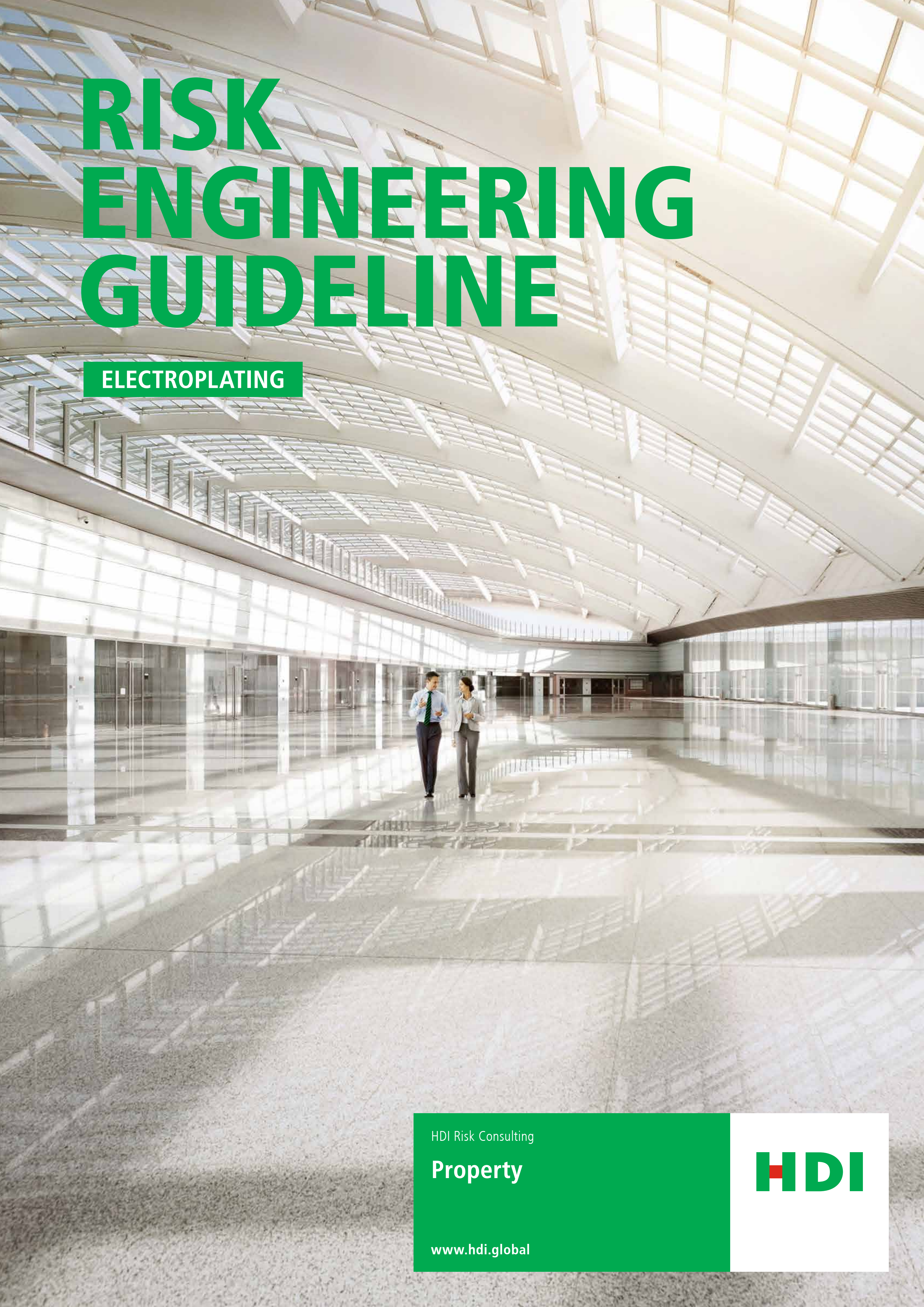
RISK ENGINEERING GUIDELINE

ELECTROPLATING



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Electroplating has a wide range of applications: In addition to conventional applications such as corrosion protection coatings on metal surfaces (sheet metal, screws and bolts, cans, automotive parts), plastics such as printed circuit boards can also be metallized by electroplating.

