THE LINDE GROUP

Linde

White paper.

EN 1090 Guideline.

Date April 2014

Contents.

Are you ready for EN 1090?

Many manufacturers of steel and aluminium structures or structural components still have a lot of doubts about EN 1090. Typical questions include:

- Does this new standard even affect me?
- If it does, what processes does it affect?
- What new standards do I have to comply with?
- What class should I be in?
- What happens if I don't comply by June 2014?
- How do I go about certification?

We created this guideline to help you answer these and other questions. It guides you through the general formalities and then looks at the precise specifications for each thermal process – from cutting and welding through holing and shaping to preheating and heat treatment.

NB: when other standards are referenced, please see those specific standards for details. This guide focuses on EN 1090 only.

Introduction.

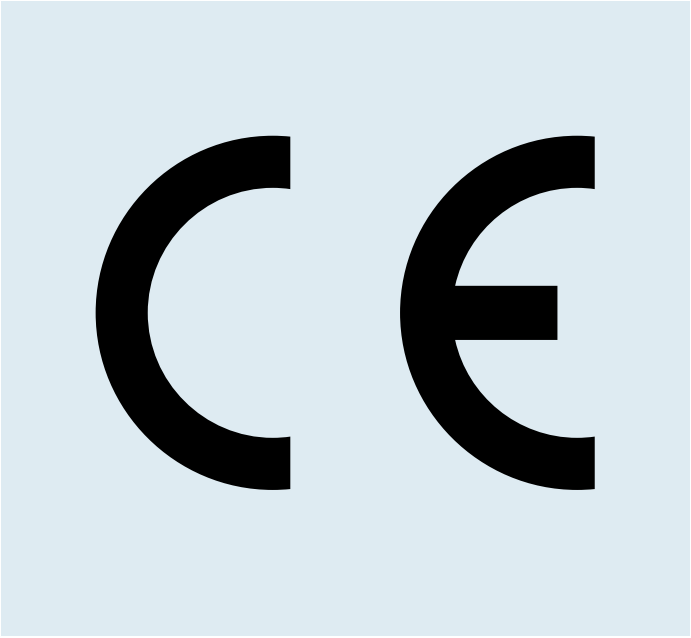
A new EU standard EN 1090 for structural steel and aluminium is due to come into effect in July 2014. From this date, all components supplied into Europe will need to conform to this standard and be CE marked.

This will have an impact on all suppliers to this market, both large and small.

This guideline gives an overview of EN 1090 and how it affects you. It also presents the key requirements and specifications that relate to thermal processes, i.e. cutting, welding, shaping and spraying of steel and stainless steel components. It is limited to the manufacture of these components and does not include design or installation.

There are three section in EN 1090:

EN 1090-1: Requirements for conformity assessment for structural components (CE marking).
EN 1090-2: Technical requirements for the execution of steel structures.
EN 1090-3: Technical requirements for the execution of aluminium structures.



Execution classes.

EN 1090 has defined execution classes (EXC), each with its own set of requirements. Classification of the execution classes is determined largely by the consequence of failure and component complexity.

Classification.

There are four execution classes (EXC1 to EXC4), with the number rising as complexity and thus compliance strictness increases. For example, a handrail may be classified as EXC1 and a bridge EXC4. EXC2 is the most common specification. Table 1 presents some typical examples.

The execution class is determined by the designer and owner of the construction works and can apply to an entire structure, parts of a structure or even specific details.

Execution classes.

The execution class determines the requirements for the various activities. Table 2 summarises the requirements for each of the execution classes that are covered in this document.

As a manufacturer, you will need to be certified to an execution class, and this will govern the items that you are entitled to produce. Selecting the right execution class is an important step. See the next section for guidance on how to select your execution class.

Please note that if no execution class is specified, EXC2 will apply even if the job in question falls under EXC1.

Table 1: Typical examples of execution classes

EXC1	Supporting structures with steel up to strength class S275, buildings with up to 2 floors (4 floors if detached), bending beams up to 5m, projection beams up to 2m. Stairs & railings in residential buildings. Agricultural buildings, e.g. barns.
EXC2	Supporting structures with steel up to strength class S700. Buildings with 2–15 floors.
EXC3	Supporting structures with steel up to strength class S700. Assemblies/stadiums with large surface roof structures. Buildings with more than 15 floors. Pedestrian, bicycle, road and railway bridges. Crane track
EXC4	Bridges (road & rail) over densely populated areas or industrial plants with high hazard potential. Safety tanks in nuclear power plants.

Selecting the right execution class.

There are some practical guidelines to help you select the execution class which applies to your business. We have summarised these in the following four-step process.

1. Define the consequence class

The purpose of defining a consequence class is to ensure that buildings (and other structures) are constructed with the appropriate level of quality control. Consequence classes are based on building type, building height (number of storeys), floor plan area per storey (for retail) and occupancy. A structure, or a part of it, could also contain components with different consequence classes. In most cases, CC2 will be suitable .

Table 1.1: Consequence class

Class	Description	Examples*
CC3	High consequence	Stadiums and concert halls for 5,000+ people, buildings storing hazardous substances
CC2	Medium consequence	Most multi-storey residential and commercial buildings, hotels, hospitals, education establishments and car parks
CC1	Low consequence	Agricultural or storage buildings

*Refer to Annex A, BS EN 1991-1-7 (Eurocode 1) for more examples of building categorisation

2. Select a service category

Service categories reflect the risk arising from the actions to which the structure and its parts are likely to be exposed during erection and use, such as fatigue and likelihood of seismic actions. They also look at the stress levels in the components in relation to their resistance.

