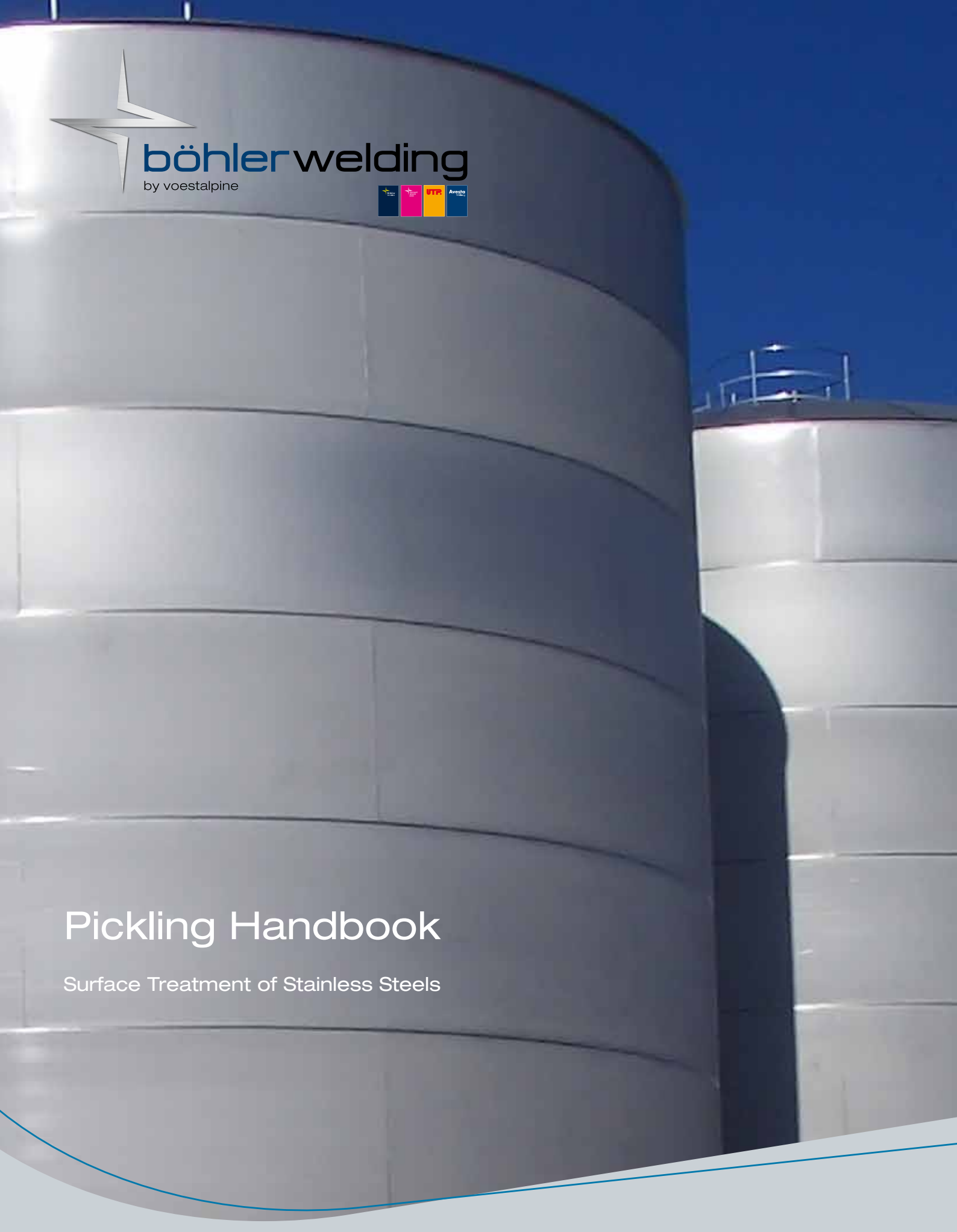


böhlerwelding
by voestalpine

# Pickling Handbook

## Surface Treatment of Stainless Steels

**voestalpine Böhler Welding**
www.voestalpine.com/welding

voestalpine
ONE STEP AHEAD.

# Index



## The purpose of this handbook

In this handbook, voestalpine Böhler Welding presents practical methods for pickling and cleaning stainless steel. It is intended to increase awareness and understanding of the need to treat stainless steel surfaces. Appropriate safety procedures when handling the products concerned are also set out.

- Explain why, after welding and processing, stainless steel structures need cleaning in order to preserve their corrosion resistance.
- Show, through a survey of typical defects, when cleaning is important.
- Describe how to clean using different cleaning techniques.
- Give practical recommendations and instructions as to what to do in order to eliminate typical problems.

# 1. Stainless steel

## The need for cleaning

A good stainless steel surface is clean, smooth and faultless. The importance of this is obvious when stainless steel is used in, for example, façades or applications with stringent hygiene requirements. However, a fine surface finish is also crucial to corrosion resistance.

Stainless steel is protected from corrosion by its passive layer – a thin, impervious, invisible, surface layer that is primarily chromium oxide. The oxygen content of the atmosphere or of aerated aqueous solutions is normally sufficient to create and maintain (“self-heal”) this passive layer. Unfortunately, surface defects and imperfections introduced during manufacturing may drastically disturb this “self-healing” process and reduce resistance to several types of local corrosion. Thus, as regards hygiene and corrosion, a final cleaning process is often required to restore an acceptable surface quality.

The extent of, and methods for, post-fabrication treatment are determined by a number of factors. These include: the corrosivity of the environment (e.g. marine); the corrosion resistance of the steel grade; hygiene requirements (e.g. in the pharmaceutical and food industries); and, aesthetic considerations. Local environmental requirements must also be considered. Both chemical and mechanical cleaning methods are available. Good design, planning and methods of manufacture can reduce the need for post-treatment and thus lower costs.

