SUPEROOT 316L

A PRACTICAL APPROACH TO ROOT PASS WELDING

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METRODE WELDING CONSUMABLES

SUPEROOT 316L

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1. SUMMARY

SUPEROOT 316L is a flux cored TIG rod specifically designed for root pass welding in stainless steel pipework. This unique product avoids the need for complex back purging as required by conventional solid wire TIG. Excellent bead profile is achieved whilst the thin slag cover prevents root underbead oxidation. Good operability is achieved in all welding positions.

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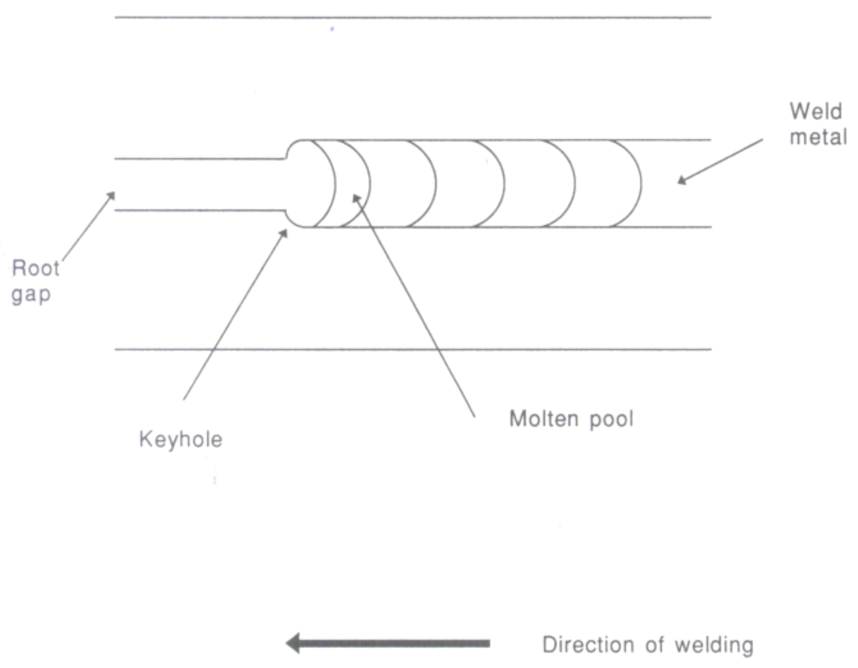
2. GENERAL DESCRIPTION

SUPEROOT 316L is available in the 316L grade only, allowing use on 304L, 347 and 316L grades of pipe and plate. Only a single diameter, 2.2mm ∅, is required which has been optimised for efficiency and operating conditions. SUPEROOT 316L is manufactured using a seamless tube to avoid moisture pick-up and contamination ensuring a consistent, even burn-off, essential for defect-free welding.



In principal, Metrode **SUPEROOT 316L** works like a covered electrode inside out. However, as with all TIG welding there is independent control of heat source (arc) and filler, allowing the welder to work with variations in fit up, root gap and welding position.

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3. FEATURES AND APPLICATIONS

Flux Cored TIG offers unique features for root pass welding where gas purging is impractical:

- A slag cover which acts to prevent oxidation on the underbead surface without the need for external purging.
- The TIG process allows the independent control of the heat source and the filler material.
- Designed for single-sided root welding in material down to about 4mm (it is not recommended for single run welds).
- Suitable for all-positional pipe welding, although horizontal joints (2G) prove more problematic owing to the increased difficulty in maintaining the keyhole.
- Used in maintenance environments where gas purging is impractical.

4. CHEMICAL COMPOSITION

Typical deposited chemistry:

	SUPEROOT 316L	316S92/93 (ER316L/316LSi)
C	0.01	0.01
Mn	1.6	1.4
Si	0.9	0.5/0.8
S	0.005	0.01
P	0.020	0.015
Cr	19.2	18.5
Ni	12.5	12.8
Mo	2.2	2.6
Cu	0.05	0.15

Ferrite (undiluted weld metal)

Deposits in both cases give about 5FN, with dilution from parent plate and some pick-up of atmospheric nitrogen.

