Sustained **Performance** and **Comfort** of Personal Protective Equipment

during wear life and the implications towards risk assessment and user specifications

2006 JOIFF Members Meeting,
BRE, Garston, Watford, UK
DuPont Personal Protection, Andreas M Fries
07th March 2006

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AGENDA

- Introduction
- Changing environment – New needs
- Examples:
  - Comfort – New EMPA research
  - Mechanical strength retention - Tear Strength
  - Sustained Protection Performance – Thermo-Man®
- Summary

EC Directive 89/686 on PPE

Requires endusers to:

- carry out risk assessment
- ensure PPE is fit for use through their entire wear life

Requires notified bodies to:

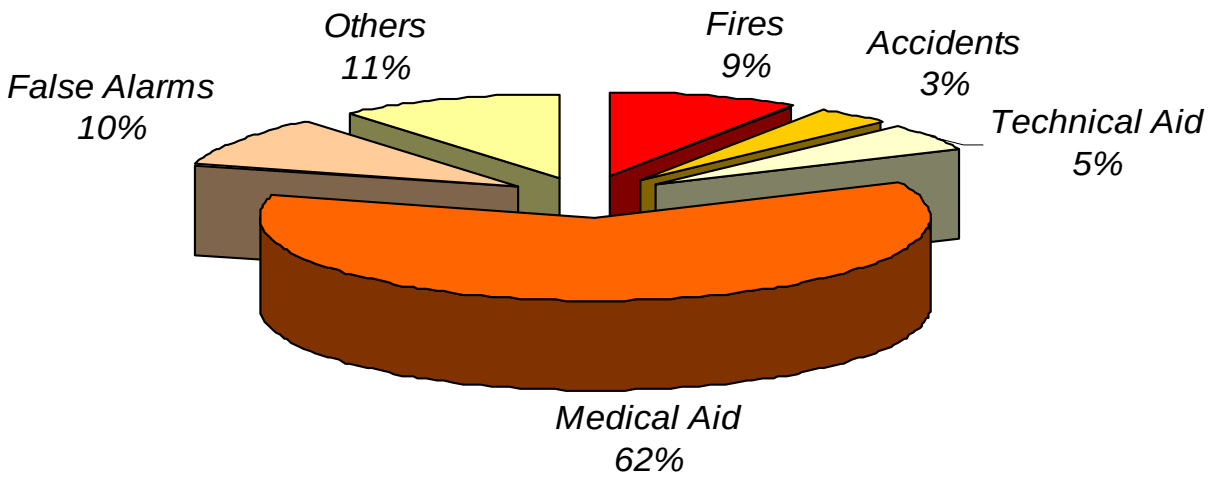
- certify compliance of PPE with the appropriate standards
- apply expert knowledge to assess criteria (not yet) described by current norms

Requires manufactures to:

- state limitations and restrictions of materials used

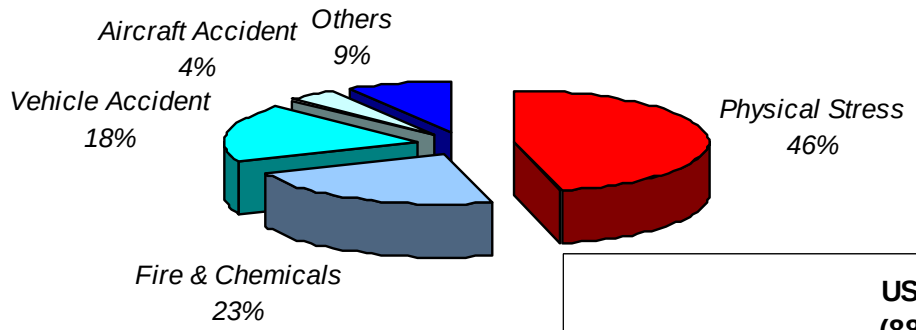
Tasks split of fire fighters – Increased diversity

Statistic on calls at fire brigades from 19 countries
Based on CTIF report No. 9, 2003



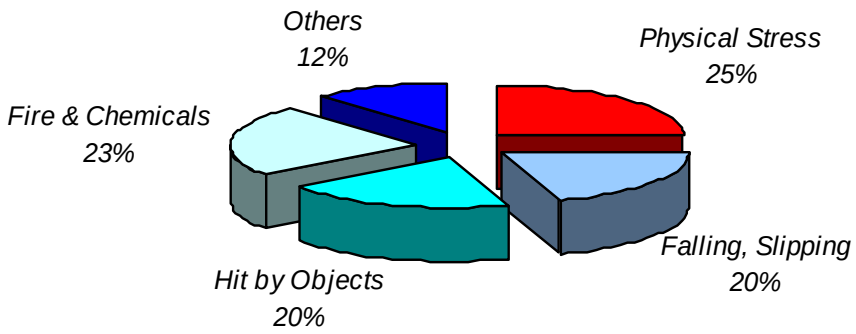
One single most important reason for **injuries** & **fatalities** amongst US fire fighters: **Heat stress**

US Fire Fighters Fatalities 1990-2001
(97 Fatalities per year on average)



NOTE: Injury data are for fireground only.
SOURCES: Injury data are from an analysis of the National Fire Incident Reporting System Firefighter Casualty Module (U.S. Fire Administration, 1998). This database captures data for approximately 10 percent of all firefighter injuries. Only moderate, severe, and life-threatening injuries occurring on the fireground, as defined by the database, are included here. Assaults and vehicle accidents are included in the "struck by or contact with object" category, and "exposure to fire products and chemicals" is broken out from that category. Fatalities data are from National Fire Protection Association (1995–2001).