Service categories are determined from Table B.1 of BS EN 1090-2. In the UK, for instance, SC1 will generally be appropriate.

Table 1.2: Service category

Category	Criteria
SC1	Structures/components designed for quasi actions only, e.g. buildings
SC2	Structures/components designed for fatigue actions to EC3 such as bridges, or located in regions with medium/high seismic activity

3. Select a production category

Production categories are determined by the risk arising from the fabrication complexity of the structure and its components. This may entail the application of particular techniques, procedures and controls.

Production categories are determined from Table B.2 of BS EN 1090-2 and it should be noted that a structure or part of a structure may contain components or structural details that belong to different production categories. However, the execution class is not always sensitive to the production category.

Table 1.3: Production category

Category	Criteria
PC1	Non-welded components or welded components from steel grades below S355
PC2	Welded components manufactured from steel grades from S355 and above

4. Use the results of steps 1, 2 and 3 and a matrix to determine your execution class

Once the consequence class, service category and production category have been determined for a building, Table B.3 of BS EN 1090-2 defines the corresponding execution class. In Germany, for instance, EXC2 will be applicable to most buildings. Where no execution class is specified, Clause 4.1.2 of BS EN 1090-2 states that EXC2 applies.

Table 1.4: Execution class

Consequence class		CC1		CC2		CC3	
Service category		SC1	SC2	SC1	SC2	SC1	SC2
Production category	PC1	EXC1	EXC2	EXC2	EXC3	EXC3	EXC3
	PC2	EXC2	EXC2	EXC2	EXC3	EXC3	EXC4

Table 2: Summary of requirements[1]

Clauses	EXC1	EXC2	EXC3	EXC2
4. Specification and documentation				
4.2.1 Quality documentation	No Requirement	Yes	Yes	Yes
5.2 Identification, inspection documents and traceability (of constituent products)				
Inspection documents	Required	Required	Required	Required
Traceability	No requirement	Yes (partial)	Yes (full)	Yes (full)
Marking	No requirement	Yes	Yes	Yes
6.4 Cutting				
6.4.3 Thermal Cutting	Free from significant irregularities. Hardness acc. to Table 5	EN ISO 9013 u = range 4, Rz5 = range 4. Hardness acc. to Table 5	EN ISO 9013 u = range 4, Rz5 = range 4 Hardness acc. to Table 5	EN ISO 9013 u = range 3, Rz5 = range 3 Hardness acc. to Table 5
6.5 Shaping				
6.5.3 Flame straightening	No requirement	No requirement	Suitable procedure to be developed	Suitable procedure to be developed
6.6 Holing				
6.7 Cut-outs	No requirement	Min. radius 5 mm	Min. radius 5 mm	Min. radius 10 Punching not permitted
7. Welding				
7.1 General	EN ISO 3834-4	EN ISO 3834-3	EN ISO 3834-2	EN ISO 3834-2
7.4.1 Qualification of welding procedures	No requirement	Qualified welding procedures	Qualified welding procedures	Qualified welding procedures
7.4.2 Qualification of welders and operators	Welders: EN 287-1 Operators: EN 1418	Welders: EN 287-1 Operators: EN 1418	Welders: EN 287-1 Operators: EN 1418	Welders: EN 287-1 Operators: EN 1418
7.4.3 Welding coordination	No requirement	Technical knowledge according to Table 9 or 10	Technical knowledge according to Table 9 or 10	Technical knowledge according to Table 9 or 10
7.5.1 Joint preparation	No requirement	No requirement	Prefabrication primers not allowed	Prefabrication primers not allowed
7.5.6 Temporary attachments	No requirement	No requirement	Use to be specified. Cutting and chipping not permitted	Use to be specified. Cutting and chipping not permitted
7.5.7 Tack welds	No requirement	Qualified welding procedure	Qualified welding procedure	Qualified welding procedure
7.5.9 Butt welds				
7.5.9.1 General	No requirement	Run-on/run-off pieces if specified	Run-on/run-off pieces	Run-on/run-off pieces
7.5.9.2 Single side welds			Continuous permanent backing	Continuous permanent backing
7.5.17 Execution of welding			Removal of spatter	Removal of spatter
7.6 Acceptance criteria	EN ISO 5817 quality level D if specified	EN ISO 5817 quality level C generally	EN ISO 5817 quality level B	EN ISO 5817 quality level B +
12. Inspection, testing and repair after welding				
12.4.2.2 Scope of inspection	Visual inspection	NDT: See Table 15	NDT: See Table 15	NDT: See Table 15
12.4.2.5 Correction of welds	No requirement	Qualified welding procedure	Qualified welding procedure	Qualified welding procedure

Evaluation of conformity and certification

As a manufacturer you will need to apply for an assessment by a designated authority. This authority will assign you to a specific execution class which, in turn, will determine the components you can produce. For example, a manufacturer certified to EXC2 is permitted to manufacture an EXC1 or EXC2 component or product, but is not permitted to manufacture an EXC3 or EXC4 component or product.

To demonstrate compliance, the assessment will cover:
- Initial type testing
- Factory production control system, including inspection and testing
- Personnel qualifications/abilities.

Please note that the assessment process can take several months to complete you should engage the designated authority as soon as possible. When applying, you need to consider what execution class you want to be tested for. You will need to be reassessed if you wish to work at a higher execution class.

