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- Life cycles of a few selected systems
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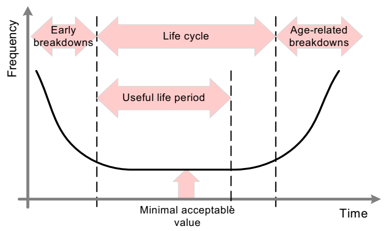
Introduction

- The importance of the technical equipment in tunnels (technical maintenance vs. total maintenance)
- Existing tools for an optimal Asset Management
- Exploration of the optimal useful life period
- Problem: The optimal useful life period of EM-Systems depends on the application area

Life Cycle & Useful Life Period



- Life cycle: max possible useful life period
- Useful life period: time in which the system can be used reasonably

Impacts on Life Cycles

- Maintenance
  - Aim: to improve the useful life period with a minimum of money & manpower, or minimize the risk of a break down
  - Different maintenance strategies:
    - High reliability, small error probability
    - Longest possible useful life period
    - Ideal conservation of value

Impacts on Life Cycles

- Refurbishment, Renovation due to external reasons

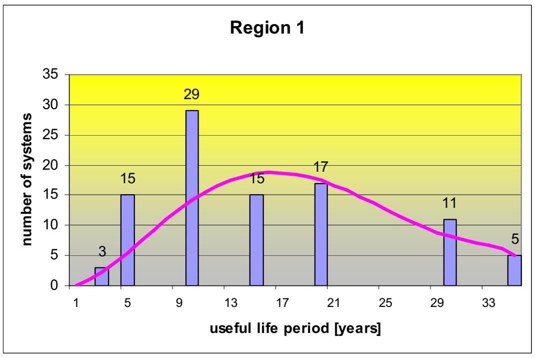
Reasons for a total renovation	Notes
Structural renovation of the tunnel	Pavement, sealing,…
New safety / environment requirements	Ventilation, escape route
Most of the equipment has reached its end of the life cycle	

Conclusions

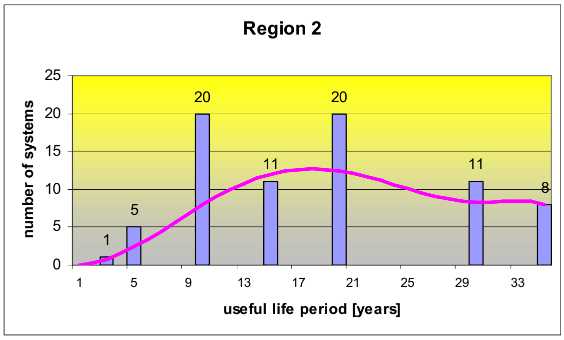
- In a systems life cycle, the replacement is influenced by:
  - Life cycle curve of the system
  - Total tunnel refurbishment
  - New requirements
  - Superior reasons (lack of maintenance,…)

