Education and Culture

Leonardo da Vinci

Course: 141 - TIG WELDING OF STAINLESS STEEL

Module 2

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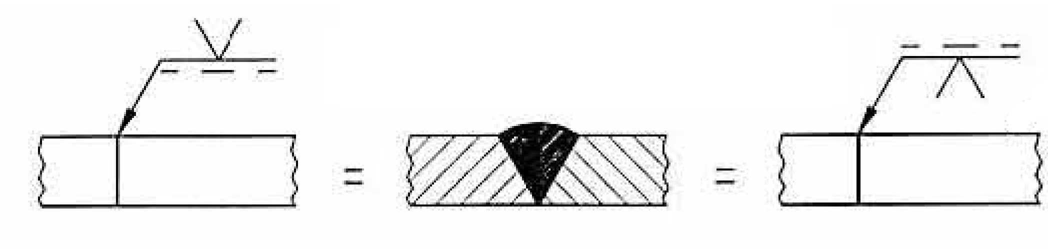
MODULE 2

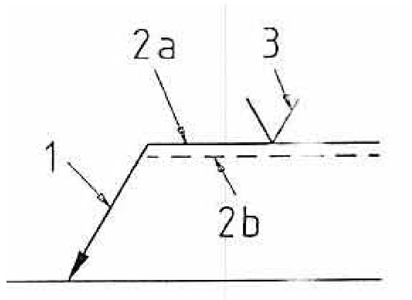
Welding symbols according ISO 2553 (A6)

The **weld joint** is where two or more metal parts are joined by welding. The five basic types of weld joints are the butt, corner, tee, lap, and edge.

Special symbols are used on a drawing to specify where welds are to be located, the type of joint to be used, as well as the size and amount of weld metal to be deposited in the joint.

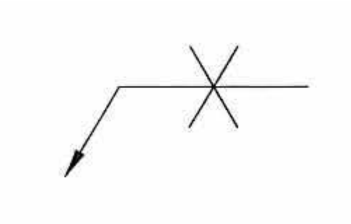


A standard welding symbol consists of a reference line, an arrow, and a tail. The reference line becomes the foundation of the welding symbol. It is used to apply weld symbols, dimensions, and other data to the weld. The arrow simply connects the reference line to the joint or area to be welded. The direction of the arrow has no bearing on the significance of the reference line. The tail of the welding symbol is used only when necessary to include a specification, process, or other reference information.

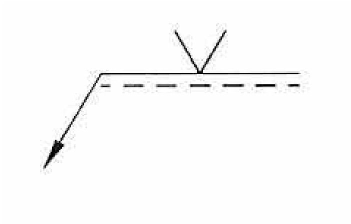


The term *weld symbol* refers to the symbol for a specific type of weld: fillet, groove, surfacing, plug, and slot are all types of welds. Some of basic weld symbols are shown in the next figures.

Types of butt welds

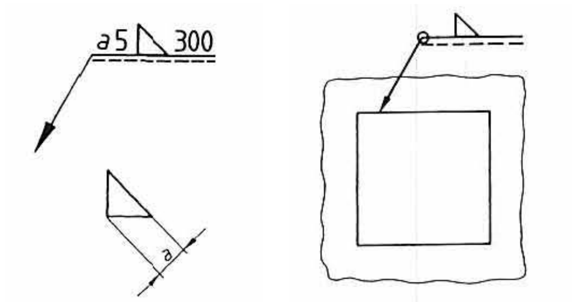


Single V preparation



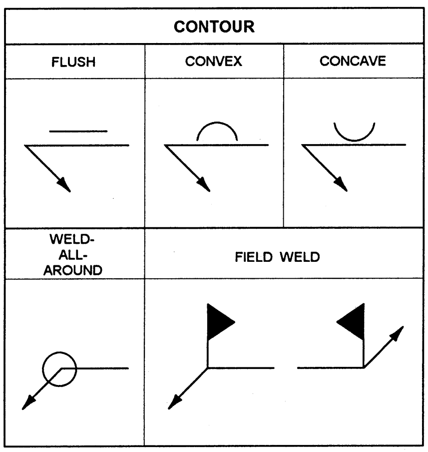
Double V preparation

Types of fillet welds

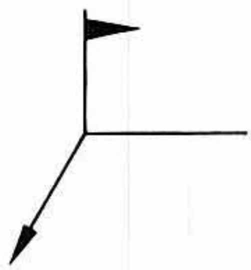


The leg length of a fillet weld is located in front of the weld symbol (triangle). The dimension is in millimeters preceded with the letter Z or by the letter ”a”.
In addition to basic weld symbols, a set of supplementary symbols may be added to a welding symbol.

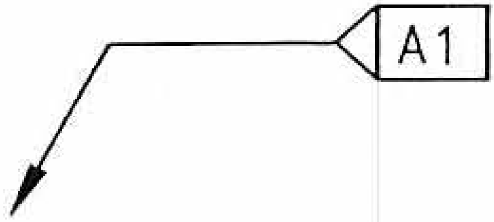
Some of the most common supplementary symbols are shown in the following figure.