If, for instance, you are thinking of applying for EXC1, it may be worth considering EXC2, as a relatively small increase in qualification effort will mean you can supply the majority of the market.

Initial type testing (ITT)

For all execution classes, you are required to produce samples for testing to demonstrate that you have the capabilities to meet this European standard. These tests are required if:
- production of a new component commences or new constituent products are used (unless the component in question is from the same family);
- a new or modified method of production is introduced that affects a performance characteristic of the product or component, e.g. change in fuel gas;
- you change production to a higher execution class.

The results from all of these initial type Evaluations tests will need to be documented and retained for at least five years.

Factory production control

To ensure that products placed on the market conform to the declared performance characteristics, you need to have a working factory production control (FPC) system in place. This needs to be documented and maintained.

The FPC system consists of written procedures, regular inspections, tests, assessments and the use of results to control the manufacturing process through to finished component.

Welding coordination

EXC2, EXC3 and EXC4 require that a welding coordinator be appointed. Based at the manufacturing site, this coordinator is responsible for overseeing welding operations.

The welding coordinator needs to be able to demonstrate experience and knowledge in the welding operations they supervise, including familiarisation with relevant standards and practices. Formal qualifications are not essential but may be helpful.

Constituent products and consumables.

A constituent product is a material or product used to manufacture a component which remains part of the finished product, e.g. raw materials and welding consumables.

These products must meet the relevant European standards or other standards as specified. The documents supplied with the constituent products (batch numbers, inspection certificates, test reports and declarations of compliance, etc.) must be checked to verify that the information on the products supplied matches the specifications for the products ordered. If these documents are not available, measures must be taken to prove that the product meets the requirements of the inspection and test plan.

Table 3: Product standards for welding consumables[1]

Welding consumables	Product standards
Shielding gases for arc welding and cutting	EN ISO 14175
Wire electrodes and deposits for gas-shielded metal arc welding of non-alloy and fine-grain steels	EN ISO 14341
Solid wires, solid wire-flux and tubular cored electrode-flux combinations for submerged arc welding of non-alloy and fine- grain steels	EN 756
Covered electrodes for manual arc welding of high-strength steels	EN 757
Tubular cored electrodes for metal arc welding with and without gas shield of non-alloy and fine grain steels	EN ISO 17632
Fluxes for submerged arc welding	EN 760
Covered electrodes for manual arc welding of stainless and heat-resisting steels	EN 1600
Rods, wires and deposits for tungsten inert gas welding of non-alloy and fine-grain steels	EN ISO 636
Covered electrodes for manual arc welding of non-alloy and fine-grain steels	EN ISO 2560
Wire electrodes, wires and rods for arc welding of stainless and heat-resisting steels	EN ISO 14343
Wire electrodes, wires, rods and deposits for gas-shielded arc welding of high-strength steels	EN ISO 16834
Wire and tubular cored electrodes and electrode-flux combinations for submerged arc welding of high-strength steels	EN 14295
Tubular cored electrodes for metal arc welding with or without a gas shield of stainless and heat-resisting steels	EN ISO 17633
Tubular cored electrodes for gas-shielded metal arc welding of high-strength steels	EN ISO 18276

Preparation and assembly.

Identification, handling and storage

For EXC2, if different grades or qualities of constituent products are at risk of getting mixed up, each item needs to have an identification mark.

For EXC3 and EXC4, a suitable system needs to be in place to identify each component at all stages of production and to link each finished component to inspection certificates.

Please note that there are restrictions on the methods to be used for marking; please see EN1090-2:2008, section 6.2.

Constituent products should be handled and stored in accordance with the product manufacturer's recommendations. If this is not the case and there is a risk of significant deterioration, these products need to be checked to ensure they still comply with the relevant product standard.

Care needs to be taken during handling and transportation of constituent products and produced items to prevent permanent distortion and surface damage. A list of preventive measures during handling and storage is provided in EN1090-2:2008, table 8.

Cutting.

The cutting process must meet the requirements for geometrical tolerances, maximum hardness and smoothness of free edges specified in this European standard.
Cutting

Please note that hand thermal cutting should be used only if it is not practical to use machine thermal cutting.

If a process fails to meet the required standard, it cannot be used until corrected and retested.

For coated materials, the cutting method must be selected to minimise damage to the coating.

Any burrs that could cause injury or prevent the proper alignment or bedding of sections or sheeting must be removed.

Please note that although the standard does not specify the need to have cutting procedures, it is good practice to have these in place, covering:

- cutting parameters
- results of mechanical tests carried out for the process approval
- testing schedule
- identification of workers entitled to apply the process.

Thermal cutting

In order to prove that the thermal cutting process meets the required standard, initial type tests (ITT) need to be completed, followed by periodic checks as described below.

Four samples need to be produced from the raw material or component to be cut by the process:
1) a straight cut from the thickest constituent product;
2) a straight cut from the thinnest constituent product;
3) a sharp corner (e.g. 90°) from a representative thickness;
4) a curved arc from a representative thickness.

On the straight samples, measurements are taken over at least a 200 mm length on each sample and checked against the required quality class. The sharp corner and curved samples must be shown to produce edges of equivalent standard to the straight cuts.

Quality of cut surfaces

EN ISO 9013 defines the geometrical specification and quality tolerances for thermal cutting which EN 1090 refers to.

Table 4 shows the quality of cut surfaces defined in accordance with EN ISO 9013 for each of the execution classes.

