MACSTEEL VRN

STAINLESS STEEL PLATE, SHEET & COIL
SAF 2205 Technical Data

INTRODUCTION

SAF 2205 (UNS No S31803) is a second generation duplex stainless steel having a nominal composition of 22% chromium, 5.5% nickel, 3% molybdenum and 0.14% nitrogen. This composition results in a stable microstructure containing about 45% ferrite and 55% austenite. SAF 2205 is characterized by:

- good resistance to stress corrosion cracking.
- high resistance to general, crevice and pitting corrosion;
- high resistance to erosion corrosion and corrosion fatigue;
- high mechanical strength;
- attractive physical properties;
- good weldability

Austenitic stainless steels generally exhibit excellent corrosion resistance in most corrosion environments, but can fail by stress corrosion cracking in hot chloride solutions under certain circumstances.

Ferritic stainless steels are generally resistant to cracking under these conditions. However, the use of ferritic stainless steels is limited due to weldability constraints in section thickness above approximately 2 mm. It is considered that the presence of ferrite in duplex stainless steels inhibits crack propagation.

Duplex steels are not totally immune to chloride stress corrosion cracking and have been made to crack in terms of somewhat unrealistically severe but popular 42% boiling magnesium chloride solution test. More significantly SAF 2205 has not cracked after extremely long test periods in less aggressive solutions which would cause failure in austenitic stainless steels such as types 304L/316L/317L.

The high proof strength of SAF 2205 roughly twice that of the traditional austenitic stainless steels allows for thickness reduction and hence weight savings.
The impact toughness of the steel is good with a ductile to brittle transition temperature of approximately - 55^{O}C.

SAF 2205 has a lower co-efficient of thermal expansion and a slightly higher thermal conductivity than austenitic stainless steels. This is of particular advantage when designing heat exchangers. This is of particular advantage when designing heat exchangers. The higher thermal conductivity improves heat transfer and the lower thermal expansions reduces the stresses incurred due to the difference in thermal expansion between the carbon steel shell and the stainless steel used for the tubes. The co-efficient of thermal expansion of SAF 2205 is close to that of carbon steel.

The material is suitable for use in production tubing and flowlines for the extraction of oil and gas from sour wells, in refineries and in process solutions contaminated with chlorides. SAF 2205 is particularly suitable for heat exchangers where chloride-bearing water or brackish water is used as a cooling medium. The steel is also suitable for use in dilute sulphuric acid solutions and for the handling of organic acids.

The high strength of SAF 2205 makes the material an attractive alternative to the austenitic steels in structures subjected to heavy loads.

2. TECHNICAL DATA

MECHANICAL PROPERTIES

SAF 2205 has higher tensile and proof strengths than the austenitic stainless steels. The mechanical properties of a number of steels are given below. SAF 2205 is normally delivered in the fully annealed condition but proof strengths in the region of 1 000 MPa can be achieved by cold working. The relatively high hardness of SAF 2205 makes it suitable for use in corrosion abrasion applications.

Mechanical Properties at Room Temperature*

	SAF 2205	SX 304L	SX 316L
Tensile strength (min)	620 MPa	485 MPa	485 MPa
0.2% Proof Strength (min)	450 MPa	170 MPa	170 MPa
Elong. (in 50mm) (min)	25%	40%	40%
Hardness (max)	290 HB	183 HB	217 HB

*ASTM A240-87

It is worth noting that while the allowable design stresses are about 40% higher for the duplex grades in the ASME Pressure Vessel Design Code they are about 100% higher, or even more, in the European codes, which are based entirely on yield strength. The high allowable design stresses for the duplex grades can be utilized to reduce wall thicknesses and cut costs considerably.

Impact Strength

SAF 2205 possesses good impact strength both at room and sub-zero temperatures. The DBTT for SAF 2205 parent plate is in the region of - 55^{o}C. The impact strength for welded SAF 2205 is also good although impact strength values in the as-welded condition are slightly lower than for the parent plate. It has been shown that the impact strength of the weld metal and heat affected zone is good down to - 50^{o}C having an impact strength of a minimum of 27 joules. Welding had been carried out by the gas shielded arc welding process.

If very high impact strengths are required in the welded condition at sub-zero temperatures, quench annealing is recommended.

