Welding duplex stainless steel the ESAB way

A FULL RANGE OF CONSUMABLES FOR ALL DUPLEX GRADES AND WELDING PROCESSES

STRENGTH THROUGH **COOPERATION**

Top quality duplex consumables and technical support...

Bridges - a relatively new applicaton area of duplex stainless steel.

Cover: Chemical tankers - a traditional application area of duplex stainless steel and ESAB consumables.

ESAB offers duplex - including lean and super duplex stainless steel - welding consumables as part of its extensive range of stainless steel welding wires fluxes and electrodes.

By choosing ESAB as their partner, customers know they have the technical support of one of the largest suppliers of welding consumables in the world. ESAB has the expertise and application experience to share with you. Any risk of what could be expensive quality problems is minimised.

ESAB is able to supply customers worldwide from an extensive manufacturing footprint and still ensure the same consistent top quality performance with centrally controlled specifications in terms of:

- raw materials
- testing methods
- quality managements systems
- ISO 14001 / OHSAS 18001

- **Full range of consumables for duplex stainless steels**
- **Consistent top quality performance**
- **Technical support**
- **Complete range of welding and cutting equipment**
- **Worldwide network of sales offices and distributors**
- **Environmental awareness**

ESAB supplies a complete range of welding and cutting equipment, filler materials and accessories for any industrial segment where duplex stainless steel is used.

We have a worldwide network of sales offices and distributors to give you service and support wherever you are. It's all here to help you boost your welding productivity. All from a single dependable source.

Working in close partnership with core teams on the ground, we harness our capacity for expertise and innovation to offer a full range of cutting and welding products and accessories tailored to suit the local market requirements.

Our global solutions are delivered with a reassuring level of environmental awareness of the health and safety issues in each sector and full knowledge of the challenges facing the wider world.

... from a world leader in welding technology

A full range of consumables for all duplex grades and welding processes

Duplex (austenitic /ferritic) stainless steels comprise a large family ranging from the lower alloyed lean grades, via the widely used 22%Cr grades to the highly alloyed superduplex and hyperduplex grades for more demanding applications. They all offer an attractive combination of high strength and good corrosion resistance thanks to their two-phase microstructure consisting of approximately 50% ferrite and 50% austenite. Duplex stainless steels typically have twice the yield strength compared to austenitic stainless steels with a corresponding corrosion resistance.

Lean duplex grades

During recent years a number of so called lean duplex stainless steels have been introduced as cost efficient alternatives to standard austenitic grades such as 304L (1.4307) and 316L (1.4401). The lean duplex steels are used successfully in numerous applications such as desalination plants, pipes, storage tanks, pressure tanks, floodgates and footbridges.

There is no clear-cut definition of lean duplex stainless steels but the term is commonly used for almost Mo-free grades with a low Ni-content. Some of the Ni in lean duplex stainless steels is often replaced by a combination of Mn and N in order to keep the alloying cost at a minimum while maintaining strength, corrosion resistance and a suitable phase balance. There are also grades with

Typical chemistry and Pitting Resistance Equivalent (PREN) of common austenitic, lean duplex and standard 22/25% Cr duplex stainless steel.

AISI/UNS No.	EN No.							
Austenitic		**Cr**	**Ni**	**Mo**	**Mn**	**Cu**	**N**	**PREN***
304L	1.4307	18	9	0	1	0		18
316L	1.4401	17	11	2	1	0		24
Lean duplex								
S32001	1.4482	20	1.7	0.3	5	0.3	0.15	23
S82011		21.5	1,5	0.3	3		0.2	26
S32101	1.4162	21.5	1.5	0.3	5	0.3	0.2	26
S32202	1.4062	22	2	0.3	1.3	0.2	0.2	26
S32304	1.4362	23	4	0.3	1		0.1	26
S32003		20	3.5	1.7	2		0.15	28
	1.4655	23	4.5	0.3	1.5	2	0.1	26
22%Cr duplex								
S31803	1.4462	22	5.3	2.8	1		0.16	34
S32205	1.4462	22.3	5.7	3.2	1		0.18	35
25%Cr super duplex								
S32550	1.4507	26	5.5	3	1		0.17	39
S32750	1.4410	25	7	4	1.2		0.27	42
S32760	1.4501	25.4	6.9	3.8	1	0.7	0.27	42
S39274		25	7	3.2	1	0.5	0.26	40

