Handbook for the pickling and cleaning of stainless steel

AvestaPolarit
STAINLESS

Index

FOREWORD 1

1 STAINLESS STEEL AND THE NEED FOR CLEANING 2
1.1 Introduction 2
1.2 Typical defects 2
1.2.1 Heat tint and oxide scale 2
1.2.2 Weld defects 2
1.2.3 Iron contamination 2
1.2.4 Rough surface 2
1.2.5 Organic contamination 2

2 CLEANING PROCEDURES 3
2.1 Mechanical methods 3
2.1.1 Grinding 3
2.1.2 Blasting 3
2.1.3 Brushing 3
2.1.4 Summary 3

2.2 Chemical methods 4
2.2.1 Electropolishing 4
2.2.2 Pickling 4
2.2.3 Summary 5
2.2.4 Passivation and decontamination 5

2.3 Choice of method 5

3 CHEMICAL METHODS IN PRACTICE 6
3.1 General requirements 6
3.2 Pre-cleaning/degreasing 6
3.3 Pickling 6
3.3.1 Pickling with paste/gel 7
3.3.2 Pickling with solution 8
3.3.3 Pickling in a bath 9

3.4 Passivation and decontamination 10

4 NEUTRALISATION AND WASTE TREATMENT 10
4.1 Neutralisation 10
4.2 Waste treatment 10

5 INSPECTION AND TROUBLESHOOTING 11
5.1 Test methods 11
5.2 Troubleshooting 11

6 SAFE HANDLING AND STORAGE OF PICKLING PRODUCTS 12
6.1 Safety rules 12
6.2 Personal safety 12
6.3 Storage 13

REFERENCES 14

DISCLAIMER Inside cover

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Foreword

AvestaPolarit is one of the world´s major manufacturers of stainless steel. The parent company´s production of plate, sheet, coils and billets provides the basis for processing operations by subsidiaries and associated companies producing piping, fittings and manufactured goods as well as rod, wire and welding consumables.

The AvestaPolarit Group includes AvestaPolarit Welding , one of Europe's largest producers of welding consumables and pickling products for stainless steel and special alloys.

In this handbook, AvestaPolarit Welding presents practical methods for pickling and cleaning stainless steel. Appropriate safety procedures when handling the products involved are also described.

The aims of this handbook are to provide a generally increased awareness and understanding of the need for surface treatment of stainless steel and in particular:

- to explain **why** stainless steel structures need cleaning after welding and processing in order to preserve their corrosion resistance,
- to show **when** cleaning is important through a survey of typical defects,
- to describe **how** to clean using different cleaning techniques, and
- to give practical recommendations and instructions as to **what** to do in order to eliminate typical drawbacks.

1 Stainless steel and the need for cleaning

1.1 INTRODUCTION

A stainless steel surface should appear clean, smooth and faultless. This is obvious when the steel is used for such purposes as façades or in applications with stringent hygienic requirements, but a fine surface finish is also crucial to corrosion resistance.

Stainless steel is protected from corrosion by a thin, impervious, invisible surface layer – the passive layer – that consists mainly of chromium oxide. The oxygen content of the atmosphere or aerated aqueous solutions is normally sufficient to create and maintain this passive layer. Unfortunately, surface defects and imperfections introduced during manufacturing operations may drastically disturb this "self-healing" process and reduce resistance to several types of local corrosion. This means that a final cleaning process will often be required to restore an acceptable surface quality with regard to hygiene and corrosion.

The extent of and methods for post-manufacture treatment will be determined by the corrosivity of the environment, the corrosion resistance of the steel grade, hygienic requirements (e.g. in the pharmaceutical and food industries) or by purely aesthetic considerations. Consideration must also be paid to local environmental requirements. Both chemical and mechanical cleaning methods are available. Good design, planning and methods of manufacture can reduce the need for finishing work and thus reduce costs. The influence of defects, and ultimately their removal, must be considered when manufacturing to specifications that relate to certain surface quality requirements. For further details and explanations, the "Avesta Sheffield Corrosion Handbook" is recommended.

1.2 TYPICAL DEFECTS

1.2.1 Heat tint and oxide scale

High temperature oxidation – caused by processes such as heat treatment or welding – produces an oxide layer with inferior protective properties, compared with those of the original passive layer. A corresponding chromium depletion in the metal immediately below the oxide also occurs. The chromium-depleted zone under normal welding heat tint is very thin and can normally be removed together with the tint. It is, however, necessary to remove this layer in order to completely restore corrosion resistance.

1.2.2 Weld defects

Incomplete penetration, undercut, pores, slag inclusions, weld spatter and arc strikes are typical examples of weld defects.

These defects have negative effects on mechanical properties, resistance to local corrosion and make it difficult to maintain a clean surface. The defects must therefore be removed, normally by grinding, although sometimes repair welding is also necessary.