Properties at Elevated Temperatures

If exposed to temperatures exceeding 300°C for prolonged periods, SAF 2205 undergoes microstructural changes and the impact strength at room temperature is lowered. These changes do not affect the performance of the steel at the operating temperature as has been demonstrated by the good performance of heat exchanger tubes.

Typical short term elevated temperature strength values are:

Temperature	Tensile Strength	0.2% Proof Strength
100°C	630 MPa	365 MPa
200°C	580 MPa	315 MPa
300°C	560 MPa	285 MPa
400°C	550 MPa	275 MPa

Generally however use of SAF 2205 is not recommended above 300°C.

HARDNESS

SAF 2205 has a relatively higher hardness which is an added advantage over standard stainless steels when used in process flow containing solids, i.e. when the conditions are erosive. Table 1 compares the typical hardness of some steels.

TABLE 1 - COMPARISON OF HARDNESS OF SOME STAINLESS STEELS

Steel Grade	Hardness HB (Typical Values)
Type 304	155
Type 316	160
Alloy 904L	160
Sanicro 28	160
SAF 2205	260
Mild Steel	150

PHYSICAL PROPERTIES

The physical properties of SAF 2205 are compared with those of Type SX 316L stainless steel and carbon (mild) steel.

		SAF 2205	SX 316L	CARBON STEEL
Density (Kg/m^3)		7.85×10^3	8.0×10^3	7.86×10^3
Modulus of Elasticity (GPa) at	20°C 100°C 200°C 300°C 400°C	200 190 180 170 160	195 190 185 177 167	206 - - - -
Thermal Conductivity (W/mK) at	20°C 100°C 200°C 300°C 400°C	16 17 19 20 21	15 16 17.5 19 20	62 57.5 54.5 49 44.5
Coefficient of Thermal Expansion (um/mK) between	0-100°C 0-200°C 0-300°C 0-400°C	13.0 13.5 14.0 14.5	15.9 16.0 16.2 16.6	12.5 13.0 13.5 14.0
Specific Heat Capacity (J/kg K) at	20°C 100°C 200°C 300°C 400°C	470 500 530 560 600	500 - - - -	455 - - - -

CHEMICAL COMPOSITION

For comparison, the composition of some other steels is given.

	%C max	%Si max	%Mn max	%P max	%S max	%Cr	%Ni	%Mo	%N	Other
Martensitic 1 AISI 410	0.15	1.00	1.00	0.040	0.030	11.5 13.5	0.75 max	-	-	-
Ferritic 1 SX 430	0.12	1.00	1.00	0.040	0.030	16.0 18.0	0.75 max	-	-	-
Austenitic 1 SX 316L	0.03	0.75	2.00	0.045	0.030	18.0 20.0	8.0 12.0	-	0.10 max	-
Austenitic 1 SX 316L	0.03	0.75	2.00	0.045	0.030	16.0 18.0	10.0 14.0	2.0 3.0	0.10 max	-
Duplex 1 SAF 2205	0.03	1.00	2.00	0.030	0.020	21.0 23.0	4.50 6.50	2.50 3.50	0.08 0.20	-
Duplex 2 1.4462	0.03	1.00	2.00	0.030	0.020	21.0 23.0	4.50 6.50	2.50 3.50	0.08 0.20	-
Duplex 3 Zeron 25	0.05	1.00	1.50	-	-	24.0 26.0	5.0 7.0	2.0 3.0	0.10 0.20	Cu 0.5% max

1. ASTM A240-87
2. DIN X2 Cr Ni Mo N 225 (equivalent to UNS S31803)
3. Proprietary Alloy.

3. CUTTING

Cutting of SAF 2205 using the oxy-acetylene or oxy-hydrogen process is not possible.

Cutting is sub-divided into the following sections:

3.1 Shearing / Guillotining

The maximum capacity of the guillotine (for mild steel shearing) should be downgraded by 50% for cutting SAF 2205 because of its greater shear strength, e.g. if maximum shearing capacity is 16 mm then the maximum shearing capacity will be 8 mm for SAF 2205.

Blade clearance should ideally be between 3-5% of material thickness.

