

## STORAGE AND HANDLING

### RECOMMENDATIONS FOR THE STORAGE, REDRYING AND HANDLING OF ESAB COVERED ELECTRODES.

#### General Information

All covered electrodes are sensitive to moisture re-absorption to a greater or lesser degree. Care must be taken during storage and handling to prevent moisture being re-absorbed.

#### Storage

Covered electrodes of any type will pick up moisture only very slowly if they are stored under the following climatic conditions:

#### At Temperatures

During winter, it is possible to have low relative humidity by keeping the temperature in the storeroom at least 10°C above the outdoor temperature. During certain periods in the summer and in a tropical climate, sufficiently low relative humidity can be maintained by air dehumidification.

#### Redrying

Low-hydrogen basic electrodes should be redried before use whenever there are application requirements relating to weldmetal hydrogen content and / or radiographic soundness (not needed for VacPac®).

Acid rutile stainless electrodes and all types of basic electrodes may produce pores in the weld if they have not been stored in sufficiently dry conditions. Redrying the electrode will restore their usability.

Mild steel rutile and acid electrodes normally need no redrying.

Cellulose electrodes must not be redried.

Electrodes which are seriously damaged by moisture can normally not be redried. These electrodes should be scrapped.

#### Redrying Conditions

Redrying temperatures and holding times are specified on the label and in the product specification.

The redrying temperature is the temperature in the bulk of the electrodes.

The redrying time is measured from the point at which the redrying temperature has been reached.

Do not stack more than four layers of electrodes in the redrying oven.

It is recommended not to redry covered electrodes more than three times.

#### Holding Oven

The holding oven is used for intermediate storage to avoid moisture pick-up in the coating of low - hydrogen electrodes and acid rutile stainless electrodes. The electrodes which should be stored in the holding oven are:

1. Electrodes that have been redried.
2. Electrodes that have been removed from their hermetically - sealed container.
3. Electrodes that are considered to be in good condition and are transferred directly from the store room after unpacking.

Holding over temperature : 120 - 150°C

#### Precautions on Site

Keep the electrodes in electrically - heated quivers at a minimum temperature of 70°C. After work return the remaining electrodes to the holding oven.

#### Damaged Coating

Mechanically damaged electrodes on which parts of the coating are missing will not perform correctly and should be scrapped.

#### VacPac®

Electrodes in VacPac® will not pick up any moisture during storage. They require no redrying before use, provided the package is undamaged. This is indicated by a vacuum in the package.

#### Handling VacPac® Electrodes

Protect VacPac® from damage at all times.

The outer board packaging offers extra protection from mechanical damage to the metal foil. Handle the single inner, metal foil, VacPac® with special care.

Do not use a knife or any other sharp object to open the outer board packaging.

#### Before using VacPac® Electrodes

Check if the protective foil still contains a vacuum. If the vacuum has been lost, redry the electrodes before use.

Cut open the protective foil at one end.

Do not take out more than one electrode at a time, thereby, ensuring that the remaining electrodes are still protected inside the package. Put the top back on the plastic capsule.

Discard or redry electrodes that have been exposed to the atmosphere in an opened VacPac® for more than 8 hours.



### **Storage and handling recommendations for OK Tubrod / Dualshield / coreweld / cored wires.**

Cored wire should be stored in conditions which prevent the accelerated deterioration of products or packaging. All cored wires should avoid direct contact with water or moisture. This could take the form of rain or the condensation of moisture on a cold wire.

Cored wires must be stored in dry conditions. The relative humidity and temperature should be monitored and the temperature should not fall below the dew point.

To avoid condensation, the wire should be kept in the original packaging and, if necessary, left to warm up to at least the ambient temperature before opening the package.

Other hydrogen-containing substances, such as oil, grease and corrosion, or substances that could absorb moisture must also be avoided on the wire surface.

Products must be stored in such a way as to avoid damage during storage.

### **Storage and handling recommendations for OK Flux**

ESAB fluxes, have a guaranteed as-manufactured moisture content from the factories. This moisture content is well - controlled by internal ESAB specifications. Before transport, each pallet is shrink wrapped in plastic foil. This precaution action is done in order to maintain the as-manufactured moisture content as long as possible. Flux should never be exposed to direct wetness such as rain or snow.

#### **Storage**

- Unopened flux bags must be kept under properly maintained storage condition as follows:
- Temperature : 20 +/- 10°C
- Relative humidity : as low as possible - not exceeding 60%.
- The content of unprotected flux hoppers should after an 8 hours shift be placed in a drying cabinet or heated flux hopper at a temperature of 150 +/- 25°C.
- Remaining flux from opened bags should be placed at a temperature of 150 +/- 25°C

#### **Recycling**

- Moisture and oil must in a suitable way be removed from the pressure air used in the recycling system.
- Addition of new flux must be done with the proportion of at least one part new flux to three parts recycled flux.

Foreign material such as millscale, dross etc. should be removed by a suitable system such as sieving.

#### **Redrying**

When handled and stored as above, the ESAB fluxes can normally be used as they are.

If, however, a severe application is considered, as given by the applicable material specification, redrying of the flux is recommended.

Furthermore, if the flux, due to unfavourable handling or storage, has picked up moisture, redrying can return the flux to its original state regarding moisture.

Redrying shall be performed as follows:

Agglomerated fluxes : 300 +/- 25°C for about 2-4 hours.

Redrying must be done on shallow plates with a flux height not exceeding 50 mm. Redried flux, not immediately used, must be kept at 150 +/- 25°C before use.

## HANDWELDING ELECTRODES

### Official approval

In addition to the official approval given in this catalogue, many electrodes are approved by shipping societies, Defence authorities, railway boards, private companies and so on. Information about the different types of approval is available on request.

### Tensile properties

Unless otherwise stated, tensile properties refer to all weld metal test pieces prepared according to the rules of the classification societies using 4 and 5 mm diameter electrodes.

### Welding current

Maximum and minimum values are given. The most suitable welding current depends largely on the size of the workpiece, the welding position and the type of joint.

Small workpieces require a lower current, larger workpieces a higher current, depending on the dissipation of heat from the joint.

### Cold cracking

Cold cracking will only occur if the following three factors are present at the same time:

1. Hard phases in the weld, preferably martensite
2. Sufficient stress
3. Hydrogen dissolved in the weld metal

Hard phases form when the weld is cooled rapidly from from melting temperature to room temperature. Alloying elements, mostly carbon, are forced to dissolve in the weld metal and make it brittle. The following formula describes this process in the case of standard carbon - manganese steel:-

$$E_c = \%C + \frac{\%Mn}{6} + \frac{\%(Cr+Mo+V)}{5} + \frac{\%(Ni+Cu)}{15}$$

Steels with  $E_c=0.35$  and below are usually weldable without any problems at normal steel sizes. For the more highly alloyed steels and steels with thicker dimensions, an elevated working temperature is necessary in order to reduce the cooling rate.

The elevated temperature also allows the hydrogen to diffuse.

To determine elevated working temperatures, please

consult BS 5135: 1984 or SS 064025. If the  $E_c$  dimension of the plates and heat input are known, these standards will state whether heating is necessary and the level at which it should take place.

Tension cannot be avoided when welding, as steel expands when heated, although correct planning and heat treatment can reduce tension considerably.

Hydrogen forms from water in the surroundings and from the electrode coating. The water is divided into oxygen and hydrogen in the arc and the hydrogen in particular has a strong tendency to dissolve in the weld metal and initiate cold cracking.

Conclusion : Dry basic electrodes when there is risk of cold cracking.

### Labelling

The electrode type is clearly marked on the coating of each electrode near the grip end, e.g. ESAB 36H.



## GENERAL INFORMATION

### Choice of suitable electrode

The electrodes in this catalogue are placed into groups according to the type of alloy deposited. Within each group of electrodes for welding mild, low-alloy and stainless steels, there are several cases in which many different electrodes are designed for welding the same type of steel. So, for each steel grade, there are often a large number of electrode types to choose from, all of which produce similar weld metal compositions but have different coatings, welding properties, welding speeds and weld metal quality. This large choice makes it possible to choose the electrode which produces the right weld metal quality at the lowest cost.

When selecting an electrode, the first rule is to select one which produces a weld metal quality equal to or better than that of the base material and, when necessary, is approved for the material in question. Welding position and type of joint are other factors which influence the choice of electrode, as different welding positions and types of joint.

### General information about the influence of coating type on welding properties, welding speed and weld metal quality

Rutile electrodes giving about 100% weld metal recovery are easy to strike and use and are particularly suitable for short welds in mild steel, for fillet welds, for welding sheet steels and for bridging large joint gaps. The welds have a fine finish and spatter losses are negligible. The welding speed is moderate.

### Unalloyed electrodes

Unalloyed rutile electrodes are not normally recommended for welding steel with a nominal tensile strength exceeding 440 MPa (45 kg/mm<sup>2</sup>). Rutile electrodes are relatively insensitive to moisture.

### High-efficiency rutile electrodes

High-efficiency rutile electrodes generally produce a higher welding speed, which increases as the weld metal recovery increases. Eg. ESAB C235.

They are all easy to use, produce excellent slag detachability, fine bead appearance and are particularly suitable for welding horizontal/vertical fillets. The weld metal has tensile properties which are as high as, or somewhat higher than, those of the weld metal from unalloyed basic electrodes but have lower elongation and impact strength.

The evenness of the weld and the smooth transition of the base material make joints produced with rutile electrodes at least as good in terms of fatigue strength as unmachined joints produced with rutile electrodes at least as good in terms of fatigue strength as unmachined joints produced using basic electrodes. Unalloyed rutile electrodes, irrespective of their efficiency, can be recommended for welding mild steel with a nominal tensile strength of 440 MPa (45 kg/mm<sup>2</sup>). When it comes to the tensile strength of the deposit, rutile electrodes can also be used for welding steels with a nominal tensile strength of more than 440 MPa (45 kg/mm<sup>2</sup>), but, as a general rule, only electrodes producing a weld metal with a low hydrogen content, e.g. basic, rutile basic or zircon-basic electrodes, should be used to weld these steels.

### Unalloyed basic electrodes

Unalloyed basic electrodes give moderate welding speed in the flat position but are faster than other types when welding vertically upwards. The reason for this is that basic electrodes can be deposited at a higher current in the vertical position than other types of electrode. In addition, the amount of weld metal deposited per electrode is greater than that of other electrodes which can be used in this position. This results in a smaller number of electrode changes. The normal result is therefore a higher fusion rate and higher arctime factor when welding vertically upwards with basic electrodes compared with other types.

The slag is normally not quite as easy to remove as the slag from acid or rutile electrodes, but, in spite of this, it can be classed as easily detachable. The slag from basic electrodes has a lower melting point than that from rutile or acid electrodes. The risk of slag inclusions during normal production welding is therefore unusually small when basic electrodes are used, even if the slag is not completely removed between beads during multi-run welding.

The weld metal from basic electrodes has a low hydrogen content and usually has good toughness even at low temperatures. Basic electrodes are less likely to produce either hot cracks or cold cracks compared with other types of electrode. The superiority of basic electrodes from this point of view appears when welding manganese alloyed structural steels, pressure-vessel steels and ship's plate with a nominal tensile strength of 490-530 MPa (50-54 kg/mm<sup>2</sup>). The higher the hardenability of the steel to be welded, the greater the necessity to use basic electrodes and the greater the need for low moisture content in the coating.

### **Cellulose electrodes**

Cellulose electrodes are easy to use in all welding positions and are particularly good for vertical and overhead welding. Cellulose electrodes are recommended for all-positional welding where the mechanical properties of the deposit are of the greatest importance and radiographic requirements must be met. Vertical and overhead welding often require an electrode one size larger in comparison to electrodes with other types of coating. Cellulose electrodes are extremely good for vertical-down welding.

Higher tensile steel requires preheating and higher interpass temperatures than when the welding is done with low-hydrogen electrodes.



## Approval in accordance with classification society rules

Welding materials are normally classified by ESAB in accordance with a standard, e.g. AWS and EN. To verify mechanical properties they are also approved in accordance with the rules of the classification societies.

### Classification

The Classification of welding products refers to standards and, when a welding product is classified, its type, properties and field of application are given. The manufacturer verifies the correct classification of a product by internal testing and / or by witness of an outside organisation.

### Approval

Shipowners and partners in offshore enterprises require welding consumables to be approved in accordance with the rules of the classification societies. Approval is also required by clients in accordance with national or international standards for boiler and pressure vessels as well as other standards to be verified by an authorized approval institute.

Approved welding products are entered on the "List of Approved Welding Consumables: distributed annually by the societies and other institutes.

This catalogue provides information about the welding position, current/polarity, low hydrogen and grading.

### Non-alloyed and low-alloyed steels

Consumables are divided into three categories based on their tensile strength level:

Normal strength steel : Indicated by the numbers 1, 2 or 3 (e.g. 3.3M) that the electrode is to be used in steel with a minimum yield strength (ReH) of 305 and a tensile strength (Rm) of 400-560 MPa.

High strength Steel : Indicated by 2Y, 3Y, 4Y, 5Y (ReH min 375 and Rm 490-660 MPa) and 2Y40, 3Y40, 4Y40 (ReH min 400 and Rm 510-690 MPa)

Extra high strength steel : Indicated by 3Y42, 4Y42, 5Y42 up to 5Y69 and so on for the different strength steel categories, where the numbers 42...69 symbolize a yield strength in MPa indicating that the electrodes can be used for extra high tensile steels.

### Toughness level

Each steel category is divided into three to five toughness levels represented by the first digit in the grade (1, 2, 3, 4 or 5)

- 1 suitable for grade A steel (impact tested at 20°C)
- 2 suitable for grade A, B and C steels (impact tested at 0°C)
- 3 suitable for grade A, B, D and E steels (impact tested at -20°C)
- 4 suitable for grade A, B, D, E and F steels (impact tested at -40°C)
- 5 suitable for grades A, B, D, E and F steels (impact tested at -60°C)

Other frequently used abbreviations

<b>T</b>	two-run welding (submerged arc welded with one run from each side)
<b>M</b>	multi-run welding (submerged arc or automatic gas-shielded arc welding)
<b>S</b>	semi-automatic, gas-shielded and flux - flux - cored arc welding
<b>H5, H10, H15</b>	low - hydrogen welding consumables
<b>DP</b>	deep penetration

### Stainless steel and other high-content alloyed steels

Grades of stainless steel for which the welding consumable is approved are indicated with respect to one or more of the types of stainless steels : 304L, 304LN, 316LN and so on.





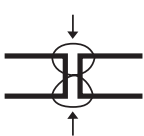
The abbreviation SS/CMn indicates approval for joining any of the austenitic types of stainless steel to any of the normal strength or higher tensile ship steels. Dup/CMn indicates approval for joining any of the duplex types of stainless steel to any of the normal strength or higher tensile ship steels.

The system described for grading the consumables in accordance with the rules of the classification societies changes as new steels appear on the market and sometimes there are changes to the approval ratings which might mean that the handbook may not be currently up-to date. To ensure that valid information is used, please request the latest issued Product Data Sheet for the consumables and / or the latest edition of the "List of Approved Consumables" and approval certificates from the most recent annual repeat test.

## Calculation of electrode consumption

In the tables, joint cross section, theoretical joint volume and kg weld metal per metre length of welded joint are given. The electrode consumption per metre of welded joint is obtained by dividing the number of kg of weld metal by N, where N is the kg of weld metal per kg of electrode and is given for each electrode on their respective pages.