When manufacturing to surface quality specifications, the impact of defects and, ultimately, the cost of removal must be borne in mind.

## 1.1 Typical Defects

### 1.1.1 Heat tint and oxide scale

Caused by processes such as heat treatment or welding, high-temperature oxidation produces an oxide layer that, compared to the original passive layer, has inferior protective properties. There is also a corresponding chromium depletion in the metal immediately below the oxide. With normal welding, the chromium-depleted zone is very thin and can normally be removed together with the tint. However, to completely restore corrosion resistance, it is vital that this zone is removed.

### 1.1.2 Weld defects

Incomplete penetration, undercut, pores, slag inclusions, weld spatter and arc strikes are typical examples of weld defects. These defects have a negative impact on mechanical properties and resistance to local corrosion. They also make it difficult to maintain a clean surface. Thus, the defects must be removed – normally by grinding, although sometimes repair welding is also necessary.

### 1.1.3 Iron contamination

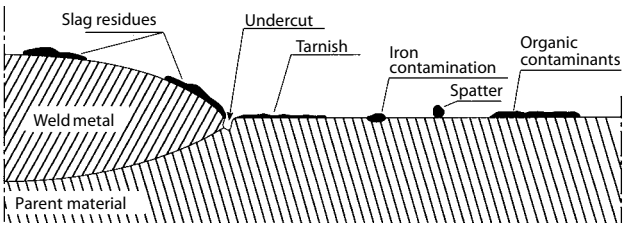
Iron particles can originate from: machining; cold forming and cutting tools; blasting grits/sand or grinding discs contaminated with lower alloyed materials; transport or handling in mixed manufacture; or, simply, iron-containing dust. These particles corrode in humid air and damage the passive layer. Larger particles may also cause crevices. In both cases, corrosion resistance is reduced. The resultant corrosion is unsightly and may also contaminate media used in/with the equipment in question. Iron contamination on stainless steels and welds can be detected using a ferroxyl test.

### 1.1.4 Rough surface

Uneven weld beads and grinding or blasting too heavily give rough surfaces. A rough surface collects deposits more easily, thereby increasing the risk of both corrosion and product contamination. Heavy grinding also introduces high tensile stresses. These increase the risk of stress corrosion cracking and pitting corrosion. For many applications, there is a maximum allowed surface roughness (Ra value). Manufacturing methods that result in rough surfaces should generally be avoided.

### 1.1.5 Organic contamination

In aggressive environments, organic contaminants in the form of grease, oil, paint, footprints, glue residues and dirt can cause crevice corrosion. They may also make surface pickling ineffective and pollute products handled in/with the equipment. Organic contaminants must be removed using a suitable cleaner. In simple cases, a high-pressure water jet may suffice.



Surface defects

Table 1. Stainless steels and their pickleability

| Stainless steel grades | | Welding method | Welding consumables | |
|---|---|---|---|---|
| EN | ASTM | | Option 1 | Option 2 |
| Group 1: Very easy to pickle* | | | | |
| 1.4006 | 410 | MMA | BÖHLER FOX KW 10 | – |
| 1.4016 | 430 | MMA | BÖHLER FOX SKWA | – |
| 1.4016 | 430 | MMA | BÖHLER FOX EAS 2 | – |
| 1.4016 | 430 | FCAW | BÖHLER EAS 2-FD | – |
| 1.4313 | 410NiMo | MMA | BÖHLER FOX CN 13/4 | – |
| 1.4313 | 410NiMo | MCAW | BÖHLER CN 13/4-MC | – |
| Group 2: Easy to pickle | | | | |
| 1.4301 | 304 | MMA | Avesta 308L/MVR | BÖHLER FOX EAS 2 |
| 1.4301 | 304 | MIG | Avesta 308L-Si/MVR-Si | BÖHLER EAS 2-IG (Si) |
| 1.4401 | 316 | MMA | Avesta 316L/SKR | BÖHLER FOX EAS 4 M-A |
| 1.4401 | 316 | MIG | Avesta 316L-Si/SKR-Si | BÖHLER EAS 4 M-IG (Si) |
| 1.4404 | 316L | MMA V-joint | Avesta 316L/SKR | – |
| 1.4404 | 316L | MMA | Avesta 316L/SKR | BÖHLER FOX EAS 4M |
| 1.4404 | 316L | MMA | Avesta 316L/SKR | BÖHLER FOX EAS 4M-A |
| 1.4404 | 316L | FCAW | Avesta 316L/SKR | BÖHLER EAS 4M-FD |
| 1.4404 | 316L | MIG | Avesta 316L-Si/SKR-Si | BÖHLER EAS 4M-IG |
| 1.4404 | 316L | MCAW | BÖHLER EAS 4M-MC | – |
| Group 3: Difficult to pickle | | | | |
| 1.4539 | 904L | MMA | Avesta 904L | – |
| 1.4539 | 904L | MIG | Avesta 904L | – |
| 1.4539 | 904L | MMA | Thermanit 625 | Avesta P12-R |
| 1.4501 | S32760 | MMA | Avesta 2507/P100 | – |
| 1.4161 | S32101 | MIG | Avesta LDX 2101 | – |
| 1.4161 | S32101 | FCAW | Avesta LDX 2101 | – |
| 1.4362 | S32304 | MIG | Avesta 2304 | – |
| 1.4362 | S32304 | FCAW | Avesta 2304 | – |
| 1.4462 | S32205 | MMA | BÖHLER FOX CN 22/9N | Avesta 2205 |
| 1.4462 | S32205 | MIG | BÖHLER CN 22/9 N-IG | Avesta 2205 |
| 2.4605 | N06059 | MMA | Thermanit Nimo C 24 | – |
| 2.4360 | N04400 | MMA | BÖHLER FOX NIBAS 400 | – |
| Group 4: Very difficult to pickle | | | | |
| 1.4547 | S31254 | MMA | Thermanit 625 | Avesta P12-R |
| 1.4547 | S31254 | MIG | Thermanit 625 | Avesta P12 |
| 1.4565 | S34565 | MMA | Thermanit Nimo C 24 | Avesta P16 |
| 1.4565 | S34565 | MIG | Thermanit Nimo C 24 | Avesta P16 |
| 1.4410 | S32750 | MMA | Avesta 2507/P100 | – |