US Injuries 1995-2000 on Fireground
(88'000 Injuries per year on average)

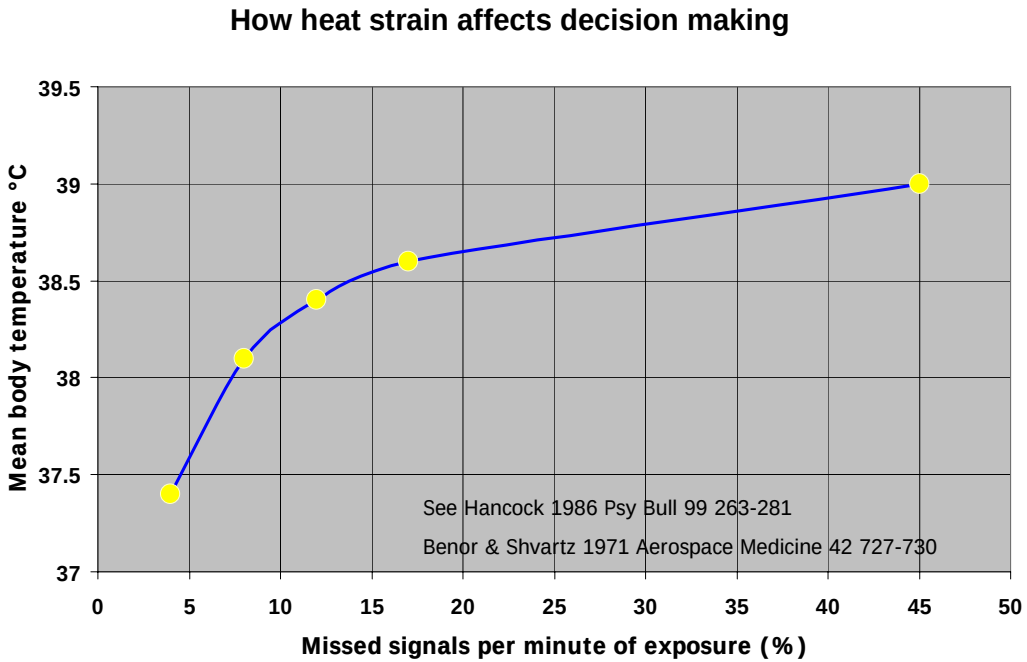


Heat Stress

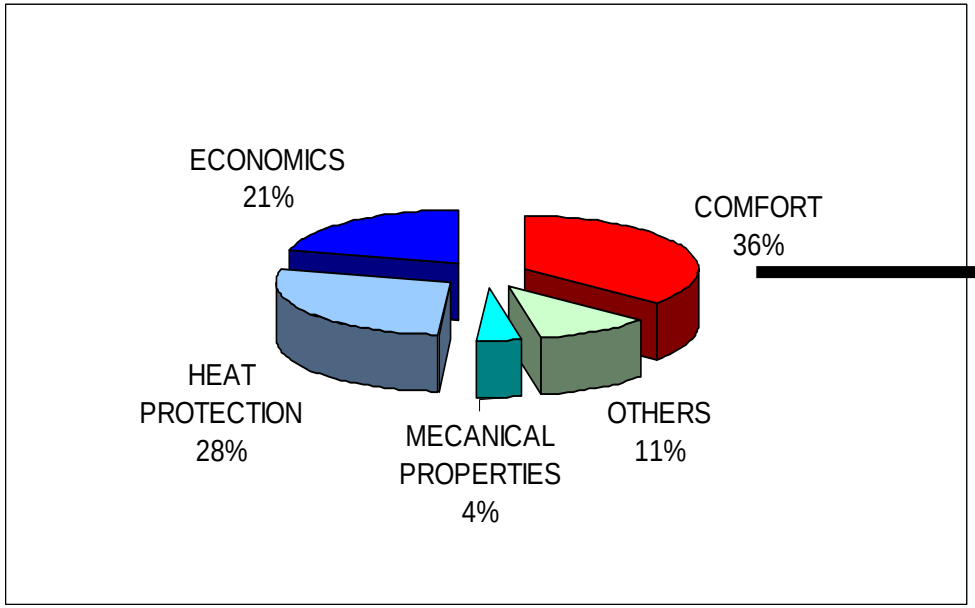
Elevated core temperature occurs performing heavy work or work in hot environments while wearing heat and flame protective garments

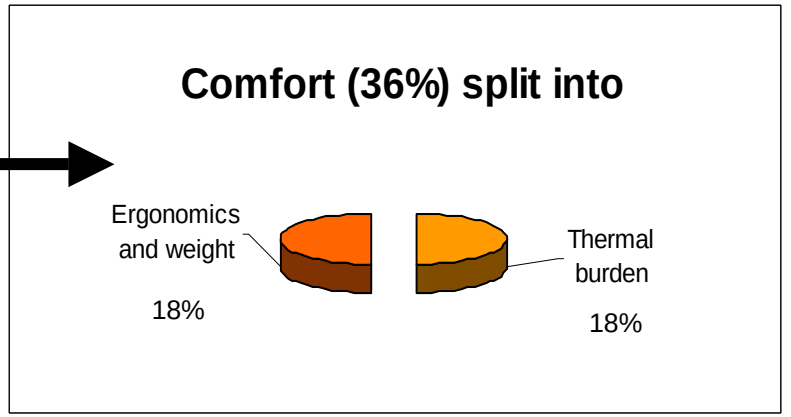
Heat stress is formed inside the body and on the skin (inside / below the garment)

Firemen start feeling uncomfortable with lack of concentration, finally loosing consciousness and possible death



Based on Voice of the Fire-Fighters in a large German City





Economics

Due to budget constraints, economics have an impact on the final decision.

Heat & Flame Protection

Heat Protection is essential but already well accepted and proven in current solutions.

Mechanical Properties

Good mechanical properties are needed but current solutions are already well addressing the fire-fighters needs.