3.2 Plasma Cutting

Plasma cutting and profiling of SAF 2205 is the fastest and most economic thermal cutting method available. Fast cutting speeds together with a clean smooth surface finish are possible. Due to the fast cutting speeds, the heat affected zone is very narrow, minimizing the effect on the properties of the material. Thin plates can be stack-cut. Any discolouration of the cut edge can be removed by grinding or by using a stainless steel wire brush. If no subsequent welding is undertaken, edge discolouration must be removed, followed by passivation.

3.2.1 Cutting Gases

Oxygen-free nitrogen is the most commonly used primary cutting gas by virtue of its cheapness. Other gases which can be used include: Compressed air, Argon/Nitrogen, Argon/Nitrogen/Hydrogen, Argon/Hydrogen and Nitrogen/Hydrogen. The use of Compressed air will necessitate the use of a modified electrode arrangement.

The secondary shielding gas can be one of many active gases. Welding grade CO_2 is often used due to its relatively low cost.

3.3 Abrasive Disc Cutting

Abrasive disc cutting is acceptable for limited lengths of cut. Only dedicated discs should be used and suitable control of these must be exercised. Excessive overheating must be avoided.

Aluminium oxide discs of the vitrified or resinoid bonded types are suitable. Zirconia and silicon carbide discs are not recommended.

3.4 Carbon-Arc Gouging

Carbon-arc gouging can be utilised for cutting provided the recommended settings are adhered to in order to produce acceptable cuts. All cut edges must be ground back to a depth of approximately 2 mm before welding. Edges not subsequently welded must be descaled and passivated.

3.5 Slitting

SAF 2205 can be successfully slit on conventional slitting equipment. Edges must be deburred after cutting. Slitting knives should be cleaned of all mild steel or other metal contamination. Refer to section 3.1 for shearing thickness capacity.

3.6 Nibbling

Nibbling may be used provided the settings are correct to produce an acceptable cut. Burred edges, chipped edges or other metal contamination should be avoided. Refer to section 3.1 for shearing thickness capacity.

3.7 Cold Sawing

Cold sawing requires a high feed rate and low cutting speeds to be maintained to produce an acceptable cut. Cutting and cooling fluids (water soluble oil type) should be used to flood the cut. More than one tooth should be in contact with the workpiece at all times, necessitating small pitched blades for cutting thinner gauges and small diameters. As the thickness/diameter increases the pitch should be increased to minimize chip packing and to give better clearance.

3.8 Blanking and Punching

These operations can be successfully carried out provided that tools and equipment used have sufficient strength and rigidity to account for the higher proof strength of SAF 2205. It is essential that the tools have sharp cutting edges.

Clearance between the punch and the die is normally held to 5% of the metal thickness per side, i.e. 10% overall. Care must also be taken to ensure that tools are free from any adhering mild steel particles from previous jobs to avoid contamination.

4. FORMING

The conditions applicable to each forming method necessary to produce acceptable products must be observed. It is important to note that due to the higher proof strength of SAF 2205, more power is required for most of these operations than for the austenitic stainless steel. Caution should be exercised to ensure that the forming tools e.g. rolls and press brake tools are free of adhering mild steel particles to avoid contamination.

4.1 Roll Forming

Rolling mill loadings are about 60% higher than for mild steel. Slower speeds should be used.

4.2 Press-Brake Forming

See cold bending (Section 4.5)

4.3 Pressing

See blanking and punching (Section 3.8)

4.4 Deep Drawing

The formability of SAF 2205 is fair. The work hardening rate is similar to that of Type 316 stainless steel. Severe deep draws may require an intermediate annealing heat treatment (Section 13).

Specialized lubricants or more generous tool radii may have to be used to prevent galling or scoring.

Tooling and equipment should have sufficient strength to account for the higher proof strength of SAF 2205.

Care must also be taken to ensure that equipment is clean to prevent mild steel contamination.

4.5 Cold Bending

More power is required to bend SAF 2205 due to its higher proof strength. The maximum capacity of the bending press is therefore reduced by 50% for SAF 2205 as compared to the austenitic stainless steels. SAF 2205 generally exhibits greater springback during bending. This should be compensated for by slight over-bending, e.g. approximately 10% on a 90^{o} bend. The use of hydraulically operated press brakes is recommended.

The minimum inner bend radius recommended for SAF 2205 is three times the plate thickness, but it is advisable to use four times the plate thickness. Severe bends should be carried out transverse to the rolling direction.

