Working for a safe world

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Why should machines be safe?

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"Safety at Work contest"

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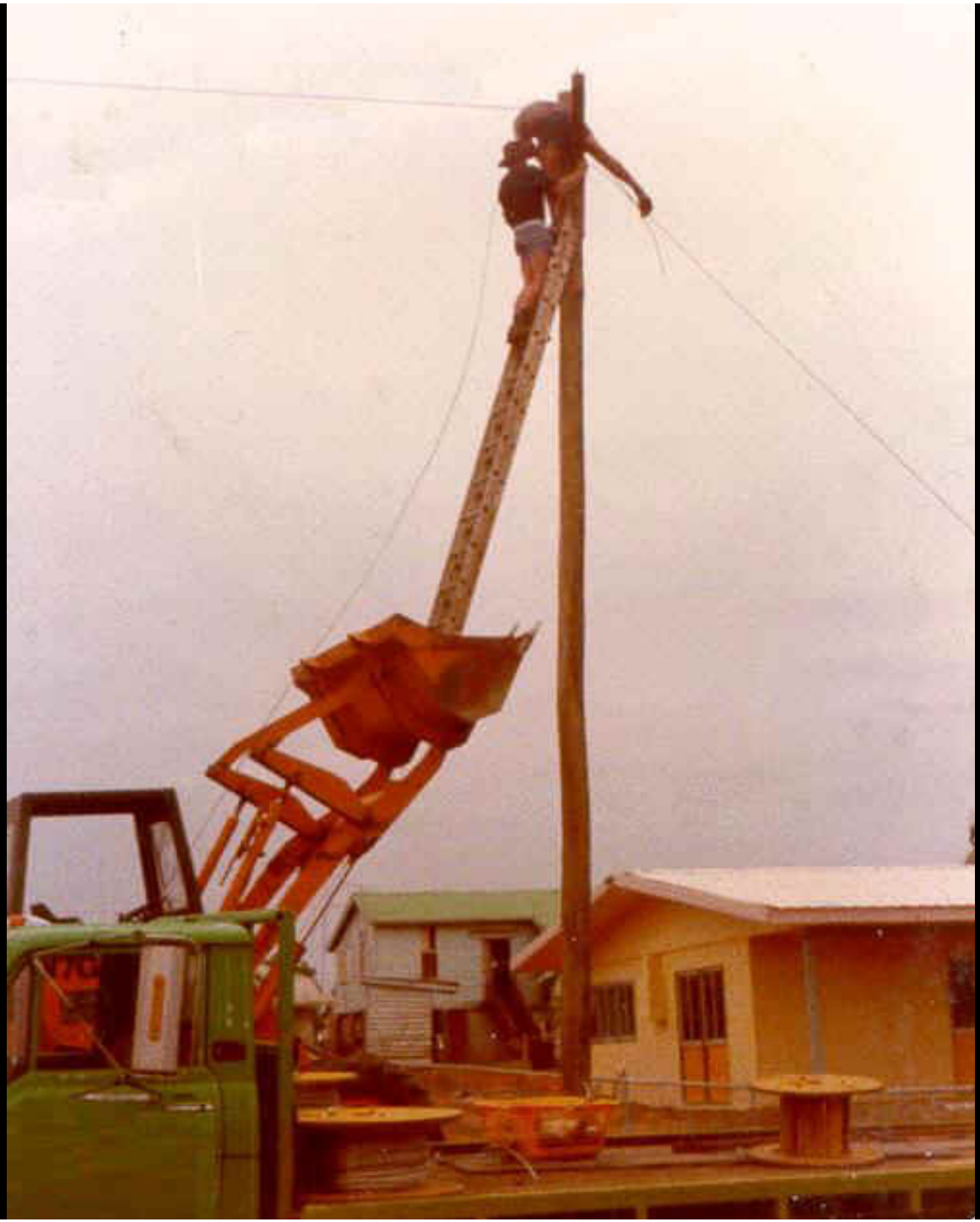
Top 6 safety hit liste:


TOYOTA
KOMATSU
MATRIA 50



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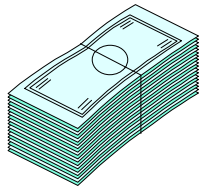

- 1. Why should machines be safe?
  - Costs of accidents vs. the price of safety
- 2. What is (machinery) safety?
  - Definitions, EN safety standards.
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  - Safety sensors and actuators, safety relays, safety controllers.
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Why should machines be safe?

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It is the moral obligation of employers to provide safe working equipment, according to article 23.1 from
the UNIVERSAL DECLARATION OF HUMAN RIGHTS*

Everyone has the right

- to work,
- to free choice of employment,
- to just and **favorable conditions of work**
- to **protection against unemployment**.

* Adopted by UN General Assembly Resolution 217A (III) of 10 December 1948
From: IEC/ISO Guide 51

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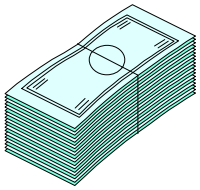

Accidents always cost a lot of money due to:

- Lost production
- Lost time of the middle management
- Compensation claim of the injured employee
- Lost time sourcing from frustrated colleagues
- Penalties imposed by health & safety authorities
- Extra expenses for finding a quick interim solution
- Negative publicity in the media

From: The costs of ACCIDENTS AT WORK, HSE UK, ISBN 0-7176-1346-7

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Statements from some business managers:

- “We only get cuts and bruises type accidents. All they cost us is the price of a band aid.”
- “Accidents don’t cost me anything. That‘s what I have insurance for!”

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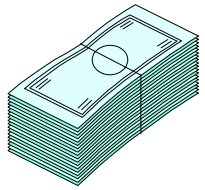

The total costs of accidents
are greater than
most people think!

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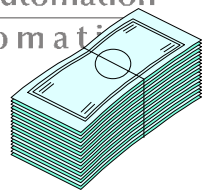
The total costs of an accident are like an iceberg!

With a real iceberg:

- 10 % is visible above sea level
- 90 % is INvisible below sea level

Why should machines be safe?



Costs usually covered by **insurance** are:

- Recovery from injury
- Employers liability
- Third party/public liability
- Product liability

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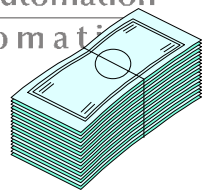

The MUCH larger, **uninsured** costs are:

- Product and material damage
- Plant and building damage
- Tool and equipment damage
- Legal costs
- Emergency supplies
- Clearing the site
- Production delays
- Overtime work
- Subtitute labour
- Investigation time
- Supervisors' time diverted
- Clerical effort
- Fines
- Loss of expertise
- Loss of experience

Parts, labor, overhead and plant downtime all add up, not to mention hours of aggravation

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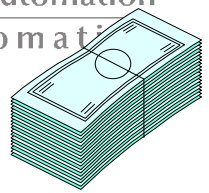
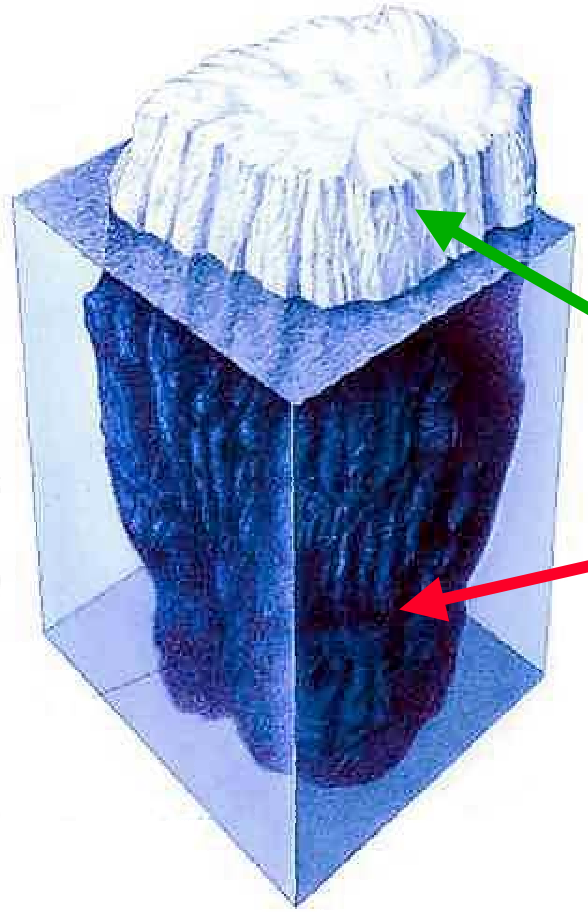
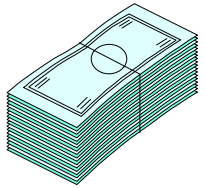


Studies on the total cost of accidents have shown:



The ratio of the costs of accidents can be even worse!

Insured costs: n US $



Uninsured costs:

8...36 times n US $!!

From: The costs of ACCIDENTS AT WORK, HSE United Kingdom,

ISBN 0-7176-1346-7

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Cost of accidents versus management control

How far should management's control efforts go to minimize accidents?

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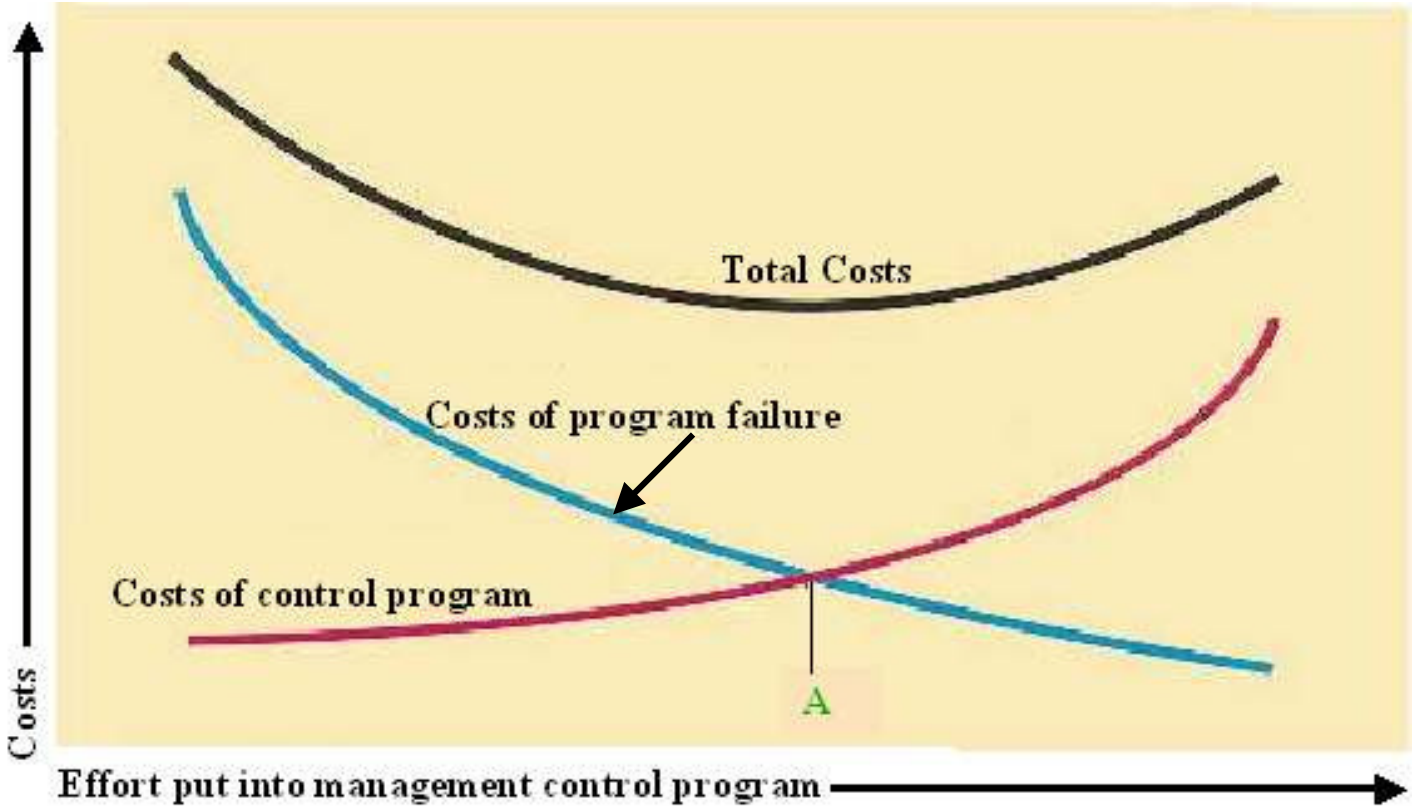
Control program costs



This model links

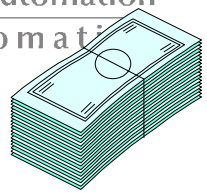
- the cost of accidents

and

- the investment in health and safety management

The total costs are lowest at point A

Why should machines be safe?



The costs of the control program include

- Decision making
- Safety hardware, e. g. ventilation systems, safeguards
- Communication and training time
- Publicity campaigns
- Ongoing inspections and audits
- Maintenance
- Program coordinator and support staff costs

From: The costs of ACCIDENTS AT WORK, HSE United Kingdom, ISBN 0-7176-1346-7

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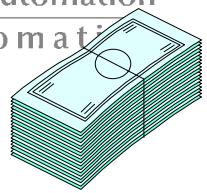

The costs of program failures include

- Major and minor personal injury accidents
- Occupational ill health
- Equipment and material damages from incidents
- Production and material losses
- Process and technical breakdowns or environmental damages