### Square butt joints: Joint volumes and weld metal weights

Position	Plate thickness mm	Gap mm	Volume/length cm <sup>3</sup> /m	Weight/length weld metal kg/m
 Flat	1	0	2	0.02
	1.5	0.5	3	0.02
	2	1	4	0.03
	3	1.5	7	0.05
 Flat	4	2	17	0.13
	5	2	21	0.16
	6	2.5	27	0.21
	7	3	36	0.28
 Horizontal-Vertical	1	0	2.5	0.02
	1.5	0.5	4	0.03
	2	1	5	0.04
	3	1.5	9.5	0.07
 Horizontal-Vertical	4	2	22	0.17
	5	2.5	25	0.20
	6	3	32	0.25
	7	3	42	0.33
 Overhead	4	2	9	0.07
	5	2	10.5	0.08
	6	2.5	13	0.10
	7	3	16	0.13
	4	2	10.5	0.08
	5	2	16	0.13
	6	2.5	18	0.14
	7	3	21	0.16

## Calculation of electrode consumption Single V-joints: volumes and weld metal weights

Plate thickness mm	Gap mm	50° Flat			60° Flat			70° Vertical			80° Overhead			60° Horizontal-Vertical		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
4	1	11.5	11	0.09	13	12.5	0.10	15	16.5	0.13	17.5	18	0.14	13	14.5	0.11
5	1	16.5	16	0.13	19.5	19	0.15	22.5	24.5	0.19	26	28	0.22	19.5	21	0.16
6	1	23	21.5	0.17	27	25.5	0.20	31	37	0.29	36	38.5	0.30	27	30	0.24
7	1.5	33.5	32.5	0.26	39	38	0.30	45	49	0.38	51.5	56	0.44	39	42	0.33
8	1.5	42	40	0.31	49	46.5	0.37	57	59.5	0.47	65.5	70	0.55	49	56	0.44
9	1.5	51	48	0.38	60.5	56	0.44	70	75.5	0.59	81.5	87.5	0.69	60.5	65	0.51
10	2	66.5	62	0.49	77.5	72	0.57	90	96.5	0.76	104	109	0.86	77.5	81	0.64
11	2	78.5	71.5	0.56	92	83.5	0.66	107	113	0.89	124	130	1.02	92	96.5	0.76
12	2	91	83	0.65	107	97.5	0.77	125	134	1.05	145	157	1.23	107	113	0.89
14	2	120	110	0.86	141	130	1.02	165	171	1.34	193	204	1.60	141	159	1.17
15	2	135	123	0.97	160	146	1.15	188	197	1.55	219	231	1.81	160	171	1.34
16	2	151	132	1.04	180	157	1.23	211	223	1.75	247	257	2.02	180	186	1.46
18	2	189	170	1.33	223	204	1.60	263	276	2.17	308	320	2.51	223	233	1.83
20	2	227	208	1.63	271	247	1.94	320	334	2.62	376	396	3.11	271	281	2.21
25	2	341	313	2.46	411	375	2.94	488	510	4.00	577	606	4.76	411	425	3.34

1 Theoretical volume  $\text{cm}^3/\text{m}$

2 Actual joint volume  $\text{cm}^3/\text{m}$  (taking account of transverse shrinkage)


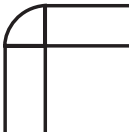


3 Deposited weld metal  $\text{kg}/\text{m}$

## The first run and backing run V-joints: Weld metal weights

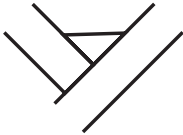
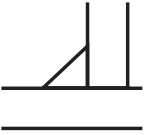


Position	Plate thickness mm	Weight/length $\text{kg}/\text{m}$	Electrode diam mm
Flat	6–12	0.10	3.25
Flat	> 12	0.15	4
Vertical	> 8	0.15	3.25
Horizontal-Vertical	> 8	0.15	3.25
Overhead	> 10	0.10	3.25

## Calculation of electrode consumption

### Corner welds: Actual joint volumes and weld metal weights

Plate thickness	Section size								
		mm	mm <sup>2</sup>	cm <sup>3</sup> /m	kg/m	cm <sup>3</sup> /m	kg/m	cm <sup>3</sup> /m	kg/m
2	2	3.5	0.03	3	0.02	3.5	0.03	3.5	0.03
3	4.5	7	0.05	7	0.05	7	0.05	7.5	0.06
4	8	9	0.07	9	0.07	9.5	0.07	10.5	0.08
5	12.5	13	0.10	13.5	0.11	14.5	0.11	16	0.13
6	18	18.5	0.15	19.5	0.15	21	0.16	22	0.17
7	24.5	25.5	0.20	26.5	0.21	27.5	0.22	31.5	0.25
8	32	33	0.26	34.5	0.27	36	0.28	40.5	0.32
9	40.5	41.5	0.33	43	0.34	45.5	0.36	51	0.40
10	50	51.5	0.40	53.5	0.42	56	0.44	64	0.50
11	60.5	63	0.49	67	0.53	72	0.57	78.5	0.62
12	72	74.5	0.58	79	0.62	84.5	0.66	93	0.73
15	113	116	0.91	123	0.97	132	1.04	141	1.11
18	162	167	0.31	174	1.37	190	1.49	204	1.60
20	200	206	1.62	206	1.62	227	1.78	252	1.98
22	242	248	1.95	255	2.00	275	2.16	204	2.39
25	323	329	2.58	331	2.60	370	2.90	405	3.18

### Fillet welds: Actual joint volumes and weld metal weights

Throat thickness	Section size								
		mm	mm <sup>2</sup>	cm <sup>3</sup> /m	kg/m	cm <sup>3</sup> /m	kg/m	cm <sup>3</sup> /m	kg/m
2	4	5	0.04	6	0.05	5.5	0.04	5.5	0.04
2.5	6.5	7.5	0.06	8.5	0.07	8	0.06	8.5	0.07
3	9	10.5	0.08	12.5	0.10	11	0.09	12	0.09
3.5	12.5	14	0.11	16	0.13	15	0.12	16.5	0.13
4	16	18	0.14	21	0.16	19.5	0.15	22	0.17
4.5	20.5	22.5	0.18	26	0.20	24.5	0.19	26.5	0.21
5	25	27.5	0.22	31.5	0.25	30.5	0.24	33	0.26
5.5	30.5	33.5	0.26	37	0.29	36	0.28	40.5	0.32
6	36	40	0.31	42	0.33	43	0.34	47.5	0.37
6.5	42.5	46.5	0.37	49.5	0.39	51	0.40	56	0.44
7	49	54.5	0.43	57	0.45	56	0.44	65	0.51
7.5	56.5	60.5	0.47	65	0.51	64	0.50	73.5	0.58
8	64	70	0.55	73.5	0.58	76.5	0.60	82.5	0.65
9	81	88	0.69	94	0.74	95	0.75	109	0.86
10	100	108	0.85	114	0.89	116	0.91	130	1.02
11	121	131	1.03	138	1.08	143	1.12	157	1.23
12	144	155	1.22	162	1.27	169	1.33	188	1.48
13	169	179	1.41	190	1.49	195	1.53	220	1.73
14	196	207	1.62	224	1.76	227	1.78	257	2.02
15	225	237	1.86	248	1.95	264	2.07	294	2.31



The weight of welding electrodes or welding wire necessary to complete a given weld joint may be calculated by the formula:

$$P = \frac{WL}{E}$$

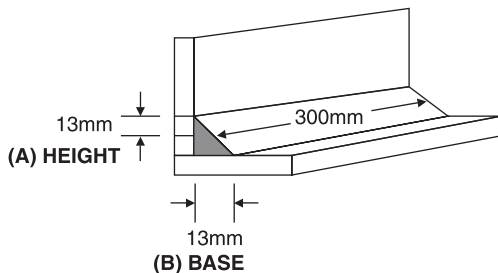
- P = Weight of electrode or wire required
- W = Weight per unit length of weldmetal
- L = Length of weld (meter)
- E = Deposition efficiency

### WEIGHT PER UNIT LENGTH OF WELDMETAL

Calculating the weight of weldmetal requires than we consider the following items.

1. Area of cross-section of the weld
2. Length of the weld
3. Volume of the weld in cubic centimetre
4. Weight of the weldmetal per cubic centimetre

The area of the cross-section (the triangle) in the fillet weld shown below is equal to one half the base times the height. The volume of the weld is equal to the area times the length, and the weight of the weld then, is the volume times the weight of the material (steel) per cubic centimetre.



This example is for a fillet weld with no reinforcement. Similar calculations can be made for butt or lap joint. The table on following pages lists the weight per metre of fillet and the more common butt joints.

### DEPOSITION EFFICIENCY

The deposition efficiency of an electrode or welding wire indicates the portion of that product you can expect to be deposited as weldmetal. Losses due to slag, spatter, fume and in the case of semi automatic or automatic welding processes, the ends cut before each weld and the wire left in the feed cable make no process 100% efficient.

For estimates of electrode or wire consumption, the following average values of deposition efficiency may be used.

PROCESS	DEPOSITION EFFICIENCY
Submerged Arc	99%
Gas Metal Arc (98% Ar, 2% O <sub>2</sub> )	98%
Gas Metal Arc (75%Ar, 25% CO <sub>2</sub> )	96%
Gas Metal Arc (CO <sub>2</sub> )	93%
Metal Cored Wires	93%
Gas Shielded Flux Cored Wires	85%
Self Shielded Flux Cored Wires	82%
* Shielded Metal Arc (Stick 300 mm long)	59%
* Shielded Metal Arc (Stick 350 mm long)	62%
* Shielded Metal Arc (Stick 450 mm long)	66%

\* Includes 2" stub loss.

It must be remembered that when deposition tests are performed in the laboratory, the deposition efficiency is calculated by the formula:

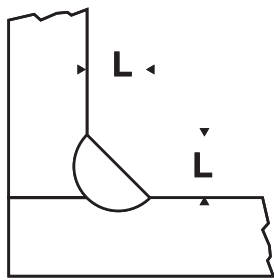
$$\text{Deposition Efficiency} = \frac{\text{Weight of metal deposited}}{\text{Weight of electrode consumed}}$$

This does not take stub loss into consideration. The chart below shows how the length of the stub effects the laboratory-established efficiency.

### STUB LOSS CORRECTION TABLE FOR COATED ELECTRODES

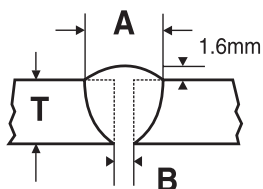
	Deposition Efficiency	50mm STUB	75mm STUB	100 mm STUB	125mm STUB
300 mm ELECTRODE	60%	50.00%	45.00%	40.00%	35.00%
	65%	54.20%	46.70%	43.30%	37.90%
	70%	58.30%	52.50%	46.60%	40.80%
	75%	62.50%	56.20%	50.00%	43.70%
350 mm ELECTRODE	60%	51.40%	47.10%	42.90%	38.30%
	65%	55.70%	51.1 0%	46.40%	41.00%
	70%	60.00%	55.00%	50.00%	45.00%
	75%	64.30%	56.90%	53.60%	46.20%
450 mm ELECTRODE	60%	53.30%	50.00%	46.60%	43.30%
	65%	57.70%	54.20%	50.50%	46.90%
	70%	62.20%	56.30%	54.40%	50.50%
	75%	66.60%	62.50%	56.30%	54.20%
	80%	71.10%	66.60%	62.20%	57.70%

The following tables show the estimated weight of consumables for some of the common weld joints.



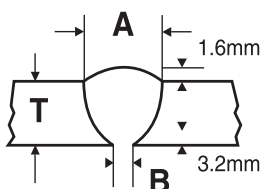
Horizontal Fillet Weld

Fillet Size L (mm)	Weldmetal Required Kg/m	Weight of electrode/Wire required per unit length of weld (Kg/m)			
		SMAW	GMAW	FCAW	Metal Cored
3	0.04	0.06	0.04	0.05	0.04
5	0.09	0.15	0.10	0.11	0.10
6	0.16	0.26	0.17	0.19	0.17
8	0.25	0.40	0.26	0.29	0.27
10	0.36	0.58	0.38	0.43	0.39
13	0.64	1.04	0.67	0.76	0.70
16	1.00	1.62	1.06	1.18	1.09
19	1.44	2.33	1.53	1.70	1.57
25	2.56	4.14	2.70	3.02	2.79



Square Butt Joint

Joint Dimensions (mm)			Weldmetal Required kg/m	Stick Electrode Required kg/m
T	B	A		
5	1.5	10	0.14	0.22
6	1.5	11	0.17	0.28
	2.5		0.21	0.34
8	1.5	13	0.20	0.33
	2.5		0.25	0.40



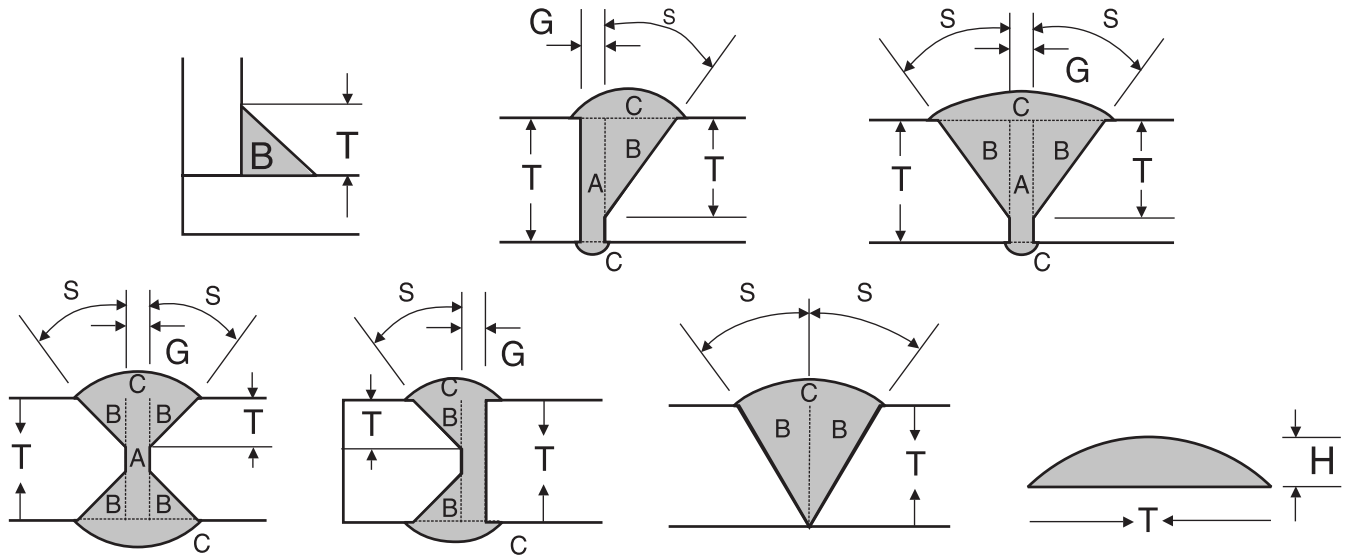
Single - V Butt Joint

Joint Dimensions (mm)			Weldmetal Required kg/m	Stick Electrode Required kg/m
T	B	A		
6	2.0	8	0.19	0.31
8	2.5	10	0.34	0.54
10	3	13	0.53	0.86
13	3	16	0.80	1.27
16	3	21	1.31	2.12
19	3	24	1.84	2.96
25	3.2	32	3.18	5.12

## WEIGHT PER METER OF WELDMETAL FOR FILLET WELDS AND ELEMENTS OF COMMON BUTT JOINTS KG! M STEEL

### INSTRUCTION

1. Make a drawing of the cross-section of the joint to exact scale.
2. Divide the cross-section into right triangles, rectangles and sketch in the desired reinforcement.
3. Dimension the thickness, angles, angle leg length, root opening and the length and height of the reinforcement.
4. Total the weight per meter of each of the elements from the chart for the weight per meter of the weld.