* Group 1 is very easy to pickle but, at the same time, difficult to treat. There is a risk of overpickling. Great attention must be paid to pickling time and temperature.

# 2. Cleaning procedures

As detailed on page 3 , the extent of, and methods for, post-fabrication treatment are determined by a number of factors. Different chemical and mechanical methods, and sometimes a combination of both, can be used to remove the defects mentioned. Chemical cleaning can be expected to produce superior results. This is because most mechanical methods tend to produce a rougher surface while chemical methods reduce the risk of surface contamination. However, chemical cleaning may be limited not only by local regulations on environmental and industrial safety, but also by waste disposal problems.

## 2.1 Chemical methods

Chemical treatments can remove high-temperature oxide and iron contamination. They also restore the steel's corrosion resistance properties without damaging the surface finish. After the removal of organic contaminants, the normal procedures are commonly pickling, passivation/decontamination and/or electropolishing.

### 2.1.1 Pickling

Pickling is the most common chemical procedure used to remove oxides and iron contamination. Besides removing the surface layer by controlled corrosion, pickling also selectively removes the least corrosion-resistant areas such as the chromium-depleted zones. Pickling normally involves using an acid mixture containing nitric acid ($HNO_3$), hydrofluoric acid (HF) and, sometimes, also sulphuric acid ($H_2SO_4$). Owing to the obvious risk of pitting corrosion, chloride-containing agents such as hydrochloric acid (HCl) must be avoided.

The main factors determining the effectiveness of pickling are as set out below.

- **Steel grade**

Table 1 (page 4) shows the most common stainless steel grades and the matching welding consumables from voestalpine Böhler Welding. Pickleability has been tested and the steels arranged into four groups. The groupings are based on the ease with which the steels can be pickled.

**Steel group 1:** Owing to the low chromium content, the corrosion resistance of this group is lower than that of the groups below. The lower resistance of the steels in this group means they are "easier" to pickle. In other words, to avoid the risk of overpickling, they need a shorter pickling time or a less aggressive pickling agent. Special care must be taken to avoid overpickling! The pickling result may be unpredictable.

**Steel group 2:** The steels in this group are standard grades and fairly easy to pickle.

**Steel groups 3 – 4:** The steels in this group are high-alloy grades. Being more corrosion resistant, they need a more aggressive acid mixture and/or higher temperature (to avoid an excessively long pickling time). The risk of overpickling these steel grades is much lower (see table 1).

- **Precleaning**

A rough, hot rolled surface may be harder to pickle than a smooth, cold rolled one.

- **Welding method and resultant oxide layer**

Thickness and type of oxide layer depend largely on the welding procedure used. To produce a minimum of oxides, weld using an effective shielding gas that is as free of oxygen as possible. Particularly when pickling high-alloy steel grades, mechanical pretreatment to break or remove the oxides might be advisable.

- **Precleaning**

The surface must be free of organic contamination.

- **Temperature**

The effectiveness of pickling acids increases with temperature. Thus, the pickling rate can be considerably increased by increasing the temperature. However, there are upper temperature limits that must also be considered. Especially when using a bath, the risk of overpickling increases with high temperatures. When using pickling paste/gel/spray/solution at high temperatures, evaporation presents the risk of poor results. Besides an uneven pickling effect, this also leads to rinsing difficulties. To avoid these problems, objects must not be pickled at temperatures above 45°C or in direct sunlight.

- **Composition and concentration of the acid mixture**

- **Pickling method**

**Pickling with pickling paste/gel:** Pickling paste (or gel) for stainless steels is suitable for pickling limited areas, e.g. weld-affected zones. It is best applied using an acid-resistant brush. Rinsing with water must be carried out before the paste dries. Even if, for environmental and practical reasons, neutralisation of the pickling paste is carried out on the metal surface, thorough rinsing with water is vital.

**Pickling with pickling solution/spray:** Pickling solution (or pickling gel in spray form) is suitable for pickling large surfaces, e.g. when the removal of iron contamination is also desired.

**Pickling in a bath** is a convenient method if suitable equipment is available.

### 2.1.2 Passivation and decontamination

This procedure is carried out in a manner similar to pickling. The passivator, applied by immersion or spraying, strengthens the passive layer. Because the passivator also removes free iron impurities from the surface, the treatment is more important after mechanical cleaning and operations involving a risk of iron contamination. It is for this reason that the method can also be referred to as decontamination.

### 2.1.3 Electropolishing

Electropolishing normally produces a surface that guarantees optimal corrosion resistance. It does not selectively remove areas of inferior corrosion resistance, but polishes microtips from the surface. The material gains a fine lustre and, most importantly, an even microprofile that meets extremely stringent hygiene requirements. For these reasons, electropolishing is normally used as a final treatment after pickling. This method is not covered in the present publication.