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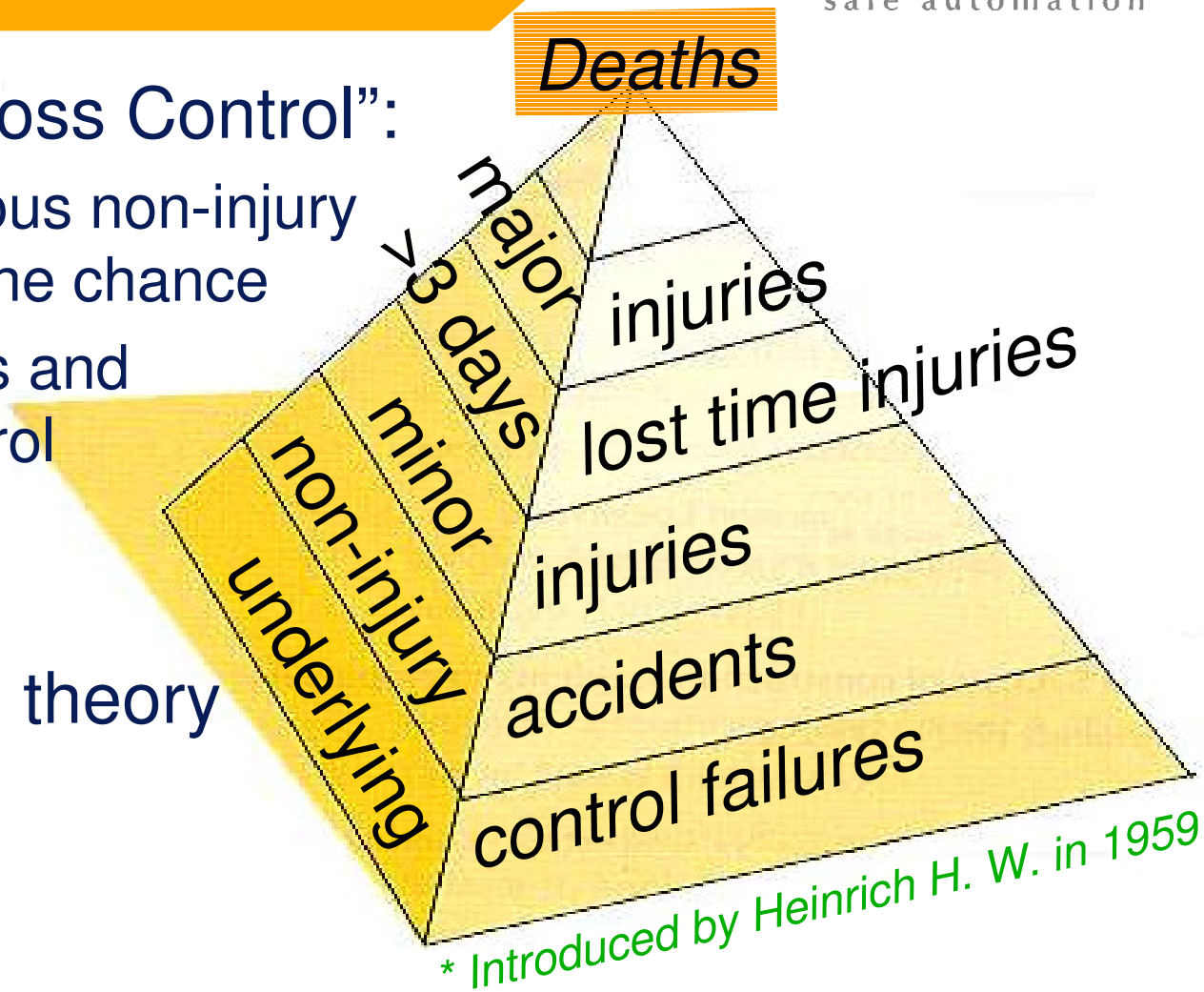
The theory of “Total Loss Control”:

- Controlling the numerous non-injury accidents will reduce the chance
- of injuries and fatalities and provide proactive control of health and safety

and

The accident Pyramid theory



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Machinery Safety

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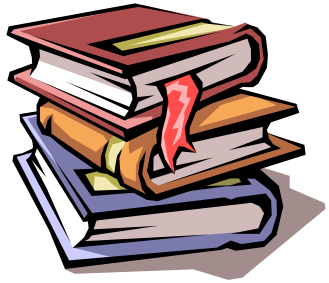

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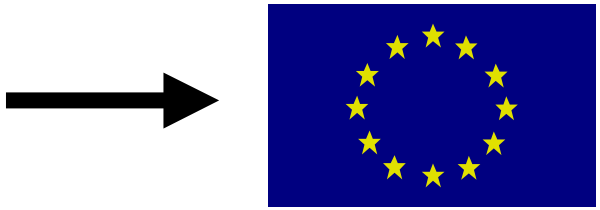

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CE

New AND ALSO second-hand machines exported to Europe have to be delivered with the CE mark!!!

- Minimal technical requirements (Annex 1) of the Machinery Directive 98/37/EC are fulfilled
- In compliance with other directives EMC/Low Voltage
- Same safety level as in harmonized EN standards
- Supplier has to fill out Declaration of Conformity
- Supplier keeps a Technical Construction File for 10 years

Why should machines be safe?

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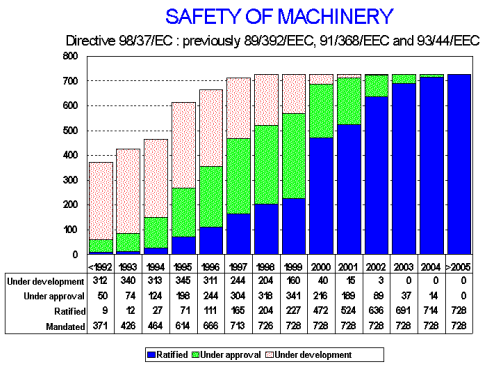

Standardization is becoming very important!

- Using harmonized European (EN) standards on machines proves Conformity
- 724 EN standards on machinery safety in 2005
- Electrical (CENELEC) and mechanical (CEN) standards are used in Europe
- EN standards are converted to IEC/ISO and vice versa
- Electrical (IEC) and mechanical (ISO) standards are used worldwide

Why should machines be safe?

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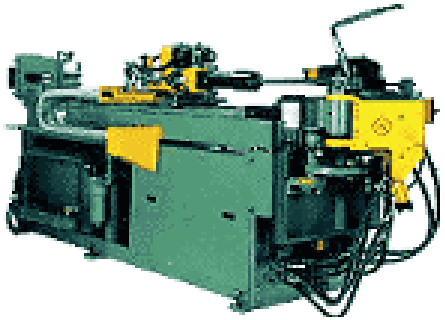

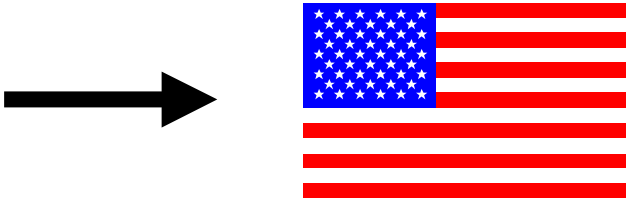

= CE

Moreover, new machines exported to America have to be delivered with the CE mark!!!

- American employers ask for CE marking on all machines from outside America!
- American machine buyers demand the CE mark more often!

Machinery Safety Standards

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Standards for compliance with the Machinery Directive and for obtaining the CE Mark

Essential reading for machinery builders!:

"A" standards - Safety of Machinery - apply to all machinery

- EN 292 - section 1 & 2, basic concepts, general design principles
- EN 414, rules for drafting and presentation of safety standards
- EN 1050, risk assessment

Machinery Safety Standards

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B and C standards

are generally subdivided into B1 and B2

- EN 954-1 (B1) Risks in safety-related control systems
- EN 60 204 (B1) Measures for risk reduction using electrical equipment
- EN 418 (B1) Emergency-Stop facilities

- EN 574 (B2) Two-Hand Control
- EN 1088 (B2) General design guidelines for safety locks
- EN 50 100-1 (B2) Electro-sensitive protective devices
- EN 60947 (B2) Switching devices: safety limit switches, guard switches etc.

Machinery Safety Standards

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The regulation EN 1050 is based on the assumption that every machine bears a risk, namely

the risk that exists without using measuring or control equipment

This risk is determined by assessing the machine void of any safety facility

If this risk is estimated to be greater than the justifiable limit risk, then measures must be taken to reduce the factual remaining risk to less than the justifiable limit risk.

Risk Assessment & Risk Reduction

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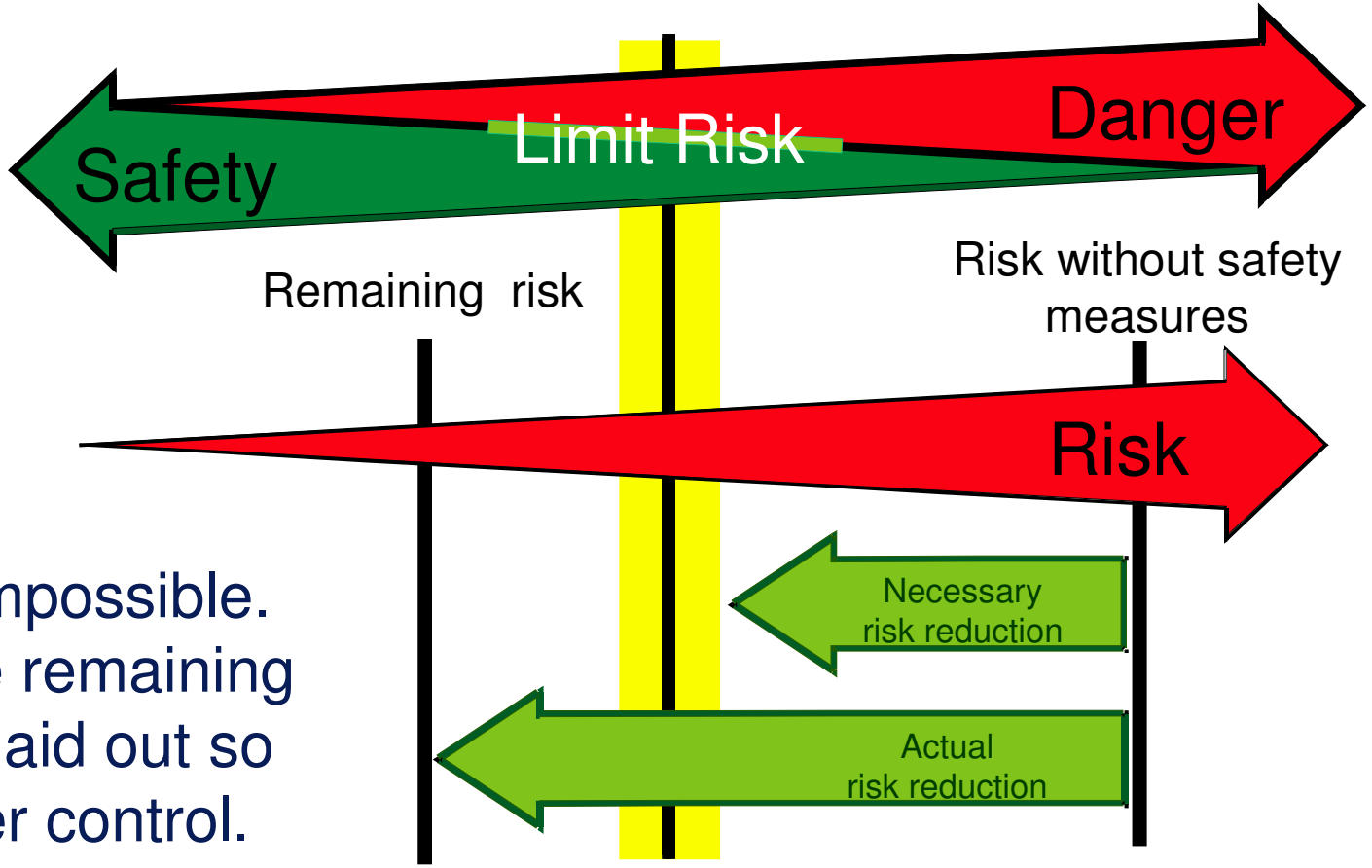

Zero risk is impossible. However, the remaining risk must be laid out so that it is under control.

Risk Assessment to EN 954-1

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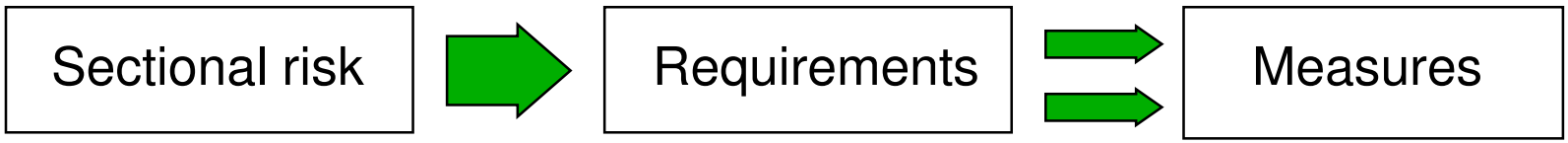
Basic reflections on safety, using measuring and control equipment:

Risk parameters

- ***Severity of injury***
- ***Frequency and exposure times***
- ***Possibilities of avoiding the hazard***



What is safety?

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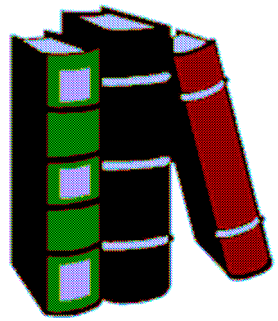

A definition:

Safety is the freedom
from unacceptable risk

From: IEC/ISO Guide 51

What is a risk?

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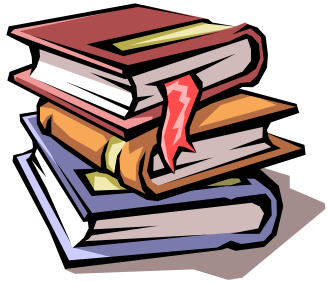


A risk is the combination of

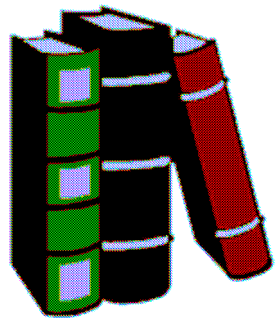
the probability of a harm occurring

and

the severity of that harm

From: IEC/ISO Guide 51

What is a harm?



A harm is
a physical injury or damage
to health caused by
a hazardous situation

From: IEC/ISO Guide 51

Risk Assessment to EN 1050

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Risk w/o safety measures:
The risk when a machine features no risk-reducing measures

Danger:
The situation where the risk is above the risk limit.

Limit Risk:
The greatest still acceptable risk of a specific technical procedure or condition. Generally the risk limit cannot be quantified. Usually it is detailed by safety definitions.