Edge cracks can be avoided by grinding the outside radius point of the bend line into a rounded profile, thus eliminating the natural stress concentration point.

SAF 2205 can be cold formed by the same methods as the austenitic stainless steels. The high proof strength, however, implies that a higher initial force is required to induce plastic flow. When this limit is reached, SAF 2205 flows as easily as the austenitic stainless steels.

Heat treatment after cold forming is normally not required, as SSAF 2205 is highly resistant to stress corrosion cracking. In cases of heavy cold deformation and severe service conditions, heat treatment is recommended. It is difficult to give specific advice as to when heat treatment is necessary. The decision is influenced by the many factors related to the application, such as temperature, pH, chloride content and tensile stresses both residual and applied. Heat treatment should be considered when the degree of cold reduction exceeds 25%. If a lubricant has been used during cold forming, it must be removed before any heat treatment.

Cold bending of tubes leads to wall thinning on the outside of the bend. The degree of thinning depends on the bending radius and the method of forming but can be up to 30%. This should be compensated for in the design stage. When manufacturing butt welding fittings according to ISO 5251 or ANSI B16.9 there is a requirement that the minimum wall of the fitting must be at least 85% of the nominal wall thickness.

4.6 Spinning

Dished ends can be produced using this method but it is recommended that power spinning rather than manual spinning be used to produce an acceptable product.

4.7 Hot Forming

Hot forming is used primarily for large tube diameters, heavy wall thicknesses and for small bending radii, it is performed at 1000^{o} - 1100^{o}C. If the temperature after the forming is still above 1000^{o}C, quenching can be done directly from the working temperature. If bending is finished at a lower temperature, or if the temperature is uncertain, it is recommended that a solution heat treatment be undertaken (Section 10).

In order to minimize the risk of carburization, the tools must be thoroughly cleaned and carbon-containing lubricants must not be used.

Depending on the bending method, wall thinning should also be considered.

In all cases close control of temperatures must be maintained. Descaling and passivation is required subsequent to hot forming (Section 12).

5. MACHINING

The machinability of the duplex steels differs somewhat from that of carbon steels and austenitic stainless steels owing to differences in strength and microstructure. This does not imply that they are difficult to machine, but they require adjustment of machining parameters and technique. The following general recommendations will assist in obtaining good results in machining.

- Machine tools should be ground to close tolerances to avoid the risk of excessive work hardening in the outer layer of the stock.
- Larger tools should be used to give stability and efficient heat dissipation.
- Tools with large rake angles, sharp edges and smooth surfaces reduce the work hardening and the risk of built-up edges.
- Relatively large feed rates and cutting depths minimize the harmful effects of the work hardened surface layer produced by previous machining.
- A suitable cutting fluid, primarily emulsion, should be used to minimize the risk of built-up edges. The work should be flooded to ensure maximum heat withdrawal. Specific advice should be obtained from your supplier.

The mechanical machining of stainless steel always requires adjustment of tool data and machining methods to give satisfactory results.

The following tables give recommended cutting fluids, cutting feeds and speeds:

TABLE 2
Cutting Fluids for SAF 2205

Machining Operation	Severity (Decreasing)
Tapping	1 A,B
Threading	1 B,C
Gear Cutting	2 A
Reaming	2 A
Drilling	3 E,A
Milling	4 C,B
Turning	5 E
Surface Grinding	6 E
Thread Grinding	6 A,B

Key
A = High Sulphur (1.5-2.5%) Mineral - Fatty Oil
B = Medium Sulphur (0.5-1.5%) Medium Chlorine (0.5-1.5%) Mineral - Fatty Oil
C = Low Sulphur (< 0.5%) Medium Chlorine (0.5-1.5%) Mineral - Fatty Oil
D = Chlorinated Mineral Oil
E = Water Soluble Oil

TABLE 3
Suggested Cutting data for drilling

Drilling diam. mm	Feed/rev mm	Speed rpm
1 3 5 8 10 15 20	0.02 0.05 0.06 0.10 0.12 0.16 0.20	4000 1250 800 500 400 250 200

TABLE 4
Suggested Cutting data for turning. Cemented carbide tools of Sandvik Coromant types.

