EPSC Conference on Process Safety
Cologne, Dec. 11/12, 2019

EPSC Human Performance Work Group:

Collection of Usefull Practises to avoid 'Human Error' Incidents

Hans Schwarz, Dec. 2019

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THE PROCESS SAFETY NETWORK

EPSC work group ‘Human Performance’

- Started March 2018, met 6 times
- Classification of human error types
- Example incidents from several companies
- **Main output:**
  List of ‘Useful Practices’, collected from several companies

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Example Incidents

- Participating companies shared typical Process Safety Incidents with human error background
  - Valves left open, confusion of equipment, flanges not correctly mounted, bypassing of interlocks,.....

- Statistics from several companies showed human error as the **most frequent 'type'** of Process Safety Incidents
  - Human & organisational failure >> 50% of PSI
  - Technical failure (Asset Integrity, Design) << 50% of PSI

- Several examples in CSB reports and videos
  - E.g. Explosion at Formosa Plastics plant, 2004
  - Link: https://www.csb.gov/videos/explosion-at-formosa-plastics-illinois/

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CSB
U.S. Chemical Safety and Hazard Investigation Board
Safety Video
Explosion and Fire at
Formosa Plastics Corp. USA
Illiopolis, Illinois
April 23, 2004

Are ‘Human Errors’ causes of incidents ?

- Historically ‘Human errors’ were seen as causes of incidents
- Today, **‘Human Errors’ seen as consequences** of deeper ‘root causes’
- **Root causes** leading to **human errors** can be grounded in
  - the person,
  - the organisation of work,
  - the technical condition of plant and equipment
  - the design of plant and equipment
- Usefull practises to **avoid human error** should therefore target
  - the organisation of work
  - Automation
  - the technical condition of plant and equipment
  - the design of plant and equipment

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Classification of Human Errors