Safety:
The situation where the risk is below the risk limit

Remaining risk:
The remaining risk after deducting all risk-reducing measures

EC Machine Directive

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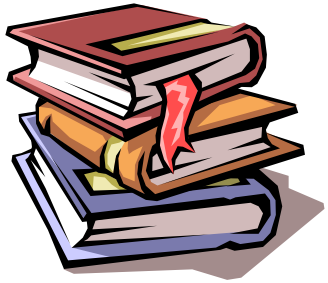

- Council Directive 89/392/EEC from 14th June 1989
- Directive 98/37/EC of the European parliament and of the Council from 22nd June 1998 on the approximation of the laws of the member states relating to machinery
- The Machinery Directive has the power of law in the EC
- Compliance with the directive can be proven by following the EN standards
- Compliance with the directive is testified by a manufacturer‘s declaration: the CE-mark

European Standards

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Structure of the European Machinery Standards

"A" Standards form the super structure of the Machinery Safety Standards, and are concerned with basic safety aspects of all machinery

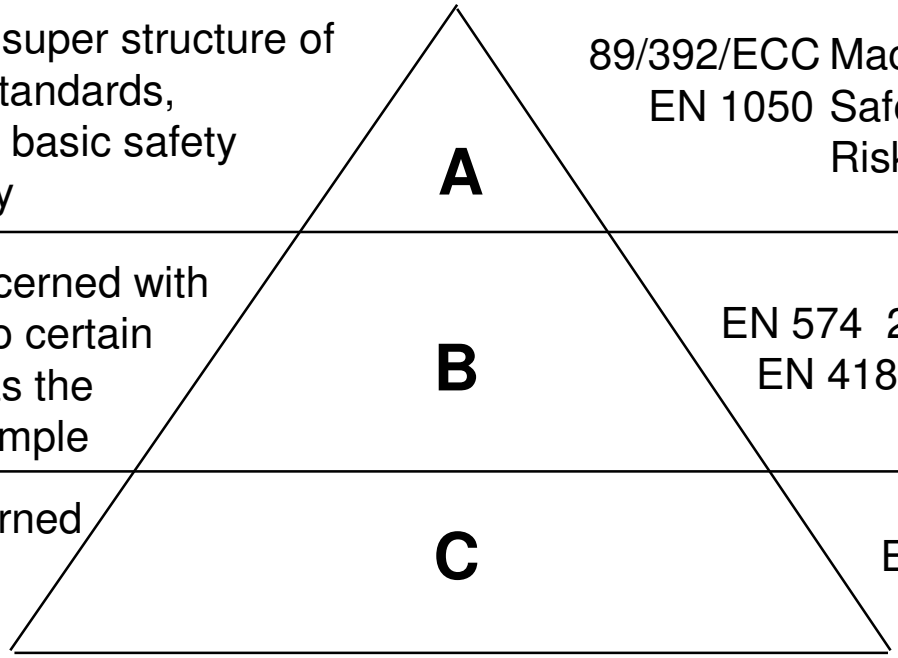
89/392/ECC Machine Guidelines
EN 1050 Safety of Machines
Risk Assessment

"B" Standards are concerned with regulations that apply to certain machine groups such as the 2-hand controls for example

EN 574 2-hand circuits
EN 418 Emergency-Stop facilities

"C" Standard are concerned with specific machines, for example hydraulic presses

EN 693 Hydraulic presses
EN 692 Mechanic presses



Safety Standards - Overview

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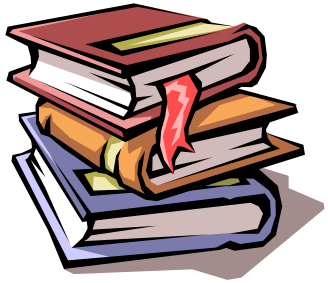
- Must be followed to fulfil the requirements of the Machinery Directive and to attain the CE mark:



  - EN 1050 Principles for risk assessment
  - EN 954-1 Safety related parts of control systems
  - EN 60204 Electrical equipment of machines Specification for general requirements
  - EN 1088 Interlocking devices associated with guards Principles for design and selection
  - EN 418 Emergency stop equipment
  - EN 61496 Electro sensitive protective equipment
  - EN … Specific standards for particular machine types

Risk Assessment to EN 954-1

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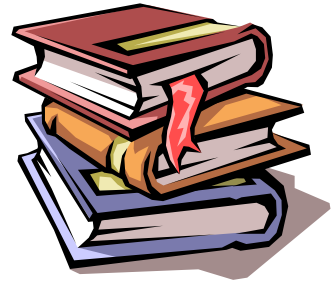
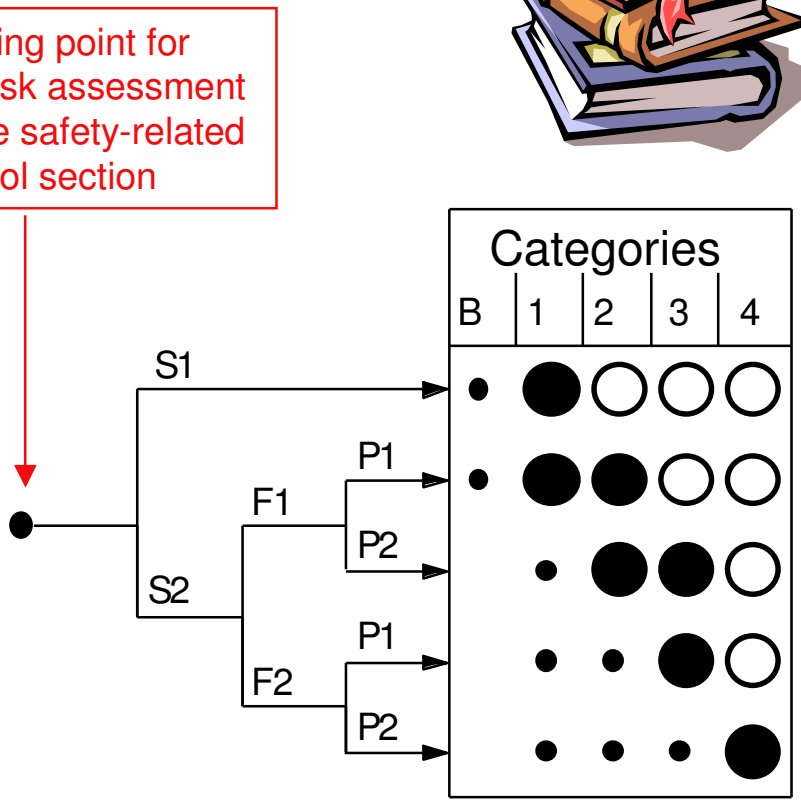
- S Severity of injury
  1 = Slight (reversible)
  2 = Serious (non-reversible) including fatal injuries

- F Frequency and exposure times
  1 = Seldom and/or short exposure
  2 = Frequent to continuous and/or long exposure

- P Possibilities of avoiding the hazard
  This is generally related to the speed and frequency at which a hazard arises and the proximity to the hazardous point.
  1 = possible under certain conditions
  2 = less possible





Risk Assessment to DIN V 19250

Extent of Damage/Injury

S 1: Slight injuries of one person; moderate environmental effects

S 2: Severe, irreversible injuries of one or several persons, or single fatality; temporary, greater harmful environmental effects

S 3: Multiple fatalities; persistent, extensively harmful environmental effects

S 4: Disastrous effects; very many fatalities

Exposure

A1: seldom to short

A2: frequent to continuous

Possibility of avoiding the hazard

G1: possible under certain conditions

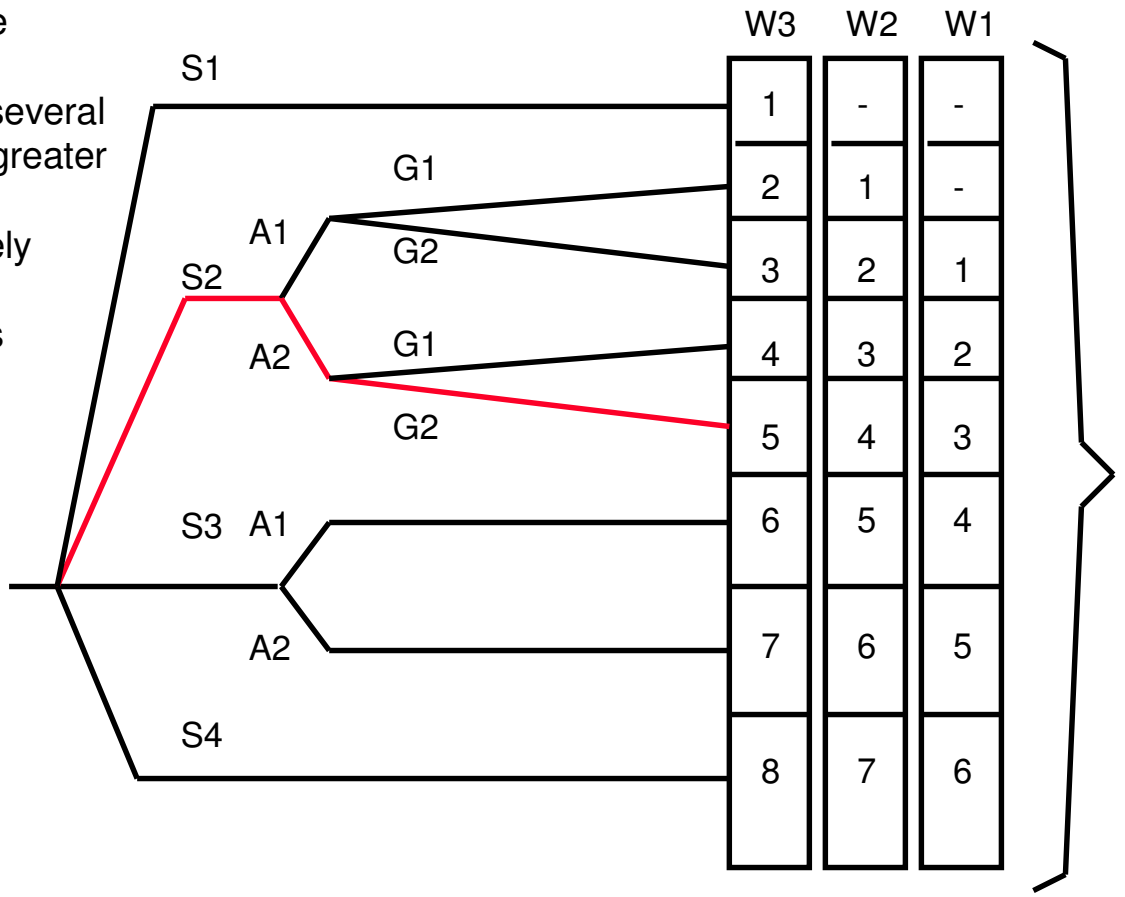
G2: less possible

Probability of unwanted event

W1: very unlikely

W2: less likely

W3: relatively high



Machines may be harmful!

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All hazards should first be identified!

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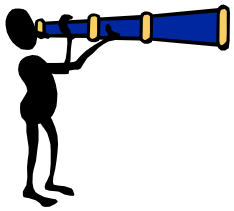


What hazards does machinery have?

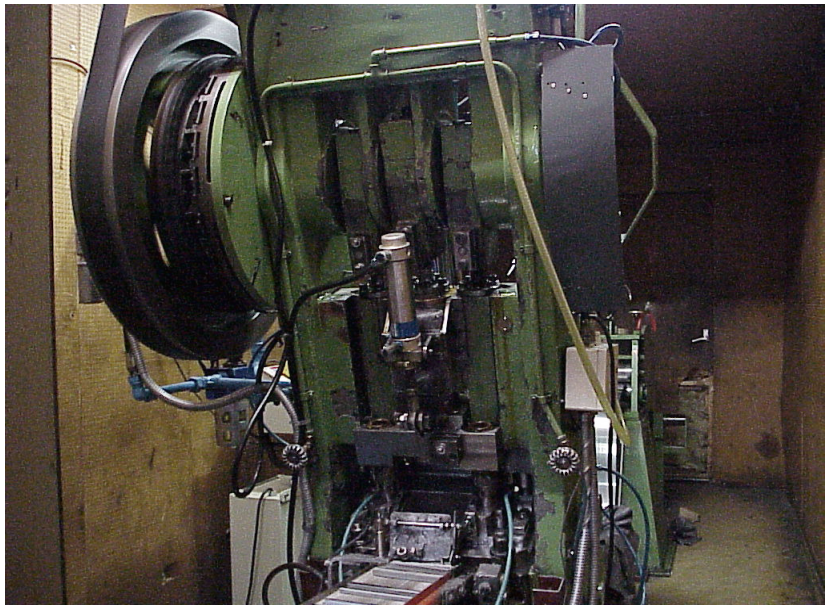
Example: metal press

Mechanical hazards:

- Crushing
- Cutting
- Shearing

See also ISO 12100-1

What hazards does machinery have?



Example: metal press (back-side)

Other mechanical hazards:

- Drawing in
- Entanglement
- Friction

See also ISO 12100-1

Other types of hazards on machinery

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- Electrical hazards: electric shock, thermal radiation etc.
- Thermal hazards: burns, scalds etc.
- Noise hazards: hearing loss, fatigue etc.
- Others

See also ISO 12100-1

Risk reduction on a machine

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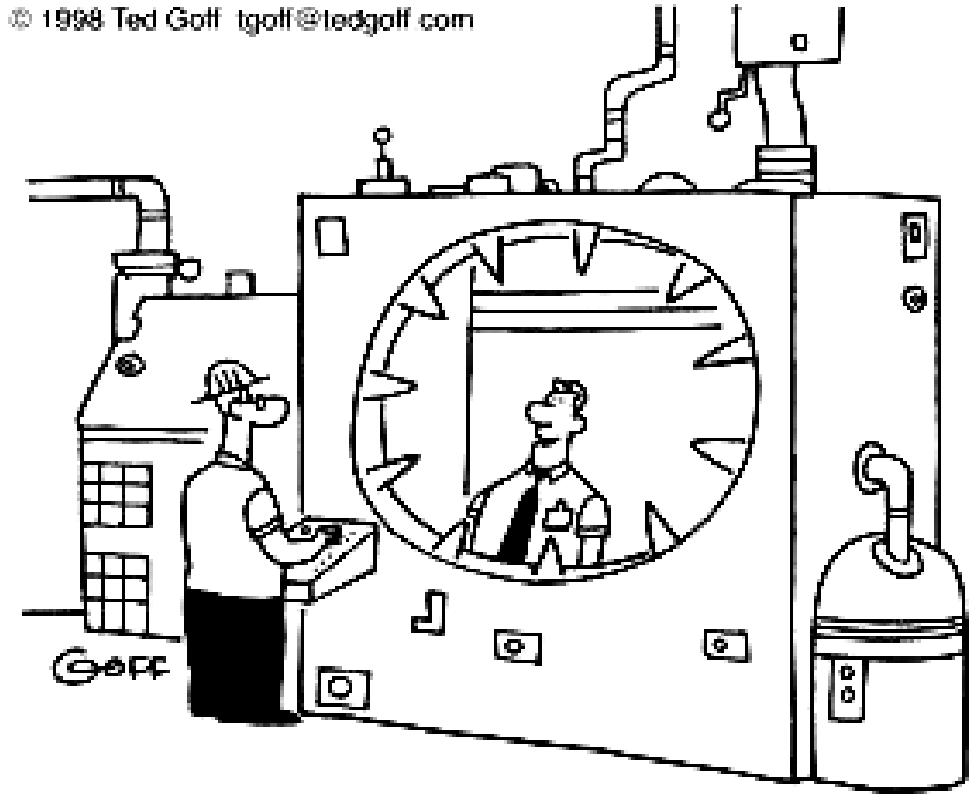

"Okay, I've put the warning signs inside the grinder. You can turn it on now."

Putting up warning signs

is NOT the first step!

