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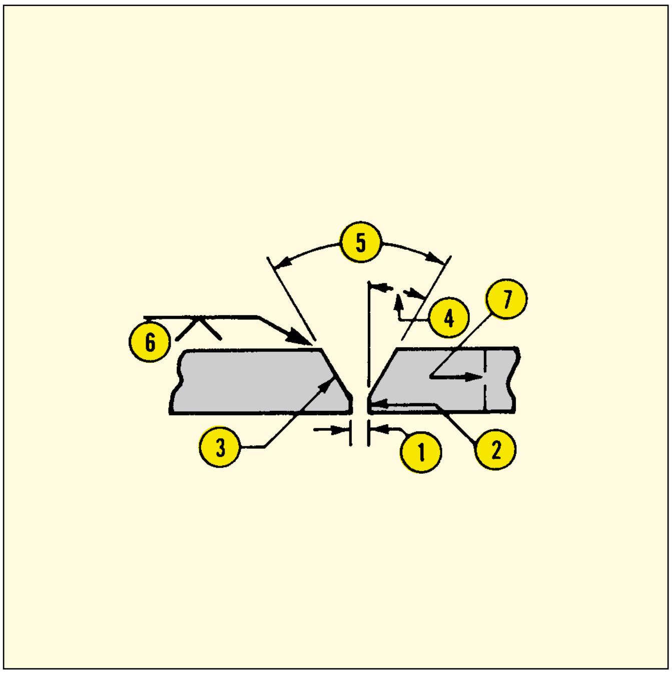
Presentation

Every day countless kilometres of steel pipelines are installed worldwide for the most varied civil and industrial uses.
They form real networks comparable to a system of road networks, which, although not so obvious, are definitely much more intricate and carry fluids that have become essential for us.
To comply with technical specifications and fulfil the necessary safety requisites, special materials and welding processes which have evolved with the sector have been developed in recent years.
The main welding process used to install the pipelines is **manual welding with coated electrode**, which, thanks to its ease and versatility, is still the one most used.
However, to limit costs and increase welding productivity, particularly on long routes, various constructors have adopted the semi-automatic or completely automatic **welding process with solid wire or wire flux coated with gaseous protection**.
This handbook describes both methods. Ample space has been dedicated, in particular, to manual welding, with particular reference to the operative practice and quality assessment, due to its considerable use still today, but not neglecting more modern and productive methods which will be increasingly used in future.
The presumption of this work is to be able to satisfy the most demanding technician and welder, but, in particular, to supply each user with useful information and a solid operative basis, as regards the processes and filler materials and the welding equipment.

INTRODUCTION

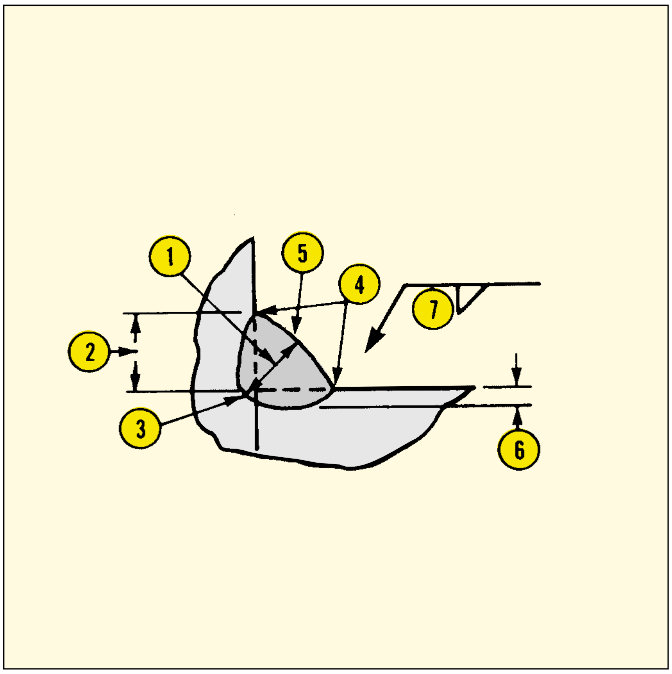
Joint details

Butt Joint



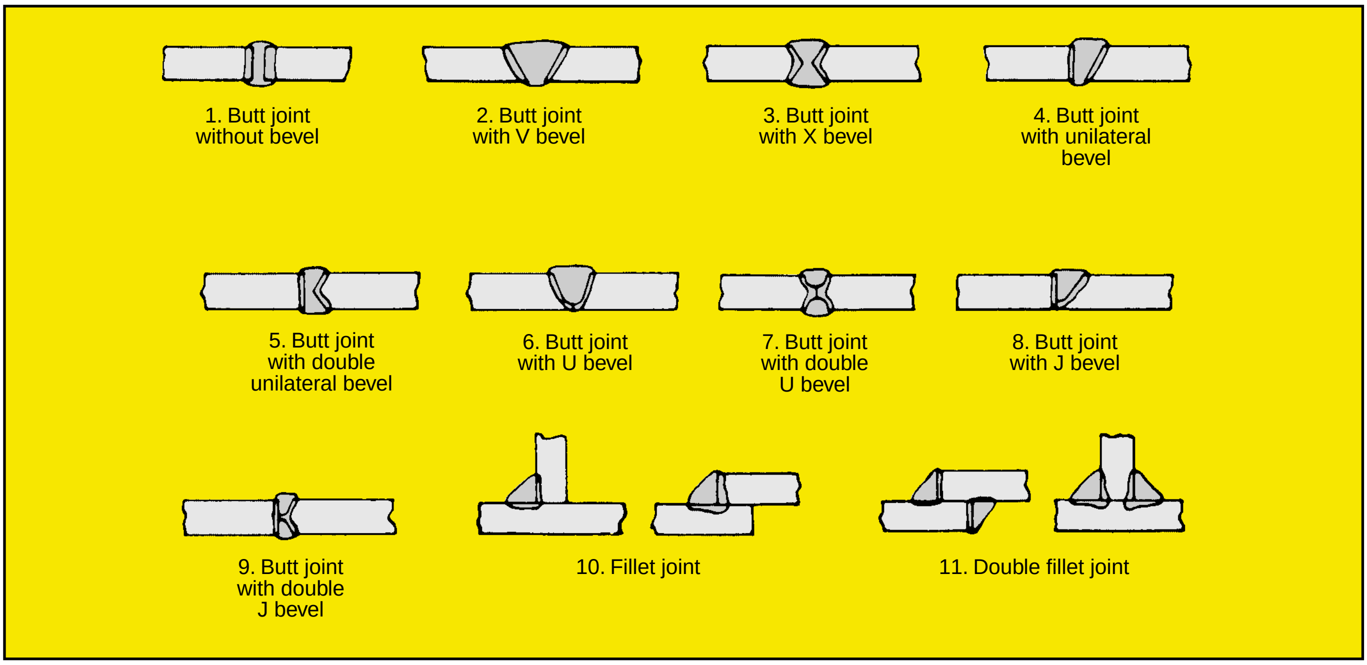
1. Root gap: separation between the edges to be welded at the root of the joint
2. Root face: surface of the joint preparation perpendicular to the surface of the plate
3. Bevel surface: oblique surface of the joint preparation
4. Bevel angle: angle between the bevelled surface and a plane perpendicular to the plate
5. Included angle: total angle between the two bevel surfaces
6. Seam width: effective width of the joint (distance between the bevels plus depth of penetration). The width of the calking iron seam and groove iron are the same thing
7. Thickness of the plate

Fillet Joint



1. Throat thickness: distance between seam root and surface measured on the bisector of the angle
2. Leg lenght: distance between seam root and edge
3. Joint root: point in which the bottom of the seam intersects the surface of the base metal
4. Joint edge: junction point between seam surface and base metal surface
5. Joint surface: external surface of the seam
6. Fusion depth: depth reached by the fusion bath from the surface of the base metal
7. Seam width: distance between the joint edges

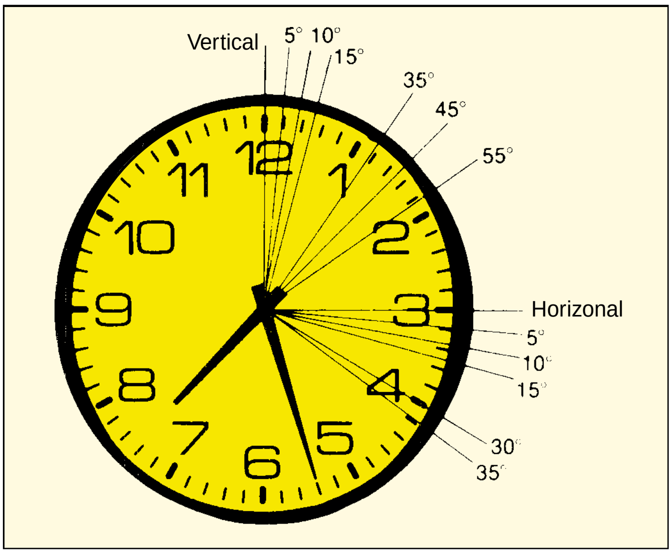
Joint types

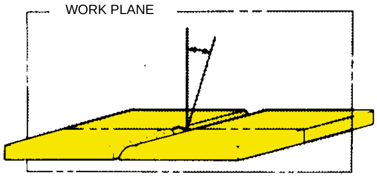


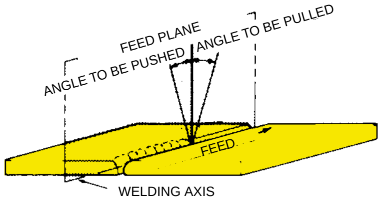
Many other variations are possible.

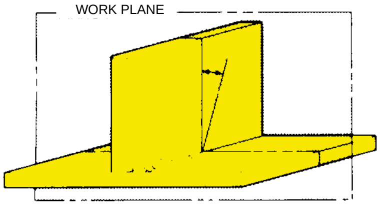
Electrode positioning angles

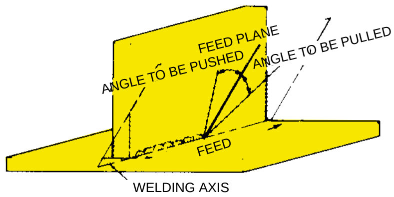
In this handbook the official AWS method is used to define the positioning angles of the electrodes (EN added).
Two angles are indicated: the feed angle and the work angle.
The feed angle is called “TO BE PUSHED” when the electrode points in the feed direction.
The feed angle is called “TO BE PULLED” when the electrode points in opposite direction to the feed.
The work angle is given in relation to a reference plane or work plane.
The figures illustrate the definition method of the angles.
Taking the clock face as reference, 1 minute corresponds to 6°.

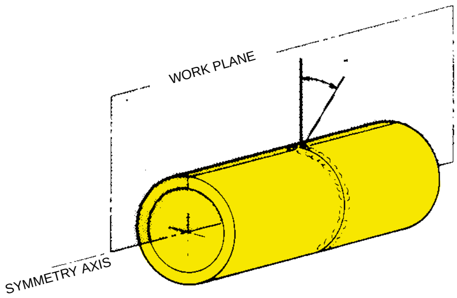


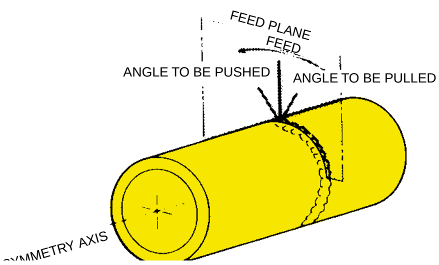












Pipe classification

Non-welded and welded pipes sized in accordance with ANSI B 36.10 and API standards

Rated size (“)	Outside diameter (mm)	RATED WALL THICKNESS (mm)													
		Sched. 5	Sched. 10	Sched. 20	Sched. 30	Standard	Sched. 40	Sched. 60	Extra strong:	Sched. 80	Sched. 100	Sched. 120	Sched. 140	Sched. 160	XX strong
1/8	10,3	—	1,2	—	—	1,7	1,7	—	2,4	2,4	—	—	—	—	—
1/4	13,7	—	1,6	—	—	2,2	2,2	—	3,0	3,0	—	—	—	—	—
3/8	17,1	—	1,6	—	—	2,3	2,3	—	3,2	3,2	—	—	—	—	—
1/2	21,3	—	2,1	—	—	2,8	2,8	—	3,7	3,7	—	—	—	4,75	7,5
3/4	26,7	1,6	2,1	—	—	2,9	2,9	—	3,9	3,9	—	—	—	5,5	7,8
1	33,4	1,6	2,8	—	—	3,4	3,4	—	4,5	4,5	—	—	—	6,4	9,1
1 1/4	42,1	1,6	2,8	—	—	3,6	3,6	—	4,8	4,8	—	—	—	6,4	9,7
1 1/2	48,3	1,6	2,8	—	—	3,7	3,7	—	5,1	5,1	—	—	—	7,1	10,2
2	60,3	1,6	2,8	—	—	3,9	3,9	—	5,5	5,5	—	—	—	8,7	11,0
2 1/2	73,0	2,1	3,0	—	—	5,2	5,2	—	7,0	7,0	—	—	—	9,5	14,0
3	88,9	2,1	3,0	—	—	5,5	5,5	—	7,6	7,6	—	—	—	11,1	15,2
3 1/2	101,6	2,1	3,0	—	—	5,7	5,7	—	8,0	8,0	—	—	—	—	—
4	114,3	2,1	3,0	—	—	6,0	6,0	—	8,6	8,6	—	11,1	—	13,5	17,1
5	141,3	2,8	3,4	—	—	6,6	6,6	—	9,5	9,5	—	12,7	—	15,9	19,0
6	168,3	2,8	3,4	—	—	7,1	7,1	—	11,0	11,0	—	14,3	—	18,2	22,0
8	219,1	2,8	3,8	6,4	7,0	8,2	8,2	10,3	12,7	12,7	15,0	18,2	20,6	23,0	22,2
10	273	3,4	4,2	6,4	7,8	9,3	9,3	12,7	12,7	15,0	18,2	21,4	25,4	28,6	—
12	323,8	4,0	4,6	6,4	8,4	9,5	10,3	14,3	12,7	17,4	21,4	25,4	28,6	33,3	—
14 Est.	355,6	—	6,4	7,9	9,5	9,5	11,1	15,0	12,7	19,0	23,8	27,8	31,8	35,7	—
16 Est.	406,4	—	6,4	7,9	9,5	9,5	12,7	16,7	12,7	21,4	26,2	31,0	36,5	40,5	—
18 Est.	457,2	—	6,4	7,9	11,1	9,5	14,3	19,0	12,7	23,8	29,4	35,0	39,7	45,2	—
20 Est.	508	—	6,4	9,5	12,7	9,5	15,0	20,6	12,7	26,2	32,5	38,0	44,5	50,0	—
22 Est.	558,8	—	6,4	—	—	9,5	—	—	12,7	—	—	—	—	—	—
24 Est.	609,6	—	6,4	9,5	14,3	9,5	17,4	24,6	12,7	31,0	38,9	46,0	52,4	59,5	—
26 Est.	660,4	—	—	—	—	9,5	—	—	12,7	—	—	—	—	—	—
30 Est.	762	—	7,9	12,7	15,9	9,5	—	—	12,7	—	—	—	—	—	—
34 Est.	863,6	—	—	—	—	9,5	—	—	12,7	—	—	—	—	—	—
36 Est.	914,4	—	—	—	—	9,5	—	—	12,7	—	—	—	—	—	—
42 Est.	1067	—	—	—	—	9,5	—	—	12,7	—	—	—	—	—	—

Prescriptions concerning the results of the traction and bending test for thicknesses ≤ 25mm[1], and for the hydrostatic test

Designation of the steels		Pipe body (unwelded and welded pipes)				Welding seam		Pipe
						HFW, SAW, COW	SAW, COW	
Alphanumeric	Numeric	Unitary yielding point $R_{10,5}$ MPa	Tensile strength R_m MPa min.	$R_{10,5}/R_m$ [2] max.	Elongation[3] ($L_0 = 5,65\sqrt{S_0}$) A % min.	Tensile strength R_m MPa min.	Diameter of the spindle for bending test[4] (see 8.2.3.5)	Hydrostatic test (see 8.2.3.8)
L245NB L245MB	1.0457 1.0418	from 245 to 440	415	0,80 0,85	22	The same values as the pipe body are applied.	3 *T*	Each pipe must take the test without showing losses or visible deformations
L290NB L290MB	1.0484 1.0429	from 290 to 440	415	0,80 0,85	21		3 *T*	
L360NB L360QB L360MB	1.0582 1.8948 1.0578	from 360 to 510	415	0,85 0,88 0,85	20		4 *T*	
L415NB L415QB L415MB	1.8972 1.8947 1.8973	from 415 to 565	420	0,85 0,88 0,85	18		5 *T*	
L450QB L450MB	1.8952 1.8975	from 450 to 570	535	0,90 0,87	18		6 *T*	
L485QB L485MB	1.8955 1.8977	from 485 to 605	570	0,90 0,90	18		6 *T*	
L555QB L555MB	1.8957 1.8978	from 555 to 675	625	0,90 0,90	18		6 *T*	

[1] The mechanical features of pipes with greater thickness values of up to 40mm must be agreed.
[2] The values of the ratio between the unitary yield point and the tensile strength are applied for the “pipe” product. They cannot be requested for the starting material.
[3] These values are applied for transversal samples withdrawn from the body of the pipe. If longitudinal samples are tested, the elongation values must be increased by 2 units.
[4] *T* = prescribed pipe thickness.

Outside diameters and preferential thicknesses (indicated in the framed zone of the table, including the frame itself)

Outside diameter	Thickness mm																										
mm	2,3	2,6	2,9	3,2	3,6	4	4,35	5	5,6	6,3	7,1	8	8,8	10	11	12,5	14,2	16	17,5	20	22,2	25	28	30	32	36	40
33,7																											
42,4																											
48,3																											
60,3																											
88,9																											
114,3																											
168,3																											
219,1																											
273																											
323,9																											
355,6																											
406,4																											
457																											
508																											
559																											
610																											
660																											
711																											
762																											
813																											
864																											
914																											
1 016																											
1 067																											
1 118																											
1 168																											
1 219																											
1 321																											
1 422																											
1 524																											
1 626																											

Mechanical features / Chemical compositions (A.P.I. steels)

A.P.I. specification	Quality	Mechanical propr. N/mm²		Chemical composition %		Carbonium (max) equivalent
		Yielding point	Tensile strength	Carbon (max)	Manganese (max)	
5 L	A 25	170	310			0,31
5 L - 5 LS	A	210	330	0,21	0,90	0,37
5 L - 5 LS	B	240	410	0,27	1,15	0,46
5 LX	X 42	290	410	0,28	1,25	0,50
5 LX	X 46	320	430	0,28	1,25	0,53
5 LX	X 52	360	500	0,28	1,25	0,53
5 LX	X 56	390	520	0,26	1,35 e/o (Nb/V/Ti)	0,48
5 LX	X 60	410	540	0,26	1,35 e/o (Nb/V/Ti)	0,48
5 LX	X 65	450	550	0,26	1,40 e/o (Nb/V/Ti)	0,49
5 LX	X 70	480	560	0,23	1,60	0,49

Consumption of electrodes

Pipeweld electrodes consumption (kg) in downhill vertical

Pipe diameter		Wall thickness 6,3 mm (1/4") – Electrode bead and Ø				9,5 mm (1,6") – Electrode bead and Ø				12,5 mm (1/2") – Electrode bead and Ø				16 mm (3/8") – Electrode bead and Ø				19 mm (3/4") – Electrode bead and Ø			
Inches	mm	First 4 mm	Second 4 mm	Filling 5 mm	Kg/ Joint	First 4 mm	Second 4 mm	Filling 5 mm	Kg/ Joint	First 4 mm	Second 4 mm	Filling 5 mm	Kg/ Joint	First 4 mm	Second 4 mm	Filling 5 mm	Kg/ Joint	First 4 mm	Second 4 mm	Filling 5 mm	Kg/ Joint
6	152	0,11	0,13	—	0,24	0,11	0,08	0,29	0,48	—	—	—	—	—	—	—	—	—	—	—	—
8	203	0,15	0,14	—	0,29	0,15	0,11	0,37	0,63	—	—	—	—	—	—	—	—	—	—	—	—
10	254	0,20	0,14	0,06	0,39	0,19	0,14	0,47	0,80	—	—	—	—	—	—	—	—	—	—	—	—
12	305	0,24	0,17	0,08	0,49	0,23	0,16	0,58	0,97	0,23	0,16	1,31	1,70	—	—	—	—	—	—	—	—
14	356	0,28	0,19	0,11	0,58	0,27	0,19	0,68	1,14	0,27	0,19	1,54	2,00	0,26	0,18	2,62	3,06	—	—	—	—
16	406	0,32	0,22	0,12	0,66	0,31	0,22	0,77	1,30	0,31	0,22	1,75	2,28	0,31	0,21	2,99	3,51	—	—	—	—
18	457	0,36	0,25	0,13	0,74	0,36	0,25	0,85	1,46	0,35	0,25	1,97	2,57	0,35	0,24	3,37	3,96	0,35	0,24	5,02	5,61
20	508	0,41	0,28	0,14	0,83	0,40	0,28	0,95	1,63	0,40	0,27	2,19	2,86	0,39	0,27	3,74	4,40	0,39	0,27	5,58	6,24
24	610	0,49	0,34	0,16	0,99	0,48	0,34	1,14	1,96	0,48	0,33	2,62	3,43	0,47	0,33	4,51	5,31	0,47	0,33	6,68	7,48
28	711	0,57	0,40	0,18	1,15	0,57	0,39	1,32	2,28	0,56	0,39	3,06	4,01	0,56	0,38	5,19	6,13	0,56	0,38	7,79	8,73
30	762	0,61	0,43	0,20	1,24	0,61	0,42	1,41	2,44	0,60	0,42	3,29	4,31	0,60	0,41	5,64	6,65	0,60	0,41	8,34	9,35
32	813	—	—	—	—	0,65	0,45	1,51	2,61	0,64	0,45	3,51	4,60	0,64	0,44	6,01	7,09	0,64	0,44	8,90	9,98
36	914	—	—	—	—	0,73	0,51	1,70	2,94	0,73	0,51	3,93	5,17	0,72	0,50	6,78	8,00	0,72	0,50	10,01	11,23
40	1016	—	—	—	—	0,81	0,57	1,89	3,27	0,81	0,56	4,38	5,75	0,80	0,56	7,53	8,89	0,80	0,56	11,11	12,47
42	1067	—	—	—	—	0,86	0,60	1,97	3,35	0,85	0,59	4,60	6,04	0,85	0,59	7,90	9,34	0,85	0,59	11,65	13,09
48	1219	—	—	—	—	0,98	0,68	2,26	3,92	0,97	0,67	5,25	6,89	0,97	0,67	9,02	10,66	0,97	0,67	13,32	14,96
60	1524	—	—	—	—	1,23	0,86	2,83	4,92	1,21	0,84	6,56	8,61	1,21	0,84	11,28	13,33	1,21	0,84	16,66	18,71
Typical number of beads		3				5				7				10				16			

