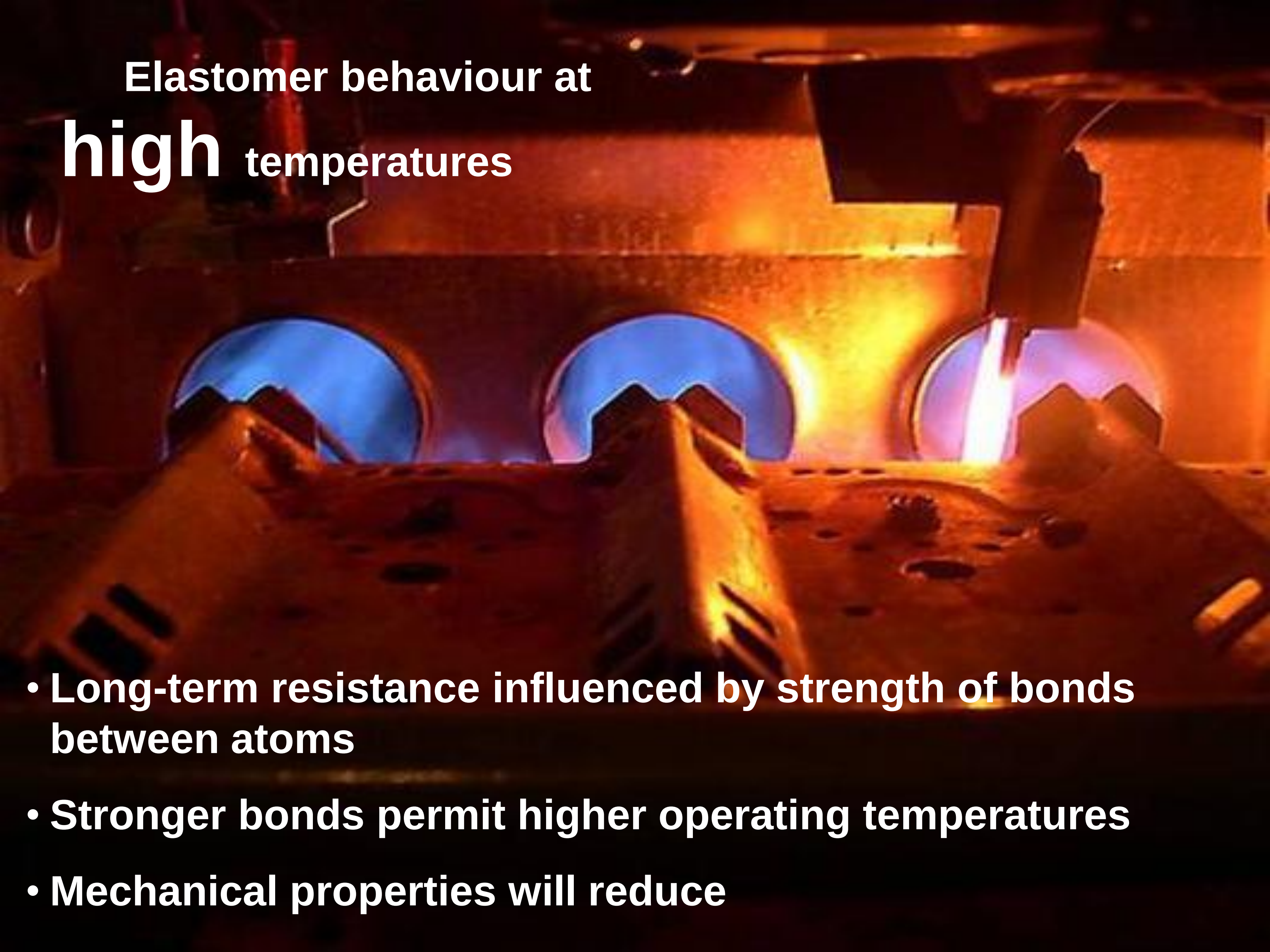
	High Quality	Low Quality
34% ACN NBR	100	100
Zinc oxide	5	5
Stearic acid	1	1
Sulphur	1	2
Accelerators	4	4
Ester plasticiser	7	-
AO_2 / AO_3	2	-
Carbon black N550	70	20
Oil extender	-	50
Chalk Dust	-	200
Talcum Powder	-	50
White filler	-	50
Wax	-	5
Total PHR	**190**	**487**