## 2.2 Choice of method

The choice of method and the amount of final cleaning required depend on: corrosion resistance requirements; hygiene considerations (pharmaceuticals, food, etc.); and, the importance of the steel's visual appearance. Removal of welding defects, welding oxides, organic substances and iron contaminants is normally a basic requirement and usually allows a comparatively free choice of final treatment.

Provided that the surface roughness so permits, both mechanical and chemical methods can be used. However, if an entirely mechanical cleaning method is decided on, the manufacturing stage has to be very well planned in order to avoid iron contamination. If it is not, decontamination, probably with nitric acid, will be necessary. Where surface finish and corrosion resistance requirements are exacting, the choice of method is more critical. In such cases, a treatment sequence based on pickling gives the best chances of superior results.

The figure below shows the results of a test where the samples (steel grade 1.4404/316L with MMA welds) were post-weld cleaned using three different methods.They were then exposed to a marine environment for two weeks.

Grinding Polishing Pickling

## 2.3 Cleaning process

After a typical manufacturing programme, a complete cleaning process could be as set out below. All these steps are discussed in greater detail in subsequent chapters.

**How to carry out a complete cleaning process**

1. Inspect
2. Pretreat mechanically
3. Preclean
4. Rinse
5. Pickle
6. Desmut
7. Rinse
8. Passivate
9. Neutralise
10. Inspect

### 2.3.1 Case story

Landaluce, a company in Spain's Cantabria, manufactured a total of 90 beer tanks for Heineken and its brewery in Seville. Made in ASTM 304 hot rolled stainless steel, the 4.5 m diameter tanks are 18 m long. The tanks went through complete cleaning using the following Avesta Products:

- Cleaner 401
- RedOne Spray 240 (tank exteriors)
- Pickling Bath 302 (tank interiors)
- FinishOne Passivator 630

Stainless steel beer tanks ready for shipping after complete cleaning using Avesta products.Photo courtesy of Landaluce.

# 3. Chemical methods in practice

## 3.1 Avesta products

voestalpine Böhler Welding offers a wide programme of cleaning preparations:

- Pickling pastes
- Pickling sprays
- Pickling baths
- Cleaners
- Passivators

## 3.2 General requirements

The choice of chemical cleaning process is primarily determined by: the type of contaminants and heat oxides to be removed; the degree of cleanness required; and, the cost. This chapter gives guidelines on suitable chemical cleaning procedures. In order to avoid health hazards and/or environmental problems, pickling must be carried out in a special pickling area, preferably indoors. In this context, compliance with the recommendations below should be regarded as compulsory.

- Handling instructions and essential information (e.g. product labels, safety data sheets, etc.) for the various products must be available. Local and national regulations must also be available. See, additionally, section 5.1.

- The personnel in charge must be familiar with the health hazards associated with the products and how these must be handled.

- Personal safety equipment must be used. See also section 5.2.

- When pickling indoors, the workplace must be separate from other workshop operations. This is not only to avoid contamination and health hazards, but also to ensure a controlled temperature.

- The area must be well ventilated and provided with fume extraction apparatus.

- Walls, floors, roofs, tanks, etc. that are subject to splashing must be protected by acid-resistant material.

- A washing facility must be available, preferably including a high-pressure water jet.

- A first-aid kit must be available against acid splashes. See also section 5.1

- If the rinse water is recycled, care must be taken to ensure that the final rinse is performed using deionised water. This is particularly important in the case of sensitive surfaces and applications.

Surface rust – before and after removal using Avesta Cleaner 401.

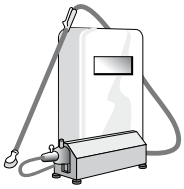
## 3.3 Precleaning/degreasing

Contamination on the surface can impair the pickling process. To prevent this, thorough cleaning prior to pickling is recommended. Where loose dust, fingerprints, shoeprints and tool marks are the contaminants, acid cleaning (e.g. Avesta Cleaner 401) is usually adequate.

### How to use Avesta Cleaner 401

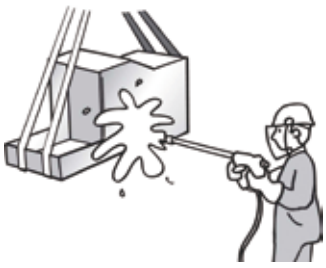
1. Inspect the surface to be treated and ensure that all non-stainless material has been protected.

2. Using an acid-resistant pump (Avesta SP-25), spray the product onto the surface. Apply an even layer that covers the entire surface. Do not apply in direct sunlight!



3. Allow the product sufficient reaction time, but avoid letting it dry. If the contaminants are stubborn (difficult to remove) and in thick layers, mechanical brushing with a hard plastic or nylon brush will help.

4. Preferably using a high pressure water jet, rinse thoroughly with clean tap water. To reduce acid splashing, prewashing at tap-water pressure (3 bars) is recommended. Ensure that no residues are left on the surface. Use deionised water for the final rinsing of sensitive surfaces.



## 3.4 Pickling

Pickling products can be applied in three different ways:

- Brushing, using a pickling paste/gel
- Spraying, using a pickling solution
- Immersion/circulation in/with a pickling bath

The different methods are presented in the following pages.

### 3.4.1 Pickling with paste/gel

Creating a better working environment, Avesta BlueOne™ Pickling Paste 130 is a unique pickling product. Using BlueOne™, there are virtually none of the toxic nitric fumes normally formed during pickling. Pickling Paste 130 can be used as a universal paste on all stainless steel grades.

### 3.4.2 Pickling with spray

Creating a better working environment, Avesta RedOne™ Spray Pickle Gel 240 is a unique pickling product. Using RedOne™ 240, toxic nitric fumes are significantly reduced.