Pipeweld electrodes consumption (kg) in uphill vertical

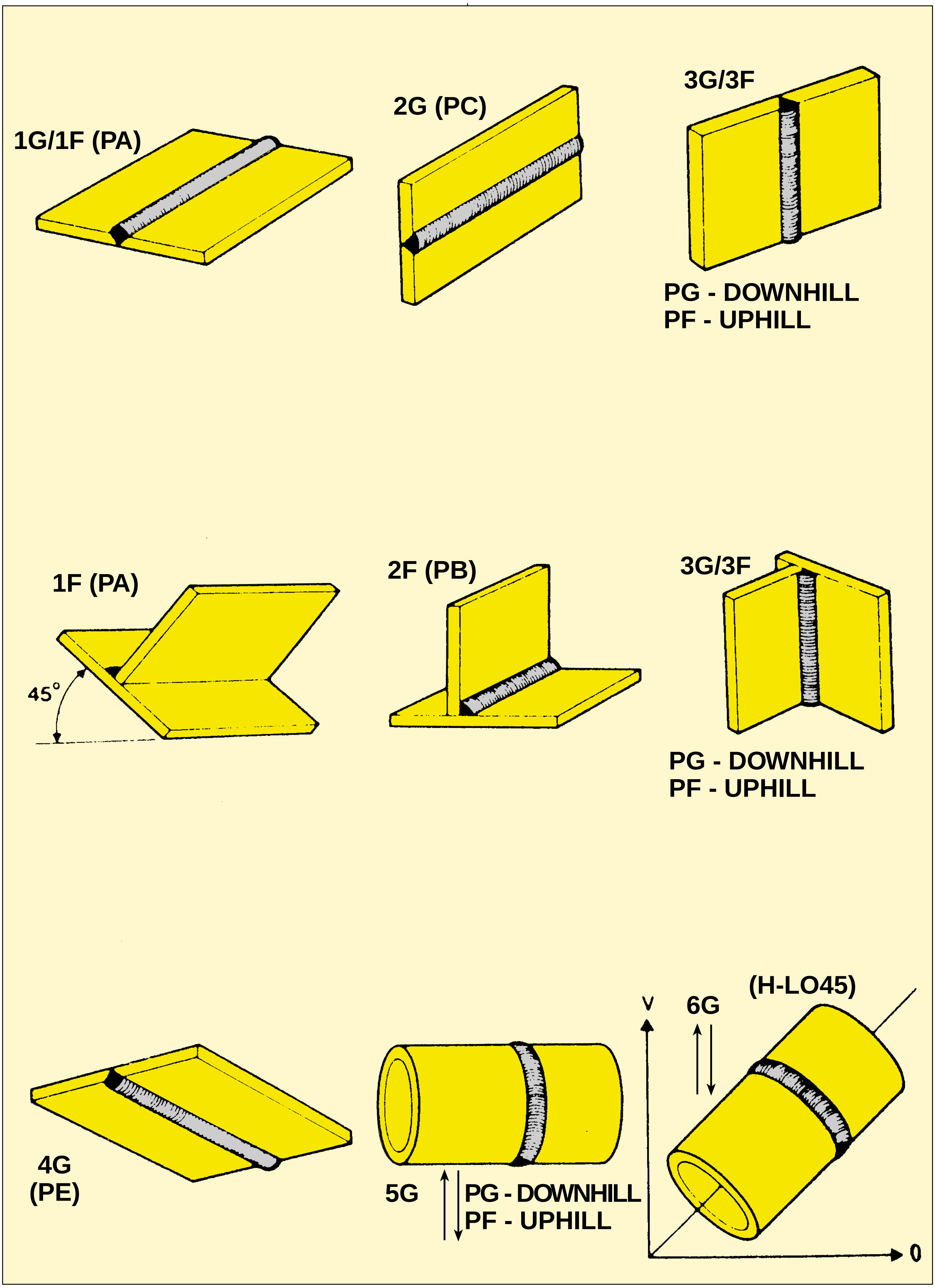
Pipe diameter		Wall thickness														
		9,5 mm (3/8'')			12,5 mm (1/2'')			16 mm (3/8'')			19 mm (3/4'')			25,4 mm (1'')		
		Electrode ∅			Electrode ∅			Electrode ∅			Electrode ∅			Electrode ∅		
Inches	mm	First 3,25 mm	Filling 4 mm	Kg/ Joint	First 3,5 mm	Filling 4 mm	Kg/ Joint	First 3,25 mm	Filling 4 mm	Kg/ Joint	First 3,5 mm	Filling 4 mm	Kg/ Joint	First 3,25 mm	Filling 5 mm	Kg/ Joint
6	152	0,23	0,61	0,84	0,23	1,05	1,28	—	—	—	—	—	—	—	—	—
8	203	0,32	0,81	1,13	0,32	1,41	1,73	0,32	2,13	2,45	—	—	—	—	—	—
12	305	0,45	1,22	1,67	0,45	2,13	2,58	0,45	3,22	3,67	0,45	4,50	4,95	0,45	7,57	8,02
16	406	0,63	1,63	2,26	0,63	2,77	3,40	0,63	4,44	5,07	0,63	5,94	6,57	0,63	10,02	10,65
20	508	0,77	2,04	2,81	0,77	3,49	4,26	0,77	5,31	6,08	0,77	7,44	8,21	0,77	12,52	13,29
24	610	0,90	2,45	3,35	0,90	4,22	5,12	0,90	6,44	7,34	0,90	8,98	9,88	0,90	15,15	16,05
28	711	1,09	2,81	3,90	1,09	4,90	5,99	1,09	7,48	8,57	1,09	10,43	11,52	1,09	17,60	18,69
32	813	1,22	3,27	4,49	1,22	5,62	6,84	1,22	8,62	9,84	1,22	12,02	13,24	1,22	20,18	21,40
36	914	1,41	3,63	5,04	1,41	6,30	7,71	1,41	9,80	11,21	1,41	13,43	14,84	1,41	22,63	24,04
40	1016	1,54	4,04	5,58	1,54	6,98	8,52	1,54	10,66	12,20	1,54	14,88	16,42	1,54	25,08	26,62
48	1219	1,86	4,90	6,76	1,86	8,39	10,25	1,86	12,84	14,70	1,86	17,92	19,78	1,86	30,21	32,07
60	1524	—	—	—	2,31	10,52	12,83	2,31	20,59	22,90	2,31	22,41	24,72	2,31	37,74	40,05

Note: for pipes of less than 152mm (6") diameter, with wall thickness up to 6.4mm, Pipeweld 6010, diameter 2.5mm, may be used for the first bead.

Approximate weight of Pipeweld electrodes

Ø 3.25 approx. 28 grams
Ø 4 approx. 40 grams
Ø 5 approx. 62 grams

ASME/EN positions



THE MANUAL METAL ARC PROCESS

General information

The main welding process used to weld pipelines is the MMA method, manual welding with coated electrodes. There are many reasons for this choice. The first is the most obvious: the manual electrode is the first product invented that is suitable for arc welding.
However, still today, when more sophisticated materials and more productive and less expensive techniques are at the users' disposal, MMA welding remains a favoured process to weld pipes. Its easy use, capacity to reach positions of difficult accessibility, the simplicity of the necessary generators (or the fact of being able to use motor generators; network power is not always available on installation sites), the fact that protective gases (difficult to find in certain countries, in particular third world countries), necessary in welding with solid or cored wires, are not required, all these and others are the reasons for this choice.
Some classes of cellulosic and basic electrodes have been specially designed to meet the requirements of the grade of steel used to manufacture the pipeline and the safety specifications laid down by standards, but also to equip the user i.e. welders with versatile products created for this specific purpose.

OK PIPEWELD CELLULOSIC ELECTRODES

OK Pipeweld electrodes have always been a safe and productive solution in the welding of pipelines.

Features

- High Cellulose content in the electrode provides an intense arc good penetration in all positions.
- High Cellulose content gives small slag covering of the weld bead, although it is easily re-melted it is advisable to remove before welding the next bead.
- The thin coating combined with the penetrating arc enables a smaller root gap to be utilised and the complete joint requires less weld metal to be deposited.
- The rapid solidification of the weld metal allows truly all positional welding

Recommended current ranges for the different welding positions.

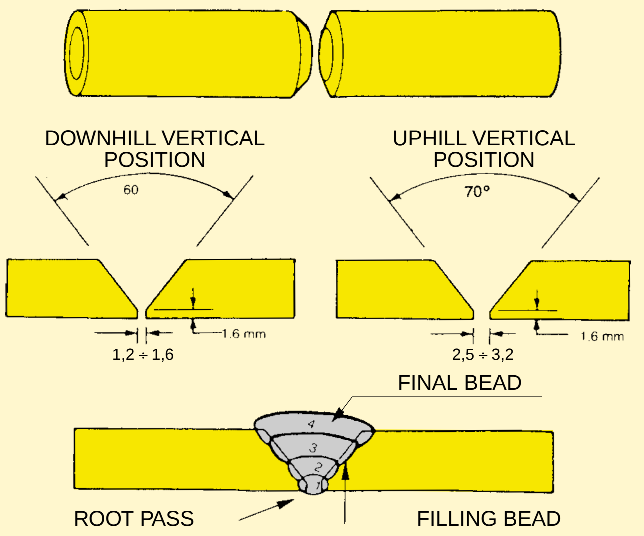
∅ mm	Flat position (A)	Uphill position (A)	Downhill position (A)
2,5	40 ÷ 70	40 ÷ 60	50 ÷ 90
3,25	70 ÷ 110	60 ÷ 90	70 ÷ 120
4	90 ÷ 130	70 ÷ 110	90 ÷ 160
5	110 ÷ 160	90 ÷ 130	110 ÷ 190

Welding equipment
The welding generators that can be used with OK Pipeweld need to have a relatively high open circuit voltage (OCV > 65V) and good dynamic characteristics. This prevents the arc snapping out during the welding operation.

Care and storage of cellulosic electrodes
Cellulosic electrodes need a definite amount of moisture, normally between 3% and 9%, to give satisfactory operation. Over drying this type of electrode will lead to charring of the organic material within the coating. This can give un-satisfactory welding performance, loss of arc voltage and weld metal porosity. These types of electrodes should NOT be re-dried.

Tin-Pac for transport and stockage in heavy environments

The ESAB range of consumables for pipeline welding has been developed to match the steel qualities and the demands from the pipeline industry for reliable, easy to use highly productive consumables. Our resources in research and development around the world have made it possible not only to meet the demands of today but also to foresee the needs for tomorrow. Cellulosic electrodes from ESAB are used for root pass, filling and capping on a wide range of steels used in the pipeline industry and pipework production.



ESAB Electrode Choice for each Bead Position

Pipe steel and grade	Root or stringer	Hot pass	Hot fill	Filler passes	Capping
5L, A25	•	•	•	•	•
5L, 5LS, A	•	•	•	•	•
5L, 5LS, B	•	•	•	•	•
5LS, 5LX42	•	•	•	•	•
5LS, 5LX46	•	•	•	•	•
5LS, 5LX52	• ◊	• ◊	◊	◊	◊
5LX56	• ◊	• ◊	◊	◊	◊
5LX60	• ❋	• ❋	❋	❋	❋
5LX65	• ❋	• ❋	❋	❋	❋
5LX70	• ❋	• ❋	❋	❋	❋

• = Pipeweld 6010 Plus
◊ = Pipeweld 7010
❋ = Pipeweld 8010

BASIC ELECTRODES

When the pipeline steel has a strength higher than X70 the need of preheat and post weld heat treatment becomes more stringent and the choice of using basic electrodes offers advantages. The reason is, of course the high amount of hydrogen in the weld metal from cellulosic electrodes. The hydrogen is a greater risk for cracks in high strength material, because of the increased sensitivity to hardening in these steels.
The properties of the basic electrodes also mean much better impact properties at low temperatures.
The disadvantage with basic electrodes welded vertically up is the low current that has to be used resulting in low productivity.
This can be avoided by using basic electrodes developed specially for welding of pipelines in the vertical-down position. These electrodes contain iron powder in the coating and therefore have higher productivity than cellulose electrodes since they also can be welded at higher currents than cellulose electrodes.
Productivity is 25-30% higher than for cellulose electrodes and 40-50% higher than for basic electrodes in vertically up welding.
In the root, the penetration and force from a cellulose electrode is however the most productive process since they can manage a small root-opening with high current resulting in fast progression. A basic electrode can be used also for the root but requirements on alignment will be higher because of the less forceful arc.
The best procedure for welding high strength pipelines is therefore to use cellulose electrodes for the root pass and basic vertical down electrodes for filling and capping passes.
The higher quality of the basic weld metal is advantageous when a pipeline is exposed to stress.
When, during its route, an underground pipe (medium and large diameters) crosses roads and railways, when greater static and dynamic stress exists for external reasons or when the pipes of medium and small diameter are submitted to high temperatures, strong pressure and vibration (heating plants, refineries etc.), it is normally preferred to carry out the first bead with Pipeweld and the filling with a basic electrode.

A.P.I. Specification	Quality	Suggested Electrode First root	Filling
5L	A 25	Pipeweld 6010	OK 48.00
5L – 5LS	A	Pipeweld 6010	OK 48.00
5L – 5LS	B	Pipeweld 6010	OK 48.00
5LX	X42	Pipeweld 6010	OK 48.00
5LX	X46	Pipeweld 6010	OK 48.00
5LX	X52	Pipeweld 6010	OK 48.00
5LX	X56	Pipeweld 6010	OK 48.00
5LX	X60	Pipeweld 6010	OK 48.00
5LX	X65	Pipeweld 6010	OK 74.70
5LX	X70	Pipeweld 6010	OK 74.70

With this, the complete penetration that only Pipeweld can guarantee and the maximum tenacity of the joint due to the electrode with basic coating are obtained.
Some mechanical characteristics, in particular the values of toughness and strength, were improved.
OK 48.00 is classified E 7018-1; this means that it supplies resiliency values of over 27j at –46°C, thanks to the purity of its components, in an even better developed formula.
It can be used to weld steels with high values of equivalent carbon and/or high elastic limit thanks to the laying which guarantees values of diffusible hydrogen of ≤ 5 ml/100 gr. and consequently makes the risk of cold cracks practically non-existent, also permitting a reduction of the pre-heating temperature required for the basic electrodes. In addition to these metallurgical and productive aspects that are important for the constructor, there is improved welding capacity. The excellent starting and restarting, the constant and regular fusion and the fine aspect of the weld seam in all positions are characteristics of fundamental importance for the welder and guarantee a high productivity.
The VacPac boxing (plastic inner box with Vac Packed aluminium foil hermetically sealed) ensures these characteristics, over a long time and allows the product to be used without redrying.

Basic electrodes for steels with medium and high yield strength

Electrode type	OK 48.00	OK 53.70	OK 74.70
Coating	Basic	Basic	Basic
Classifications	AWS A/SFA 5.1: E7018-1 EN 499: E42/46 4 B 42 H5 ISO 2560: E51 5 B 120 20 H	AWS A/SFA 5.1: E7016-1 EN 499: E42 5 B 12 H5 ISO 2560: E51 5 B 24 H	AWS A/SFA 5.5: E8018-G EN 499: E46 Mu Mo B 32
Recovery	115	115	115
Mechanical properties	R ≥ 510 MPa S ≥ 420 MPa A ≥ 26% KV ≥ 48J at – 40° C KV ≥ 27J at – 46° C	R ≥ 550 MPa S ≥ 430 MPa A ≥ 26% KV ≥ 150J at – 20° C KV ≥ 100J at – 46° C	R ≥ 510 MPa S ≥ 420 MPa A ≥ 26% KV ≥ 48J at – 40° C KV ≥ 27J at – 46° C
All weld metal analysis wt %	C ≤ 0,10 Mn ≤ 1,60 Si ≤ 0,60	C ≤ 0.04 ÷ 0.08 Mn ≤ 0.95 ÷ 1.35 Si ≤ 0.3 ÷ 0.6 Ni < 0.1	C ≤ 0.06 ÷ 0.1 Mn ≤ 1.3 ÷ 1.6 Si ≤ 0.25 ÷ 0.50 Mo 0.3 ÷ 0.5
Applications	Electrode suitable for welding in all positions of carbon steels with medium and high yeld strength. The low hydrogen content in the deposited metal minimises the risk of cracks. Excellent radiographic qualities. For naval constructions, structural fabrication, boilers, etc. Excellent welding aspect also in a vertical position.	A low hydrogen AC/DC electrode for one side welding of pipes and general structure. The root penetration is good, leaving a flat bead with easy removable slag. Suitable for welding of pipeline up to API 5L X56 it is aiso suitable for root pass welding up to API 5L X80	Electrode used for welding high tensile low alloyed steels API 5L X60, X65, X70
Welding Current	DC+	AC, DC+(–)	DC+
Welding parameters	Ø / Amp 2 / 50 ÷ 80 2.5 / 70 ÷ 100 3.2 / 90 ÷ 140 4 / 120 ÷ 180 5 / 180 ÷ 230	Ø / Amp 2.5 / 60 ÷ 90 3.2 / 80 ÷ 130 4 / 115 ÷ 190 5 / 180 ÷ 290	Ø / Amp 2.5 / 60 ÷ 90 3.2 / 90 ÷ 130 4 / 140 ÷ 180 5 / 190 ÷ 220

Basic electrodes for vertical-down welding

Electrode type	Filarc 27P	Filarc 37P	Filarc 108MP
Coating	Basic	Basic	Basic
Classifications	AWS A/SFA 5.5: E8018-G EN 499: E46 5 B 41 H5	AWS A/SFA 5.5: E9018-G EN 499: E55 5 1NiMo B 41 H5	AWS A/SFA 5.5: E10018-G EN 757: E55 4 Z B 41 H5
Recovery	120	120	120
Mechanical properties	TS > 550 MPa YS > 460 MPa A_5 ≥ 25%	TS > 620 MPa YS > 550 MPa A_5 ≥ 24%	TS > 690 MPa YS > 620 MPa A_5 ≥ 22%
All weld metal analysis wt %	C: 0,06-0,09 Si: 0,30-0,70 Mn: 1,0-1,4	C: 0,06-0,09 Si: 0,30-0,70 Mn: 1,0-1,4 Ni: 0,6-0,99 1,0 Mo: 0,3-0,6	C: 0,06-0,09 Si: 0,30-0,70 Mn: 1,6-2,0 Ni: 1,30-1,60
Applications	Filarc 27P is specially designed for downhill welding of circumferential welds joints in pipes. Suitable for pipe steels API 5LX52 – X70	Suitable for welding high strength pipe steels such as API 5LX75. Performance and productivity is similar to Filarc 27P.	Suitable for welding high strength pipe steels such as API 5LX80. Performance and productivity is similar to Filarc 27P.
Welding Current	DC+	DC+	DC+
Welding parameters	Ø / Amp 2.5 / 80 ÷ 100 3.2 / 110 ÷ 150 4 / 180 ÷ 220 4,5 / 230 ÷ 270	Ø / Amp 3.2 / 110 ÷ 150 4 / 180 ÷ 220 4,5 / 230 ÷ 270	Ø / Amp 3.2 / 110 ÷ 150 4 / 180 ÷ 220 4,5 / 230 ÷ 270

Cellulosic electrodes for pipes

Electrode type	Pipeweld 6010 PLUS	Pipeweld 7010
Coating	Cellulosic	Cellulosic
Classifications	AWS/SFA 5.1: E6010 EN 499: E 38/3 C 21	AWS A/SFA 5.5: E7010-G (P1) EN 499: E42/3 Z C 21 ISO 2560: E51 4 C 10
Recovery	90	90
Mechanical properties	R ≥ 420 MPa S ≥ 350 MPa A ≥ 22%	R ≥ 560 MPa S ≥ 480 MPa A ≥ 20% KV ≥ 27J at – 30° C
All weld metal analysis wt %	C ⩽ 0,13 Mn ⩽ 0,4 Si ⩽ 0,25	C ⩽ 0,12 Mn 0,30 ÷ 0,60 Si ⩽ 0,30 Ni 0,50 ÷ 0,80 Mo 0,10 ÷ 0,25
Applications	Electrode suitable for welding of root pass on every API 5L grade pipe, designed for vertical down DC – (main line welding)	Electrode suitable for welding in all positions of pipes in steel type API 5LX – X63 – X65 – X70. Easy to use, smooth running and penetrating. Particularly suitable for welding on site, in downhill and overhead. Excellent radiographic qualities.
Welding Current	DC+(-)	DC+
Welding parameters	Ø / Amp 2.5 / 60 ÷ 80 3.2 / 80 ÷ 140 4 / 100 ÷ 180 5 / 150 ÷ 250	Ø / Amp 3.2 / 60 ÷ 110 4 / 90 ÷ 140 5 / 110 ÷ 170

Pipeweld 8010	Pipeweld 9010
Cellulosic	Cellulosic
AWS A/SFA 5.5: E8010-G (P1) EN 499: E46/3 Z C 21	AWS A/SFA A5.5: E9010-G EN 499: E50 3 Z C 21
90	90
R ≥ 560 MPa S ≥ 480 MPa A ≥ 20% KV ≥ 27J at – 30° C C ⩽ 0,12 Mn 0,30 ÷ 0,60 Si ⩽ 0,30 Ni 0,50 ÷ 0,80 Mo 0,10 ÷ 0,25	R ≥ 630 MPa S ≥ 540 MPa A ≥ 18% KV ≥ 27J at – 30° C C ⩽ 0,12 Mn ⩽ 1,0 Si ⩽ 0,30 Ni 0,60 ÷ 0,80 Mo 0,20 ÷ 0,30
Electrode suitable for welding in all positions of pipes in steel type API 5LX – X63 – X65 – X70. Easy to use, smooth running and penetrating. Particularly suitable for welding on site, in downhill and overhead. Excellent radiographic qualities.	Electrode suitable for welding in all positions of pipes in steel type API 5LX – X65 – X70 – X75 – X80. Easy to use, smooth running and penetrating. Particularly suitable for welding on site, in descending vertical and overhead. Excellent radiographic qualities.
DC+(-)	DC+
Ø / Amp 3.2 / 60 ÷ 110 4 / 90 ÷ 140 5 / 110 ÷ 170	Ø / Amp 3.2 / 60 ÷ 110 4 / 90 ÷ 140 5 / 110 ÷ 170

WELDING TECHNIQUES AND OPERATIVE PRACTICES

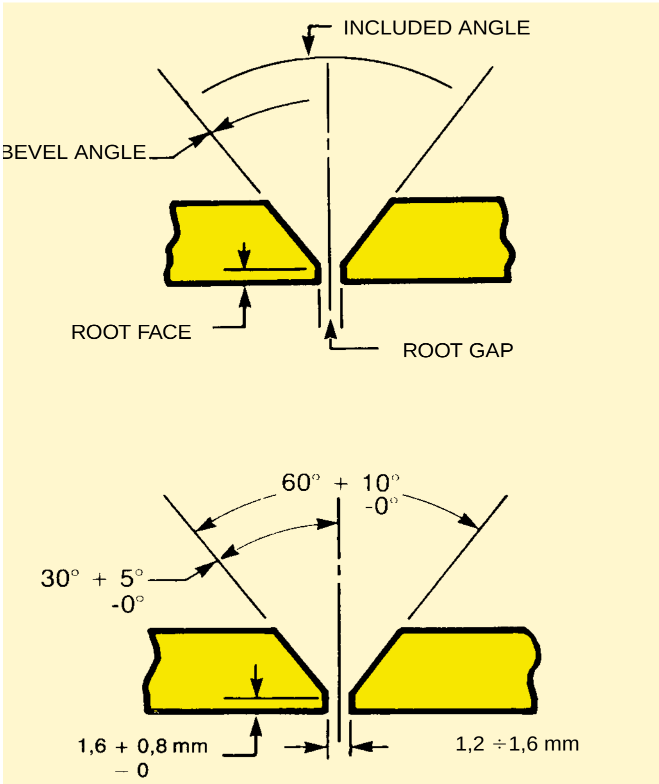
General information

Cellulosic electrodes, suitable for use in vertical up and vertical down directions, are normally chosen to weld steel pipes. The fastest and therefore most productive method is welding downhill with cellulosic electrodes. However, when it is necessary to guarantee particularly high integrity for pipes submitted to high static or dynamic stress (for example, underground pipes of medium or large diameter in the crossing of roads or railways, or small or medium pipes subject to vibrations, temperature, pressure), the technique of mixed welding, cellulosic plus basic in vertical up, is sometimes preferred. The following chapters illustrate the most frequent operating practices used in manual pipe welding and the different techniques adopted, starting from preparation and closing with a thorough examination of the potential defects, their causes and the necessary remedies.