ANGLE 'V' JOINT - 60° Included Angle 'V'

FILLET WELD

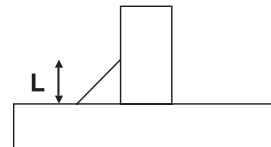
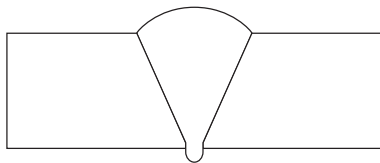


PLATE THK Mm	ROOT GAP mm	THEORETICAL VOLUME mm	Weld cm3/m	WEIGHT WELD METAUm kg/m
4	1	13	12.5	0.1
5	1	19.5	19	0.15
6	1	27	25.5	0.2
7	1.5	39	38	0.3
8	1.5	49	46.5	0.37
9	1.5	60.5	56	0.44
10	2	77.5	72	0.57
11	2	92	83.5	0.66
12	2	107	97.5	0.77
14	2	141	130	1.02
15	2	160	146	1.15
16	2	180	157	1.23
18	2	223	204	1.6
20	2	271	247	1.94
25	2	411	375	2.94

FILLET SIZE mm	THEORETICAL WELD VOLUME cm3/m		WEIGHT WELD METAUm kg/m	
	L	T	L	T
2		6.0		0.05
3	4.5	12.5	0.036	0.10
4	8.0	21.0	0.064	0.16
6	18.0	42.0	0.142	0.33
8	32.0	73.0	0.252	0.58
10	50.0	114.0	0.394	0.89
12	72.0	162.0	0.567	1.27
15	112.0	248.0	0.887	1.85
18	162.0		1.277	
20	200.0		1.576	
25	312.5		2.463	

The figures above are for accurate weld volumes of exact dimensions. In practice it is difficult to obtain mitre shaped fillet welds, actual welds are generally convex in profile and an allowance of approximately 15% should be made when calculating consumable requirements.

T mm	Weight of rectangle A G						Weight/m Triangle B S						Weight/m Reinforcement C			
	1.5	3	5	6	10	13	5	10	15	22 1/2	30	45	2	3	5	6
3	0.04	0.08	0.12	0.16	0.24	0.32	0.00	0.01	0.01	0.02	0.02	0.04	-	-	-	-
5	0.06	0.12	0.18	0.24	0.36	0.48	0.01	0.02	0.02	0.04	0.05	0.09	0.04	-	-	-
6	0.08	0.16	0.24	0.32	0.48	0.64	0.01	0.03	0.04	0.07	0.09	0.16	0.05	0.00	-	-
8	0.10	0.20	0.30	0.40	0.59	0.80	0.02	0.04	0.07	0.10	0.14	0.25	0.07	1.33	-	-
10	0.12	0.24	0.36	0.48	0.72	0.96	0.03	0.06	0.10	0.15	0.21	0.36	0.08	0.16	-	-
11	0.14	0.28	0.42	0.56	0.84	1.12	0.04	0.09	0.13	0.19	0.28	0.49	0.09	0.19	-	-
13	0.16	0.32	0.48	0.64	0.96	1.28	0.06	0.11	0.17	0.26	0.37	0.64	0.11	0.21	0.32	-
14	0.18	0.36	0.54	0.72	1.08	1.44	0.07	0.14	0.22	0.33	0.47	0.68	0.12	0.24	0.36	-
16	0.20	0.40	0.60	0.80	1.20	1.60	0.09	0.18	0.27	0.41	0.58	1.00	0.13	0.27	0.40	0.53
17	0.22	0.44	0.66	0.88	1.32	1.76	0.11	0.21	0.32	0.49	0.70	1.21	0.15	0.29	0.44	0.59
19	0.24	0.48	0.72	0.94	1.50	1.92	0.13	0.26	0.39	0.59	0.83	1.44	0.16	0.32	0.48	0.64
21	0.26	0.52	0.78	1.04	2.04	2.08	0.15	0.30	0.45	0.69	0.98	1.68	0.17	0.35	0.52	0.69
22	0.28	0.56	0.84	1.12	1.68	2.24	0.17	0.35	0.53	0.81	1.13	1.96	0.19	0.37	0.56	0.75
24	0.30	0.60	0.90	1.20	1.80	2.40	0.20	0.40	0.60	0.93	1.30	2.25	0.20	0.40	0.60	0.80
25	0.32	0.64	0.96	1.28	1.92	2.56	0.22	0.45	0.69	1.06	1.48	2.56	0.21	0.43	0.64	0.85
29	0.36	0.72	1.08	1.44	2.16	2.88	0.28	0.57	0.87	1.34	1.87	3.24	0.24	0.48	0.72	0.96
32	0.40	0.80	1.20	1.60	2.40	3.21	0.35	0.71	1.08	1.66	2.31	4.01	0.7	0.53	0.80	1.07
35	0.44	0.88	1.32	1.76	2.64	3.53	0.42	0.86	1.3	2.01	2.80	4.85	0.29	0.59	0.88	1.17
38	0.48	0.96	1.44	1.92	2.88	3.85	0.50	1.02	1.54	2.39	3.33	5.77	0.32	0.64	0.96	1.28
41	0.52	1.04	1.56	2.08	3.12	4.17	0.59	1.20	1.71	2.80	3.91	6.77	0.35	0.69	1.04	1.39
44	0.56	1.12	1.72	2.24	3.37	4.49	0.67	1.39	2.10	3.25	4.53	7.85	0.37	0.75	1.12	1.49
48	0.59	1.20	1.80	2.40	3.61	4.81	0.79	1.59	2.41	3.73	5.20	9.01	0.40	0.80	1.13	1.60
51	0.64	1.28	1.92	2.56	3.85	5.13	0.90	1.81	2.75	4.25	5.92	10.26	0.43	0.85	1.28	1.71
57	0.72	1.44	2.16	2.88	4.33	5.77	1.14	2.29	3.48	5.38	7.49	12.98	0.48	0.96	1.44	1.92
64	0.80	1.60	2.40	3.21	4.81	6.41	1.40	2.83	4.29	6.64	9.25	16.3	0.53	1.07	1.60	2.14
70	0.88	1.76	2.64	3.53	5.29	7.05	1.70	3.42	5.20	7.76	11.20	19.39	0.59	1.17	1.76	2.35
76	0.96	1.93	2.88	3.85	5.77	7.69	2.02	4.07	6.18	9.56	13.32	23.08	0.64	1.28	1.92	2.56



## DATA SHEETS - PIPE WELDING

### ESAB Pipe Welding Electrodes

The following electrodes are specially designed for pipeWeldin

Designation	AWS classification	For line pipe steels API 5 LX
Pipeweld 6010	E 6010	X42,X46
Pipeweld 6010	E 6010	X42,X46
OK 22.46 P	E 7010	X46,X52,X56
OK 22.47 P	E 8010-G	X60,X65

Pipeweld 6010 is ideally suited for root bead welding. The welding technique, i.e. the use of Pipeweld 6010 for the root bead and also in some cases for the hot pass, together with a high strength electrode for the other passes, gives maximum resistance to cracking.

The practical technique is described in detail in the following pages.

### Joint Preparation

Careful joint preparation, as shown in fig.1, is of utmost importance to achieve a perfect weld. With flame-cut edges the required tolerance are in general not obtained, so it has become common practice to machine the pipe ends. To avoid porosity and lack of fusion the weld faces must be free from foreign matter, such as oil, grease, mill scale, dirt and other destructive material.

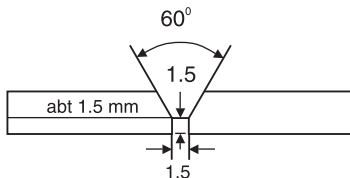
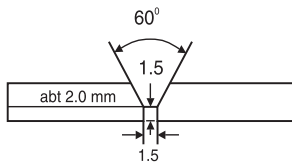


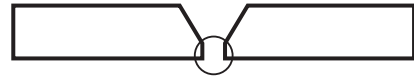
Fig. 1 Recommended joint preparation for pipe diameters up To 300 mm. Pipeweld 6010, 3.20 mm dia. for root bead.



For pipe diameters larger than 300 mm. Electrode Pipeweld 6010, 3.20 or 4 mm dia. for root beads.

### Welding Procedure and Technique

The following schedule shows the range of application for all the electrode grades indicated. Selection of these electrodes depends on the line pipe steel grade used.



Root pass Pipeweld 6010 3.20 or 4 mm dia.



Filler passes  
Pipeweld 6010  
OK 22.46 P  
OK 22.47 P  
4 or 5 mm dia.



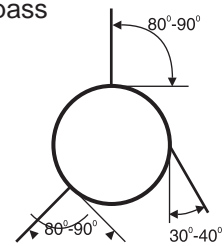
Hot pass Citoflex  
OK 22.46 P  
OK 22.47 P  
4 or 5 mm dia.



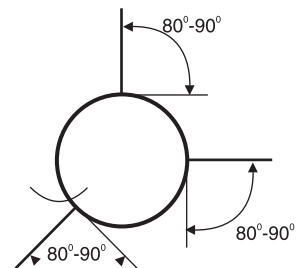
Capping pass  
Pipeweld 6010  
OK 22.46 P  
OK 22.47 P  
4 or 5 mm dia.

### ESAB Pipe Welding Electrodes

Welding the hot pass



Welding the root bead, filler And capping passes



### Line Pipe Steel Grades

The most common steels used for oil and gas cross-country pipelines conforming to API 5 L, 5 LS, and 5 LX.

Table 1, shows the chemical requirements to API Standard 5 LX for the individual line pipe steel grades. Chemistry of the pipe material is an important consideration prior to welding; otherwise difficulties may be experienced on high strength pipe material from the high carbon and manganese contents, particularly in cold weather. It is therefore advisable, depending on the surrounding temperature and weather conditions, to pre-heat the entire pipe circumference before applying the stringer bead.

Table 2, Shows the physical requirements to API 5 LX.

### Composition and characteristics of cellulose pipeline electrodes

Cellulose electrodes contain a high amount of organic material; about 35% of the coating consist of cellulose powder, which in the arc is transformed into a shielding gas at high pressure. This results in a fierce, concentrated arc giving deep penetration. This is one of the reasons why cellulose pipeline electrodes - even in large electrode diameters - can be used for vertical down welding with excellent results.

### Welding current ranges (DC positive or negative)

ESAB Designation	AWS Classification	Electrode diameters (mm) and currents (amp)		
		3.25	4.0	5.0
Pipeweld 6010	A5.1:E 6010	50-150	120-200	160-250
OK 22.46 P	A5.1:E 7010-G	50-150	120-200	160-250
OK 22.47 P	A5.1 :E 8010-G	50-150	120-200	160-250

### Selecting the correct electrodes for API 5 LX steels

Esab Pipe Welding Electrode									
API 5 LX Grade	Pipeweld 6010			OK 22.46 P			OK 22.47 P		
	root bead	hot pass	filler and cover	root bead	hot pass cover	filler and	root bead cover	hot pass	filler and
X42	X	X	X						
X46	X	X	X						
X52	X	X		X	X	X			
X56	X	X		X	X	X			
X60	X	X		X	X	X		X	X
X65	X	X						X	X
X70	X	X						X	X

**Table 1: Chemical requirements**

API 5 LX Grade	Ladle analysis %					
	Cmax.	Si	Mn	Nbmin.	Vmin.	Ti
X42	0.28	-	<1.25	-	-	-
X46	0.28	-	<1.25	-	-	-
X52	0.28	-	<1.25	-	-	-
X56	0.26	-	<1.35	0.005	0.02	0.03
X60	0.26	-	<1.350	.005	0.02	0.03
X65	0.26	-	<1.35	0.005	0.02	-
X70	0.23	-	<1.60	-	-	-

**Table 2: Physical requirements**

API 5 LX Grade	Yield stress min. N/mm <sup>2</sup> (PSi)	Tensile strength min. (psi) N/mm <sup>2</sup> (psi)	Elongation min.%
X42	290 (42)	410 (60)	25
X46	315 (63)	430 (63)	23
X52	360 (66)	450 (66)	22
X56	385 (56)	490 (71)	22
X60	415 (60)	520 (74)	22
X65	450 (65)	550 (77)	20
X70	485 (70)	580 (85)	20



## General recommendations

### GMAW

#### GMAW - Gas Metal Arc Welding

The electrodes and joint faces should be clean. This is particularly important when welding aluminium and aluminium alloys. The shielding gasses which are used must be of a purity suitable for welding. Moisture in the gas can produce porous welds.

#### Shielding gas for mild and low-alloy steels

Carbon dioxide, CO<sub>2</sub>, is the cheapest and most commonly used gas and, in most cases, it produces satisfactory welds in both mild and low alloy steel.

Mixed gas, of which the most commonly used consists of 80% Ar + 20% CO<sub>2</sub>, is clearer than pure CO<sub>2</sub> but produces a softer arc, quieter welding, better bead appearance and less spatter. It is therefore often used, in spite of its higher price, for welding sheet steel 0.8-1.5 mm thick, which is more difficult to weld with pure CO<sub>2</sub>. A further advantage of mixed gas is the higher quality, in particular notch toughness, compared with CO<sub>2</sub>. For this reason, mixed gas is often recommended for welding low-alloy steels, such as creep-resistant steels, even in thicknesses greater than 1.5 mm. Mixed gas of the 80/20 type, in which the argon is of a lower purity, is also available. These gases are less expensive than those based on pure argon and can often be used with equally good results.

One drawback of argon/CO<sub>2</sub> mixtures is that they lead to increased ozone formation, compared with pure CO<sub>2</sub>, when used as shielding gas in arc welding.

Another drawback when using the mixture is that the current load capacity of the welding gun is reduced by about 30% compared with welding with CO<sub>2</sub>.

#### Shielding gas for stainless and heat resistant steels

Argon containing 1% oxygen is normally used for welding stainless and heat-resistant steels, but argon containing 2% O<sub>2</sub> or 5% O<sub>2</sub> is also available. The latter produces a more fluid weld pool. A shielding gas which consists of 98% argon + 2% CO<sub>2</sub> has gained favour for MIG welding stainless steels. It can often replace argon/helium mixtures, which are used to help fusion when welding thick stainless steel, and can very often replace argon/oxygen mixtures.

## Choice of welding Process

#### Short arc or spray arc

The electrodes for gas metal arc welding listed in these pages are suitable for short arc welding in the smallest diameters and for spray arc welding in diameters 1.2-2.4 mm. Short arc welding (welding with short circuiting droplet transfer) can be carried out in all positions and is the best process for welding sheet material approximately 0.8-3 mm thick and for making the root run in prepared butt joints.