1.2.3 Iron contamination

Iron particles can originate from machining, cold forming and cutting tools, blasting grits/sand or grinding discs contaminated with lower alloyed material, transport or handling in mixed manufacture, or simply from iron-containing dust. These particles corrode in humid air and damage the passive layer. Larger particles may also cause crevices. Reduced corrosion resistance will result in both cases. This type of corrosion produces unsightly discoloration and may also contaminate media used in the equipment in question. Iron contamination can be detected using the ferroxyl test; see chapter 5.

1.2.4 Rough surface

Uneven weld beads and grinding or blasting too heavily will result in 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, which increase the risk of stress corrosion cracking and pitting corrosion. There is a maximum allowed surface roughness (Ra-value) for many applications, and manufacturing methods that result in rough surfaces should generally be avoided.

1.2.5 Organic contamination

Organic contaminants in the form of grease, oil, paint, footprints, glue residues and dirt can cause crevice corrosion in aggressive environments, render surface pickling activities ineffective, and pollute products handled in the equipment. Organic contaminants should be removed using a suitable pre-cleaning/degreasing agent (chlorine-free). In simple cases, a high-pressure water jet can be used.

2 Cleaning procedures

Different chemical and mechanical methods, and sometimes a combination of both, can be used to remove the defects mentioned. Generally, cleaning based on chemical methods can be expected to produce superior results since most effective mechanical methods tend to produce a rougher surface whilst chemical cleaning methods reduce the risk of surface contamination. Local regulations in respect of environmental and industrial safety as well as waste disposal problems may, however, limit their application.

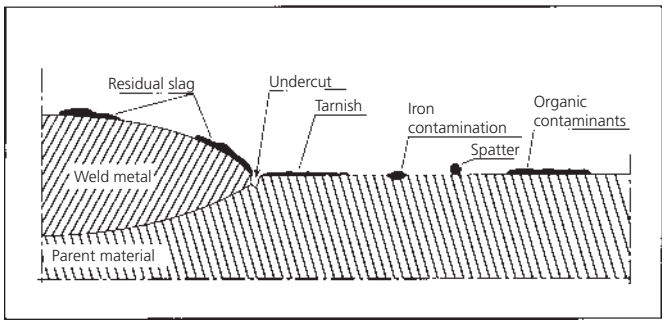


Figure 1. Surface defects

2.1 MECHANICAL METHODS

2.1.1 Grinding

Grinding is normally the only method that can be used to remove defects and deep scratches. A grinding disc is usually adequate for treating defects of this type. The grinding methods used should never be rougher than necessary, and a flapper wheel is often sufficient for removing weld tint or surface contamination.

The following points must always be considered:

- Use the correct grinding tools – self-sharpening, iron-free discs should always be used for stainless steel – and never use discs that have previously been used for grinding low alloy steels.
- Avoid producing a surface that is too rough. Rough grinding with a 40-60 grit disc should always be followed by fine grinding using, for example, a higher grip mop or belt to obtain a surface finish corresponding to grit 180 or better. If surface requirements are very exacting, polishing may be necessary.
- Do not overheat the surface. Apply less pressure when grinding in order to avoid creating further heat tint.
- Always check that the entire defect has been removed.

2.1.2 Blasting

Sand and grit blasting (peening) can be used to remove high temperature oxide as well as iron contamination. However, care must be taken to ensure that the sand (preferably of olivine type) or grit is perfectly clean. The blasting material must therefore not have been previously used for carbon steel; not should the sand or grit be too old, since it becomes increasingly polluted, even if it has only been used for blasting contaminated stainless steel surfaces. The surface roughness is the limiting factor for these methods. Using low pressure and a small angle of approach, a satisfactory result can be achieved for most applications. For the removal of heat tint, shot peening using smooth glass beads produces a good surface finish and introduces compressive stresses which improve stress corrosion cracking resistance and resistance to fatigue.

2.1.3 Brushing

For the removal of heat tint, brushing using stainless steel or nylon brushes usually provides a satisfactory result. These methods do not cause any serious roughening of the surface, but do not guarantee complete removal of the chromium-depleted zone. As regards the other mechanical methods, the risk of contamination is high, and it is therefore important that clean tools that have not been used for processing carbon steels are used.

2.1.4 Summary

A final mechanical cleaning stage following a typical manufacturing programme could be as follows:

- Removal of welding defects by grinding;
- Removal of material affected by high temperatures and, if possible, removal of iron impurities. The surface must not become unacceptably rough;
- Removal of organic contaminants (see section 1.2.5);
- A final acid treatment – passivation/ decontamination – is strongly recommended. A thorough rinsing with fresh water, preferably using a high-pressure water jet must follow the acid treatment. In exceptional cases, however, rinsing by high-pressure water jet only may suffice as the final treatment.

2.2 CHEMICAL METHODS

Chemical methods can remove high temperature oxide and iron contamination without damaging the surface finish. Electropolishing may improve the surface finish. Since they remove the surface layer by controlled corrosion, chemicals will also selectively remove the least corrosion-resistant areas such as the chromium-depleted zones.

After the removal of organic contaminants (section 1.2.5), the following procedures are commonly used.

