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Title:	<b>Technical Guideline for Welding Practices</b>
Purpose:	Guideline for the execution of welding practices for the FAIR project
Organisational unit:	Quality Assurance (QUA)
Valid for:	Project "FAIR Accelerator and Experiments"

### Document history:

Version	Created, Date	Reason for modification
V001	D. Freire, 09.06.2020	Initial version (translation from German version)
V002	D. Freire, 24.07.2020	Translation of "F-TG-QUA-de-Schweisstechnik-V002"
V003	D. Freire, 26.04.2021	Corrections from the ZFP vacuum container and a note from DIBt
V004	D. Freire, 04.05.2022	Added ISO 17637 and welding of reinforcing steel
V005	D. Freire, 04.10.2023	Added ISO 15609 ff, 3.1 Repair welding
V006	D. Freire, 10.05.2024	Permissible tempering colors for CrNi steels
V 007	C. Ferling, 05.09.2024	DEKRA, Erlaubnisschein für feuergefährliche Arbeiten, VL 5131

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## 1. Scope

Welding is defined as a special process. Special processes are activities, the results of which cannot be determined in full by subsequent quality checks on the product, so that errors in the process only become apparent after the product has been used. For such processes, it must be ensured that the executing company and its employees are suitable and demonstrate the necessary qualifications. In addition, constant monitoring and qualification must be provided during execution.

This applies in particular to welding work on pressurized components and in the building inspection area. If you have any questions about welding practices, contact the FAIR / GSI welding supervisor.

## 2. Definitions

Abbreviation	Definition
AD	Working group for pressure vessels
BauPVO	Regulation for construction products (EU) No. 305/2011
DGRL	Directive for pressure equipment 2014/68/EU
DIBt	German Institute for Construction Technology
DOP	Declaration of Performance
EXC	Execution Class
MT	Magnetic Test
NB	Notify Body
PMI	Positive Material Inspection
PT	Penetration Test
pWPS	pre Welding Procedure Specification
RT	X-Ray Testing
SAPL	Welding Supervisor Supplier
SFI/EWE/IWE	International Welding Engineer
SG	Weld Metal
SWM/EWS/IWS	International Welding Specialist
SWN	Welding Seam
SWT/EWT/IWT	International Welding Technician
SZW	Filler Metal
US	Ultrasonic Test
UVV	Accident Prevention Regulation
vSAP	Welding Supervisor for the FAIR Project
VT	Visual Test
WEZ	Heat-affected zone
WPQ	Welding Procedure Qualification
WPQR	Welding Procedure Qualification Record
WPS	Welding Procedure Specification
ZfP	Non-destructive material test
ZP	Destructive material test

### 3. Codes and Standards

This Technical guideline describes the general minimum requirements that must be met in order for welding works can be carried out for the FAIR project. If component-specific higher quality requirements than the requirements listed here are to be met, these are specified by applicable regulations or specified in the FAIR / GSI component specification/ detailed specification and common specification.