Supplementary symbols

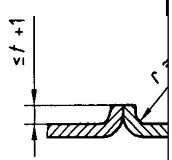


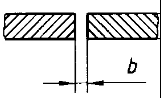
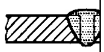
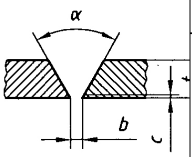
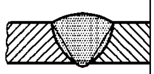
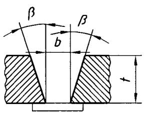
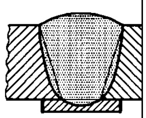
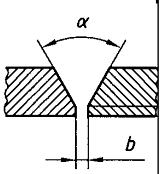
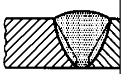
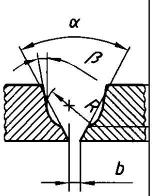
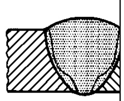
Weld this joint on site

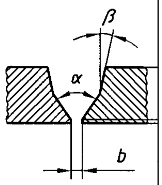
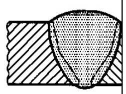


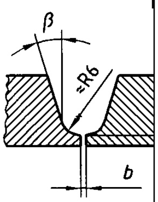
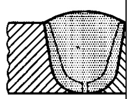
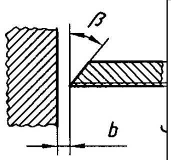
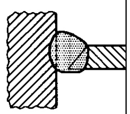
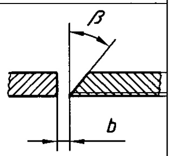
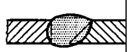
Inspect by NDT, Weld, Paint, etc.

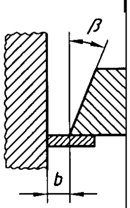
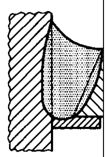
Joint preparation for butt welds, welded from one side

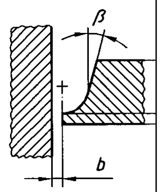
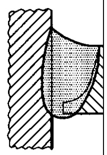
Ref. No.	Workpiece thickness t mm	Designation	Symbol ISO 2553	Cross section	Dimensions				Welding process ISO 4063	Illustration	Remarks
					Angle ,	Gap b mm	Thickness of root face c mm	Depth of preparation h mm			
1.1	≤ 2	Butt weld between plates with raised edges			-	-	-	-	3 111 141 512		Usually without filler metal

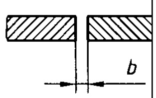
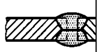
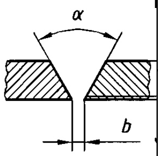
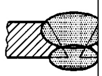
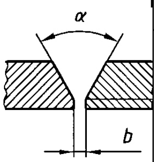
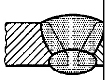
1.2.1 1.2.2	≤ 4 3 < t ≤ 8 ≤ 15	Square butt weld	||		-	~ t 6 ≤ b ≤ 8 ~ t ≤ 10	-	-	3 111 141 13 141 52		- With temporary backing
1.3	3 < t ≤10 8 < t ≤12	Single V butt	V		40^{0} ≤ ≤ 60^{0} 6^{0} ≤ ≤ 8^{0}	≤4 -	≤ 2	-	3 111 13 141 52		
1.4	> 16	Steep-flanked single-V butt with backing			5^{0} ≤ ≤ 20^{0}	5 ≤ *b* ≤ 15	-	-	111 13		With permanent backing
1.5	5 ≤ t ≤ 40	Single –V Butt weld with broad root face	Y		~ 60^{0}	1 ≤ b ≤ 4	2 ≤ c ≤ 4	-	111 13 141		-
1.6	> 12	Single-U butt weld with V root	 e		60^{0} ≤ ≤ 90^{0} 8^{0} ≤ ≤ 12^{0}	1 ≤ b ≤ 3	-	~ 4	111 13 141		6 ≤ R ≤ 9

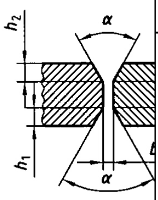
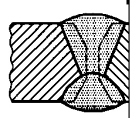
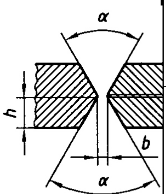
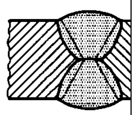
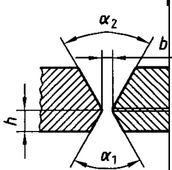
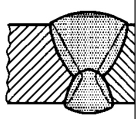
1.7	> 12	Single –V butt weld with V root	 e		60^{0} ≤ ≤ 90^{0} 10^{0} ≤ ≤ 15^{0}	2 ≤ b ≤ 4	**> 2**	**-**	111 13 141		-

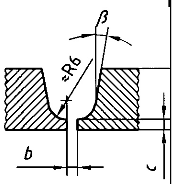
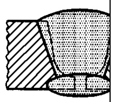
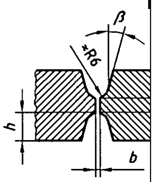
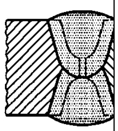
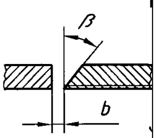
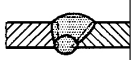
1.8	> 12	Single-U butt weld (sloping sides)			8^{0} ≤ ≤ 12^{0}	≤ 4	≤ 3	**-**	111 13 141		-
1.9.1	3 < t ≤10	Single-bevel butt weld			35^{0} ≤ ≤ 60^{0}	2 ≤ *b* ≤ 4	1 ≤ *c* ≤ 2	**-**	111 13 141		-
1.9.2											