General.

Electroplating is an electrochemical process for functional and/or decorative deposition of a metal layer (e.g. zinc, nickel, chrome, noble metals) as a surface refinement of workpieces made of metal, plastics or ceramics (figure 1).

The refinement processes usually take place at low voltage levels and high electric current intensities. Chemical metal deposition represents an exception.

Electroplating plants differ both in size and volume of the electrolytic baths and in terms of current intensity required for the process. The product range starts with small workpieces such as bolts, screws and jewellery and ends with workpieces such as rollers weighing tons.

The present Risk Engineering Guideline deals with electroplating plants for industrial production purposes exclusively. Even if the hazard focus and the hazards involved with pickling lines, used to remove impurities on a metal surface, must be rated similar, these are not explicitely taken into account here.

1 Risk situation and examples of losses.

Electroplating plants have a high loss potential which essentially results from the fire load of the electrolytic baths and exhaust ductwork, the ignition potential of the electrical systems and the explosion hazard due to the release of flammable gases within the process.

1.1 Risk situation

Losses in electroplating plants are mainly characterized by fires, explosions and releases of hazardous substances. These events can be sub-divided as follows: 43 % fires,

Fig. 1: Corrosion protection layers on metal surfaces.

37 % releases of substances and 20 % explosions. Technical defects, at 40 %, are the most frequent origin of losses. More than 30 % of the losses are attributable to human error and frequently due to incorrect operation. The origin of the loss remains unrevealed in roughly a quarter of the events which is mostly due to destruction following the loss.

The extensive electric installations frequently constitute the ignition sources in electroplating plants:

- electric heaters in the electrolyte and pretreatment tanks,
- mechanically and/or chemically loaded electric cables,
- electric overload of DC cables due to corrosion induced reduction of line cross sections.

An increased fire load results from the use of chemically resistant, but combustible plastic tanks and exhaust ductwork usually made of PP and PE and partly of PVC and PVDF, from GRP grating and from the use and storage of flammable chemicals and organic solvents. In case of fire, such conditions favour fire spread. Large amounts of smoke are generated and toxic and corrosive pyrolysis gases (HF, HCl, dioxines, CO, polycyclic aromatic hydrocarbons) are released, making fire fighting more difficult. In case of fire, release of large amounts of pollutants and contaminated fire water must also be expected.

Expensive decontamination and restoration works is required following fires.

Under unfavourable conditions, suction and exhaust ductwork lines extending across several areas may contribute to fire and smoke spread both in the entire electroplating areas and in adjoining areas if no protective measures have been taken.

In the chemical pre- and post-treatment and the metallizing process of workpieces, e.g. in pickling operations, in electroless plating and some electroplating operations, hydrogen is usually released from these processes. Explosible mixtures can form above the baths in cases where there are inadequate safety monitoring and protective measures (see figures 2 and 3).

Fig. 2: Release of hydrogen and foam building up in electrolytic degreasing operations. The workpieces are usually immersed into an alkaline solution containing tensides and are connected either to the anode or the cathode. The current densities of up to 15 A/dm² applied here cause violent hydrogen and oxygen development. The tiny gas bubbles rising from the workpiece surface remove the remaining lubricating oil and grease particularly thoroughly.

Fig. 3: Electropolishing of a workpiece while releasing hydrogen. This method is used predominantly above all for levelling stainless steel surfaces. After immersing in strong acids, the workpieces are connected as an anode and metal out-of-flatness in the micrometer range is removed by electrochemical means so that a smooth and shiny surface is obtained. Current densities of up to 100 A/dm² are employed here.

1.2 Examples of losses

Example 1
In an electroplating facility with a total of three automatic electroplating lines, a nightly large-scale fire caused total loss of all the equipment and of the building.

Night shift employees had detected heavy smoke development on one of the chrome bath lines and immediately attempted to fight the fire with a fire extinguisher.

The fire fighting attempt failed because of very dense and pungent smoke. The fire was detected at a late stage due the high rate exstraction systems installed above the bath despite the smoke detection system present.