Spray arc welding (welding with finely divided free flight drop transfer) is carried out at higher currents and voltages than short arc welding and is therefore generally faster and more economical than short arc welding for plate thicknesses exceeding 2 - 3 mm. It is only used for welding in the horizontal or horizontal/vertical positions. The gas consumption is 6-10 litres/min for short arc welding and 12-20 litres/min for spray arc welding. The higher the welding current, the higher the gas flow required.

#### Welding technique

The welding gun is normally held in the right hand, which means that the weld is made from right to left with the gun directed away from the deposited weld at an angle of 75-80° between the electrode and the workpiece, thereby giving the operator a good view of the weld pool and the joint. This produces a smoother weld bead than if the gun is directed towards the finished weld.

#### Abbreviations

MIG welding = metal inert gas welding = metal arc welding in an atmosphere consisting mainly of an inert gas such as argon.

MAG welding = metal inert gas welding = metal arc welding in an atmosphere consisting mainly of an inert gas such as argon.

MAG welding = metal active gas welding = metal arc welding in an atmosphere consisting of an active gas, usually carbon dioxide. Gas mixtures containing 20% or more CO<sub>2</sub> are usually classified as active.

## DATA SHEET - GTAW/GMAW

### Solid wire classification for GTAW/GMAW

Indicates in 1000 PSi increments the minimum tensile strength of the weldmetal produced by the electrode when tested acco-diy to A5.18 specification. In this case 70 indicate 70,000 PSi.

**ER 70 S - X**

E indicates a filler wire/rod

Indicates chemical compisition (%) of Solid electrode indicates that the filler metal is solid

X	C	Mn	Si	S	P	Ti	Zr	Al	Cu
2	0.07	0.90 /1.40	0.40 /0.70	0.035	0.025	0.05 -0.15	0.02 -0.12	0.05 -0.5	0.5
3	0.06 /0.15	0.90 /1.40	0.45 /0.75	0.035	0.025	-	-	-	0.5
4	0.06 /0.15	1.00 /1.50	0.65 /0.85	0.035	0.025	-	-	-	0.5
6	0.06 /0.15	1.40 /1.85	0.80 /1.15	0.35	0.25	-	-	-	0.5
7	0.07 /0.15	1.50 /2.00	0.50 /0.80	0.35	0.25	-	-	-	0.5
G	Chemical Compositions are not specified, however requirements shall be agreed to by the purchase & supply.								

Note : Cr, Ni & Mo content not to exceed 0.15 each.

# GENERAL RECOMMENDATIONS

## DATA SHEET - GTAW/GMAW

### Introduction

In recent years, pressure to increase productivity and reduce costs has been the main driving force behind the adoption of flux cored wires by fabricators. Productivity, ease of use and quality are the three main virtues on which the increasing popularity of Flux cored wires rest.

The welding processes with which flux cored wire must mainly compete are MMAW and semi automatic welding with solid wire (MIG/MAG). The superior productivity and the accompanying improved economics of flux cored wire welding over MMAW are very apparent. Even at the same duty cycle as MMAW cored wire process can give much higher productivity because it can operate at much higher current densities.

The deposition data of around 03 - 93% may be less convincing in case of flux-cored wire welding in comparison to MIG/MAG welding. Which is morly 96-90%. The ease of use of flux cored wires in out of position welding coupled with its greater process tolerance and comfort is an important aspect. The amount of time and money spent on reworking defects are less in flux cored welding in comparison to MIG welding and it becomes a very viable alternative to MIG/MAG welding. Possible elimination of quality problems like lack of fusion, cold laps, danger of hydrogen embrittlement etc. through the use of flux-cored wires has been a very important criterion for its selection all around the world for critical fabrication.

### THE CORED WIRE PROCESS

#### Main Features

Fundamentally the process of MIG/MAG welding and utilises the same equipment as that for solid wire albeit of larger capacity in some cases. The important difference between MIG/MAG welding with solid wire and cored wire is performance, productivity, welding characteristics and Weldmetal integrity. Variations to suit a particular application or physical requirement are more easily achieved than with solid wire. This involves changes in the filling formulation and percentage in a similar way to that of manual arc electrodes. The coating formulation and thickness can have a significant effect, whereas little can be done with the electrode core wire alone to improve aspects of performance.

#### Economics

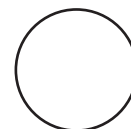
Whilst there are higher productivity processes available, such as submerged arc and robotics, cored wire semiautomatic MIG offers the fabricator a more flexible process with genuine increases in productivity for the least capital expenditure. Where solid wire is already in use this may only involve a change of accessories such

as feed rolls and torch consumables. A move to cored wire MIG/MAG from the use of manual arc will obviously involve the purchase of new equipment but the undisputed increase in productivity will usually guarantee a return on capital invested in less than one year.

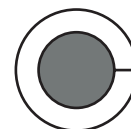
### Deposition

The higher deposition rate from cored wires relies upon the  $I^2R$  heating effect that is greater than with solid wires, for a given current.

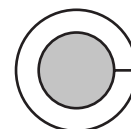
With the solid wire the total cross section carries all of the current but with metal cored wires a partial amount is carried by the core and in the case of flux cored wire all of the current is conducted by the tube. Thereby the current density and heating effect ensures a higher burn-off rate from cored wires.



SOLID



METAL CORED



FLUX CORED

### ESAB Cored Wire Range

The ESAB range consist of rutile and fully basic flux cored wires, some of which are self-shielded, and a range of metal cored wires. For general fabrication work the metal cored type could satisfy the majority of applications, so the need for three principal types may be questioned.

There are a number of factors to be considered and can be summarised as follows:

- Downhand Rutile Flux Cored Wires are easy to use with a smooth arc action giving excellent weld appearance with easy slag detachment.
- Positional Rutile Flux Cored Wires when used with Argon rich gas offer spray transfer welding with a high level of operator appeal.
- Basic Flux Cored Wires produce a higher and more consistent level of mechanical properties. They also produce radiographic standard deposits with ease when compared to both rutile and metal cored wires.
- Metal Cored Wires when used on good quality clean plate will produce very little slag-similar to that of solid wires.
- Self-Shielded Wires produce their own gas shield via decomposition in the arc of various elements within the core.

## OPERATING CONDITIONS

### Polarity

DC electrode positive is recommended for the cored wires since the use of the negative pole produces inferior running characteristics and can occasionally produce porosity.

Some Cored wires however, are designed to operate on both DC positive & negative polarity.

### Voltage

Arc voltage has a direct influence on the arc length that controls the weld shape depth of penetration and spatter level. As the arc voltage is reduced the penetration increases and this is particularly important in V butt joints. An increase in voltage will result in a long arc length and increase the risk of porosity and undercut.

When operating on dip transfer for positional welding at comparatively low currents the arc voltage should be kept at the highest practicable level to ensure adequate sidewall fusion.

### Amperage

With flux cored wires the amperage used is ideally at the top half of the range specified for a particular size, except

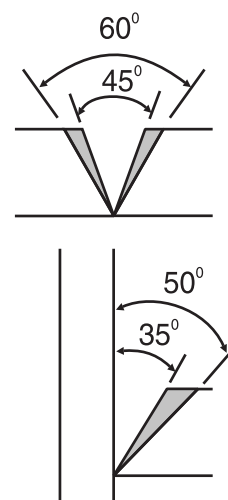
when positional welding with 1.0mm, 1.2mm, and 1.4 mm wires, and when the dip transfer mode is used at current below 220 amps.

Metal cored wires eliminate the need for current variations relative to plate thickness since one current setting

for a given wire size will cater to 90% of flat and HV applications. The weld cross-section is controlled by the travel speed whereas solid wire would require considerable current resetting to achieve the same flexibility.

### Plate preparation

Due to superior sidewall fusion obtained particularly from the metal cored wires the combined angles of preparations can generally be reduced. A V-butt joint for instance that would normally need a 60° included angle for manual arc welding can be reduced to 45° thereby saving plate and hence weldmetal to fill the joint.



The higher levels of de-oxidation and higher current density available with cored wires allows them to be used where mill scale and primer have to be tolerated. This is particularly so with the metal and basic cored wires, since the rutile types are the least tolerant. However, in case of primer the degree of success will depend on the type and thickness, but generally Tubrod basic wires will achieve porosity free welds at speeds 45% faster than solid wires and the Tubrod metal cored wires are approximately 35% faster

For optimum radiographic standards with flux cored wires excessive rust and scale should be removed by grinding which will also serve to reduce slag formation to a minimum when using metal cored wires.

Further economies can be achieved from a reduction in Weldmetal required on single pass fillet joints.

The often-greater depth of fusion can increase the effective throat thickness and consequently allow a reduction in leg length by up to 20%. The savings in Weldmetal are considerable as can be seen from FIG.6 and some certification authorities will permit a reduction of 50% in weld dimensions for single pass fillets when produced fully automatically.



## WELDING TECHNIQUES

### Torch angles

#### Flux cored wires

With OK Tubrod / Dualshield flux cored wires the torch angle has a significant effect on slag control and weld deposit profile. For both fillet and butt joints the recommended angle between the wire axis and the line of joint is between  $60^{\circ}$  -  $70^{\circ}$  and using a backhand technique i.e. pulling, with the wire pointing toward the completed weld. In this way the arc force prevents the slag from running in front of the line of the weld pool and reduces the risk of slag traps. For HV fillets the wire tip should be directed toward the bottom plate at approximately 3-mm from the line of the joint with a torch angle of  $45^{\circ}$  from the vertical plate.

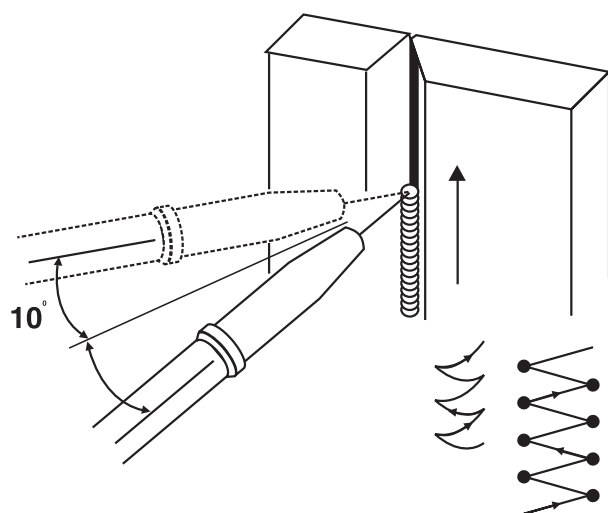
In certain circumstances the forehand technique i.e. pushing can be used to advantage. On small fillet welds where penetration is not of paramount importance the higher welding speeds required are such that the molten slag is prevented from running ahead of the weld pool. This also has the advantage of producing a mitre fillet where as the backhand method tends to produce a more convex profile.

#### Metal cored wires

Maximum penetration is obtained using a backhand (pulling technique with a torch angle of  $70/80^{\circ}$  between the wire axis and the joint line. This will also serve to optimise gas coverage and is particularly relevant to multi-pass butt welds. The fillet and lap welds superior weld appearance is achieved using a torch angle of  $60/70^{\circ}$  and a forehand technique (push). This results in a more even distribution of Weldmetal, accompanied by a reduction in penetration.

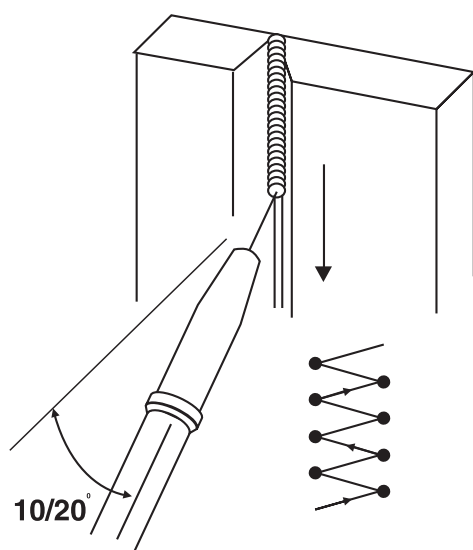
## Torch angles and manipulation

### Vertical butt-welds



Preparation with root face

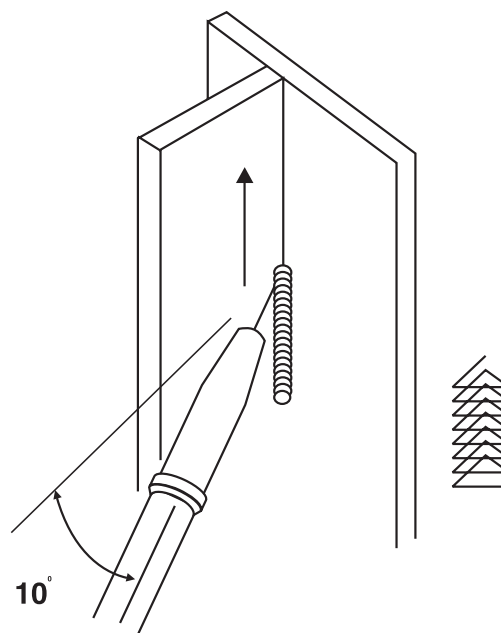
A torch angle of 100 above the horizontal may be used for root passes to assist arc stability and penetration control.



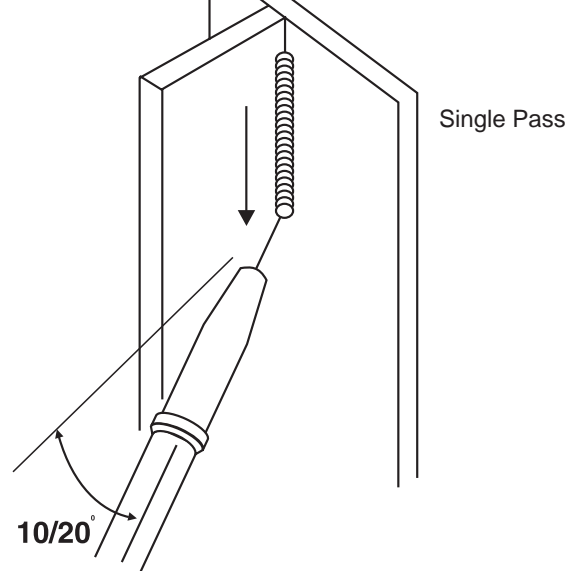
Preparation with feather edges

## Torch angles and manipulation

### Vertical fillet welds



Triangular weaves for single pass fillets. If necessary subsequent weld runs should be deposited using techniques similar to that for Filling vertical butt joints. No weaving is necessary for single pass fillets when using OK Tubrod 15.15



Restrict vertical down technique to thin plate or leg lengths of 6 mm maximum. May be used for first pass of multipass joints.



## Travel Speed

Travel speed has an important influence on penetration. For example when using a 1.6mm metal cored wire at 305A an increase in travel speed from 30cms/min to 60cms/min approximately doubles penetration beyond the root of a fillet. At speeds in excess of 80/100 cms/min penetration will decrease. Similarly a reduction in penetration will occur if the welding speed should fall to below 30cms/min, as the arc can impinge on the molten pool in preference to the base material.

In addition the use of slow travel speeds should be avoided when low temperature impact properties are required. While the joint may be filled in fewer passes the individual weld deposits will be of large cross-section and therefore impact resistance will be reduced. Apart from this, in the case of flux cored wires there is the obvious difficulty of slag control to be considered.

## Positional Welding

The majority of Tubrod cored wires are capable of positional welding in the smaller sizes. However, the choice of consumable must be given careful consideration in relation to the proposed applications because the various ranges require quite different manipulation techniques for optimum results.