	High Quality	Low Quality
Cure	6 minutes at 180ºC	
Hardness (IRHD)	78	72
Tensile Strength (MPa)	19.3	2.4
E @ B (%)	300	100
Modulus at 25% strain (MPa)	1.3	0.8
Modulus at 50% strain (MPa)	2.2	0.9
Modulus at 100% strain (MPa)	4.8	1.0
Tear strength (N/mm)	42	9
Compression Set, 24hr @ 70ºC (%)	7	40
Specific gravity	1.2	1.6

One piece of rubber looks pretty much like another….

Elastomer behaviour at **low** temperatures

- Decrease in energy
- Polymer chains lose flexibility
- ‘Leathery phase’ before taking on the properties of glass
- Properties vary depending on the polymer type/formulation



Elastomer behaviour at **high** temperatures

- Long-term resistance influenced by strength of bonds between atoms
- Stronger bonds permit higher operating temperatures
- Mechanical properties will reduce

Elastomer behaviour in contact media

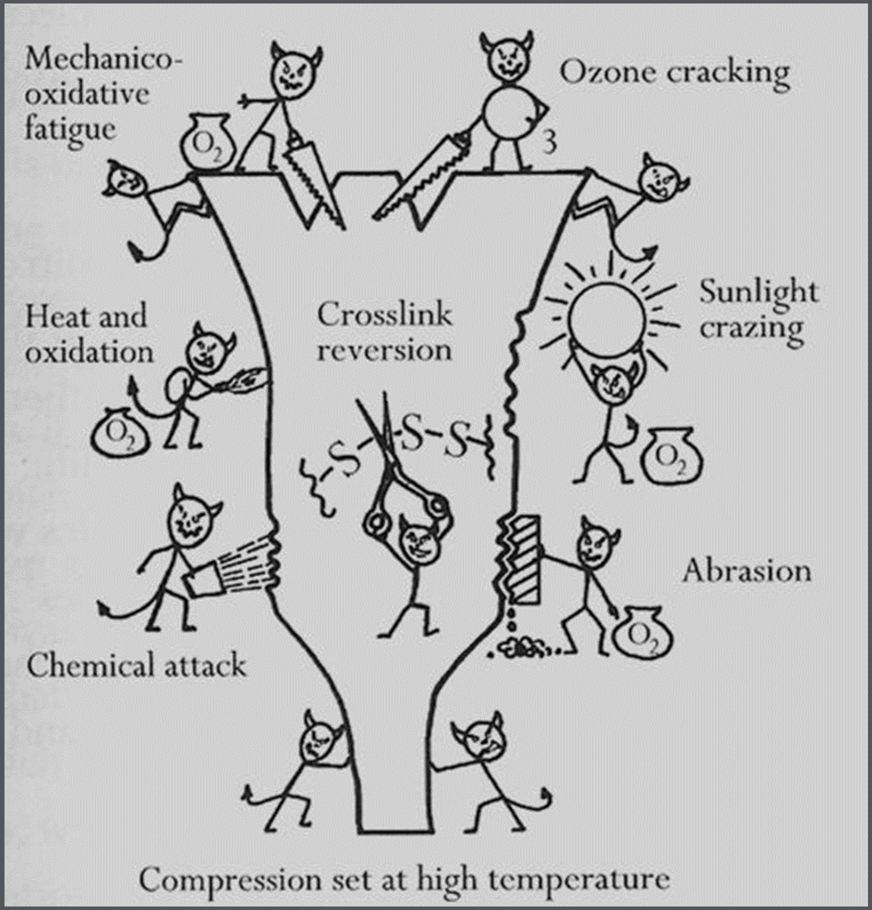
Swelling

- Elastomer will absorb the contact media and swell
- Physical effect, which is to some extent reversible

Chemical Attack

- Polymer chain is altered / attacked by the contact media
- Irreversible

Can occur at the same time


Mechanico-
oxidative
fatigue
Ozone cracking
Heat and
oxidation
Crosslink
reversion
Sunlight
crazing
Abrasion
Chemical attack
Compression set at high temperature