Further delays occured due cutting the energy supply of the building. The ventilation system kept running all this time and spread the smoke all over the building. The combustible plant equipment made of PP has additionally contributed to full-scale fire development and spread.

Despite quick fire detection and alarm and arrival of the fire brigade after a short time, fire fighting took several days, producing more than 3,000 m³ of contaminated fire water.

The fire was caused by a technical defect. Corrosion of an electric copper cable (200 A, 8 V, DC) reduced the conductor cross-section and caused increased electrical resistance. The resulting temperature rise was so high that the copper cable finally melted and ignited the adjoining plastic equipment.

Business interruption and reconstruction work took more than one year. The property loss was in excess of 20 million Euro.

Example 2
A large-scale fire occurred at night in the aluminium anodizing and chromating plant of a medium-sized metal-processing company.

A night shift employee called the volunteer fire brigade which arrived at the premises within a few minutes. In view of heavy smoke development and the danger of the fire spreading to the adjoining hazardous materials store, further fire brigades had to be called in. The additional fire fighters were able to clear the hazardous materials store.

Fire fighting took 17 hours in total and around 1.5 m³ of foaming agent were used for fire fighting.

Due to the degree of destruction, the exact reason of the loss could not be finally settled. The building and the entire electroplating equipment were destroyed in the fire. The production halls adjoining the electroplating hall were also exposed to corrosive smoke and had to be refurbished.

The property and business interruption loss totalled more than 15 million Euro.

Example 3
As a result of a short circuit in the interior of one of seven rectifiers (nominal current of 5,000A each), a spark ended up onto the bath surface. Thereby, the hydrogen produced during chromium plating was ignited above the 30 m³ electrolyte bath of a hard chrome system. This lead to a considerable flash fire because at the time when the loss occurred, a steel workpiece of around 4 m x 2 m was being chrome-plated by electroplating at a current intensity of 12,000 A.

Example 4
Following a chrome removal process in a electroplating unit, an oxyhydrogen gas reaction occurred, involving the hydrogen released during the process.

The contact bar was not properly disconnected from the rectifier by actuating the "OFF" button before changing workpieces. The electric current was merely reduced at the potentiometer, leaving a residual voltage applied to the contact bar. When the contact bar with the attached workpieces was pulled out of the electrolyte bath, an electric arc occurred and the hydrogen accumulated within the foam of the chrome removal emulsion containing wetting agent was ignited.

2 Process fundamentals.

The electroplating process includes essentially three steps: Pre-treatment, metal deposition and post-treatment (see figure 4).

Whereas electrically induced metal deposition is suitable only for coating electrically conductive metal workpieces, chemical processes allow metal coatings of non-conductive surfaces such as plastics and ceramics as well. Both processes are based on an electrochemical redox reaction. In an electroplating process, the metal layer thickness can be controlled by the duration of the deposition process and the current setting.

In electroless processes, the deposition rate and consequently the metal layer thickness are essentially controlled by the concentration of the metal salt to be deposited and by temperature. The temperature of the electrolyte bath in electroless processes is usually higher than in metal electroplating processes and may reach up to 90 °C.

01 Pre-treatment

Mechanical
Polishing, blast-cleaning, grinding, etc.

Chemical
Electrolytic degreasing, pickling, electropolishing, etc.

02 Metal deposition

Electroplating
Electrolysis Electrochemical metal deposition on electrically conductive workpieces immersed into an aqueous electrolyte solution, by using an electric current through an external DC circuit.
Current density from 0.1 A/dm^2 up to 100 A/dm^2
Examples: Galvanizing, corrosion protection (Cu/Ni/Cr)

Chemical
Catalysis Electrochemical metal deposition on surfaces of workpieces (metal, plastic or ceramics) activated by seeding with a catalytic metal (e.g. palladium) and immersed into an aqueous electrolyte solution containing a reduction agent, without using any external electric DC source.
Deposition rates from 10 ·m/h up to 20 ·m/h
Examples: Chemical nickel coating, tin-plating, copper-plating of printed circuit boards

03 Post-treatment

Mechanical
Greasing, oiling, electrostatic oiling, etc.