Thermal Burden

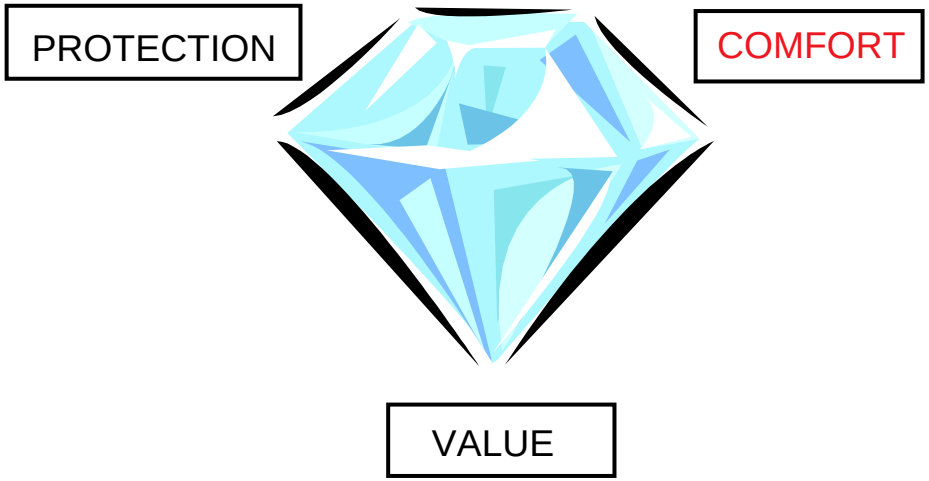
Today's turnout coat system are causing sweating and feeling hot after a short time therefore comfort is rated very high by the fire-fighters.

Ergonomics and Weight

As the turn out coat's are heavy and reduce movements the ergonomics are getting considered as important.

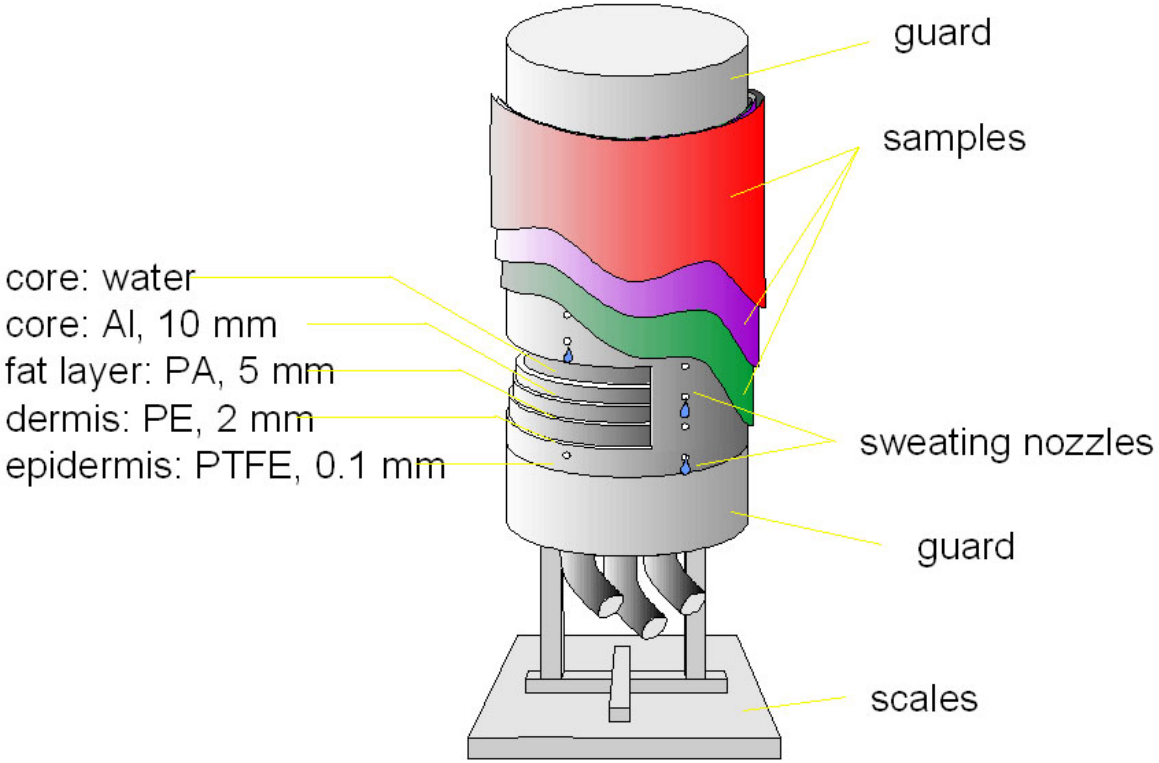
Modern solutions for PPE have to be a balance between:

- Protection
- Comfort and Ergonomics
- Value in use



How to measure **Comfort** ?