Environmental Qualification

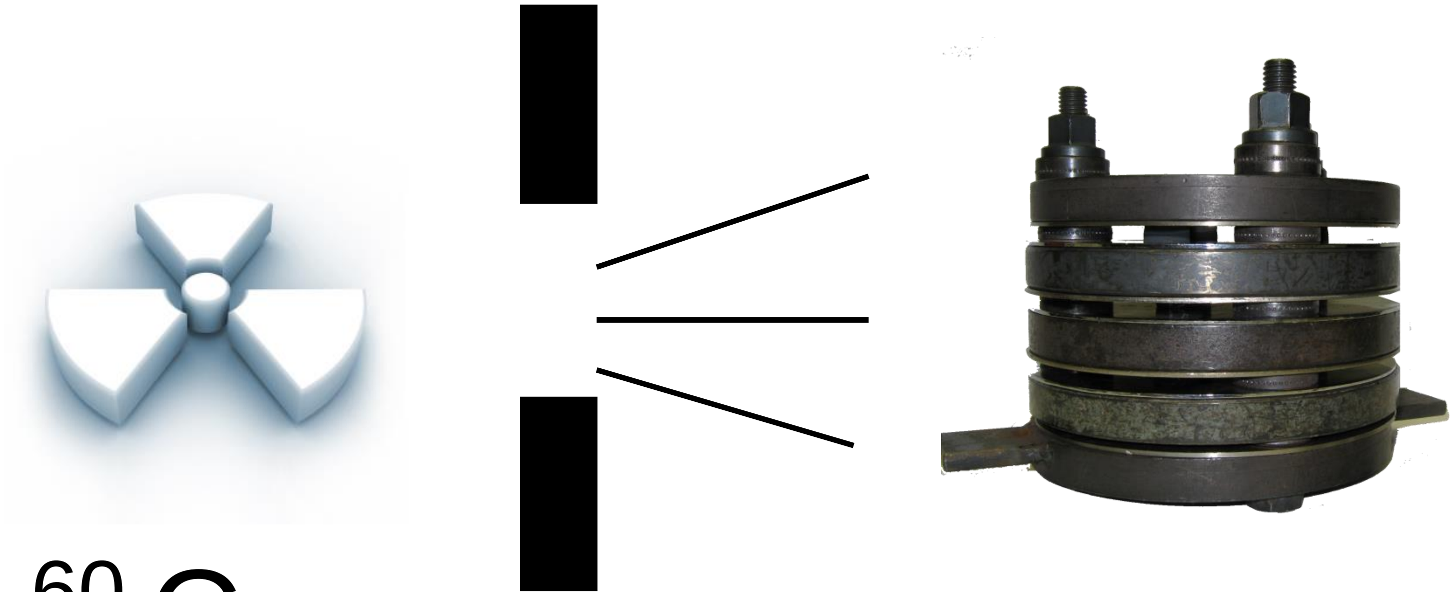
Fixed formulations – fantastic

But…

Legacy materials – availability of raw ingredients

Shieldseal® 661, 663 and 664 Elastomers

Radiation testing carried out by Wood Group