Chemical
e.g. electroless chromating

Fig. 4: Fundamental process steps of electroplating process
The individual process steps are connected by several back-washing steps with demineralized water. Finally, following post-treatment and back-washing, the workpieces are dried in warm air.

2.1 Hazard sources

The loss events show that fire outbreak and spread in electroplating operations are mainly due to the following reasons:
Electric ignition sources due to
- overheating of electric heater bars,
- insufficient/defective insulation of electrodes (figure 5c),
- short-circuits,
- defective electrical installations.

Combustible materials (plastics)
- trays,
- fume extraction ducting (figures 6a and b),
- GRP grating etc..

Process-related hazards
- corrosion on clamping contacts of electrodes and electric connections (figures 5a and b),
- increased operating temperatures,
- drying-out of electrolyte baths,
- hydrogen release.

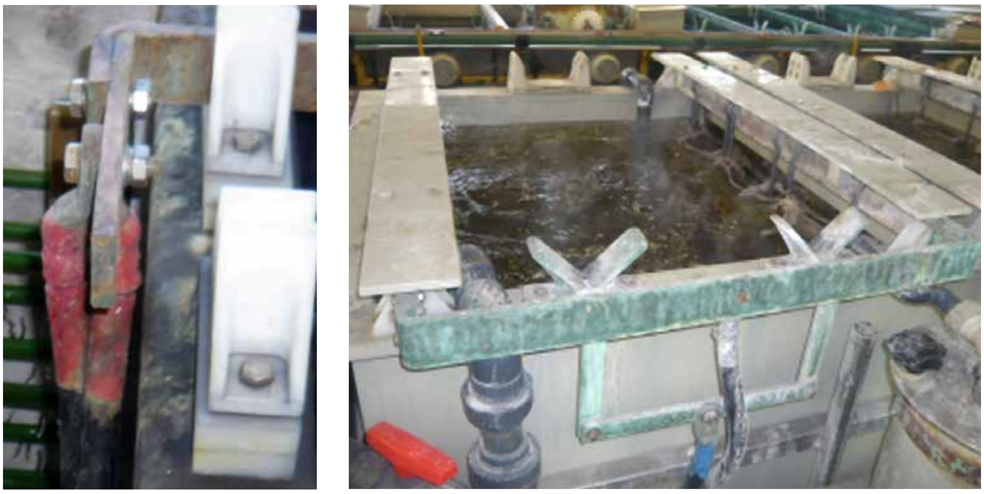

Fig. 5a and b: Electrodes showing corrosion damage.

Fig. 5c: Improperly installed electrodes (kinked copper cable).

Fig. 6a and b: Fume extraction ducting as well as plastic equipment and supply units of electrolyte baths contribute to quick fire spread in the entire area of use in case of fire.

3 Protective measures.

3.1 Plant safety

3.1.1 Process-relevant equipment
To reduce the risk of rapid fire spread, the process-relevant equipment, in particular electrolyte baths and grating should be made of non-combustible materials.

Steel tanks with a rubber-coated surface can be used especially for the electrolyte tanks (electrostatically neutral natural rubber).

Non-combustible galvanized steel grating should be used as a basic rule. The use of chemically resistant GRP (Glassfibre Reinforced Plastic) grating should be limited to areas where particularly corrosive ambient conditions prevail.

3.1.2 Electrical systems

In view of the corrosive atmosphere prevailing in electroplating plants, particular requirements must be made on electrical systems and power supply equipment such as transformers, switchgear and rectifiers.

The functional readiness and insulating properties of the electric equipment must be adapted to suit the corrosive atmospheric ambient conditions and be maintained permanently.

Electric connections between items of electric equipment must be provided by permanent connections. Clip Connectors are to be avoided.

Electric equipment must meet degree of protection IP 64 (splashwater-proof and dust-tight) as a minimum requirement.

All electric drives must be protected by motor circuit-breakers without exception.

The line cross-sections of the DC power supply cables must be generously dimensioned.