Sweating Torso at EMPA, St.Gallen

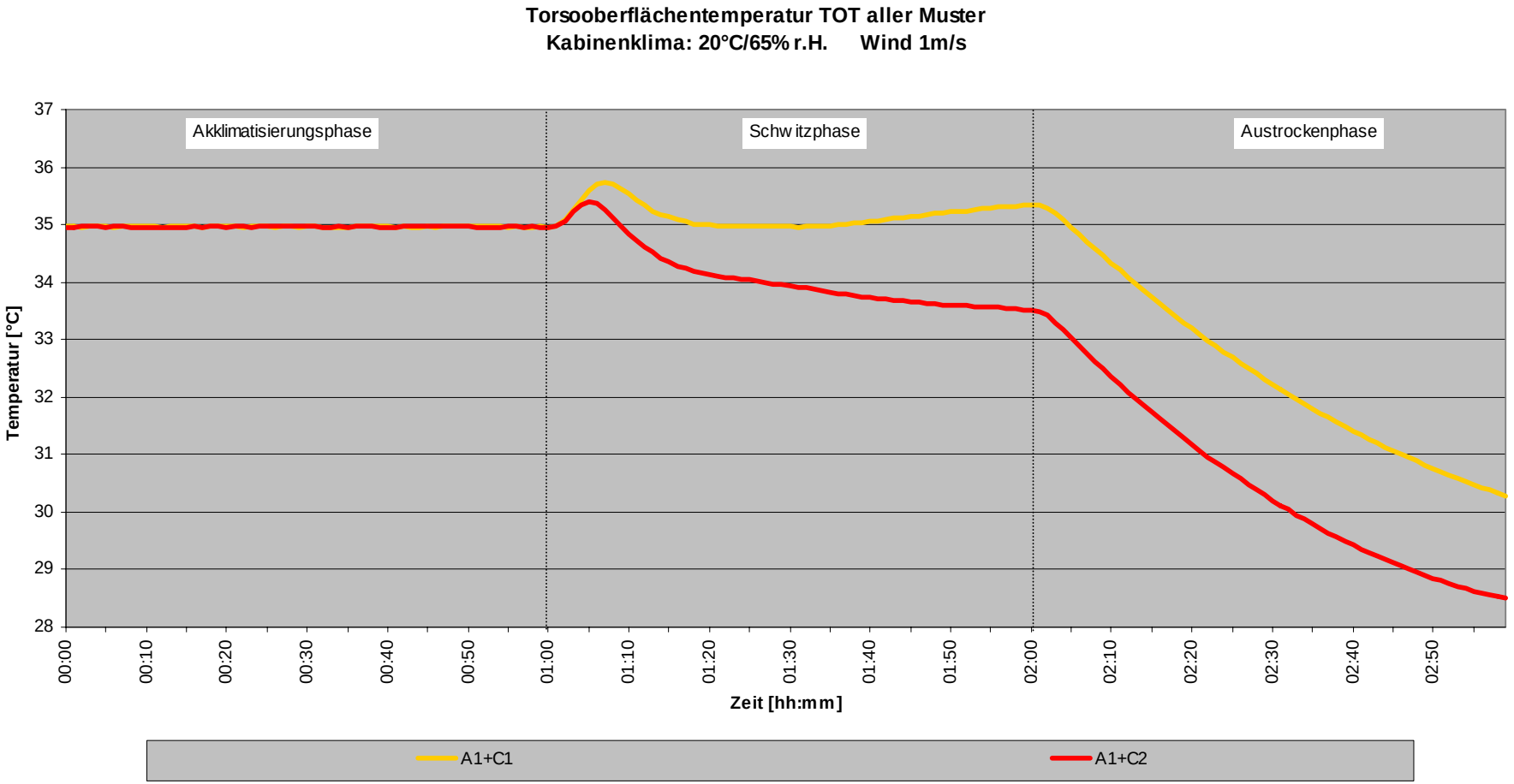


EMPA project No.204114

Torso temperature on sweating torso (EMPA)

A1+C1 = cotton underwear and conventional system

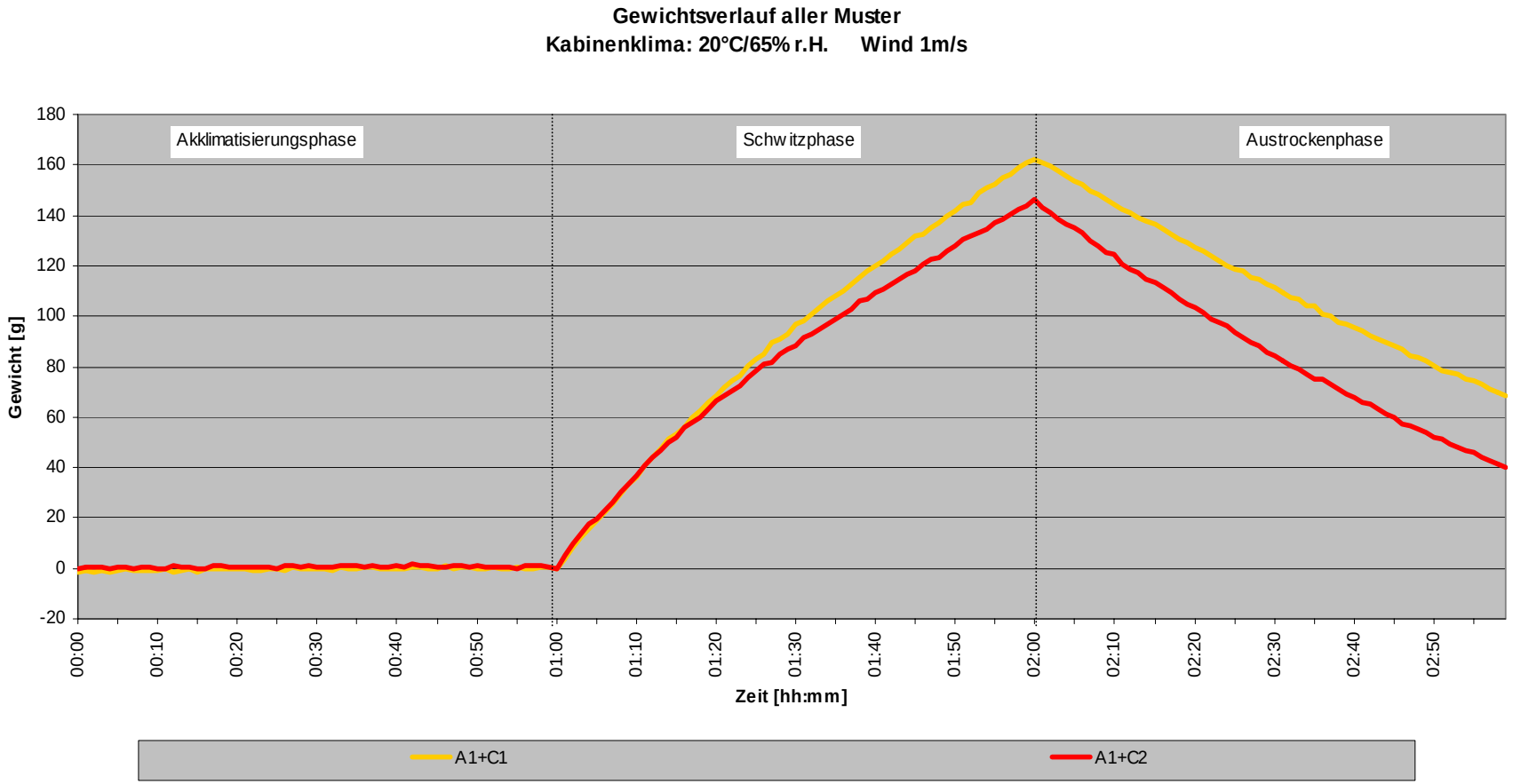
A1+C2 = cotton underwear and new system



EMPA project No.204114

Weight over time on sweating torso (EMPA)