*PREN = %Cr + 3.3%Mo +16%N

A full range of consumables for all duplex grades and welding processes

Offshore industry - duplex stainless steel is widely used for the processing and transport of oil and gas.

intermediate Mo-contents or with significant Cu-additions often described as lean grades (see Table 1). As can be seen from the table, lean duplex grades typically have a pitting corrosion resistance better or on par with standard austenitic grades.

Recommended ESAB consumables

The lean duplex, duplex and super duplex consumables are designed in such a way that minimum matching mechanical properties and corrosion resistance can be guaranteed. They are therefore higher in elements promoting austenite formation, compared to the corresponding steel grade, to avoid excessively high weld metal ferrite contents.

With few exceptions all lean duplex grades can be welded with 2209 type consumables providing excellent mechanical properties and corrosion resistance. However, lean duplex consumables are more cost efficient and metallurgically designed to give the weld properties similar to the base material. There are also some applications where Mo has a negative effect on corrosion resistance making 2209-type consumables less suitable. The Mo-alloyed lean grade S32003 is however preferably welded with 2209-type consumables to ensure matching corrosion resistance.

			Lean duplex grades					Duplex grades					Super duplex grades				
AISI/ UNS No.	**EN No.**	**Grade**	**OK 67.56***	**OK Autrod 2307**	**OK Tigrod 2307**	**Shield-Bright 2307**	**OK Autrod 2307/ OK Flux 10.93**	**OK 67.50, OK 67.53, OK 67.55**	**OK Autrod 2209**	**OK Tigrod 2209**	**OK Tubrod 14.27, OK Tubrod 14.37**	**OK Autrod 2209/ OK Flux 10.93**	**OK 68.53, OK 68.55**	**OK Autrod 2509**	**OK Tigrod 2509**	**OK Tubrod 14.28**	**OK Autrod 2509/ OK Flux 10.93**
S32001	1.4482	19D	x*	x	x	x	x	1	1	1	1	1					
S82011		2102	x*	x	x	x	x	1	1	1	1	1					
S32101	1.4162	LDX 2101®	x*	x	x	x	x	1	1	1	1	1					
S32202	1.4062	2202	x*	x	x	x	x	1	1	1	1	1					
S32304	1.4362	2304	x*	x	x	x	x	1	1	1	1	1					
S32003		2003	2	2	2	2	2	1	1	1	1	1					
	1.4655		3	3	3	3	3	1	1	1	1	1					
S31803	1.4462	2205						x	x	x	x	x	x	x	x	x	x
S32205	1.4462	2205						x	x	x	x	x	x	x	x	x	x
S32550	1.4507	255											x	x	x	x	x
S32750	1.4410	2507											x	x	x	x	x
S32760	1.4501	Zeron 100											x	x	x	x	x
S39274		DP3W											x	x	x	x	x

* Apply stringer beads or moderate weaving. Excess weaving affects the slagdetachability. AC/DC+ polarity.
x: Well suited.
1: Suitable except when Mo-alloying has negative effect on corrosion resistance.
2: Suitable if slightly undermatching corrosion resistance is acceptable.
3: Suitable except when Cu-alloying is required.

The paper and pulp industry - a classic application area for duplex stainless steel and ESAB consumables.