Most effective order* of risk reduction

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Step 1: Change design and eliminate the hazard source

Step 2: Implement safeguards

Step 3: Implement personal protection equipment

Step 4: Inform the user about residual risks and take organizational measures

* Mandatory in some country legislations

See also ISO 12100-1

Change of the design
Risk reduction step 1

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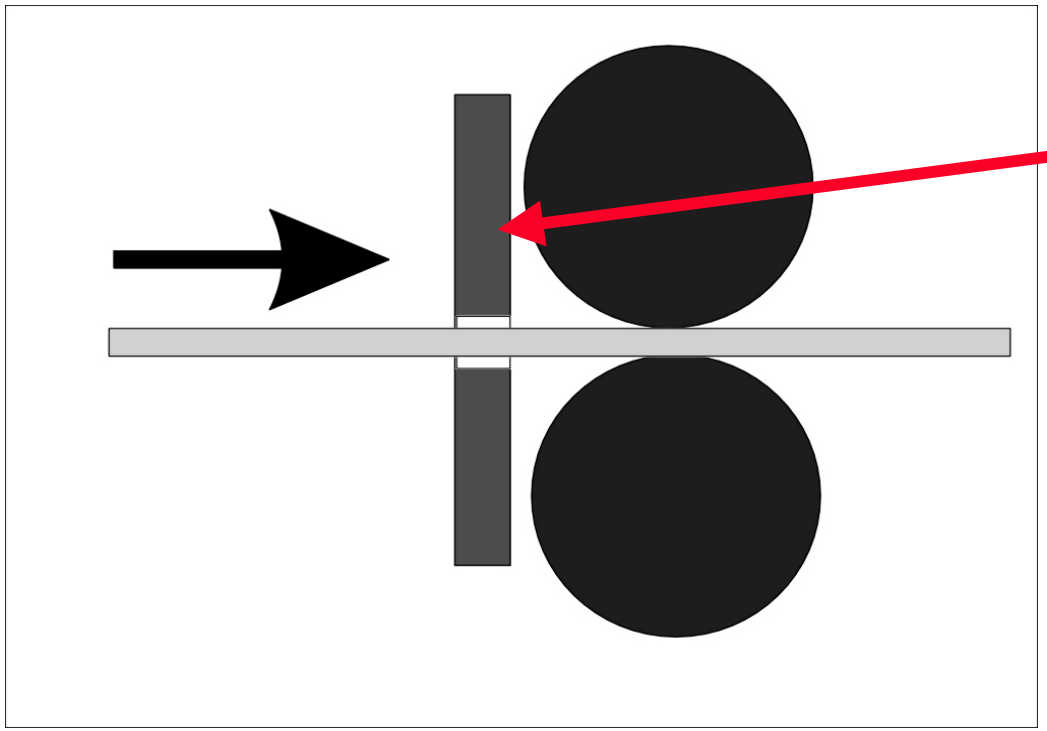
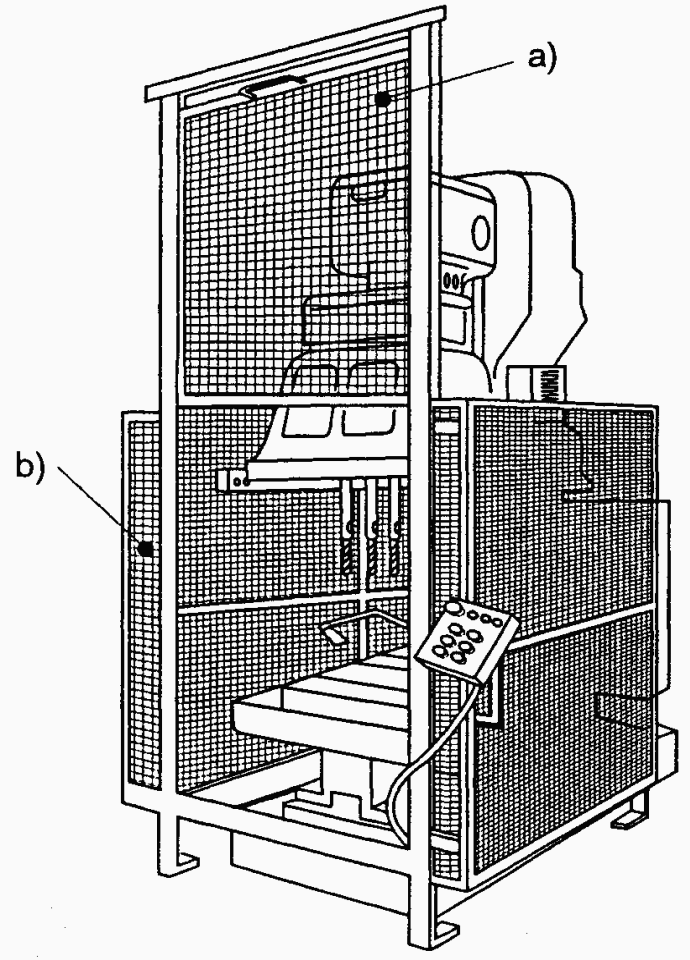


Avoid drawing in by change of the design!

Implement safeguards
Risk reduction step 2



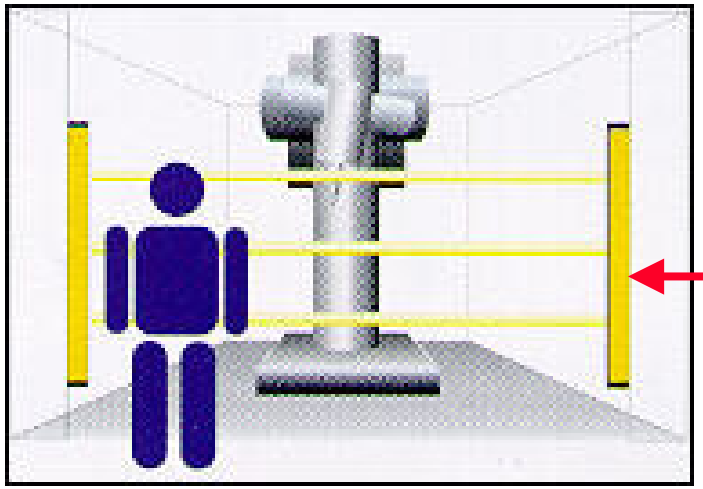
Example 1:

a) Movable guards with interlocking*

b) Fixed guards

* Safe prevention of unexpected start-up

Implement safeguards
Risk reduction step 2



Example 2:

Light curtains*

Safety mats*

* With interlocking

Implement safeguards
Risk reduction step 2

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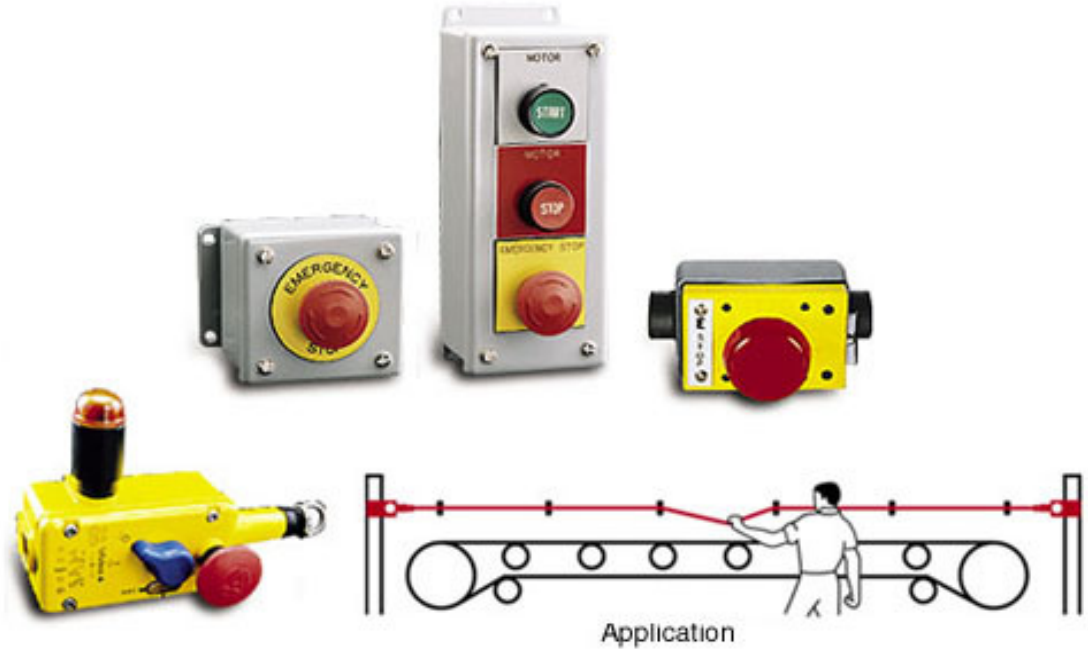
safe automation



Example 3:

Emergency stop devices*

* With interlocking

Implement safeguards
Risk reduction step 2

Example 4:

Safety strips*
Safety edges*
Safety bumpers*

* With interlocking

Implement safeguards
Risk reduction step 2

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Example 5:

Two-hand controls*

* With interlocking

Implement personal protection equipment risk reduction step 3

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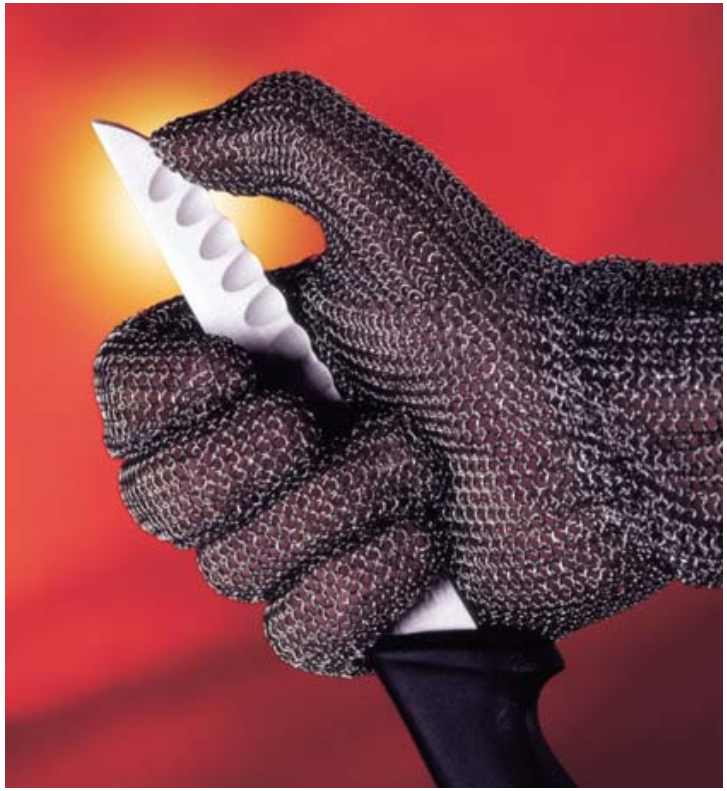


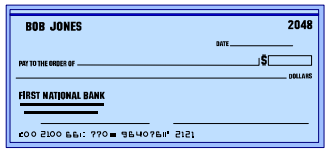
Ear protector

Safety glasses

Gas mask

Inform users and take organizational actions risk reduction step 4

Fix warning signs



Create safe working procedures

Train the user(s), etc.

How do safeguards implement safety?

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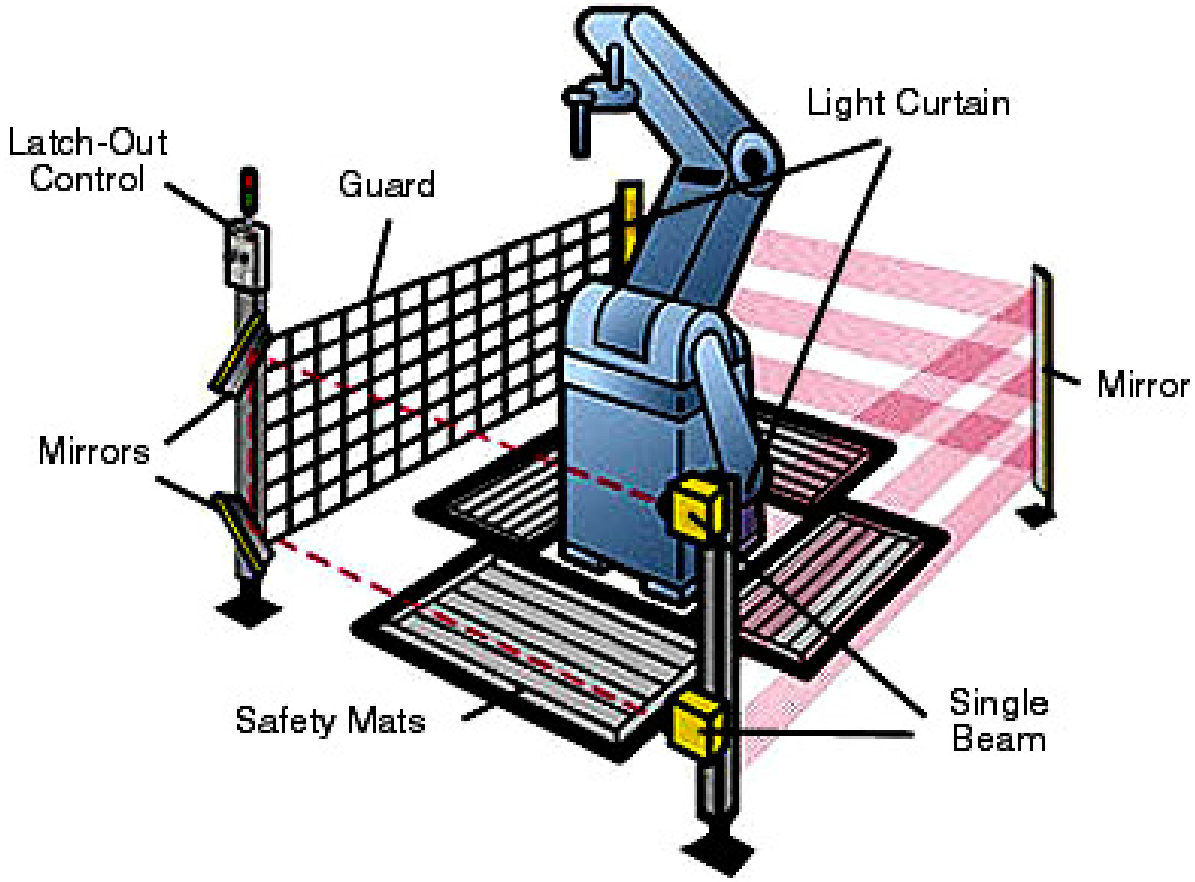
Gate Open

Gate Closed

- Movement of dangerous parts is only allowed by the control system when the gate is closed
- The hands of the operator are in a safe area

How do safeguards implement safety?



Safeguarded Work Envelope of Robot has Perimeter Guards, Light Devices, Safety Mats and Latch-Out Reset Unit

- Movement of dangerous parts is only allowed by the control system when all safeguards are not activated

Importance of a failsafe control system

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The reliability of the control system is very important!