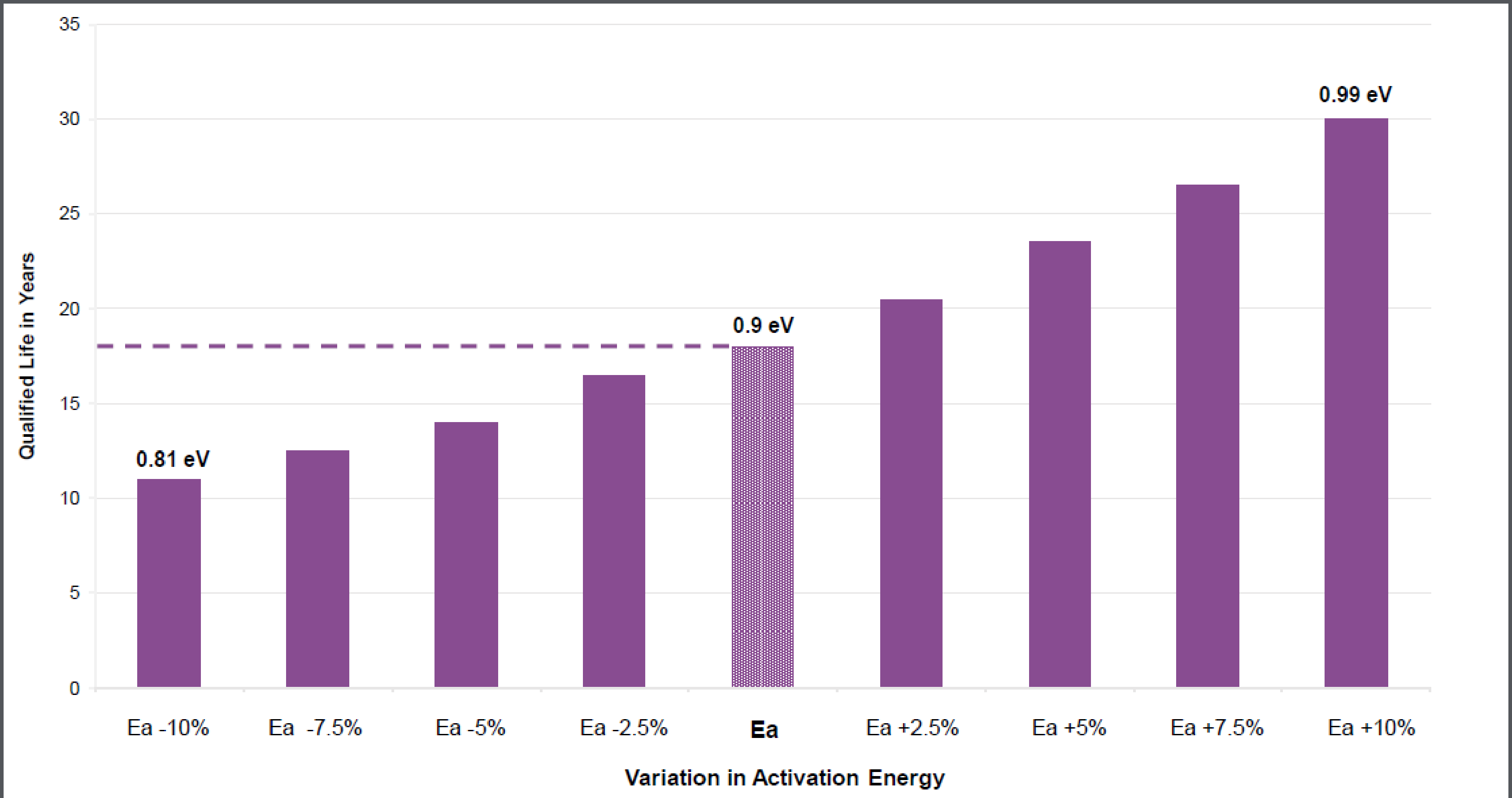


^{60}Co

- Exposure to gamma radiation
- 1kGyhr^{-1} up to 1000 kGy
- Followed by further 600 kGy
- Aged and unaged samples
- Intended to replicate LOCA – broadly based on IEEE 383 / IEC 60780 standards