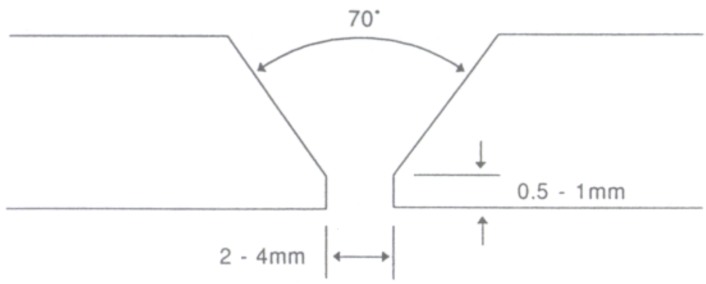
Specification

AWS A5.22 R316LT1-5

5. WELDING PARAMETERS

General recommendations are as follows:

5.1 Weld preparation and keyhole formation



Typical preparations are illustrated above, it is important to maintain sufficient root gap to ensure adequate underbead slag protection. As with solid wire TIG welding, filler addition has to be balanced:

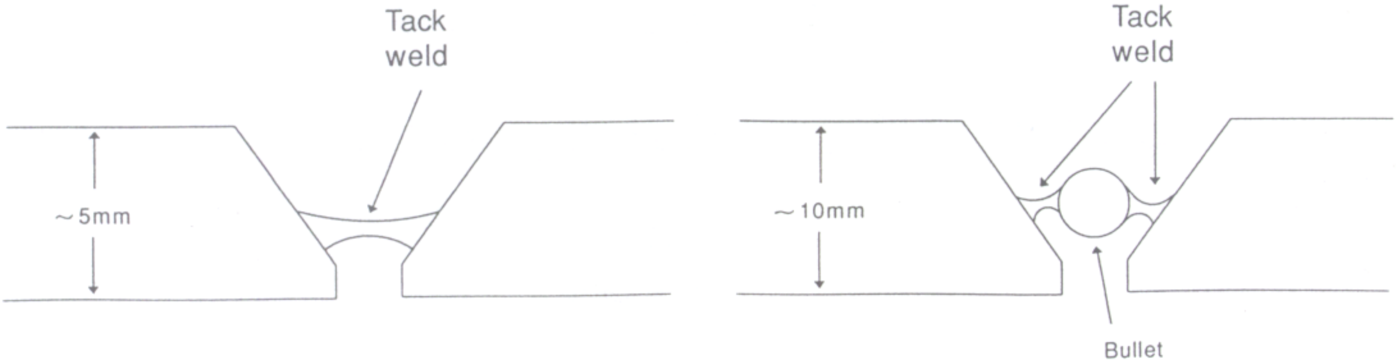
- Excess filler leads to unmelted filler and possible slag traps.
- Insufficient filler leads to poor profile and insufficient underbead slag protection.

General experience shows that wire feed rate needs to be faster than with conventional solid wire (typically twice the rate). The optimum technique is to add wire by dipping the filler into the leading edge of the weld pool on alternate sides of the joint. This technique is preferable to continuous wire addition into the centre of the weld pool.

5.2 Tack welds

To maintain the root gap, tacks should be used, a minimum of four spaced equi-distant round the pipe and removed as welding proceeds.

To ensure a smooth uninterrupted root profile tack welds in the root should be avoided. For smaller diameter, thinner walled pipe, use bridging tacks; for larger diameter, thicker walled pipe, use bullet tacks.



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5.3 Welding conditions

Typical welding current is 70-100 Amps, thicker plate sections may require slightly higher currents.