**Combined Method:** For some purposes, brushing and spraying methods can be combined. When only a mild pickling effect is required (on sensitive surfaces), pickling paste can first be applied to the weld joints and then an acidic cleaner (e.g. Avesta Cleaner 401) can be sprayed onto the surface.

Brush pickling

Spray pickling

## How to use Avesta pickling pastes/gels

1. Pretreat oxides, slags and weld defects mechanically. This should preferably be done while the welds are still warm and the weld oxides less hard.

2. After any welding, give the area to be pickled time to cool down to below 40°C.

3. To remove organic contamination, degrease using Avesta Cleaner 401.

4. Before using, stir or shake the paste.

5. Using an acid-resistant brush, apply the pickling paste. Do not pickle in direct sunlight!

6. Give the product sufficient time to react (see table 4). At high temperatures, and when prolonged pickling times are required, it might be necessary to apply more of the product after a while. This is because the product can dry out and thus cease to be as effective.

7. Preferably using a highpressure water jet, rinse thoroughly with clean tap water. Ensure that no pickling residues are left on the surface. Use deionised water for the final rinsing of sensitive surfaces.

8. Collect the waste water so that it can be neutralised, See also chapter 4.

## How to use Avesta pickling spray

1. Inspect the surface to be treated and ensure that all non-stainless material has been protected.

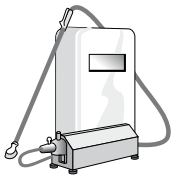
2. Pretreat oxides, slags and weld defects mechanically. This should preferably be done while the welds are still warm and the weld oxides less hard.

3. After any welding, give the area to be pickled time to cool down to below 40°C.

4. To remove organic contamination, degrease using Avesta Cleaner 401.

5. Before using, stir the spray gel well.

6. Using an acid-resistant pump (Avesta SP-25), apply the product as a spray. Gently apply an even layer of acid that covers the entire surface. Do not pickle in direct sunlight!

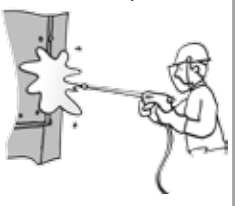


7. Allow the product sufficient pickling time.

8. Desmutting is necessary if dark areas appear on the surface. Apply either more solution or Avesta Finish-One™ to these spots until they disappear. This must be done when the surface is still wet (i.e. “wet on wet”), just before the pickling spray is rinsed off. Spraying Finish One™ on top of the pickled surface also reduces the production of $NO_x$ gases.

9. When pickling, the pickling spray must not be allowed to dry. Drying may cause discoloration of the steel surface. This means that at high temperatures, and when prolonged pickling times are required, it may be necessary to apply more of the product after a while.

10. Preferably using a high-pressure water jet, rinse thoroughly with clean tap water. To reduce acid splashing, prewashing at tap-water pressure (3 bars) is recommended. Ensure that no pickling residues are left on the surface. Use deionised water for the final rinsing of sensitive surfaces.



11. Passivation must be carried out directly after wet-on-wet rinsing. Spray Avesta FinishOne™ Passivator 630 evenly over the entire surface.

12. Leave to dry.

13. Carry out inspection and process verification.

14. All treated surfaces must be ocularly inspected for oil residues, oxides, rust and other contaminants.

15. Collect the waste water so that it can be neutralised. See also chapter 4.

Table 2: Typical pickling times for brush and spray pickling (cold rolled surfaces)

| Stainless steel grades | | Welding method | Welding consumables | | Finishing chemicals | | | |
|---|---|---|---|---|---|---|---|---|
| EN | ASTM | | Option 1 Product name | Option 2 Product name | Pickling paste Product name | Recommended time (minutes) | Pickling spray Product name | Recommended time (minutes) |
| Group 2: Easy to pickle | | | | | | | | |
| 1.4301 | 304 | MMA | Avesta 308L/MVR | BÖHLER FOX EAS 2 | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| 1.4301 | 304 | MIG | Avesta 308L-Si/MVR-Si | BÖHLER EAS 2-IG (Si) | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| 1.4401 | 316 | MMA | Avesta 316L/SKR | BÖHLER FOX EAS 4 M-A | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| 1.4401 | 316 | MIG | Avesta 316L-Si/SKR-Si | BÖHLER EAS 4 M-IG (Si) | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| 1.4404 | 316L | MMA V-joint | Avesta 316L/SKR | – | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| 1.4404 | 316L | MMA | Avesta 316L/SKR | BÖHLER FOX EAS 4M | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| 1.4404 | 316L | MMA | Avesta 316L/SKR | BÖHLER FOX EAS 4M-A | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| 1.4404 | 316L | FCAW | Avesta 316L/SKR | BÖHLER EAS 4M-FD | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| 1.4404 | 316L | MIG | Avesta 316L-Si/SKR-Si | BÖHLER EAS 4M-IG | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| 1.4404 | 316L | MCAW | – | – | Avesta BlueOne™ 130 | 30 – 60 | Avesta RedOne™ 240 | 45 – 90 |
| Group 3: Difficult to pickle | | | | | | | | |
| 1.4539 | 904L | MMA | Avesta 904L | – | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 1.4539 | 904L | MIG | Avesta 904L | – | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 1.4539 | 904L | MMA | Thermanit 625 | Avesta P12-R | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 1.4501 | S32760 | MMA | Avesta 2507/P100 | – | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 1.4161 | S32101 | MIG | Avesta LDX 2101 | – | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 1.4161 | S32101 | FCAW | Avesta LDX 2101 | – | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 1.4362 | S32304 | MIG | Avesta 2304 | – | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 1.4362 | S32304 | FCAW | Avesta 2304 | – | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 1.4462 | S32205 | MMA | BÖHLER FOX CN 22/9N | Avesta 2205 | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 1.4462 | S32205 | MIG | BÖHLER CN 22/9 N-IG | Avesta 2205 | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 2.4605 | N06059 | MMA | – | – | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| 2.4360 | N04400 | MMA | – | – | Avesta BlueOne™ 130 | 90 – 180 | Avesta RedOne™ 240 | 120 – 240 |
| Group 4: Very difficult to pickle | | | | | | | | |
| 1.4547 | S31254 | MMA | Thermanit 625 | Avesta P12-R | Avesta BlueOne™ 130 | 120 – 240 | Avesta RedOne™ 240 | 150 – 300 |
| 1.4547 | S31254 | MIG | Thermanit 625 | Avesta P12 | Avesta BlueOne™ 130 | 120 – 240 | Avesta RedOne™ 240 | 150 – 300 |
| 1.4565 | S34565 | MMA | Thermanit Nimo C 24 | Avesta P16 | Avesta BlueOne™ 130 | 120 – 240 | Avesta RedOne™ 240 | 150 – 300 |
| 1.4565 | S34565 | MIG | Thermanit Nimo C 24 | Avesta P16 | Avesta BlueOne™ 130 | 120 – 240 | Avesta RedOne™ 240 | 150 – 300 |
| 1.4410 | S32750 | MMA | Avesta 2507/P100 | – | Avesta BlueOne™ 130 | 120 – 240 | Avesta RedOne™ 240 | 150 – 300 |