Pipe welding in vertical down (downhill) with cellulosic electrodes

Preparation and tac‡king

The scope of this chapter is to suggest a preparation and tacking procedure for the construction of a standard joint on sections of mild steel pipe, for the purposes of developing welding procedures or welder training. Note that for welding procedure qualification, EN 288-9 requires that tests be made between full pipe lengths unless otherwise agreed between the contracting parties.



STANDARD JOINT

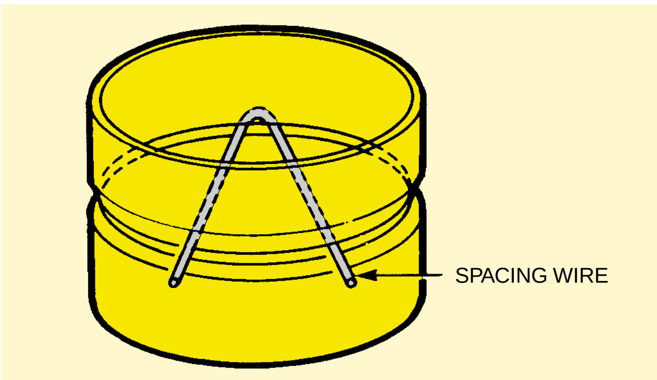
Eliminate burrs caused by the grinding operation.

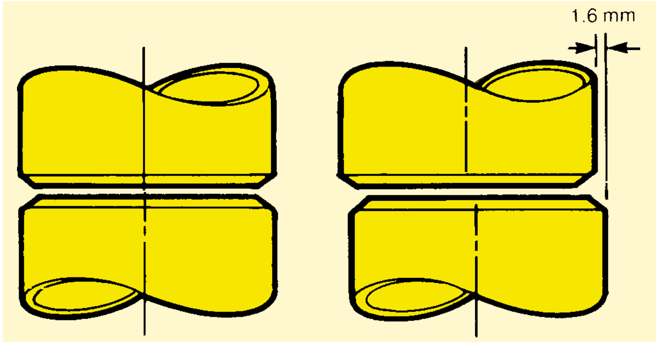
Welding parameters for tacking

Electrode E6010 Ø 2.5 mm, Current 70 ÷ 100A
or
Electrode E6010 Ø 3.2 mm, Current 100 ÷ 120A

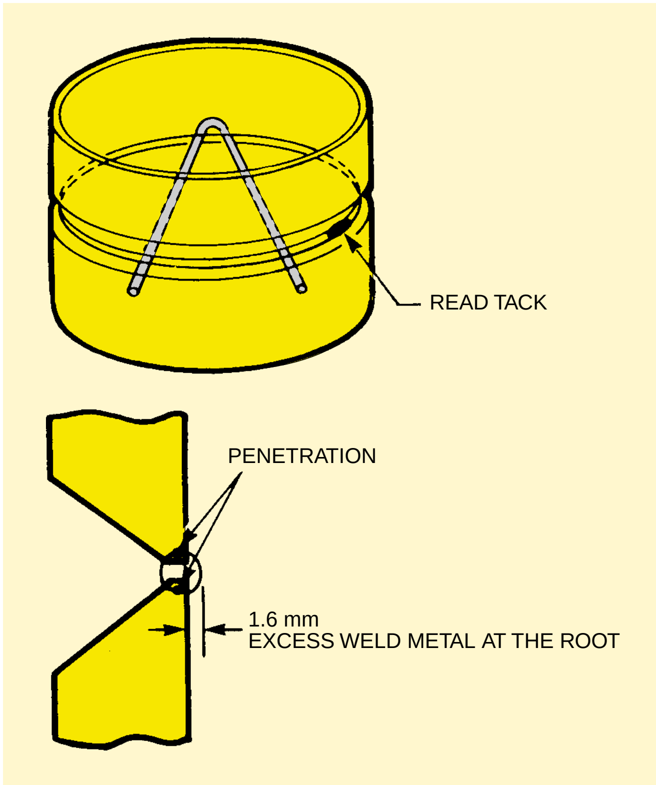
Operations

Rest one of the pipe sections on the worktop with the bevelled edge facing upwards.



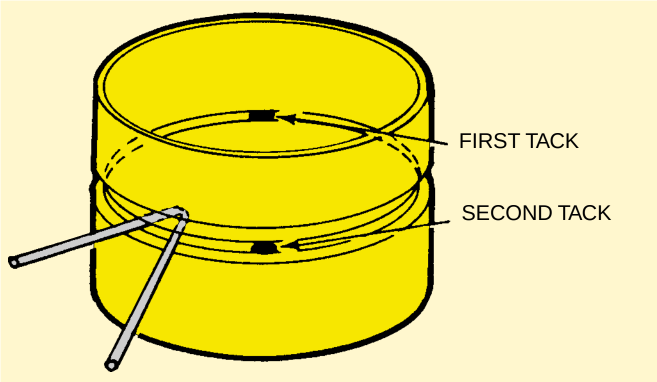


Place a spacing wire of 1.6 mm diameter on the bevelled edge then rest the second pipe section on the spacing wire with the bevelled edge facing downwards. Align the two sections to form the desired bevelling.
In accordance with the API code the misalignment must not exceed 1.6 mm.
At this point start the tacking operation, laying a 12 to 22mm long seam.

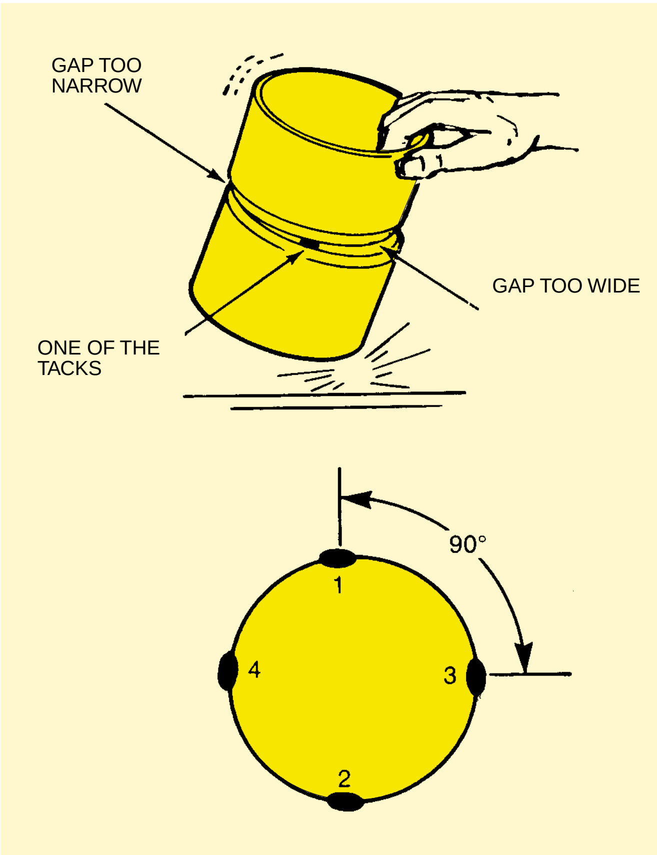


The tack bead should penetrate the root in order to form an internal projection of 1.6 mm and both edges of the bevel must be fused.

Then reposition the spacing wire and deposit a second tack.

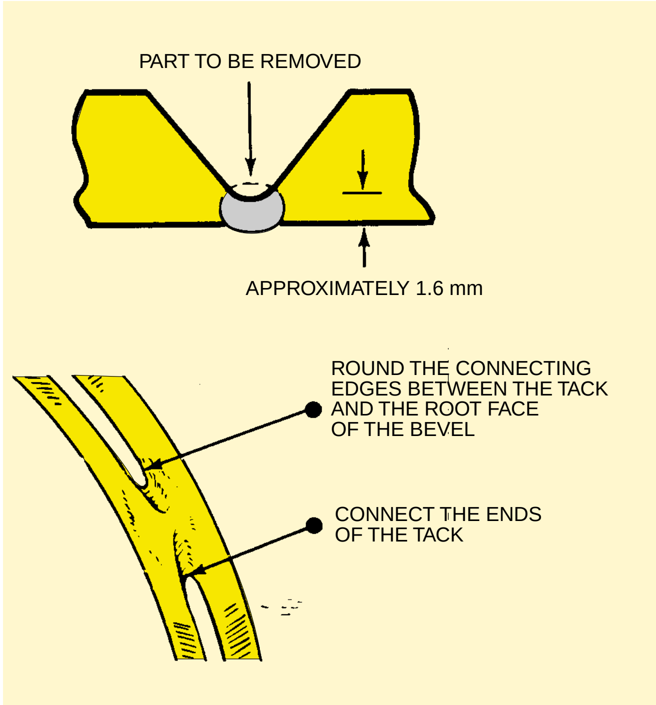


Remove the spacing wire. If in root gap is uneven, make a third tack where the gap is greatest, in such a way that weld shrinkage will close it up. If the distance between the edges on the most open side is too great to permit the third tack, first correct the distances compressing the most open side.



Place the third and fourth tacks at right angles to the first and second.

Grind the external surface of the tacks in such a way that their thickness is approximately 1.6 mm, to facilitate the start of the first bead.



To obtain a quality weld, correct joint preparation and accurate tacking are necessary. Faulty tacking will cause defects in the final welding.

2 - Joint in 5G / PG

This type of joint and position is commonly used to weld a line of steel tubes of medium-large diameters, of 8" and more.

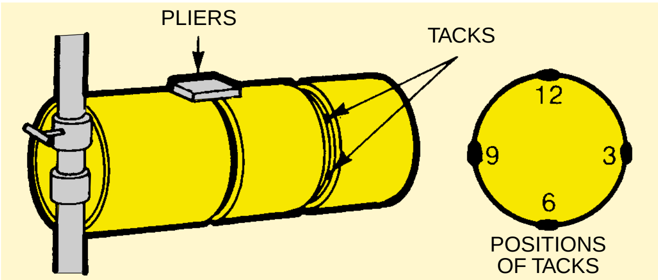
Welding parameters

Electrode E6010 Ø 4.0 mm, DC+, Current 120 ÷ 160A (root)
Electrode E7010-G-(P1)* Ø 4.0 mm, DC+, Current 150 ÷ 1 60A (hot pass)
Electrode E7010~G~(P1)* Ø 5.0 mm, DC+, Current 150 ÷ 160A (fill and cap)
* or alternatively, according to the type of base steel to be welded, substitute with electrode E8010-G-(P1) or E9010-G.

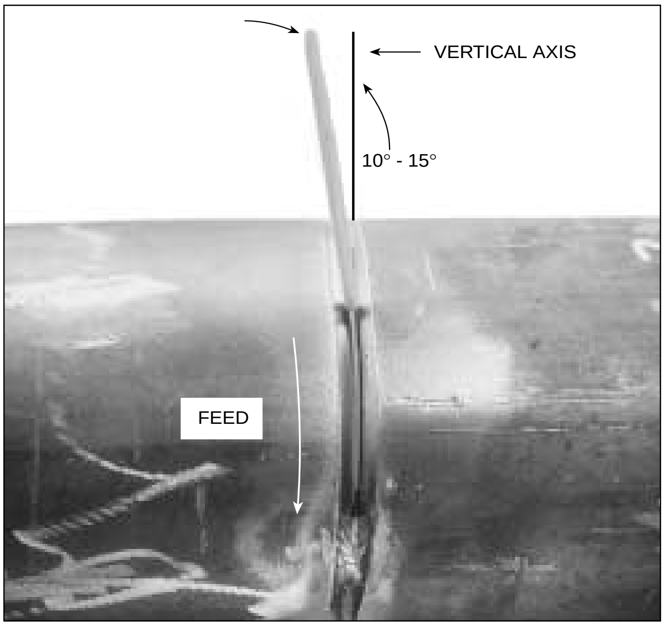
It is important that the generator has a minimum open circuit voltage of 70V.

Operations

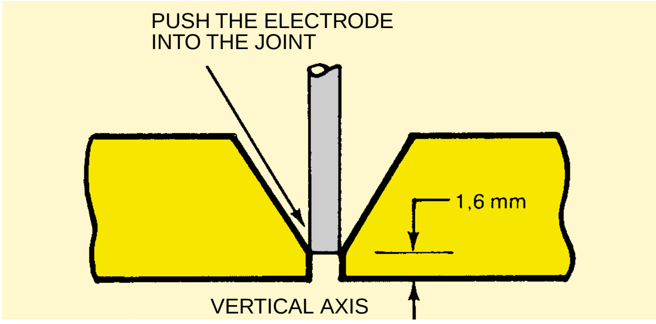
After having carried out the preparation and tacking as described in chapter 1, use pliers and clamps to fix the piece in a horizontal position with the tacks placed at 3, 6, 9 and 12 o'clock. It is recommended to place the tack with the smallest root gap at 12 o'clock.



Make the root (stringer) bead with a 4.0 mm diameter electrode. The current must be set at 120 ÷ 160A.

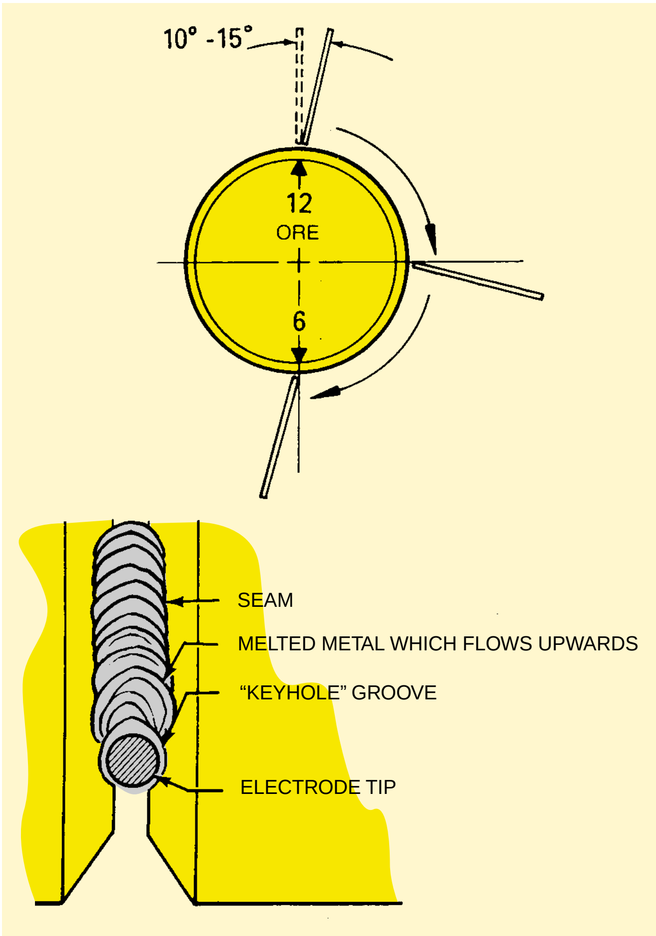


Start with the electrode at 12 o'clock, with a trailing electrode angle of 10 ÷ 15° and the electrode in the plane of the joint.

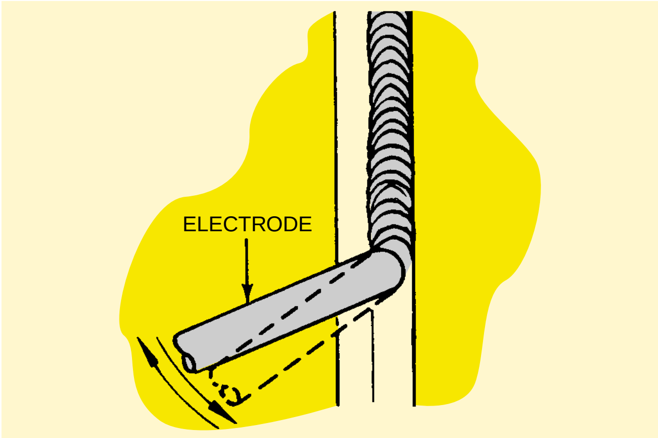


Start the arc at the root of the joint (never on the edge of the tack towards the external surtace of the pipe), push the electrode into the joint and advance in a regular manner.

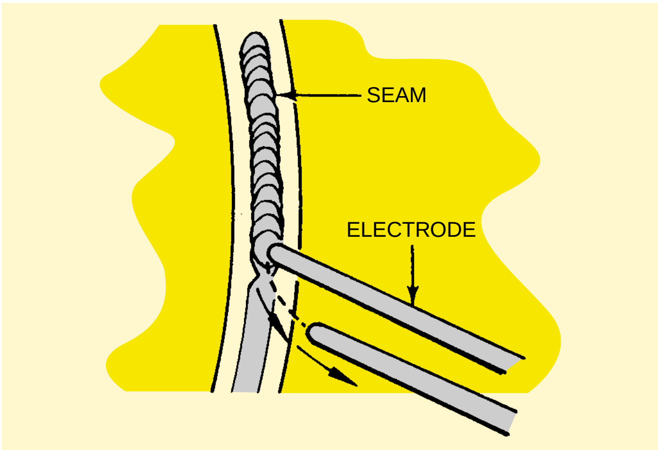
To better check the weld pool, it may be necessary to vary the trail angle from 10 ÷ 15° to 0 ÷ 30°. Use the dragging or "hidden arc" technique, always keeping the electrode at the bottom of the joint. A "keyhole" groove, which follows the top of the electrode in its movement, is thus formed.



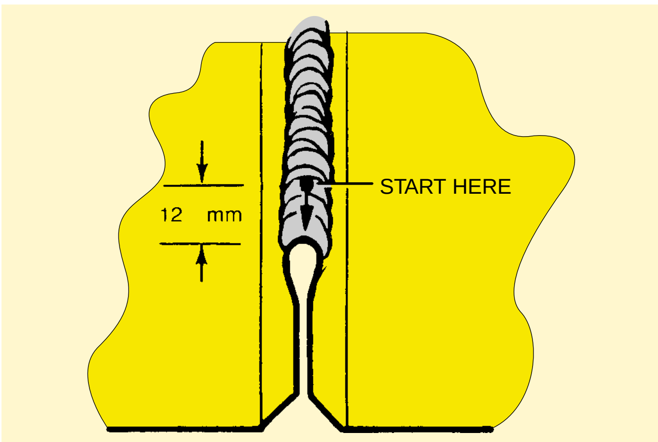
If blowholes form, slightly swing the electrode from one side to the other as shown in the figure.



If it is necessary to interrupt the arc before the run is ended, the tip of the electrode must be rapidly snapped down.

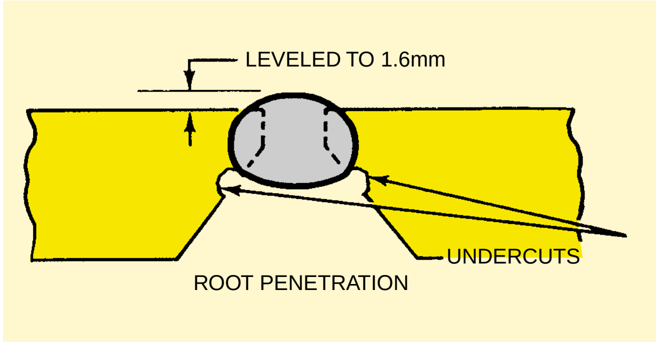


This prevents slag inclusion in the weld pool. Remove the slag from the crater and from the last 50 mm of the weld. The restart should be made starting on the weld metal approximately 12 mm before the crater and moving towards it with an arc length slightly above normal. Then push the electrode to the bottom of the joint to fill the crater and continue welding in the normal manner.