A1+C1 = cotton underwear and conventional system
A1+C2 = cotton underwear and new system



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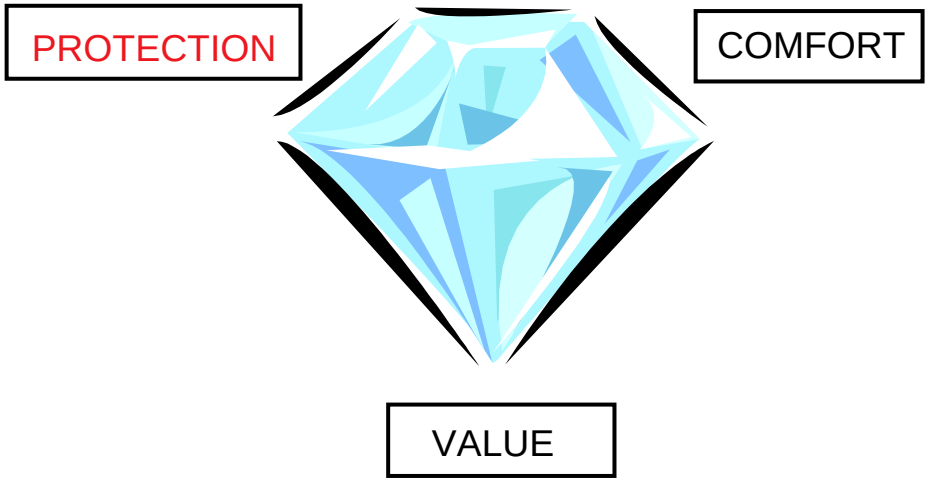


Current Firefighter PPE varies in **protection level**

NOMEX® Quality TOG's may achieve 0 – 2% total body burns in 8s flash over THERMO-MAN® burn.

HuPf certified garments may produce up to 42% total body burns.

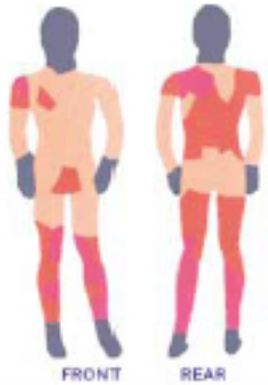
Protection level decreased over the last 9 years, due to cost savings in garment manufacturing and as requirements of HuPf kept unchanged.

1997 approx 25% was an average total body burn result for the full garment (jacket & trousers).

NOMEX® Tough^{Plus}

- Building on a successful trusted solution

COMPARISON OF PROTECTIVE PERFORMANCE OF TWO CLOTHING SYSTEMS AFTER THERMO-MAN® FLASH-FIRE EXPOSURE OF 8 SECONDS.



▲ Protected by NOMEX® Tough^{Plus}.

TOTAL BURN INJURY 2%

▲ Protected by certified HuPF (parts 1 and 2) clothing.

TOTAL BURN INJURY 42%

* Based on a study by the American Burn Association (1991-1993)