## Rutile (EX1 T-1) Types

This type of wire allows the use of the spray transfer mode in all positions including overhead and as such affords very high deposition rates. In addition, the exceptional fusion Characteristics that results will have significant effect on the production of defect free welds. This is particularly relevant when compared to solid wire that by necessity can only be used for positional welding in the dip transfer mode. The reduced depth of fusion involved together with the greater degree of skill and concentration demanded will increase the risk of fusion related defects. OK Tubrod 15.15 can achieve in excess of 4kg/hr in the vertical position compared to manual arc at approximately 2kg/ hr.

The required techniques for vertical up welding is almost identical to those employed by manual metal arc for both fillet and butt joints. However, root panes in open butt welds where a uniform bead of penetration required, when welded from one side are not recommended. This is due to the high arc energy and fluidity of the weld pool as well as the need to maintain highly accurate joint preparation that is considered not practical. In such circumstances the use of non-fusible back-

ing is recommended and this type of wire is eminently suitable for use with these materials and the speed of welding will be significantly higher.

## Metal Cored (EX1T-G) and Fully Basic (EX1T-5)

These two groups may be treated as one with regard to positional welding techniques. To maintain optimum control welding is limited to the 1.0mm and 1.4mm sizes and is restricted to the dip transfer mode where greater welder skill is involved. The manipulation required be similar to that used for solid wire in that initial passes in the vertical position are completed using a triangular weave motion.

This is to ensure that the weld profile remains flat and not peaked, which would otherwise occur leading to possible lack of fusion defects at the edges after further welding as in the case of multipass joints.

The conventional straight weave may be used but only in circumstances when the face of the previous pass is wide enough such that the effect of heat sink will maintain a flat profile automatically.

Whilst the dip transfer method is slow and often demanding in terms of operator concentration the arc energy is greater than with solid wire and the possibility of defects, especially cold lapping is substantially reduced.

The root pass in an open butt weld, where full penetration is required from one side is always the most difficult regardless of welding process or position. However, when using Tubrod metal and basic cored wires the use of dip transfer and vertical down welding can be used to good advantage. Excellent results can be achieved more easily if it is rapid and dispensing with a root face can reduce plate preparation costs.

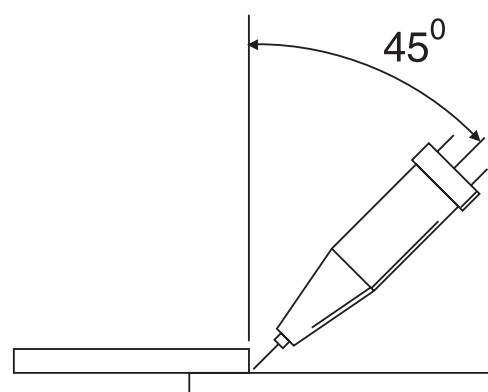
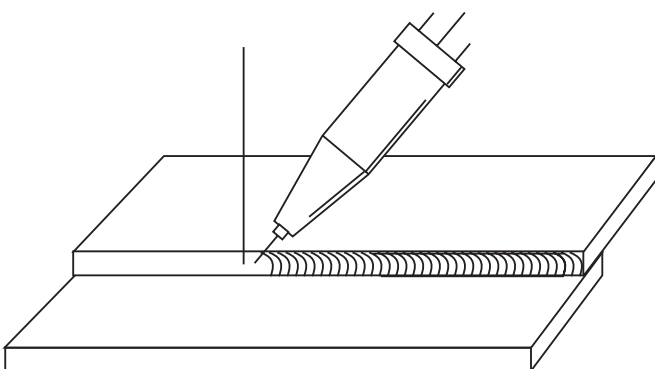
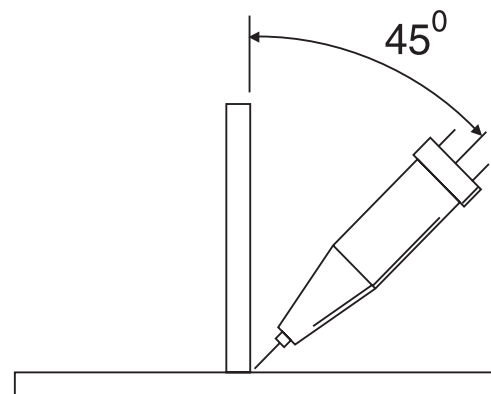
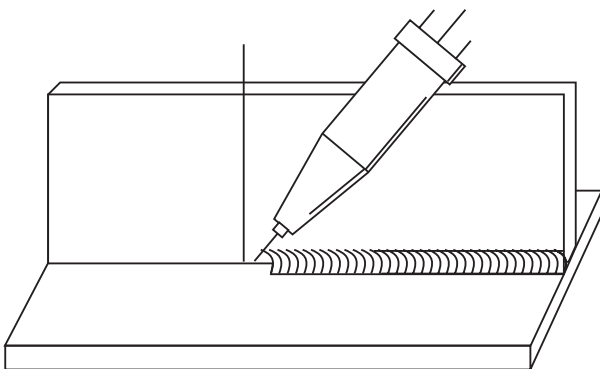
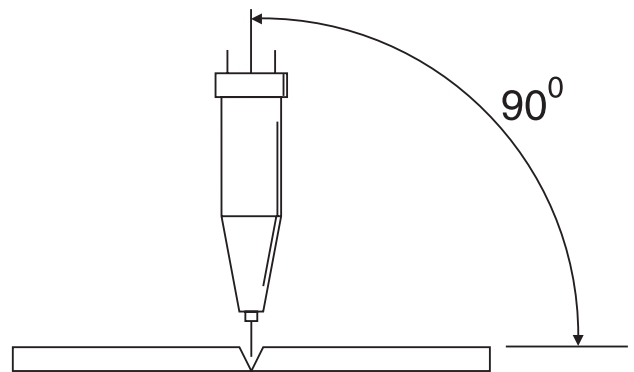
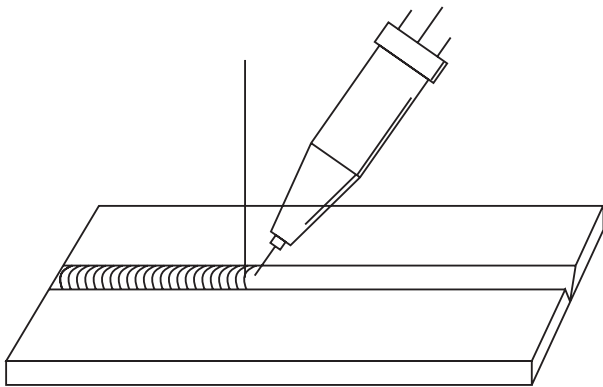
Fillet joints may be welded using either the vertical up or vertical down techniques. The choice will depend on the thickness of material and degree of root penetration desired. Multi-pass joints should be completed on a similar basis to that of butt welds using the vertical up technique.

## Metal cored wire

### Electrode extension

This term describes the distance between the contact tip of the torch and the work piece, sometimes described as 'electrode stickout'. The current conditions should be set for the job in hand but during welding it may be nec-

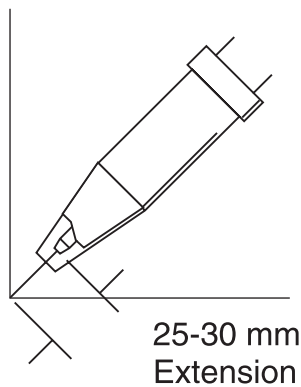
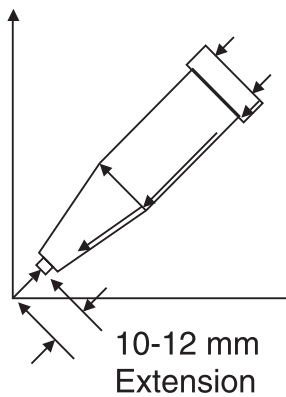
essary to reduce the amount of heat in the weld pool to accommodate poor fit-up or out of position welding. An increase in the stickout length and the extra electrical resistance that results will produce a cooler less fluid weld pool. Similarly any decrease in electrode extension will have the effect of increasing welding current and this characteristic can be of benefit in controlling penetration; especially where inconsistent fit-up is encountered.



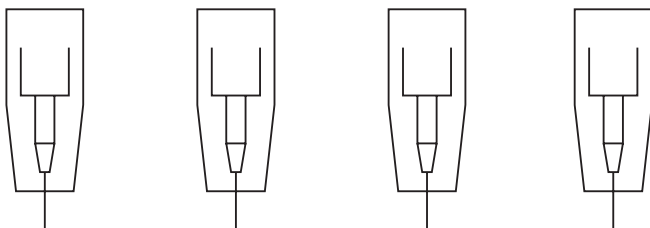


When operating with dip transfer an extension of 12 mm will suffice for most applications whereas spray transfer produces a greater amount of radiated heat and should have an extension of approximately 20-30 mm.

During actual welding any large variation will produce an inconsistent weld deposit and excessive electrode extension has the effect of reducing the amperage drawn from the power source. Increasing the wire feed speed to compensate for the current drop will result in a significant increase in weldmetal deposition.



#### ELECTRODE EXTENSIONS RELATED TO DEPOSITION RATE



EXTENSION MM	12	18	25	25
WIRE FEED M/Min	5.8	5.8	5.8	8.4
CURRENT AMPS	350	320	280	350
DEP RATE KGS/HR	4.7	4.7	4.7	6.5

## DATA SHEET - FCAW

Flux cored wires classification E 71T-X E80T-X

Indicates the primary welding conditions for which the electrode is designed;  
0 - Flat and horizontal positions  
1 - All positions

Designates an electrode

Designator identifying as flux cored electrode

Tensile Strength designator in units of 10 KSi

Shielding Gas Designator C=100% Co<sub>2</sub>, M = 80% Ar 20% Co<sub>2</sub> in AWS + 5.20

Deposit Composition Designator in AWS A5.29)

**E X X T - X X**

### Indicates usability and performance capabilities

1. Electrode classified for used with CO<sub>2</sub> or CO<sub>2</sub>+Ar mixture to improve usability especially for out of position welding. Designed for single and multi-pass welding characterized by spray transfer, low spatter loss and a moderate volume of slag. Generally are rutile based and operate on DC+
4. Self-shielded electrode for single and multi pass welding in the flat and horizontal verticals positions. Operates on DC+ and gives globular transfer.
5. Designed for use with CO<sub>2</sub> (Ar based gases may be used) for single and multi pass welding in the flat and horizontal verticals positions. Electrodes of this group have a lime fluoride based slag and produce weldmet having improved impact properties and crack resistance in comparison to rutile type.
8. Self shielded electrode operating on DC with negative polarity. Designed for all positions and provides a weldmet with very good low temperature impact properties. Used for single and multi pass welding.

X	C	Mn	Ni	Cr	Mo	V	Al
Carbon - Molybdenum steel electrodes							
A1	0.12	1.25	-	-	0.40-0.65	-	-
Chromium - Molybdenum steel electrodes							
B2	0.05 - 0.12	1.25	-	1.0-1.5	0.40-0.65	-	-
B2L	0.05	1.25	-	2.0-2.5	0.90-1.20	-	-
B3	0.05 - 0.12	1.25	-	2.0-2.5	0.90-1.20	-	-
B3L	0.05	1.25	-	2.0-2.5	0.90-1.20	-	-
Nickel steel electrodes							
Ni1	0.12	1.50	0.80-1.10	0.15	0.35	0.05	1.80*
Ni2	0.12	1.50	1.75-2.75	-	-	-	1.80*
Ni3	0.12	1.50	2.75-3.75	-	-	-	1.80*
Manganese - Molybdenum steel electrodes							
D1	0.12	1.25-2.00	-	-	0.25-0.55	-	-
D2	0.15	1.65-2.25	-	-	0.25-0.55	-	-
D3	0.12	1.00-1.75	-	-	0.40-0.65	-	-
All other low alloyed electrodes							
K2	0.15	0.50-1.75	1.00-2.00	0.15	0.35	0.05	1.80*
K4	0.15	1.20-2.25	1.75-2.60	0.20-0.60	0.20-0.65	0.03	-
W2	0.12	0.5-1.3	0.4-0.8	0.45 - 0.70	-	-	Cu = 0.3-0.75

\* Refer applicable code for detail.



## Cored Wire Fault Finding

POSSIBLE CAUSE	REMEDY
<b>POROSITY</b> Insufficient shielding gas Excessive electrode extension Gas Nozzle too short Plate condition and impurities Equipment fault on gas control	Check recommended flow rate Reduced extension . refer notes Replace Remove non-metallic substances Check for leaks and air ingestion
<b>POOR WIRE FEED</b> Incorrect tip size Damaged liner or tip Incorrect types, size and pressure of feed rolls Spool brake too tight Blocked liner	Check and replace Replace Refer equipment manual Check tension and slacken if necessary Remove obstruction or replace
<b>SLAG INCLUSIONS</b> Incorrect welder technique Direction of travel	Refer to notes Refer to recommended technique
<b>UNDERCUT</b> Travel speed too fast parameters Incorrect torch angle Voltage too high	Reduced travel speed or check parameters Refer to notes on torch angels Reduce voltage

POSSIBLE CAUSE	REMEDY
<b>LACK OF FUSION</b> Current too low Electrode extension too long for current being used Incorrect or inconsistent travel speed Torch angel or direction of travel Narrow joint preparation Root face too large	Refer to notes on electrode extension Adjust travel speed to suit desired degree of penetration Refer to welding techniques Modify preparation Modify preparation
<b>LACK OF FUSION</b> Direction and speed of travel Incorrect torch angle Incorrect parameters or torch manipulation	Refer to notesillustration Refer to notesillustration Check against recommended values for the wire in question and notes on torch manipulation
<b>EXCESSIVE SPATTER</b> Dirty plate Voltage too high for amperage being used Shielding gas pressure too high Poor current pick-up	Clean plate-wire brush or grinding Check against recommended values Check against recommended flow rates Check size or replace worn contact tip.

## General recommendations for Submerged Arc Welding

1. **The flux must be dry.** Agglomerated fluxes must be protected from moisture pick-up.

**In tropical, humid areas,** re-drying agglomerated fluxes at 250-350°C before use is recommended. The remaining flux in the welding machine container should be removed and stored in a dry cabinet and should therefore not be left in the open container during the night.

During the transport of fluxes, a maximum of two pallets should be stacked to prevent the grains being crushed.

2. The fusion faces and the plate in the vicinity of the joint should be clean and dry. The cleaner the joint, the better the chances of obtaining a satisfactory weld. Rust, mill scale, paint, oil and residue from arc-air gouging or grinding can adversely affect the quality of the weld metal. The more impurities on the fusion faces, the greater the risk of weld metal defects.

3. The arc voltage must be kept constant. Increased arc voltage results in higher flux consumption. If the flux contains alloying elements, the amount transferred to the weld metal will increase as the arc voltage increases.
4. As a general rule, multi-run deposits made at moderate welding currents have better mechanical properties than one-or two-layer deposits made at high currents in similar plate thicknesses.

**N.B.** The chemical analyses given in this catalogue are for all weld metal deposited with DC+, 580 A, 29 V, 33 m/h, except for OK Flux 10.92, where DC+, 420 A, 27 V and 30 m/h has been used (wire Ø4 mm) and for OK Flux 10.90, where DC+, 300A, 30V, 24 m/h has been used (wire Ø2.4 mm).