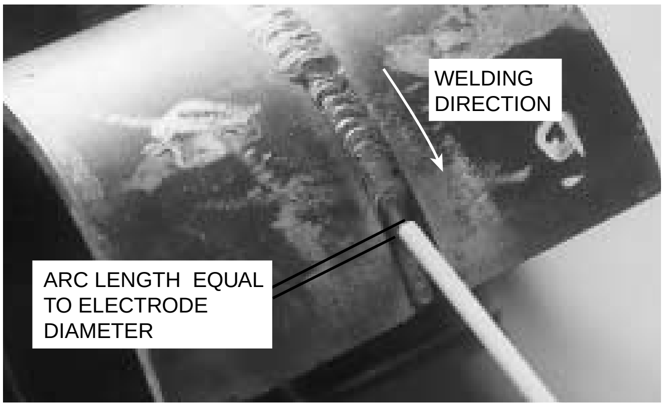
RESTARTING PROCEDURE

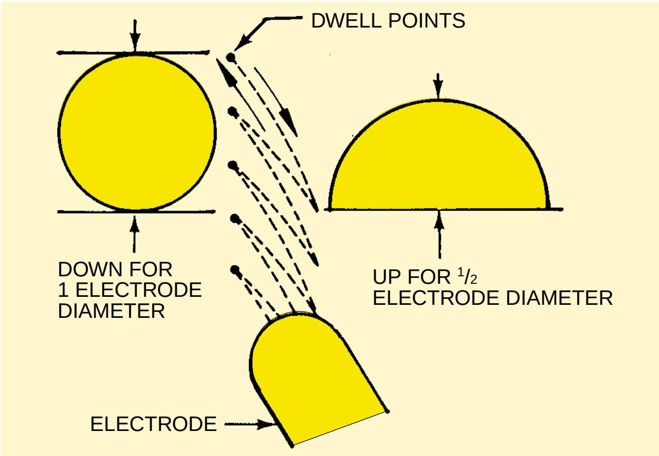
The finished bead must form a 1.6 mm thick weld reinforcement at the root.



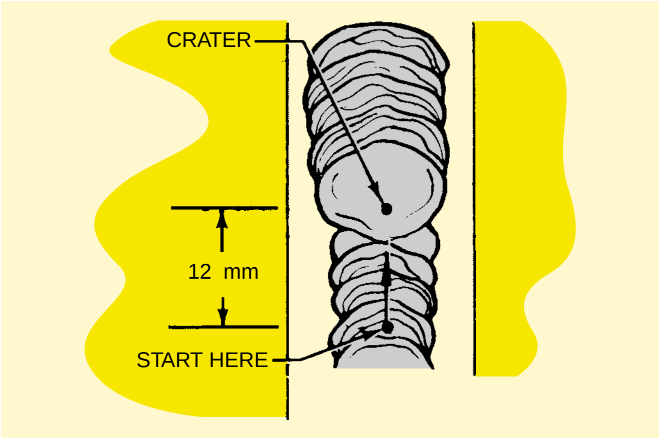
When the first half of the bottom bead is completed, remove the slag then repeat the process on the second half of the joint.

For the hot pass use E7010-G(P1), E8010-G(P1) or E9010-G electrodes, depending on the class of the steel to be welded, in 4.0 mm diameter
Start with the electrode at 12 o'clock, maintaining the same angles indicated for the bottom bead, towards 6 o'clock. Use a light up and down movement to check the weld pool. Move the tip in the forward direction for a length equal to the diameter of the electrode to allow the pool to solidify slightly then move the tip back for a length equal to half of the diameter. At this point wait until the crater is full before moving onwards.





Maintain an arc length equal to the electrode diameter. Do not increase the arc length during movement. If the arc is interrupted before the bead is complete, remove the slag from the crater, restart the arc starting on the bottom bead, approximately 12 mm in front of the second bead and move back up to the crater.



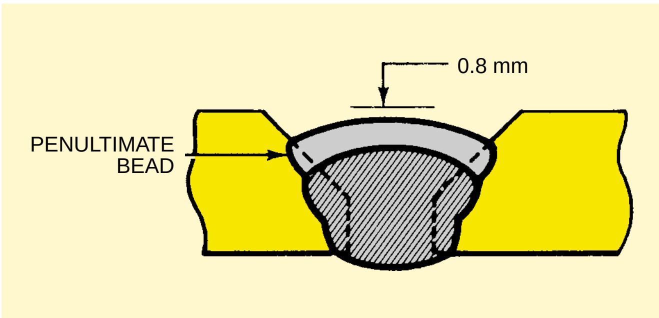
Make sure that you have filled the crater then restart welding as indicated previously. Carry out the second half of the run with the same procedure.

It should be noted that the "pulling" technique with which the root bead is laid causes an incomplete fusion and slag inclusion ("tramlines") at the seam edges.

Due to the higher current used, the second or "hot" pass does not transfer much metal to the joint, but its greater heat frees the slag and completes the fusion between the weld edges and the base metal.

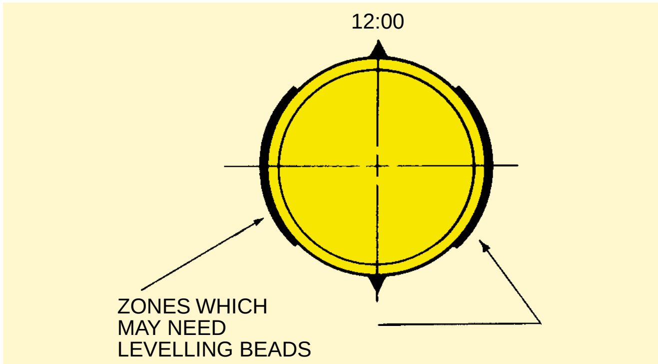
To carry out the **filling pass** (third pass), the starting position and trailing angles of the electrode are the same as indicated for the root and hot passes, but electrodes of 5.0 mm diameter with current set at 150-1 80A must be used. Use a swinging movement, maintaining an arc length equal to the electrode diameter. Pause with the tip of the electrode on the edge of the previous bead. Move towards the opposite edge with descending by half the electrode diameter.

If it is necessary to restart the arc use the same procedure as indicated for the second pass. After having welded the second half of the joint, completely remove the slag.

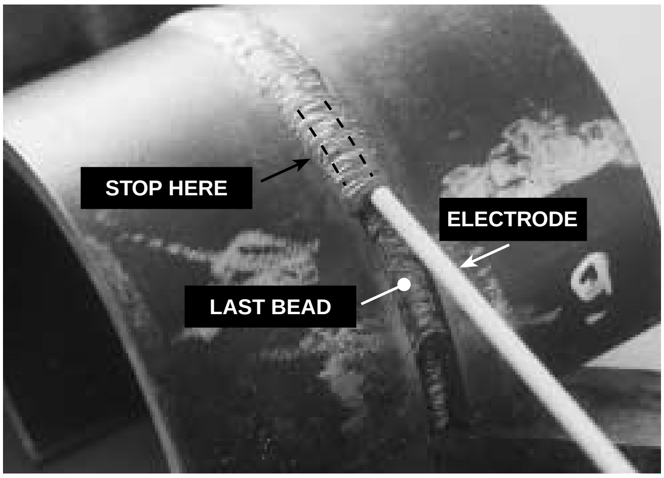


To fill the joint up to **0.8 mm from the external pipe surface** it may be necessary to deposit **additional passes** on the whole circumference.

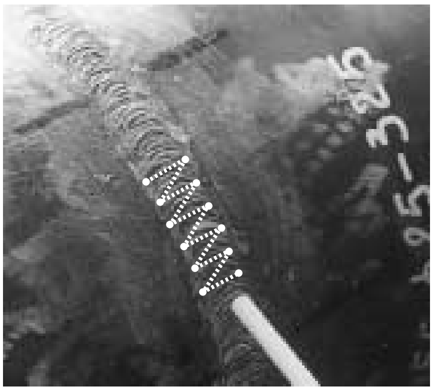
These beads should generally add a 1.6 mm thick layer. Use the same techniques indicated for the previous passes. Often, after having made all these layers, the joint is thicker in the upper and lower zone than in the side zones of the pipe, making it necessary to fill it evenly before making the cap. In this case **stripper beads** are laid with the same techniques illustrated previously.



The technique used for the cap pass is the same as indicated for the penultimate bead, but the swinging movement must be wider. Dwell with the tip of the electrode on the edges of the previous bead.

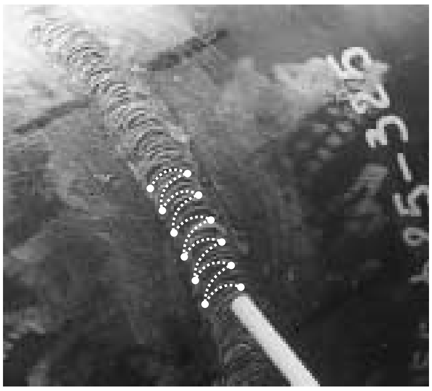


Use a Z or half-moon oscillation with adequate arc length, travel speed and electrode slope.

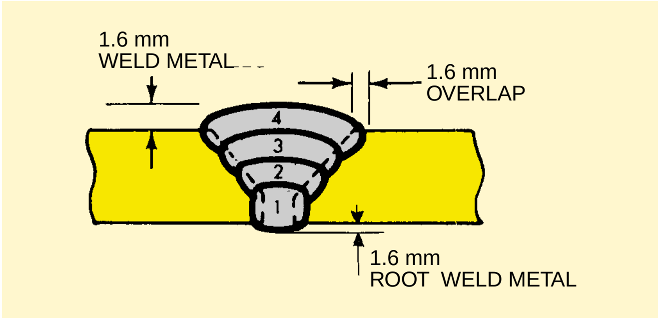


Z - OSCILLATION

HALF-MOON OSCILLATION



Advance at a speed that makes it possible to obtain a 0.8 to 1.6 mm thick reinforcement and an overlap of approximately 1.6mm at the edges.



API standards provide visual analysis and relevant **quality assessment** of the weld sample. After having carried out the preparation and tacking, the piece is marked for identification then welded in the 5G position as previously indicated. A visual analysis of the weld is then carried out.

Acceptability criteria are as follows:

- Cracks: the weld must not present cracks.
- Penetration: the joint root must show complete penetration.
- Fusion: fusion between the base metal and filler metal must appear complete.
- Slag inclusion: the hollow in the melted zone containing slag must not exceed 3.2 mm for each 152 mm of weld.
- Gaseous inclusion: a section affected by porosity cannot be longer than 1.6mm and their total must not exceed the length of 3.2mm each 6.5 cm2 of weld surface.
- Undercuts: they must not exceed a width of 0.8mm, a depth of 0.8 mm and their total length must not exceed 50.8mm in each 152mm of weld or 5% of the wall thickness, if the weld is shorter.
- Weld metal: the surface and root reinforcements must not exceed the indicated dimensions, must be evenly connected with the surfaces of the base metal and their edges must be free from undercuts.

3 - Joint in 6G / H-L045

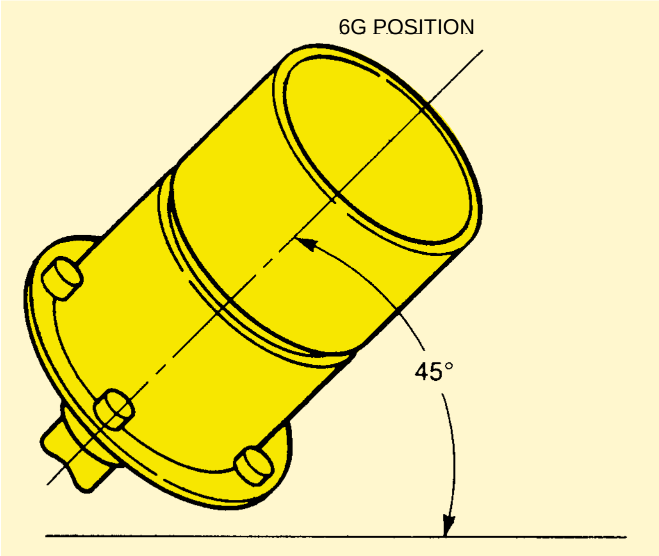
Use: welding all mild steel pipes of 8” (203 mm) diameter and wall thickness of 8.2mm.

Welding parameters

Electrode E6010 Ø 2.5mm, Current 70 ÷ 100A
Electrode E6010 Ø 3.25mm, Current 100 ÷ 120A
The generator must have an open circuit voltage of 70V

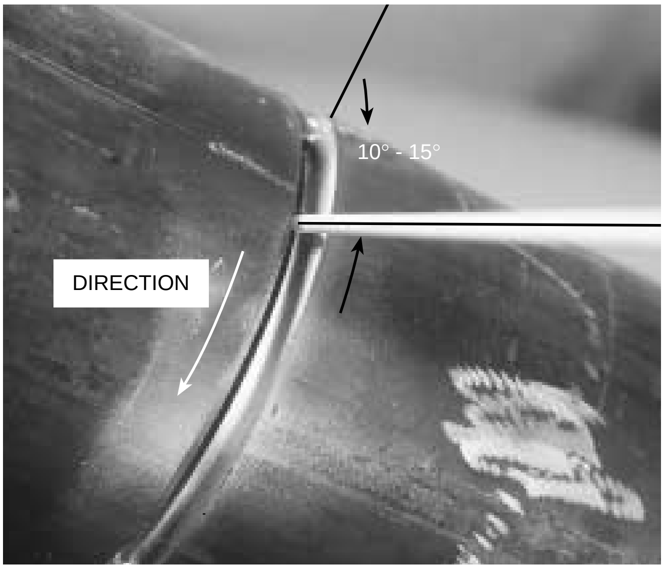
Operations

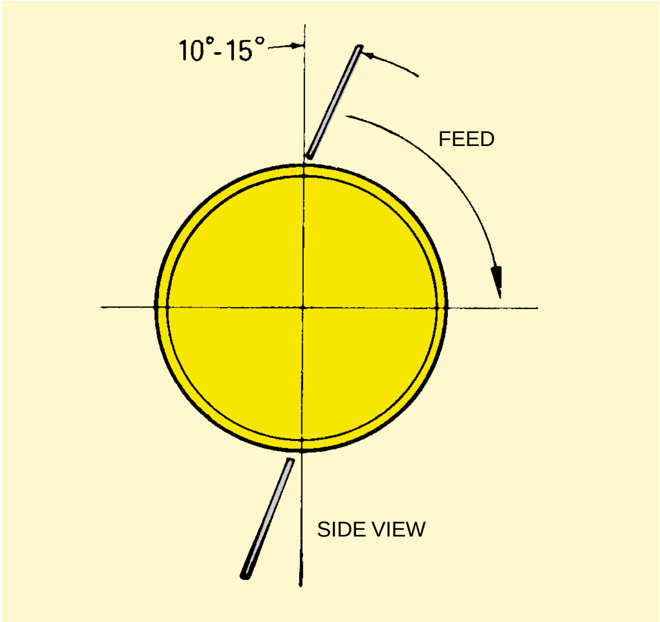
After having carried out the preparation and tacking operation as described in chapter 1, fix the piece using pliers and/or clamps with its axis at 45° to the horizontal plane and with tacks placed at 3, 6, 9 and 12 o’clock. Place the tack where there is the smallest root gap at 12 o’clock.



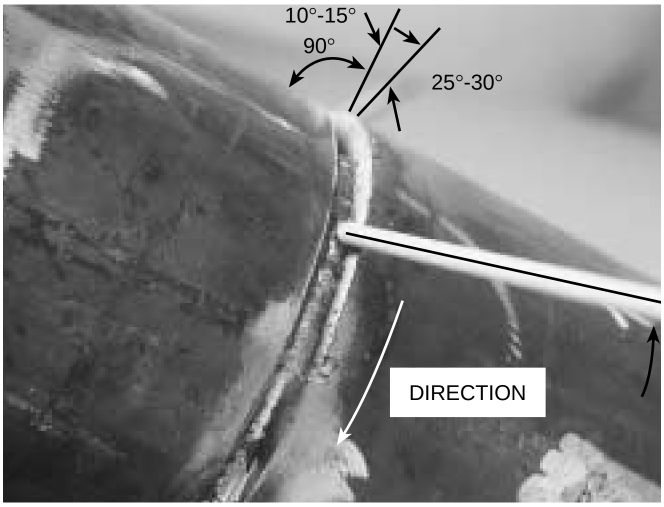
Carry out the root bead with the same technique used in chapter 2, page 29.

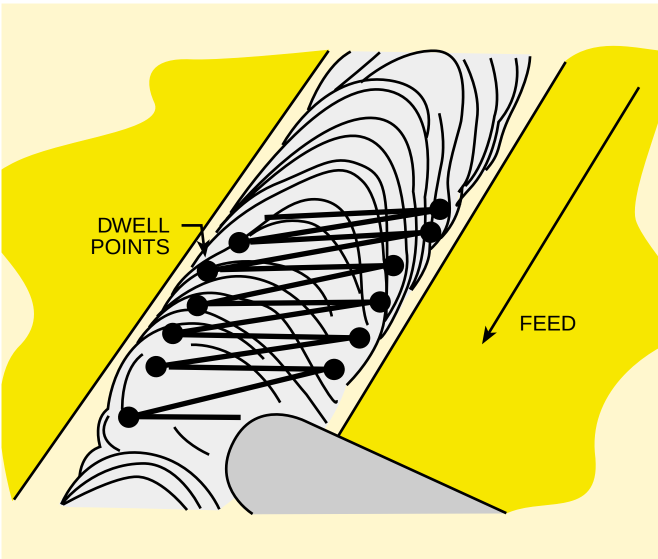
Keep the electrode parallel to the plane of the joint and use a trailing angle of 10÷15°. It the electrode coating melts in an irregular manner, slightly move the tip from one edge to the other. Weld both halves of the joint with the same technique. The bottom bead should penetrate inside the pipe not more than 1.6 mm.



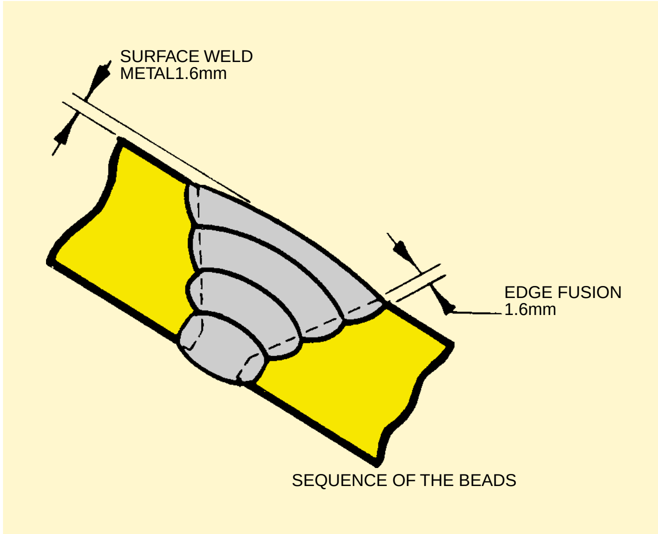


For the **hot pass** use E6010 electrodes of 3.25 mm diameter. Start the arc at 12 o'clock with the same electrode angles used for the bottom bead.
Use a similar movement to that described for the second bead in chapter 2, page 29.
For the **filling passes** start from 12 o'clock with a work angle of 80-90° to the pipe axis supported at the sides at the top of the seam.



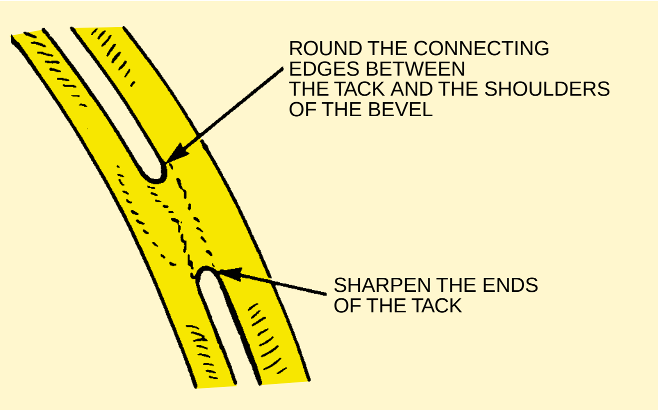


Advance from 12 o'clock to 6 o'clock using an elongated oscillating movement, then, if necessary, execute leveling beads.

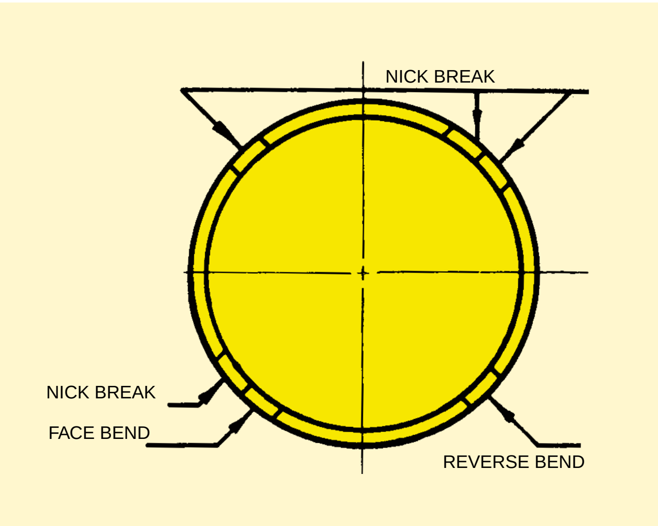


Execute the capping pass using the same electrode angles and technique as the filling technique. The external bead should create a 1.6 mm thick reinforcement and penetrate the beveled edge up to 1.6 mm. Weld both halves of the joint then remove the slag.