Single point turning	Forming	SAF 2205 Cutting speed			AISI 316 Cutting speed			SAF 2205, AISI 316 Cutting speed
Feed (mm/rev)	Feed (mm/rev)	SIP (m/min)	GC135 (m/min)	S6 (m/min)	SIP (m/min)	GC135 (m/min)	S6 (m/min)	High-speed steel (m/min)
0.05	0.02	170	-	-	280	-	-	35
0.15	0.03	140	120	-	250	230	-	30
0.5	0.08	-	80	60	-	130	80	25
1.0	1.15	-	50	40	-	70	50	15

6. WELDING

SAF 2205 has good weldability in most applications, provided that the recommended procedures are adopted. The quality and integrity of welds is a crucial feature of any fabrication. When weld quality standards are demanding, it is recommended that recognized welding procedure testing (e.g. BS 4870 or equivalent) be carried out and that experienced coded welders be used.

When the modern duplex stainless steels were first introduced, most steel producers and several inspection authorities restricted the welding arc energy to 1.5 kJ/mm and interpass temperature to 150^{o}C. It was generally believed that this would limit the high temperature region of the HAZ and would avoid precipitation of chromium nitrides in multilayer welds, thus contributing to welds of acceptable toughness and corrosion resistance. It has since become known that the mechanical properties and corrosion resistance of duplex stainless steel welds depends on the proportions of ferrite and austenite in the weld metal and HAZ, a high ferrite content generally has an adverse effect.

During welding, in the regions of the HAZ which attain temperatures of over 1000^{o}C, the austenite fraction transforms to high temperature ferrite. This tends to produce a fully ferritic structure. The degree of grain growth is more pronounced as the crystal structure becomes more single phase.

On cooling, reformation of austenite takes place. Additional reformation of austenite also results from the subsequent reheating to lower intermediate temperatures in multi-pass welding.

The mechanical properties (particularly toughness) are critically dependent on achieving a sufficiently high austenite content.

Due to the higher heat conductivity of SAF 2205 as compared to austenitic stainless steels, a faster cooling rate is obtained.

The extent of reformation of austenite depends on the cooling rate. Rapid cooling associated with low heat input (or other means of heat extraction from the weld zone), depresses the extent of austenite reformation. Generally it is recommended that such conditions be avoided, which is in contrast to the welding of other grades of stainless steel.

From the above, it should be appreciated that the thermal cycling during welding is of great importance.

Welding conditions which result in higher heat input and/or slow cooling tend to promote a greater reformation of austenite (beneficial); and an increase in the ferrite grain size, (non beneficial). Fast cooling rates depress the reformation of austenite, resulting in a higher level of retained ferrite which adversely affect the ductility, toughness and corrosion resistance.

A critical balance between these two extremes must be attained to optimise the crystal structure within the HAZ. Welding conditions have to be determined for different thicknesses and weld geometry as part of the welding procedure qualification; and thereafter controlled and monitored.

Because of the relatively lower coefficient of thermal expansion of duplex stainless steels, the stresses imposed in the weld zone are less than those experienced with austenitic stainless steels.

6.1 Welding Processes

Both Shielded Metal Arc (SMAW or MMA) and Gas Metal Arc (GMAW or MIG) welding processes have been used extensively with great success on SAF 2205. Gas Tungsten Arc Welding (GTAW or MIG) is usually used to weld the thinner sheet thicknesses e.g. 1.0 - 3.0 mm. The use of combined processes, e.g. GTAW root followed by GMAW or SMAW filler and cap can be considered. As a means of improving both quality and productivity the Submerged Arc Welding Process can be utilized.

Consumables are available locally which are specially formulated. Only those specified for SAF 2205 must be used. Ordinary austenitic stainless steel consumables are not suitable.

6.1.1 Shielded Metal Arc Welding (SMAW or MMA).

Electrical Characteristics:
D.C.E.P. (Direct Current Electrode Positive) - Reverse polarity.

Consumable:- Typical chemical composition 22% Cr, 9% Ni, 3% Mo.

Many proprietary electrodes are available locally with similar chemical compositions.

Electrodes having acid-rutile, neutral or basic flux coatings are all acceptable, although acid rutile or neutral fluxes are generally preferred as they reduce the likelihood of slag inclusions.