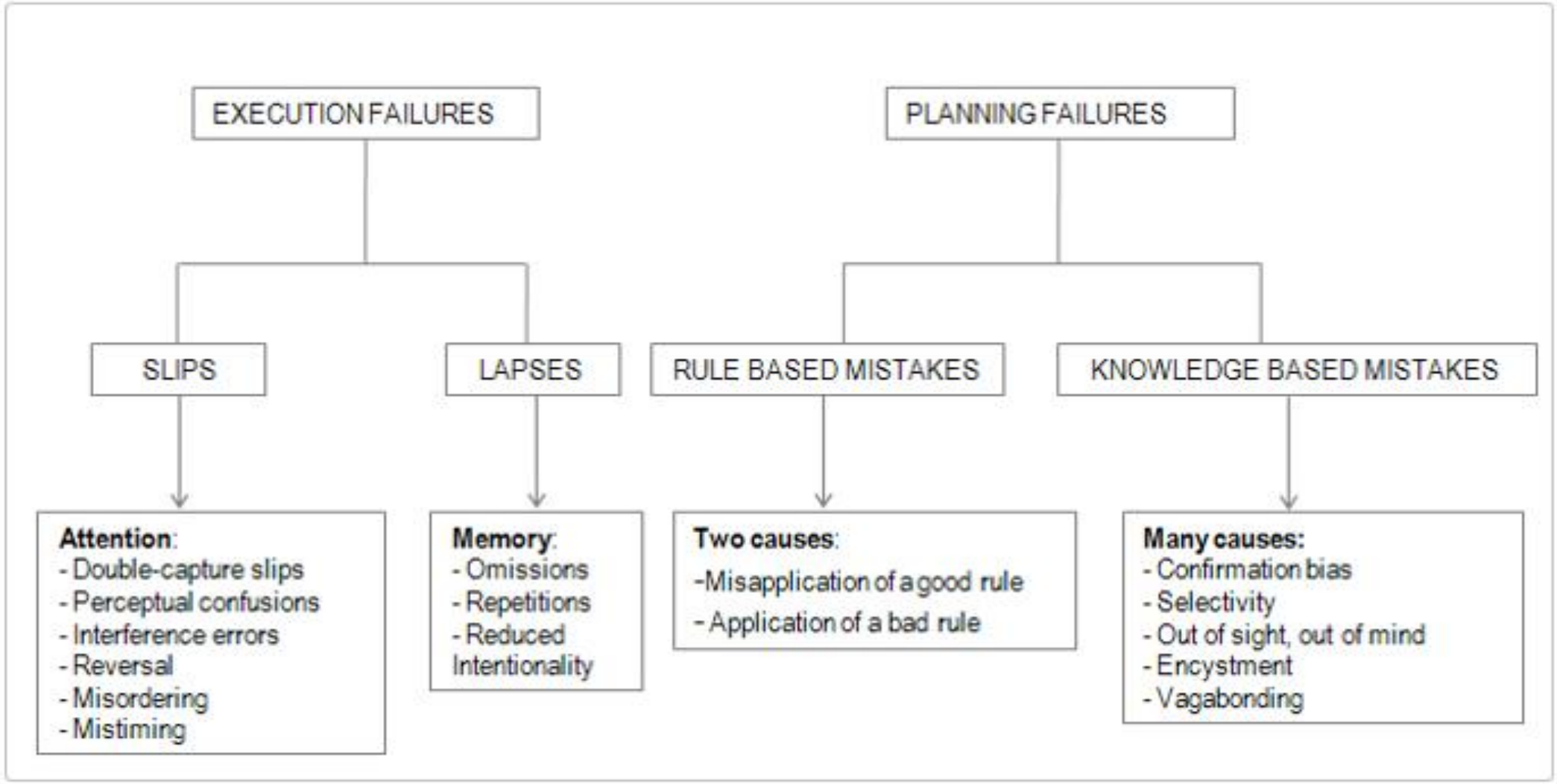

Figure 1: execution and planning failures adapted from Rasmussen

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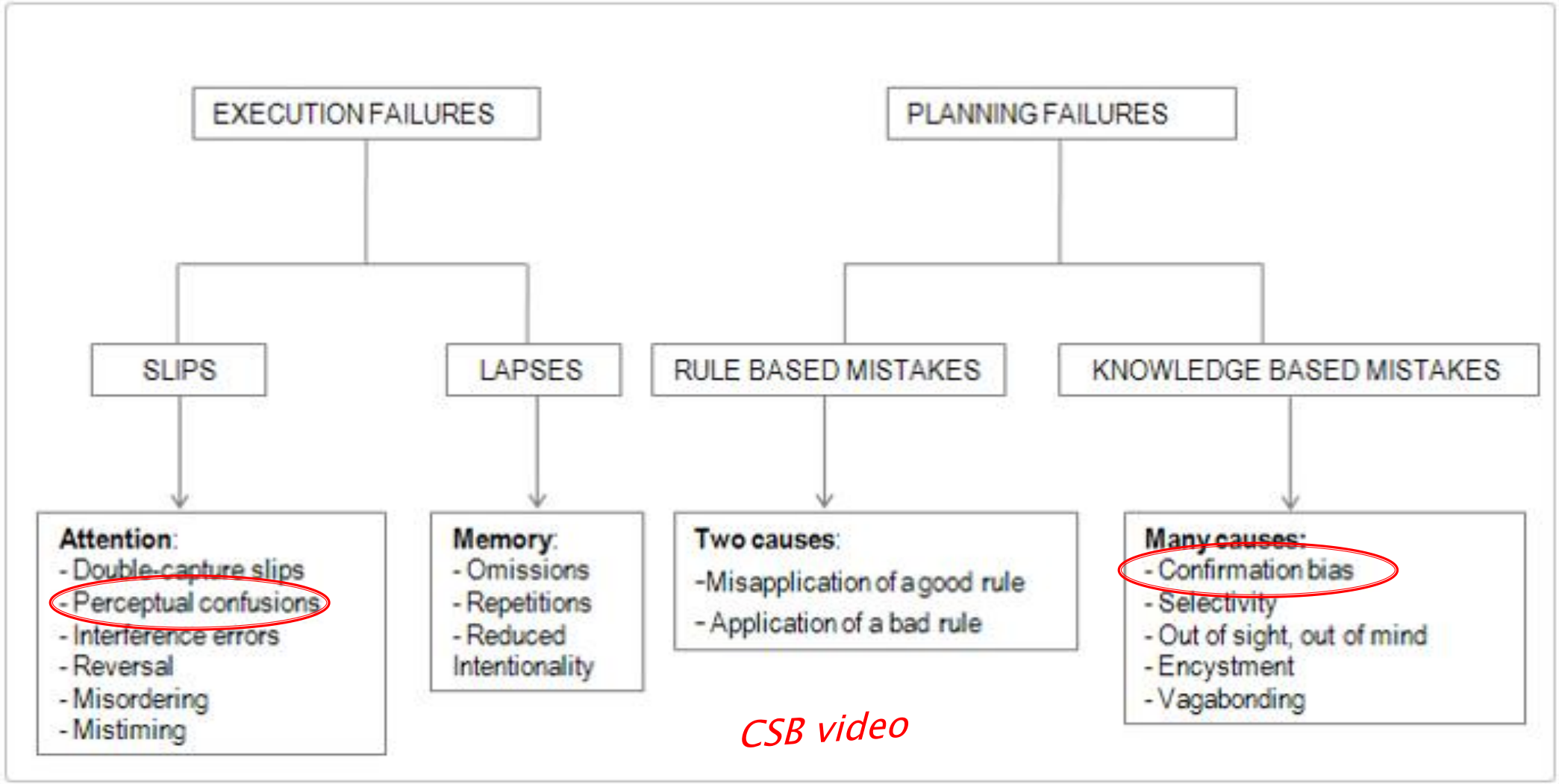
Classification of Human Errors



CSB video

Figure 1: execution and planning failures adapted from Rasmussen

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Classification of Human Errors

- **Slips:** **Execution failure** **related to attention, perception**

  E.g. Pushing the wrong button, opening the wrong flange

- **Lapses:** **Execution failure** **related to memory**

  E.g. Forgetting a step in a checklist

- **Mistakes:** **Planning failure** **related to judgement, knowledge**

  E.g Making a wrong decision, based on limited information,
  Confusing two similar looking equipments

- **Violations:** **Intentional deviation** **related to circumstances, habits**

  E.g. Normalized deviation from procedures

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  E.g. Normalization of deviation