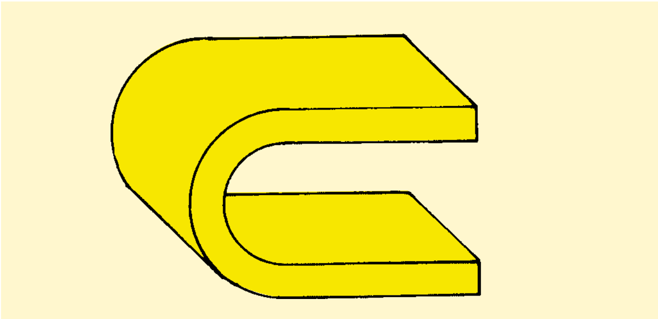
To pass the **qualification test** in a welding process in the 6G position — which covers all the others– some mechanical tests must be performed on a sample. For this purpose prepare and tack a piece as described in chapter 1.



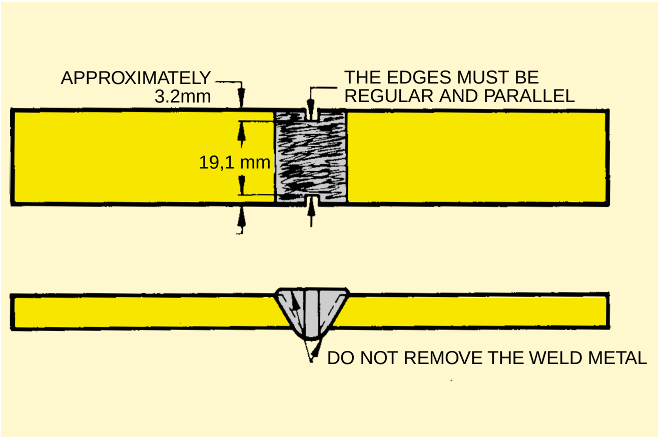
Carry out the welding as described in this chapter. Take care to remove the largest irregularities using a grinder with flexible disk and fine grain before laying the second bead. Make a visual check as indicated in chapter 2, page 29. From the welded piece will be obtained six sections which must be previously marked for identification by the operator. Proceed with pipe cutting to obtain six strips of a width of 25mm, as illustrated below.



The coupons for the **bend tests** must be ground on both surfaces of the weld up to the thickness of the pipe wall, but without notching the base metal.
Using a jig, bend the strips over a mandrel 3 times the pipe thickness, one with the root on the outside and one the opposite way.



The acceptability standard is satisfied if no cracks or other defects of over 3.2 mm or half the wall thickness, if this is lower, appear after bending in the weld seam or fusion zone in each direction. No cracks starting from the edge of the samples, if smaller than 6.4 mm measured in each direction, should be taken into consideration, unless accompanied by other defects.
To carry out the **nick break tests**, a notch is made in the centre of the weld with the 3.2 mm deep saw cut on all sides of the sample. The internal and external reinforcement must not be removed.

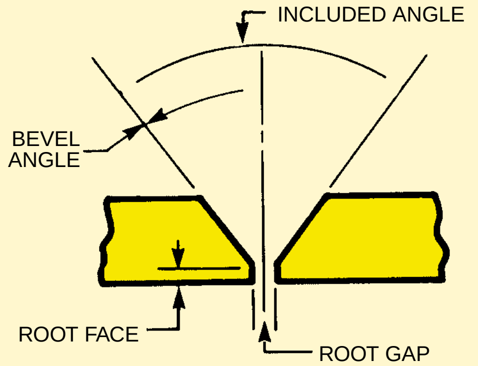


The samples may be broken under tension with a special machine, or by striking their centre with a hammer after having supported their ends, or striking one end of them after having fixed the other. The acceptability standard is satisfied when the exposed surfaces of each sample show complete penetration and fusion. The maximum size of porosity must not exceed 1.6mm and the total porosity areas must not exceed 2% of the examined surfaces. Slag inclusion must not exceed 0.8mm in depth, 3.2mm in length, or half the wall surface if this is smaller. Furthermore, there must be at least 12mm of sound metal between one inclusion and the other.

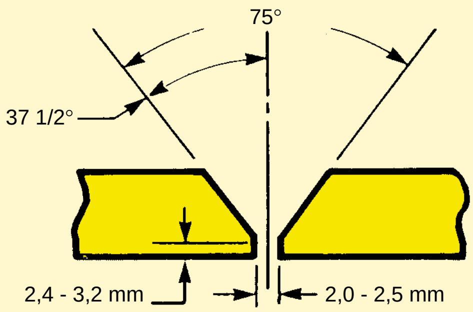
Welding of pipes in vertical up (uphill) with mixed cellulosic/basic technique

1 - Preparation and tacking

The scope of this chapter is to provide correct preparation and tacking procedure for a standard joint on pipe sections with 8” diameter (203 mm). The joint is prepared by making a bevel as indicated in the figures.



CHARACTERISTICS OF THE BEVEL

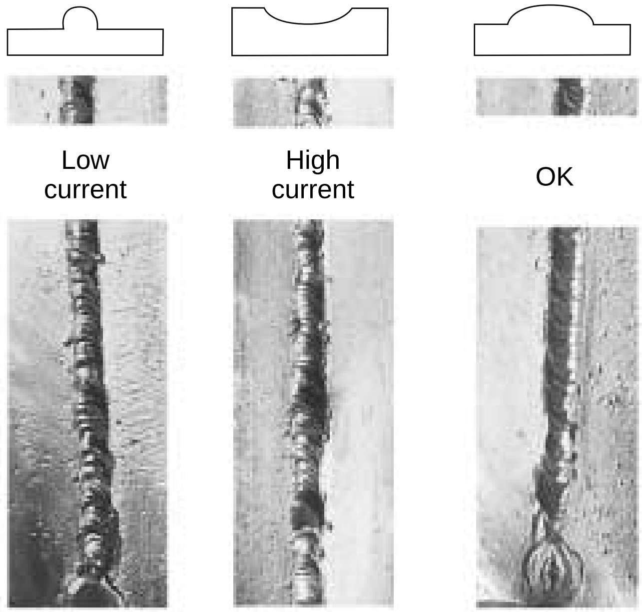


STANDARD JOINT DIMENSIONS

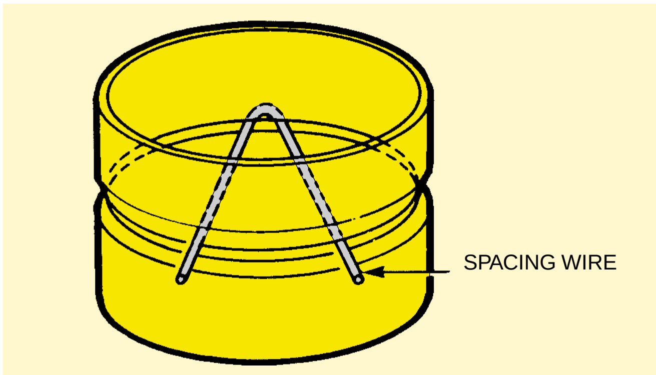
Remove burrs caused by the grinding operation.

Welding parameters for tacking
Electrode E6010 Ø 3.2mm, DC+, Current 85 ÷ 110A

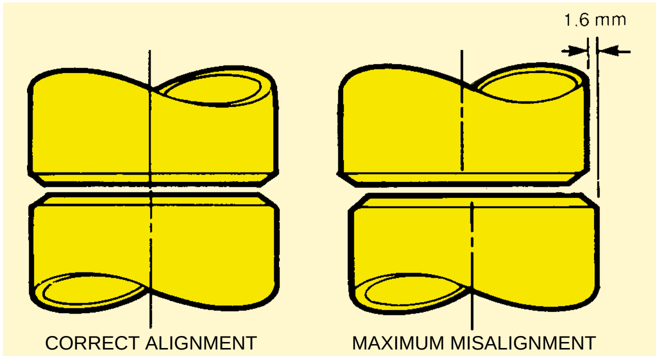
If the power source has no ammeter, the current may be empirically set by proceeding as follows: place a 6mm thick strip of mild steel in horizontal position, start the arc and lay down a straight seam, which must be even, with a regular ripple and 1.6 mm thick. If the seam is uneven and strongly convex, the current must be increased. If it is flat and there is excessive spatter, the current must be reduced.



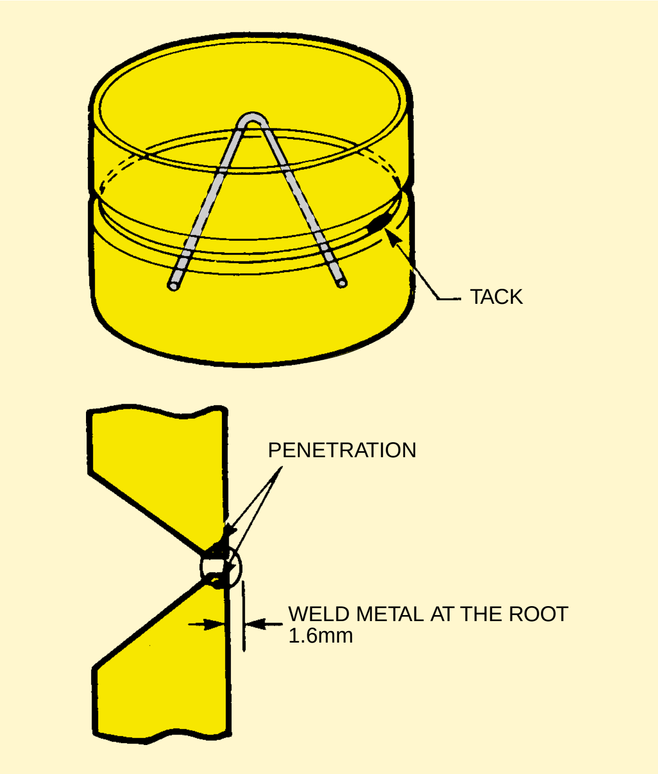
Operations
Rest one of the pipe sections on the worktop with the bevelled edge facing downwards.



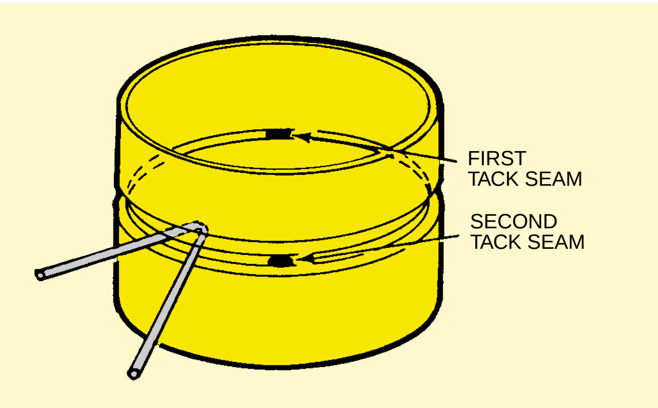
Place a spacing wire of **3.2mm** diameter on the bevelled edge then rest the second pipe section on the spacing wire with the bevelled edge facing downwards. Align the two sections to form the desired joint preparation. In accordance with the ASME code, misalignment must not exceed 1.6mm.



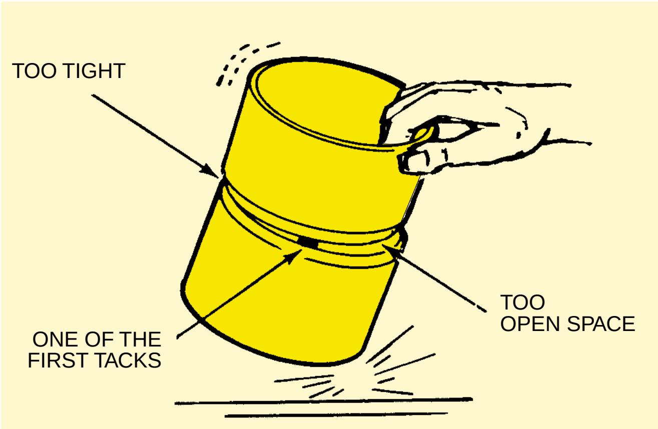
At this point the tacking operation starts, laying a 12 to 20mm long bead.

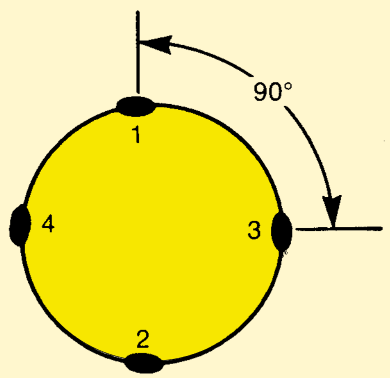


The tack must penetrate the root so as to form a bead 1.6mm high inside the pipe and both sides of the preparation must be fused. Then reposition the spacing wire and deposit a second tack.



Remove the spacing wire. If in one of the spans the root gap is greater than on the opposite side, place a third tack where the gap is widest, so that weld shrinkage will even the difference. If the gap at its widest point is too great to permit a third tack, first correct the gap by compressing the most open side. Make the third and fourth tacks at right angles to the first and second.





To obtain a quality weld, correct joint preparation and accurate tacking are necessary. Faulty tacking will cause defects in the final welding.

2 - Joint in 5G / PF

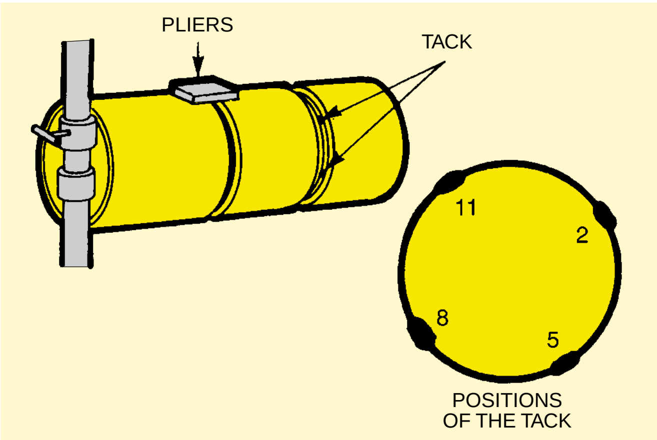
This type of joint and position is used to weld moulded bends, flanges, forged pieces, concentrated works, in all diameters. The following example regards the welding of pipes with 8" (203 mm) diameter.

Welding parameters (*)
Electrode E6010 Ø 3.2mm, DC+, Current 85 110A root
Electrode E7018 Ø 2.5 / 3.25mm, DC+, Current 85 ÷ 110A filling
Electrode E7018 Ø 3.2mm, DC+, Current 110 ÷ 140A cap

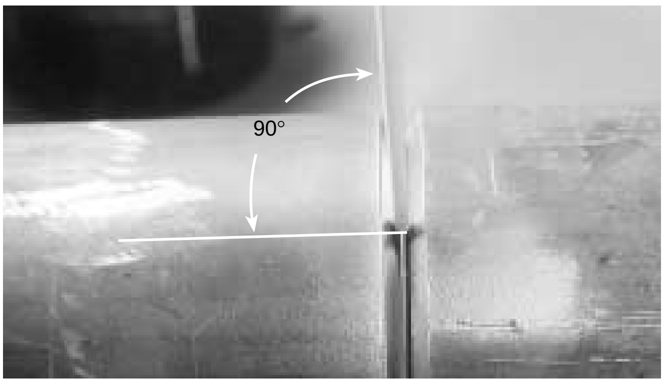
The power source must have an OCV of at least 70 V

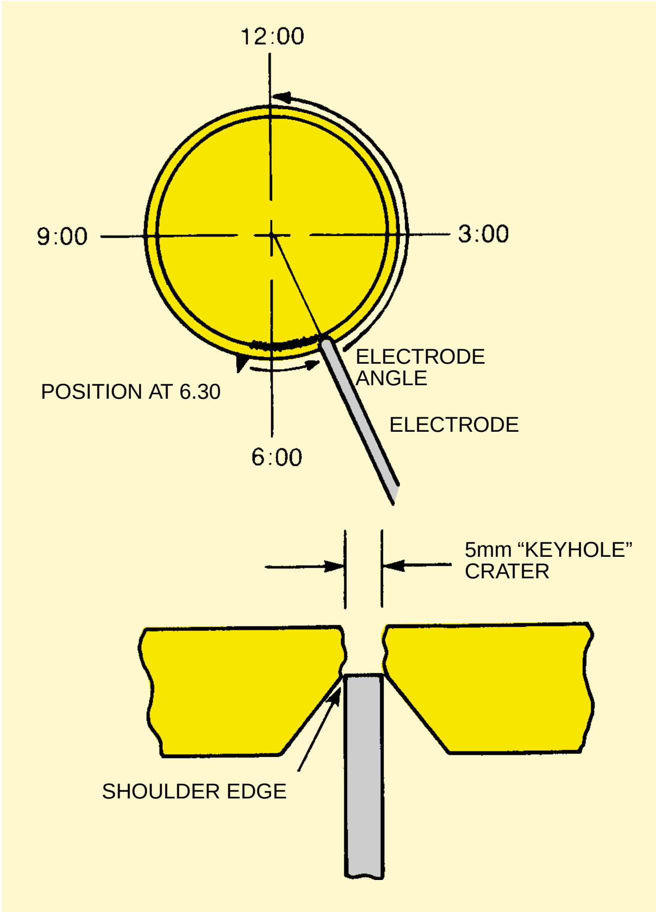
(*) For process with mixed cellulosic/basic technique

Operations
After having carried out the preparation and tacking as described in chapter 1, use pliers and clamps to fix the piece in a horizontal position with the tacking placed at 2, 5 ,8 and 11 o'clock. The tack with the smallest root gap should be at 6 o'clock.

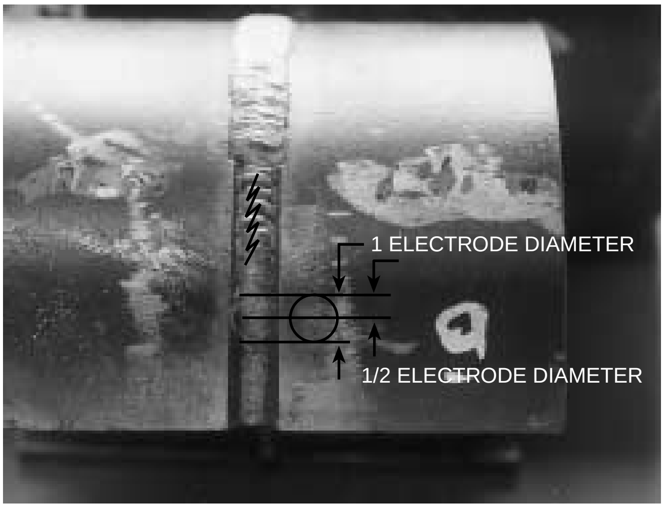


To carry out the **root bead** start with the electrode at 6:30, at right angles to both the pipe axis and the pipe surface. Start the arc at the root of the joint (never on the edge of the tack or the external pipe surface). Maintain an arc length double the electrode diameter and swing from one edge to the other, to and fro, to pre-heat the edges of the shoulders.

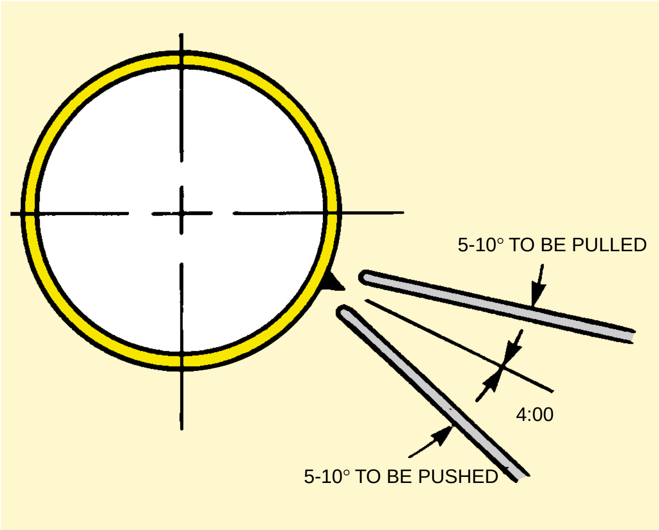




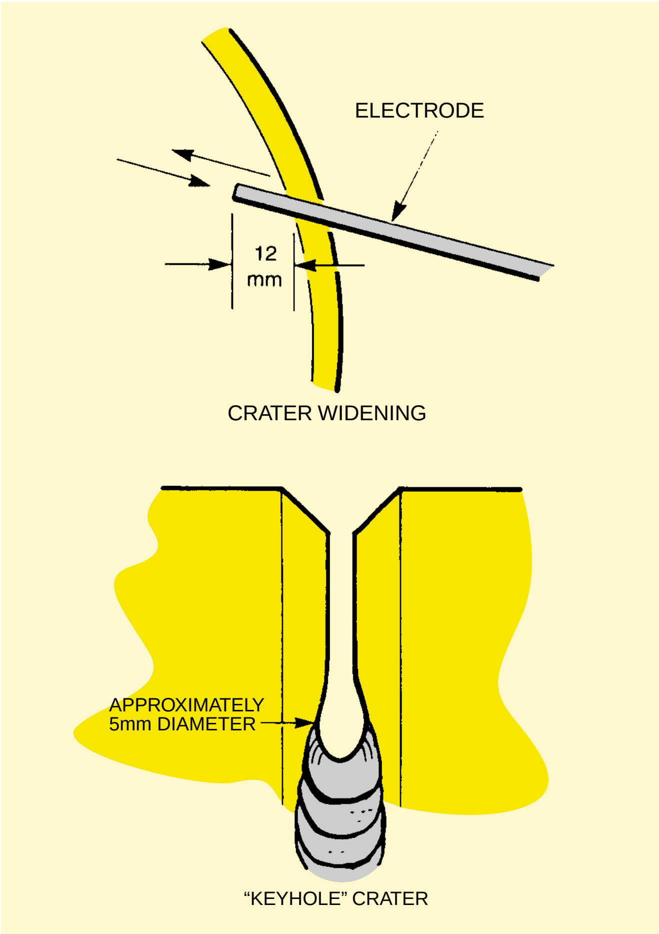
After two or three movements reduce the arc length to one electrode diameter and form the "keyhole" crater, then keep the arc on the edge of the shoulders and advance. Use a light up and down swinging movement. To maintain a crater of the correct dimensions the movements must be rapid and precise.