The pickling was preceded by mechanical pretreatment of the weld joints and precleaning using Avesta Cleaner 401.

### 3.4.3 Typical pickling times for brush and spray pickling

The pickling times given in table 2 must be seen as indicative only. They are stated as intervals because, for the same steel grade, the time required depends on the surface finish and the welding method (see also chapter 1). For hot rolled surfaces, pickling times should normally be increased. Similarly, depending on the shielding gas used, MIG welds might need longer than MMA or FCAW welds.

**Pickling equipment:** To achieve a good spraying result, a suitable pump is necessary. The pump must be made of an acid-resistant material and must provide an even application pressure. Avesta Spray Pickle Pump SP-25 was specially designed to meet these requirements. It is a pneumatic, quarter inch pump of the membrane type and has an adjustable valve.

### 3.4.4 Pickling in a bath

The stainless steel grade and the type of heat oxide determine the acid mixture and the bath temperature (20 – 65ºC). Pickling low-alloy stainless grades at excessive temperatures, or for a long period of time, presents the risk of overpickling. This gives a rough surface.

The effectiveness of pickling is affected not only by acid concentration and temperature, but also by the free metal content (mainly iron) in the bath. For pickling times to be the same, the temperature in a bath with an elevated iron content has to be higher than that in a bath with a lower iron content. A rough guideline is that the free iron (Fe) content measured in grams per litre must not exceed the bath temperature (ºC). When metal contents in the bath reach excessive levels (40 – 50 g/l), the bath solution should be partially or totally emptied out and fresh acid added.

Avesta Pickling Bath 302 is a concentrate that, depending on the steel grade being cleaned, can be diluted with water. The ferritic and martensitic steels in group 1 are normally not pickled in a bath. Thus, they are not mentioned here.

The pickling acid must be added to the water, **not** the other way round.

**Group 2 steels:** 1 part 302 into 3 parts water

**Group 3 steels:** 1 part 302 into 2 parts water

**Group 4 steels:** 1 part 302 into 1 part water

Temperature, composition and circulation need to be controlled to get the best results. The composition of the bath is controlled through regular analysis. Together with new mixing instructions to optimise the effect of the bath, voestalpine Böhler Welding can offer such analyses.

The pickling times given in the table below must be seen as indicative only. They are stated as intervals because, for the same steel grade, the time required depends on the surface finish and the welding method (see also chapter 1). For hot rolled surfaces, pickling times might be increased by 50%. Similarly, depending on the shielding gas used, MIG welds might need longer than MMA or FCAW welds.

Table 3: Typical pickling times using Avesta Pickling Bath 302

| Stainless steel grades | | Welding method | Welding consumables | | Typical pickling times (minutes) | | |
|---|---|---|---|---|---|---|---|
| | | | Avesta | Böhler | | | |
| EN | ASTM | | designation | designation | 20°C | 30°C | 45°C |
| Group 2: Easy to pickle* | | | | | | | |
| 1.4301 | 304 | MMA | 308L/MVR | FOX EAS 2 | 30 | 15 | 10 |
| 1.4401 | 316 | MMA | 316L/SKR | FOX EAS 4M | 40 | 20 | 10 |
| 1.4404 | 316L | MMA | 316L/SKR | FOX EAS 4M | 40 | 20 | 10 |
| Group 3: Difficult to pickle** | | | | | | | |
| 1.4539 | 904L | MMA | 904L | – | 120 | 90 | 60 |
| 1.4362 | S32304 | MMA | 2304 | – | 120 | 90 | 60 |
| 1.4462 | S32205 | MMA | 2205 | FOX CN 22/9N | 120 | 90 | 60 |
| Group 4: Very difficult to pickle*** | | | | | | | |
| 1.4547 | S31254 | MMA | P12-R | FOX NIBAS 625 | 240 | 120 | 90 |
| 1.4410 | S32750 | MMA | 2507/P100 | FOX CN 25/9CuT | 240 | 120 | 90 |

* 1 part 302 into 3 parts water
** 1 part 302 into 2 parts water
*** 1 part 302 into 1 part water

Bath pickling.
Photo courtesy of Kurt Jensen

## How to use Avesta pickling bath

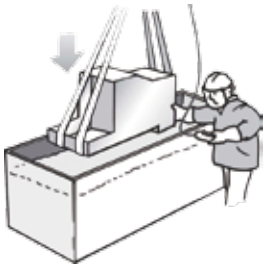
1. Pretreat oxides, slag and weld defects mechanically.