Accelerated Thermal Ageing

Potential impact of variations in Activation Energy



Victoria Smith Wood Group EQSA Seminar Sept 2019

Martin Baker – Ejector seats – O


NASA
EL ONIZUKA
MIKE SMITH
DICK
RON McNAIR
USA

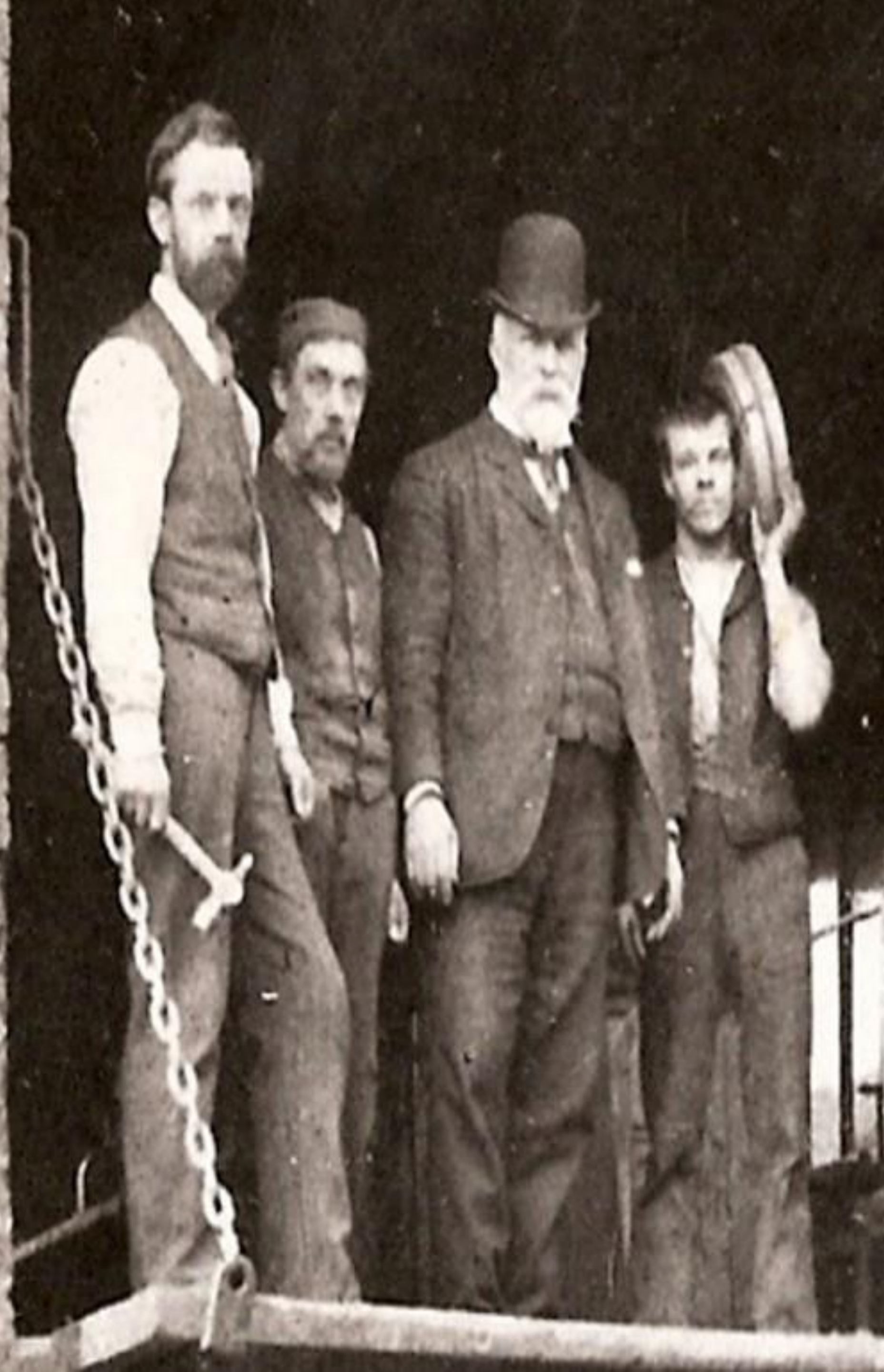
James Walker

Thank you!

andrew.douglas@jameswalker.biz

juhana.virkkunen@teknoma.fi

kenneth.ahlberg@galindberg.se



Copyright notice

Important Notice - Product & Material Claims

Product and material information given in this presentation is given in good faith and represents the results of specific individual tests carried out by James Walker or third parties in accordance with the methodologies described in this presentation or supplementary publication supplied, performed in a laboratory. No representation or warranty is given in relation to such information.

Values and/or operating limits given in this presentation are not an indication that these values and/or operating limits can be applied simultaneously. While such results may comprise useful additional information and are industry standard tests, they are no substitute for conducting (or procuring from James Walker) your own tests and engineering analysis and satisfying yourself as to the suitability of the product you select.

Please also note that a product tested in accordance with the published methodology may not perform to such values in application and/or under different test conditions or methodologies for a variety of reasons, including but not limited to the environment in which it is used/tested or which passes through it or otherwise affects the product, or due to the handling, storage or installation, or due to the effect of housing or other parts. Our personnel will be happy to discuss any historical examples we have of a product having been previously used in a particular application.