Useful Life Period in Practice

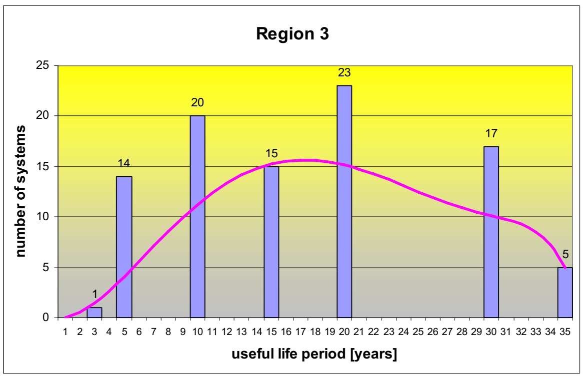
Example 1



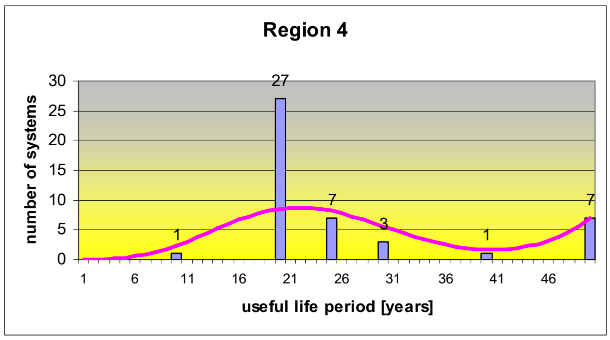
Example 2



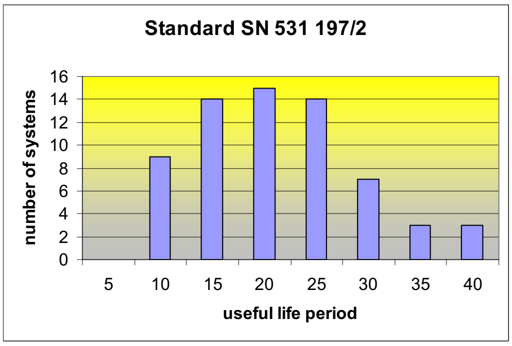
Example 3



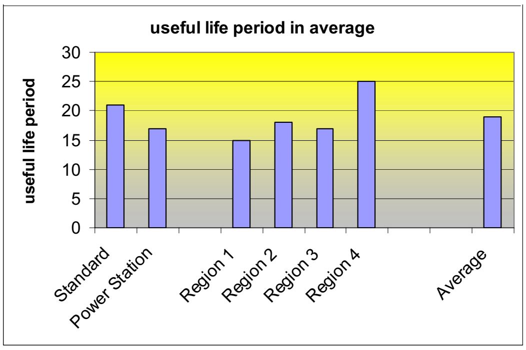
Example 4



Example 5



Average



Life Cycles of a Few Selected Systems

- Illumination
- Control and communication systems
- Energy cabling systems
- Fibre optic cabling systems

Illumination

Illumination System

- The illumination is part of a system including:
  - Control system
  - Luminaire
  - Lamp
  - Electronic ballast

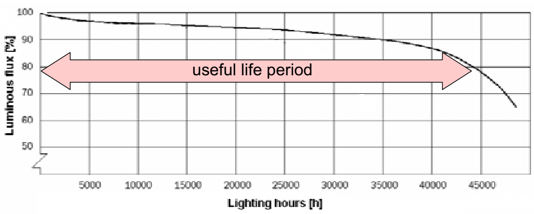
thermal influences
mechanical influences
electronic influences
electrical influences
environmental influences

Illumination System Life Cycle

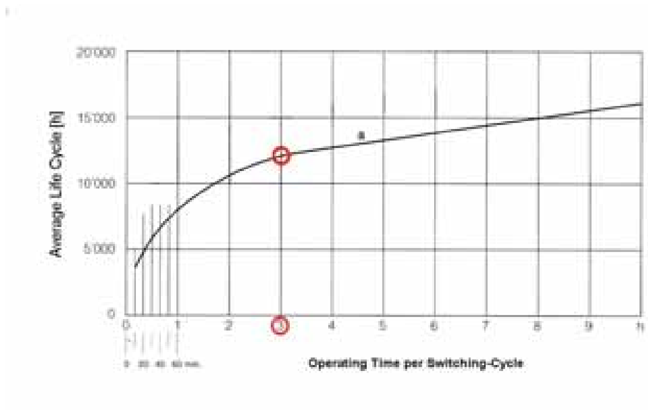
- Mainly used components:
  - Fluorescent lamp
  - High pressure sodium lamp

Illumination System Life Cycle

- Useful life period ends if:
  - The luminous flux is lower than 70-80% of the original luminous flux



Life Cycle vs. Switching Periods



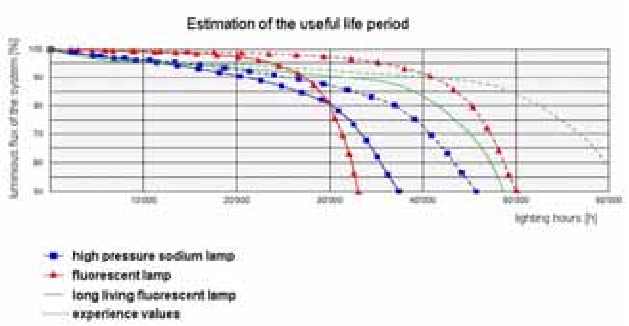
How to Define Replacement Cycle

Criteria	Comment
Operating hours	Best practice
Luminance measuring	Difficult due to changing conditions