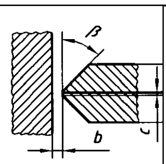
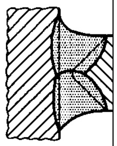
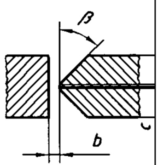
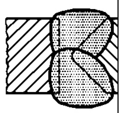
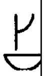
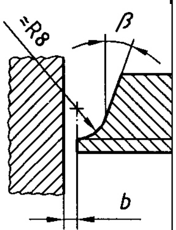
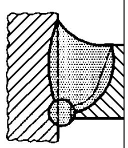
1.10	> 16	Steep-flanked single-bevel butt weld			15^{0} ≤ ≤ 60^{0}	6 ≤ *b* ≤ 12 / ~ 12	**-**	**-**	111 / 13 141		With permanent backing

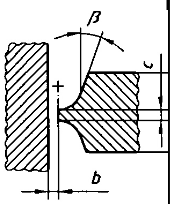
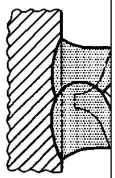
1.11	> 16	Single –J butt weld			10^0 ≤ ≤ 20^0	2 ≤ *b* ≤ 4	1 ≤ *c* ≤ 2	-	111 13 141		-

Ref. No.	**Workpiece thickness** t mm	**Designation**	Symbol ISO 2553	**Cross section**	Dimensions				**Welding process** ISO 4063	**Illustration**	Remarks
					Angle ,	Gap b mm	**Thickness of root face** c mm	**Depth of preparation** h mm			
2.1	≤ 8 ≤ 15	Square butt weld	||		-	~ t/2 ≤ t/2 0	-	-	111 141 13 52		
2.2	3 ≤ *t* ≤ 40	Single-V preparation			~ 60^0 40^0 ≤ ≤ 60^0	≤ 3	≤ 2	-	111 141 13		-
2.3	> 10	Single-V butt weld with broad root face and backing run			~ 60^0 40^0 ≤ ≤ 60^0	1 ≤ *b* ≤ 3	2 ≤ *c* ≤ 4	-	111 141 13		-

2.4	> 10	Double -V butt weld with broad root face			~ 60^0 40^0 ≤ ≤ 60^0	1 ≤ *b* ≤ 4	2 ≤ *c* ≤ 6	$h_1 = h_2 = \frac{t - c}{2}$	111 141 13		-
2.5.1	> 10	symmetrical X			~ 60^0 40^0 ≤ ≤ 60^0	1 ≤ *b* ≤ 3	≤ 2	~ $\frac{t}{2}$	111 141 13		-
2.5.2		asymmetrical X			$_1$ ~ 60^0 $_2$ ~ 60^0 40^0 ≤ $_1$ ≤ 60^0 40^0 ≤ $_2$ ≤ 60^0			~ $\frac{t}{3}$	111 141 13		-

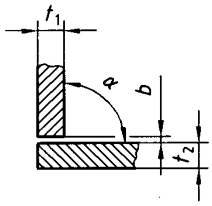
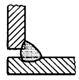
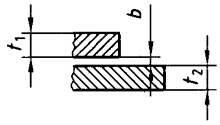
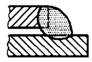
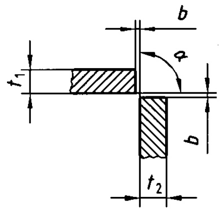
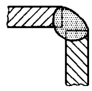
2.6	> 12	Single-U butt weld with backing run			$8^0 \leq$ $\leq 12^0$	$1 \leq b \leq 3$ ≤ 3	~ 5	-	111 13 141 c		Root run may be necessary
2.7	≥ 30	Double-U butt weld			$8^0 \leq$ $\leq 12^0$	≤ 3	~ 3	$\sim \frac{t - c}{2}$	111 13 141		This type of joint preparation can also be produced asymmetri-cally in a similar manner to the asymmetrical X butt weld
2.8	$3 \leq t \leq 30$	Single-bevel butt weld			$35^0 \leq$ $\leq 60^0$	$1 \leq b \leq 4$	≤ 2	-	111 13 141		Root run may be necessary

2.9.1	> 10	T-joint both sides bevelled preparation	K		$35^0 \le$ $\le 60^0$	$1 \le b \le 4$	≤ 2	$= \frac{t}{2}$ sau $= \frac{t}{3}$	111 13 141		This type of joint preparation can also be produced asymmetric-ally in a similar manner to the asymmetrical X
2.9.2											
2.10	> 16	Single-J butt weld with backing run			$10^0 \le$ $\le 20^0$	$1 \le b \le 3$	≥ 2	-	111 13 141		Root run may be necessary

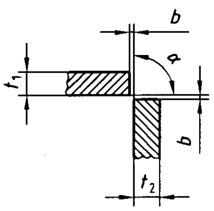
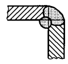
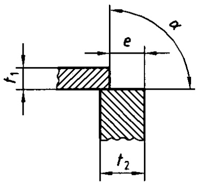
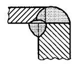
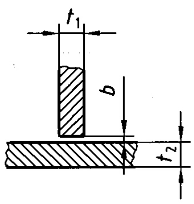
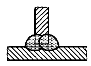
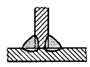
2.11	> 30 ≤ 170	Double- J butt weld for single pass welding process		 	$10^0 \le$ ≤ 20^0	**≤ 3**	≥ 2	= $\frac{t - c}{2}$	111 13 141		This type of joint preparation can also be produced asymmetric-ally in a similar manner to the asymmetrical X
							< 2	~ $\frac{t}{2}$			
									51		