The mechanical properties are obtained according to the welding conditions given in EN 756 (i.e. the same welding data as in EN 760).

Other welding conditions may produce weld metal analyses and mechanical properties which differ from those given in the handbook.

# DATA SHEET - SAW

## SAW Classification

Indicates the minimum tensile strength of the weldmetal, welded in accordance with AWS specifications.

Indicates a solid electrode

**F X X X - E X X X**

Indicates Flux

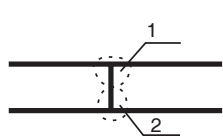
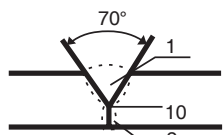
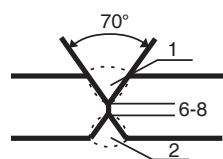
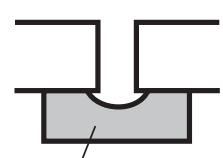
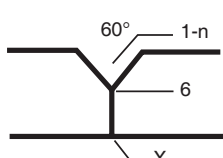
Designed the condition of heat treatment in which tests were conducted.  
 "A" as welded  
 "P" Post weld heat treated

Digit	Test Temperature		Average Energy Level (min)
	F	C	
Z	No impact requirements		27J
0	0	-18	
2	-20	-29	
4	-40	-40	
5	-50	-46	
6	-60	-51	
8	-80	-62	
10	-100	-73	
15	-150	-101	







XXX	C	Mn	Si
Low Manganese Electrodes			
EL8	0.10	0.25/0.60	0.07
EL8K	0.10	0.25/0.60	0.10/0.25
EL12	0.04/0.12	0.25/0.60	0.10
Medium Manganese Electrodes			
EM12	0.06/0.15	0.80/1.25	0.10
EM12K	0.05/0.15	0.80/1.25	0.10/0.35
EM13K	0.06/0.16	0.90/1.40	0.35/0.75
EM14K	0.06/0.19	0.90/1.40	0.35/0.75
EM15K	0.10/0.20	0.80/1.25	0.10/0.35
Hi91:1 Manganese Electrodes			
EH11 K	0.07/0.15	1.40/1.85	0.80/1.15
EH12K	0.06/0.15	1.50/2.00	0.25/0.65
EH14	0.10/0.20	1.70/2.20	0.10

## Welding data and joint preparation

Typical welding data and recommended joint preparation for submerged arc welding mild steel and carbon-manganese structural steels with OK Flux 10.40, OK Flux 10.47, OK Flux 10.70, OK 10.71, OK Flux 10.72, OK Flux 10.76 and OK Flux 10.81.

Type of joint	Plate thickness mm	Wire diameter mm	Run No	Arc voltage V	Welding current A	Welding speed cm/min.
	6	3	1	33	400	80
	8	4	2	33	430	60
			1	34	480	
	10	4	2	34	550	55
			1	34	550	
	12	4	1	35	650	50
2			35	700		
14	4	1	35	700	40	
		2	35	750		
	16	4	1	32	600	50
	18	4	2	35	650	50
			1	34	700	
	20	4	2	35	650	40
			1	36	750	
		2	35	650		
	18	6	1	36	700	30
	20	6	2	36	850	25
			1	36	800	
	25	6	2	36	850	20
			1	36	850	
	30	6	2	36	950	15
1			36	900		
		2	36	1000		
	2	2	1	28	325	125
	4	2.5	1	30	450	70
	6	3	1	31	510	50
	8	3	1	32	525	45
	10	3	1	33	600	35
	20	4	1	29	650	50
			2	32	750	50
			3	34	750	40
			X	30	550	50
	25	4	1	29	650	50
			2	30	700	50
			3, 4	32	750	40
			5	36	750	40
			X	30	550	50
	30	4	1	29	650	50
			2	30	700	50
			3-5	32	750	50
			6	34	750	40
			7-8	36	750	40
		X	30			

Typical welding data and for submerged arc fillet welding mild steel and carbon-manganese structural steels with OK Flux 10.47, OK Flux 10.71 and OK Flux 10.81.

Type of joint	Plate thickness mm	Wire diameter mm	Throat thickness mm	Arc voltage V	Welding current A	Welding speed cm/min.
Single welding head						
	≥ 6	3	3	30-32	500	100
	≥ 8	4	4	30-32	450	60
	≥ 10	4	5	30-32	650	50
	≥ 8	4	4	32-34	700	115
	≥ 12	4	4	32-34	800	140
	≥ 15	4	7	36	800	45
	≥ 15	4	-	36	750	45
	≥ 20	4	-	36	750	40
	Twin wire					
	-	2x1.6	4	32	800	120
	-	2x2.0	5	34	300	110
Two welding heads + ~						
	-	4	4	+32	800	140
	-	4	4	~38	700	
	-	4	4	+32	800	140
	-	4	5	~38	700	
	-	4	4	+32	800	140
	-	4	5	~35	700	90

Submerged arc welding "18/8" stainless steel. Joint preparation and typical welding data for filler materials OK Autrod 16.10 + OK Flux 10.92, 10.93 and similar OK - combinations.

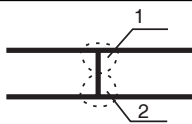
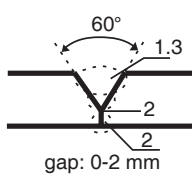
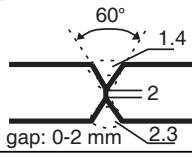
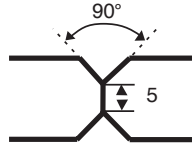
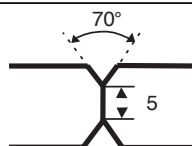
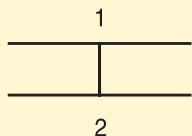
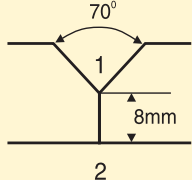
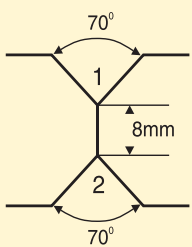
Type of joint	Plate thickness mm	Wire diameter mm	Run No	Arc voltage V	Welding current A	Welding speed m/h
	6	3	1 2	34	400 500	80 60
	8	4	1 2	34	500 600	80 60
Manual welded root bead						
	10	4	1 2	34	600 600	40 60
	12	4	1 2	34	600 600	35 50
	20	4	1 2 3	34	600 600 600	35 30 40
	25	4	1 2 3 4	34 34	600 600 600 600	40 35 35 40
	8	4	1 2	34 34	450 550	55 50
			1 2	34 34	500 600	40 50
		10	4	1 2	34 34	500 600
12		4	1 2	34 34	500 600	35 40
	1 2		34 34	550 600	35 35	
	14	4	1 2	34 34	550 600	35 35

Table 3: Typical welding data for different types of joint OK Flux 10.61 Land 10.62

Type of Joint	Plate Thickness mm	Wire mm	Run No.	Arc Voltage V	Welding Current A	Welding Speed m/h	
	6	3	1	29	350	40	
	8	3	2	30	425	40	
		3	1	31	450	40	
	10	3	2	31	500	40	
		4	1	30	500	40	
	12	4	2	30	575	40	
	16	5	1	32	750	35	
		5	2	32	800	35	
	20	6	1	31	950	23	
		6	2	32	950	23	
		25	6	1	31	1000	21
		30	6	2	31	1000	21
6			1	31	1000	20	
35		6	2	30	1050	20	
		6	5.1 :1*	30	1050	23	
6		2	32	900	30		
6	5.2:1**	30	1100	25			
6	2	32	900	30			

\* First side

\*\* Second side

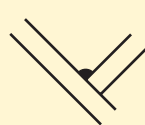

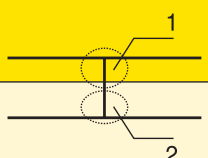
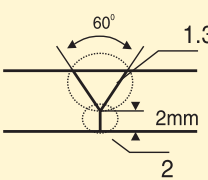
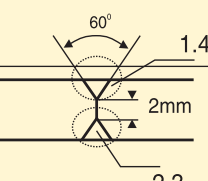
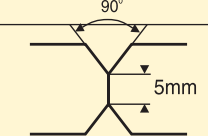
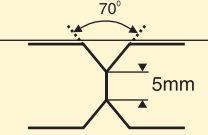
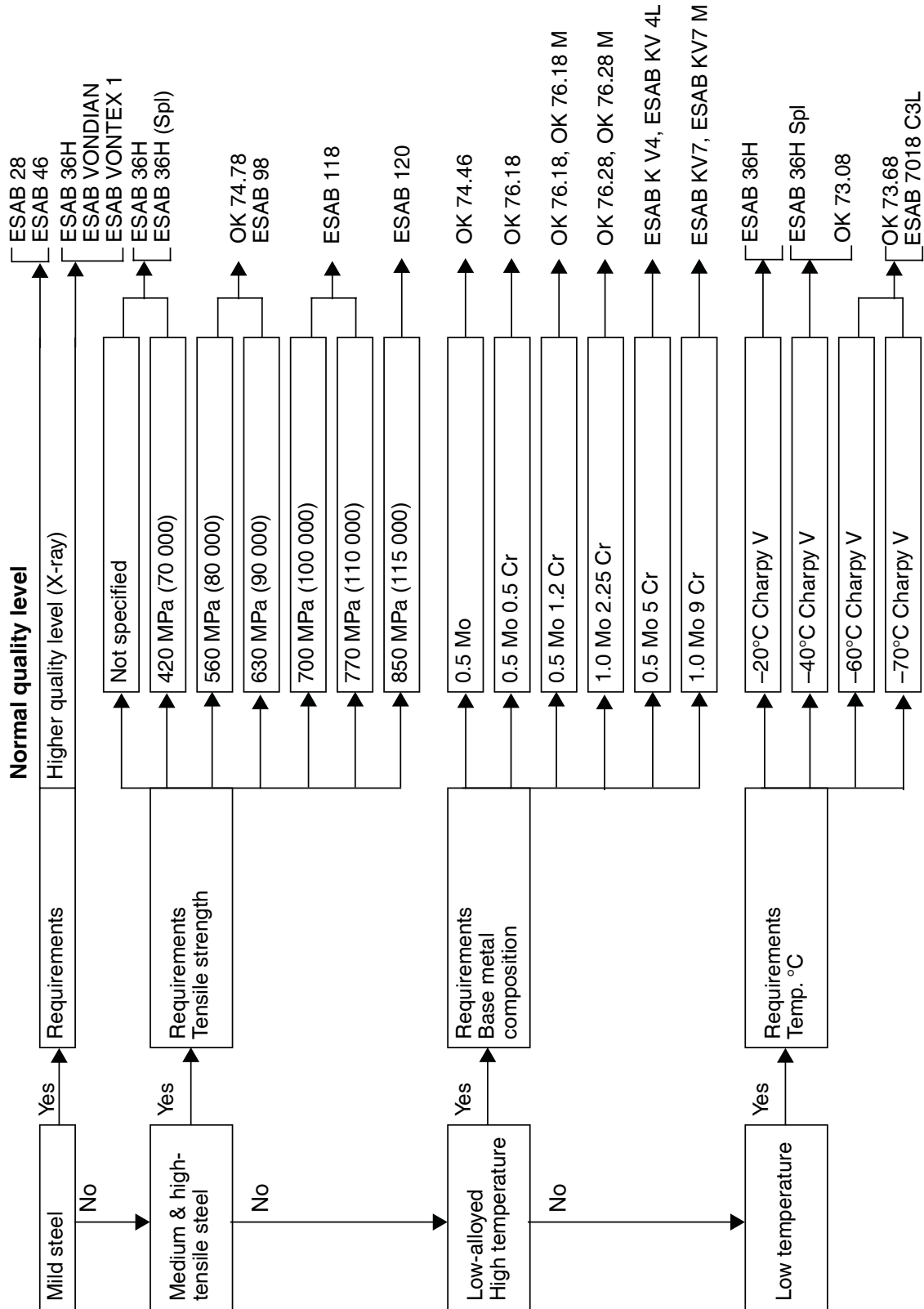
Fillet	Throat Thickness a-mm	Wire Dia. mm	Arc Voltage V	Welding Current A	Welding Speed m/h
	6.0	5	32	800	30
	6.5	5	31	850	30
	7.0	5	30	900	30
	3.5	4	29	650	60
	4.5	4	29	650	50
	5.5	4	29	650	40

Table 4: Submerged arc welding “18/9” stainless steel. Joint preparation and typical welding data for filler materials OK Autrod 16.1 O+OK Flux 1 0.92L and similar OK - combination.

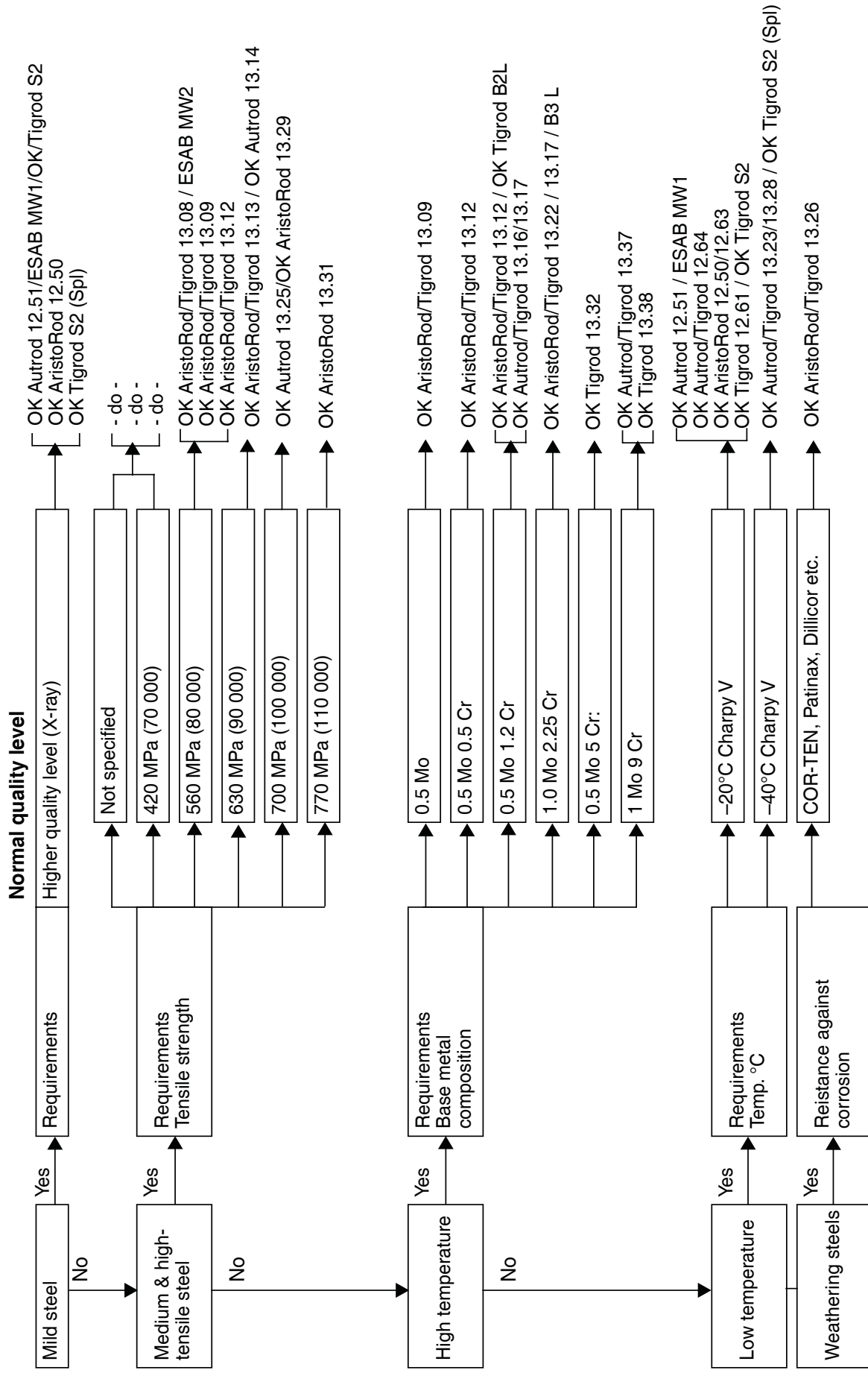
Type of Joint	Plate Thickness mm	Wire mm	Run No.	Arc Voltage V	Welding Current A	Welding Speed m/h
	6	3	1	34	400	80
			2		500	60
	8	4	1	34	500	80
			2		600	60
Manually welded root bead						
	10	4	1	34	600	40
			2		600	60
	12	4	1	34	600	35
			2		600	50
	20	4	1	34	600	35
			2		600	30
			3		600	40
			4		600	40
	25	4	1		600	40
			2	34	600	35
			3		600	35
			4	34	600	40
	8	4	1	34	450	55
			2	34	550	50
	10	4	1	34	500	40
			2	34	600	50
	12	4	1	34	500	35
			2	34	600	40
	14	4	1	34	550	35
			2	34	600	40