Product data

	Product name	Description	Classification	Typical all weld metal chemical composition, %	Mechanical properties	Ferrite content/ CPT*/PRE**	Approvals
MMA	OK 67.50	Duplex acid- rutile MMA stick electrode	AWS A/SFA 5.4 E2209-17 E 22 9 3 N L R 32	C 0.03 Si 0.8 Mn 0.8 Cr 23.2 Ni 8.8 Mo 3.2 N 0.16	$R_{p0.2}$ 691 MPa Rm 820 MPa A5 25% Charpy-V +20°C 50 J	FN 45/ 27.5°C/ 36	ABS BV CE CWB DNV GL TÜV
	OK 67.53	Duplex rutile MMA stick electrode	AWS A/SFA 5.4 (E2209-16) E 22 9 3 N L R 12	C 0.03 Si 1.0 Mn 0.7 Cr 23.7 Ni 9.3 Mo 3.4 N 0.16	$R_{p0.2}$ 660 MPa Rm 840 MPa A5 25% Charpy-V +20°C 56 J	FN 40/ 27.5°C/ 36	TÜV DNV CE
	OK 67.55	Duplex basic MMA stick electrode	AWS A/SFA 5.4 E2209-15 E 22 9 3 N L B 22	C 0.04 Si 0.7 Mn 1.0 Cr 23.2 Ni 9.1 Mo 3.2 N 0.15	$R_{p0.2}$ 650 MPa Rm 800 MPa A5 28% Charpy-V +20°C 100 J, -20°C 85 J, -40°C 75 J, -60°C 65 J	FN 45/ 27.5°C/ 36	DNV TÜV
	OK 67.56	Lean duplex acid-rutile MMA stick electrode	EN 1600 E Z 23 7 N L R	C 0.03 Si 0.9 Mn 0.7 Cr 23.7 Ni 6.9 Mo 0.4 N 0.15	$R_{p0.2}$ 609 MPa Rm 754 MPa A5 26% Charpy-V +20°C 47 J, -30°C 38 J	FN 35-65	CE
	OK 68.53	Superduplex basic-rutile MMA stick electrode	EN 1600 E 25 9 4 N L R 32 AWS A/SFA 5.4 E2594-16	C 0.03 Si 0.6 Mn 0.7 Cr 25.2 Ni 10.2 Mo 4.0 N 0.25	$R_{p0.2}$ 700 MPa Rm 850 MPa A5 30% Charpy-V +20°C 50J, -40°C 40J	FN 42/ 60°C/ 43	CE DNV TÜV
	OK 68.55	Superduplex basic MMA stickelectrode	EN 1600 E 25 9 4 N L B 42 AWS A/SFA 5.4 E2594-15	C 0.04 Si 0.6 Mn 0.9 Cr 25.2 Ni 10.4 Mo 4.3 N 0.24	$R_{p0.2}$ 700 MPa Rm 900 MPa A5 28% Charpy-V +20°C 90 J, -40°C 55 J, -60°C 45 J	FN 45/ 60°C/ 43	DNV LR (Pending)
MIG/TIG	OK Autrod 2209/ OK Tigrod 2209	Duplex solid wire electrode	AWS A/SFA 5.9ER2209 EN ISO14343-A G/W 22 9 3 N L	C 0.02 Si 0.5 Mn 1.6 Cr 22.5 Ni 9 Mo 3 N 0.15	$R_{p0.2}$ 600 Rm 765 MPa A5 28% Charpy-V +20 °C >100 J	FN 30-45/ 25-30°C/ 35	TÜV DNV & GL valid for Autrod only
	OK Autrod 2307/ OK Tigrod 2307		T 23 7 N L P M21 2 EN ISO 17633-A	C 0.03 Si 0.7 Mn 0.8 Cr 23.7 Ni 8.4 N 0.12	$R_{p0.2}$ 626 Rm 774 MPa A5 33%		
	OK Autrod 2509/ OK Tigrod 2509	Superduplex solid wire electrode	EN ISO 14343-A G/W25 9 4 N L	C 0.02 Si 0.4Mn 0.4 Cr 25 Ni 10 Mo 4 N 0.25	$R_{p0.2}$ 670 MPa Rm 850 MPa A5 30% Charpy-V +20°C 150 J (MIG), +20°C 150 J (TIG)	FN 30-50/ 50-60°C/ 42	TÜV