For EXC1 the basic requirement is that cut edges must be free from significant irregularities and any dross removed.

Table 4: Quality of the cut surfaces[2]

Clauses	Perpendicularity or angularity tolerance, u	Mean height of the profile, Rz5
EXC1	Range 5	Range 5
EXC2	Range 4	Range 4
EXC3	Range 4	Range 4
EXC4	Range 3	Range 3

Hardness of free edge surfaces

Table 5 specifies the hardness of free edge surfaces for carbon steels. Any cutting processes that are likely to produce local hardness need to be tested.

Please note that the hardness specifications are dependent on steel grade and not execution class. They therefore apply to all components covered by this standard.

The hardness testing process (unless it is otherwise specified) must be as follows:

- Four samples are produced from the procedure tests, encompassing the range of constituent products processed that are most likely to produce local hardening.
- Four local hardness tests (in accordance with EN ISO 6507) are completed on each sample in locations likely to be affected.

Methods to correct hardness include:

- grinding
- preheating
- process change (e.g. plasma to oxy-fuel cutting)
- process parameter change (e.g. reduction in cutting speed for LPG)
- fuel gas change (e.g. propane to acetylene).

Table 5: Permitted maximum hardness values (HV10) [2]

Product standards	Steel grades	Hardness values
EN10025-2 to 5		
EN10210-1, EN10219-1	S235 to S460	380
EN10149-2, EN10149-3	S260 to S700	450
EN10025-6	S460 to S690	

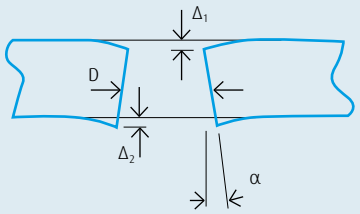
These values are in accordance with EN ISO 15614-1 applied to steel grades listed in ISO/TR 20172.

Holing.

Execution of holing

Holes for fasteners or pins can be made by any process including thermal cutting as long as the cutting requirements for cut quality and hardness are met. In addition, the taper angle and burrs must not exceed the values shown in Figure 1.

Figure 1. Permitted distortions of cut holes[1].



$$D = \frac{d_{max} + d_{min}}{2}$$

max (Δ_1 or Δ_2) ≤ max (D/10; 1mm)

α ≤ 4° (i.e. 7%)

The holing process will need to be periodically checked:

- Eight samples are produced covering the range of hole diameters, constituent product thickness and grades processed.
- Go/no-go gauges used to check both ends of each hole.

Unless otherwise stated, hole tolerances are given as:

- Holes for fit bolts and fitted pins: class H11 according to ISO 286-2.
- Other holes: ±0.5mm, using average of entry and exit diameters.

If the process does not conform it must be corrected before it can be used.

Cut outs

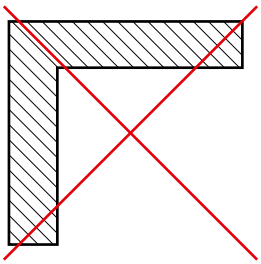
Over-cutting (cutting beyond the corner) of re-entrant corners is not be permitted. Re-entrant corners are those where the open angle between the faces is less than 180°.

Re-entrant corners and notches must be rounded off with a minimum radius of:

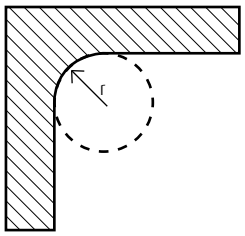
- 5 mm for EXC2 and EXC3.
- 10 mm for EXC4.

Examples of cut-outs are given in Figure 2.

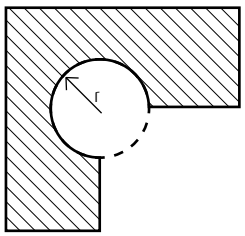
Figure 2.Examples of cut-outs[1]



Not permitted



Form A
(Recommended for fully mechanised or automatic cutting)



Form B (Permitted)

Shaping.

When shaping a component by bending, pressing or forging either by hot or cold process, its properties must not fall below those specified. The component product standards should provide requirements and recommendations for forming and flame straightening. See also CEN/TR 10347.

Please note that if a component shows signs of cracking, lamellar tearing or damage to surface coatings, it must be treated as a non-conforming product. Testing is required to prove conformance.

Hot forming

If the material is heated up to above recrystallisation temperature to aid in shaping, this process is referred to as hot forming.

For hot forming requirements and recommendations, refer to the component or product standard and steel manufacturer. Table 6 provides a summary of hot forming requirements for common steel grades.

Table 6: Hot forming requirements

Steel grade	Hot working requirements
EN 10025-4	
Quenched and tempered	Not permitted
Cold-formed thin-gauge components and sheeting	Shaping by hot forming (T > 580°C) is not permitted if nominal yield strength can be achieved by cold forming.
S195–S355	Performed in red-hot state.
S450+N (or +AR)	Temperature, timing and cooling rate to match the particular type of steel. Bending and forming in blue heat range (250°C to 380°C) is not permitted.
EN 10025-2	Temperature range 960°C to 750°C with subsequent cooling at air temperature.
S420 and S460 EN 10025-3	The cooling rate should be such as to prevent hardening as well as excessive grain coarsening. If this is not practicable, a subsequent normalising treatment must be carried out.
S450 if no delivery condition indicated	Not permitted

Flame straightening

There are no requirements for EXC1 and EXC2 for flame straightening applications.