## QUICK GUIDE

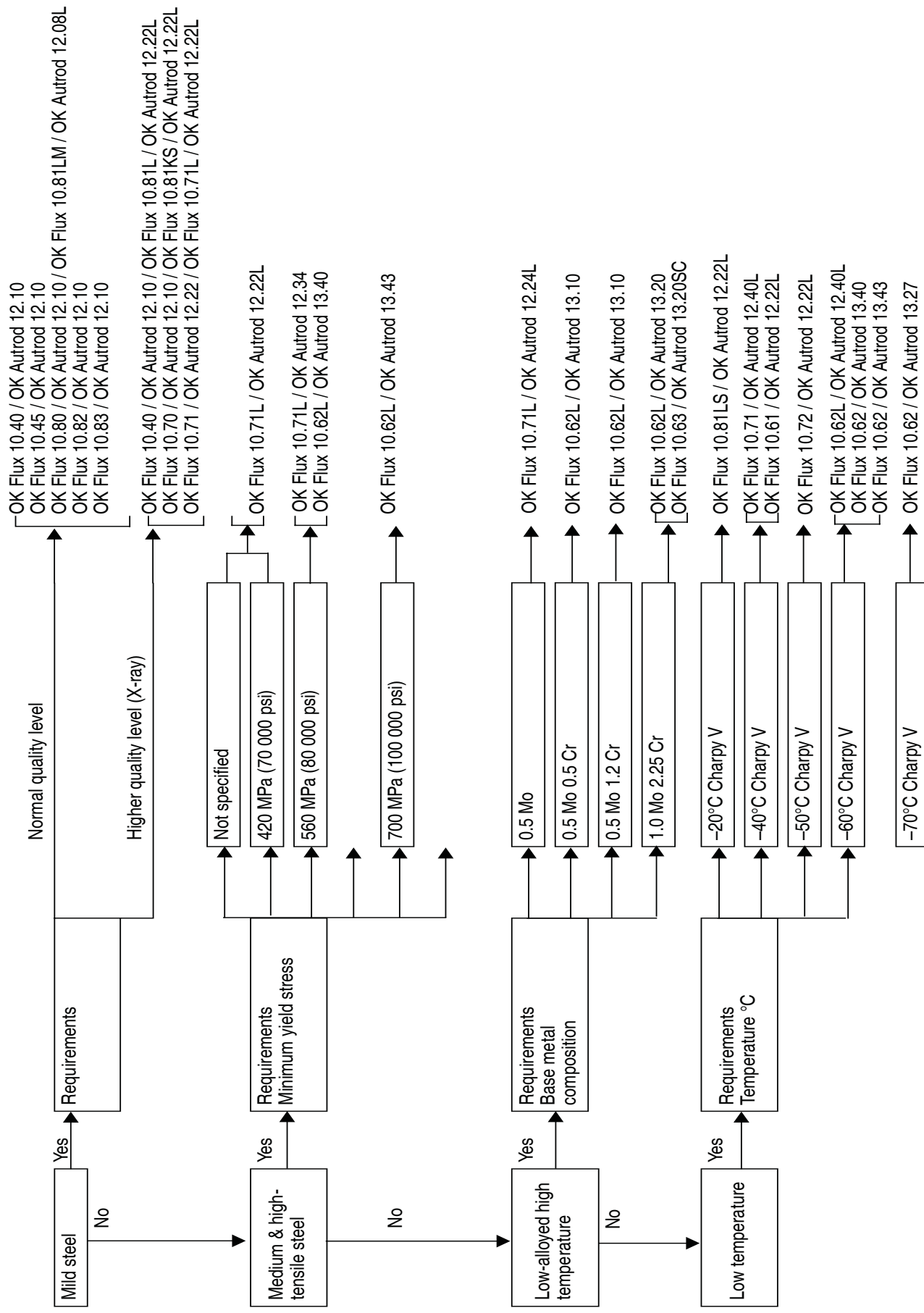
### 1. MMA electrodes for mild and low-alloyed steels



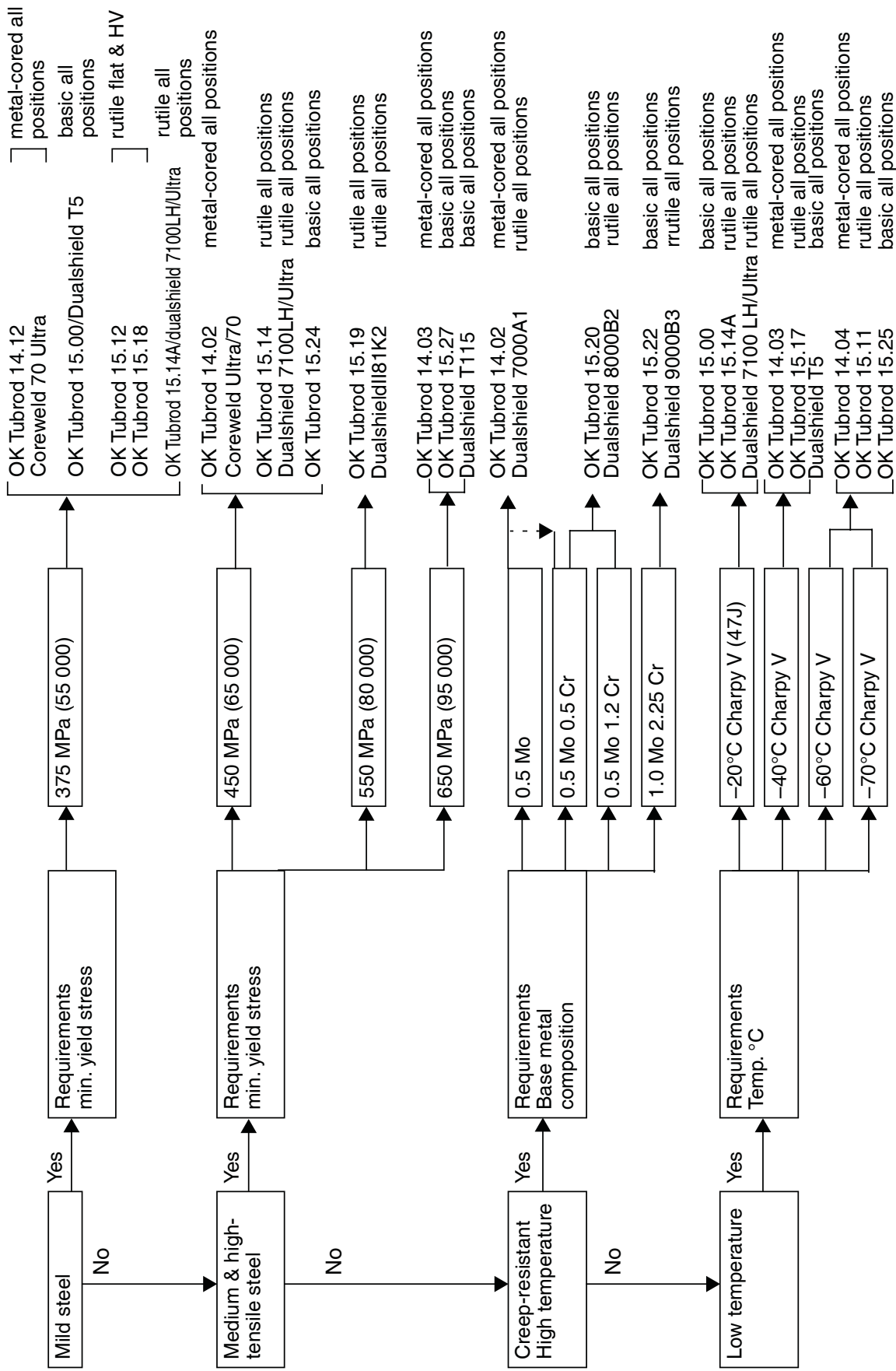
## 2. Solid wires



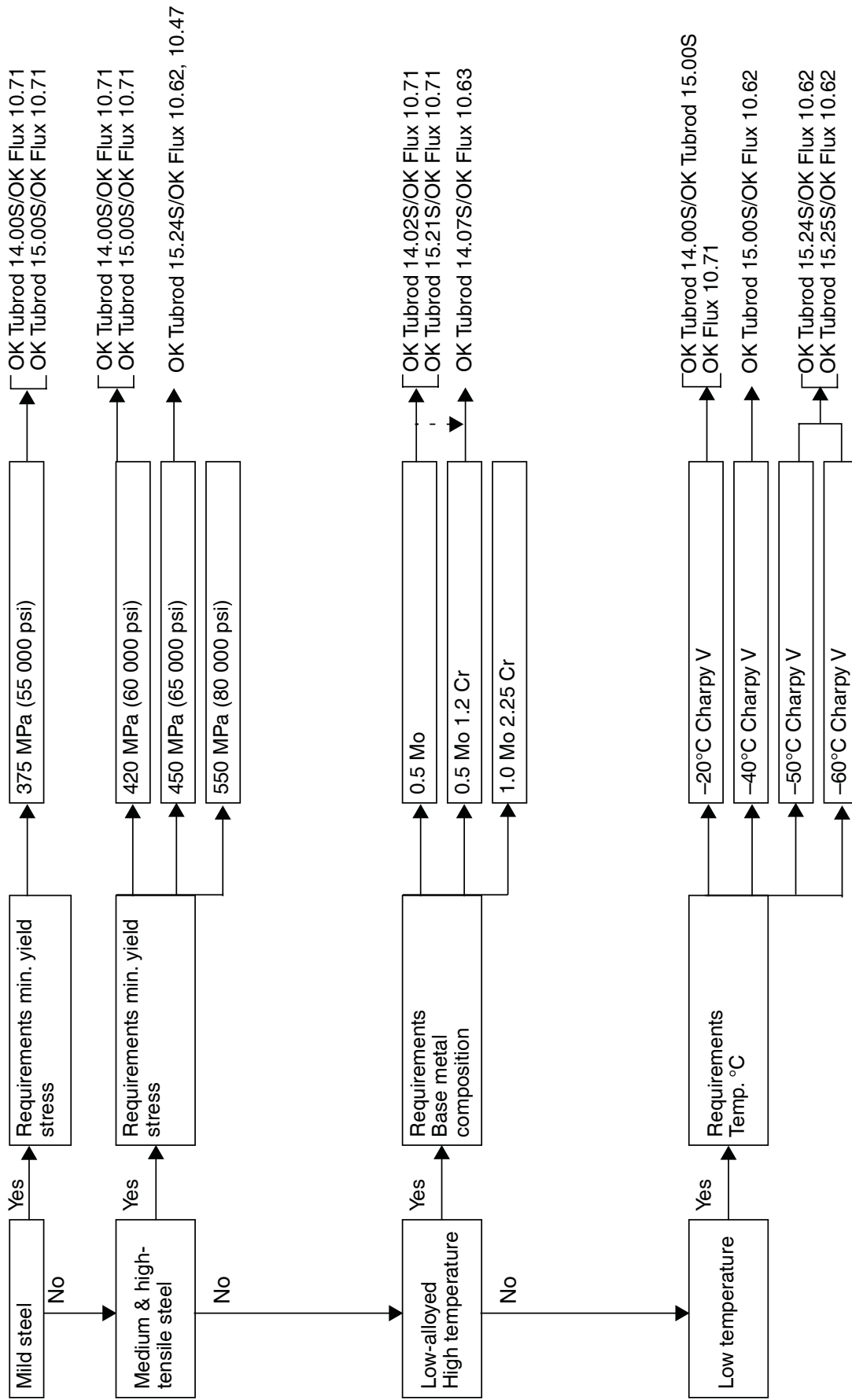
### 3. Fluxes and submerged arc wires



## 4. Cored wires



### 5. Submerged arc cored wires and fluxes



## 6. Wires for stainless steels. Selection by wire classification

EN 10088-1 Designation	Werkstoff. No	AISI	C	Cr	Ni	Mo	Other elements	MIG OK Autrod	TIG OK Tigrod
<b>Austenitic</b>									
X10CrNi18-8	1.4310	302	< 0.12	18	8			16.10	16.10
X5CrNi18-10	1.4301	304	< 0.07	18	10			16.10	16.10
X6CrNiTi18-10	1.4541	321	< 0.08	18	11		Ti 0.7	16.11	16.11, 16.10
X6CrNiNb18-10	1.4550	347	< 0.08	18	11		Nb 0.7	16.11	16.11, 16.10
X8CrNiS18-9	1.4305	303	< 0.12	18	9		S 0.2	16.53	16.53, 309L
X2CrNi18-9	1.4307	304L	< 0.03	18	10			16.10	16.10
X2CrNiN18-10	1.4311	304LN	< 0.03	18	10		N 0.15	16.10	16.10
		304N	< 0.08	18	9		N 0.15	16.10	16.10
X3CrNiMo17-13-3	1.4436	316	< 0.05	18	12	2.5		16.30	16.30
X5CrNiMo17-12-2	1.4401	316	< 0.05	18	12	2.5			
X2CrNiMo17-12-2	1.4404	316L	< 0.03	18	12	2.5		16.38	16.38
X2CrNiMo18-14-3	1.4435	316L	< 0.03	18	13	2.5		318Si, 16.30	318Si, 16.30
X6CrNiMoTi17-13-2	1.4571	316Ti	< 0.08	18	12	2.5	Ti 0.7	16.30	16.30
X2CrNiMoN17-13-3	1.4429	316LN	< 0.03	18	12	2.5	N 0.5	16.95	16.95
X12CrMnNiN	1.4372	202	< 0.15	18	5	3.5	Mn 8	317L	317L
X2CrNiMo18-15-4	1.4438	S31703	< 0.03	18	16	3.5		385	385
X1NiCrMoCuN25-20-5	1.4539	N08904	< 0.03	20	25	4.5	Cu 1.5	19.81, 19.82	19.81, 19.82
X1CrNiMoCuN20-18-7	1.4547	S31254	< 0.02	20	18	6.2	Cu 0.8, N 0.2	19.81, 19.82	19.81, 19.82
X1NiCrMoCu31-27-4	1.4563	N08028	< 0.02	27	31	3.5	Cu 1.5	19.81, 19.82	19.81, 19.82
-	1.4652	S32654	< 0.02	24	22	7.3	Cu 0.5, N 0.5	19.81	19.81
X9CrNiSiN21-11-2	1.4835	S30815	< 0.10	21	11		N 0.17 + Ce	310	310
<b>Austenitic-ferritic (Duplex)</b>									
X2CrNiN23-4	1.4162	S32101	0.03	21.5	1.5		Mn 5	16.86	16.86
X2CrNiMoN22-5-3	1.4362	S32304	< 0.03	23	4		N 0.10	16.86	16.86
X2NiMoN25-7-4	1.4462	S31803	< 0.03	22	5	3	N 0.10	16.86	16.86
X2CrNiMoCuWN25-7-4	1.4410	S32750	< 0.03	25	7	4	N 0.25	16.88	16.88
	1.4501	S32760	< 0.03	25	6	3	N 0.25 W 0.7	16.88	16.88