- Example 1: control system with auxiliary relays
- Example 2: control system with a standard PLC* or IPC**
- Example 3, 4, 5: applying safety components

* Programmable Logic Controller

**Industrial Personal Computer

Example 1: a safeguard connected to the auxiliary relay control system

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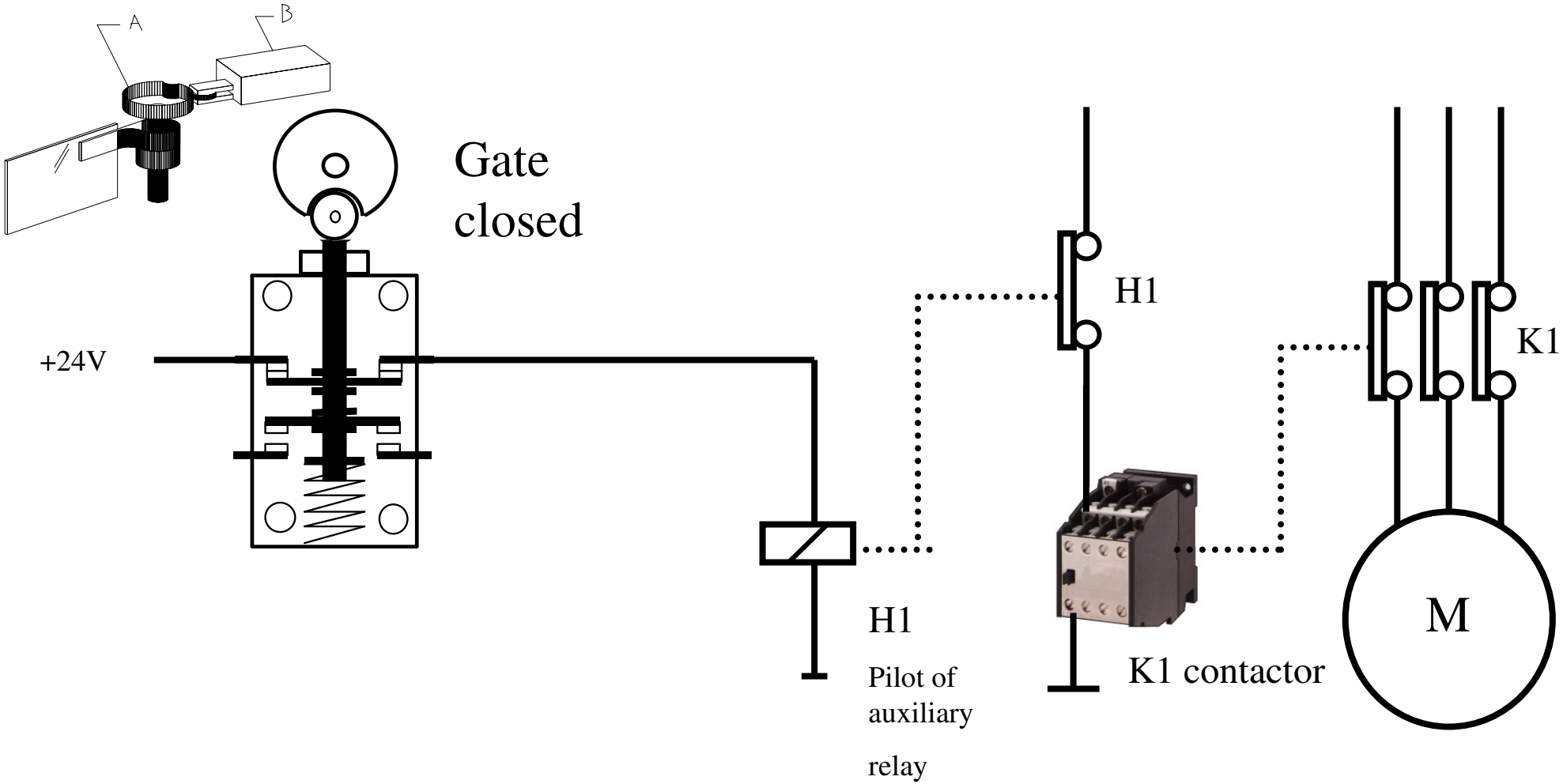

Example 1: Safety problem with one single fault!

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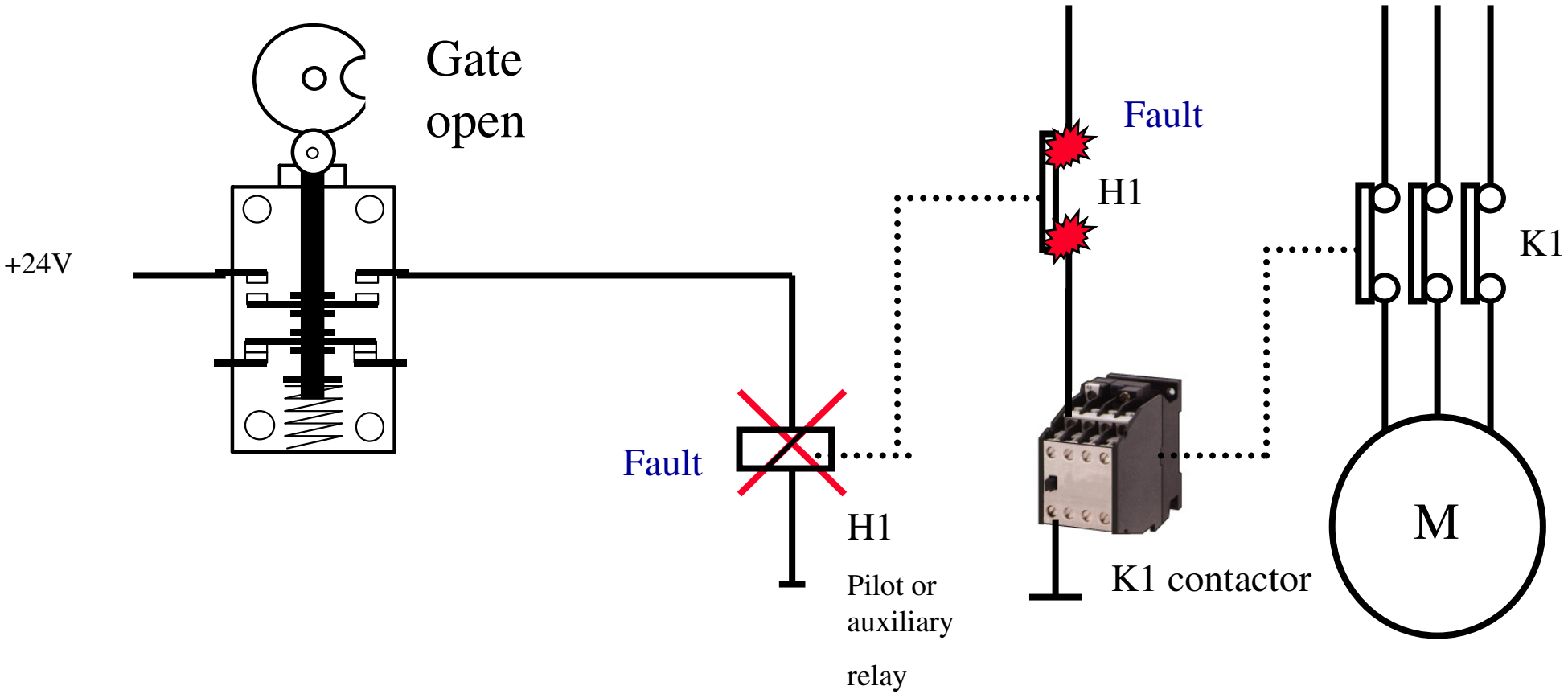
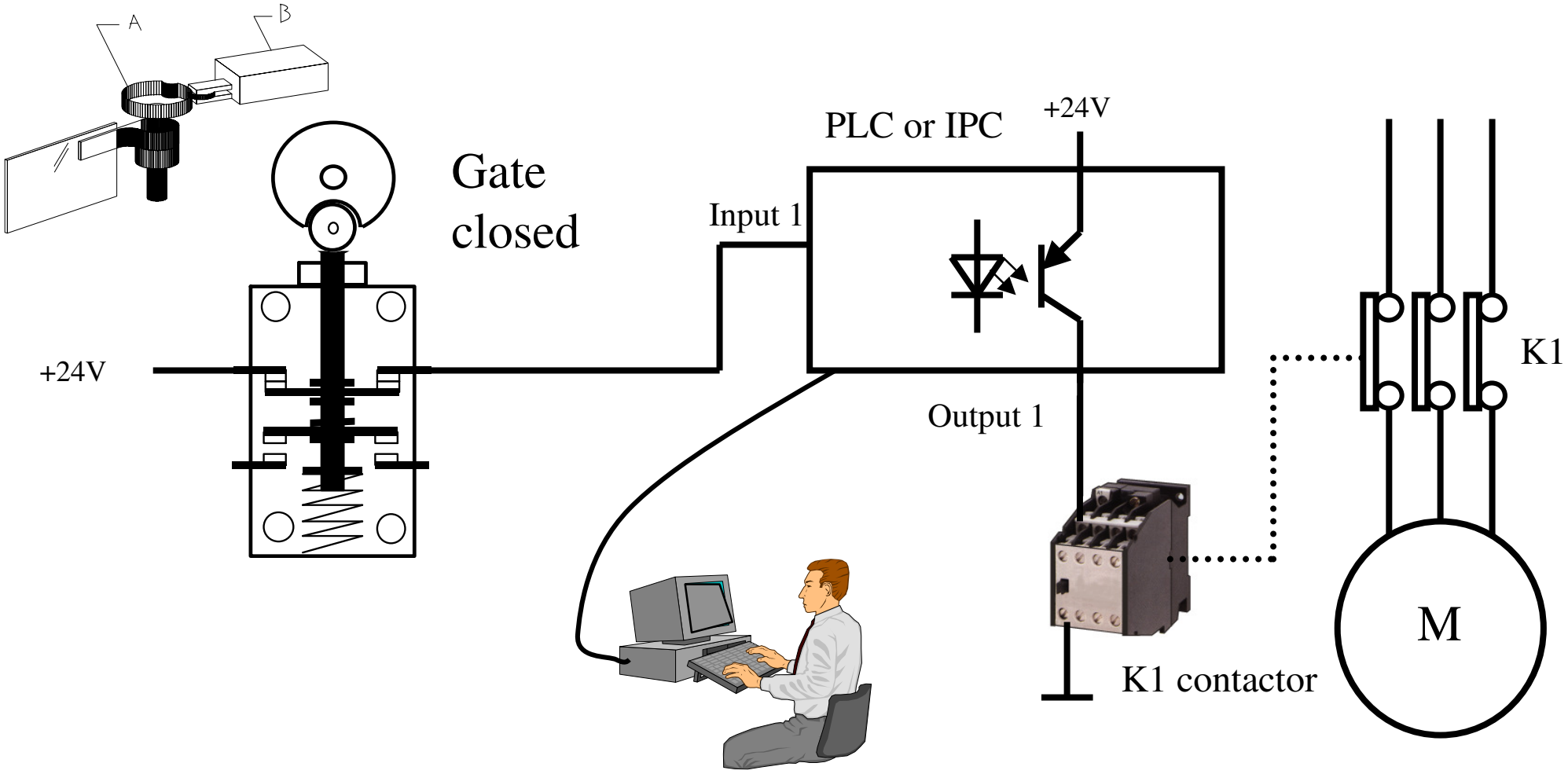


Example 2: a safeguard connected to the PLC/IPC control system



Example 2: Safety problem with one single fault!

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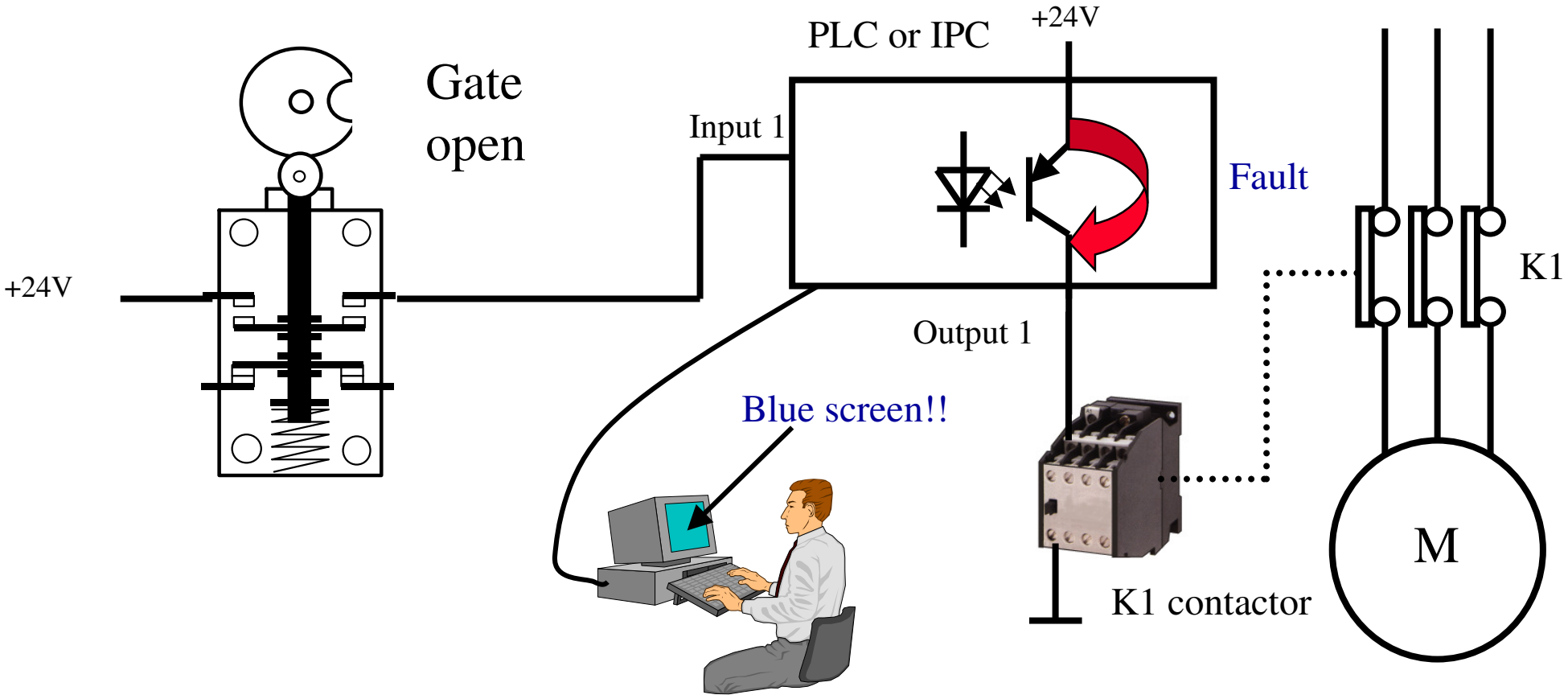
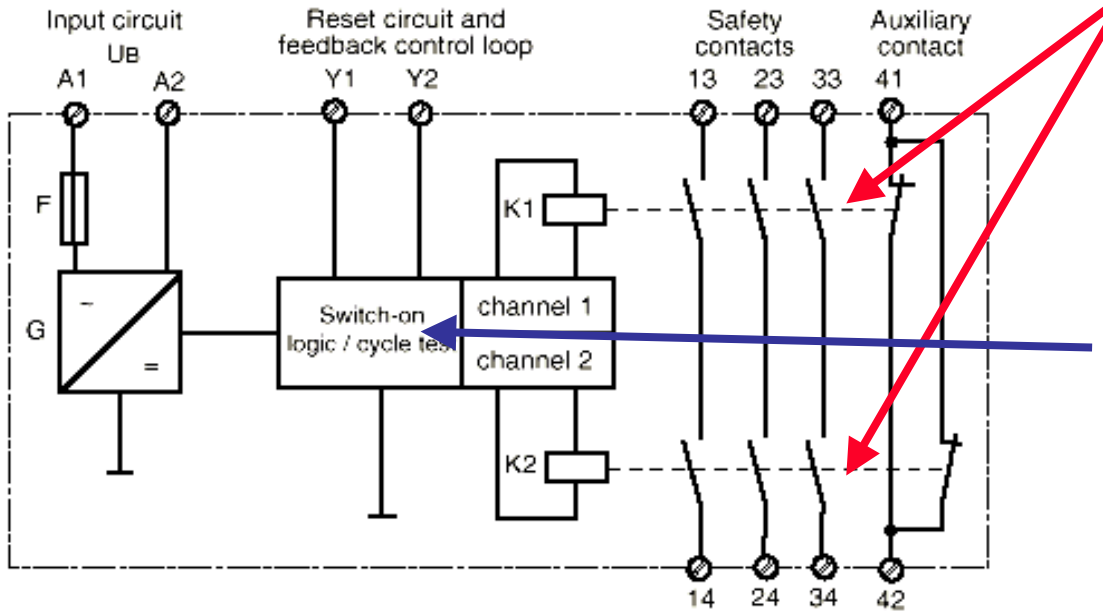