EXC3 and EXC4 require a suitable procedure to be developed that includes:

- maximum steel temperature and procedure of cooling allowed;
- method of heating;
- method used for temperature measurements;
- results of mechanical tests carried out for the process approval;
- identification of workers entitled to apply the process.

Preheating.

Preheating is used to avoid conditions such as hydrogen cracking (also known as cold cracking).

Preheating.
If preheating is required, the method needs to be included in the welding procedure specifications and needs to cover any tack welding and welding of temporary attachments.

EN 1011-2 provides information on when preheating is needed and how to calculate what temperatures are required. EN ISO 13916 presents the methods of temperature measurement and reporting. These standards have been summarised in the following sections.

Preheat requirements

The need to preheat depends on the material composition, thickness, heat input from welding process and hydrogen content of welding consumables.

Table 7 provides examples of the maximum combined thicknesses that can be welded without the need for preheating, for S275.

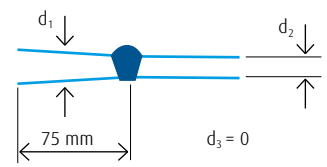
For EXC1 and EXC 2, preheating is not normally required on materials up to S355 with a maximum combined thickness of 75mm.

Table 7: Examples of maximum combined thickness weldable without preheating, steel grade S275

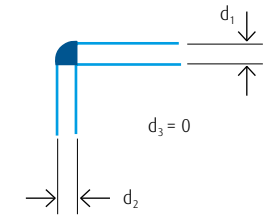
Welding process	Heat input (kJ/mm)	Max combined thickness (mm)
Manual metal arc welding	1.1	20
Flux cored	2.0	45
Solid wire	3.0	100

Combined thickness is the sum of parent material thicknesses averaged over a distance of 75mm from the weld line. This approach is used to assess the heat sink of a joint which governs the cooling rate. Examples for some typical joints are shown in Figure 3.

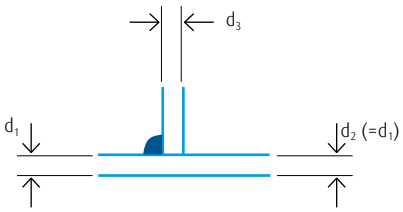
Figure 3. Examples for the determination of combined thickness[3]

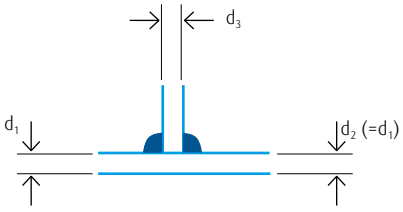


d1 = average thickness over a length of 75mm

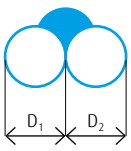


Combined thickness = $(d_1+d_2+d_3)$





For simultaneously deposited directly opposed twin fillet welds, combined thickness = $½(d_1+d_2+d_3)$



Combined thickness = $½(D_1+D_2)$

Maximum diameter 40mm

Determining the preheat temperatures

There are a couple of methods used to determine required preheat temperatures and these are presented in EN1011-2, 2001, Annex C.

Point of measurement

If the material thickness does not exceed 50mm, the preheat temperature (Tp) measurement is made on the surface of the workpiece facing the welder. The temperature is measured at a distance of 4 times the material thickness from the longitudinal edge of the groove, up to a maximum of 50mm.

For materials over 50mm in thickness, the parent metal must be at the required temperature at a minimum distance of 75mm (or as otherwise agreed) in any direction from the joint. Preferably the temperature is measured on the face opposite to that being heated. If this is not possible, the temperature is taken at a set time after removal of the heat source. This is to allow equalisation of the temperature.

If fixed permanent heaters are used and there is no access to the reverse face for temperature measurement, readings are taken on the exposed side immediately adjacent to the weld preparation.
For multi-run welds, the interpass temperature (Ti) is measured on the weld metal or the immediately adjacent parent metal. The interpass temperature needs to be below the given maximum value before the next weld can be laid down.

Time of measurement

For each 25mm of the parent material thickness, allow 2 minutes for the temperature to equalise before taking a measurement.

Interpass temperatures are measured immediately before passage of the arc.

If a preheat maintenance temperature (Tm) is specified, it need to be monitored while welding operations are interrupted.

Test equipment

The welding procedure specifications should define the temperature measurement equipment to be used. For example:

- Temperature-sensitive materials (e.g. crayons or paints) (TS)
- Contact thermometer (CT)
- Thermocouple (TE)
- Optical or electrical devices for contactless measurement (TB).

Test report

If required, a test report must specify the following minimum information in accordance with the specification in the welding procedure specification (WPS):

- measured preheating temperature (°C),
- measured interpass temperature (°C),
- measured preheat maintenance temperature (°C),
- any deviation from the given standard, if applicable.

Below are a couple of examples of the designation that should be used in test reports.

Example 1
A preheating temperature (T_p) measured only once in accordance with this standard as 155°C (T_p 155) using a contact thermometer (CT)

Temperature EN ISO 13916 – T_p 155 – CT

Example 2
An interpass temperature (Ti) measured more than once in accordance with this standard as 128°C, 142°C and 159°C (Ti 128/160) using a thermocouple (TE)

Temperature EN ISO 13916 – Ti 128/160 – TE

Welding.

Standard welding parameters and specifications generally apply (EN ISO 3834 or EN ISO 14554 as applicable). This section covers any specific parts that relate to EN 1090-2, in particular execution classes and welding coordinator qualifications.