EN 10088-1 Designation	Werkstoff. No	AISI	C	Cr	Ni	Mo	Other elements	MIG OK Autrod	TIG OK Tigrod
<b>Ferritic-martensitic</b>									
X6Cr13	1.4000	403	< 0.08	13				16.10	16.10
X2CrNi12	1.4003	S41050	< 0.03	12	0.7			16.10	16.10
X12Cr13	1.4006	410	0.1	13				16.53	16.53
<b>Ferritic</b>									
X6Cr17	1.4016	430	< 0.08	16.5				430Ti, 430LNb, 16.10	430Ti, 16.10
X6CrTiNb18	1.4509	441	< 0.03	18			Ti, Nb	16.10	16.10
X6CrTi17	1.4510	439	< 0.8	17			Ti	430Ti, 430LNb	430Ti
X2CrMoTi18-2	1.4521	S44400	< 0.03	18		2		430Ti	430Ti
-	-	446	< 0.20	26				16.30	16.30
								16.13	16.13

## 7. The most common fluxes and wires for SAW of stainless steels

European standard EN 10082-1 Designation steel	German DIN 17440		England BS 970; 1=Part 1 BS 1449; 2=Part 2	France AFNOR NFA 35-572 to NFA 35-578	SS steel No	USA AISI	Recommended SAW consumables OK Flux + OK Autrod
	No	Designation steel					
X 6 Cr 13	1.4000	X 7 Cr 13	403 S 17	Z 6 C 13	2301	403	10.92L+16.10 or 308H/10.92L+16.10
X 12 Cr 13	1.4006	X 10 Cr 13	410 S 21	Z 12 C 13	2302	410	10.92L+16.10 or 308H/10.92L+16.10
X 20 Cr 13	1.4021	X 20 Cr 13	420 S 37	Z 20 C 13	2303	420	10.92L+16.10 or 308H/10.92L+16.10
X 30 Cr 13	1.4028	X 30 Gr 13	420 S 45	Z 30 C 13	2304	-	10.92L+16.10 or 308H/10.92L+16.10
X 6 Cr 17	1.4016	X 6 Cr 17	430 S 17	Z 8 C 17	2320	430	10.92L+16.11 or 308H/10.92L+16.10
X 17 Cr Ni 16-2	1.4057	X 20 Cr Ni 17 2	431 S 29	Z 15 CN 16.02	2321	431	10.92L+16.11 or 10.92L+16.11
		-	-	Z 10 C 24	2322	446	10.92L+16.13
		X 8 Cr Ni Mo 27 5 2 <sup>1)</sup>	-	-	2324	329	10.92L+2209 or 2509/10.94+2509
X 2 Cr Ni N 23-4	1.4362		-	-	2327	S32304	10.92L+2209 or 2509/10.94+2509
X 2 Cr Ni Mo N 22-5-3	1.4462		-	-	2377	S31803	10.92L+2209 or 2509/10.94+2509
X 2 Cr Ni Mo N 25-7-4	1.4410		-	-	2328	S32750	10.94+2509
X 2 Cr Ni Mo Ca WN 25-7-4	1.4501		-	-	-	S32760	10.94+2509
X 10 Cr Ni 18-8	1.4310	-	302 S 31	Z 10 CN 18.09	2331	302	10.92L+16.10/10.92L+16.10
X 5 Cr Ni 18-10	1.4301	X 5 Cr Ni 18 10	304 S 31	Z 6 CN 18.09	2332	304	10.92L+16.10/10.92L+16.10
X 5 Cr Ni 18-10	(1.4301)	(X 5 Cr Ni 18 10)	(304 S 15)	(Z 6 CN 18.09)	2333	(304)	10.92L+16.10/10.92L+16.10
X 6 Cr Ni Ti 18-10	1.4541	X 6 Cr Ni Ti 18 10	321 S 31	Z 6 CNT 18.10	2337	321	10.92L+16.11 or 10.92L+16.11
X 6 Cr Ni Nb 18-10	1.4550	X 10 Cr Ni Nb 18 10	347 S 31	Z 6 CNNb 18.10	2338	347	10.92L+16.11 or 10.92L+16.11
X 3 Cr Ni Mo 17-13-3	1.4436	(X 5 Cr Ni Mo 17 13 3)	(316 S 33)	(Z 6 CND 17.12)	2343	(316)	10.92L+16.30 or 10.92L+16.30
X 5 Cr Ni Mo 17-12-2	(1.4401)	(X 5 Cr Ni Mo 17 12 2)	(316 S 31)	(Z 6 CND 17.11)	2347	(316)	10.92L+16.30 or 10.92L+16.30
X 2 Cr Ni Mo 17-12-2	1.4404	X 2 Cr Ni Mo 17 13 2	316 S 11	Z 2 CND 17.12	2348	316 L	10.92L+16.30 or 10.92L+16.30
X 6 Cr Ni Mo Ti 17-12-2	1.4571	X 6 Cr Ni Mo Ti 17 12 2	320 S 31	Z 6 CNDT 17.12	2350	316 Ti	(10.92L+16.30) or (10.92L+16.30)
X 2 Cr Ni 18-9	1.4307	X 2 Cr Ni 18 10	304 S 11	Z 2 CN 18.10	2352	304 L	10.92L+16.10 or 308H/10.92L+16.10
X 2 Cr Ni Mo 18-14-3	1.4435	X 2 Cr Ni Mo 18 14 3	316 S 3	Z 2 CND 17.13	2353	316 L	10.92L+16.10 or 10.92L+16.10
(EN 10095)	1.4845	X 12 Cr Ni 25 21 <sup>1)</sup>	(310 S 24)	(Z 12 CN 25-20)	2361	310 S	10.92L+310
X 8 Cr Ni 25-21							
X 2 Cr Ni Mo 18-15-4	1.4438	X 2 Cr Ni Mo 18 16 4	-	Z 2 CND 19.15	2367	317 L	10.92L+317L or 10.92L+317L
X 2 Cr Ni N 18-10	1.4311	X 2 Cr Ni N 18 10	-	Z 2 CN 18.10 Az	2371	304 LN	(10.92L+16.10) or (10.92L+16.10)
X 2 Cr Ni Mo N 17-13-3	1.4429	X 2 Cr Ni Mo N 17 13 3	-	Z 2 CND 18.10 Az	2375	316 LN	(10.92L+16.30) or (10.92L+16.30)

1) not standard



## 9. MIG and TIG wires for aluminium

### Base material

EN 573 Alloy designation Numerical	Chemical symbols	The Aluminum Association	ESAB filler metal OK Autrod/Tigrod
EN AW-1050A	EN AW-Al 99,5	AA 1050A	1070,1100, 1450
EN AW-1070A	EN AW-Al 99,7	AA 1070A	1070,1100, 1450
EN AW-1100	EN AW-Al 99,0Cu	AA 1100	1070,1100
EN AW-1200	EN AW-Al 99.0	AA 1200	1070,1100
EN AW-3003	EN AW-Al Mn1Cu	AA 3003	4043, 4047
EN AW-3103	EN AW-Al Mn1	AA 3103	4043, 5356
EN AW-3004	EN AW-Al Mn1Mg1	AA 3004	4043, 5356
EN AW-4045	EN AW-Al Si10	AA 4045	4043,4047
EN AW-5005	EN AW-Al Mg1(B)	AA 5005	5356
EN AW-5019	EN AW-Al Mg5	AA 5019	5356
EN AW-5050	EN AW-Al Mg1,5(C)	AA 5050	5356
EN AW-5052	EN AW-Al Mg2,5	AA 5052	5356
EN AW-5083	EN AW-Al Mg4,5Mn0,7	AA 5083	5183
EN AW-5086	EN AW-Al Mg4	AA 5086	5356
EN AW-5454	EN AW-Al Mg3Mn	AA 5454	5554
EN AW-6013	EN AW-Al Mg1Si0,8CuMn	AA 6013	4043, 5356
EN AW-6060	EN AW-Al MgSi	AA 6060	4043, 5356
EN AW-6061	EN AW-Al Mg1SiCu	AA 6061	5356
EN AW-6063	EN AW-Al Mg0,7Si	AA 6063	5356
EN AW-6082	EN AW-Al Si1MgMn	AA 6082	4043, 5356
EN AW-7005	EN AW-Al Zn4,5Mg1,5Mn	AA 7005	5356
EN AW-7021	EN AW-Al Zn5,5Mg1,5	AA 7021	5356
EN AW-7029	EN AW-Al Zn4,5Mg1,5Cu	AA 7029	5356
EN AW-7039	EN AW-Al Zn4Mg3	AA 7039	5356
EN AW-7050	EN AW-Al Zn6CuMgZr	AA 7050	5356

## CHOOSE THE CORRECT OK ELECTRODES, WIRES AND FLUXES FOR HARFACING AND MAINTENANCE.

Recommendations for the right choice and electrodes for joining dissimilar materials can be found in Figs 1 and 2 on the next page.

The conditions to be considered when choosing the correct electrode, wire and flux for hardfacing and maintenance are summarised in the following outline.

A classification of weld metal resistance to different kinds of working condition can be found in Table 1.

The working conditions for an object that is going to be repaired are often known. The table provides information about suitable electrodes and the different kind of attack which must be taken into account.

The recommended OK electrodes, wires and fluxes for some of the most common objects for hardfacing and maintenance by welding can be found in Table 2.

### Short rules for choosing the correct type of weld metal alloy for hardfacing and cladding

With regard to:

1. Type of wear
2. Working conditions
3. Machinability requirements

Useful information when choosing the correct type of alloy

1. The composition of the material to be welded when deciding.
  - a) Which types of welding alloy are usable and suitable
  - b) If preheating is favourable
  - c) If welding a buffer layer is necessary
2. Conditions for welding
  - a) Is preheating possible or not?

If it is not possible, hardenable welding alloys can only be used to a very limited extent.

For steel and cast iron weldments:

austenitic or non-ferrous alloys are preferable:

OK 67.45, OK 67.75 - austenitic

OK 68.81 and OK 68.82 - austenitic - ferritic

OK 92.18, OK 92.58, OK 92.35 - non-ferrous.

- b) The welding position
- c) Can submerged arc welding or gas metal arc welding be applied?
- d) For which of the applicable welding processes is suitable filler material available?

### 3. Working conditions for the repaired workpiece

- a) Type of wear : abrasive, erosive or cavitation

To resist abrasive wear by sharp - edged blast stone and ore, a hard surface or a work-hardening surface is required or desirable.

Recommended:

OK 84.78, OK 84.80

OK 84.58, OK 83.65

OK 86.28, OK 86.08

To resist erosive wear, a hard surface and a fine-grained microstructure in the weld metal is required.

Recommended :

OK 84.80

OK 84.78

OK 85.65, OK 84.58

OK 83.65

OK 84.52

Cavitation attacks in water turbines can usually be prevented by cladding with austenitic electrodes.

OK 63.35 is the most frequently - used electrode for this purpose, but the following are also suitable :

OK 67.70, OK 67.71

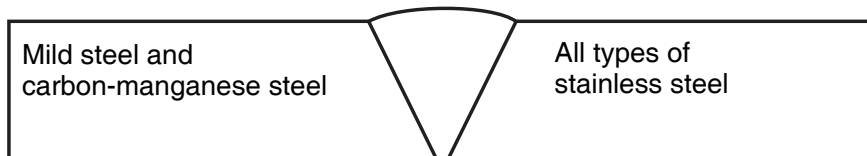
### 4. Environment

- a) Corrosive or non-corrosive?
- b) The temperature, high or low?
- c) To resist wear in a corrosive environment, the weld metal must be resistant to both corrosion and wear. So, depending on the severity of the corrosion attacks, an alloy with some degree of corrosion resistance is required.

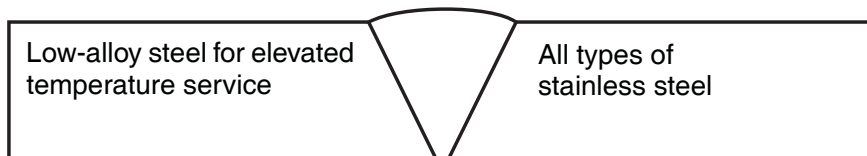
**Choose the right OK Electrodes for joining dissimilar materials**

1. OK 67.70, OK 67.75
2. OK 67.45, OK 68.81, OK 68.82

**Fig. 1**



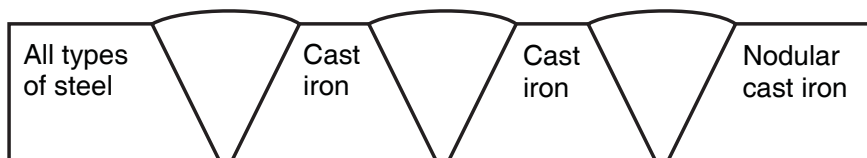
1. OK 92.26
2. OK 67.70, OK 67.75, OK 67.45
3. OK 63.30, OK 63.35



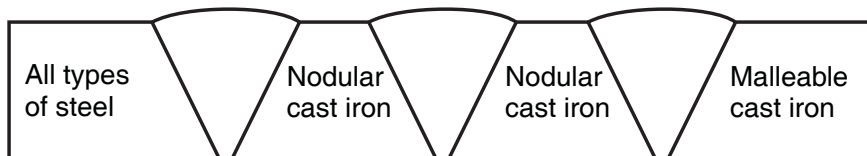
Never use unalloyed electrodes for these joints

1. OK 92.18
2. OK 92.60, OK 92.58

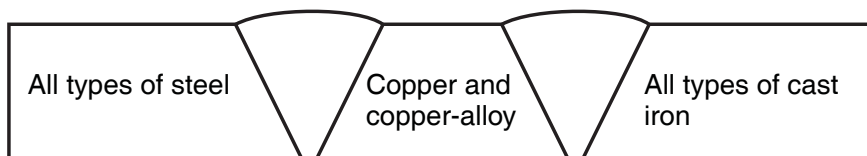
**Fig. 2**



1. OK 92.60, OK 92.58
2. OK 92.18



**OK 94.25**



1. First hand choice
2. Second hand choice
3. Third hand choice