FCAW	OK Tubrod14.27	Duplex rutile, all- positional, flux-cored wire	AWS A/SFA A5.22 E2209 T1-1 and T1-4 EN 12073T 22 9 3 N L P M 2T 22 9 3 N L P C 2	C 0.03 Si 0.9 Mn 1.0 Cr 22.6 Ni 9.0 Mo 3.0 N 0.15	$R_{p0.2}$ 637 MPa Rm 828 MPa A5 26% Charpy-V -20°C 58 J	FN 30-45/ 30°C/ 35	ABS DNV GL LR RINA VdTUV
	OK Tubrod14.37	Duplex rutile, downhand, flux-cored wire	AWS A/SFA A5.22 E2209 T0-1 and T0-4 EN 12073T 22 9 3 N L R M 3T 22 9 3 N L R C 3	C 0.03 Si 0.7 Mn 0.9 Cr 22.6 Ni 8.9 Mo 3.1 N 0.13	$R_{p0.2}$ 633 MPa Rm 768 MPa A5 31% Charpy-V +20°C 55 J, -40°C 40 J	FN 30-45/ 27.5-30°C/ 36	
	OK Tubrod14.28	Superduplex rutile all positional flux-cored wire	AWS A/SFA A5.22 E2553 T1-G	C 0.03 Si 0.6 Mn 0.9 Cr 25.2 Ni 9.2 Mo 3.9 N 0.25	$R_{p0.2}$ 650 MPa Rm 820 MPa A5 18% Charpy-V +20°C 45 J, -40°C 35 J	FN 30-45/ 60°C/ 43	
	Shield-Bright 2307	Lean duplex, all positional rutile flux-cored wire	EN ISO 17633-A T 23 7 N L P M21 2	C0.028 Si 0.72 Mn 0.78 Cr 23.7 Ni 8.4 N 0.12	Rp0.2 626 MPa Rm 774 MPa A5 33% Charpy-V -20°C 62 J, -30°C 63 J	Charpy-V -20°C 62 J, -30°C 63 J	FN 35-65
SAW	OK Flux 10.93/ OK Autrod 2209	Basic flux/duplex solid wire for SAW welding	EN 760 SA AF 2 DC EN ISO 14343-A S 22 9 3 N L	C 0.03 Si 0.5 Mn 1.4 Cr 22 Ni 9 Mo 3 N 0.15	$R_{p0.2}$ 630 MPa Rm 780 MPa A5 30% Charpy-V +20°C 140 J, -60°C 80 J	FN 30-50/ 27.5-30°C/ 34	TÜV CE DNV LR GL Rina BV ABS
	OK Flux 10.93/ OK Autrod 2307	Basic flux/lean duplex solid wire for SAW welding	EN 760 SA AF 2 DC EN 14343-A S Z 23 7 N L	C 0.02 Si 0.7 Mn 1.1 Cr 22.5 Ni 7.5 N 0.12	$R_{p0.2}$ 640 MPa Rm 840 MPa A5 28% Charpy-V +20°C 85 J, -40°C 60 J	FN 35-65	CE
	OK Flux 10.93/ OK Autrod 2509	Basic flux/super duplex solid wire for SAW welding	EN 760 SA AF 2 DC EN ISO 14343-A S 25 9 4 N L	C 0.02 Si 0.5 Mn 0.5 Cr 24.5 Ni 9.5 Mo 4 N 0.25	$R_{p0.2}$ 640 MPa Rm 840 MPa A5 28% Charpy-V +20°C 85 J, -60°C 50 J	FN 30-50/ 60°C/ 43	TÜV
	OK Flux 10.94/ OK Autrod 2509	Basic Cr-alloying flux/ super duplex solid wire for SAW welding	EN 760 SA AF 2 Cr DC EN ISO 14343-A S 25 9 4 N L	C 0.02 Si 0.5 Mn 0.5 Cr 25 Ni 9.5 Mo 4 N 0.25	$R_{p0.2}$ 626 MPa Rm 830 MPa A5 28% Charpy-V +20°C 90 J, -60°C 50 J	FN 30-50/ 60°C/ 43	