Table 8: Relevant parts of EN ISO 3834 according to execution class[1]

EXC1	Part 4	Elementary quality requirements
EXC2	Part 3	Standard quality requirements
EXC3 and EXC4	Part 2	Comprehensive quality requirements

Welding plan

With the exception of EXC1, welding needs to be carried out with qualified procedures using a welding procedure specification (WPS) in accordance with the relevant part of EN ISO 15609, EN ISO 14555 or EN ISO 15620.

The following steps are needed to develop a WPS:

1. Develop a preliminary welding procedure specification (pWPS)
2. Complete a welding procedure test
3. Complete a welding procedure qualification record (WPQR)
4. Prepare welding procedure specifications (WPS) for production based on the WPQR

The pWPS can be based on previous experience or using some of the published resources that are available.

Qualification of welding procedures

Welding procedure test pieces need to be produced under supervision of a notified body, and then tested in accordance with the relevant standard of qualification.

Pre-qualified welding procedures

For EXC2 and materials ≤ S355, it is acceptable to use pre-qualified welding procedures. These are WPSs that have been qualified by a notified body.

Welders and welding operators

Welders need to be qualified to EN 2877-1.
Welding operators need to be qualified to EN 1418.

Details of welder and welding operator qualifications need to be documented and stored.

Welding coordination

EXC2, EXC3 and EXC4 require that a welding coordinator be appointed. Based at the manufacturing site, this person is responsible for overseeing welding operations.

The welding coordinator needs to be suitably qualified or experienced in the welding operations they supervise, as specified in EN ISO 14731.

Table 9 and Table 10 show the technical knowledge required by the welding coordinator. B – basic, S – standard and C – comprehensive as specified in EN ISO 14731.

Please note that the welding coordinator will be assessed by the notified body. Experience and knowledge of the relevant standards is more important than formal qualifications.

Table 9: Welding coordinator technical knowledge – structural carbon steels[1]

EXC	Steels (steel group)	Reference standards	T < 25[a]	25<t<50[b]	t>50
EXC2	S235 to S355 (1.1, 1.2, 1.4)	EN 10025-2 EN 10025-3 EN 10025-4 EN 10025-5 EN 10149-2 EN 10149-3 EN 10210-1 EN 10219-1	B	S	C[c]
	S420 to S700 (1.3, 2, 3)	EN 10025-3 EN 10025-4 EN 10025-6 EN 10149-2 EN 10149-3 EN 10210-1 EN 10219-1	S	C[d]	C
EXC3 EXC4	S235 to S355 (1.1, 1.2, 1.4)	As EXC2	S	C	C
	S420 to S700 (1.3, 2, 3)	As EXC2	C	C	C
	All	All	C	C	C

a) Column base plates and endplates ≤50 mm
b) Column base plates and endplates ≤75 mm
c) For steels up to and including S275, level S is sufficient
d) For steels N, NL, M and ML, level S is sufficient

Table 10: Welding coordinator technical knowledge – stainless steels[1]

EXC	Steels (steel group)	Reference standards	T < 25	25<t<50	t>50
EXC2	Austenitic (8)	EN 10088-2, Table 3 EN 10088-3, Table 4 EN 10296-2, Table 1 EN 10297-2, Table 2	B	S	C[c]
	Austenitic-ferritic (10)	EN 10088-2, Table 4 EN 10088-3, Table 5 EN 10296-2, Table 1 EN 10297-2, Table 3	S	C	C
EXC3	Austenitic (8)	As EXC2	S	C	C
EXC4	Austenitic-ferritic (10)	As EXC2	C	C	C
	All	All	C	C	C

Joint preparation

Joint preparation must be suited to the welding process and defined in the WPS, along with tolerances for joint preparation and fit-up.

Prefabrication (shop) primers should generally not be left on the fusion faces unless:

- Primers do not adversely affect the welding process – this applies to EXC1 and EXC2
- Qualification tests have been completed using such primers – this applies to EXC3and EXC4

EN ISO 17652-2 describes tests for assessing the influence of shop primers on the weldability.

Table 11: Execution class quality levels according to EN ISO 5817[1]

EXC1	Quality level D "Elementary quality requirements"
EXC2	Generally quality level C with the following exceptions: quality level D for "Undercut" (5011, 5012), "Overlap" (506), "Stray arc" (601) and "End crater pipe" (2025)
EXC3	Quality level B
EXC4	Quality level B+ (see EN 1090-2:2008. Comprehensive quality requirements)

Storage and handling of welding consumables

Welding consumables must be stored, handled and used according to the manufacturer's recommendations.

Weather protection

Both the welder and the working area must be adequately protected against the effects of wind, rain and snow.

Surfaces to be welded must be maintained dry and free from condensation.

If the temperature of the material falls below 5°C, suitable heating needs to be provided.

Tack welds

EXC2, ECX3 and EXC4 require that tack welds are included in a qualified welding procedure.

Butt welds

EXC3 and EXC4 (also EXC2 if specified) require the use of run-on/run-off pieces to ensure full-throat thickness at the edge. The material used must not have a weldability that is lower than that of the parent metal.

Execution of welding

Precautions must be taken to avoid stray arcing. If a stray arc does occur, the surface of the steel needs to be lightly ground and checked. Visual checking should be supplemented by penetrant or magnetic particle testing.

Precautions also need to be taken to avoid weld spatter. For EXC3 and EXC4, it needs to be removed by light grinding.

Any visible imperfections that are not permitted such as cracks and cavities must be removed from each run before deposition of further runs.