Joint preparation for T - joints, welded from one side

Ref. No.	**Workpiece thickness** t mm	**Designation**	Symbol ISO 2553	**Cross section**	**Dimensions** **Angle** ,	Gap b mm	**Welding process** ISO 4063	**Illustration**

3.1.1	t 1 > 2 t 2 > 2	Single fillet weld			70 ⁰≤ ≤ 100 ⁰	≤ 2	3 111 13 141	
3.1.2	t 1 > 2 t 2 > 2	Single fillet weld	 b		-	≤ 2	3 111 13 141	
3.1.3	t 1 > 2 t 2 > 2	Single fillet weld			60 ⁰≤ ≤ 120 ⁰	≤ 2	3 111 13 141	

Ref. No.	**Workpiece thickness** t mm	**Designation**	Symbol ISO 2553	**Cross section**	**Dimensions**		**Welding process** ISO 4063	**Illustration**
					Angle ,	Gap b mm		

4.1.1	$t_1 > 3$ $t_2 > 3$	Single fillet weld			$70^0 \le$ $\le 100^0$	≤ 2	3 111 13 141	
4.1.2	$t_1 > 2$ $t_2 > 5$	Single fillet weld						
4.1.3	$2 \le$ $t_1 \le 4$ $2 \le$ $t_2 \le 4$	Single fillet weld	b 		$60^0 \le$ $\le 120^0$	-	3 111 13 141	
	$t_1 > 4$ $t_2 > 4$				-	≤ 2 -	3 111 13 141	 

Role of inspection and quality control (B9)

To ensure that a product has the right level of quality, some form of inspection is often required. This can involve such things as measuring the dimensions of a welded part. The measurement result is then compared with the applicable requirement for the welded part in question. If the requirements are fulfilled, the part can be approved. If the requirements are not fulfilled, the part will not be approved. A standard definition of Inspection is: "Measurement, investigation, testing or other classification of one or more characteristics or properties of a product and the comparison of the results with set requirements to determine whether they are fulfilled".

<u>Accreditation</u>

Within the European system, there are a number of standards (EN 45000 series) that include regulations for testing the ability of inspection organs. Its aim is to ensure that inspection organs in Europe carry out equivalent assessments so that the results can be approved by all the member countries. The inspection organs that are approved according to these requirements become accredited for a certain task.

The following bodies can be accredited:

1 Laboratories.
2 Certification organs for products, quality systems, personnel.
3 First, second and third party inspection organs.

Welding is a special process, which requires the coordination of welding operation in order to establish confidence in welding fabrication and reliable performance in service. The tasks and responsibilities of personnel involved in welding related activities, e.g. planning, executing, supervising and inspection, needing to be clearly defined. Welding coordination requirements can be specified by a manufacturer, contract or an application standard.

Quality control

The operations of a company are controlled to give products the right level of quality. This means that the daily activities follow the company's quality system, applying the directions contained in the quality manual and the instructions that are to be available at each workplace. One example of quality control is the application of welding procedure specification (WPS) in order to obtain the right level of quality in welds.

Quality control as applied to welded products includes those activities which monitor the quality of the product – the operational techniques of checking materials, dimensional checks, inspection before, during and after welding, non-destructive testing, hydraulic or leak testing – in other words, activities which take place after the event and which check that everything has been carried out correctly.

Introduction to ISO 3834 (B9)

ISO 3834: „**Quality requirements for fusion welding of metallic materials”**

ISO 3834 consists of 5 parts, under the general title *Quality requirements for fusion welding of metallic materials*:

- *Part 1: Criteria for the selection of the appropriate level of quality requirements*
- *Part 2: Comprehensive quality requirements*
- *Part 3: Standard quality requirements*
- *Part 4: Elementary quality requirements*
- *Part 5: Applicable documents*

ISO 3834 is not a quality management system standard replacing ISO 9001:2000 but a useful tool when ISO 9001:2000 is applied by welding manufacturers.

ISO 3834 identifies measures that are applicable for different situations. They may be applied in the following circumstances:

- in contractual situations: specification of welding quality requirements;
- by manufacturers: establishment and maintenance of welding quality requirements;
- by committees drafting manufacturing codes or application standards: specification of welding quality requirements;
- by organizations assessing welding quality performance, e.g. third parties, customers, or manufacturers.

ISO 3834 can be used by internal and external organizations, including certification bodies, to assess the manufacturer's ability to meet customer, regulatory or the manufacturer’s own

requirements.
ISO 3834 therefore provides a method to demonstrate the capability of a manufacturer to produce products of the specified quality.

It was prepared such that:
a) it is independent of the type of construction manufactured;
b) it defines quality requirements for welding in workshops and/or on site;
c) it provides guidance for describing a manufacturer's capability to produce constructions to meet specified requirements;
d) it provides a basis for assessing a manufacturer’s welding capability.

ISO 3834 is appropriate when demonstration of a manufacturer's capability to produce welded constructions, fulfilling specified quality requirements, is specified in one or more of the following:
- a specification;
- a product standard;
- a regulatory requirement.