2.2.1 Electropolishing

Electropolishing normally produces a surface that guarantees optimal corrosion resistance. The material gains a fine lustre, and, above all, an even micro-profile that meets extremely stringent hygienic requirements.

2.2.2 Pickling

Pickling is the most common chemical procedure used to remove oxides and iron contamination. Thorough rinsing with clean tap water must follow pickling. The water quality requirements, including acceptable chloride content, increase with the surface requirements. Pickling normally involves using an acid mixture containing 8-20 vol% nitric acid (HNO_3) and 0.5-5 vol% hydrofluoric acid (HF). Chloride-containing agents such as hydrochloric acid (HCl) should be avoided, since there is an obvious risk of pitting corrosion.

The effectiveness of pickling depends on the following factors:

- **The surface.** This must be free of organic contamination;
- **The temperature.** The effectiveness of the acids increases strongly with temperature. This means, for example, that the pickling rate can be increased considerably by increasing the temperature. There are, however, upper temperature limits that must also be considered. See below.
- **The composition and concentration of the acid mixture.**
- **The steel grade.** Highly alloyed grades need a more aggressive acid mixture and/or higher temperature in order to avoid an excessively long pickling time. See table 1.
- **The thickness and type of the oxide layer.** This depends largely on the welding procedure used. Welding using an effective shielding gas will produce a minimum of weld oxides. Such a gas should be as free of oxygen as possible. For further information, see the AvestaPolarit Welding Handbook on welding stainless steel. Mechanical pre-treatment to break or remove the oxide might be advisable, particularly when pickling highly alloyed steel grades.
- **The surface finish.** A rough hot rolled surface may be harder to pickle than a smooth cold rolled one.

A number of different pickling methods can be used:

- **Pickling in a bath** is a convenient method if suitable equipment is available. The composition of the acid mixture and the bath temperature (20-65ºC) are chosen with regard to the stainless steel grade and the type of heat oxide. Overpickling, resulting in a rough surface, may result when pickling the lowest alloyed stainless grades at excessive temperatures.

Table 1. Stainless steel grades and their pickleability

Group	International steel number/name EN	ASTM	AvestaPolarit steel name	AvestaPolarit chemical composition, average % C	Cr	Ni	Mo	Others	DIN	SS	Pickleability
1	1.4301	304	4301	0.04	18.1	8.3	–	–	1.4301	2333	1
	1.4401	316	4401	0.02	17.2	10.2	2.1	–	1.4401	2347	2
	1.4404	316L	4404	0.02	17.2	10.2	2.1	–	1.4404	2348	2
	1.4571	316Ti	4571	0.04	16.8	10.9	2.1	Ti	1.4571	2350	2
	1.4436	316	4436	0.02	16.9	10.7	2.6	–	1.4436	2343	2
2	1.4362	S32304	SAF 2304™	0.02	23	4.8	0.3	–	1.4362	2327	3
	1.4462	S32205	2205	0.02	22	5.7	3.1	–	1.4462	2377	3
	1.4439	S31726	4439	0.02	17.8	12.7	4.1	–	1.4439	–	3
	1.4539	N08904	904L	0.01	20	25	4.3	1.5 Cu	1.4539	2562	3
3	1.4410	S32750	SAF 2507™	0.02	25	7	4	–	–	2328	4
	1.4547	S31254	254 SMO®	0.01	20	18	6.1	Cu	–	2378	4
	1.4652	S32654	654 SMO®	0.01	24	22	7.3	3.5 Mn, Cu	–	–	4

The steels have been divided into three groups. The pickleability of these steel grades ranges from 1 (very easy) to 4 (very difficult). SAF 2304 and SAF 2507 are manufactured under licence granted by AB Sandvik Steel.

The effectiveness of pickling is influenced not only by the acid concentration and the temperature, but also by the free metal content (mainly iron) in the bath. An increased iron content requires a higher bath temperature. A rough guideline is that the free iron (Fe) content measured in g/l should not exceed the bath temperature (ºC). When metal contents in the bath reach excessive levels (40-50 g/l), the bath solution can be partially or totally emptied out and fresh acid added.

- **Pickling with pickling paste.** Pickling paste for stainless steels consists of an acid mixture (normally HF/HNO_3) with added binding agents. It is suitable for pickling limited areas, e.g. weld-affected zones. It is normally applied using an acid-resistant brush. The paste is not effective at low temperatures (5-10ºC). The risk of overpickling at high temperatures is less than when using bath pickling. A greater risk is that of the paste drying out due to evaporation, resulting in reduced pickling effect and rinsing difficulties. Objects should therefore not be pickled at temperatures higher than 40ºC or in direct sunlight. Rinsing with water should be carried out before the paste dries. Even if neutralisation of the pickling paste is carried out on the metal surface for environmental and practical reasons, a thorough rinsing with water is vital.
- **Pickling with pickling solution.** Pickling solution (or pickling gel in spray form) normally consists of a mixture of nitric acid and hydrofluoric acids (phosphoric acid can be used to obtain mild pickling properties), with binding agents and surface-active agents to obtain good thixotropy and the right viscosity. It is suitable for pickling large surfaces, e.g. when the removal of iron contamination is also desired.