CSB video

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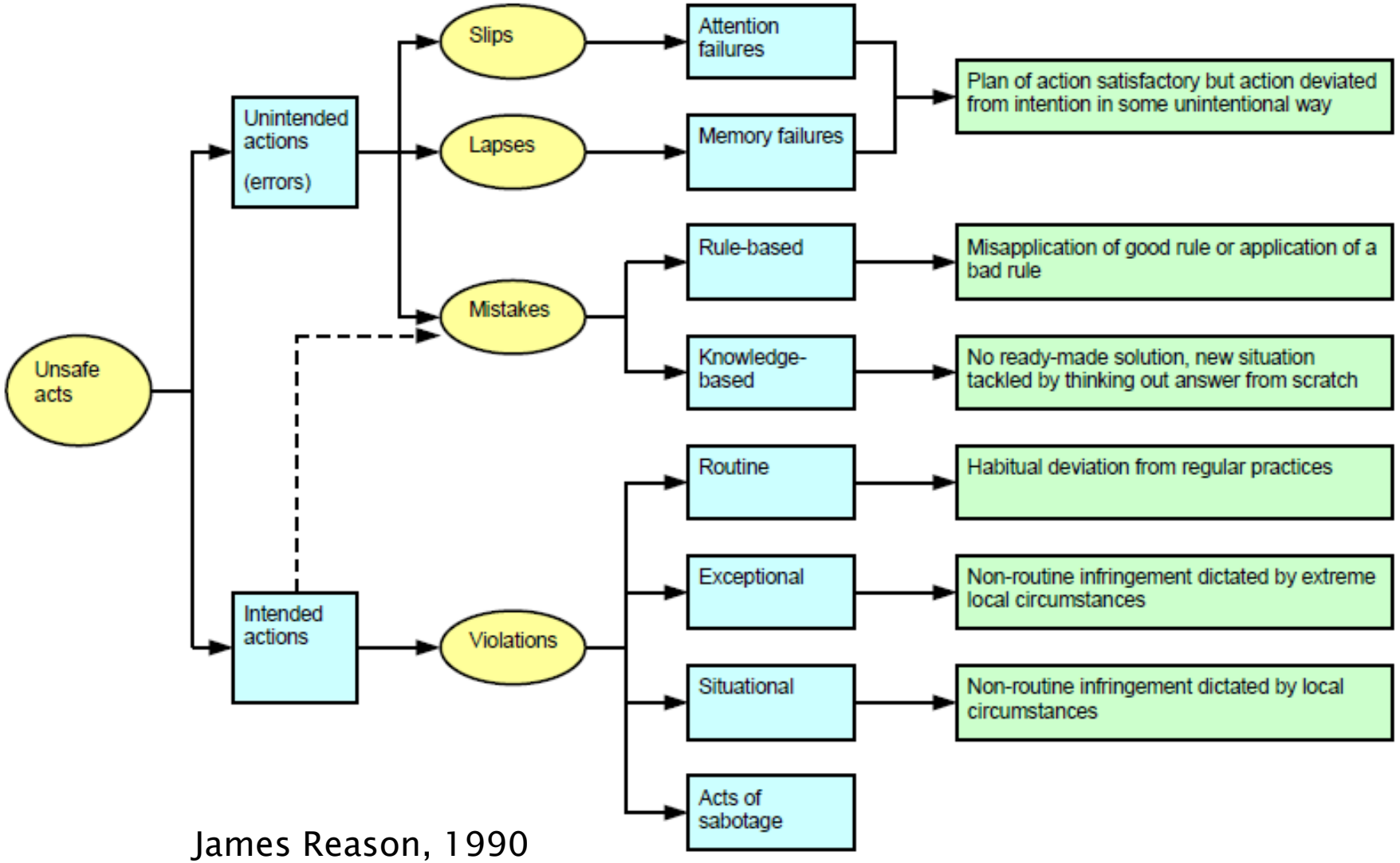
Classification of Human Errors (HSE, UK)



James Reason, 1990

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How to reduce Human Errors

Unconscious, Unintended:
→ Slips
→ Lapses
→ Mistakes

Training, Competency
Safer design, Automation,
Signs and Colours,..

→ **Useful Practises**

Conscious, Intended:
→ Violations

Leadership, Organisation

In hindsight, most such incidents are easily understood and apparently easy to avoid

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Useful Practises, sorted by Type of Incident or Equipment

- Manual valve position
- Flange leak
- Overfills
- Breaking off small nozzles
- Wrong equipment (opened)
- Equipments which invite human error
- Wrong material or chemical
- Hose issues
- Plant isolation issues
- Interlock issues
- Loading, unloading
- Organisational practises
- Competency related

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Identify Valve Positions

Problem

Manual valve left in the wrong position after maintenance, start-up, cleaning, etc. can cause incidents

Solution

- Make it easier to spot a valve in wrong position.
  Colour code for manual valve handles, e.g.
  green for normally open and
  red for normally closed
- **Tag numbers** at manual valves that correspond to procedures and P&ID
- Add a label to the valve in case of a special operation that requires a position different from normal

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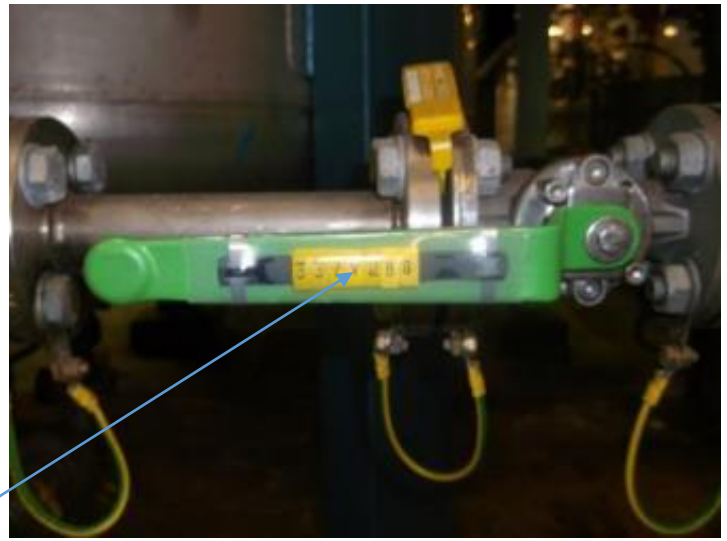
Colour coded and tagged valves (examples):



Normally Open: Green

Normally Closed: Red

LOTO to assure valve position

Problem

Especially after repairs, turnarounds and washout or purging procedures, **valves are left open**, leading to the release of a chemical

Solution

Applying **Lock-out /Tag-out (LOTO)** system will help to ensure that no valves, openings or devices are left in the incorrect position

Sign-off each item on the LOTO checklist

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Lock-out /Tag-out cards (examples):

Mechanical locks (example):

Wrong Manual Valve

Valve position

Problem

Operation of the wrong manual valve due to lack of labelling in the field, leading to potential for loss of containment.
Original labels may have not existed or been painted over.