2. After any welding, give the area to be pickled time to cool down to below 40°C.

3. To remove organic contamination, degrease using Avesta Cleaner 401.

4. Check the bath temperature (refer to table 3).

5. Immerse the object in the bath. Typical pickling times are shown in table 2. Avoid over-pickling. This can produce a rough surface.



6. Allow the product sufficient pickling time.

7. If dark spots appear on the surface, desmutting is necessary. Apply either more solution or Avesta Finish-One™ to these spots until they disappear. This must be done when the surface is still wet (i.e. “wet on wet”), just before the pickling spray is rinsed off. Spraying Finish-One™ on top of the pickled surface also reduces the production of $NO_x$ gases.

8. When lifting the object, allow time for the bath solution to flow off above the bath.

9. Rinse thoroughly using a high-pressure water jet. Ensure that no pickling residues are left on the surface. Use deionised water for the final rinsing of sensitive surfaces.

10. Collect the waste water so that it can be neutralised. See also chapter 4.

11. As the pickling acid in the bath is being constantly consumed and metals precipitated, analysis of bath contents is important. Bath contents affect the pickling reaction.

### 3.4.5 Fume reduction during pickling

#### Environmental impact

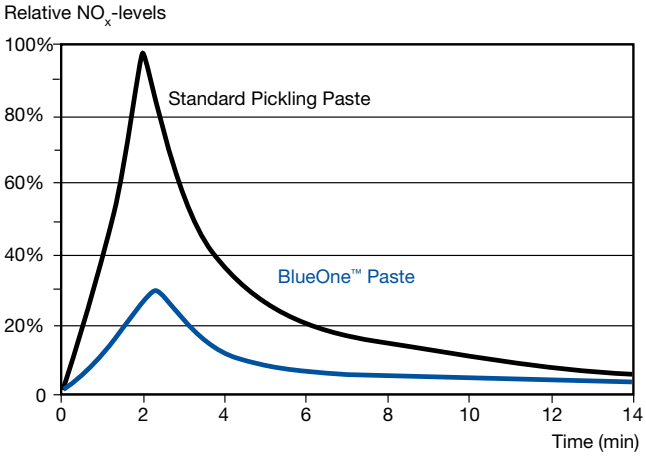
The toxic nitric fumes generated during pickling have a number of effects.

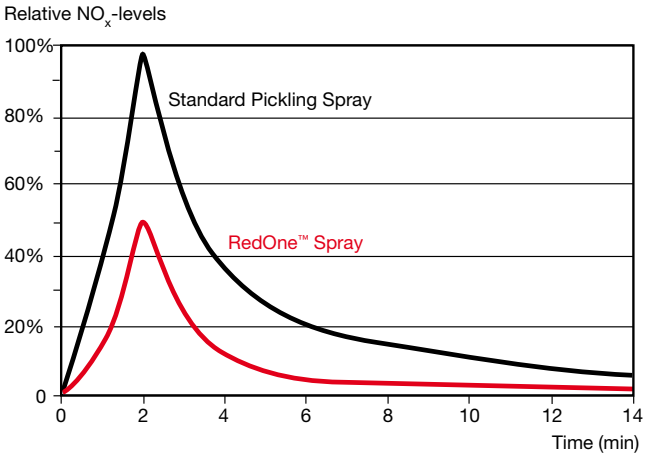
**Health:** High nitric fume levels may lead to respiratory problems (e.g. infections). In the worst case, inhalation may cause lung oedema.

**Environmental:** Acidification of groundwater and damage to plants.

Using modern pickling products such as Avesta BlueOne™ Picking Paste 130 and Avesta RedOne™ Spray 240, toxic fume levels can be reduced by up to 80%.

Fume reduction using Avesta Pickling products




Fume reduction using Avesta pickling products
BlueOne™ Pickling Paste
RedOne™ Pickling Spray

#### How to use Avesta FinishOne™ passivator

- To passivate after mechanical treatment, first use Avesta Cleaner 401 to preclean the surface. Next, rinse with water and apply the passivator "wet on wet". Leave it to react for 3 – 5 minutes.
- To desmut or avoid smut formation during spray pickling, the passivator must be applied before rinsing while the surface is still wet ("wet on wet"). Leave it to react for 10 – 15 minutes.
- To use for fume reduction after bath pickling, lift the object over the surface of the bath and spray Finish-One™ as a mist on the object's surface ("wet on wet").
- To passivate after spray pickling, first rinse off the pickling spray and then apply the passivator. Leave it to react for 20 – 30 minutes.
- Using an acid-resistant pump (Avesta SP-25), apply the product as a spray. Apply an even layer of acid that covers the entire surface.
- Using an acid resistant pump (Avesta SP-25); apply the passivator as an even layer that covers the entire surface.
- Preferably using a high-pressure water jet, rinse thoroughly with clean tap water. Ensure that no acid residues are left on the surface. Use deionised water for the final rinsing of sensitive surfaces.
- There is no need to neutralise the waste water (it is neutral and acid free).

## 3.5 Passivation and desmutting

Avesta FinishOne™ Passivator 630 is a passivating agent that is free of nitric acid and has a low environmental impact. Because it is neutral after passivation, there is no need for a neutralisation stage. The product can passivate, desmut and reduce fumes.