2.2.3 Summary

A final pickling/cleaning operation following a typical manufacturing programme could be:

- Grinding for removal of defects caused by welding. It is important that slag is removed after welding.
- Removal of organic contamination (section 1.2.5).
- Pickling using a bath, paste or solution, possibly in combination with a careful mechanical treatment to break oxides.
- A thorough rinsing with water, preferably using a high-pressure water jet.

2.2.4 Passivation and decontamination

This procedure is carried out in a manner similar to pickling, but in this case the active agent is nitric acid only, 18-30 weight % at around 20ºC. The acid is applied by immersion or spraying. This treatment strengthens the passive layer. The treatment is more important after mechanical cleaning and operations involving a risk of iron contamination, since the acid also removes iron impurities from the surface. Consequently, the method could also be referred to as decontamination. As after every acid treatment, rinsing with water is vital.

2.3 CHOICE OF METHOD

The choice of method and the extent of final cleaning required will depend on the need for corrosion resistance, hygienic considerations (pharmaceuticals, food) or whether visual appearance is the sole criterion. The routine 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 considered, the manufacturing stage has to be very well planned in order to avoid iron contamination, since decontamination, probably with nitric acid, will otherwise be necessary (section 2.2.4).

When requirements as to surface finish and corrosion resistance are exacting, the choice of method is more critical. A treatment sequence based on pickling (section 2.2.3) will in such cases provide the best chances of a superior result.

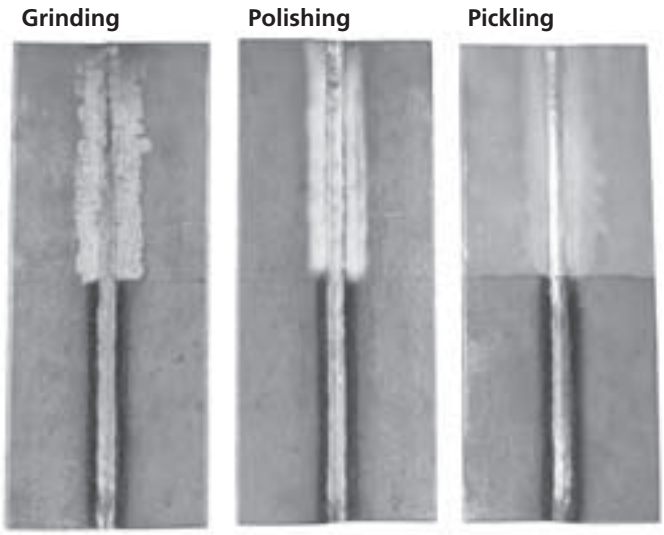


Figure 2. Pickling offers better results than alternative surface treatments such as grinding and polishing.

3 Chemical methods in practice

3.1 GENERAL REQUIREMENTS

The practical use of cleaning chemicals is demanding, and certain working procedures need to be followed. The choice of chemical cleaning process mainly depends on the type of contaminants and heat oxides to be removed, the degree of cleanness required and the cost. This chapter gives guidelines for the application of suitable chemical cleaning procedures.

In order to avoid health hazards or environmental problems, pickling should be carried out in a special pickling area indoors. In this context, the following recommendations should be met:

- Handling instructions, essential product information, such as product labels, and safety data sheets for the various products must be available. Local and national regulations should also be available. See also section 6.1.
- Responsible staff should be familiar with the health hazards associated with the products and how these should be handled.
- Personal safety equipment, including suitable protective clothing and facemask should be used. See also section 6.2.
- When pickling indoors, the workplace should be separated from other workshop operations in order to avoid contamination and health hazards and to ensure a controlled temperature.
- The area should be ventilated and provided with fume extraction apparatus.
- Walls, floors, roofs, vessels, etc. that are subject to splashing should be protected by acid-resistant material.
- A washing facility should be available, preferably including a high-pressure water jet.
- A first aid spray must be available. See also section 6.1.
- A facility for the collection and neutralisation of rinsing water should be available. See also section 4.1.
- If the rinsing water is recycled, care must be taken to ensure that the final rinse is performed using de-ionised water. This is particularly important in the case of sensitive surfaces and applications.
- A storage facility should be available. See also section 6.3.

3.2 PRE-CLEANING/DEGREASING

Organic contaminants such as grease, oil and paint, and also soil, grit, etc., have to be removed. This can be done using the product Avesta Cleaner (contains phosphoric acid), which is sprayed onto the surface to be pickled using an acid-resistant pump. The Avesta Spray-Pickle Pump is recommended for this purpose. Avesta Cleaner provides a mild degreasing effect and is sufficiently effective in most cases. However, heavily contaminated surfaces may require a stronger (non-chlorinated) solvent. Avesta Cleaner also removes surface rust and brightens the surface. After the use, the surface must be rinsed with clean water. The use of a high-pressure water jet supports rinsing and in some cases can also be an alternative to chemical products for removing lightly attached grease, oils and chemical deposits.