Solution

Tag manual valves with visible **labels**;

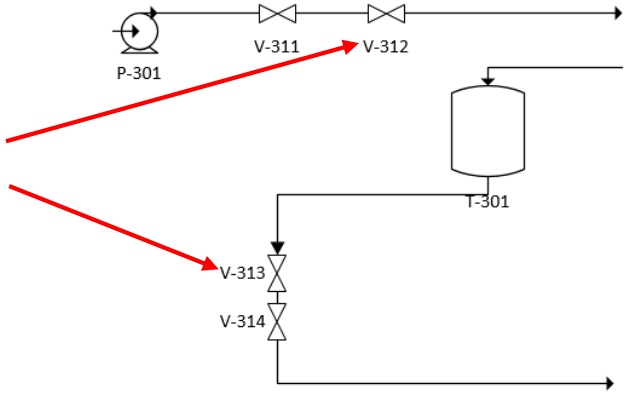
Use **numbers** from P&IDs.

Walk the line, for safety-critical isolations to verify the valve numbers in the field.

Which is the correct valve to close ?

Nothing is labelled/ tagged in the field

Valves are in a similar location but on completely different systems



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Unique Identification

Problem

Wrong manual valves in the field are **operated** by process operators or maintenance craftsmen

Solution

Unique identification of all components in the field and on P&ID.

In example **stainless steel ID plates** are used to prevent wear of inscription.
Example of unique ID: 030-CC02-HV25:

- 030: plant code
- CC02: main equipment code (centrifuge 02)
- HV25: handvalve 25

Valve position

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Enforcing the right sequence of operation

Problem

A **deviation from the sequence of steps** can result in a hazardous situation.

Solution

Mechanical interlocks can enforce the right sequence of opening/closing valves or other steps. Unique keys are used to only allow the right equipment to be operated in the correct order.

The color of the key in the cabinet in the control room shows the line-up in the field

Well known suppliers are: Netherlocks, Wermac, Castel lock, Alcatraz

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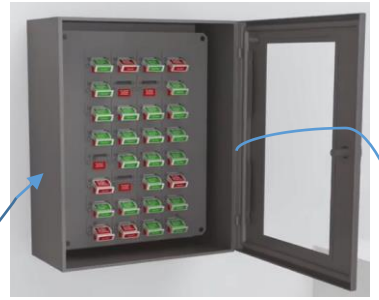
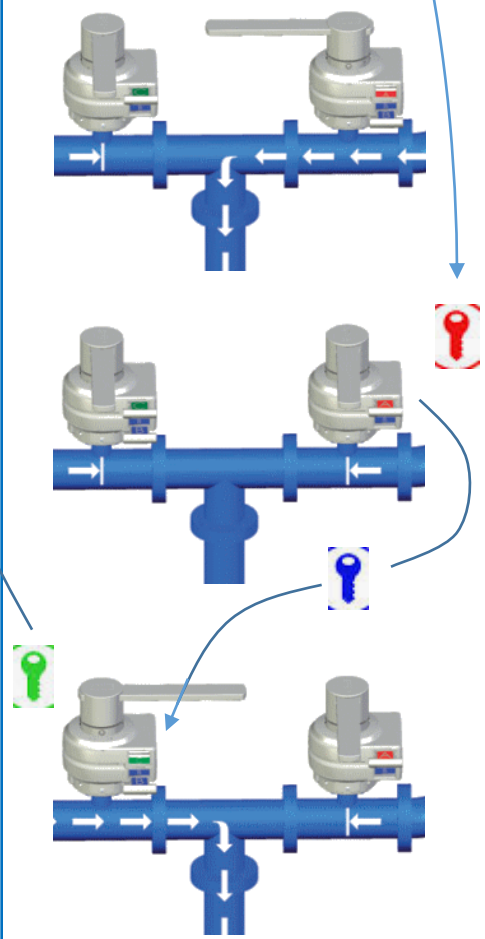
Valve position



Key cabinet in control room with unique keys



Switch over chemical:

Right valve is locked open. The blue key is trapped in the shaft. The left valve is locked closed.

Red key from key cabinet is inserted into the right interlock. Right valve can be closed and then the blue key is released. Valve is now locked closed.

Blue key is inserted in left interlock. Left valve can be opened. Then the **green key** is removed and placed in key cabinet. Valve is locked open.

Manual Valve position recorded by portable device

Problem

Manual valves in the field are in wrong position, e.g. causing release through a left open valve that should be closed.

How to ensure all valves are in correct position and how to record closing or opening ?

Solution

Operator records valve position with ex-proof **portable device**, which identifies the valve by the valve's NFC code (see yellow dot near valve). No batteries needed. Manual valve position is shown on DCS screen.

Available **also as automated** version, where the valve communicates its position by wireless FID signal directly to DCS. This requires a position indicator with battery.

The portable device, can also inform operators on the desired position of the valve, depending on plant situation (normal operation, vs e.g. lock out/tag out)