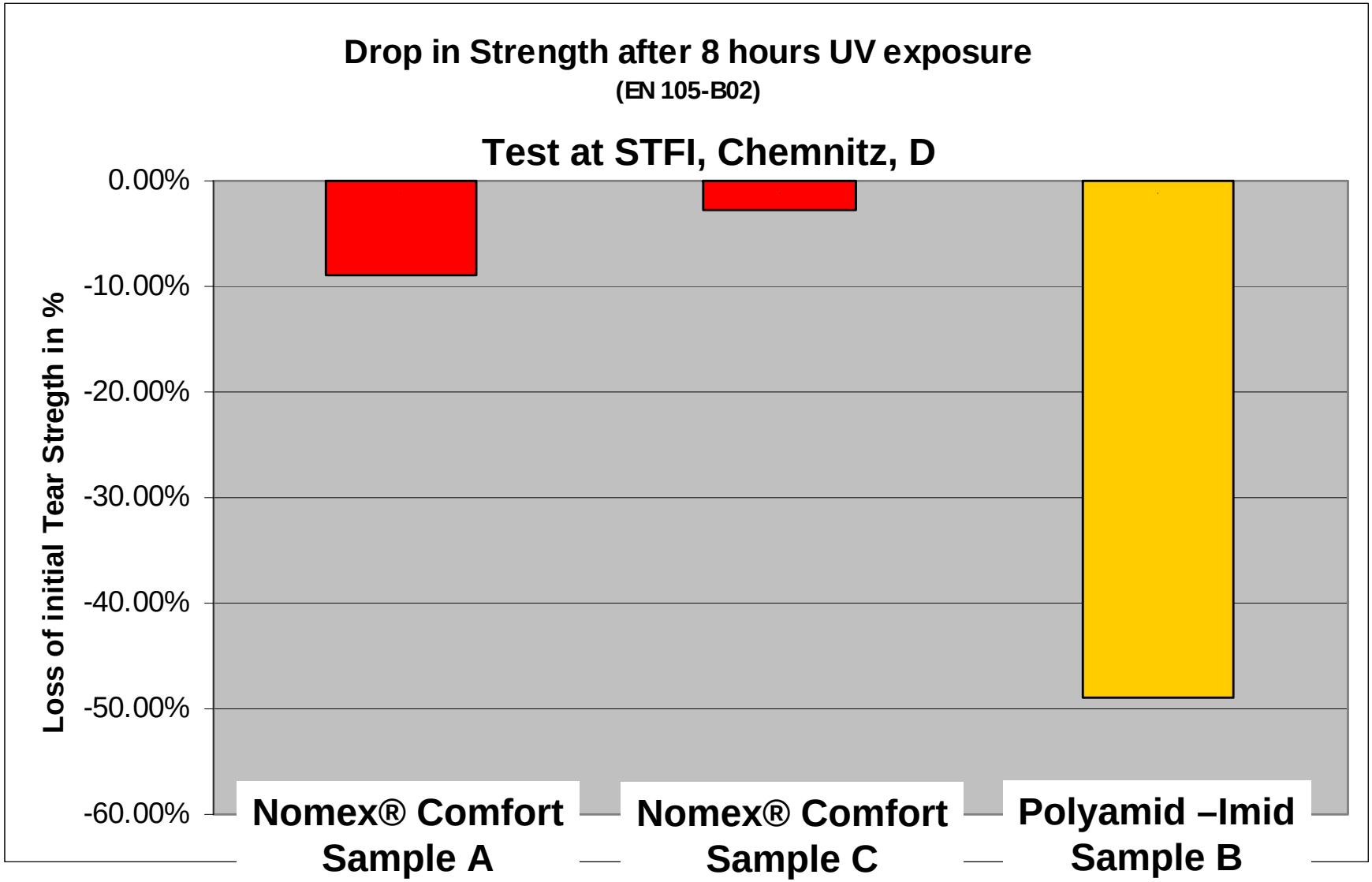
Wear life and aging criteria

Solar radiation has a known adverse effect on color fastness and mechanical resistance of fabrics beeing used in FF PPE (Aramids, PBI, PBO) - (Lion Apparel, US, report on « Effects of light on Outer Shell Materials », 2003).

Life time assessments in the past have demonstrated the sustained protection level of TOC's using NOMEX® outershells.

THERMO-MAN® tests on 14 years old TOC demonstrated successful the retention of the protection level (FB Munich).

More recently, new outershell materials show significant difference in mechanical strength retention after UV exposure and natural weathering



Source: Results of STFI on Tear Strength measurements after 8h UV exposure according to EN/ISO EN ISO105-B02,project 1678/05 , 2005

How does lab testing corelate to real life use ?

Permanent Measurement of UVA, UVB, HR%, RAIN, LIGHT

Source: Fraunhofer, ISE, project TAG3-MH-0511-E05

Natural weathering of fabrics and TOC's

2x3 identical TOC's, except for the outershell, have been exposed with the chest facing south, mounted on torsos on a roof at ISE in Freiburg.

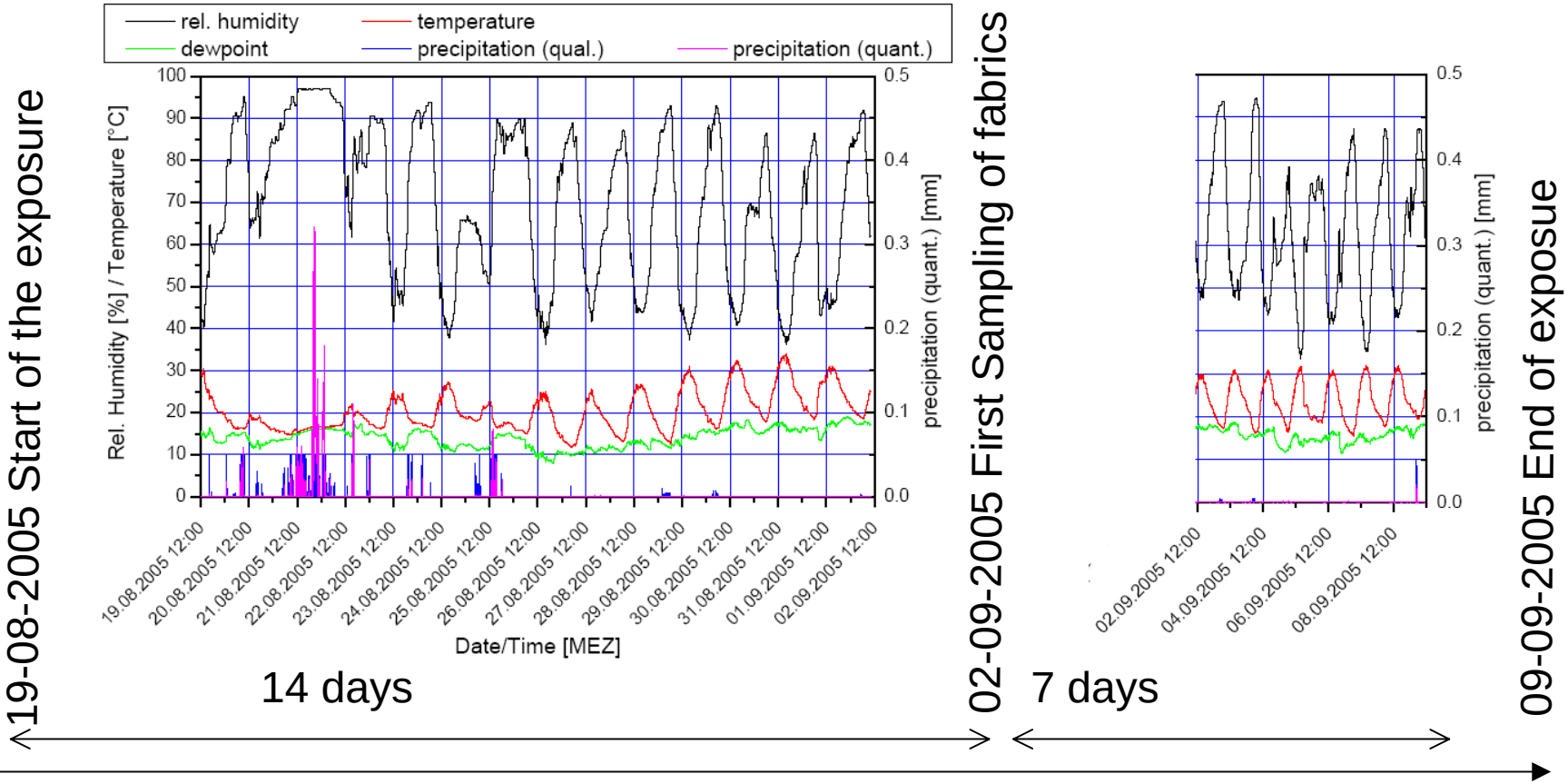
- Identical cut, membrane, thermal barrier, Innerliner and size ensured comparability of outershell materials