Before a weld run is deposited on top of another run, all slag needs to be removed from the surface. Also slag should be removed from the surface of the final weld. Particular attention needs to be paid to the junctions between the weld and the parent metal.

Acceptance criteria

Unless otherwise specified, the acceptance criteria for weld imperfections is as given in Table 11.

Welding of ferritic and stainless steels

Arc welding of ferritic steels and stainless steels should follow the requirements and recommendations of EN 1011-1, EN 1011-2, EN 1011-3 with amendments as shown in Table 12 and 13.

Table 12: Amendments to EN 1011-11

Clause	Para.		
13	1	Addition	Contact pyrometers shall be used to measure temperature unless other methods are specified. Temperature-indicating crayons shall not be used.
19		Addition	Welding procedure qualification records and associated WPSs that do not include a thermal efficiency factor in a heat input calculation may be used provided the heat input is adjusted in accordance with the appropriate thermal efficiency factor.

Table 13: Amendments to EN 1011-3

Section	Para.		
7.1	1	Modification	The required surface finish of the weld zones shall be specified. It shall be specified if the coloured oxide films formed during welding shall be removed. Due consideration should be given to corrosion resistance, environment, aesthetics and the implications of dressing off and cleaning the weld zone. All slag associated with welding shall be removed unless otherwise specified. Shall not be used.
7.1	5	Modification	After preparation of joint faces, oxidation, hardening and general contamination from thermal cutting processes may need to be eliminated by mechanically machining to a sufficient depth from the cut face. During shearing, cracking may occur; these cracks shall be removed prior to welding.
7.3	3	Addition	At the beginning of the paragraph: Copper backing shall not be used unless otherwise specified.
10		Addition	Appropriate care shall be taken in the disposal of all post weld cleaning materials
A.1.2	1	Modification	The approximate microstructure, which will form in the weld metal, may be indicated from the balance of ferrite and austenite stabilising elements using a Schaeffler, DeLong, W.R.C. or Espy diagram. If used, the appropriate diagram shall be specified.
A.2.2	4	Modification	The Schaeffler, DeLong, W.R.C. or Espy diagrams may be used to indicate if the consumable will provide the correct ferrite content, taking dilution effects into account. If used, the appropriate diagram shall be specified.
A.4.1		Addition	Welded connections shall not be subject to heat treatment after welding unless permitted by the specification.
C.4		Addition	Welded connections shall not be subject to heat treatment after welding unless permitted by the specification.

Post-weld heat treatment.

Post-weld heat treatment can be used to control hydrogen cracking. It does this by controlling cooling in the lower part of the thermal cycle, typically from 300°C to 100°C. This allows the hydrogen to disperse from the welded joint.

Either the minimum interpass temperature (see preheating) is maintained or the temperature is raised to 200°C to 300°C immediately after welding. The weld region must not cool below the minimum interpass temperature.

Typically post-heating is applied for two hours, but thicker sections will require longer periods at higher temperatures.

It will be necessary to prove that the procedure is satisfactory and it will need to be included in the welding procedure specifications.

ISO/TR 17663 gives guidance for quality requirements governing heat treatment.

Welding inspection, testing and correction.

Inspection before and during welding

Welding inspection, testing and correction
An inspection and testing plan needs to be developed and documented according to EN ISO 3834. The testing and any associated corrections also need to be documented.

With the exception of visual inspection, selection of non-destructive testing (NDT) methods must be made by personnel qualified according to Level 3 in accordance with EN 12062, and carried out by personnel qualified according to Level 2, as defined in EN 473.

Generally:
- Butt welds require ultrasonic or radiographic testing.
- Fillet welds require penetrant testing or magnetic particle inspection.

Inspection after welding

The supplementary NDT of a weld must generally not be completed until after the minimum hold time after welding has expired as shown in Table 14.

Table 14: Minimum hold times[1]

Weld size (mm)[a]	Heat input Q (kJ/mm)[b].	Hold time (hours)[c] S235 to S420	S460 and above
a or s ≤ 6	All	Cooling period only	24
6 < a or s ≤ 12	≤ 3	8	24
a or s > 12	> 3	16	40
	≤ 3	16	40
	> 3	40	48

a) Size applies to the nominal throat thickness a of a fillet weld or the nominal material thickness s of a full penetration weld. For individual partial penetration butt welds, the governing criterion is the nominal weld depth a, but for pairs of partoial penetration butt welds welded simultaneously, it is the sum of the weld throats a.
b) Heat input Q to be calculated in accordance with clause 19 of EN 1011-1:1998.
c) The time between weld completion and commencement of NDT shall be stated in the NDT report. In the case of "cooling period only", this will last until the weld is cool enough for NDT to commence.

The entire length of all welds needs to be visually inspected before any other NDT inspection is carried out. This includes:
- Presence and location of all welds
- Inspection of welds in accordance with EN 970
- Stray arcs and areas of weld spatter

If surface imperfections are detected, surface testing by penetrant testing or magnetic particle inspection needs to be carried out on the weld.

Unless otherwise specified no supplementary NDT is required for EXC1 welds.

For EXC2, EXC3 and EXC4 welds, the extent of supplementary NDT is as specified below.

The first 5 joints made to a new WPS must meet the following requirements:

a) the quality level B is required for demonstration of the WPS in production conditions;
b) the % to be tested must be double the values in Table 15 (max. 100 %);
c) the minimum length to be inspected is 900 mm.