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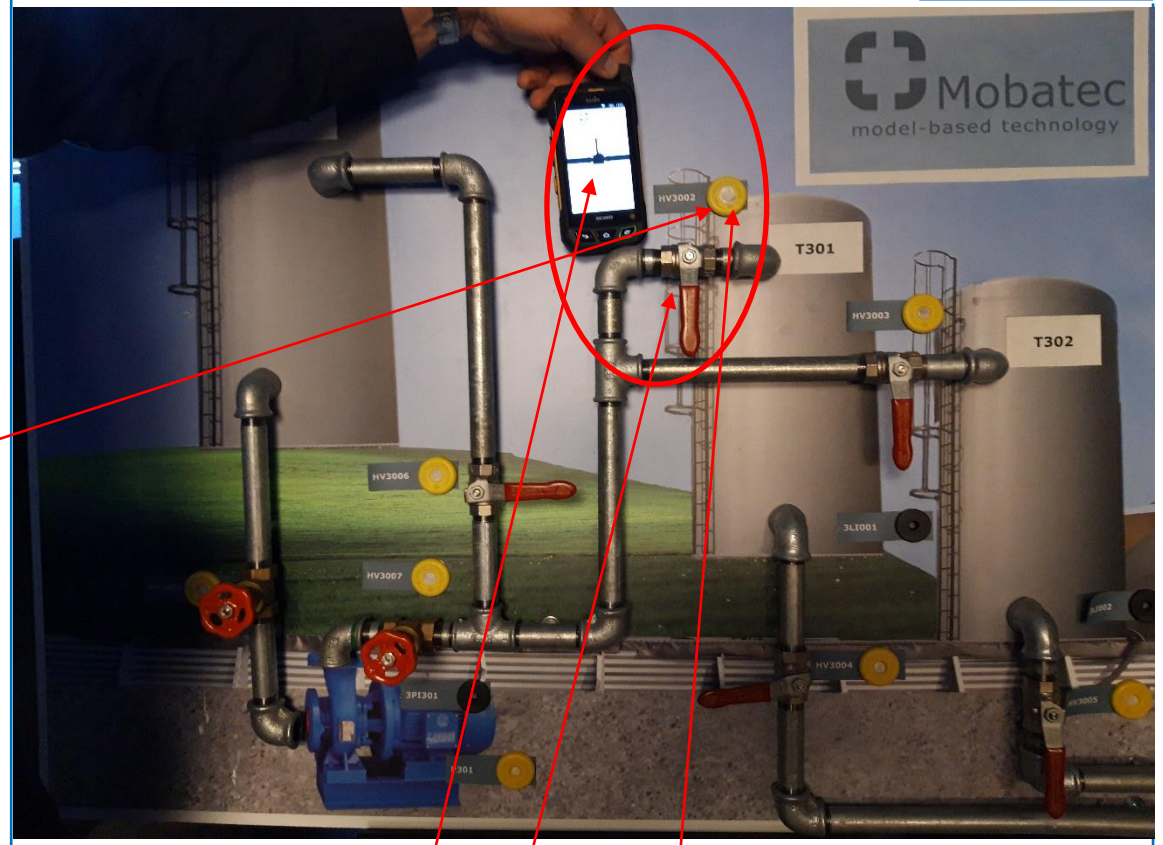
Valve position



Portable device for registration of valve open/close

Wireless FID contact point, Allowing the portable device To identify valve

Manual valve

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- Manual valve position
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Flange 4 step Label

Flange

Problem

Flanges can leak if certain steps are forgotten or not well executed

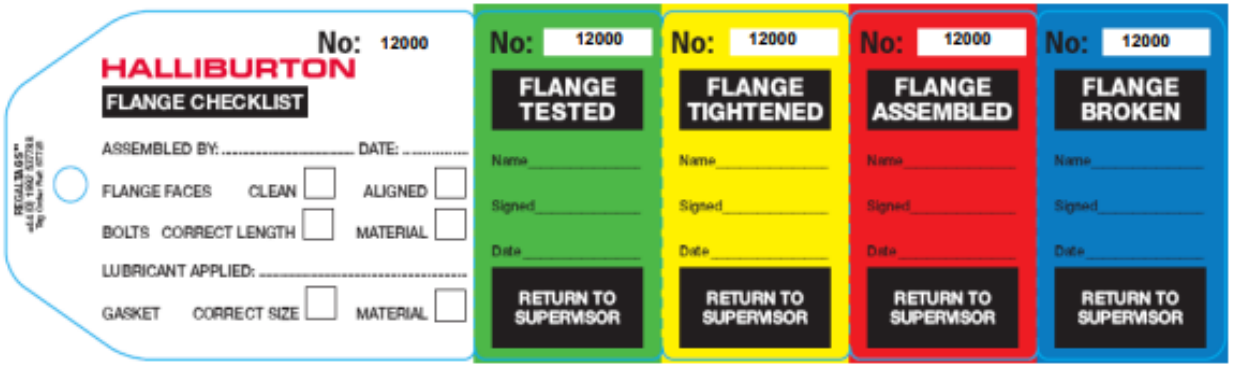
Story

Companies / Contractors use a 3 or **4 folded label** that indicates the critical steps and bolt tension. At each step a part of the label is removed and given back to the foreman or to production

Solution:

Use a label at flanges that need to be opened, so that the critical **steps can be validated, step by step**. The label is made of strong and water resistant material. Each part can be torn off, after completion.

Four folded flange label, attached to flanges before opening. From outside: 1 Broken, 2 Assembled, 3 Tightened at set tension, 4 Leak test performed



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Personalization of Flanges

Flange

Problem

Leaking flanges because **bolts not tightened** with the correct torque, **or missing**;
or the **flange seal face** damaged,
or **gaskets** not suitable or incorrectly installed.

Story

Make the Craftsman, who assembles the flange, **'sign' his work**. Instill sense of responsibility for the correct installation.

Solution:

All flanges get seals or **labels with a personal identifier for employee / contractor** worker who assembles the flange, + for the person who ensures the tightness of the flange (seal quality). + technical information, e.g. type & material of gasket
Modern version: **QR code**

Flanges identified by lead seal system:

QR code identification:

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Flange

Tightness of large flanges

Problem

Large flanges leaking due to different torques on the bolts

Solution

Use of **bolts with force indicator** or use of **hydraulic torque tensioning tool** during flange assembly.

Tightness test with e.g. nitrogen, gradually increase the nitrogen pressure and perform check with an adequate leak detection substance (e.g. spray) or pressure hold test

Tightness check (examples):

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Avoid working on the wrong equipment

Problem

Many incidents have occurred because of **field work on the wrong equipment or pipe** such as:

- Working on pump A when pump B was locked out
- Line breaking on the line next to the one that was emptied and flushed

Solution

Instruct contractors/maintenance **at the worksite** and point out exact location just before starting the work

Add a **label to identify the exact work location** (pump or flange to be opened)

Indicate ‘State of operation’, e.g. in Batch Process

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Right Location

A&B pump Confusion is probable

Point out equipment in the field

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Removal of gearbox or actuator from valves

Problem

During removal of an inoperable gearbox on a plug valve, the operator **mistakenly removed critical bolts** securing the pressure-retaining component of the valve. The valve came apart and released the process fluid.