*CPT= Critical Pitting Temperature (CPT) in ferric chloride,according to ASTM G48 **PRE=% Cr+ 3.3%Mo+16%NComposition and property data are subject to change without notice.

Welding duplex stainless steel the ESAB way

Before welding

- A slightly wider root gap and joint angle than those applied for standard stainless steel should be used to obtain good penetration.
- Use ceramic backing to facilitate root pass welding.
- The joint and the adjacent base metal should be thoroughly cleaned.
- Only stainless brushes should be used for cleaning.
- Preheating is normally not recommended.
- Dry electrodes should always be used. ESAB can supply the duplex electrodes in ESAB VacPac™ which is an effective system for handling welding electrodes. Two package sizes are adapted to match consumption during a normal working shift. This eliminates costly re-drying procedures.

Heat input and interpass temperature recommendations

- **Heat input: 0.5-1.5 kJ/mm and Ti_{max}=150°C for lean duplex grades e.g. UNS S32101. Heat inputs up to 2.5kJ/mm can in most cases be applied, but it is recommendable to check with the steel supplier.**
- **Heat input: 0.5-2.5 kJ/mm and Ti_{max}=200°C for duplex grades, e.g. EN 1.4462, UNS S31803**
- **Heat input: 0.2-1.5 kJ/mm and Ti_{max}=150°C for super duplex grades e.g. UNS S32750**

Shielding and backing gases

- **TIG Ar or Ar-He mixtures**
- **MIG Ar-O_2 (1-3%), Ar-CO_2 (1-3%) or Ar-He-O_2 (1-3%) mixtures**
- **FCAW Ar-CO_2 (25%) mixtures or pure CO_2**

During welding

- The heat input should be related to the plate thickness and welding method. A heat input which is too low or too high should be avoided
- Super duplex steels are particularly sensitive to high heat input and interpass temperatures. The heat input should not exceed 1 kJ/mm when welding thin plates.
- Avoid striking the arc outside the joint. Arc strikes can act as initiation points for pitting corrosion and cracks.
- Maintain proper arc length and stick-out to avoid nitrogen pick-up.
- A correct root gas shield is important. Suitable backing gases are high-purity Ar and mixtures containing N_2 and H_2.
- Excessive weaving should be avoided. It can result in an overly high heat input.

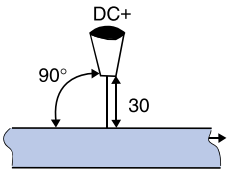
After welding

- Thorough cleaning after welding is essential to obtain good corrosion resistance. All slag and oxide on and around the weld must be removed.
- Brushing should be done manually and only with stainless brushes.
- Rotating brushes can result in micro-crevices in the weld metal.
- Subsequent heat treatment is normally not needed. Duplex steels and weld metals can, however, be solution heat treated (see steel producer's recommendations).
- Stress relieving should be avoided as this can cause embrittlement of the steel and the weld metal.
- The flame straightening of deformed plates can be used, if the recommended procedure from the steel supplier is followed.

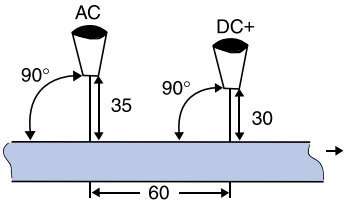
One-sided welding for productive panel fabrication

ESAB has developed a highly-productive alternative to the standard two-sided joining of the panels in chemical tankers using one-sided SAW

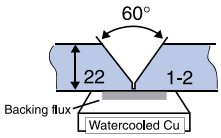
(OSW) welding procedures with a special backing flux and with the support of a copper backing. Using this technique, the panels do not need to be moved from the welding station, turned and replaced before completing the weld. Instead, the joint can be completed from one side. Needless to say, this is a cost-effective alternative that can easily be implemented with a low investment cost.