The water-break test is a simple way of assessing the effectiveness of degreasing. See also section 5.1.

3.3 PICKLING

Pickling products can be applied in three different ways:

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

The different methods are presented on the following pages.

Figure 3. Application of Avesta Spray Pickle Gel

3.3.1 Pickling with paste (gel)

AvestaPolarit Welding has three different products that can be brushed onto the surface:

- Avesta BlueOne® Pickling Paste 130
- Avesta Pickling Gel 122
- Avesta Pickling Paste 101

BlueOne® Pickling Paste 130 is a new unique patented pickling paste, which creates a better working environment. BlueOne® 130 makes it possible to pickle virtually without the toxic nitric fumes that are normally formed during pickling. It has a good heat stability and is well suited also for use in a warm climate. BlueOne® 130 is a universal paste that can be used on all stainless steel grades.

Pickling Gel 122 is more free flowing, which ensures a good penetration of weld joints. This product also withstands heat better than Paste 101 and retains its effectiveness and viscosity even when stored at high temperatures in warm climates.

Pickling Paste 101 is one of the few products on the market with a true paste consistency. This feature reduces the risk of splashing and gives good adhesion to the surface.

Stainless steel brushes (for mechanical pre-treatment) and acid-resistant brushes (for brushing on) are also available.

Table 2. Typical pickling times for Avesta Pickling Paste/Gel

Steel group	AvestaPolarit steel name	Typical pickling time (min.) 10°C	20°C	35°C	Pickling product
1	4301 4401 4404 4571 4436	120	60	40	BlueOne® 130 Pickling Gel 122 Pickling Paste 101
2	SAF 2304™ 2205 4439 904L	2x120*	180	100	BlueOne® 130 Pickling Gel 122 Pickling Paste 101
3	SAF 2507™ 254 SMO® 654 SMO®	2x180*	270	150	BlueOne® 130

* Brushing/rinsing prior to second application

The pickling was carried out after mechanical pre-treatment of the weld joints and pre-cleaning using Avesta Cleaner on cold rolled stainless steels with a 2D finish welded using covered electrodes. These pickling times are experimental results. The pickling time may vary for the same steel grade depending on the surface finish and the welding method; on a hot rolled surface, the pickling time might be increased by 50%, and MIG welds might need longer times than those obtained using covered electrodes.

Figure 4: Application of Avesta Pickling Paste/Gel

1. Pre-treat oxides, slags and weld defects mechanically, preferably when the welds are still warm and the weld oxides less hard.
2. Give the area to be pickled time to cool down to below 40ºC (after welding).
3. Degrease using Avesta Cleaner to remove organic contamination.
4. Stir or shake the paste before use.

5. Brush on the pickling paste using an acid-resistant brush. **Do not pickle in direct sunlight.**

6. Give the product sufficient time to react. See table 2. At high temperatures and when prolonged pickling times are required, it might be necessary to apply more of the product after a while, since it might dry out and hence cease to be as effective.
7. Rinse thoroughly with clean tap water, preferably using a high-pressure water jet. Ensure that no pickle residues are left on the surface. For sensitive surfaces, use de-ionised water for the final rinse.

8. Collect the resulting waste water for neutralisation. See also chapter 4.

3.3.2 Pickling with solution (spray-pickle gel)

AvestaPolarit Welding has four different pickling solutions that can be sprayed onto large surfaces and equipment to facilitate their application:

- Avesta BlueOne® Spray Pickle Gel 230
- Avesta GreenOne Spray Pickle Gel 220
- Avesta Spray Pickle Gel 215
- Avesta Spray Pickle Gel 204
- Avesta Spray Pickle Pump SP-25
- Avesta Indicator 701

BlueOne® Spray Pickle Gel 230 is a new unique patented pickling spray, which creates a better working environment. BlueOne® 230 makes it possible to pickle virtually without the toxic nitric fumes, that are normally formed during pickling.

GreenOne Spray Pickle Gel 220 is a new spray that makes it possible to pickle bright or sensitive surfaces without dulling or damaging the finish.

Spray Pickle Gel 215 is intended for pickling common steel grades, e.g. ASTM 304 and 316.

The Spray Pickle Gel 204 has a thixotropic consistency. This feature makes it suitable for the spraying of surfaces, since the product will "thicken-up" on agitation and hence attach well to the surface without being too thick.

Pickling equipment: A suitable pump is necessary in order to achieve a good spraying result. The pump must be made of acid-resistant material and should provide an even application pressure. AvestaPolarit Welding´s pump for spray application – SP-25 "a quarter inch pump" of membrane type – is pneumatic with an adjustable valve and was specially designed to meet these requirements. The Indicator 701 can be mixed into the pickling fluid before application in order to improve the visibility of the spray; it will also reduce the formation of nitrous fumes.