Note: Welding electrode storage, handling and operating conditions are detailed on the electrode container. For more detailed information the electrode manufacture should be contacted.

6.1.2 Gas Metal Arc Welding (GMAW or MIG)

GMAW welding is very versatile, in that a wide range of material thicknesses and positions can be accommodated. Weld quality and achievable weld speeds are high with GMAW welding. Lack of side wall fusion problems commonly associated with this process must be guarded against by employing the correct welding techniques.

Electrical Characteristics:
D.C.E.P. (Direct current electrode positive)- Reverse polarity.

Consumables:
(a) Filler Wire: Typical chemical composition 22% Cr, 8% Ni, 3% Mo.

(b) Shielding Gas: Argon, 1% or 2% O_2

Note: The electrode supplier should be contacted for the appropriate welding parameters.

The gas flow rate under shielded welding conditions must be in accordance with the manufacturer's recommendations. Higher gas flow rates will be required if welding is being carried out in draughty or exposed conditions.

9.1.3 Gas Tungsten Arc Welding (GTAW or TIG)

This process is generally used for welding light gauge sheet. Autogenous welding (using no filler wire) is acceptable for sheet thicknesses up to 3.0 mm. Above 3.0 mm, filler wire should be used in order to ensure adequate ductility and corrosion resistance in the weld metal.

Electrical Characteristics:

D.C.E.N. (Direct current electrode negative) Straight polarity.

Electrode: 1-2% thoriated tungsten.

Consumables:

(a) Filler Wire: Typical chemical composition 22% Cr, 8% Ni, 3% Mo
(b) Shielding Gas: Argon

Typical flow rates are between 8 and 14 L/min depending on material thickness, join geometry, welding position, location etc.

Technique:

Tungsten inclusions occur most commonly on striking the arc and the use of striker pads is recommended. Use of a high frequency spark initiation unit is preferred.

The use of a backing gas shield (purging) is necessary. Argon is generally used for this purpose, although cheaper gasses such as nitrogen or a gas mixture consisting of argon and nitrogen may also be used. The additional gas shield at the rear of the groove enables a fine, oxide-free root surface to be more easily achieved. This is of particular advantage when the root surface is not accessible for grinding, or pickling and passivating.

10. SOLUTION ANNEALING HEAT TREATMENT

The recommended solution anneal heat treatment parameters are as follows:

Heat slowly and evenly up to 1040^{o}C. Hold at temperature for 10 minutes. Quench in an agitated water bath down to room temperature.

It is vitally important that the recommended cooling cycle is adhered to, as an air cool or furnace cool will result in the precipitation and formation of brittle intermetallic sigma phase which will adversely affect the mechanical properties, more specifically the cold formability and toughness of the material.

Removal of scale is required followed by passivation (Section 12)

11. FASTENERS

Mild steel and coated bolts should be avoided as they will corrode rapidly and cause staining of the SAF 2205 material. Stainless steel bolts are recommended when they will not be exposed to the same corrosion environment as the SAF 2205 material. Material with similar corrosion resisting properties should be used if it will be in contact with the same corrosion environment.

12. SURFACE CLEANING

12.1 Descaling

After hot working and/or heat treatment, the material is covered with a scale that can be removed by machining, shot blasting or pickling. In the case of pickling, the following procedure is recommended.

1. Pretreatment in alkaline $KMnO_4$ solution for 2 hours at 90 - 100^{o}C.

   Composition:

   75 g/l $KMnO_4$ (potassium permanganate)

   75 g/l NaOH (sodium hydroxide)

   Water

2. Rinsing in water.

3. Pickling in HF-HNO_3, 20 - 60 minutes, 40 - 50^{o}C.

   Composition:

   160 - 250 g/l HNO_3 (nitric acid)

   40- -50 g/l HF (hydrofluoric acid)

   Water

4. Rinsing in water.

12.2 Post-Weld Cleaning

Post weld cleaning should be undertaken on all weld areas (weld metal and HAZ), arc strikes, and points where cleats, lugs, etc have been ground off. Where practical, the root side and face side of all welds should be treated.

It is considered absolutely essential that this procedure be carried out if the material is in contact with aqueous solutions in its working environment. In some instances, eg welded tube, both exposed weld surfaces must be treated. Irrespective of which post-weld cleaning method is used (eg mechanical or chemical), it is essential to remove all surface discolouration and scale from weld areas.