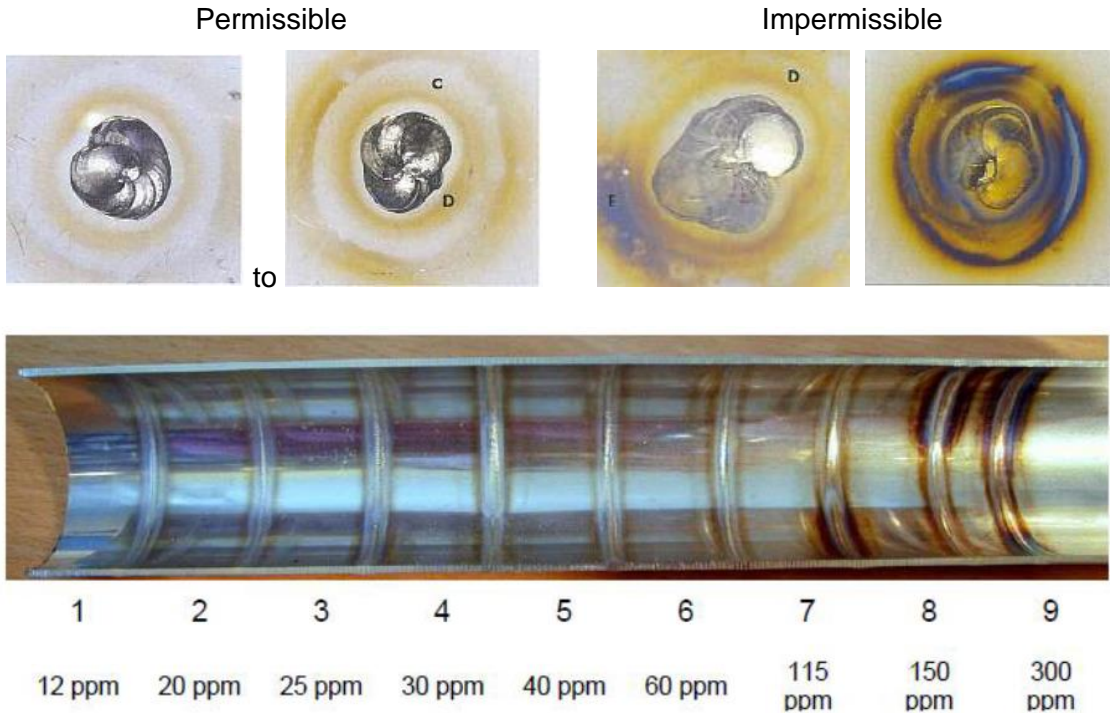
For all welding operations that are carried out on the FAIR / GSI campus, the "work permit for hot work" F.18 must be available. When carrying out welding work in buildings of the FAIR facility, the DEKRA permit for hazardous work (VL 5131) must be approved. The necessary occupational safety for welding work (welding fume extraction and personal protective equipment) must be observed. Only portable welding machines with a current UVV test according to DIN EN 60974-4 may be used.

#### 3.1. Minimum requirements to be met for all welding operations at FAIR

- For the welding operations to be carried out, at least compliance with the qualitative requirements of DIN EN ISO 3834-3 must be demonstrated. For welding work on:
  - Pressure-carrying components from the classification in category II of the DGRL is an approval according to DGRL/ AD-regulations
  - In the area of building supervision, there is an approval according to DIN EN 1090 required that corresponds to the requirements of the applicable regulations
- The welders must have a valid certificate from the welder's test in accordance with DIN EN ISO 9606 for the welding task to be carried out and the base material to be welded. \*)
- When using mechanized/ automated welding processes, the machine operator/ welder must present a valid certificate for the operator test according to DIN EN ISO 14732 for the application. \*)
- A welding supervisor (SAPL) of the executing company, with appropriate knowledge and qualifications for the task in accordance with DIN EN ISO 14731, must accompany and check the welding work.
- A welding specification (WPS) corresponding to the welding task must be available. The qualification of the welding specifications must be carried out in accordance with the task-specific and regulatory-compliant requirements according to DIN EN ISO 15610 to 15614 (see F-DO-QUA-de-Anforderungen\_an\_Schweißbetriebe-001) welding task to be carried out correspond and are available. \*)
- Work samples can be requested from the contractor before the start of the welding work to prove the proper handling of the welding process by the client FAIR / GSI.
- The base materials to be welded must correspond to the specified base material and have at least an acceptance test certificate 3.1 in accordance with DIN EN ISO 10204. \*)
- The filler metal with welding auxiliary used must be matched to the base material or combination of base materials and the operating conditions of the component. The processing instructions/ product information and at least one batch-related material certificate according to DIN EN ISO 10204 must be available from the manufacturer of the SZW. \*)
- Non-destructive weld seam tests for seams on vacuum containers or vacuum pipelines (no pressure equipment) are defined in evaluation group B for UHV and evaluation group C for HV & V with 100% visual test (VT). For particularly critical welds, higher requirements can be specified in the component specification. The RT method should preferably not be used in the non-destructive weld inspection of welds in the vacuum area due to the necessary cleanliness of the surfaces.
- A 100% visual inspection (VT) must be carried out and recorded on every weld seam according to DIN EN ISO 17637. The qualitative assessment criteria of DIN EN ISO 5817 assessment group C must be observed. The executive examiner must be

qualified and certified in accordance with DIN EN ISO 9712. Further non-destructive weld inspections must be carried out and documented in accordance with the applicable regulations or component specifications.