3.1.3 Bath heating

Heating of the electrolyte baths should be indirect by water or steam. This can be realized e.g. by using instantaneous water heaters in connection with heat exchangers. The instantaneous water heaters must be separated from the electroplating unit with a fire rating (e.g. 90 minutes fireproof).

Accelerated wear of electric bath heaters must be expected due to the permanent direct contact with corrosive electrolytes. The direct proximity of combustible electrolyte baths involves an increased fire hazard.

If the use of electric bath heaters cannot be avoided, particular safety requirements must be met:

The standards and rules below shall be observed when installing electric heaters:

- EN 60519-1; VDE 0721-1, Safety in electric heating systems – Part 1: General requirements (IEC 60519-1)
- EN 60519-2; VDE 0721-2, Safety in electric heating systems – Part 2: Particular requirements made on resistance heating equipment (IEC 60519-2)

Electric heating systems must be hard wired and connected using separate residual-current circuit-breakers (RCD) with a rated differential current of 300 mA max. We recommend RCDs with a tenth of that rated differential current, i.e. 30 mA max.

It must be possible to safely disconnect electric heating systems from the power supply at any time.

The minimum clearance between the electric bath heaters and the flammable electrolyte bath surface as specified by the installation company must be respected. A safety distance of 50 mm must be observed. To avoid mechanical loads and movements of the bath heaters by recirculating the electrolyte, especially screw-in radiators have proved their worth.

3.1.4 Ventilation

The ventilation system for the electroplating unit must be executed separately.

Any necessary ventilation systems for power supply equipment such as transformers, switchgear and rectifiers must be technically separated from process air equipment.

The waste air from the electroplating unit must be monitored for critical temperatures and shut down automatically when the set temperature is exceeded, if necessary also in order to detect a developing fire.

3.1.5 Safety monitoring of process characteristics

To avoid critical operating conditions, safety-relevant process characteristics, especially temperatures, electrolyte bath levels and current intensities must be monitored with a redundancy.

- Heater elements of electric bath heaters must be equipped with temperature sensors and separate safety temperature limiters each in order to reliably exclude critical temperatures of the heater elements (figures 7a and b). Automatic restarting is not permitted.
- Electrolyte bath levels must be monitored for Lmin and Lmax. If levels are outside the usual parameter ranges, both the electroplating process and the electric bath heaters must be de-energized automatically.
- In case of current intensities outside of the parameters to be expected in the electroplating process (DC current via cathodes, anodes, reference electrodes), the plant must be de-energized (automatically in an ideal configuration) since this points to short-circuits or corrosion-induced increased resistance.
- Electric electrode clamping contacts on the electrolytic baths must be fitted with temperature sensors and de-energized automatically when reaching critical temperatures.

Fig. 7a: Heating elements with thermal discolourations of heating cartridges and electric cables.

Fig. 7b: Safety bath heater with integrated safety monitoring against overheating.

- Pneumatically operated electric clamping contacts must be monitored if they meet the critical minimum pressure and de-energized when the value drops below this pressure.

Operating faults shall be removed by qualified specialists.

The alarms of the safety-relevant process characteristics must be reported to a permanently manned station.

3.2 Structural fire protection

3.2.1 Location of electroplating operations
Electroplating operations must be considered as special-use plants and/or rooms involving an increased fire hazard.

Electroplating operations must be preferably set up in separate and single-storey buildings. The buildings must be built with a fire rating. Good fire brigade access must be ensured.

3.2.2 Building materials
The aggressive ambient conditions must be considered when selecting the building materials.

Combustible building materials are to be avoided.

3.2.3 Structural separation
Electroplating operations must be realized as separate fire compartments or at least separated from adjoining operation areas with a fire rating (e.g. 90 minutes fire resistant).

The NFPA 221 regulation must be considered for the execution of fire walls.

Fig. 8: Four rectifiers of 8 V 600 A each, with 215 kg oil for cooling. The missing separation of rectifiers with a fire rating creates the danger of fire spread into adjoining rooms. In addition, setting up and operating the rectifiers in shelves creates the danger of underfiring. For this reason, the rectifiers should be set up on level ground and at a minimum clearance of 2.50 m from one another as well as free of fire loads.