Use of special “safety components” as a pilot (auxiliary) relay

PNOZ safety relay



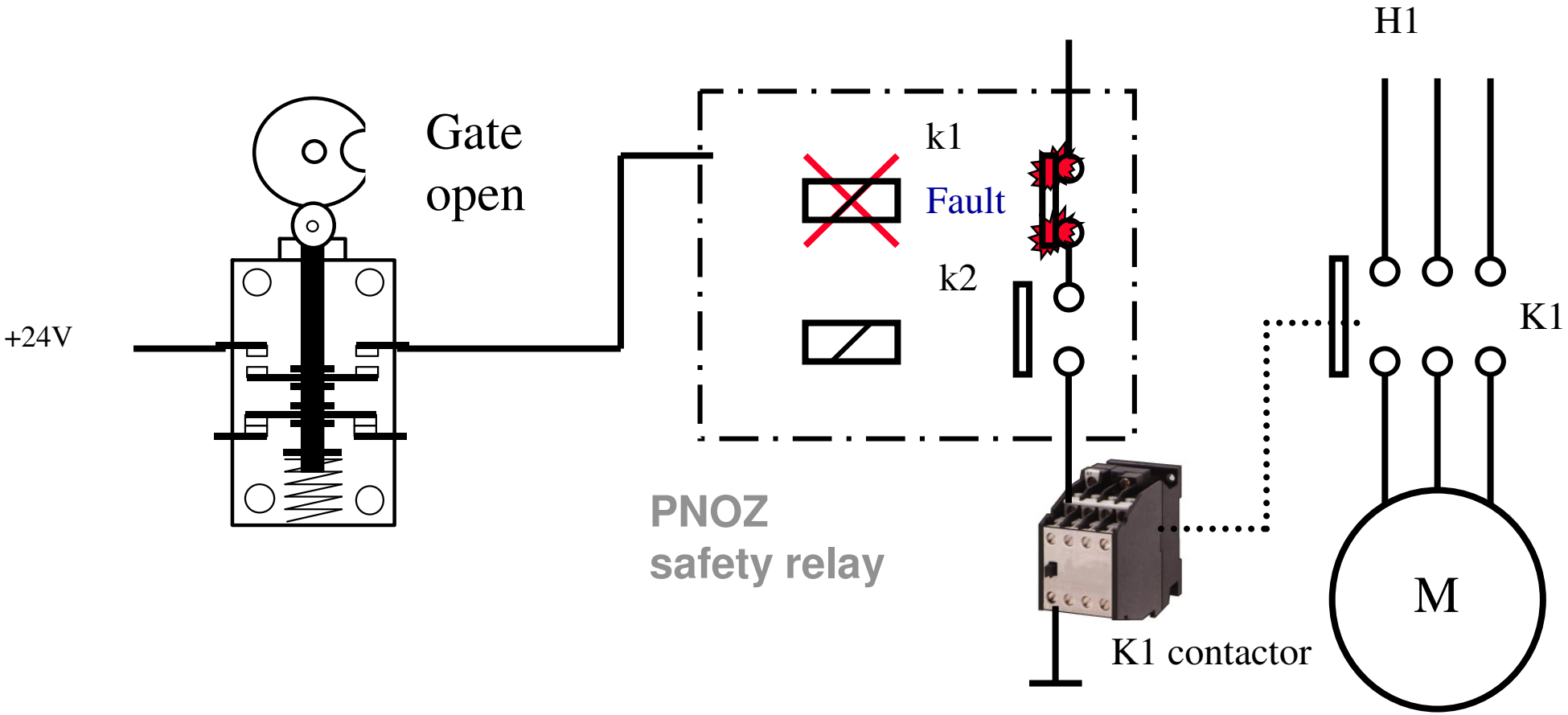
Positive-guided contacts

Redundancy

Start control

Monitoring

Example 3: No safety problem with one single fault!



Example 4: No safety problem with one single fault!

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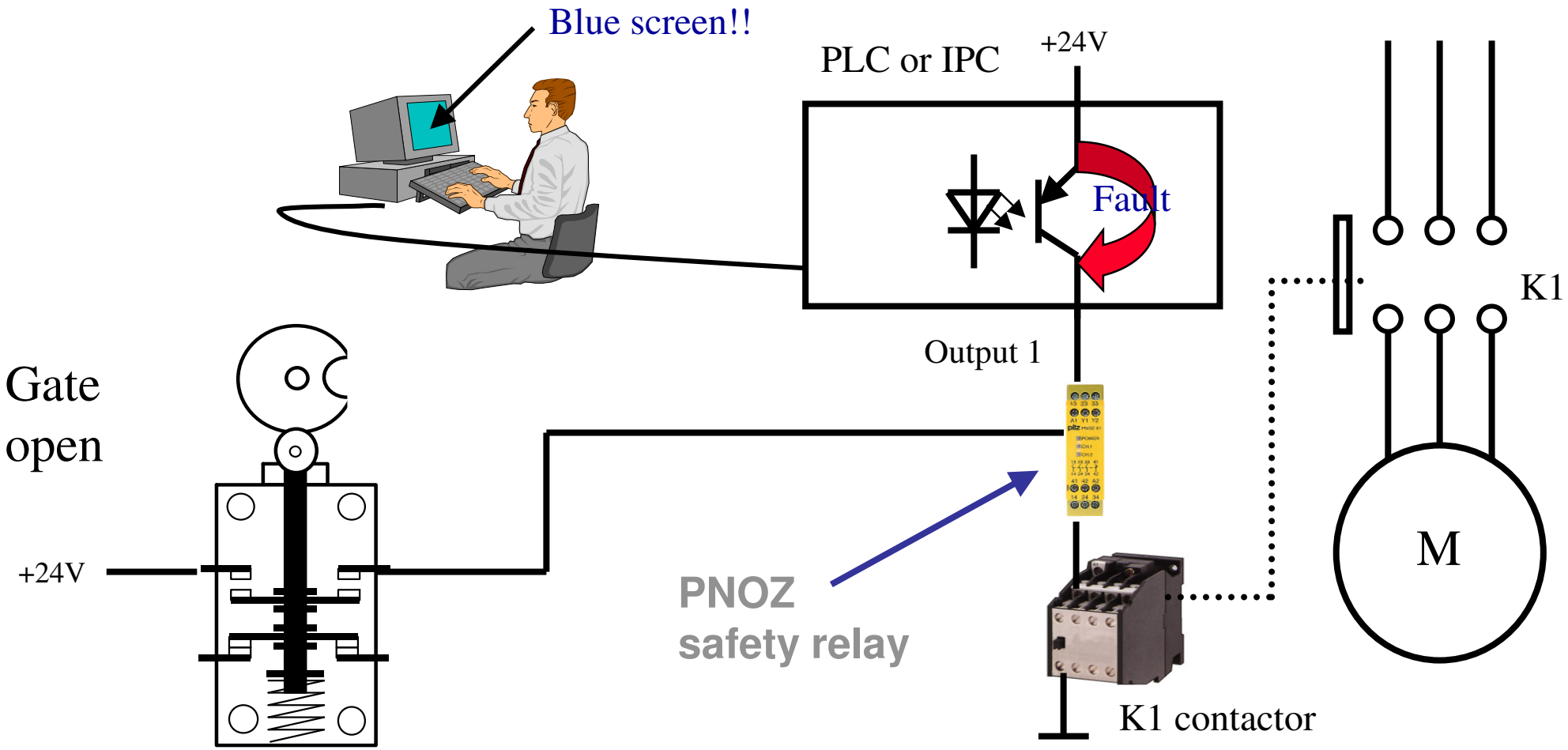
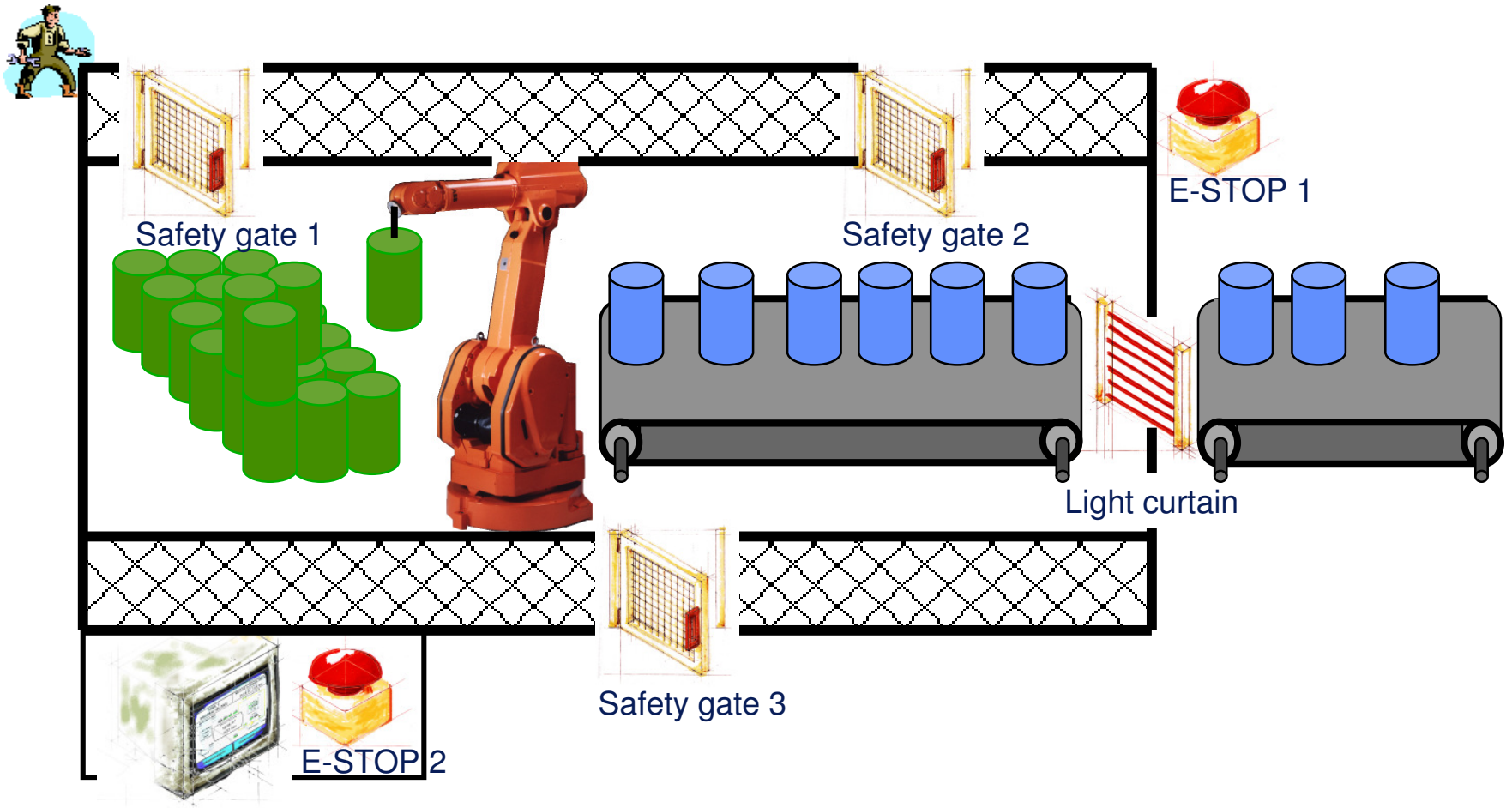


Example 5: robot cell



Machinery Safety

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- 1. Why should machines be safe?
  - Costs of accidents vs. the price of safety
- 2. What is (machinery) safety?
  - Definitions, EN safety standards.
- 3. What are safety systems?
  - Safety sensors and actuators, safety relays, safety controllers.
- 4. Applications of safety systems

What are Safety Systems?

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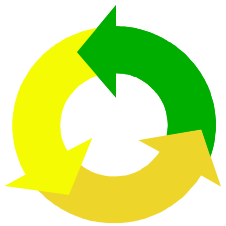
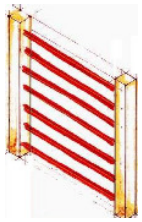
- Any technical device can fail and most parts will eventually fail. Thus, the question is not if, but when!
- This event must not lead to a dangerous situation!
- The reaction to a fault makes the difference between standard technology and safety technology.
- If a fault occurs in a standard control (switch, relay, PLC or PC) the outputs are in an undefined state.
- If a fault occurs in a safety control unit (PNOZ, PSS) the outputs are in an pre-defined, safe state.
- Safety controllers must be single-fault tolerant and fail-safe!

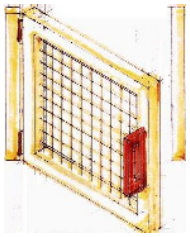
Safety Systems: Actuators



Emergency-Stop



Light curtain



Safety gate

Safety mat and bumper

Two-hand control

Why Safety Relay Technology?

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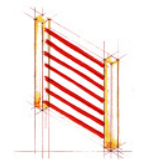
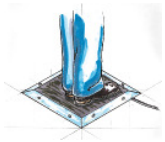
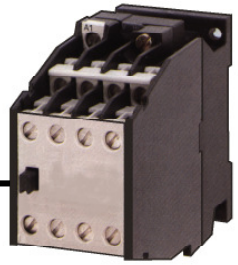




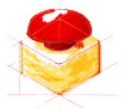


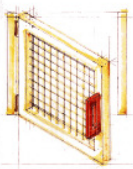
RELAY

- Maximum: 1 Million cycles
- 600...1000 cycles per day
- 300 days per year:
  180.000...300.000 cycles per year

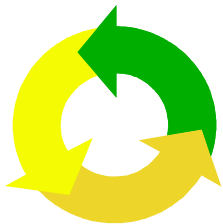
Lifetime: 3...5 years !

After 3...5 years DANGEROUS SITUATION !