Table 3. Typical pickling times for Avesta Spray Pickle Gel

Steel group	AvestaPolarit steel name	Typical pickling time (min.) 10°C	20°C	35°C	Pickling product
1	4301 4401 4404 4571 4436	150	75	60	Spray Pickle Gel 204 BlueOne® 230
2	SAF 2304™ 2205 4439 904L	2x140*	200	120	Spray Pickle Gel 204 BlueOne® 230
3	SAF 2507™ 254 SMO® 654 SMO®	2x200*	300	180	BlueOne® 230

*Brushing/rinsing prior to second application.

Combined Method: For some applications, the brushing and spraying methods can be combined. When only a mild pickling effect is required (on sensitive surfaces), the pickling paste can be applied to the weld joints and then the acid cleaner sprayed onto the surface.

Figure 5: Application of Avesta Spray Pickle Gel

1. Pretreat oxides, slags and weld defects mechanically, preferably while the welds are still warm and the weld oxides less hard.
2. Give the area to be pickled time to cool down to below 40ºC (after welding).
3. Degrease using Avesta Cleaner to remove organic contamination.
4. Stir the spray gel well before use. Avesta Indicator 701 can be added.
5. Spray on the product using an acid-resistant pump (Avesta SP-25). Gently apply an even layer of acid that covers the whole surface. **Do not pickle in direct sunlight!**

6. Allow the product sufficient pickling time. A light green colour should appear on the surface when pickling is finished. The appearance of brown spots might indicate that there are some remaining contaminants on the steel that could have interfered with the pickling reaction. This can be compensated for by applying more solution onto these spots. When pickling outdoors, the solution should not be allowed to dry because this 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.
7. Rinse thoroughly with clean tap water preferably using a high-pressure water jet. Ensure that no pickle residues are left on the surface. For sensitive surfaces, use de-ionised water for the final rinse.

8. Collect the resulting waste water for neutralisation. See also chapter 4.

◁ The pickling was carried out after mechanical pre-treatment of the weld joints and pre-cleaning using Avesta Cleaner on cold rolled stainless steels with a 2D finish welded using covered electrodes. These pickling times are experimental results. The pickling time may vary for the same steel grade depending on the surface finish and the welding method; on a hot rolled surface, the pickling time might be increased by 50%, and MIG welds might need longer times than those obtained using covered electrodes.

3.3.3 Pickling in a bath

AvestaPolarit Welding also offers a pickling bath:

- Avesta Bath Pickling 302
  The concentrate Bath Pickling 302 should be mixed with water, depending on the steel grade to be pickled.
  Steel group 1: Mix 1 part 302 into 3 parts water.
  Steel group 2: Mix 1 part 302 into 2 parts water.
  Steel group 3: Mix 1 part 302 into 1 part water.

A pickling bath gives the best pickling result because the temperature and composition of the bath can be controlled.

Table 4: Typical pickling times for the use of fresh Avesta Bath Pickling 302

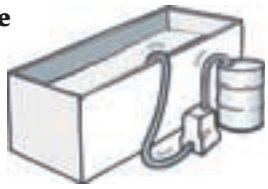
Steel group	AvestaPolarit steel name	Typical pickling time (min.) 20°C	30°C	45°C
1*	4301 4401 4404 4571 4436	20	10	5
2**	SAF 2304™ 2205 4439 904L	120	90	60
3***	SAF 2507™ 254 SMO® 654 SMO®	240	120	90

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

Pickling was carried out after mechanical pre-treatment of the weld joints and pre-cleaning using Avesta Cleaner on cold rolled stainless steels with a 2D finish welded using covered electrodes. These pickling times are experimental results. The pickling time may vary for the same steel grade depending on the surface finish and the welding method; on a hot rolled surface, the pickling time may be increased by 50% and MIG welds may need longer times than those obtained using covered electrodes.

Figure 6. Application of Avesta Bath Pickling

1. Pretreat oxides, slag and weld defects mechanically.
2. Give the area to be pickled time to cool down to below 40°C (after welding).
3. Degrease using Avesta Cleaner to remove organic contamination.
4. Mix the concentrated bath pickling solution with water. **Remember to add the acid to the water, not the other way round!** Set the batch solution circulating using a pump in order to obtain a homogenous acid concentration in the bath.



5. Check the bath temperature. See table 4.
6. Immerse the object in the bath. Typical pickling times are shown in table 4. Avoid overpickling, which will produce a rough surface.

7. When removing the object, allow time for the bath solution to flow off above the bath.
8. A first rinse should be performed by dipping into a rinsing vat containing water. Then rinse thoroughly using a high-pressure water jet. Ensure that no pickle residues are left on the surface. For sensitive surfaces, use de-ionised water for the final rinse.

9. Collect the resulting waste water for neutralisation. See also chapter 4.
10. Analysis of the contents of bath acid and free metal ions is important since there will be a constant consumption of pickling acids and a simultaneous precipitation of metals in the bath, which will affect the pickling reaction. See also 2.2.3. AvestaPolarit Welding can offer such an analysis as an extra service to its customers.