5.4 Shielding gas

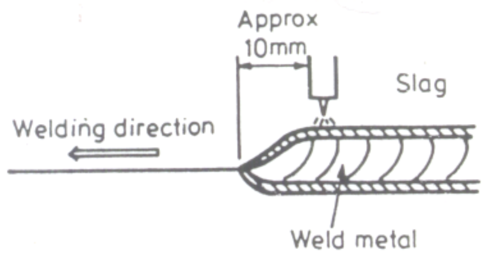
Pure argon is typically used as the shielding gas, no purging gas is required.

5.5 Stop/starts

Starts should be carried out by arcing onto the joint side and adding filler as quickly as possible to establish slag/gas protection.

Stops should also be carried out by back-stepping the weld bead on the side of the joint preparation.

Standard crater-fill techniques should be used to avoid visible and internal shrinkage (crater) cracks. Starts can be carried out directly on to the slag covered bead if it is still hot.



If cold, the top slag should be removed, but not the underside, for a distance of about 10mm. Inclined vertical-up welding tends to give easier keyhole reformation in difficult or narrow gap stop/start positions.

Tie-ins, eg. on pipe joints, are an area where some care is required to ensure satisfactory results. There are two points on which the best procedure varies from that used with solid TIG wires with a gas purge.

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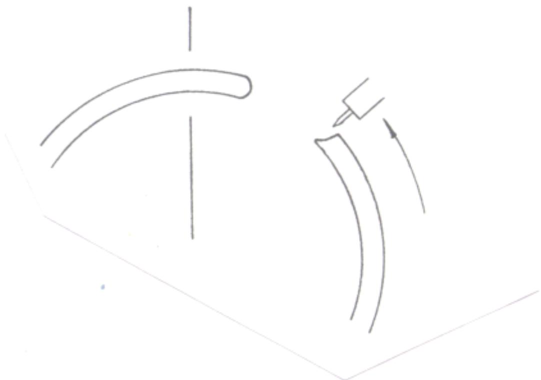
Firstly, the position of the tie-in should be placed so that it is not top-dead-centre (TDC) of the pipe:



Secondly, the standard technique of feathering the end of the bead to be tied-in should be reduced to a maximum of 3mm. This minimises the length of weld produced without underbead flux protection (since the keyhole, by which flux flows to reach the bead underside, closes up). An alternative technique involves no feathering but utilises a current surge to ensure satisfactory tie-in with minimal potential loss of underside flux protection.

5.6 Second runs

Flux cored TIG rods are not designed to be used for the second and subsequent runs; there is too much flux/slag and risk of slag traps. If the TIG process is to be used for fill/cap passes then solid TIG wire should be used. Slag should be removed from the upper surface of the bead prior to depositing fill/cap passes.

The use of a 316L root bead is considered fully compatible with subsequent filling using 308L, 347 or 316L fillers as appropriate (see comments on nitric acid service in section on corrosion, section 6).

Subsequent filling must be carefully controlled to avoid detrimental re-heating effects which can lead to unacceptable coking of the underbead.

In principal, the fill passes can be carried out with any process - guidelines considered here are specific to the TIG process. Plate thickness is probably the guiding factor in determining "coking" tendency; see figures on next page.

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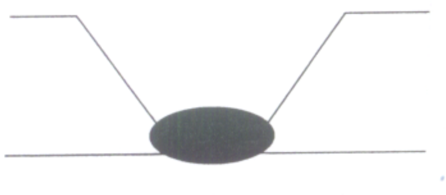
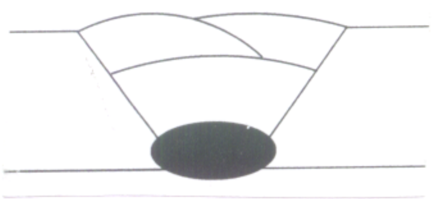
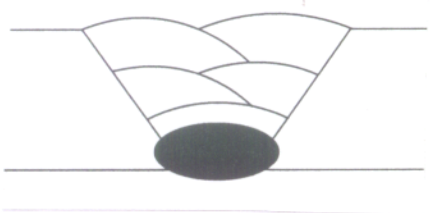
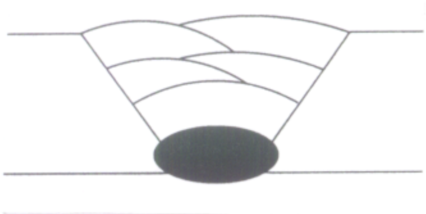
WELD PROCEDURE	PRACTICAL RESULT
FIRST PASS 90A/1.3kJ/mm 	Acceptable root bead profile and appearance.
SECOND PASS 2.3kJ/mm 	Excessive coking of underbead surface.
SECOND PASS 1.2kJ/mm 	No underbead surface damage.
SECOND PASS 1.5kJ/mm 	Limited underbead surface coking.

