



**OFFSHORE
DESIGN
SECTION**

**WELDING OF
DUPLEX
STAINLESS
STEEL**



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ANNEXURE I

WELDING OF DUPLEX STAINLESS STEEL

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WELDING SPECIFICATION FOR DUPLEX STAINLESS STEELS

1.0 WELDING PROCESS

Shielded Metal Arc Welding (SHAW), Gas Tungsten Arc Welding (GTAW), Submerged Arc Welding (SAW) and Plasma Arc Welding (PAW) processes are suitable for Duplex stainless steel. These Welding methods along with the related operational precautions such as cleanliness and protective gas shielding should be used for making duplex stainless steel welds. Shielding / purging gases shall be selected ensuring freedom from hydrogen.

2.0 MICROSTRUCTURE

The ferrite content of the weld metal estimated through metallographic examination, should be between 30% to 55% to obtain weld joints with the best ductility and corrosion resistance. The filler metal composition and the welding heat input should be so selected as to give the ferrite content of the weld metal between 30% to 55%.

3.0 FILLER METALS (Welding Consumables)

Table 1 enclosed herewith tentatively lists the different filler metals used for duplex stainless steels conforming to UNS S 31803. Welding consumables shall be used only after conducting consumable qualification tests. Consumables shall be degreased or baked and stored in accordance with the manufacturer's recommendations.


4.0 MECHANICAL PROPERTY REQUIREMENTS

The weld metal should have the following mechanical properties :

4.1	Tensile Strength	-	680 – 880 N/mm ²
4.2	Yield Strength (0.2% Offset)	-	450 N/mm ² (Min.)
4.3	Elongation	-	25% (Min.)
4.4	Impact Energy (Charpy V-notch Valves)		
	At + 20°C (68°F)	-	100 Joules Average (72 ft. lb) 75 Joules Average (54 ft. lb)
	At -30°C (-22°F)	-	60 Joules Average (43.2 ft. lb) 40 Joules Average (28.8 ft. lb)

5.0 QUALIFICATION TESTS

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5.1 Welding Procedure Qualification Tests

5.1.1 General

Each particular welding procedure shall be specially qualified for the job; no previous test reports shall be recognized as a qualification of the work to be performed. The welding filler metal to be used shall be of a grade, which will yield a weld metal equivalent to that of the base metal. Welding consumables shall be subjected to initial qualification testing and the consumable shall require company's approval. During Procedure Qualification, the heat input for 22% Cr Duplex steels shall be limited to 0.8 – 2.5 KJ/mm. In production welding, the heat input shall not deviate from that qualified by more than +/- 10%. P numbers shall not apply to duplex stainless steels. Each alloy designation shall be separately qualified in accordance with this specification.

5.1.2 Welding consumable qualification tests and welding procedure qualification tests shall be conducted before the start of procurement by employing an approved welding procedure in presence of the Company's Representative. The welding procedure shall be prepared by the Contractor based on the information provided by the Supplier of raw materials and/or electrodes Supplier and approved by the Company. Welding procedure shall be such that it gives maximum hardness on the outer surface of pipe.

All the mills supplying the raw material/pipes etc. shall be required to pass the tests required for procedure qualification testing. Approved procedure shall be common to all the mills.

Laboratory tests shall be performed at an official Laboratory approved by the Company. Sufficient advance notice shall allow the Company to witness all or part of the tests.

5.1.3 Test Samples


Tests mentioned below shall be performed on welded test pieces and shall include the parent metal, heat affected zone and the weld metal.

5.1.4 Procedure Qualification Tests shall be carried out as given below :

i) Chemical Composition and Microstructure Examination

The ferrite content measurement of test pieces shall be carried out by both the following methods:

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a) Metallographic determination and

b) Magnegage method (According to Kotecki)

The procedure of ferrite measurement and the calibration of measuring instrument shall bear the approval of the Company before being employed.

ii) Mechanical Properties

These tests shall include tensile testing, impact strength and bend test. Bend tests shall be performed in accordance with ASTN A 370 with a plunger dia equal to 4 times the thickness. No defect shall be visible on bending.

iii) Hardness Tests

Each qualification test shall include a cross sectional hardness survey.