SAFETY RELAY



- Detects faults
  - in the button
  - in the safety circuit
  - of short to earth
- Safe automation by means of:
  - special internal wiring
  - specific relay technology

Safe control technology – PNOZ® safety relays

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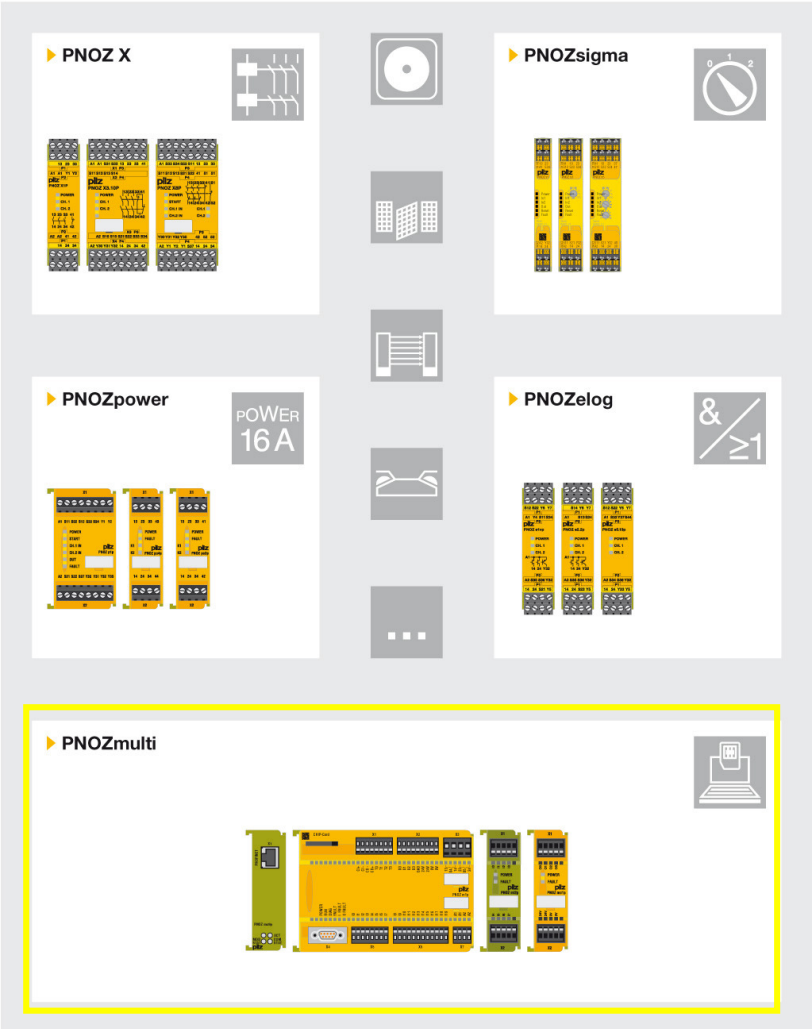

- **PNOZ X**
  - Customised safety for each function, electromechanical, volt-free, AD/DC versions
- **PNOZsigma**
  - Maximum function in minimum width, selectable operating modes, diagnostics in seconds
- **PNOZpower**
  - High loads from 8 A to 16 A, switch motor loads safely, modular output contacts
- **PNOZelog**
  - Linkable, non-wearing, extended diagnostics
- **PNOZmulti**
  - Freely configurable, multifunctional, modular

Safety Relays:
PNOZ Sigma Range

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base units

Contact expander modules

PNOZmulti – as simple as a PNOZ, flexible like a controller

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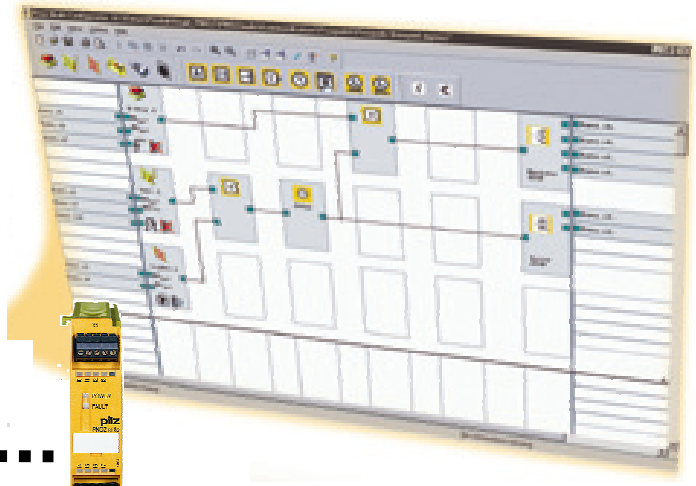
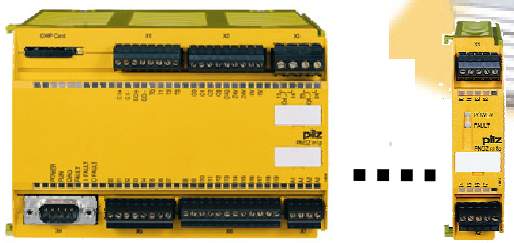


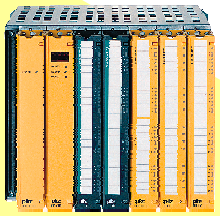


COMPLETE Safety & Control AUTOMATION

PNOZmulti modular safety system

PNOZ
safety relays

+



programmable
safety systems PSS

Pilz offers a universal concept

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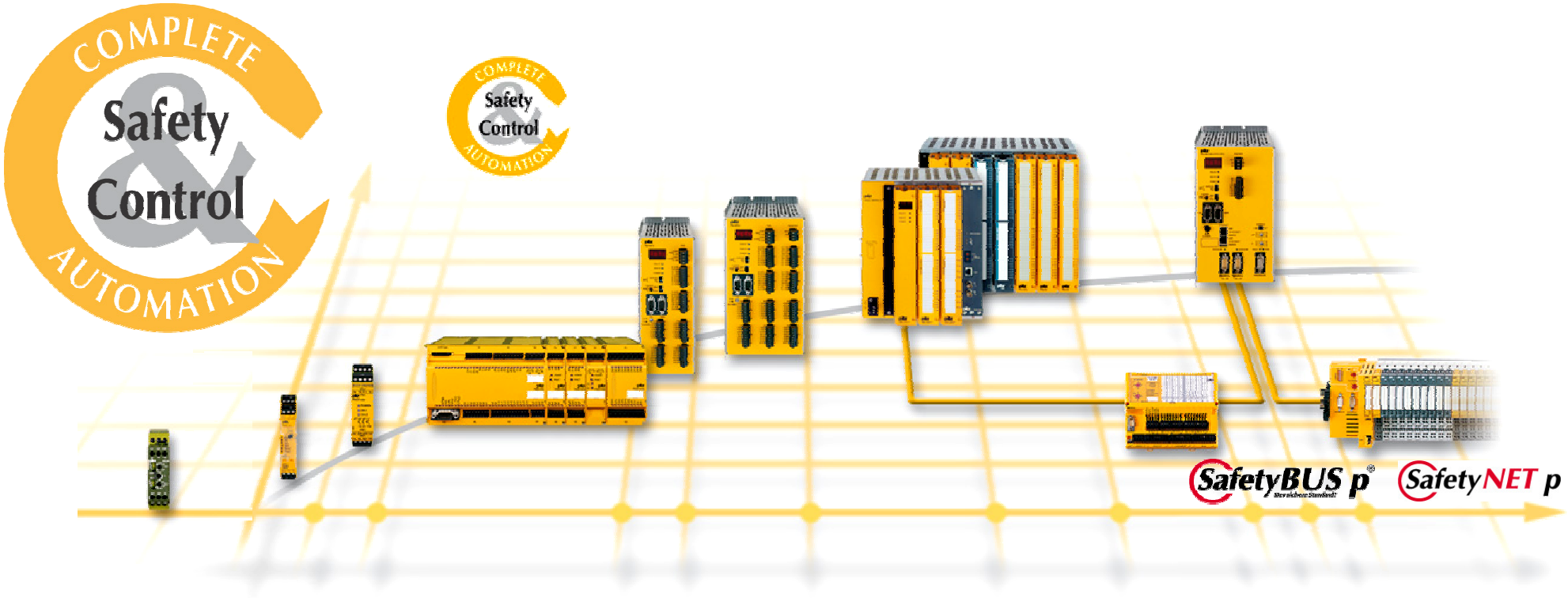
- PNOZmulti - economical for monitoring 3 or more safety functions



What makes the programmable Safety Systems (PSS) safe?

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- Redundancy
- Dual channel diversity
- Cyclical self-check
- Separate memory space
- Watchdog
- Voltage monitoring
- No wearing parts

Tested/Approved Software Blocks

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- For all safety and standard functions, as well as for complete machines
- Significant reduction in the test time for the software and for TÜV, BG approval etc.
- Enhanced security for your process and for your program function
- Manipulation/unauthorized editing can be excluded
- All you need to do is to set parameters

PSS range overview

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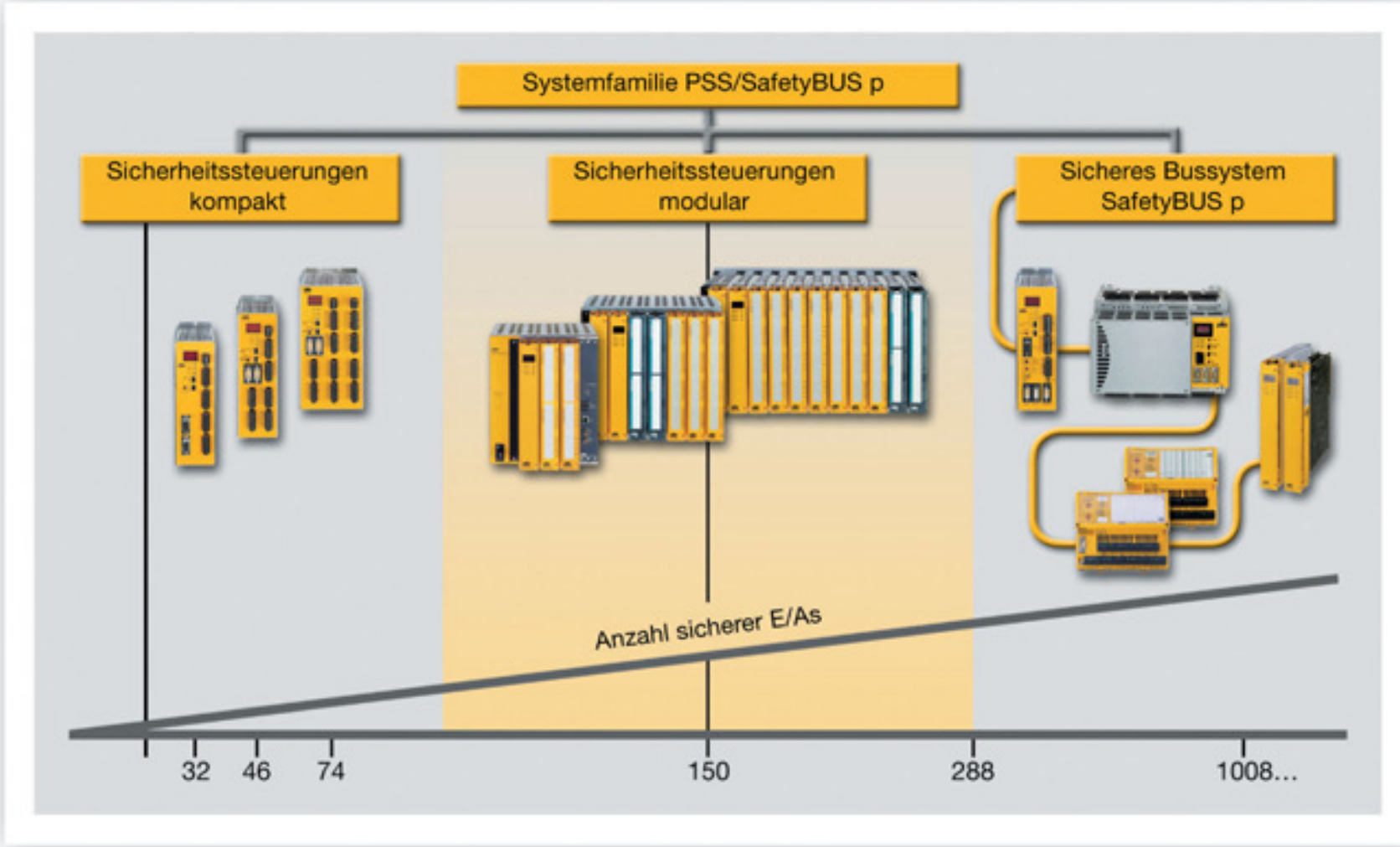

SafetyBUS p - safe networking

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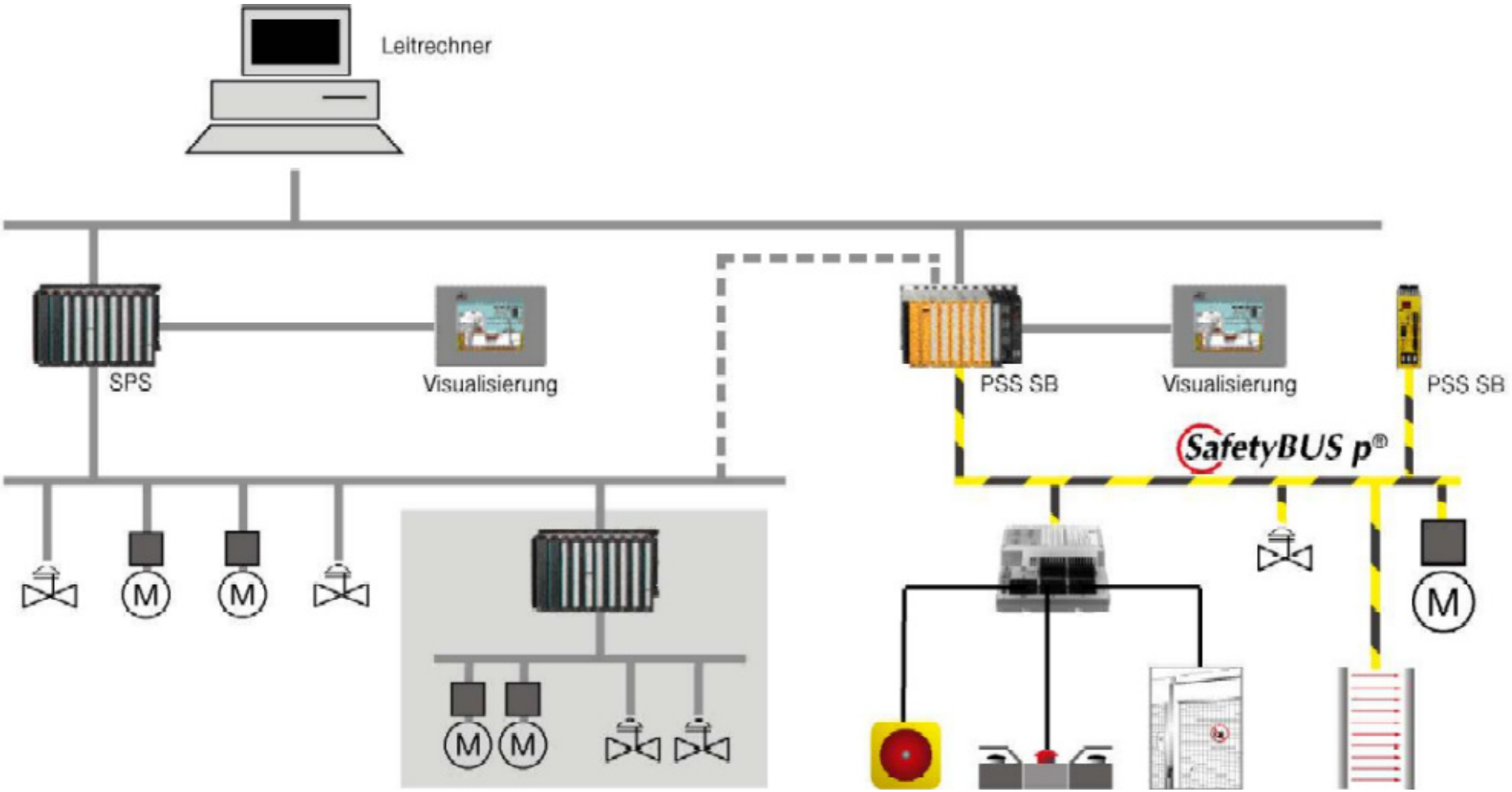