ONE-SIDED SAW-SINGLE WIRE
One-sided SAW of 22 mm duplex steel with multi-pass single wire. All distances are given in mm.



ONE-SIDED SAW-TANDEM WIRE
One-sided SAW of 22 mm duplex steel with multi-pass tandem wire.



Joint figuration suitable for the one-sided SAW of panels in duplex chemical tankers.

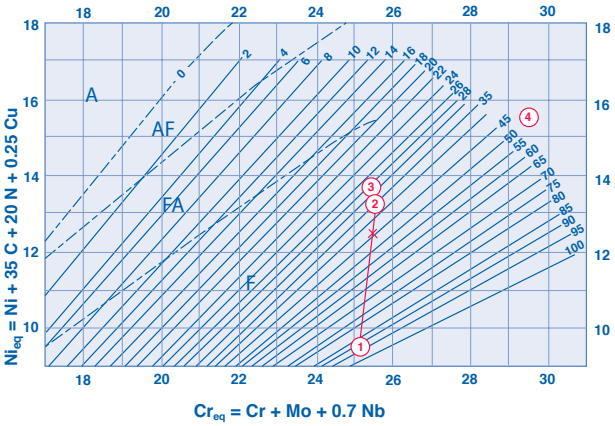
Ferrite content prediction

The phase balance of the weld metal and the heat affected zone (HAZ) is vital when it comes to obtaining good properties in welds in duplex stainless steel. Excessively high ferrite will cause brittleness, whereas a lack of ferrite will cause a loss of resistance to stress corrosion cracking. The weld metal ferrite content should normally be in the range of FN 30-100 (approximately 22-70%).
The WCR-92 diagram is a useful tool for calculating the ferrite content of weld metals. The location of some ESAB consumables and the use of the diagram is illustrated below.

The WRC 1992 constitution diagram

The Creq and Nieq of the steel and the all-weld metal are calculated from their chemical compositions, plotted on the diagram and joined by a line.
This line represents all the possible compositions of the weld metal for different degrees of dilution.
In the present example, a 30% dilution has been used and the predicted ferrite content of the weld is approximately FN 45.

Location of:
1 Base material, SAF 2205 (EN 1.4462), remelted.
2 Duplex MMA weld metal, deposited with OK 67.50.
3 Duplex MIG weld metal, deposited with OK Autrod 2209.
4 Superduplex MMA weld metal, deposited with OK 68.53.
X Location of weld in SAF 2205 (EN 1.4462) welded with OK 67.50 MMA electrode assuming 30% dilution.



(Published in Welding Journal by D.J. Kotecki and T.A. Siewert)

World leader in welding and cutting technology and systems.

Desalination plants - a less commonly known application area of duplex stainless steel and ESAB consumables.

ESAB operates at the forefront of welding and cutting technology. Over one hundred years of continuous improvement in products and processes enables us to meet the challenges of technological advance in every sector in which ESAB operates.

Quality and environment standards

Quality, the environment and safety are three key areas of focus. ESAB is one of few international companies to have achieved the ISO 14001 and OHSAS 18001 standards in Environmental, Health & Safety Management Systems across all our global manufacturing facilities.

At ESAB, quality is an ongoing process that is at the heart of all our production processes and facilities worldwide.

Multinational manufacturing, local representation and an international network of independent distributors brings the benefits of ESAB quality and unrivalled expertise in materials and processes within reach of all our customers, wherever they are located.

ESAB Sales and Support Offices worldwide

*** Includes manufacturing facilities of ESAB North America, a wholly owned subsidiary of Anderson Group Inc.**

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