3.4 PASSIVATION AND DECONTAMINATION

After certain types of production processes, passivation/decontamination may suffice as a cleaning method. The method is also strongly recommended after mechanical treatment as well as after pickling in special cases. Avesta Passivating Agent 601 should be used as follows:

1. Spray on the product using an acid-resistant pump (Avesta SP-25). Apply an even layer of acid that covers the whole surface.
2. Give the product 20-30 minutes to react.
3. Rinse thoroughly with clean tap water, preferably using a high-pressure water jet. Ensure that no acid residues are left on the surface. For sensitive surfaces, use de-ionised water for the final rinse.
4. Collect the resulting waste water for neutralisation. See also chapter 4.

4 Neutralisation and waste treatment

4.1 NEUTRALISATION

After pickling, the waste water is acidic and contaminated with heavy metals, mainly iron, chromium and nickel that have been dissolved from the steel. The waste water must therefore undergo neutralisation.

The waste water should be treated in accordance with local regulations. It can be neutralised using an alkaline agent – preferably Avesta Neutralising Agent 502, technical grade slaked lime, or soda – together with a settling agent. Thus, the pH can be adjusted from 1-2 to 7-10 (depending on the amount of rinsing water used). The heavy metals can then be separated from the neutralised clear water as sludge. This sludge should be treated as heavy metal waste and be disposed of accordingly.

4.2 WASTE TREATMENT

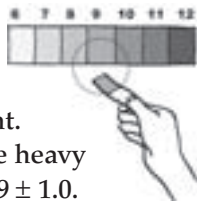
Pickling creates waste that requires special treatment. This waste comes from the chemicals themselves and from the packaging.

The waste sludge obtained after neutralisation contains heavy metals, mainly iron, chromium and nickel. This sludge should be sent away for waste disposal in accordance with local waste regulations. There is an increasing public demand for the recycling of packaging. All materials used in the packaging of AvestaPolarit Welding's pickling products are made of recyclable material, including the plastic containers, cardboard boxes, etc.

Figure 7: The neutralisation procedure

Avesta Neutralising Agent (or technical grade slaked lime) should be used as follows:

1. Add the neutralising agent to the rinse water while stirring.
2. The reaction will take place instantly.



3. Check the pH of the mixture using, for instance, litmus paper and adjust the pH by adding more neutralising agent. An optimal precipitation of the heavy metals will be obtained at pH 9 ± 1.0.
4. When the waste water has reached an acceptable pH, time should be allowed for the sludge to sink to the bottom and for the water to become clear. Precipitation of heavy metals can be improved by adding a special settling agent.
5. If analysis shows the treated water to be in accordance with local regulations, it may be let out into the sewage system. In order to increase the degree of treatment, an extra filter can be inserted before the water reaches the sewer.

6. The sludge, which contains heavy metals, should be sent to a waste-treatment plant.

5 Inspection and troubleshooting

The final step after pickling and prior to delivery should be an inspection of the result of the cleaning process.

5.1 TEST METHODS

- **Test for free-iron contamination:**
  One test that is often used is to repeatedly wet the surface with tap water and allow it to dry so that the surface remains dry for a total of 8 h of a 24 h test period. Any residual-iron rust is visible after the test cycle.
  The ferroxyl test is another highly sensitive method for the detection of iron contamination (ASTM A-380).
- **Test for organic contamination:**
  As mentioned previously, the water-break test is a simple way of assessing the effectiveness of degreasing. A thin sheet of water that is applied to a surface will break around any surface contamination.
- **Test for pickling-agent residues:**
  The pH-value of the final rinse water gives a rough indication of residual acids. The value should be pH >7. Attention must be focused on tight corners, narrow crevices, etc. that may hide residues.

5.2 TROUBLESHOOTING

The inspection of the surface may reveal some remaining defects. The examples below show the most common types.

Table 5: Surface defects and corrective action.

Surface defects	Caused by	Corrective action	Precautions
• Residual weld oxides	1. Insufficient cleaning	1. Mechanical pre-treatment/more intensive pickling	
• Rough surface	1. Overpickling 2. Intercrystalline corrosion	1. Mechanical treatment/re-pickle 2. Mechanical polishing	1. Avoid pickling in direct sunlight 2. Weld with lower heat input Use a low-carbon or stabilised grade of steel
• Uneven finish (shading)	1. Organic contaminants 2. Uneven application 3. Sensitive surface 4. Intercrystalline corrosion	1. Degrease, re-pickle 2. Re-pickle 3. Mechanical polishing improves the result 4. Mechanical polishing improves the result	3. Milder pickling 4. Weld with lower heat input Use a low carbon or stabilised grade of steel
• Discoloration	1. Dried-on pickling chemicals (e.g. pickling residues in crevices) 2. Surface contaminants (e.g. iron particles) 3. Insufficient cleaning 4. Contaminated rinse water 5. Poor rinsing	1. Rinse with high-pressure water jet and re-pickle 2. Passivate/decontaminate or re-pickle 3. Remove spots 4. Passivate/decontaminate When surface requirements are exacting, de-ionised water should be used Rinse with high-pressure jet 5. Remove the spots with a cleaning agent Use de-ionised water for final rinse	
• Water stains	1. Contaminated rinse water 2. Dust	1. Use clean rinse water and/or re-pickle 2. Use clean rinse water and work in dust-free environment	2. Work in dust-free environment