Application of Safety Systems

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Application of Safety Systems

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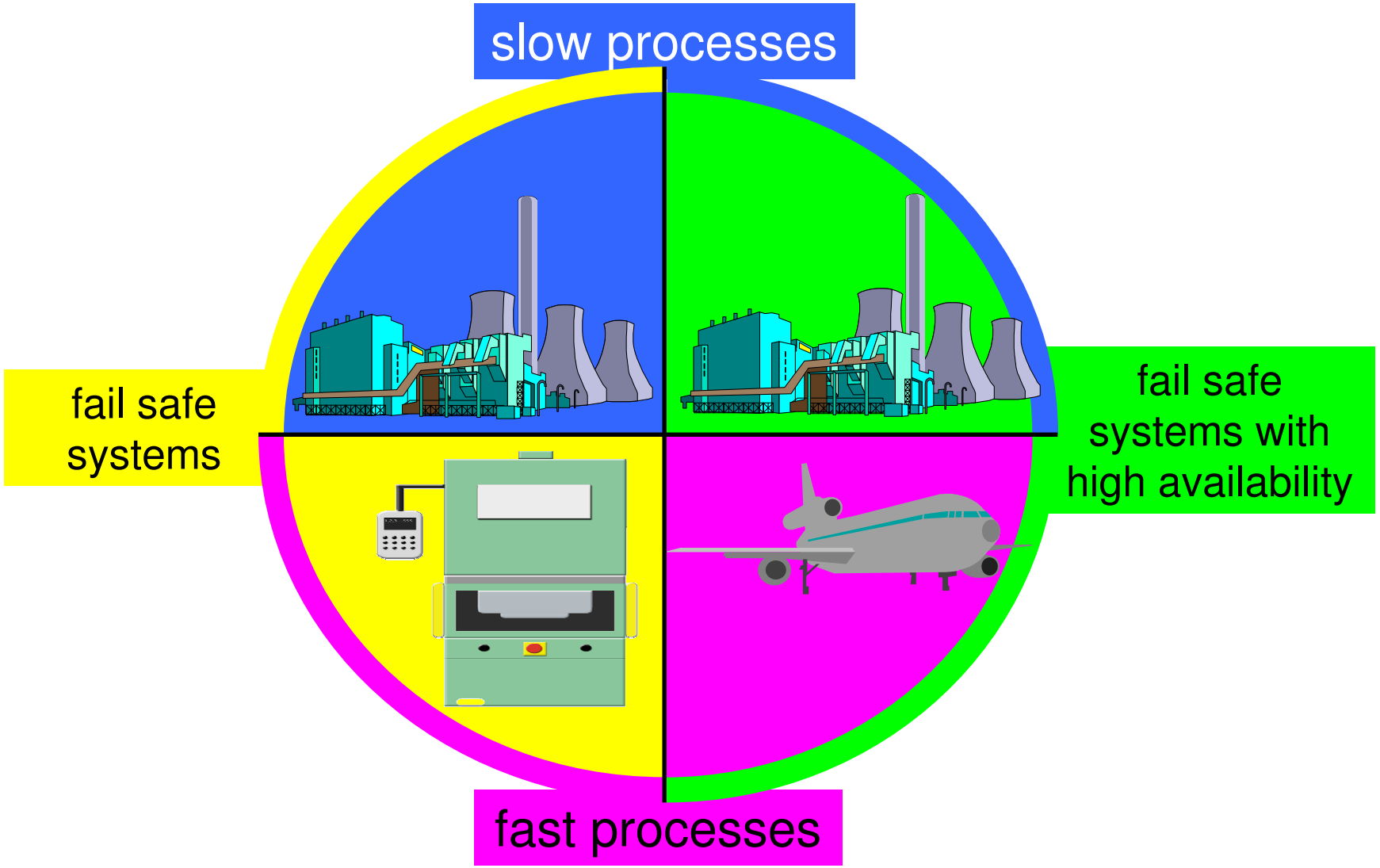

The optimum safety solution for each and every requirement

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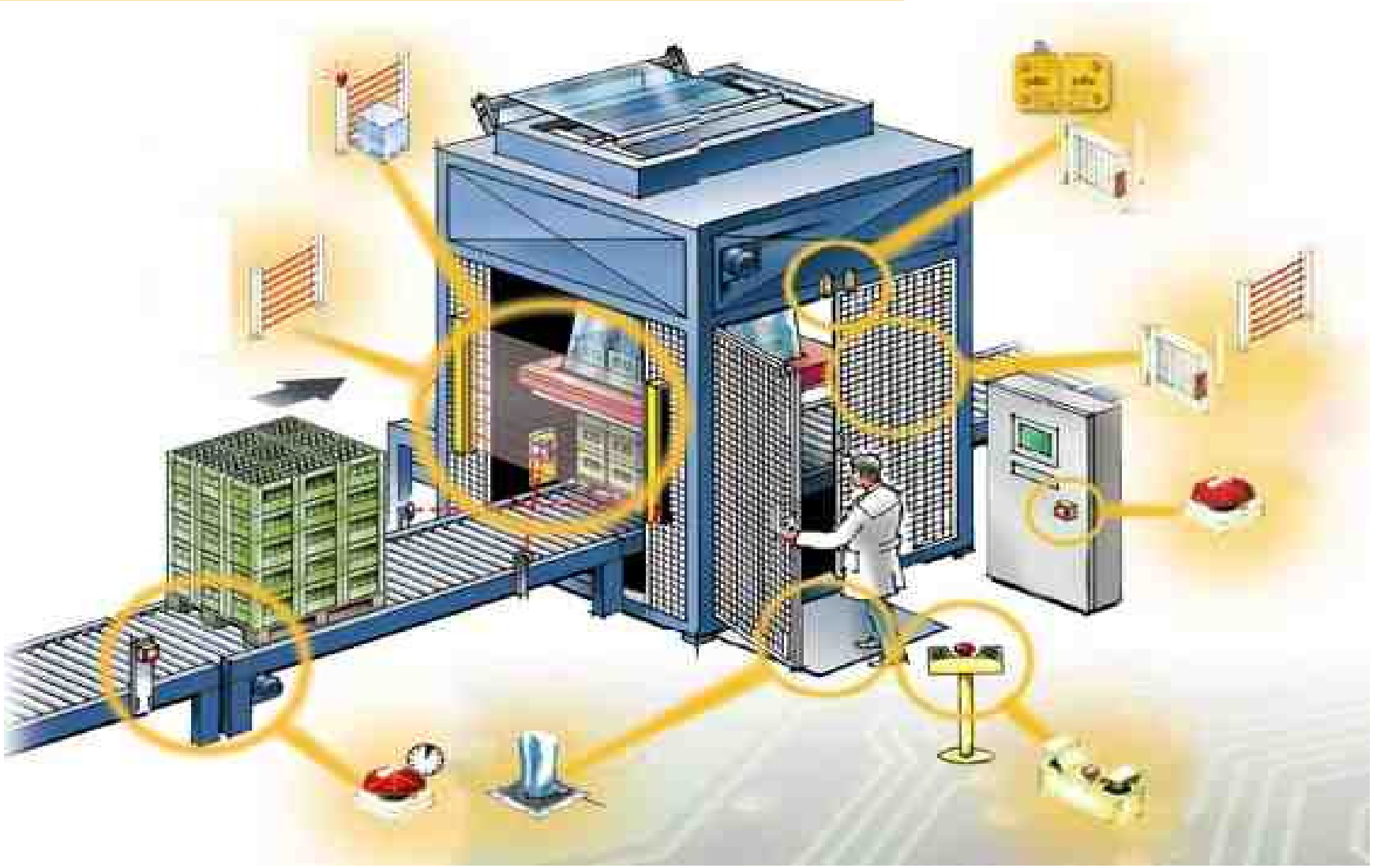

Applications

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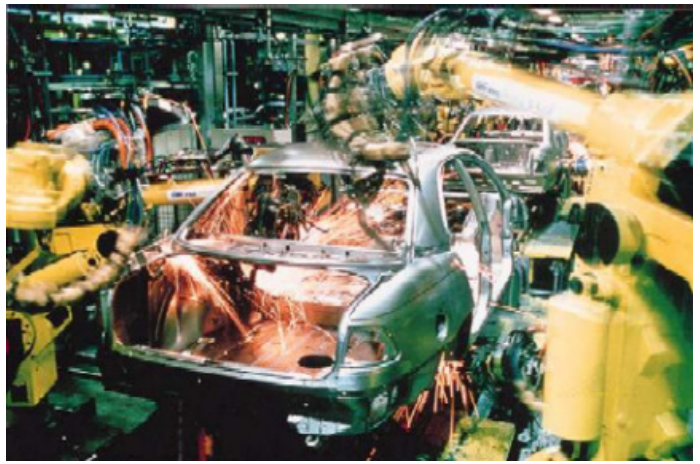
Presses

Palletising



Robot lines

Applications

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Cable cars

Amusement rides

Power plants

Applications – Airports
Inchon, Korea

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Applications – Burner Control

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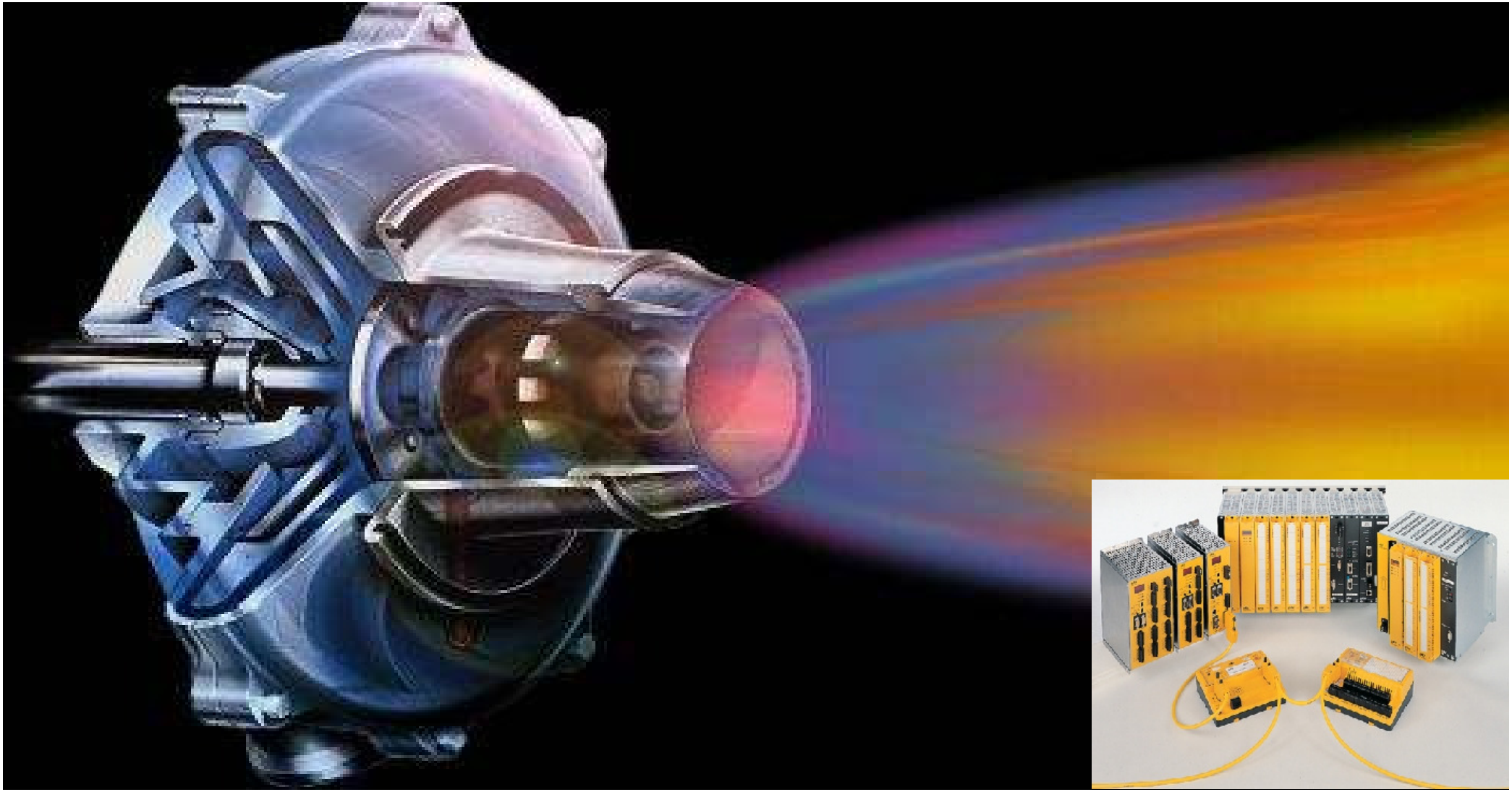

For your information: Websites about safety (1)

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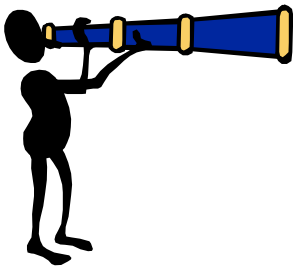

Websites of the European community:

http://europa.eu/
http://europa.eu.int/comm/enterprise/index_en.htm

European laws:

http://eur-lex.europa.eu/en/index.htm

Harmonized Standards:

http://ec.europa.eu/enterprise/newapproach/standardization/harmstds/index_en.html

New Approach Directives

http://www.newapproach.org

European Agency for Safety and Health at Work

http://osha.europa.eu/er

For Your Information: Websites about safety

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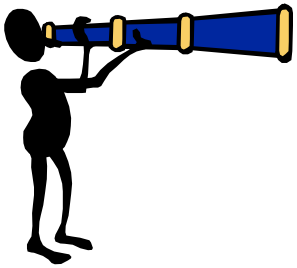
European Standardisation



- http://www.cenelec.org
- http://www.cenorm.ch

International Standardisation

- http://www.iec.ch
- http://www.iso.ch

For Your Information: Websites about safety

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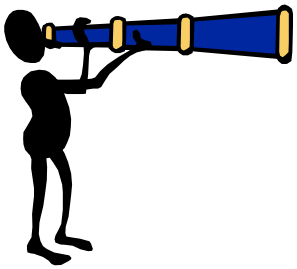
Commercial websites



www.pilz.com

SafetyBUS p®
Der sichere Standard!

www.safetybus.com

For Your Information:
Books on machinery safety

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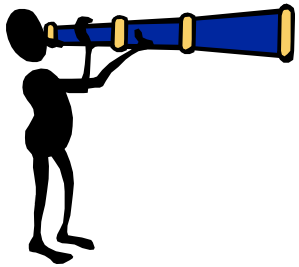

"Useful facts in relation to Directive 98/37/EC"

ISBN 92-828-6653-X

"Comments on Directive 98/37/EC"

ISBN 92-828-5659-3

(see website of the European Committee)

Why safety? – Summary

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Safe Automation protects your Investment

- Accidents are expensive → cost reduction
- Downtime is reduced → smooth production
- Diagnosis easily possible → high availability
- Imposes diligence and continuity → quality standard
- State-of-the-art equipment → market perception
- Sense of responsibility → overall reputation

Modern products are safe products