- Permissibility of tempering colors for CrNi steel on top layer and/or root



Influence of the oxygen content in the forming gas and the resulting degree of discoloration.

- If rectification or repair welds are necessary, they must be coordinated in advance with the responsible WPL, vSAP and QUA, and the planned procedure must be specified in writing.
- For welding works on reinforcing steel, the manufacturer's qualification must be available in accordance with DIN EN ISO 17660-1 or DIN EN ISO 17660-2, and the welders must be specially trained and tested in accordance with DIN EN ISO 17660 Part 1.

*\*) Documents must be carried during welding work on the construction site/ campus FAIR/ GSI and submitted to FAIR SAP before starting work.*

### 3.2. Additional requirements for pressurized components

- Welding companies must at least meet the standard quality requirements according to DIN EN ISO 3834-3 (see AD HP0 paragraph 3) and have a certification for the category in which the pressure equipment is classified according to DGRL. (see DGRL Annex II & III)
- Welder and operator tests must be carried out and issued by an independent body (see AD HP3 Paragraph 3.2)
- Welding supervision according to DIN EN ISO 14731 must belong to the manufacturing plant and have technical/ personal knowledge for the welding requirements (see AD HP3 Paragraph 2)
- Welding process tests are required according to DIN EN ISO 15614 ff or DIN EN ISO 15613 for the component-specific welding tasks (see AD HP2 / 1)

- Welding filler metal with welding auxiliary must have a suitability assessment, the proof of a suitability assessment is made via the VdTÜV identification sheet (see AD W0 Paragraph 4). A batch-related acceptance test certificate 3.1 in accordance with DIN EN ISO 10204 must be available for the used filler metal.
- For pressurized pipelines, assessment group B according to DIN EN ISO 5817 applies with 100% visual testing (VT) and at least 10% X-ray inspection (RT) according to AD HP 100 R.
- All other welds on pressure vessels and pressure equipment must be checked non-destructively with at least a 100% visual inspection and 10% crack inspection (PT/ MT). Further test specifications depending on the shape of the seam, position, material, etc. see AD HP0 Tab. 1b. For particularly critical welds, higher requirements can be specified in the component specification.

As an alternative to the AD2000 regulations, after prior consultation and approval by FAIR/ GSI, DIN EN 13445 "Unfired pressure vessels" can be used for design, manufacture and testing.

### 3.3. Additional requirements in the area of building supervision

- Welding companies for the execution of steel structures must meet the quality requirements in accordance with the Execution Class (EXC; see note) according to DIN EN 1090-2 (see table A3, paragraph 7.1).
- Welder and operator tests should be carried out by an independent body
- Requirements for the welding supervision according to DIN EN ISO 14731 are defined according to DIN EN 1090-2 table 14 & 15 (see table A3, paragraph 7.4.3)
- Welding process tests are regulated in accordance with the EXC in accordance with DIN EN 1090-2 in Table 12 (see table A3, paragraph 7.4.1.2)
- Welding consumables must be labeled with the current CE mark and the manufacturer's DOP belonging to the CE mark must be available (see DIN EN 13479 Annex ZA).
- Non-destructive weld inspection is defined in Table 24 in accordance with the EXC in accordance with DIN EN 1090-2. (see table A3, section 7.6.1)

**Note:** In addition to the requirements for welding technology, DIN EN 1090 also specifies requirements for the manufacturing steps: design, coating, connecting means and assembly. The execution class (EXC) is determined by the structural engineer according to the design/ calculation according to Euro Code. The manufacturer or his authorized representative based in the EU must draw up the CE marking for the construction product and provide the declaration of performance in English/ German. With the CE marking, the manufacturer assumes responsibility for the conformity of the construction product with its declared performance.