If non conforming welds are found during testing, the cause needs to be identified and tests repeated. The guidance in Annex C of EN 12062:1997 should be followed.

Please note that these tests are intended to prove that your WPS produces conforming results before you go into production.

Once in production, the sampling rates given in Table 15 must be used to ensure that production continues to produce conforming welds.

Correction of welds

For EXC2, EXC3 and EXC4, welding repairs need to be done in accordance with the qualified welding procedures.

Corrected welds need to be checked and must meet the requirements of the original welds.

Production tests on welding

If specified, for EXC3 and EXC4, production tests must be carried out as follows:

a) Each welding procedure qualification used for welding steel grades higher than S460 must be checked with a production weld. Testing includes visual examination, penetrant testing or magnetic particle inspection.
b) Inspection, ultrasonic testing or radiographic testing (for butt welds), hardness testing and macroscopic examination. The tests and results must be in accordance with the relevant standard for welding procedure test.
c) If the deep penetration of a welding process is used for fillet welds, the penetration of the welds must be checked. The results of the actual penetration must be documented.

Table 15: Extent of supplementary NDT[1]

Type of weld	Shop and site welds		
	EXC2	EXC3	EXC4
Transverse butt welds and partial penetration welds in butt joints subjected to tensile stress:			
U≥ 0,5	10%	20%	100%
U< 0,5	0%	10%	50%
Transverse butt welds and partial penetration welds:			
In cruciform joints	10%	20%	100%
In T joints	5%	10%	50%
Transverse fillet welds in tension or shear:			
With a > 12 mm or t > 20 mm	5%	10%	20%
With a ≤ 12 mm and t ≤ 20 mm	0%	5%	10%
Longitudinal welds and welds to stiffeners	0%	5%	10%

Longitudinal welds are those made parallel to the component axis. All the others are considered as transverse welds.
U = Utilisation grade for welds for quasi-static actions. U = Ed/Rd, where Ed is the largest action effect of the weld and Rd is the resistance of the weld in the ultimate limit state.
Terms a and t refer respectively to the throat thickness and the thickest material being joined.

Surface treatment and corrosion protection.

The execution specifications, as agreed by the manufacturer and purchaser, need to provide requirements or specifications for any corrosion protection in terms of expected life and corrosivity category, along with any preference on finish. This needs to give, for example; details of surface preparation, paint system, work methods, thermal spraying and any special requirements for inspection and checking.

The work methods form part of the quality plan (see EN1090-2 Annex C) developed by the manufacturer from the execution specifications, and define when the protection is to be applied, use of products in accordance with manufacturers recommendations, handling, storage & transportation requirements, etc.

Preparation for painting and metal spraying of carbon steels

All surfaces that are to be painted must meet the criteria of EN ISO 8501. EN 14616, EN15311 and EN ISO 14713 provide the requirements for thermal spraying.

Thermally cut surfaces, edges and welds need to be suitably smooth and able to achieve the required roughness. Sometimes, especially with slower-burning fuel gases, the cut surfaces can be too hard for the abrasive material and so do not reach the required specification. If this is the case, the surface will need to be ground down to remove the heat-affected zone.

Procedure tests will need to be completed on the blast cleaning process to make sure that the required cleanliness and roughness have been achieved. These tests will need to be repeated at intervals during production.

Measurement and assessment of surface roughness must be undertaken according to EN ISO 8503-1 and EN ISO 8503-2.

If coated materials are to receive further treatment, the surface preparation must be appropriate to the subsequent treatment.

Any non-conforming components will need to be retreated, and then go through further testing and inspection.

Metal spraying

Thermal spraying of zinc, aluminium or zinc/aluminium 85/15 alloys needs to be done in accordance with EN ISO 2063.

If the thermally sprayed surfaces are to be painted, a suitable sealer needs to be applied as soon as the coating has cooled, to avoid oxidation or trapping of moisture. The sealer needs to be compatible with the overcoat paint.

Inspection and checking

The quality plan should define the requirements for inspection and checking, whilst the execution specification will specify any additional inspection and testing requirements. Any inspection, checking and testing needs to be recorded.

References.

[1] EN 1090-2:2008, Execution of steel structures and aluminium structures – Part 2: Technical requirements for steel structures
[2] EN 1011-2:2001, Welding. Recommendations for welding of metallic materials – Part 2: Arc welding of ferritic steels
[3] FORCE Technology Report No. 94.34, Reference colour charts for purity of purging gas in stainless steel tubes. J. Vagn Hansen. Revised May 2006.

Getting ahead through innovation.

With its innovative concepts, Linde is playing a pioneering role in the global market. As a technology leader, it is our task to constantly raise the bar. Traditionally driven by entrepreneurship, we are working steadily on new high-quality products and innovative processes.

Linde offers more. We create added value, clearly discernible competitive advantages, and greater profitability.
Each concept is tailored specifically to meet our customers' requirements – offering standardized as well as customized solutions. This applies to all industries and all companies regardless of their size.

If you want to keep pace with tomorrow's competition, you need a partner by your side for whom top quality, process optimization, and enhanced productivity are part of daily business. However, we define partnership not merely as being there for you but being with you. After all, joint activities form the core of commercial success.

Linde – ideas become solutions.

Linde AG
Gases Division, Seitnerstrasse 70, 82049 Pullach, Germany
Phone +49.89.7446-0, Fax +49.89.7446-1216, refrigerants@linde-gas.com, www.linde-gas.com/EN109