12.3 Mechanical Cleaning

(a) Wire brushing: It is often possible to remove a substantial amount of discolouration and detritus from weld areas by vigorous brushing with stainless steel wire brushes. Brushes must not previously have been used on materials other that stainless steel.

(b) Grinding: Dressing of welds and removal of discolouration can be carried out by grinding. Only dedicated grinding wheels and discs should be used. The presence of iron, iron-oxide and other undesirable materials in the grinding medium can adversely affect corrosion resistance.

(c) Abrasive blast cleaning. The abrasive should be stainless steel shot, copper slag (angrit) or alumina, free of metallic iron, iron oxides or chlorides. A surface finish equivalent to SA 3 (as per Swedish Standard SIS 05 5900) is recommended. Surface profile is not considered critical for most applications.

12.4 Pickling

(a) Composition: Pickling of SAF 2205 should be carried out using formulations based on nitric (HNO_3) and hydrofluoric (HF) acid.

Formulations based on hydrochloric acid (HCL) are unsuitable.

Pickling formulations made up of 15 - 20% HNO_3; 1 - 2% HF; balance H_2O are considered suitable. The acids used must conform to commercial purity standards and the water must be of potable quality.

(b) Application procedure: The formulation must be generously applied to weld areas by brush, cloth, spray or dipping. The formulation should not be allowed to dry while in contact with the steel surface as significant staining of the SAF 2205 can result.

Use of thixotropic pastes is recommended to ensure that contact with the steel surface is maintained for the required period.

Intermittent scrubbing with a stainless steel wire or fibre bristle brush can assist in removal of the discolouration. The temperature of the pickling formulation should not exceed 30^{o}C.

(c) Exposure period. The exposure time required for pickling will vary according to a number of factors (strength of pickling formulation, ambient temperature, extent and nature of discolouration, weld metal composition). No specific recommendation concerning exposure time can be made. Pickling formulations are aggressive towards SAF 2205 and pickling should be supervised to ensure that exposure times are no longer than the minimum required to remove discolouration. If necessary, the pickling operation must be repeated in areas where complete removal of discolouration has not been achieved.

(d) Use of proprietary pickling formulations: Proprietary Pickling formulations based on nitric and hydrofluoric acid are available and are suitable for post-weld cleaning of SAF 2205.

The manufacturer's directions concerning application procedure must be adhered to.

Proprietary pickling formulations can vary significantly in terms of acid concentration (and quite commonly contain acid levels greater than those noted previously). Such formulations may therefore be particularly corrosive towards SAF 2205 and close control and supervision must be exercised in limiting exposure times to the minimum required to remove discolouration and scale.

Intermittent vigorous brushing using stainless steel wire brushes or fibre bristle brushes can assist in removing discolouration.

(e) Washing: Thorough washing with copious quantities of clean cold water is required after pickling to remove all traces of acids used.

12.5 PASSIVATING

Passivation of SAF 2205 should be carried out within as short a period after post-weld cleaning as possible.

A solution made up of 10 - 20% HNO_3; balance H_2O is suitable for passivating SAF 2205. The acid used must conform to commercial purity standards and the water must be of potable quality. The temperature of the passivating solution should not exceed 30oC.

The solution must be generously applied to the steel by brush, cloth, spray or dipping. The solution should not be allowed to dry on the steel surface as staining can result. Use of thixotropic pastes is recommended to ensure that contact with the steel surface is maintained for the required period.

Thorough washing with clean cold water after passivation is necessary to remove all traces of the acid used.

12.6 GENERAL

Post-weld cleaning (particularly pickling) and passivation are operations which are affected by a number of factors - some of which are peculiar to local conditions. It is not possible therefore to provide procedure details which satisfy all possible conditions.

Individual fabricators are advised to develop procedures which take into account all those factors which influence the post-weld cleaning and passivation of SAF 2205 fabrications.

Pickling and passivation is normally undertaken using formulations based on acids which are harmful if ingested or allowed to come into contact with the skin. Suitable precautions (eg. protective face masks, rubber gloves, availability of first aid) must be observed.

Disposal of pickling and passivation formulations (eg. via municipal drainage systems) may be controlled and this should be clarified with the relevant authorities.