Electric power supply equipment such as transformers, switchgear and rectifiers must also be separated with a fire rating (figure 8).

The control systems and control cabinets in electroplating plants are particularly sensitive to smoke, high temperatures and corrosive atmospheres. These systems must be separated from electroplating operations and adjoining operation areas at least with a fire rating (e.g. 90 minutes fire resistant).

Installation breakthroughs e.g. for suction and ventilation lines and cables must be closed to suit the fire resistance class of the wall and the ceiling. When waste air lines go through fire walls, they must be protected by fire dampers automatically controlled by the fire alarm system. The fire dampers must be suitable for the corrosive atmosphere in the fume extraction ducts.

The hazardous materials stores must be separated from electroplating operations and adjoining operation areas at least with a 90 minutes fire rating.

3.3 Fixed fire protection

3.3.1 Fixed fire protection systems
Experience from losses shows that quick fire spread must be expected in electroplating operations because of the increased fire loads; effective fire fighting by the fire brigade is no longer possible in such conditions. This usually results in total loss of production facilities. To avoid this, installing automatic fire protection systems is indispensable.

In the past, the options below have in particular proved their worth for limiting the loss:
- full-scale automatic sprinkler systems as room protection,
- automatic low-pressure fine spray protection systems as local equipment protection.

The following must be observed when installing automatic fire protection systems: Design and installation of a fire protection system must follow a recognised rule or standard, e.g. CEA4001 "Sprinkler systems, planning and installation"

The items below should be agreed with the property insurer:
- scope of protection, e.g. in areas beneath the electrolyte baths and outside/inside the waste air lines,
- execution (e.g. water supply, foam addition).

Extended protective measures on transformers, switchgear or rectifiers can be required, depending on size or availability requirements. In general, gas extinguishing systems (N2, Ar) are to be preferred.

The installation of local equipment protection systems requires proof of its effectiveness.

Actuation of automatic fire protection systems is to be directly connected to the fire brigade or a permanently manned station.

The entire protection concept is to be agreed with the property insurer in advance.

3.3.2 Fire alarm system

Experience with losses shows that in view of the quick fire spread in electroplating operations, automatic fire alarms alone are not sufficient. All the same, secondary areas such as technical rooms should be monitored by automatic fire alarm systems. The entire ventilation system should also be integrated in this monitoring area. In view of the corrosive atmosphere, the type of fire alarms employed inside the ventilation systems should be agreed with the property insurer. Planning and installation must comply with a recognized set of rules, e.g. VdS 2095en or NFPA 72, and be carried out by a recognized installation company.

3.3.3 Fire control matrix

Fire controls must be defined and should be documented in a matrix. All relevant media such as electric energy, air (ventilation, compressed air), heating system etc. should be considered. The dependencies and functions must be checked at regular intervals.

Shutting-down of the feed air and waste air systems and of the rectifiers and bath heaters in case of fire should be ensured. This should be done both automatically by way of the fire event control and manually by EMERGENCY OFF switches in the escape and rescue routes.

To minimize the period for which the fan continues rotating and consequently spreads smoke, the drive motor must be actively decelerated.

3.3.4 Smoke and heat ventilation systems

Any existing automatic fire protection systems must be considered in the design. In this process, the regulations on which the fire protection systems are based must be taken into account. Information about the interaction of water-based fire protection systems and smoke and heat ventilation systems can be taken from e.g. VdS sheet 2815en.

3.4 Explosion protection

Processes involving the release of flammable gases, e.g. hydrogen, or the use of flammable solvents must meet the explosion protection requirements. To this end, a hazard assessment must be carried out and an explosion protection document must be prepared on this basis.

Explosion protection measures must be taken in order to cover the risk revealed in the hazard analysis, e.g.

- monitoring of critical concentrations (lower explosion limit LEL) in areas where an explosive atmosphere must be expected;
- electrical systems and installations must be realized in accordance with 2014/34/EU (ATEX) or NFPA 70;
- the fume extraction system must be designed so that formation of an explosive atmosphere is reliably avoided at any time;
- if the generation of critical hydrogen concentrations cannot be reliably excluded in case the power supply or the fume extraction system fails (possible in pickling operations or when employing electroless processes), separation of the workpiece from the electrolyte or from the acid solution must be ensured when the above situation occurs. This can be achieved either be removing the workpiece or by draining the bath into an emergency tank (surge tank) by means of a de-energized safety valve.