6 Safe handling and storage of pickling products

6.1 SAFETY RULES

Pickling products are hazardous substances that must be handled with care. A good, safe working environment requires the observance of certain rules:

1. The handling of pickling chemicals should be limited to persons with a fundamental knowledge of the health hazards associated with such chemicals. This means that the Material Safety Data Sheet and the product label should be thoroughly studied before the chemicals are used.
2. Eating, smoking and drinking should be forbidden in the pickling area.
3. Employees handling pickling chemicals should wash their hands and faces before eating and after finishing work.
4. An acid-resistant material such as polyethylene (PE), polypropylene (PP) or polyvinyl chloride (PVC) plastic should protect all parts of the skin that are exposed to splashing. This means that employees handling pickling chemicals (including during rinsing) should wear a facemask, rubber gloves, rubber boots and an overall.
5. Avesta First Aid Spray 910 should be readily available when handling Avesta Pickling Paste/ Gel/Spray for immediate treatment of smaller acid splashes on the skin or in the eyes. When handling larger volumes of acids, such as Avesta Pickling Bath, Hexafluorine® in larger packages should be used. A physician should be consulted for subsequent treatment.
6. The pickling area should be ventilated.
7. To avoid unnecessary evaporation, the containers should be kept closed as much as possible.
8. In order to protect the environment, all pickling residues should be neutralised and the heavy metals present separated and sent to waste treatment plant.

6.2 PERSONAL SAFETY

Health hazards can be avoided by means of air protection and skin protection. We recommend that the following measures be adopted if a high degree of personal safety is to be assured (see also figure 8).

For personal safety, a facemask (equipped with breathing apparatus) should always be worn in connection with pickling operations. This mask should be equipped with a breathing filter, type B (grey) and a dust filter, type P2, all according to the Central European Norm (CEN).

The pickling acids are aggressive and can cause burns by skin-contact. This can be avoided by protecting all exposed parts of the skin with acid-resistant clothing. As a personal security measure, Avesta First Aid Spray 910 should be readily available at the workplace, in the event of acid splashes.

All pickling chemicals from AvestaPolarit Welding are provided with:
- Product Information (PI) with reference numbers;
- Material Safety Data Sheets (MSDS) according to ISO 11000.

These documents give the information necessary for the safe handling of the product, and they should always be consulted before using the product. For further information, the local dealer should be contacted and if necessary, AvestaPolarit Welding's office in Malmö, Sweden.

For non-stop 24-hour emergency assistance, an **Emergency Response Centre** (ERC) could be contacted. They should have all the necessary information concerning AvestaPolarit Welding's pickling products and be able to give an immediate recommendation in the case of an accident. Such centres exist in the following countries: Australia, Austria, Belgium, Brazil, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Netherlands, New Zealand, Norway, Poland, Portugal, Singapore, South Africa, Spain, Sweden, UK, USA. Consult the new AvestaPolarit Welding Material Safety Data Sheets, according to ISO 11000, for the telephone numbers.

Figure 8. Personal protection equipment

Figure 9. Avesta First Aid Spray 910 comes in a handy spray can for immediate use on smaller splashes of pickling products. The spray may be used for both skin and eye treatment.

6.3 STORAGE

Containers of pickling chemicals should be stored indoors at 20°C. They should be kept in an upright position with the lids tightly closed. The storage area should be clearly defined and beyond the access of unauthorised persons. Pickling chemicals are sensitive to high temperatures.

Caution: Storage temperatures higher than 45°C must be avoided since they accelerate the ageing process and destroy the product. The longest shelf life that can be guaranteed for all AvestaPolarit Welding's standard pickling chemicals is ONE YEAR. Pickling chemicals are perishable goods. They give the best pickling result when they are fresh. This means that they should not be kept on the shelf longer than necessary, and it is better to buy less each time than more occasionally. Their composition and pickling activity alters and decreases with time and heat exposure. Their stated shelf life is valid for storage indoors at 20°C in an unbroken package with the lid tightly closed.

All AvestaPolarit Welding pickling products are delivered in UN-certified, PE containers, which are approved for hazardous goods. All packages are made using exclusively recyclable materials.

References

1. ”Avesta Sheffield Corrosion Handbook for Stainless Steels” 1999.
2. ”Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment and Systems” ASTM A-380.
3. ”Code of Practice for Cleaning and Preparation of Metal Surfaces” BSI CP 3012.
4. ”Rahmenvorschrift für die Oberflächenbehandlung austenitischer CrNi-Stähle, Chromstähle, Nickellegierungen”, KWU Arbeitsvorschrift RE-AVS 8.
5. ”Beizen von nichtrostenden austenitischen Stählen”, Hoechst AG, Praxis WN 87-0417.
6. ”Traitement de Surface”, Framatome RCCM F-5000-6000.
7. ”Cleaning & Maintenance. An Owner’s Manual for Stainless Steel in Chemical Tankers” by B. Leffler, AvestaPolarit AB.

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