Solution

Evaluate human factors associated with equipment design and apply the hierarchy of controls e.g. **improve design to mitigate identified hazards**

Establish detailed and accurate written procedures and provide training to ensure workers know the hazards and how the plug valve gearbox should be disassembled safely.

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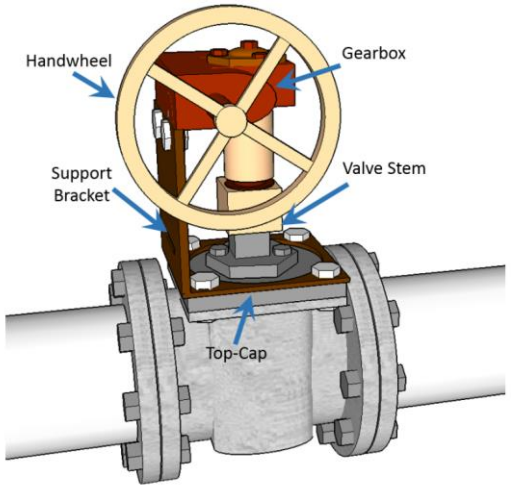
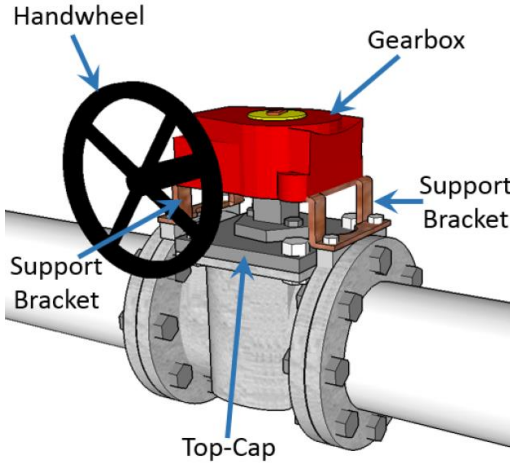
Different design



By design, removing the gearbox did not require removing the four vertical bolts that secured the pressure-retaining top-cap



Improved design, showing how gearbox connects to all four dedicated attachment points on the valve flanges that are not pressure-retaining parts.

Reference: CSB see https://www.csb.gov/

Rupture disk installation

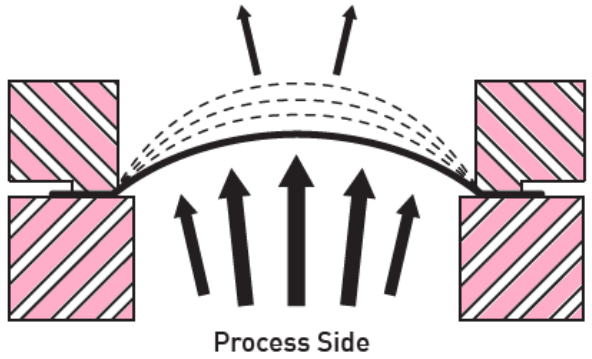
Poka Yoke

Problem:

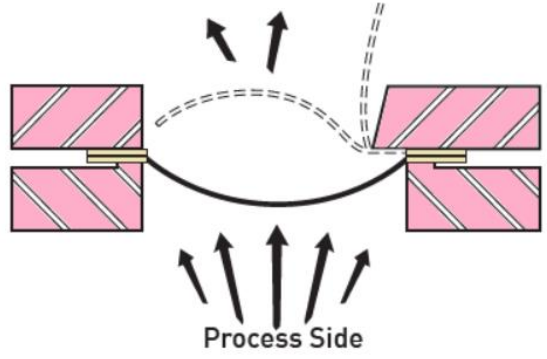
Rupture disks can be of the type "Forward-acting" or "Reverse-acting". Depending on the type, the dome must be placed upwards or downwards. **Installing a rupture disc upside down, is an easy mistake**, that changes the bursting pressure, and may result in tank rupture before the rupture disk breaks.

Solution:

- 1 Use **disk holders that only allow right installation** (Poka Yoke).
- 2 If not available: Always check the **flow direction indicator** on the rupture disc, and have an independent verification by 4-eye principle to confirm correct installation.

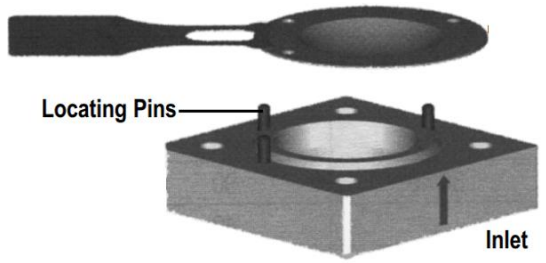


Forward-acting (Tension loaded) type Rupture DisK



Reverse-acting(Compression loaded) Type Rupture Disk

1 Disk holder with locating pins to assure right installation



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Indication of flow direction

Bob van Woezik DSM

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Pipe station with hose connectors minimize hoses for special line-up

Hoses

Problem

Long hoses in the plant can cause **a weak point in the line-up** and also cause a trip hazard. When the connection points **cannot be seen, wrong line-ups** can be made.

Solution

Not-dedicated piping with manual valves can be used with **short hoses** to couple pipelines from one part of the plant to another part.
Indication on valve location where pipeline is going.
Information labels to indicate the transferred chemical.

Photo: connection board with ‘from’ (red) ‘to’ (blue) locations

Monsanto/Bayer

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Protection of Interlocks

Interlock

Problem

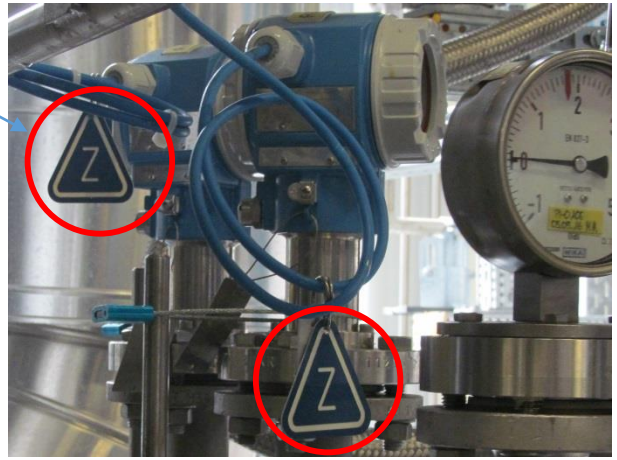
Safety interlocks are sometimes **deactivated** (unintentionally, or intentionally to solve production issues) during operation **without proper permission**. Accidents can result.