The selection of the appropriate part of ISO 3834 should be in accordance with the product standard, specification, regulation or contract.

The manufacturer selects one of the three parts specifying quality requirements based on the following related to products:
- the extent and significance of safety-critical products;
- the complexity of manufacture;
- the range of products manufactured;
- the range of different materials used;
- the extent to which metallurgical problems may occur;
- the extent to which manufacturing imperfections, e.g. misalignment, distortion or weld imperfection, affect product performance.

A manufacturer that demonstrates compliance to a level of this document is also considered to have established compliance to all lower levels without further demonstration (e.g. a manufacturer compliant to ISO 3834-2 demonstrates compliance with ISO 3834-3 and ISO 3834-4).

Summary comparison of ISO 3834, Parts 2, 3 and 4

Criteria	ISO 3834-2	ISO 3834-3	ISO 3834-4
Requirements review	review required		
	record is required	record may be required	record is not required
Technical review	review required		
	record is required	record may be required	record is not required
Sub-contracting	treat like a manufacturer for the specific subcontracted product, services and/or activities, however final responsibility for quality remains with the manufacturer		
Welders and welding operators	qualification is required		
Welding co-ordination personnel	required		no specific requirement
Inspection and testing personnel	qualification is required		
Production and testing equipment	suitable and available as required for preparation, process execution, testing, transport, lifting in combination with safety equipment and protective clothes		
Equipment maintenance	required to provide, maintain and achieve product conformity		no specific requirement
	documented plans and records are required	records are recommended	
Description of equipment	list is required		no specific requirement
Production planning	required		no specific requirement
	documented plans and records are required	documented plans and records are recommended	
Welding procedure specifications	required		no specific requirement
Qualification of the welding procedures	required		no specific requirement
Batch testing of consumables	if required		no specific requirement
Storage and handling of welding consumables	a procedure is required in accordance with supplier recommendations		in accordance with supplier recommendations
Storage of parent material	protection required from influence by environment; identification shall be maintained through storage		no specific requirement

The manufacturer shall review the contractual requirements and any other requirements, together with any technical data provided by the purchaser when the construction is designed by the manufacturer. The manufacturer needs to establish that all information necessary to carry out the manufacturing operations is complete and available prior to the commencement of the work.

The manufacturer shall affirm its capability to meet all requirements and shall ensure adequate planning of all quality-related activities. A review of requirements shall be carried out by the manufacturer to verify that the work content is within its capability to perform, that sufficient resources are available to achieve delivery schedules and that documentation is clear and unambiguous.

The manufacturer shall ensure that any variations between the contract and any previous quotation are identified and the purchaser notified of any programme, cost or engineering changes that may result.

Items considered at or before the time of the review of requirements review:
a) The product standard to be used, together with any supplementary requirements;
b) Statutory and regulatory requirements;
c) Any additional requirement determined by the manufacturer;
d) The capability of the manufacturer to meet the prescribed requirements.

Sub-contracting

When a manufacturer intends to use sub-contracted services or activities (e.g. welding, inspection, NDT, heat treatment), information necessary to meet applicable requirements shall be supplied by the manufacturer to the sub-contractor.
The sub-contractor shall provide such records and documentation of his work as may be specified by the manufacturer.
A sub-contractor shall work under the order and responsibility of the manufacturer.
The manufacturer shall ensure that the sub-contractor can comply with the quality requirements as specified.
The information provided by the manufacturer to the sub-contractor shall include all relevant data from requirements review and technical review. Additional requirements may be specified as necessary to assure sub-contractor compliance with technical requirements.

Welding personnel

The manufacturer shall have at his disposal sufficient and competent personnel for the planning, performing and supervising of the welding production according to specified requirements.
Welders and welding operators shall be qualified by appropriate tests.
The manufacturer needs to have appropriate welding coordination personnel. The welding coordinator shall have sufficient authority to enable any necessary action to be taken.

Inspection and testing personnel

The manufacturer shall have at his disposal sufficient and competent personnel for planning, performing, and supervising the inspection and testing of the welding production according to specified requirements.
The non-destructive testing personnel shall be appropriate qualified/certified. When a qualification test is not required, competence shall be verified by the manufacturer.

Inspection and testing

Applicable inspections and tests shall be implemented at appropriate points in the manufacturing process to assure conformity with contract requirements. Location and frequency of such inspections and/or tests will depend on the contract and/or product standard, the welding process and the type of construction.

Inspection and testing before welding

Before the start of welding, the following shall be checked:
- suitability and validity of welders’ qualification certificates;
- suitability of welding-procedure specification;
- identity of parent material;
- identity of welding consumables;
- joint preparation (e.g. shape and dimensions);
- fit-up, jigging and tacking;
- any special requirements in the welding-procedure specification (e.g. prevention of distortion);
- arrangement for any production test;
- suitability of working conditions for welding, including environment.

Inspection and testing during welding

During welding, the following shall be checked at suitable intervals or by continuous monitoring:
- essential welding parameters (e.g. welding current, arc voltage and travel speed);
- preheating/interpass temperature;
- cleaning and shape of runs and layers of weld metal;
- back gouging;
- welding sequence;
- correct use and handling of welding consumables;
- control of distortion;
- any intermediate examination (e.g. checking of dimensions).