3.4.1 Organisational measures

The organisational explosion protection measures defined in the explosion protection document must be implemented for the explosion-hazardous areas. This includes e.g.

- cleaning of explosion-hazardous areas at regular intervals,
- removal of incrustations inside the suction hoods above the baths at regular intervals in order to ensure suction system efficiency,
- regular maintenance of explosion-protected systems and protection systems,
- instructions and trainings regarding explosion protection for employees working in explosion-hazardous areas,
- explosion protection instructions for outside personnel prior to starting and performing work in explosion-hazardous areas,
- regular risk analyses for explosion-hazardous areas,
- update of the explosion protection document by a capable person at regular intervals,
- emergency planning.
  An example of an interactive checklist by HDI Risk Consulting, referred to as "Measures for organisational explosion protection", is available for downloading on www.hdi.global.de. This checklist should be adapted to the prevailing operational requirements.

Fig. 9: Salt deposits on the metal housings of electric equipment result in both accelerated corrosion and overheating by restricted cooling.

Fig. 10a: Open storage of flammable chemicals and solvents can also contribute to fire spread and should be avoided as a basic rule.

Fig. 10b: Safe storage of chemicals in a hazardous substance cabinet with a fire rating.

3.5 Organisational fire protection

In view of the particular ambient conditions, accelerated ageing of the operational equipment must be expected. For this reason, maintenance, preventative maintenance and housekeeping are particularly important.

3.5.1 Maintenance

3.5.1.1 Electrical systems

The safety-relevant equipment and apparatus as well as the connections of lines/cables/electrodes (on DC side) must be inspected in weekly intervals. Any existing oxide layers must be removed (see figure 5a & b).

To enable early detection of hot spots, especially at the DC circuit terminal connections, thermographic inspections must be carried out by a designated thermographic expert which has to be qualified in compliance the ISO 9712 "Non-destructive testing - Qualification of NDT personnel" standard. Experts must to be reached at least level 2 of ISO 9712 and must have skills in the construction and design of electrical installations, for conducting infrared thermographic testing at electrical installations. All thermographic inspections have to be reported and documented; the inspection interval has to be conducted at least every 6 months.

A shorter monitoring interval is necessary for highly flexible electrical cables caused by mechanical load they are exposed during operation. Thermographic inspections of these cables must be carried out once a month.

The inspections including the revealed and removed shortcomings must be documented in a shift log or operations log. If shortcomings cannot be removed immediately, repairs must be scheduled within a short time.

Mobile electric equipment must be visually inspected at regular (e.g. 6-monthly) intervals.

3.5.1.2 Fire protection equipment

The proper function of fixed fire protection equipment such as fire extinguishing and fire alarm systems as well as smoke and heat ventilation systems must be ensured.

Fixed fire protection systems must be serviced by the installation company at regular intervals. The maintenance intervals must be adapted to the corrosive ambient conditions and should not exceed one year.

Fixed fire protection systems must be inspected at regular intervals, preferably annually.

3.5.2 Operational safety

Storage of solid and liquid hazardous materials and especially of those marked as easily flammable, flammable and favouring a fire (F and O) in the quantities required for one day should be in ventilated safety cabinets with a fire rating of at least 90 minutes (figure 10b).

Adapted cleaning intervals should keep all operating equipment free of incrustations and/or lubricant films.

Regular training and instructions of operating personnel regarding safety precautions and measures in case of

- a technical accident,
- fire.

A suitably qualified fire protection officer must be nominated.

The use of private electric appliances such as radios, refrigerators, water heaters etc. should be banned in electroplating areas.

Unattended operation of electroplating plants and supply units must be avoided as a basic rule. This in particular refers to the automatic operation of the bath heater outside of operating hours. If operating the bath heater outside of operating hours is necessary for process and/or quality reasons, indirect bath heating is particularly recommended.