Solution

- Make Safety interlocks visible e.g.: label in the field, on documents, P+IDs and DCS-screens.
- Avoid easy bypassing by technical means, e.g. use **key cards or passwords** for DCS-systems or locks at operation panels.
- **Enforce the rule,** to work on safety interlocks **never** without a specific authorization/Permit to Work

Key card to protect access to SIS

Labeling of Safety Interlock Instrumentation



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- DOW: O. Fuente
- Bayer: A. Seidel
- DSM: B. van Woezik
- Merck: R. Hoss
- Lyondell Basell: M. De Zeeuw
  M. Occhulipo
- Huntsman: A. Lenham
- Akzo: J. Rood
- Janssen: F. de Proft
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You find the Useful Practises on

EPSC.be

Thanks for listening !

Hans Schwarz, Dec. 2019

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THE PROCESS SAFETY NETWORK

Title – the aspect (Template)

Category

Problem

Telling the issue to be solved

Solution

Telling how the issue can be solved / explaining the best practice

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Explaining foto 1

Explaining foto 2

Similar equipment, but very different

Problem

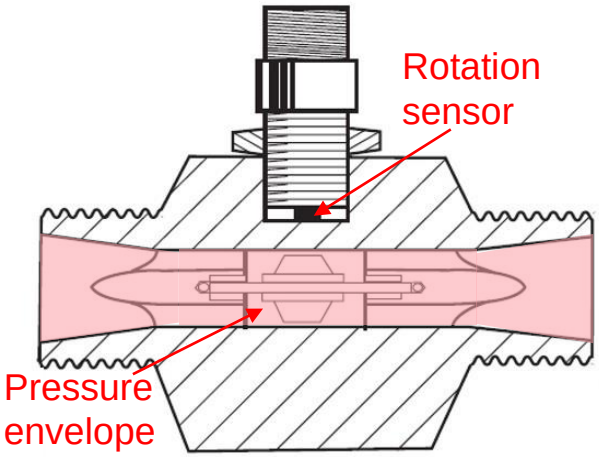
Potential for loss of containment where there are two **similar pieces of equipment but with different pressure envelopes**. One can be safely maintained whilst in service and it might be assumed by staff that this is the case for both items. However, the other **loses containment when similar work is performed**. E.g. Removal of turbine flowmeter rotation sensors (example shown) or valve gearbox bolts (CSB video https://youtu.be/QyIIe5T5beM)

Solution

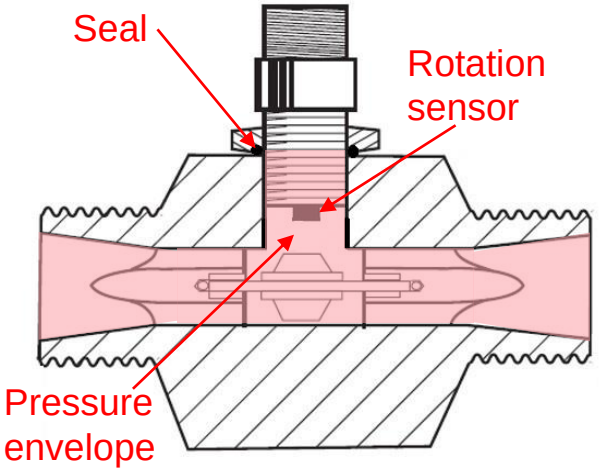
- **Standardise to one design** and ensure the pressure envelope is clearly identified and understood/ documented to prevent future mistakes.
- In case more designs exist, maintenance has to be made aware and special procedures must be established to avoid mistakes
- Field labeling of the hazardous designed equipment can help to make maintenance people aware

Different design

Safe to remove rotation sensor without compromising pressure envelope



Removal of rotation sensor will lead to loss of containment!



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- **Flange leak**
- **Overfills**
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- **Wrong material or chemical**
- **Hose issues**
- **Plant isolation issues**
- **Interlock issues**
- **Loading, unloading**
- **Organisational practises**
- **Competency related**

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Validate Chemical

Wrong Material

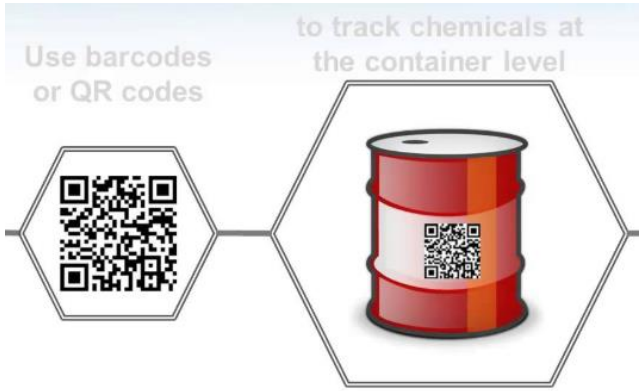
Topic (problem)

When a **wrong chemical** or a wrong quantity is dosed to a reactor a hazardous reaction can occur

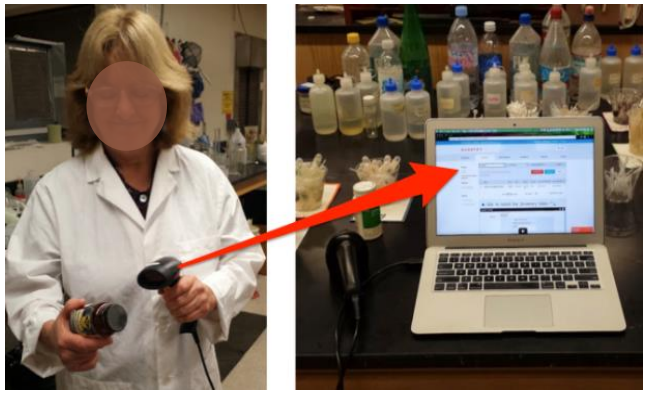
Story (solution)