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6. CORROSION PERFORMANCE

Owing to the nature of the process (ie. root welds without purging), when subsequent fill passes are deposited there is the potential for oxidation of the root bead as the slag covering the root falls off on reheating. This would not occur in a purged system, assuming the gas purge was maintained for a sufficient number of fill passes. This can be verified in sample welds because purged joints retain their shiny root appearance whereas root beads deposited using SUPEROOT 316L exhibit a dull/oxidised appearance after being reheated by subsequent fill passes when no purging is applied.

In an ideal situation this oxidation/heat tinting would be removed to obtain optimum corrosion resistance but in situations where SUPEROOT 316L has been used this is almost never possible. Some corrosion tests were carried out on root beads deposited with both standard solid wire (316S92) and SUPEROOT 316L.

Root weld samples in matching 316L material were tested in the as-welded condition with only the slag being removed from the SUPEROOT 316L samples. In a sulphuric acid-copper sulphate intergranular corrosion test (ASTM A262E), no intergranular corrosion was detected in any of the samples. Ferric chloride pitting corrosion tests (ASTM G48A) were also carried out (35°C for 24 hours), these results can be summarised as follows:

PROCESS	CORROSION RATE
A. 316S92 (root + 2nd run) - Ar purge for both	4.47 $g/m^2/h$
B. SUPEROOT 316L (root) + 316S92 (2nd run with Ar purge)	4.20 $g/m^2/h$
C. SUPEROOT 316L (root) + 316S92 (2nd run no purge)	5.19 $g/m^2/h$

For comparison, a 308S92 (ER308L) root weld in 304L plate, with back purging had a corrosion rate of 14.45 $g/m^2/h$.

Although SUPEROOT 316L matches or overmatches ER308L and ER347 weld metal in the majority of corrosive media, it is not suitable for applications involving exposure to nitric acid. Like all other 316L weld metals it is balanced to contain a controlled level of ferrite (for optimum resistance to hot cracking) and this molybdenum-bearing ferrite is prone to preferential attack by nitric acid.

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7. ECONOMICS

The use of SUPEROOT 316L and the omission of purge/backing gas can result in significant savings in terms of both time and gas usage. The two tables below show the difference in time and gas consumption for joints in two pipe sizes (2" NB and 12" NB) made using SUPEROOT 316L and standard solid wire with gas purge. These reductions in time and gas can result in large cost savings.

Effect on welder time:

Pipe size	2" (50mm) nominal bore			12" (300mm) nominal bore		
Consumable/purge	Superoot 316L no purge	Solid wire local purge*	Solid wire general purge*	Superoot 316L no purge	Solid wire local purge*	Solid wire general purge*
Set-up of dams etc., min.	-	10	-	-	10	-
Prepurge, min.	-	0.5	4	-	5	105
Welding, min.	6	5.2	5.2	35	30	30
Total TIME, mins.	6	15.7	9.2	35	45	135

Effect on gas required:

Pipe size	2" (50mm) nominal bore			12" (300mm) nominal bore		
Consumable/ purge	Superoot 316L no purge	solid wire local purge*	solid wire general purge*	Superoot 316L no purge	solid wire local purge*	solid wire general purge*
Prepurge, l	-	5	95	-	120	2450
Backing gas, l	-	42	42	-	240	240
Shielding gas, l	45	40	40	265	225	225
Total GAS, litres	45	87	177	265	585	2915

Note: Back shield conditions from AWS D10.11

* Local purge along 300mm pipe length; general purge along 6m pipe length.