4 fabric samples have been exposed on 45° angle in southern direction on a roof at ISE in Freiburg:

- NOMEX® Tough, Twill
- NOMEX® Tough^{Plus}
- Polyamid-Imide, Twill
- Polyamid-Imide / Viscose

Source: Fraunhofer, ISE, project TAG3-MH-0511-E05

Natural weathering of fabrics and TOC's
Weather data scanned 4 times / minute

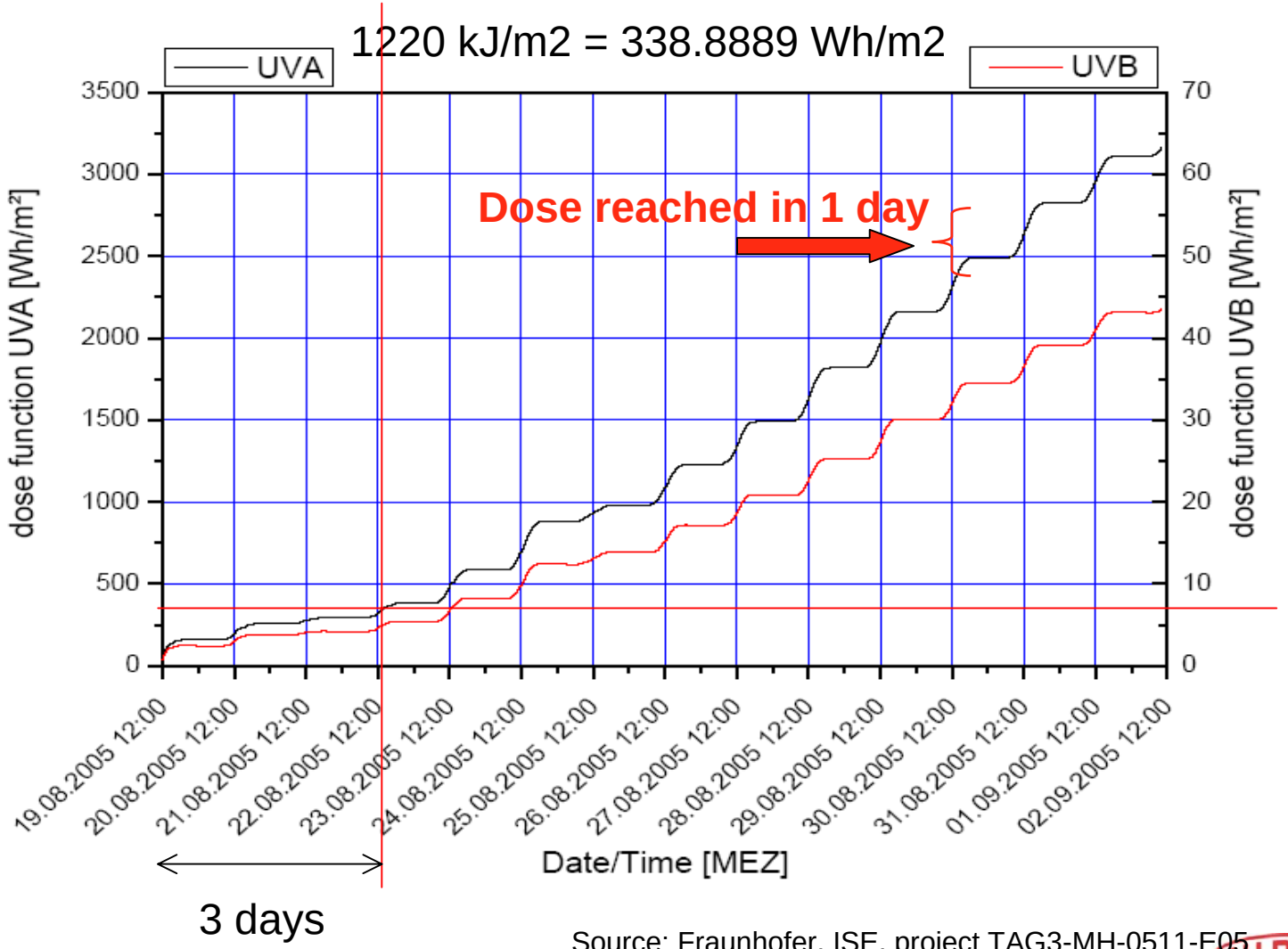


Source: Fraunhofer, ISE, project TAG3-MH-0511-E05

Integrated UVA – UVB radiation

1 kJ= 0.2777778 Wh

1220 kJ/m2 = 338.8889 Wh/m2



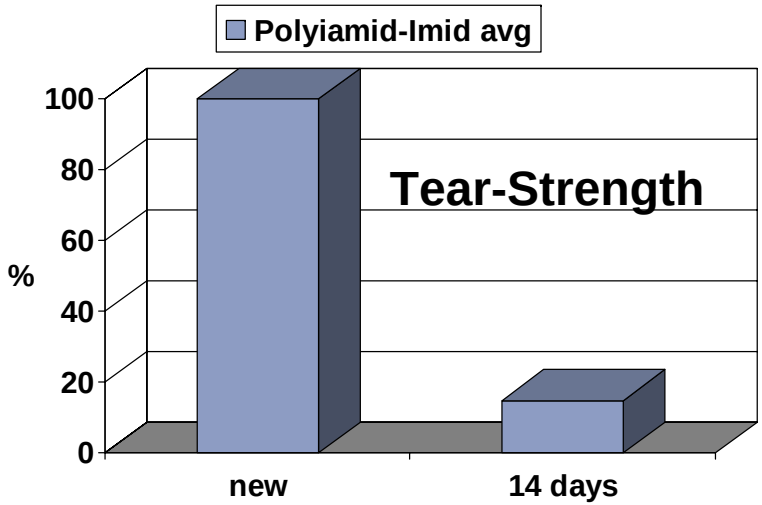
Source: Fraunhofer, ISE, project TAG3-MH-0511-E05

Environmental influence on wear-life and protection level

Solar radiation (UVB/UVA) may have significant influence on protection level and overall wear-life.