A complete survey of the weld, heat affected zone and the base metal shall be performed according to the following procedure :

- the test method shall be as per ASTM E 18.
- the distance between indentations shall be a maximum of 1 mm.
- The results shall not exceed RC 28.

iv) Corrosion Tests

a) Intergranular Corrosion Tests (HUEY)

The welds shall be subjected to ASTM A 162 practice C (HUEY Test). Weight loss shall not exceed 3 to 4 mils/month.

b) Chloride Stress Corrosion Cracking Test.


This type of test shall be conducted on the material at 155° C with aeration in 45% MgCl₂ solution as per ASTM G 36. Stress to cause repute in 500 hours shall exceed 0.35 times the ultimate tensile strength. This test is required to be done per heat for each mill before start of procurement.

c) SSCC Test

Resistance of the material to SSCC shall be tested using :

a) NACE TM 01-77 test solution (Test temp. 24 Deg. C). Minimum stress for cracking in 720 Hrs shall be 350 N/mm².

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b) NACE TM 01-77 test solution (test temp. 90 Deg C and total pressure of H₂S = 16 Bars).

Min. stress for cracking in 720 Hrs = 325 N/mm².

v) Radiography

The welds shall be 100% radio graphed shall be as per ASME, Section – VIII, Division – I, UW – 51.

vi) Dye Penetrant / MP Testing

All fillet and groove welds other than these radio graphed shall be tested by dye penetrant testing or by magnetic particle testing method. No defect shall be accepted.

vii) Heat Treatment (if required)

Suitable heat treatment procedure shall be established for retaining the Duplex S.S. properties of welded joints which shall be approved by the Company before implementing.

5.2 Welder Qualification Tests

Welders shall be qualified at the fabrication yard / barge employing the qualified welding procedure. The test pieces of each welder shall be subjected to mechanical tests, radiographic examination, DPT/MP Test, microstructure examination and cross-sectional hardness survey with the same test procedure and acceptance criteria as mentioned in 5.1 above.


6.0 FABRICATION

6.1 No fabrication shall start until the Company has approved the chemistry of the materials, the results of welding procedure qualification tests and welders are qualified as per the approved procedure.

6.2 Working practices shall be designed to minimize contamination and before welding, internal and external surfaces shall be cleaned for a distance of at least 50mm from the fusion face.

6.2 In production welding the heat input shall be monitored and the same shall not deviate from the qualified WPS by more than +/- 10%.

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6.2 Production/Fabrication Tests

Shop/Site Fabrication Tests for each weld shall include :

- Non – destructive hardness tests by portable hardness tester
- Radiography
- DPI/MP Examination
- Ferrite Measurement by either
 - a) Magnegage method (extended range, according to Kotecki)

OR

 - b) Forster Probe Method.

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Procedure	Supplier Commercial Name	Typical Chemical Composition in %	Comments
Plasma auto or Manual	Smitweld SW 4462 (Revised Composition)	C:0.010 Mn:1.6 Si:0.25 P:0.20 S:0.008 Cr:23.0 Ni:8.8 Mo:3.1 N:0.012	Filler metal recommended when as welded
	Thyssen	C:0.016 Mn:1.57 Si:0.17 Cr:22.8 Ni:9.18 N:0.04	Very low nitrogen (traces) ferrite level practically identical to 22-6-31.
	Thermanit 22-09		Excellent results when welded with nitrogen in welding gas.
SAW	Thyssen Thermanit	C:0.016 Mn:1.57 Si:0.17 Cr:22.8 Ni:9.18 N:0.04	With flux SAP CN 100 – as welded condition gives ferrite range 35-65%
SMAW	Thermanit 22-09	C ≤ 0.030 Cr:22.0 to 23.0	
	Sandvik 22-9-3LR Smitweld Arosta 4462 Philips Rs 22-9-3LC Avesta 223 FAL-PW	Ni:9 to 10 Mo ≈ 3, N:0.10 to 0.15	These electrodes even with low heat input, give welds with specified ferrite range.