Inspection and testing after welding

After welding, the compliance with relevant acceptance criteria shall be checked:
- by visual inspection;
- by non-destructive testing;
- by destructive testing;
- form, shape and dimensions of the construction;
- results and records of post-weld operations (e.g. post-weld heat treatment, ageing).

Inspection and test status

Measures shall be taken, as appropriate, to indicate, e.g. by marking of the item or a routing card, the status of inspection and test of the welded construction.

Non-conformance and corrective actions

Measures shall be implemented to control items or activities, which do not conform to specified requirements in order to prevent their inadvertent acceptance. When repair and/or rectification is undertaken by the manufacturer, descriptions of appropriate procedures shall be available at all workstations where repair or rectification is performed. When repair is carried out, the items shall be re-inspected, tested and examined in accordance with the original requirements. Measures shall also be implemented to avoid recurrence of non-conformances.

Calibration and validation of measuring, inspection and testing equipment

The manufacturer shall be responsible for the appropriate calibration or validation of measuring, inspection and testing equipment. All equipment used to assess the quality of the construction shall be suitably controlled and shall be calibrated or validated at specified intervals.

Identification and traceability

Identification and traceability shall be maintained throughout the manufacturing process, if required.

Quality records

Quality records shall include, when applicable:

- record of requirement/technical review;
- material certificates;
- welding consumable certificates;
- welding-procedure specifications;
- equipment maintenance records;
- welding-procedure qualification records (WPQR);
- welder or welding-operator qualification certificates;
- production plan;
- non-destructive testing personnel certificates;
- heat-treatment procedure specification and records;
- non-destructive testing and destructive testing procedures and reports;
- dimensional reports;
- records of repairs and non-conformance reports;
- other documents, if required.

Quality records shall be retained for a minimum period of five years in the absence of any other specified requirements.

Application

Conformity to ISO 3834-2 to 4 shall be claimed by a manufacturer using the normative references given in this part. Conformity to ISO 3834-2 to 4 may also be claimed by adopting other standards that provide equivalent technical conditions.

Where other standards are adopted, they should only be used when they are referenced in product standards for constructions being made by the manufacturer.

It is the responsibility of the manufacturer to demonstrate technically equivalent conditions when normative references other than those listed in this part are applied. Certificates issued following assessment by independent certification organizations or claims of compliance by a manufacturer with any part of ISO 3834 shall clearly identify the normative references or specifications used by the manufacturer.

Stainless steel compared to unalloyed steel and aluminium alloys (PSS1)

The consumption of stainless steel is increasing and will continue to do so. The reason of growth is increasingly demanding environment in the petrochemical industry and the process industry.

Demand for these materials is also growing in industrial sectors such as foodstuffs, electronics, biochemistry and nuclear power.

Stainless steel have also replaced other structural materials in many applications where it has been realized that stainless steel is cheaper in the long term, if both capital outlay and maintenance costs are taken into account.

Two types of stainless steel have been more and more important: ferrite-austenitic (duplex) and fully-austenitic steels.

The advantages of duplex steel are as follows:

- good weldability
- considerably higher yeld strength
- good resistance to stress corrosion, above all, but also to general corrosion and pitting.

Aluminum and aluminum alloys are structural materials with many good properties: with a proper design they do not corrode, they conduct electricity and they combine strength with low weight.

Aluminum is considered to be a very important construction material in the future, especially in the automotive industry.

Definition of stainless steel

Stainless steels are defined as iron base alloys, which contain at least 11 % chromium.

There are five types of stainless steels depending on the other alloying additions present, and they range from fully austenitic to fully ferritic.

Identification of stainless steel

The most important property of the high-chromium stainless steels is their corrosion resistance, without which they would find little commercial use, as their general level of mechanical properties and forming characteristics can be equaled or exceeded by many other types of steel at a much lower cost. A chromium content above 12% also provides a considerable measure of oxidation resistance.

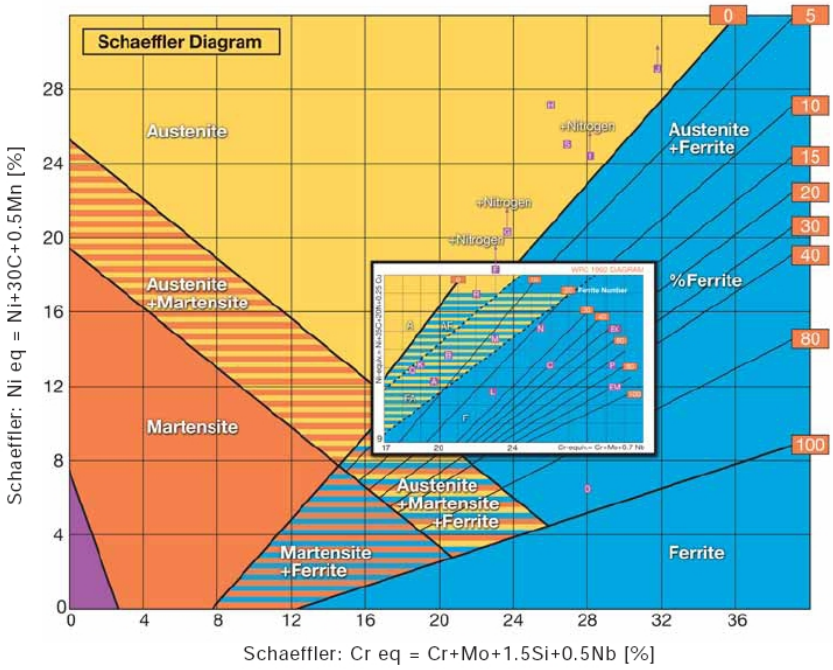
Thus the stainless steels are used for both corrosion resisting and high-temperature creep resisting and heat resisting applications, the temperature of application usually increasing with increasing chromium content.