Conclusion

- The optimal life period can be defined by:
  - Supplier data & special "tunnel effect"

Data vs. Actual Experience



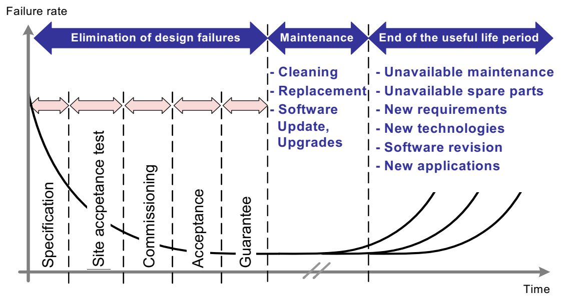
Control & Communication Systems

Control Systems are Used for:

- Traffic
- Technical systems
- Alarms
- Messages

Bath Tub Curve of Control Systems

- Typical life cycle of control systems



Theoretical Life Cycle Data is Basing on:

- Room temperature: 20-25°C
- Humidity: 40-60%
- No vibrations

Typical Elements of Control Systems

- Active components without moving parts and hot spots

- Active components with moving parts (PC, Server,…)

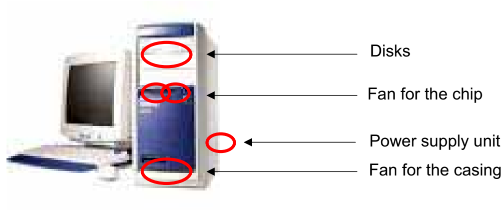
Typical Elements of Control Systems

- Joining elements (sockets, plugs,…)

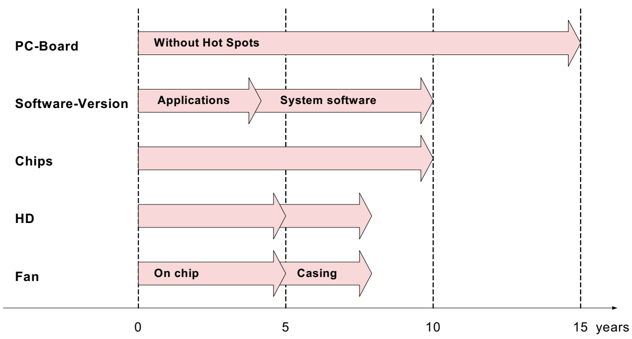
- Passive components like communication networks (fibre glass,…)

- Software

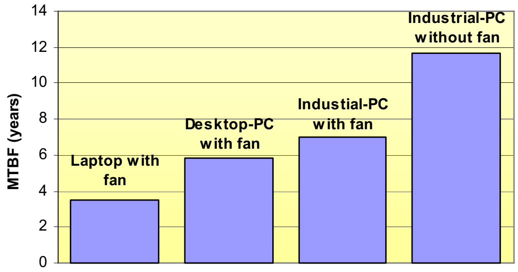
Example: PC



Life Cycles

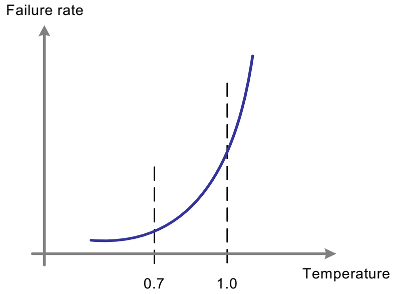


Measures for Better Life Cycles: PC



Measures for Better Life Cycles: Temperature

- $T \le 0.7\ T_{max}$ (28°C –rule)