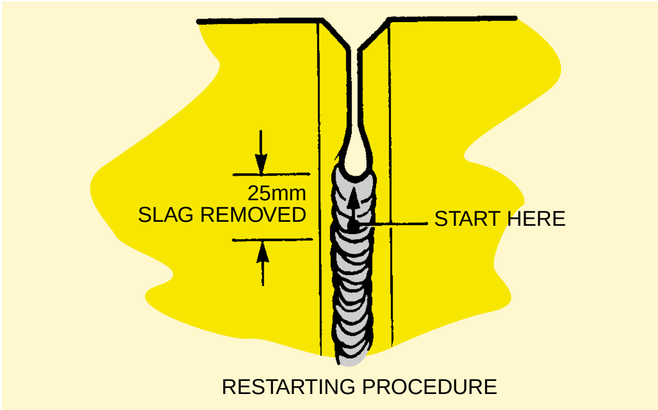
When approaching a tack, reduce travel speed and slightly increase arc length. If the crater tends to close, use a trailing angle (pulling) of 5 ÷ 10° and/or reduce feed speed. If instead it tends to widen, use a leading angle (pushing) of 5 ÷ 10° and/or increase feed speed.



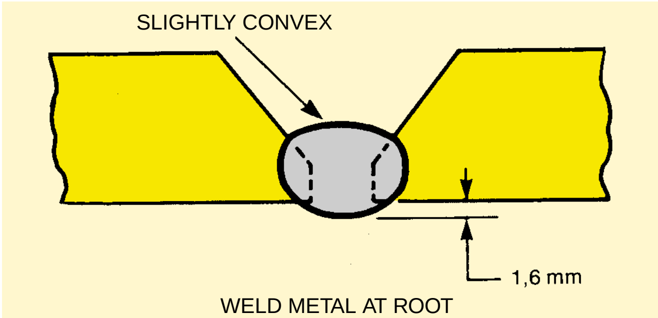
If necessary interrupt the arc before the seam is finished, form a “keyhole” crater of approximately 5 mm diameter by rapidly pushing the electrode point through the joint for approximately 13 mm, then completely withdraw the electrode. In this way complete penetration is assured at restart.



Remove the slag from the crater and from the last 25 mm of seam. Restart should be carried out starting on the weld approximately 20 mm before the crater and moving towards it with a slightly higher than normal arc length. Move back and forth on the crater to preheat the edges then reset the normal arc length.

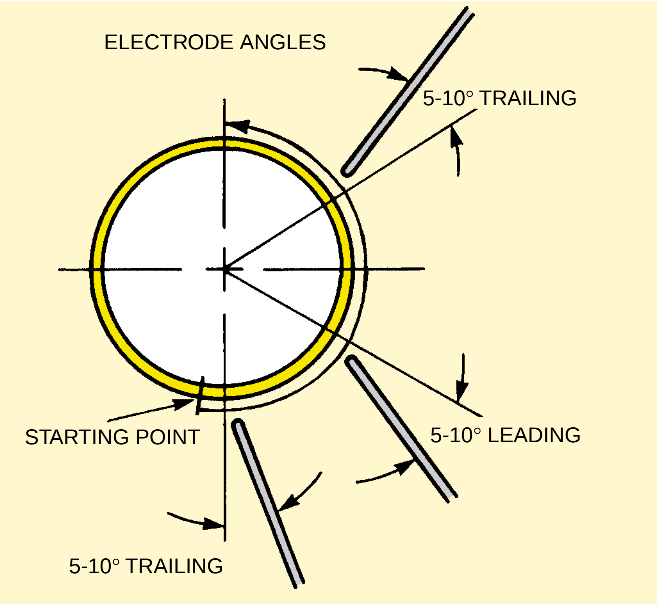


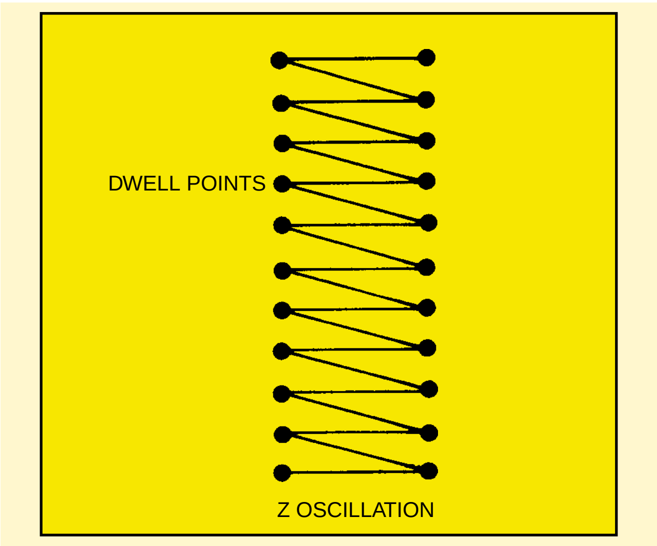
When the first half of the bottom bead has ended, remove the slag then repeat the operation on the second half of the joint.
The finished bead should have a slightly convex surface and be up to 1.6mm high.



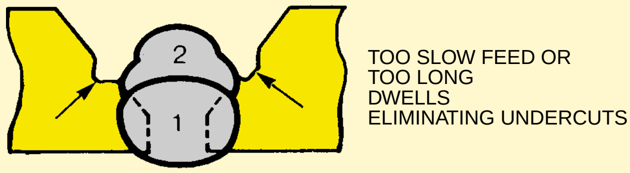
At this point, the filling and capping passes may be executed either continuing with cellulosic electrodes or using the mixed cellulosic/basic technique.

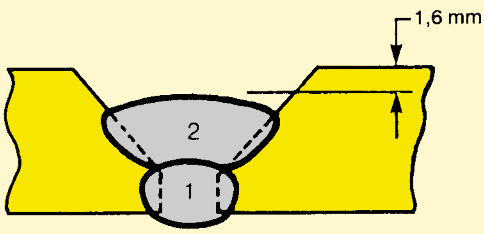
Filling and capping beads with basic electrodes
If after the first bead you wish to use electrodes with a basic coating, proceed as follows:
For the second bead use E7018 electrodes with 2.5 / 3.5mm Ø. Start the arc at 6:30 and stabilise it at 6 o'clock keeping a rather small arc length at angles as shown in the following figure.





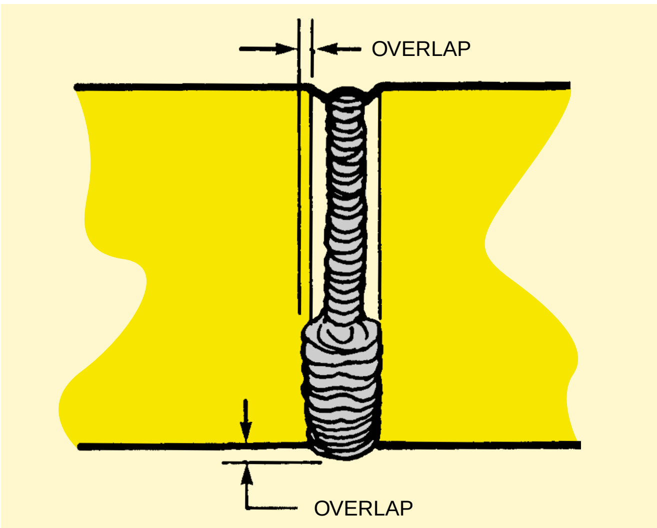
Use a Z oscillating movement, pausing with the electrode at the joint edges. The travel speed and dwell time determine the result. Too slow a speed or an excessive dwell cause the pool to be too wide and difficult to control, while too fast a speed and a short dwell create lack of fusion on the previous seam, with a very convex seam and undercut.





A correct joint filling reaches approximately 1.6mm from the pipe surface. If the **penultimate bead** does not reach this level, carry out another with E7018 Ø 2.5 (or 3.2) mm using the same procedure. If the arc is interrupted before the bead is complete, remove the crater slag, restart the arc starting on the last bead approximately 12mm in front of the crater then turn back until the crater is full and resume normal travel. Finally, remove the slag from the weld ends and carry out the second half of the joint.

For the **cap bead** use E7018 electrodes in Ø 3.2mm, using the same technique as the filling beads but with a wider swinging movement, pausing on the joint edges. The overlap on the joint edges must measure approximately 1.6mm and the thickness of the weld metal#from 0.8 to 1.6mm.



ASME (*) standards provide a visual analysis and relevant quality assessment of the weld on a sample, After having carried out#preparation and tacking, the piece is marked for identification then welded in the 5G position as previously indicated. A visual examination of the weld is then carried out.

The acceptability criteria are as follows:
- Cracks: the weld must not present cracks.
- Penetration: the joint root must show complete penetration.
- Fusion: fusion between the base metal and filler metal must appear complete.
- Slag inclusion: the cavities in the melted zone containing slag must not exceed 3.2 mm for each 152 mm of weld.
- Gaseous inclusion: a section affected by porosity cannot be longer than 1.6 mm and their total must not exceed the length of 3.2mm each 6.5 cm^2 of weld surface.
- Undercuts: they must not exceed a width of 0.8mm, a depth of 0.8mm and their total length must not exceed 50.8mm in each 152mm of weld or 5% of the wall thickness, if the weld is shorter.
- Weld metal: the surface and root reinforcements must not exceed the indicated dimensions, must be smoothly merged with the surfaces of the base metal and their edges must be free from undercuts.

2.1 Cap and finishing beads by means of cellulosic electrode

After the root bead made with Pipeweld 6010 Plus, further filling and capping beads can be carried out using cellulosic electrodes.
Proceed again in the vertical up position, by using the 3.2 mm diameter and the 4 mm if bevel and pipe diameter are suitable.
Welding current should be lower than that used in the root and is determined by the pipe size.
Current values normally used are:
Ø 3,2mm – 60A ÷ 100A
Ø 4mm – 80A ÷ 120A
Depending on the width of the bevel, welding is carried out with Z or half-moon weaving movements, pausing with the electrode at the joint edges.

3 - Joint in 2G / PC

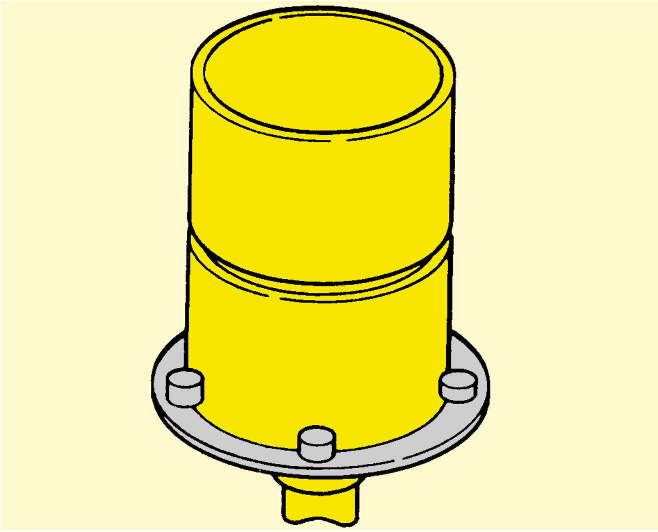
This type of joint and position is used on pipes, piles, small vessels. The following example relates to the welding of pipe with 8” (203 mm) diameter.

Welding parameters (*)
Electrode E6010 Ø 3.2mm, DC+, Current 85 ÷ 110A root
Electrode E7018 Ø 2.5mm, DC+, Current 85 ÷ 110A filling
Electrode E7018 Ø 3.2mm, DC÷, Current 110 ÷ 140A cap

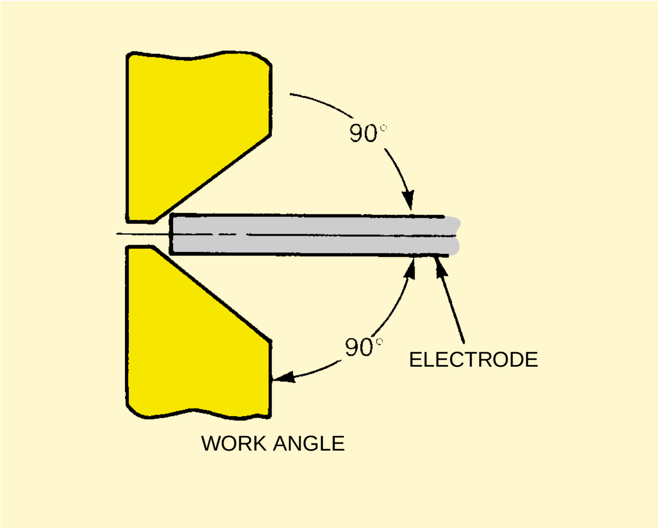
The power source must have an OCV of at least 70 V

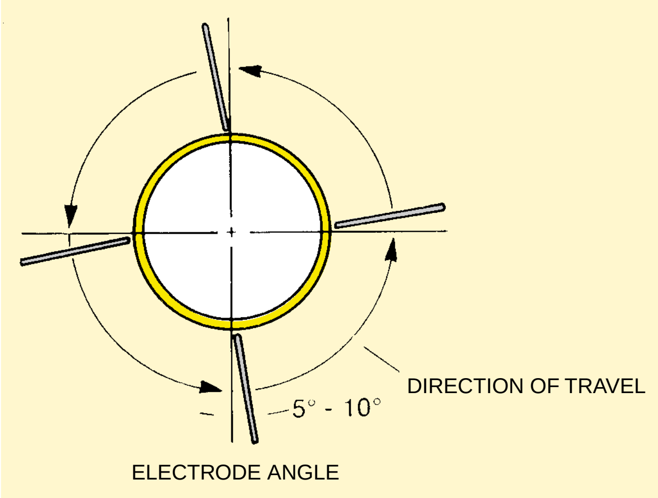
(*) For process with mixed cellulosic/basic technique

Operations
After having carried out the preparation and tacking, fix the piece in the 2G position (vertical axis).

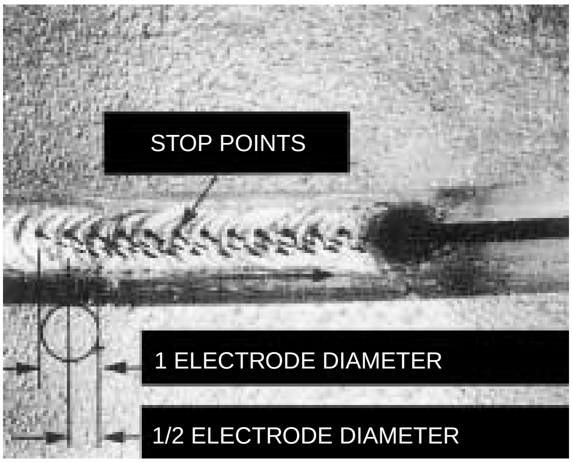


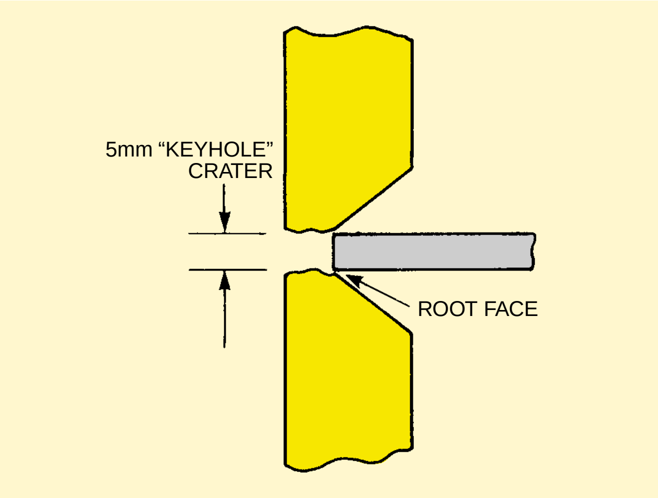
Then make the **root bead** with E6010 electrodes of 3.2 mm diameter.

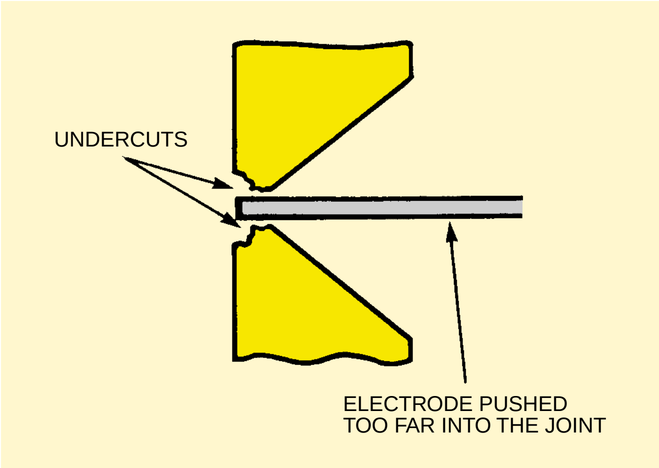




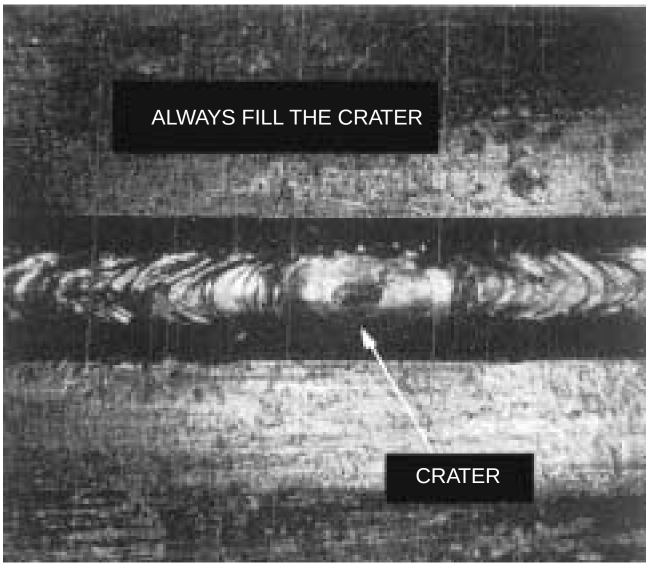
The electrode must be held horizontally with a trailing angle of 5 ÷ 10°. Start the bead 50 mm from the tack, form the “keyhole” crater and advance with a slightly swinging movement similar to that used for the 5G position. Keep the electrode on the edges of the shoulder.





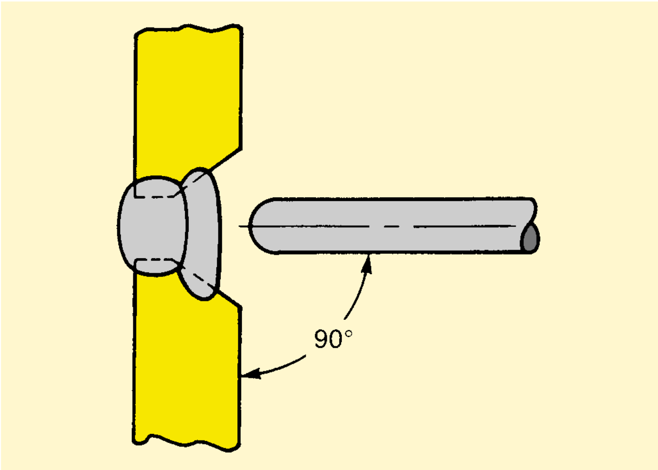


If the crater tends to widen, increase the trailing angle from 5 to 10°. If the electrode tip is pushed too far into the joint, undercuts form along the root and excessive penetration and defects occur. If the electrode is not pushed deep enough into the joint, insufficient penetration and undercuts on the beveled surfaces of the preparation are obtained.

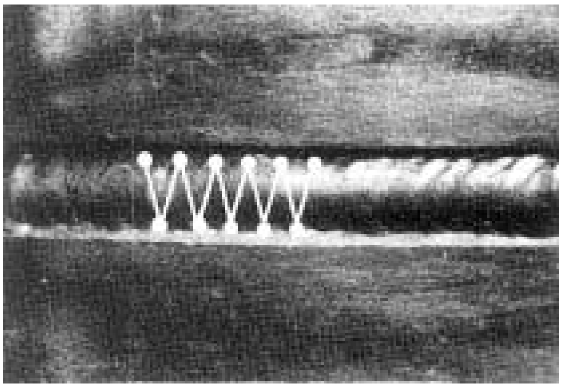


If the arc is interrupted before the bead is complete, clean the crater and restart as described in the previous paragraph, not forgetting to fill the crater.

The **second or filling bead pass** be carried out with an E7018 electrode in 2.5 mm diameter.

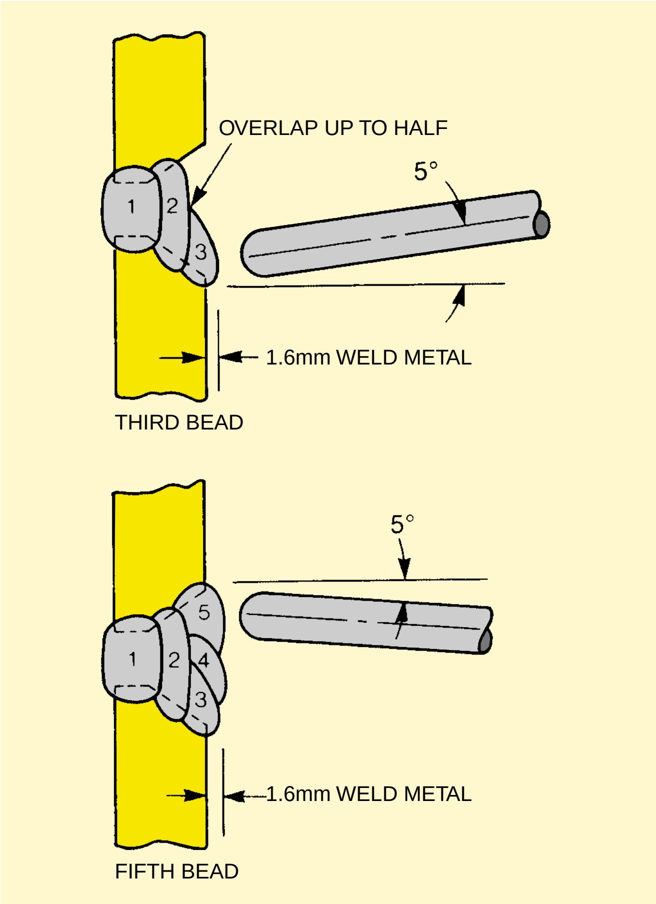


The electrode must be held horizontally with a trailing angle of 5 ÷ 10°.



Use a perpendicular W motion, with pauses at the points indicated in the figure to correctly fill the welding crater. Keep the arc as short as possible. The bead must be flat or slightly convex with good fusion on the edges.