- **DIBt extract from:**
  - Sample administrative regulation for technical building regulations (MVV TB) 2020/1 (340 pages)
  - Edition 2020/1; Official notices 2021/1 (edition: January 19, 2021)
  - Appendix A 1.2.4/ 5 to DIN EN 1090-2:

The technical rule has to be applied as follows:

- a) The production of load-bearing components made of steel in the specified execution classes may only be carried out by manufacturers whose in-house production control is certified by a notified body in accordance with EN 1090-1: 2009 + A1: 2011.
- b) The execution of welded components, supporting structures and building structures made of steel in the specified execution classes may only be carried out by companies on the construction site that have a certificate of suitability for

the execution of welding work in the corresponding execution classes. Alternatively, the following applies as proof of suitability:

- a welding certificate issued or confirmed by a notified body in accordance with EN 1090-1: 2009 + A1: 2011, if the company's in-house production control is certified by this body in accordance with EN 1090-1: 2009 + A1: 2011;
- a welding certificate based on DIN EN 1090-2: 2011-10 in conjunction with EN 1090-1: 2009 + A1: 2011, Table B.1, issued by a body recognized by the building authorities.

### 3.4. List of Standards

2014/68/EU	European Pressure Equipment Directive
AD 2000 Leaflet A ...	Execution of components for pressure vessels
AD 2000 Leaflet B ...	Calculation of pressure vessels
AD 2000 Leaflet HP ...	General principles for design, manufacture and related tests
AD 2000 Leaflet W ...	General principles for materials
DIN EN 1090-1	Requirements for conformity assessment for structural components (CE-Marking)
DIN EN 1090-2	Technical requirements for the execution of steel structures
DIN EN 1090-3	Technical requirements for the execution of aluminum structures
DIN EN 13445 ff	Unfired pressure vessels
DIN EN 13479	Welding consumables - General product standard for additives and powders for fusion welding of metallic materials
DIN EN 60974-4	Arc welding equipment - Part 4: Periodic inspection and testing
ISO 13920	Welding - General tolerances for welded structures - Length and angle measurements; Form and position
ISO 14731	Welding supervisor - tasks and responsibilities
ISO 14732	Welding staff - testing of operators and setters for mechanical and automatic welding of metallic materials
ISO 15607	Requirement and qualification of welding processes for metallic materials - general rules
ISO 15609 ff	Specification and qualification of welding procedures for metallic materials - Welding procedure specification, part ...
ISO 15610	Requirement and qualification of welding processes for metallic materials - qualification based on the use of tested welding consumables
ISO 15611	Requirement and qualification of welding processes for metallic materials - qualification based on existing welding experience
ISO 15612	Requirement and qualification of welding processes for metallic materials - qualification by using a standard welding process
ISO 15613	Requirement and qualification of welding processes for metallic materials - qualification based on an early work test
ISO 15614 ff	Requirement and qualification of welding processes for metallic materials - welding process test part
ISO 17637	Non-destructive testing of welded joints - Visual inspection of fusion welded joints
ISO 17637 ff	Welding of reinforcing steel

ISO 2553	Welding and related processes - Symbolic representation in drawings - Welded connections
ISO 2768-1	General tolerances: Tolerances for linear and angular dimensions without individual tolerance entries
ISO 3834 ff	Quality requirements for fusion welding of metallic materials
ISO 4063	Welding and related processes - list of processes and serial numbers
ISO 5817	Welding - fusion welded joints on steel, nickel, titanium and their alloys (without beam welding) - assessment groups of irregularities
ISO 6520-1	Welding and related processes - Classification of geometrical irregularities in metals - Part 1: Fusion welding
ISO 9606 ff	Testing of welders - fusion welding
ISO 9712	Non-destructive testing - Qualification and certification of non-destructive testing personnel
Regulation (EU) No. 305/2011	EU Construction Products Regulation (EU-BauPVO)

#### 4. Required Documents

The following documents should be part of the documentation to be supplied when ordering:

- Approval/ certification of the welding company \*
- Certificate for welding and/ or operator testing \*
- Welding instructions for all occurring welding connections \*
- Report on the welding process test and/ or report on the early work test \*
- Welding sequence and inspection plan \*
- Acceptance certificates of the processed basic materials with tabular assignment
- Processing information and approvals of the necessary SZW (VDTüV / DOP) \*
- Factory certificates 2.2 according to EN 10204 for the welding consumables used
- Test reports for non-destructive weld inspection and protocols for pressure and tightness tests
- Certification of test personnel
- CE marking and EU declaration of conformity according to the category according to the Pressure Equipment Directive 2014/68 / EU
- CE marking of the steel structure and documents that relate to the provisions of the EU Construction Products Regulation (EU Building Regulation).

\* must be submitted for inspection before the contract is awarded!

#### 5. Applicable Documents

Title	No.	Link / Document
Presentation "Requirements for Welding Companies"		<a href="https://edms.cern.ch/document/2383347">https://edms.cern.ch/document/2383347</a>
Procedure Welding Practice in GSI/ FAIR (Schweißtechnik bei GSI/FAIR)		<a href="https://edms.cern.ch/document/2150873">https://edms.cern.ch/document/2150873</a>
Technical Guideline - Supports - Weld flanges for pressure vessels and process apparatus of non-alloy st	3.16e	<a href="https://edms.cern.ch/document/1172959">https://edms.cern.ch/document/1172959</a>

Technical Guideline - Supports - Documentation of Quadrupoles	10.2e	<a href="https://edms.cern.ch/document/1173066">https://edms.cern.ch/document/1173066</a>
Technical Guideline - Supports - Documentation of magnets	10.1e	<a href="https://edms.cern.ch/document/1173065">https://edms.cern.ch/document/1173065</a>
Technical Guideline - Constructive design of Welding Seams for Vacuum Chambers	3.1e	<a href="https://edms.cern.ch/document/1172883">https://edms.cern.ch/document/1172883</a>
Technical Guideline - Vacuum - Welding of CF-Flanges on Tubes	3.9e	<a href="https://edms.cern.ch/document/1172886">https://edms.cern.ch/document/1172886</a>
Technical Guideline - Vacuum - Mechanical Acceptance Test for UHV Components	7.1e	<a href="https://edms.cern.ch/document/1172905">https://edms.cern.ch/document/1172905</a>
Technical Guideline - Vacuum - Recommended Guidelines for the Purchase of Beam Vacuum Chambers SIS100	8.15e	<a href="https://edms.cern.ch/document/1172920">https://edms.cern.ch/document/1172920</a>
Technical Guideline - Cryogenics - Documentation and Certificates for Cryostat Vacuum Vessels	10.8e	<a href="https://edms.cern.ch/document/1172853">https://edms.cern.ch/document/1172853</a>
Common Specification of the common functional requirements of the Super-FRS Local Cryogenics System		<a href="https://edms.cern.ch/document/1174179">https://edms.cern.ch/document/1174179</a>
Detailed Specification for the preparation of production-ready engineering design and documentation of the SIS100 local cryogenic Feed Box types		<a href="https://edms.cern.ch/document/1911585">https://edms.cern.ch/document/1911585</a>
Technical Guideline - Cryogenics - Materials Compensation Bellows at Cryogenic Temperatures	2.38e	<a href="https://edms.cern.ch/document/1172135">https://edms.cern.ch/document/1172135</a>
Technical Guideline - Cryogenics - Materials Cryogenic Tubing	2.35e	<a href="https://edms.cern.ch/document/1172134">https://edms.cern.ch/document/1172134</a>
Technical Guideline - Cryogenics - Safety Devices for Cryogenics	52.0	<a href="https://edms.cern.ch/document/1172861">https://edms.cern.ch/document/1172861</a>
Technical Guideline - Cryogenics - Acceptance Test for Cryostat Thermal Shields	7.20e	<a href="https://edms.cern.ch/document/1172843">https://edms.cern.ch/document/1172843</a>