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8. APPLICATION STUDIES

Metrode SUPEROOT 316L has been used on a number of projects where the ability to produce satisfactory root welds without gas purging has proved beneficial. Three examples of these applications are summarised here:

Application 1

Project: Sour water (H_2S) Stripper Pipeline

Fabricator: UK Construction Ltd.

User: BP Chemicals, Grangemouth

Application: Site fabrication and installation of 8" NB line in 316L stainless steel

Joint welded: Root runs in 12mm thickness pipe, all welded in 2G position. Completed with 316S92 TIG. Procedure welds subject to:
- mechanical testing
- ferrite checks
- corrosion testing
- radiography

Production welds (1993) subject to 100% radiography and inspection for corrosion resistance this year (1997).

Benefits:
1. Saving in back purge gas volume.
2. Setting of individual purge dams and testing as the line progressed.
3. Allowed line to be installed and tacked and progressively welded with significant time and cost saving.

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Application 2

Construction: Resin process vessels with heating/cooling limpet coils

Fabricator: Leon Frenkel Ltd., UK

Users: Various

Application: Repair and fabrication of limpet coils

Joint welded: Butt welds in preformed coil, grade 316L stainless steel. Some welded in vertical position. Completed with 316L MMA electrodes. Welds subject to X-ray inspection.

Benefits: Saving of total purge volume of $15m^3$ + time needed to purge and test. In maintenance environment when enforced stops are inevitable, no need for purging.

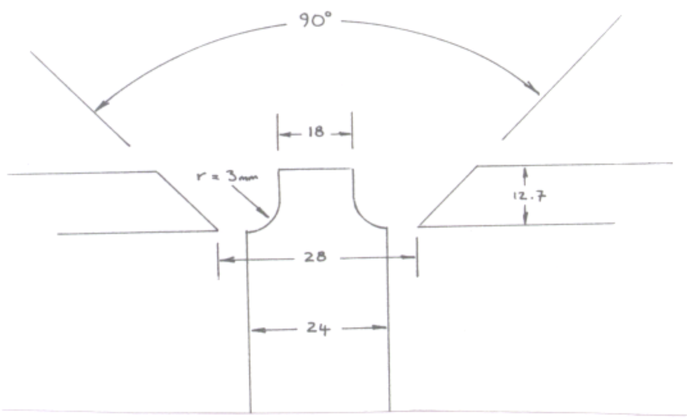
Application 3

Construction: Complex stainless fabrication 7.5m in length, 400mm dia., 12mm wall thickness.

Fabricator: Heatfab Services, UK

Users: British Nuclear Fuels plc

Joint welded: 360 off butt welds between the solid bars and the shell. Roots all completed with SUPEROOT.



Benefits: The entire vessel could have been purged but this would have precluded inspection of each weld as it was made. To design and fit an individual purge box would have been costly and very time consuming. A shouldered prep on the bar allowed satisfactory fusion to both bar and shell.

METRODE WELDING CONSUMABLES

Weld Procedure Record

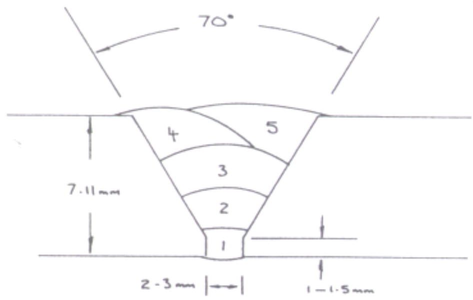
TIG (GTAW) PIPE WELD IN 316L STAINLESS STEEL

Ref SR316L/1

Material	ASTM A312 316L
Filler Metal	SUPEROOT 316L/316S92
Classification	AWS A5.22 R316LT1-5 AWS A5.9 ER316L
Process	TIG
Gas Shield	Ar (99.9%)
Current	DC-
Position	6G
Preheat/Interpass Temperature	None/150°C max.