The important factors, which must be considered in the design of the various types of stainless steels, are:

- corrosion and oxidation resistance in the operating environment
- mechanical and physical properties
- fabrication characteristics from the point of view of both hot and cold working

- welding - many of the stainless steels are required to be readily weldable, and welding must not impair the corrosion resistance, creep resistance or general mechanical properties.

There are many different stainless steels, see figure, and the main types are listed below.



a) **Ferritic steels**, containing 11,5 – 30% Cr, up to 0,20% carbon, no nickel and often some molybdenum, niobium or titanium. They are ferritic at all temperatures and, therefore, do not transform to austenite and are not hard enable by heat treatment.

Some of these can be highly corrosion resistance, and being fully ferritic are reasonably formable. They can in the less severe applications, replace the more expensive austenitic stainless steels.

They are characterized by weld and HAZ grain growth, which can result in low toughness of welds.

To weld the ferritic stainless steels, filler metals should be used which match or exceed the Cr level of the base alloy.

To minimize grain growth, weld heat input should be minimized and preheat should be limited, and used only if necessary.

b) **Martensitic steels** containing 11 – 18% Cr, 0 – 4% Ni, 0,1 – 1,2%C, and sometimes additions of molybdenum, vanadium, niobium, aluminum and copper. These are often alloyed to produce the required tempering resistance and strength. They are austenitic at temperatures of 950 – 1000 ^{o}C but transform to martensite on cooling, and the high hardenability makes them martensitic air hardenable even in large section sizes.

This can lead to difficulty in softening for machining and fabrication, particularly as they frequently alloyed to produce a high degree of tempering resistance.

The steels are usually tempered to produce useful combinations of strength, ductility and toughness, and may be precipitation hardened.

They have a tendency toward weld cracking on cooling when hard brittle martensite is formed.

Chromium and carbon content of the filler metal should generally match these elements in the base metal.
Preheating and interpass temperature in the 204 to 316 °C range is recommended for most martensitic stainless steel.
Steel with over 0,20 % C often require a post weld heat treatment to soften and toughen the weld.

c) **Austenitic steels** which contain 16 – 26% Cr, 8 – 20% Ni, up to 0,40% C. These steels also often contain additions of molybdenum, niobium or titanium and are predominantly austenitic at all temperatures, although depending o the composition and consequent constitution, some delta ferrite may be present.
The austenite may have a varying degree of stability with respect to the formation of martensite, being transformed by cold work at room temperature in some compositions.
The balance between the Cr and Ni + Mn is normally adjusted to provide a microstructure of 90 - 100% austenite.
These alloys are characterized by good strength and high toughness over a wide temperature range and oxidation resistance to over 538 °C.
Filler metal for these alloys should generally match the base metal but for most alloys, provide a microstructure to avoid hot cracking.
Two problems are associated with welds in the austenitic stainless steels:
- sensitization of the weld heat affected zone
- hot cracking of weld metal.

d) **Precipitation hardening stainless steel** are martensitic, semiaustenitic and austenitic.
The martensitic stainless steel can be hardened by quenching from the austenitizing temperature (around 1038 °C) then aging between 482 to 621 °C. Since these steels contain less than 0,07% C, the martensite is not very hard and the main hardening is obtained from the aging (precipitation) reaction.
The semiaustenitic stainless steel will not transform to martensite when cooled from the austenitizing temperature because the martensite transformation temperature is below room temperature. These steels must be given a conditioning treatment which consists heating in the range of 732 to 954 °C to precipitate carbon and/or alloy elements as carbides or intermetallic compounds.
The austenitic precipitation hardening stainless steel remains austenitic after quenching from the solutioning temperature even after substantial amounts of cold work. They are hardened only by the aging reaction. This would include solution treating between 982 to 1121 °C, oil or water quenching and aging at 704 to 732 °C for up to 24 hours.
If maximum strength is required in martensitic precipitation hardening stainless steels, matching or nearly matching filler metal should be used and the component, before welding, should be in the annealed or solution annealed condition. After welding, a complete solution heat treatment plus an aging treatment is preferred.
The austenitic precipitation hardening stainless steel are most difficult to weld because of hot cracking. Welding should preferably be done with the parts in the solution treated condition, under

minimum restraint and with minimum heat input.

e) **Duplex stainless steel** are the most recently developed group of stainless steel and have a microstructure of approximately equal amounts of ferrite and austenite.
These steels have advantages over the conventional austenitic and ferritic steels in that they offer higher strength and greater stress corrosion cracking resistance.
The duplex microstructure is attained in steels containing 21 - 25% Cr and 5 – 7 % Ni by hot working at 1000 to 1050 °C followed by water quenching. Weld metal of this composition will tend to be mainly ferritic because the deposit will solidify as ferrite and will transform only partly to austenite without hot working or annealing.