**Passivation** is strongly recommended after mechanical treatment (to remove remaining iron contamination) and, in some cases, after spray pickling.

**Desmutting** removes the dark spots caused by excessive iron left on the surface by faulty cleaning.

**Fume reduction:** While bath pickling, spraying Avesta Finish-One™ Passivator 630 on the pickled object while lifting it from the bath reduces the toxic nitric fumes generated during bath pickling.

# 4. Neutralisation and waste treatment

## 4.1 Neutralisation

The waste water from pickling is acidic and contaminated with heavy metals (mainly chromium and nickel that have been dissolved from the steel). This waste water must be treated in accordance with local regulations. It can be neutralised using an alkaline agent (slaked lime, or soda) in combination with a settling agent.

Adjusting the pH value of the waste water causes the heavy metals to be precipitated as metal hydroxides. Precipitation is optimal at pH 9.5.

The heavy metals form a sludge that can then be separated from the neutralised clear water. This sludge must be treated as heavy metal waste and disposed of accordingly.

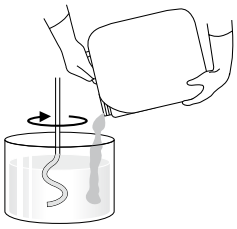
## 4.2 Waste treatment

Pickling creates waste that requires special treatment. Besides what comes from the chemicals themselves, the packaging must also be considered as waste.

The sludge obtained after neutralisation contains heavy metals. This sludge must be sent away for disposal in accordance with local waste regulations.

All materials used in the packaging (plastic containers, cardboard boxes, etc.) of Avesta Finishing Chemicals' products are recyclable.

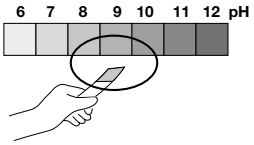
### How to neutralise



1. Stirring all the time, add the neutralising agent to the rinse water.

2. The neutralising reaction takes place instantly.

3. Using litmus paper (for example), check the pH of the mixture. Precipitation of the heavy metals is optimal at pH 9.5.




4. When the waste water has reached an acceptable pH value, wait for the sludge to sink to the bottom and for the water to become clear. Adding a special settling agent improves the precipitation of heavy metals.


5. If analysis shows that the treated water satisfies local regulations, it can be released into the sewage system. To increase the degree of treatment, an extra filter can be inserted before the water reaches the sewage system.

6. The sludge contains heavy metals and must be sent to a waste-treatment plant.

Passivation of what will be part of a chemical tanker bulkhead in duplex stainless steel

Smut

# 5. Safe handling

## 5.1 Safety rules

Pickling products are hazardous substances and must be handled with care. Certain rules must be followed to ensure that the working environment is good and safe:

### Safety rules

1. Pickling chemicals must only be handled by persons with a sound knowledge of the health hazards associated with such chemicals. This means that the material safety data sheet (MSDS) and the product label must be thoroughly studied before the chemicals are used.

2. Eating, smoking and drinking must be forbidden in the pickling area.

3. Employees handling pickling chemicals must wash their hands and faces before eating and after finishing work.

4. All parts of the skin that are exposed to splashing must be protected by an acid-resistant material, according to MSDS. This means that employees handling pickling chemicals (including during rinsing) must wear protective clothing as stipulated in the MSDS for the product in question.

5. A First Aid kit containing calcium glucontate gel, Hexaflourine® (Avesta First Aid Spray ) or other products suitable for an immediate treatment/rinsing of acid splashes caused by pickling products, should be easy available. For more information check the MSDS for the Avesta Pickling Products.

6. The pickling area must be ventilated.

7. To avoid unnecessary evaporation, the containers/jars must be kept closed.

8. To minimise the environmental impact, all pickling residues must be neutralised and all heavy metals separated from the process water and sent to a waste treatment plant.

## 5.2 Personal safety

Health hazards can be avoided by the use of breathing equipment and skin protection. If a high degree of personal safety is to be ensured, we strongly recommend that the following measures be regarded as compulsory.

For personal safety, a face mask (equipped with breathing apparatus) must always be worn in connection with pickling. Pickling acids are aggressive and, on contact, can burn the skin. This can be avoided by protecting all exposed skin with acid-resistant clothing.

All cleaning chemicals from Avesta Finishing Chemicals are supplied with:

- Product information (PI) with reference numbers
- Material safety data sheets (MSDSs) as per ISO 11014-1 and 2001/58/EC

These documents give the information necessary for the safe handling of the product. They must always be consulted before using the product in question.

Personal protection equipment

## Disclaimer

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# voestalpine Böhler Welding

voestalpine Böhler Welding is a leading manufacturer and worldwide supplier of filler metals for industrial welding and brazing applications. With more than 100 years of experience, the enterprise has decisively influenced the development of welding technology, setting the benchmark with its innovative solutions. Avesta Finishing Chemicals is part of voestalpine Böhler Welding and a leading producer of superior pickling products for stainless steel and special alloys.

böhler welding by voestalpine

More than 2000 products for joint welding in all conventional arc welding processes are united under the Böhler Welding brand in a product portfolio that is unique throughout the world. Böhler Welding creates lasting connections, both in welding and between people.

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Decades of industry experience and application know-how in the areas of repair as well as wear and surface protection, combinded with innovative and custom-tailored products, guarantee customers an increase in the productivity and protection of their components.

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Through deep insight into processing methods and ways of application, Fontargen Brazing provides the best brazing and soldering solutions based on proven products with German technology. Expertise based on many years of experience from countless application cases.

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