The **capping passes** should be made with E7018 electrodes of 3.2 mm diameter. The work angle varies, with respect to the horizontal plane, from 5° above for the third bead, to 5° below for the fifth.



A correct work angle assures good fusion on the joint edges. The beads must overlap up to half of the previous one. Use the same swinging movement described for the second bead. The finished joint must have a projecting machine allowance of 1.6mm and the slightly convex surface must not present undercuts.

ASME (*) standards provide a visual analysis and relevant **quality assessment** of the weld on a sample. After having carried out the preparation and tacking, the piece is marked for identification then welded in the 5G position as previously indicated. A visual analysis of the weld is then carried out.

The acceptability criteria are as follows:
- Cracks: the weld must not present cracks.
- Penetration: the joint root must show a complete penetration.
- Fusion: fusion between the base metal and filler metal must appear complete
- Slag inclusion: the cavity in melted zone containing slag must not exceed 3.2mm for each 152mm of weld.
- Gaseous inclusion: a section affected by porosity cannot be longer than 1 .6mm and their total must not exceed a length of 3.2mm each 6.5 cm^2 of weld surface.
- Undercuts: they must not exceed a width of 0.8mm, a depth of 0.8mm and their total length must not exceed 50.8mm in each 152mm of weld or 5% of the wall thickness, if the weld is shorter.
- Weld metal: the surface and root reinforcements must not exceed the indicated dimensions, must be evenly connected with the surfaces of the base metal and their edges must be free from undercuts.

4 - Joint in 6G / H-LO45

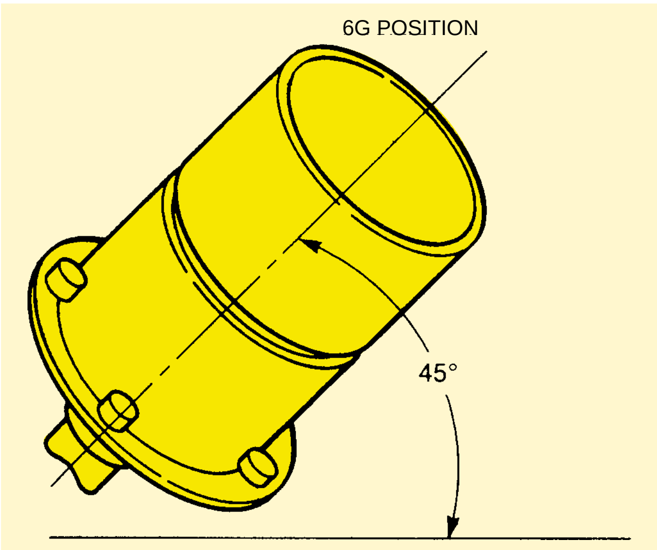
This type of joint and position is used to weld bends, flanges, fittings. The following example shows the welding of pipes of 8” (203mm) diameter. The 6G welding position qualifies all the others.

Welding parameters (*)
Electrode E6010 Ø 3.2mm, DC÷, Current 85 ÷ 110A root bead
Electrode E7018 Ø 2.5mm, DC+, Current 85 ÷ 110A filling
Electrode E7018 Ø 3.2mm, DC+, Current 110 140A cap

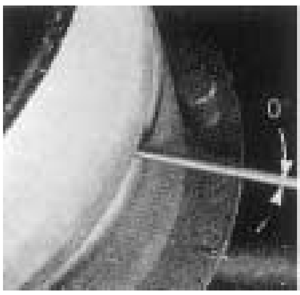
The power source must have an OCV of at least 70 V

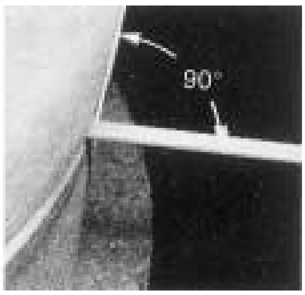
(*) For process with mixed cellulosic/basic technique

Operations
After having carried out the preparation and tacking, fix the piece in the 6G position (axis 45° to the horizontal plane) The tack must be placed at 2, 5, 8 and 11 o’clock.



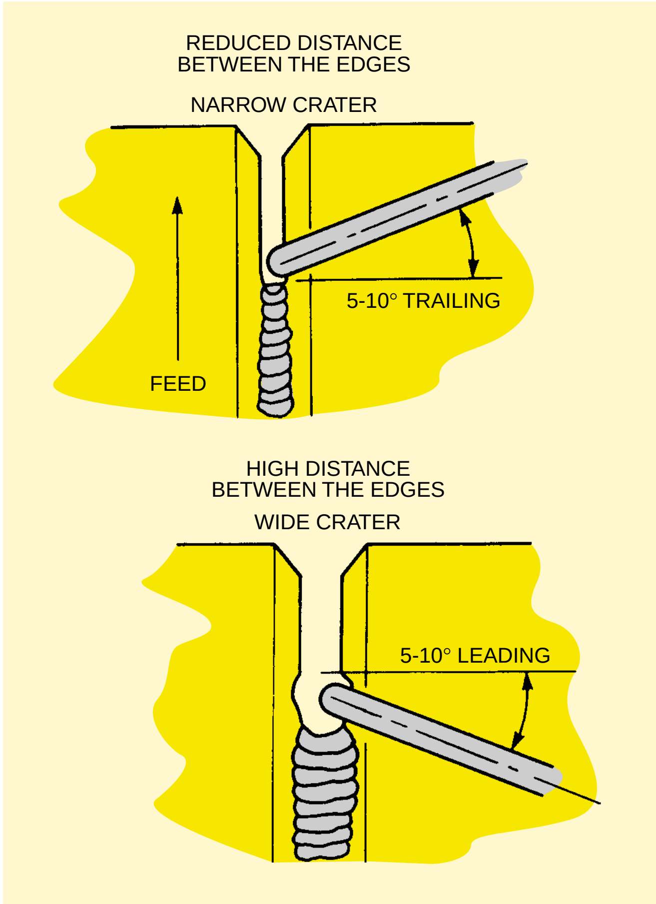
Then carry out the **root bead** with E6010 electrodes of 3.2 mm diameter. Start with the electrode at 6:30, with the electrode in the plane of the joint and at right angles to the direction of travel.


FEED ANGLE

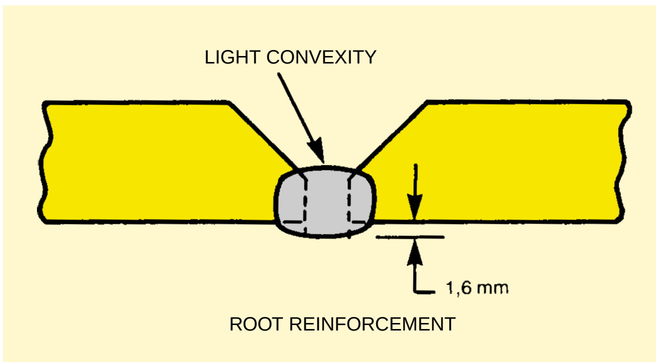


WORKING ANGLE

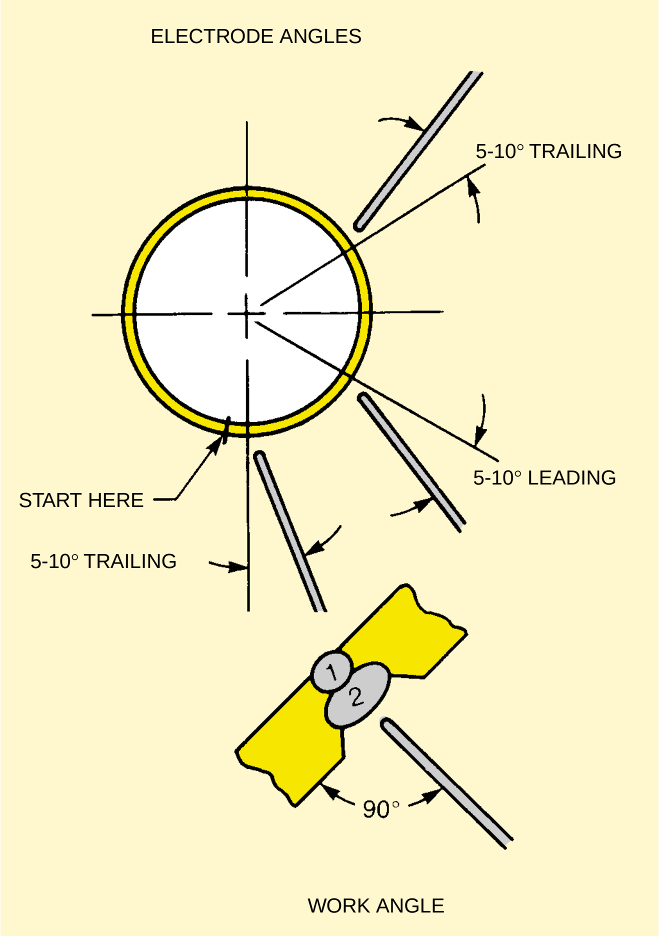
Use a light swinging movement. The tip of the electrode should be kept on the edges of the shoulder but without exerting pressure on them. If the crater tends to close, use a slight trailing angle and/or reduce travel speed. If the crater tends to widen, use a slight leading angle and/or increase travel speed.



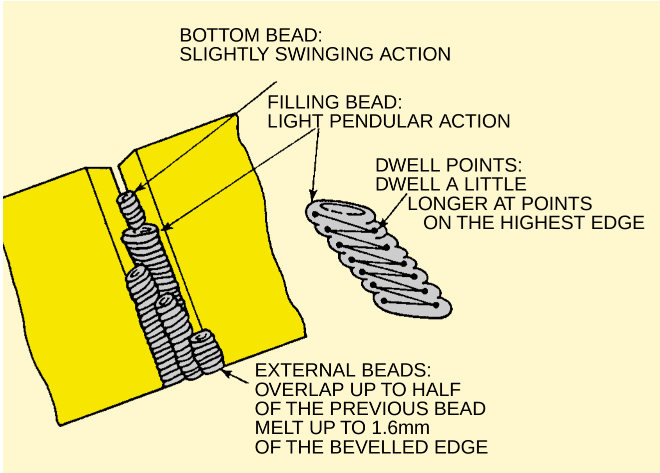
The arc interruption and reinsertion procedures are similar to those described in chapter 2, page 40. Execute both halves of the bead and remove the slag before laying the **second bead**.



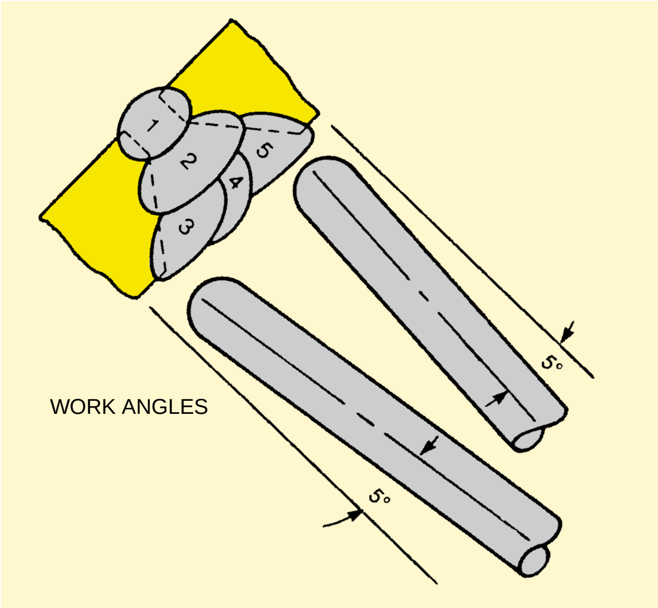
The **filling pass** should be carried out starting the arc at 6:30 and stabilising it at 6 o'clock on a fairly reduced width. Angles as per figure. Use E7018 electrodes of 2.5mm diameter. The filling pass should reach approximately 1.6 mm from the external surface of the pipe.

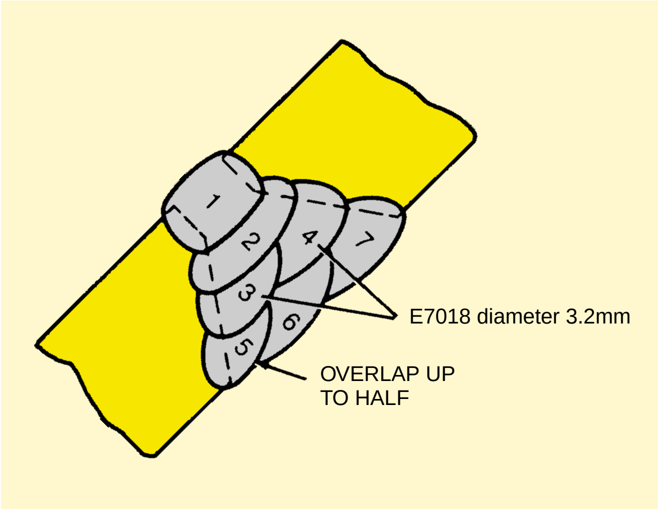


Then carry out the **capping passes** with E7018 electrodes of 3.2mm diameter, using a 110 ÷ 140A current.



The electrode angles of the are the same as those used for filling.



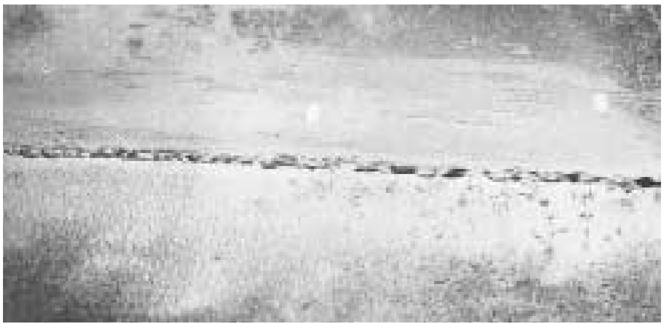


Take note of the number of beads for each layer.

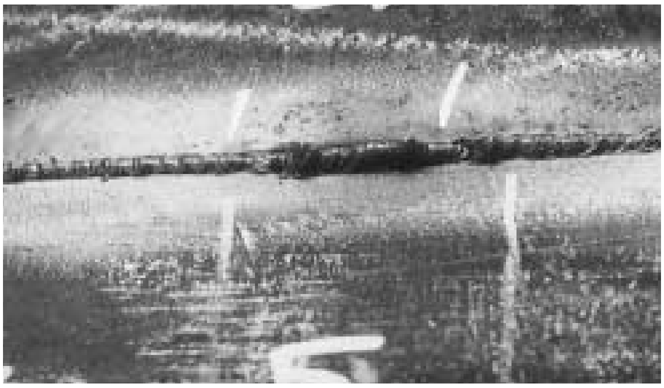
DEFECTS : CAUSES AND REMEDIES

To find and possibly prevent welding defects, the operator must acquire familiarity with the form and dimension of the weld pool and its relation to the form and appearance of the finished weld seam.
The filler metal is generated by the electrode, which through the arc starts mixing with the melted base metal. In **vertical down** welding, the arc force tends to make the melted metal flow towards the rear part of the crater to form the seam, while the force of gravity tends to counterbalance that of the arc, making the fusion pool flow in feed direction.
On the contrary, in **vertical up** welding, the force of the arc and that of gravity push the melted metal back in the crater to form the seam.
The movement of the melted metal towards the back of the crater and its form provide the operator with a means of continuous quality control, without interrupting the arc. The **essential variables** by which the operator interprets the fusion bath on which he must intervene to prevent welding defects are: **electrode diameter, current, arc length, feed speed and electrode positioning angles**.

One of the most important factors is **penetration**. There is correct penetration when the weld completely crosses the joint thickness, leaving a small seam of continuous penetration well-fused at the back. One of the commonest defects in pipe welding is **insufficient penetration**, which consists in discontinuity between the two edges of the bevel due to the fact that the filler metal has not completely penetrated the joint. This takes place as, during welding, the groove starts to close, the seam becomes narrow and the welding bath stagnant. To prevent this problem, a possible remedy is to decrease feed speed or reduce the electrode drive angle to increase the temperature of the bath and therefore the penetration. If this is not sufficient, interrupt welding and increase the current or use the grinder to redece the root face.

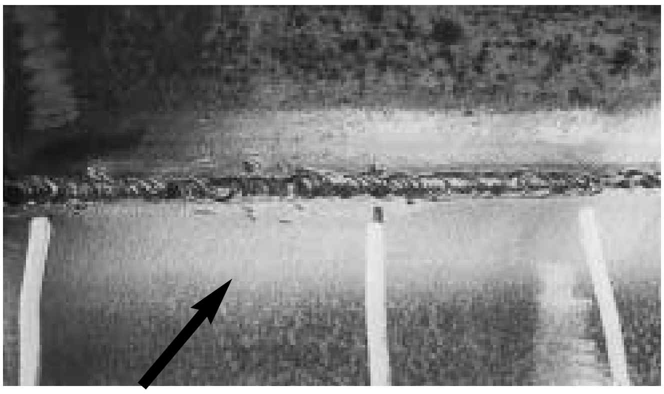


The opposite defect is **excessive penetration**, which is marked by an excessive reinforcement on the back of the joint, higher than required.

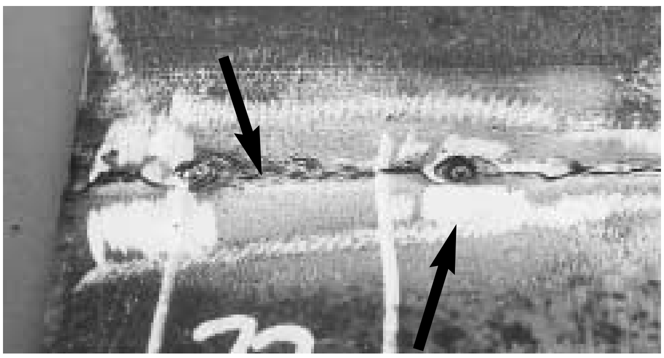


In this case, during welding the groove becomes too wide and the weld pool control is difficult due to its size and fluidity. To reduce penetration and eliminate this problem feed speed may be increased, possibly also increasing the electrode drive angle. If this is not sufficient, interrupt welding and reduce the current.

An excessive heat supply may cause **shrinkage** This makes the internal surface of the joint concave. It is a common defect when welding overhead: the force of gravity causes the internal surface of the seam to become concave and the external surface convex**.**

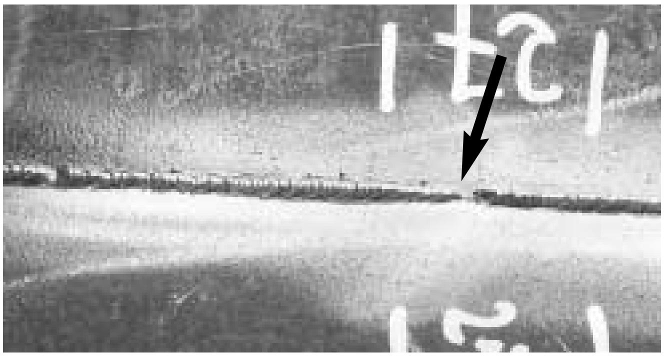


In both cases it is necessary to reduce the heat supply to the melted bath, the methods are the same as those described in the previous case.



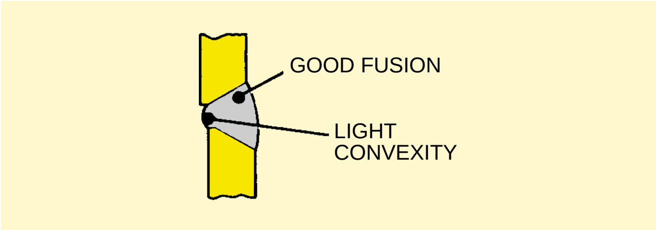
Vertical welding, too high a heat input causes **burn** through and fall of melted metal.

Another cause of defects is often linked to an imperfect **restart** of the arc, generally due to too low current or insufficient pre-heating; the start of the connecting seam is too wide and the end has a contour degrading towards the crater.



To prevent this type of defect, the electrode must be removed towards the end of the crater, keeping the arch slightly long for pre-heating. At the end reduce the arc length to melt the thin bridge of metal, waiting until the seam is of equal length to the existing one, then restart feed. When the arc is correctly started, the electrode must be turned towards the end of the crater.
Also in the case of ascending restart with **electrodes with low alloy and/or low carbon contents** (basic), the arc must be restarted upstream of the crater then moving towards the other end and should be kept slightly longer than normal. To restart on the filling or external beads, with cellulosic or basic electrodes, switch on the arc approximately 13mm in front of the crater then move back until it is filled. In this way the previous seam is correctly pre-heated.

Another typical welding defect consists of **undercuts**. These are furrows displayed at the seam edges at the connection with the surface of the base metal. They reduce thickness and cause burn through. This defect is due to the excessive length of the arc. The larger the arc cone, the wider the cuts will be, and the filler metal is laid in drops and there is excessive spatter with consequent loss of filler material.
Also the vertical down root often causes small undercuts at the edges of the external surface of the seam, but this is mainly due to an over-high travel speed. The second bead usually fills the cuts at the edges and prevents the lack of fusion and slag inclusion.
The undercuts at the root inside the pipe are caused by an over-short arc. The tip of the electrode is pushed too far into the joint and the filler material which is pushed through the joint is laid at the root.



Finally, we must draw your attention to a series of welding defects caused by incorrect **joint preparation**. The root gap, the root face and cleaning of the joint are all factors directly related to the future quality of the finished weld.
An excessive distance between the edges or a too small may cause excessive penetration, shrinking effect, breakage or undercuts. An excessive root gap makes it necessary to increase travel speed otherwise there would be an excessive heat supply with excessive penetration or burn through. Similarly, if the shoulder surface is too small, the arc heat makes the edges melt at the root and this leads to the previous situation in which the distance between the edges is excessive.
On the contrary, too small a root gap or too large a root face may cause insufficient penetration, lack of fusion and convexity of the seam surface with possible slag inclusion. If the root face is too high, the arc cannot melt the joint edges to create the groove and the metal is laid between the edges with insufficient penetration.
Insufficient or inadequate cleaning of the joint and base material before welding may cause further defects, generally gaseous inclusion (porosity if ≤ 1mm, blowholes if ≥ 1mm). The presence of oil or dirt on the surfaces to be welded causes spherical porosity. Other causes of porosity may be the presence of humidity on the base metal, excessive feed speed or excessive undulation of the electrode.
Finally, it is important to mention the effect of the **electrode angle** as a means of temperature control. The feed angles, “to be pushed” or “to be pulled”, influence heat supply, arc force and the quantity of material laid. Since the arc force is always exerted in the same direction as the electrode, if this is not centred on the joint the arc causes undercuts along the edges. Welding in upwards, gravity moves the melted metal towards the lowest point of the crater in which large undercuts have not been filled. Undercuts, which may however be caused by excessive arc length, may also occur along the edges of the joint root.