•The alloying elements which appear in stainless steels are classed as ferrite formers and austenite formers:

Ferrite formers

- Chromium - provides basic corrosion resistance
- Molybdenum - provides high temperature strength and increases corrosion resistance
- Columbium, Titanium - strong carbide formers
- Phosphorous, Sulfur, Selenium - improves machinability, causes hot cracking in welds

Austenite formers

- Nickel - provides high temperature strength and ductility
- Carbon - carbide former, strengthener
- Nitrogen - increases strength, reduces toughness

The working environment of the fabrication shop, general hazards, dust, heavy and hot material, cables (A4)

The welding processes are characterized by high temperatures, extensive fumes, light and heat radiation and risks from electric power. All these phenomena can endanger welder health, and potentially they are also dangerous for the environment.
The basic task for health and safety is to eliminate these dangerous aspects of welding.

General Hazards

The general hazards in welding and cutting are:
•Fire from sparks and spatter
•Explosion and fires from reaction with welding gases
•Asphyxiation
•Electric shock
•Inhaling toxic fumes and gases
•Eye injuries from heat rays

There are many regulations regarding safety in welding, which are derived from more general safety regulations, like 'General rules for hygienic and technical safety measures at work' and 'Regulations for personal safety means'. Every welder has the right and obligation to be protected under these regulations.

The owner/operator is obliged to have a safety inspection performed on the welding equipments at least once every 12 months.
A safety inspection, by a trained and certified electrician, is prescribed:
- after any alterations
- after any modifications or installations of additional components
- following repairs, care and maintenance
- at least every twelve months.

<u>Measures - technical devices and equipment</u>
When planning a workplace, the working height plays an important part in creating the correct working position. In this context, positioners and lifting tables can be very useful. The working position is partly determined by the welder’s need to have his/her eyes close to the workpiece to be able to see the molten pool clearly while welding. If the working height is too low, the welder has to bend to see properly. A chair or stool might then be very useful. Working with the hands in a high position at or above shoulder level should be avoided whenever possible.
In conjunction with heavier welding, the gun and hoses are also heavier and the load on the body is more static. A balanced load-reduction arm is very useful in this situation. Lifting the hoses off the floor also protects them from wear and tear, as well as facilitating wire feed.
It is also a good thing if the workpiece is placed in a positioner and is positioned to ensure the best accessibility and height. A more comfortable working position can be created and, at the same time, welding can be facilitated as the joint is in the best welding position.
Roller beds can be used for welding tubes or other cylindrical items. A hook or some other device on which the welding gun can be placed when it is not in use is another valuable piece of equipment.

Hot work exposes workers to:
- Molten metal
- Toxic gases
- Fumes and vapors
- Harmful radiation
- Excessive noise
- Electrical shock
- Fire hazards.
Appropriate personal protective equipment (PPE) must be selected to protect the worker from these hazards. Fire watches in the area are required.

Hot work operations include:
- Gas Welding and Cutting
- Electric Arc Welding
- Carbon Arcing or Plasma Arc Cutting

Each of these operations may present unique hazards.

Electro- magnetic effects

Current gives rise to a magnetic field around the conductor. The magnetic field is stronger closer to the conductor and rapidly subsides as the distance increases. A magnetic field is created around the welding cable and earth cable when welding is in process.

Studies have indicated that one should not be exposed to strong magnetic fields. However, there is no evidence of any injuries. No limits have been yet set.

Recommendations: You should make sure that as little as possible of the welding cable is directly adjacent to your body when welding. If you are right-handed, the welding machine should be placed on your right-hand side to avoid laying the welding cable on your lap or around your body. It is not a good idea to rest the welding cable around your body while erection welding (with the welding machine on the ground).

Do not forget that MAGNETIC FIELDS can affect pacemakers and hearing aids.

Recommendations:
- Pacemaker wearers keep away.
- Wearers should consult their doctor before going near arc welding, gouging, or spot welding operations.

Ancillary measures for preventing EMC problems:

a) Mains supply
- If electromagnetic interference still occurs, despite the fact that the mains connection is in accordance with the regulations, take additional measures (e.g. use a suitable mains filter).

b) Welding cables
- Keep these as short as possible
- Arrange them so that they run close together (to prevent EMI problems as well)
- Lay them well away from other leads.

c) Equipotential bonding

d) Workpiece grounding (earthing)
- where necessary, run the connection to ground (earth) via suitable capacitors.

e) Shielding, where necessary
- Shield other equipment in the vicinity
- Shield the entire welding installation.
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Handling of stainless steel in the workshop and the use of tools for stainless steel (PSS2)

For welding of stainless steels we have to respect following:

- welding will be made in special arranged spaces, where no other type of steel or material or alloys will be welded;
- the necessary tools and devices for welding and cleaning must be form stainless steel in order to avoid surfaces pollution elements welded;
- an accentuate cleaning of the elements and equipments has to be maintained; touching of the components will be made only with white cotton gloves in order to avoid surfaces degradation through impurities, dust ,metallic powder, oils;
- components manipulation will be carefully realized to avoid the damaging of the surfaces;
- in welding spaces air currents have to be avoid;
- welding has to be stopped if the outside temperature is bellow than + 5º C.

Example of stocking pipes and fittings, separating steel and stainless steel .