Temperature = Most Important Stress Factor

Arrhenius

- Higher temperatures → faster chemical reactions
- T+10° → double reaction rate

$$r = \frac{dq}{dt} = A * \exp^{\left(-\frac{E}{kT}\right)}$$

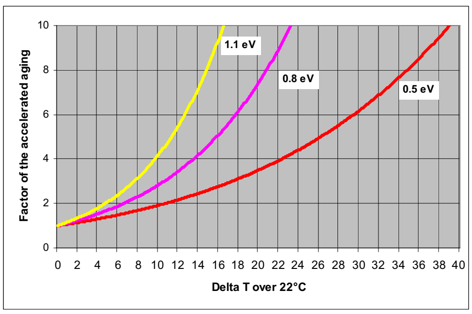
Svante Arrhenius 1859-1927

q	Chemical reaction
r	Reaction rate
A	Absolute Material term
E	Activation Energy [eV]
k	Boltzmann-term 8.6*10^-5 eV/K
T	Absolute temperature

Aging Factor

ts	Reaction rate at room temperature
ta	Reaction rate at a higher temperature
E	Activation Energy
k	Boltzmann-term
Ts	Room temperature
Ta	High temperature

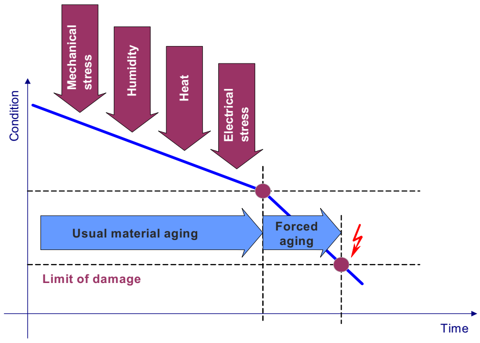
$$\frac{ts}{ta} = \exp^{\frac{E}{k}*\left(\frac{1}{Ts}-\frac{1}{Ta}\right)}$$



Energy Cabling Systems

- Operational life cycle: 30-40 years
- Main reason for damages: short circuit → damages to other systems
- Aging is influenced by high operating voltages & high temperatures (Arrhenius)

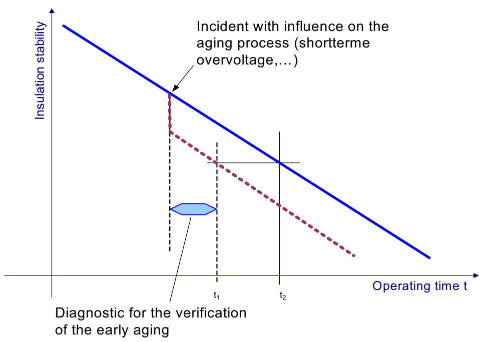
Risk Factors (Cables PE, XPE)



Preventive Actions to Avoid Early Breakdowns

- Overload protection
- No damages at the cable jacket
- Overvoltage protection
- Periodic isolation tests

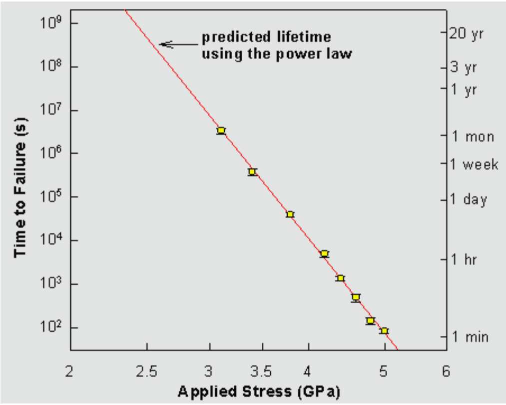
Conclusion



Fibre Optic Cabling Systems

- The useful life period is affected by:
  - Intrinsic factors: surface conditions, micro cracks
  - Extrinsic factors: bending, torsion, temperature, humidity, gases
  - Optical factors: short term optical overstress

Static Stress



Preventive Measures for Long Life Cycles

- No variations in temperature (cable conduit)
- No humidity (cable conduit)
- Good mechanical support
- Bending rules

- Reduction in stress & protection from environmental effects
  → longer life cycle

Summary & Recommendations

- Extrinsic factors have a high influence on a systems life cycle
- Empirical evaluation and observation necessary
- Analysis and diagnostics on a case-to-case basis