Label chemicals upon arrival with a **barcode/QR code**. Scan the barcode before adding the chemical to the reactor and validate by the computer that it is the right component

Label chemicals with a bar code upon arrival



Scan when using, to validate the right chemical is used
Also for batch tracability



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Job cycle check to avoid Normalization of Deviation

Competency

Problem

Operators may deviate from an operating procedure if it is an outdated procedure, the described task is difficult to execute, or because operators do not understand/know the critical steps in a procedure, e.g. for lack of training.

A **deviation** from the procedure, perceived as an improvement, **can become normal practice** without a formal review.

This is also known as normalization of deviation.

Solution

To avoid “normalization of deviation”, a Job Cycle Check (JCC) can help

- Define Safety Critical Tasks in operations and **review the procedures periodically**
- **Observe** employee while doing the task and identify if he/she follows the procedure in detail and give feedback
- **Update** behavior or the procedure as needed, so the work will be done in line with the procedure

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Visualization of bypassed SIL interlocks

Interlock

Problem

Bypassing **SIL rated interlock (Z-switch)**, e.g. on testing, **without a permit** (and appropriate authorization), or **without signaling that Interlock is bypassed**.

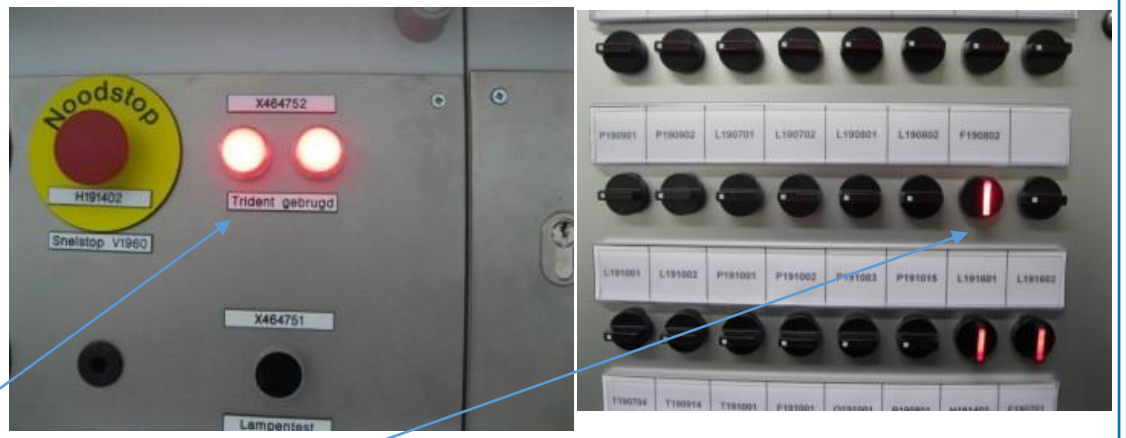
Mistakes can lead to severe accidents, when the interlock is not available on demand, or to spurious shutdowns, with costs associated

Solution

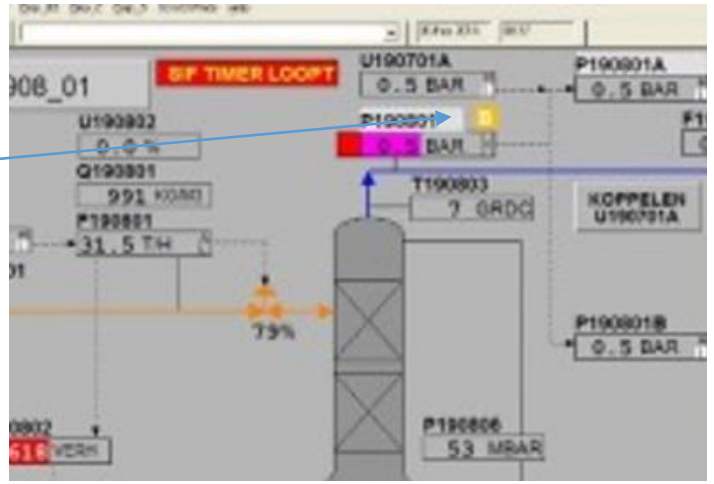
Visualisation of properly authorized bypass of a SIL rated interlock:

- Lamps in the control room, which light up if an interlock is bypassed.
- Clear information in the switch room (LOTO or special cable color for hardwired systems)
- Visualization on the DCS schematics
- **Complete an interlock test preferably before the end of a shift** – if not, ensure good shift-handover of the bypassed interlocks

Visualization in the control room:



Visualization on the actual DCS page:
Here: purple is bypassed



EPSC

Useful Practises, sorted by Type of Incident or Equipment

- Manual valve position
- Flange leak
- Overfills
- Breaking off small nozzles
- Wrong equipment (opened)
- Equipments which invite human error
- Wrong material or chemical
- Hose issues
- Plant isolation issues
- Interlock issues
- Loading, unloading
- Organisational practises
- Competency related

EPSC

Prevent hose leakage through hose testing/certification program

Hoses

Problem

Hose leakage by failure of the hose, because of

a) Wrong hose, **not suited for the chemical**

b) Wrong hose, **not suited for the pressure**

c) Hose too old, **aging** of the hose

Solution

Operator can see from the **colour coding** (**green** ring) easily whether the hose has been tested. The colour code changes each period (year). Only two collors allowed

Pressure rating mentioned on metal ring (10 bar)

Barcode is used by inspection

The colour stripe (red) indicates the product for which the hose can be used

Still visually inspect hoses before using them

EPSC