Weld Details

6" ⌀



Run No	Φ mm	Current Amp	Arc Volts	Travel Speed mm/min	R.O.L mm	Heat Input kJ/mm
1	2.2	90-120	12-16	60	-	1.4
2*	2.4	110-140	12-18	90	-	1.2
3	2.4	110-140	12-18	65	-	1.7
4	2.4	110-140	12-18	105	-	1.0
5	2.4	110-140	12-18	85	-	1.3

Procedural Comments

No purge.

Gas flow rate 12-15 l/min.

2% thoriated tungsten, 2.4mm ⌀

* Run 2 - 1.6mm filler preferred 80-110A to minimise root side discolouration.

Analysis	C	Mn	Si	S	P	Cr	Ni	Mo	Nb	Cu	FN
SR316L	.019	1.45	.84	.006	.024	18.0	11.6	2.2	.02	.10	-
316S92	.014	1.78	.44	.003	.014	18.0	12.3	2.60	-	.09	5

Tensile Transverse UTS:
568N/mm²
572N/mm²
Failed in parent

Bends:
Root - satisfactory
Face - satisfactory

Ferrite:
cap 4-5FN
root 3-4FN

Corrosion:
ASTM A262 practice E - pass

Charpy Impact	10x5mm	-196°C	LE,mm
Weld		46 46 45	0.99 1.05 1.10
FL		61 79 74	1.60 1.86 1.83
FL + 2		74 75 87	1.68 1.69 2.02
FL + 5		75 81 82	1.43 1.83 2.00

Hardness	PM	HAZ	Weld Metal	HAZ	PM
Cap HV10	164	160	164-171	162	168
Root HV10	171	175	167-179	170	174

Orig. GBH

Date 19.3.97

METRODE WELDING CONSUMABLES

SUPEROOT 316L

Flux cored TIG wire for root welds without back purge

Product description

Flux cored TIG wire **Superoot 316L** is made with a seamless austenitic stainless steel sheath, which results in a robust moisture resistant wire and rutile flux system. Superoot 316L is designed specifically for situations where it is impractical to apply back-purge for the TIG root run, or to gain the economic benefit of eliminating back-purge. For most applications, the use of a 316L root bead is considered compatible with subsequent filling with 308L, 347 or 316L as appropriate.

Metal recovery is 90% with respect to the whole wire.

Specifications

AWS A5.22 R316LT1-5

ASME IX Qualification

QW432 F-No 6, **QW442** A-No 8

Composition (weld metal wt %)

	C	Mn	Si	S	P	Cr	Ni	Mo	Cu
min	--	1.0	0.2	--	--	17.0	11.0	2.0	--
max	0.04	2.0	1.0	0.025	0.03	20.0	14.0	3.0	0.5
typ	0.01	1.6	0.8	0.005	0.020	19.2	12.5	2.2	0.05

Typically 5FN.

All-weld mechanical properties

As welded		typical
Tensile strength	MPa	605
0.2% Proof stress	MPa	450
Elongation on 4d	%	38

Note: In practice, mechanical properties of the root bead are assessed with the whole joint and subsequent filler.

Typical operating parameters

	TIG
Shielding	Argon*
Current	DC-
Diameter	2.2mm
Voltage	90A, 12V

* No back-purge is required.

Satisfactory application of **Superoot 316L** requires the use of a keyhole welding technique. Further details are available on request.

Packaging data

ø mm	TIG
2.2	1kg tube

Fume data

Fume composition (wt %)

Fe	Mn	Ni	Cr^3	Cu	F	OES (mg/m³)
30	12	11	15	< 0.5	--	3.3