3.5.3 Hot works
When performing hot works such as welding, torch-cutting, brazing/soldering, roofing work etc., the HDI Risk Engineering Guideline "Hot works" must be observed.

A hot work permit specifying the necessary safety measures to be taken before, during and after the work must be prepared. The "Hot work permit" form by HDI Risk Consulting can be used as a template for this purpose.

3.5.4 Manual fire fighting
Hose reels and portable fire extinguishers must be made available for manual fire fighting by own personnel. The use of powder-type fire extinguishers must be generally banned because uncontrolled reactions of the powder with electrolyte components cannot be excluded.

Foam-type fire extinguishers should be provided as a general rule. In areas where electrical systems are installed, these should be supplemented by CO_2 fire extinguishers.

The employees must be instructed and trained in how to handle fire extinguishers and hose reels at regular intervals.

3.6 Fire fighting

3.6.1 Fire water supply
Sufficient supply of fire fighting water shall be ensured.

The minimum fire water supply should be 192 m^3/h during a 2-hour period minimum.

For further information about fire water supply, please consult the homonymous Risk Engineering Guideline by HDI Risk Consulting. Foaming agent should be available on the premises if possible by coordination with the fire brigade.

Appropriate fire water retention capacity must be provided, considering the stored and circulating type and quantity of hazardous substances.

3.6.2 Fire brigade
Effective fire fighting operations by the fire brigade can be assumed only if the fire brigade can fight the developing fire without delay. This can be ensured only if the fire brigade is thoroughly familiar with the premises. For this reason, regular exercises, but at least annually surveys, should be carried out by the responsible fire brigade.

To provide support for the fire brigade, fire brigade plans indicating concentrated hazards and lists of hazardous materials should be developed.

3.7 Measures against theft

The safety concept for protection against burglary and theft, especially of noble metals, should always be discussed with the property insurer.

4 References.

Local standards shall be complied with.

1. **EN 60519-1; VDE 0721-1** — Safety in electric heating installations - Part 1: General requirements (IEC 60519-1).

2. **EN 60519-2; VDE 0721-2** — Safety in electric heating installations - Part 2: Particular requirements made on resistance heating equipment (IEC 60519-2).

3. **NFPA 70** — National Electrical Code (NEC)

4. **NFPA 72** — National Fire Alarm and Signaling Code

5. **NFPA 221** — Standard for High Challenge Fire Walls, Fire Walls and Fire Barrier Walls

6. **NFPA 318** — Standard for the Protection of Semi-conductor Fabrication Facilities

7. **VdS 2095en** — Automatic fire detection and fire alarm systems, planning and installation.

8. **VdS 2815en** — Interaction of water extinguishing systems and smoke and heat exhaust ventilation systems (SHEVS).

9. **VdS CEA 4001** — Sprinkler systems, planning and installation.

10. **Risk Engineering Guidelines,** forms and checklists by HDI Risk Consulting GmbH, are available for downloading on the home-page of HDI Global SE at www.hdi.global

About HDI Risk Consulting.

HDI Risk Consulting GmbH supports major corporations, industrial and mid-size companies with loss prevention and in establishing risk management systems.

HDI Risk Consulting offers its' customers access to some 180 engineers and experts from a wide range of technical disciplines. We aim to support companies with the management of risks and the development of individual risk-based concepts for insurance cover.

HDI Risk Consulting operates globally in the Property, Motor, Engineering and Marine markets, with particular focus on the identification and assessment of risks and the development of appropriate, individual protection concepts.

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Imprint
Responsible for the content:
HDI Risk Consulting GmbH

Layout: Insignio Kommunikation GmbH
Fotos: picture-alliance/ZB_by: Jan-Peter Kasper, fotolia.com_by: preferi, lev, kuassimodo; panthermedia.net_by: fotos4people, kzeon; Fischer Leiterplatten GmbH, Schlötter Galvano-technik GmbH & Co. KG, Mazurczak GmbH, Metoba Metalloberflächenbearbeitung GmbH, Poligrat GmbH, DENIOS AG

403-HRC/REG133GB 201605