To sum up, the quality of the weld depends on the operator’s ability, on his knowledge of the appropriate techniques and on his capacity to control the five essential variables mentioned at the start. Joint preparation, and its cleaning before welding, must be accurate.

AUTOMATIC PIPE WELDING

General information

For decades the largest companies specialising in pipe construction at world level have adopted automatic welding systems, immediately finding their choice rewarded.
The main reasons for the conversion are:

- Increased productivity
- Lower welding costs
- Use of fewer staff
- Operators (welders) are trained in a few weeks
- Lower repair percentage
- Perfect repeteability of a test joint

Different alternatives can be chosen when the conversion has to take place:

- One side welding with internal line-up clamp using copper backing
- Performing of internal root pass with a “welding internal line-up clamp”

Both of those give good productivity and low repairing rate, but their respective advantages are:

One side welding
- Low cost equipment
- Higher speed on root pass (the first pass gives the production speed to the main line welding phase)

Internal pass
- Can be used when copper backings are not allowed
- Can ensure better penetration on high-low conditions

SOLID WIRES

ESAB, which follows the natural development of the sector, has set up and has now sold for years to all companies in the sector a complete range of solid wires for pipe welding which covers the entire range of steels.

OK Autrod 12.66

Classification
SFA/AWS A5.18-93 : ER 70S-6
EN 440 : G 42 2 C G4Si1
EN 440 : G 46 3 M G4Si1

OK Autrod 12.66 is a copper-coated solid wire with low content of impurity elements for downhill circumferential GMAW welding on pipe qualities such as API 5L, grade X52 to grade X70. The wire permits welding with high current (spray-arc) and also with short-circuiting transfer in all positions. Shielding gas Ar/CO^2.

Typical all-weld metal composition - %
C = 0.07
Si = 0.8
Mn = 1.4

Typical properties all-weld metal
Yield stress : 535 Mpa
Tensile strength : 600 Mpa
Elongation : 26%
Charpy V : 100J at –20°C

OK Autrod 13.13

Classification
SFA/AWS A5.28 : ER 100S-G
EN 12534 : GMn3NiCrMo

A copper-coated, low-alloy, chromium-nickel-molybdenum (0.5% Cr, 0.5% Ni, 0.2% Mo), solid wire for the GMAW of high tensile strength steels with a minimum yield strength (0.2% offset) of less than 610 MPa and a minimum tensile strength exceeding 710 Mpa. Also suitable when welding steels where good impact strength at lower temperatures is required.
OK Autrod 13.13 is usually welded with $Ar/2\ CO^2$ as the shielding gas. The mechanical properties are given in the as-welded condition. After stress relieving, the mechanical properties decrease by about 30 Mpa in the case of yield and tensile strength.

Typical all-weld metal composition - %
C = 0.1
Si = 0.7
Mn = 1.4
Cr = 0.6
Ni = 0.6
Mo = 0.2

Typical properties all-weld metal
Yield stress : 690 Mpa
Tensile strength : 770 Mpa
Elongation : 20%
Charpy V :
80J at 0°C
50J at –60°C

CORED WIRES

For even more extreme applications, where productivity, quality and mechanical features must be guaranteed, ESAB, thanks to its preferred partner relationship with large contractors specialised in the offshore sector, has prepared a series of cored wires which permit a considerable increase in productivity.

FILARC PZ6104

Classification
SFA/AWS A5.18 : E70C-GM H4
EN 758-1997 : T42 5 Z MM 2 H5

Metal-cored wire providing a ductile weld metal alloyed with 1% Ni for good CVN toughness down to –50°C. Developed for applications involving thick plates, high restraint and/or low-temperature toughness requirements, as in offshore construction. Primary use comprises multi-layer butt and fillet welds in the downhill and horizontal/vertical positions. Root passes without backing are welded in the short-arc mode. Pulsed MIG operation is applied to optimise the filling of positional joints, using Ar/8%CO^2 shielding gas. Suitable for semiautomatic and fully automatic orbital welding machines.

Typical all-weld metal composition - %
C = 0.03 – 0.07
Si = 0.4 – 0.7
Mn = 1.2 – 1.6
Ni = 0.7 – 0.95

Typical properties all-weld metal
Yield stress : 420 Mpa
Tensile strength : 520 - 620 Mpa
Elongation : 22%
Charpy V :
54J at -40°C
47J at –50°C

Welding techniques and operational practices for automatic orbital welding

Welding with mixed technique

Electrode+wire welding may be considered the first step towards complete automation of the welding process; although large companies adopted this solution in the early Eighties to limit investments in the first phase.
It could work on a standard API bevel (30°+30°) without using bevelling machine (very expensive device), performing root and hot passes by cellulosic electrodes and filling and cap by solid or cored wires. Very common using of self-shielded cored wire where good quality of gas is not easy to find.

Wire welding

Wire welding, with reduced bevel and use of an internal clamp with copper supports is definitely the cheapest, safest and most productive solution to adopt and has been used for years to construct sea and land pipes by numerous companies in the sector.

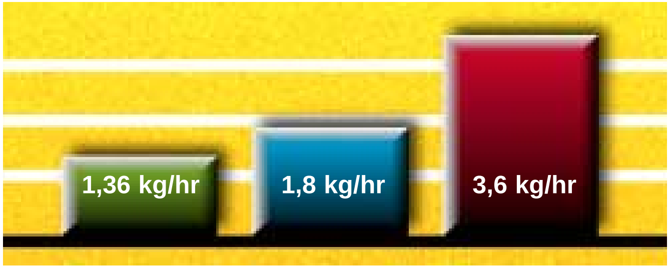
How automatic equipment work

The welding torch moves downhill at a speed programmed by a selector. The speed is determined for each pass, on the half circumference. At the end of each pass the torch moves back to the starting position and restarts, after the welding parameters have been regulated or automatically set. The operation is carried out by means of two carriages on the same weld, to increase productivity.

Advantages

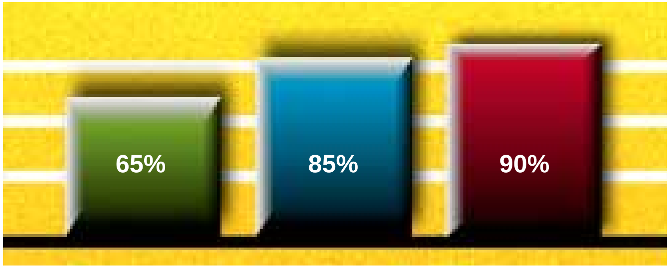
Operators, even if recruited among generic personnel, can be trained in two-weeks time.
Number of personnel dedicated to the welding phase can be reduced by 30% (it's not necessary to grind and brush joints – welding wire does not produce slag).
Working time is completely productive. Dead times between each pass are reduced to a minimum.

DEPOSITION RATE
Weld metal deposition per hour



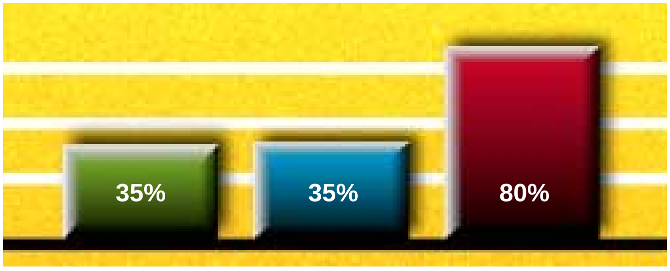
Electrode | Cored wire-manual | Automatic welding

DEPOSITION EFFICIENCY
Ratio of weight of weld metal deposited to the weight used



Electrode | Cored wire-manual | Automatic welding

DUTY CYCLE FACTORS
Ratio of arc time to working time

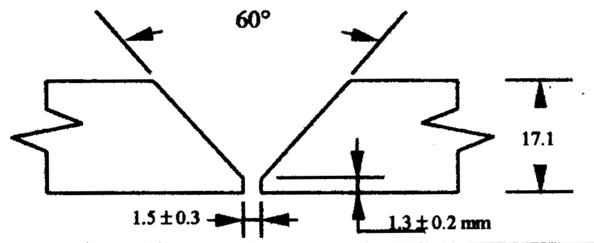


Electrode | Cored wire-manual | Automatic welding

Examples of WPS - Welding Procedure Specifications

ESAB AB MSL DEPT	WELDING PROCEDURE SPECIFICATION CORESHIELD 8 NI 1	PQR	
		WPS	
		DATE	20/12/01
		SHEET	1 OF 3

JOINT DETAIL (QW 402)



BASE METALS (QW 403)

BASE METAL (1) SPC.:	ASTM A333 Gr. 6
BASE METAL (2) SPC.:	ASTM A350 LF2
P No (1):	1
Gr. No (1):	1
P No (2):	1
Gr. No (2):	2
PIPE DIAMETER:	20 "
WALL THICKNESS:	14.1 mm
JOINT TYPE (S):	See Joint Detail

FILLER METALS (QW 404)

WELD METAL THICKNESS:

WELDING PROCESS	AWS SPEC.	AWS CLASS	SIZE Ø MM	TUNGSTEN Ø MM	MANUFACTURER AND TRADE NAME	BATCH NUMBER	F No.	A NO.
SMAW	A 5.1	E 6010	3.25	N.A.	PIPEWELD 6010 PLUS			
SMAW	A 5.1	E 8010-P1	4.0	N.A.	PIPEWELD 8010			
FCAW	A 5.29		2.0	N.A.	CORESHIELD 8 NI 1			

POSITIONS (QW 405)

POSITION(S) OF GROOVE:	5G
WELDING PROGRESSION:	DOWNHILL
POSITION(S) OF FILLET:	N.A.

PREHEAT (QW 406)

PREHEAT TEMPERATURE:	100 °C
INTERPASS TEMP. MAX.:	100 °C
PREHEAT MAINTENANCE:	N.A.

POSTWELD HEAT TREATMENT (QW 407)

PWHT TEMPERATURE RANGE:	N.A.
PWHT TIME RANGE:	
NORMALISATION RANGE:	
OTHER:	

GAS (QW 408)

TYPE OF SHIELDING GAS(ES):	N.A.
PERCENT COMPOSITION (MIXTURES):	N.A.
FLOW RATE OF SHIELDING GAS(ES):	N.A.
BACKING GAS:	N.A.
FLOW RATE OF BACKING GAS:	N.A.

ELECTRICAL CHARACTERISTICS (QW 409) SEE SHEET 2 of 3

WELD PASS(ES)	WELDING PROCESS	FILLER METAL CLASS	FILLER METAL DIAMETER	CURRENT (DC) POLARITY	CURRENT (DC) AMPS	CURRENT (DC) VOLTS	ARC TIME SEC	TRAVEL SPEED CM/MINUTE	HEAT IMPUT MAX KJ/MM

TECHNIQUE (QW 410)

	SMAW	FCAW		
STRING OR WEAVE BEAD:	WEAVE	WEAVE UP TO 3th FILL	AFTER STRING	
CONTACT TUBE TO WORK DISTANCE	N.A.	15 – 25 mm		
MULTIPLE OR SINGLE ELECTRODE:	SINGLE	SINGLE		
MULTIPLE OR SINGLE PASS (FOR SIDE):	MULTIPLE	MULTIPLE		
MANUAL / SEMIAUTOMATIC / AUTOMATIC:	MANUAL	SEMIAUTOMATIC		
ORIFICE, CUP, NOZZLE SIZE:	N.A.	12 mm		
CLEANING:	Grinding and/or Brushing	Grinding and/or Brushing		

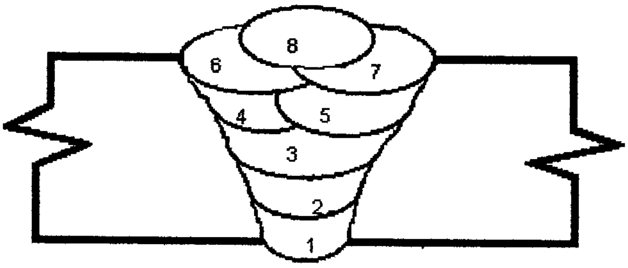
NOTE: WELDER's NAME : FERRARI Roberto

ESAB AB	
NAME: V. CARUCCI	NAME:
SIGNATURE:	SIGNATURE:

ESAB AB MSL DEPT	WELDING PROCEDURE SPECIFICATION CORESHIELD 8 NI 1	PQR WPS DATE SHEET	 20/12/01 2 OF 3

SEE ATTACHED BODYCOTE TESTING LABORATORY CERTIFICATES.

ARC FORCE 5 INDUCTANCE 90% SINERGIC MIG/MAG PROGRAMME HOT START 1 sec

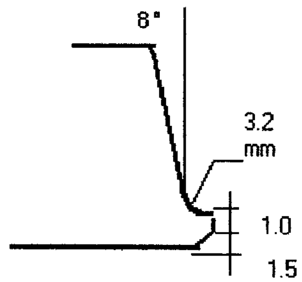


ELECTRICAL CHARACTERISTICS (QW 409)									
WELD	WELDING	FILLER METAL		CURRENT (DC)			ARC TIME	TRAVEL SPEED	HEAT IMPUT MAX
PASS(ES)	PROCESS	CLASS	DIAMETER	POLARITY	AMPS	VOLTS	SEC	CM/MINUTE	KJ/MM
1	SMAW	E 6010	3.25 mm	+	80-90	25-27	/	/	/
2	SMAW	E 8010-P1	4.0 mm	+	130-150	24-26	/	/	/
3			2.0 mm	+	165-180	20-21	/	22	/
4			2.0 mm	+	165-180	20-21	/	22	/
5			2.0 mm	+	165-180	20-21	/	22	/
6			2.0 mm	+	165-180	20-21	/	22	/
7			2.0 mm	+	160-170	20-21	/	20	/

ESAB AB NAME: V. CARUCCI SIGNATURE:	 NAME: SIGNATURE:

ESAB®	**WELDING PROCEDURE SPECIFICATION**	**Wps** *1000/00* **Rev.** *0* **Date** *03/11/00* **Sheet** *1 di 2*

CLIENT	**PROJECT**			
PROCESS FOR	*Mainline welding*			
WELDING PROCESS	*SMAW*			
BASE MATERIAL	*API Standard 5L Grado X 65*			
	Diam.Ex.	*24"*	**Thickn.**	*17.1 mm*



	Filler metal			AWS
Run	**Type**	**Diam**		**Classification**
All passes	*OK AUTROD 12.66*	*1.0 mm*		*AWS 5..18 E R 70S-6*

N° of passes		***Position***	*5G*
Welding direction		*Downhill*	
Gas Shielding	*CO2*	*L/min*	*25/30*

ESAB®	WELDING PROCEDURE SPECIFICATION	Wps *1000/99* Rev. *0* Date *09/10/99* Sheet *2 di 2*

Welding parameters

Run N° Both sides	Current CC o CA	Polarity	Ampere	Volt	Travel Speed Cm/min	Wire Speed Mt/min	
Root	CC	INV.	270	30	550	11.5	
Hot	CC	INV.	250	28	450	11.0	
1°Fill	CC	INV.	190-220	23-24	350	10.5	
2° Fill	CC	INV.	190-220	23	350	10.5	
Strip	CC	INV.	180-200	20	380-400	9.5	
Cap	CC	INV.	135-170	19	180	6.5	

Number of welders 2 min.

Time between first and second run 3 minutes

Time between second and start of other ones 5 minutes

Number of run before cooling allowed 50% of thickness

Type of clamp/ fit up internal clamp with cooper backing shoes

Cleaning Brush/ Grind

Preheat temperature: 100° C

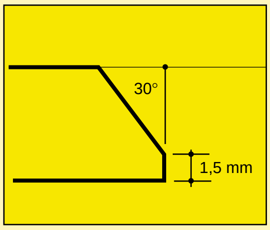
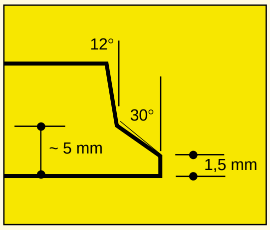
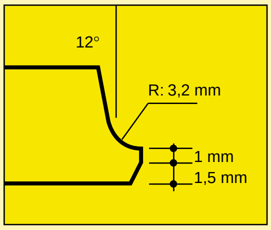
Preheat system: propane

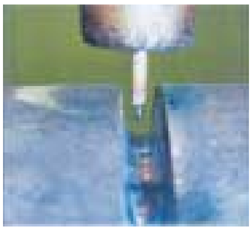
Interpass temp. Min 70°C max. 250°C **PWHT n.a.**

Note:.

Comparison between three welding methods

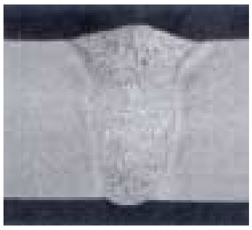
36" pipe, 14 mm thickness

	Electrode	Electrode + wire	Wire + copper backing
Type of bevel			



The bevel = volume reduction

The finished weld



Welding Procedure Specification

I° pass	Pipeweld 6010 Plus ∅ 4 mm	Pipeweld 6010 Plus ∅ 4 mm	OK Autrod 12.66 ∅ 1 mm
II° pass	Pipeweld 7010/8010 ∅ 4 mm	Pipeweld 7010/8010 ∅ 4 mm	OK Autrod 12.66 ∅ 1 mm
Filling	Pipeweld 7010/8010 ∅ 5 mm	OK Autrod 12.66 ∅ 1 mm	OK Autrod 12.66 ∅ 1 mm
Capping	Pipeweld 7010/8010 ∅ 5 mm	OK Autrod 12.66 ∅ 1 mm The joint could be also filled with self shielded cored wire (Coreshield 8NiA) or OK Tubrod 15,17 in semiautomatic technique	OK Autrod 12.66 ∅ 1 mm

Times

Arc time	64 minutes	41 minutes	25 minutes
Efficiency	35%	35% + 80%	80%
Total time	182 minutes	68 minutes	31 minutes

Costs (only an example)

Manpower 34 Euro/hour
Electrodes 5 Euro/kg
Wire 3 Euro/kg + 0,5 Euro/kg gas

Manpower cost	102 Euro	38 Euro	17 euro
Welding weight	2 kg	1,6 kg	1,2 kg
Consumables cost	11 Euro	6 Euro	4 Euro
Total weld cost	113 Euro	44 Euro	21 Euro

Defects and remedies

Hollow bead

The x-ray shows how a hollow channel inside the first bead may be caused by the presence of dirt inside the pipe, by inaccurate grinding of the internal wall of the pipe near the bevel, by bad weather conditions which make water or steam reach the weld while the first bead is being carried out or by incorrect welding parameters (too much current, too much gas).

Remedies

Check internal cleaning of the pipe, all the circumference, by means of manual grinding (brushing is not sufficient) for a section of at least 2 cm from the bevel.

In bad weather conditions, manual cleaning with cloths of the internal wall of both the pipes to be joined even before carrying out the first bead and before the overhead section (6:00) as it is that most likely to convey water or steam.

Periodic check of welding parameters

Lack of penetration

This presents itself as an interruption, perhaps of considerable length or with sections of the insideweld seam, which should instead be uniform after the first bead. In pipes with a sufficiently large diameter to permit internal accessibility it is visible to the naked eye and, in some cases, the intact bevel is visible (a welding process for instantaneous repair of the fault from the inside) is recommended. It may be caused by incorrect geometrical dimensions of the bevel, incorrect welding parameters, bad fit up (excessive misalignments) or poor operator skill.

Remedies

Check bevel, check welding parameters, pipe rotation (always compatible with the position of the longitudinal welds which must be spaced a certain length) or application of shims on the internal clamp expanders to reduce misalignments.
We will not dwell on the skill of the operators; the most expert should be chosen and reserved for the first bead (a delay in execution stops the whole “welding train”).

Lack of fusion

The main defect of wire processes. In x-ray it appears as a continuous or short dashed line on one or both sides of the joint; by assessing its position as regards the first bead (whiter seam at the centre of the film), you can assume its depth.
The main causes are: incorrect bevel dimensions, incorrect welding parameters or operator negligence.

Remedies

Constant check of all process geometrical and functional parameters and informed operators.
A second case exists. Less common than the lack of fusion called INTERPASS, caused by the dropping of the weld pool in the vertical section of the pipe (2:00-5:00) due to incorrect welding parameters; it appears in the x-ray as a darker veil between two successive beads.

Porosity

In a coated electrode process, the weld pool is protected from external oxidation by combustion of the coating, but in a wire process it is protected by a protective gas, introduced into the arc zone by a torch; the lack of gas causes porosity.

Remedies

Check the good state of maintenance of coverages for protection from the wind, check the good state of maintenance of sleeves, connections, gas diffusers and, more as recommendation than a technical remedy, substitute gas cylinders before they finish completely.

Slag inclusion

Defect found only in the mixed (electrode+wire) technique, it presents itself in the slab as an elongated, cracked inclusion of a certain thickness, usually positioned on one side of the bevel. It is caused by bad slag cleaning in the second bead, which remains imprisoned and does not melt in the successive wire bead.
A sporadic case, mentioned for comprehensiveness, is slag inclusion due to its entrapment in the hollow created between the second bead and the bevel wall if this, in the section at 30°, has not been completely filled.
To be more clear, if you start to weld with wire before filling the bevel section at 30° with the electrode, this could cause defects (even lack of fusion).

Remedies

Thorough cleaning of the second bead

External defects (undercuts and excess weld metal)

These cannot be considered real welding defects which cause joint seal problems, but are “to be repaired” due to the possibility of the start of corrosion or fatigue failure (cuts) or to facilitate subsequent operations of coating and installation (excess weld material)

Remedies

Good preparation of the joint before executing the finishing bead: the underlying bead must be uniform, perfectly clean and leave 1mm from the pipe surface to permit the voluminous pool of the last bead to rest smoothly and create a 1-1.5mm seam for the widest part of the joint.

At the end of the “welding train”, it is advisable to provide a tractor, even of small size for the manual repair of defects on the external bead.