Natural weathering @ Fraunhofer Institut, ISE, Freiburg in August/September 2005:

- Reduction of inital tear strength by more then 85% after 14 days exposure
- Reduction of absolute tear strength below the standard (25 N as of EN 469:2006; 35N as of HuPF (German National Standard))

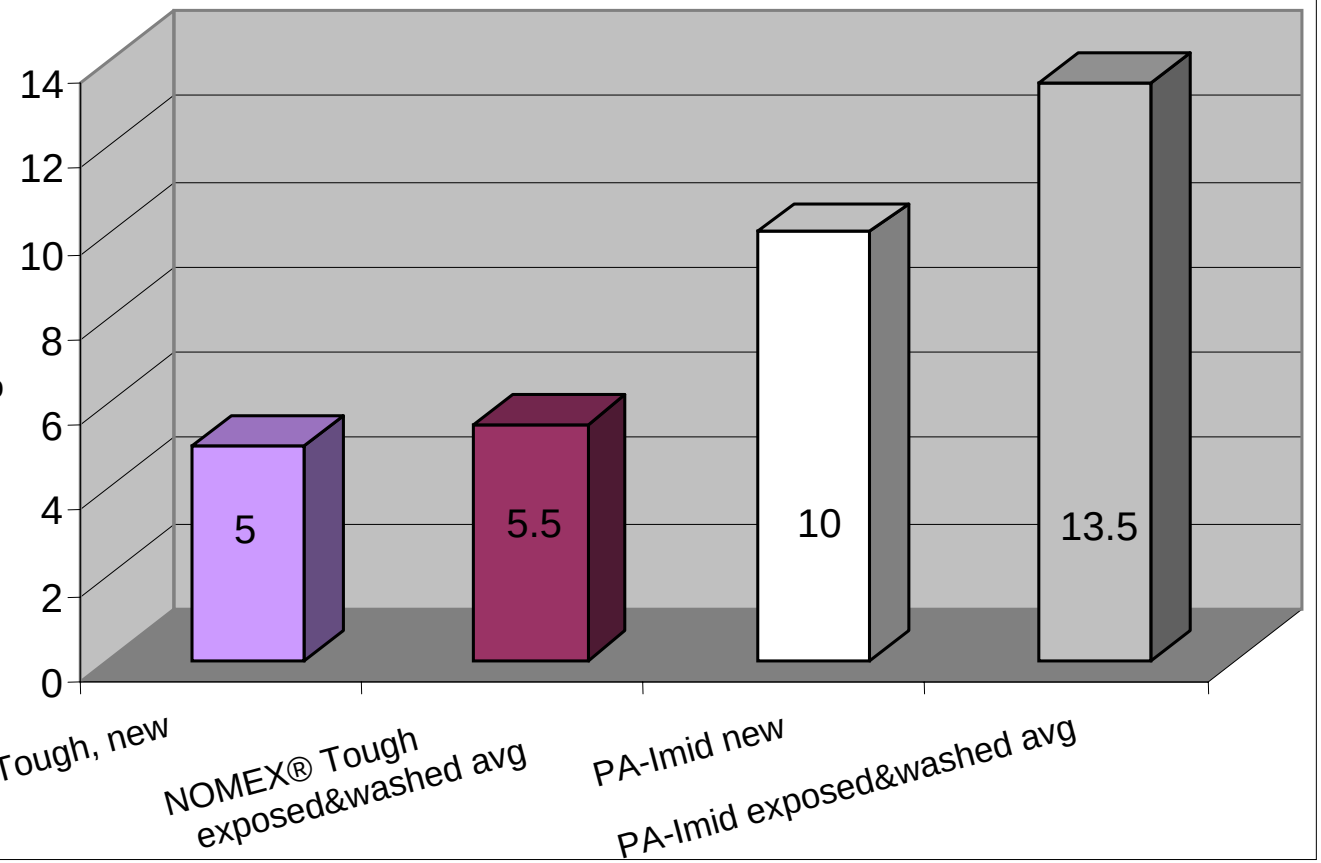


Source: Fraunhofer, ISE, project TAG3-MH-0511-E05, physical testing DPP laboratory, Meyrin 09/2005

THERMO-MAN® tests of exposed HuPF jackets (TOC) after 5 wash & drying cycles

Total body burns on TOC's on THERMO-MAN® test, exposed (21 days), washed & dried TOC's versus New TOC

Total % body burns excluding legs and head



Source: Fraunhofer, ISE, project TAG3-MH-0511-E05, physical testing DPP laboratory, Meyrin 09/2005

Polyamid-Imid Exposed and washed 5x

Source: Fraunhofer, ISE, project TAG3-MH-0511-E05, physical testing DPP laboratory, Meyrin 09/2005

NOMEX® Tough exposed and washed 5x

Polyamid-Imid exposed and washed 5x

Break-open went through until the inner liner

Source: Fraunhofer, ISE, project TAG3-MH-0511-E05, physical testing DPP laboratory, Meyrin 09/2005

Summary

- **Comfort** can be qualified and quantified by appropriate testing and monitored through the wearlife of the PPE in order to minimize the risks of **Heatstress**

- Harmonization and standardisation (without adoption to the current needs) may not **sustain protective levels** of PPE (HuPF 97)

- Total **useful wearlife** of PPE can be assessed using known testing methods of aging materials and subsequently analysing compliance to the existing standards

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