TECHNICAL REPORT

# ISO/TR 17671-1

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# Welding — Recommendations for welding of metallic materials —

## Part 1: General guidance for arc welding

*Soudage — Recommandations pour le soudage des matériaux métalliques —*

*Partie 1: Lignes directrices générales pour le soudage à l'arc*



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# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this part of ISO/TR 17671 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 17671-1 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Unification of requirements in the field of metal welding*.

ISO/TR 17671 consists of the following parts, under the general title *Welding — Recommendations for welding of metallic materials*:

— *Part 1: General guidance for arc welding*

— *Part 2: Arc welding of ferritic steels*

— *Part 3: Arc welding of stainless steels*

— *Part 4: Arc welding of aluminium and aluminium alloys*

# Introduction

ISO/TR 17671 is being issued in several parts in order that it may be extended to cover the different types of metallic materials which will be produced to all International Standards for weldable metallic materials.

This part of ISO/TR 17671 gives general guidance for the satisfactory production and control of welding, and details some of the possible detrimental phenomena which may occur, with advice on methods by which they may be avoided. It is generally applicable to fusion welding of metallic materials and is appropriate regardless of the type of fabrication involved, although the application standard or design specification can have additional requirements. More information is contained in other parts of ISO/TR 17671. Permissible design stresses in welds, methods of testing and acceptance levels are not included because they depend on the service conditions of the fabrication. These details should be obtained from the relevant application standard or design specification.

It has been assumed in the drafting of this part of ISO/TR 17671 that the execution of its provisions is entrusted to appropriately qualified, trained and experienced personnel.

# Welding — Recommendations for welding of metallic materials —

# Part 1:
# General guidance for arc welding



## 1 Scope

This part of ISO/TR 17671 gives general guidance for fusion welding of metallic materials in all forms of product (e.g. cast, wrought, extruded, forged).

The processes and techniques referred to in this part of ISO/TR 17671 may not all be applicable to all materials. Additional information relevant to specific materials is given in the relevant parts of ISO/TR 17671.

## 2 References

ISO 2553, *Welded, brazed and soldered joints — Symbolic representation on drawings*

ISO 3834-1, *Quality requirements for welding — Fusion welding of metallic materials — Part 1: Guidelines for selection and use*

ISO 3834-2, *Quality requirements for welding — Fusion welding of metallic materials — Part 2: Comprehensive quality requirements*

ISO 3834-3, *Quality requirements for welding — Fusion welding of metallic materials — Part 3: Standards quality requirements*

ISO 3834-4, *Quality requirements for welding — Fusion welding of metallic materials — Part 4: Elementary quality requirements*

ISO 4063, *Welding and allied processes — Nomenclature of processes and reference numbers*

ISO 9606-1, *Approval testing of welders — Fusion welding — Part 1: Steels*

ISO 9606-2, *Approval testing of welders — Fusion welding — Part 2: Aluminium and aluminium alloys*

ISO 9606-3, *Approval testing of welders — Fusion welding — Part 3: Copper and copper alloys*

ISO 9606-4, *Approval testing of welders — Fusion welding — Part 4: Nickel and nickel alloys*

ISO 9606-5, *Approval testing of welders — Fusion welding — Part 5: Titanium and titanium alloys, zirconium and zirconium alloys*

ISO 9956-2, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedure specification for arc welding*

ISO 13916, *Welding — Guidance for the measurement of preheating temperature, interpass temperature and preheat maintenance temperature*

ISO 14175, *Welding consumables — Shielding gases for arc welding and cutting*

ISO 14732, *Welding personnel — Approval testing of welding operators for fusion welding and for resistance weld setters for fully mechanized and automatic welding of metallic materials*

## 3 Terms and definitions

For the purposes of this part of ISO/TR 17671, the following terms and definitions apply.

**3.1**
**arc welding current**
$I$
current passing through the electrode

**3.2**
**arc voltage**
$U$
electrical potential between contact tip or electrode holder and workpiece

**3.3**
**interpass temperature**
$T_i$
temperature in a multi-run weld and adjacent parent metal immediately prior to the application of the next run

**3.4**
**heat input**
$Q$
energy introduced into the weld region during welding per unit run length

**3.5**
**preheat temperature**
$T_p$
temperature of the workpiece in the weld zone immediately prior to any welding operation

**3.6**
**thermal efficiency**
$k$
ratio of heat energy introduced into the weld to the electrical energy consumed by the arc

**3.7**
**welding speed**
$v$
travel speed of the weld pool

**3.8**
**detrimental effect**
imperfections and other harmful influences in the welded area

**3.9**
**run-on plate**
piece of metal so placed as to enable the full section of weld metal to be obtained at the beginning of a joint

**3.10**
**run-off plate**
piece of metal so placed as to enable the full section of weld metal to be maintained up to the end of a joint

**3.11**
**wire feed rate**
$w_f$
length of wire consumed per unit time

**3.12**
**welding consumables**
materials consumed in the making of a weld, including filler metals, fluxes and gases

## 4 Symbols and abbreviated terms

See Table 1.

**Table 1 — Symbols of the terms used**

| Abbreviations and symbols | Term | Unit |
|---|---|---|
| $I$ | Arc welding current | A |
| $k$ | Thermal efficiency factor | 1 |
| $l$ | Length of a run | mm |
| $Q$ | Heat input | kJ/mm |
| $d$ | Material thickness | mm |
| $T_i$ | Interpass temperature | °C |
| $T_p$ | Preheat temperature | °C |
| $U$ | Arc voltage | V |
| $v$ | Welding speed | mm/s |
| $w_f$ | Wire feed rate | mm/min or m/min |
| WPS | Welding procedure specification | — |

## 5 Provision of quality requirements

The contract gives the information necessary for the execution of the welding. If the manufacturer chooses to have a quality system, the information should be in accordance with the appropriate part of ISO 3834 (see annex A for further information).

## 6 Storage and handling of parent materials

Storage and handling is carried out so that the parent material is not adversely affected.

## 7 Fusion welding processes

This part of ISO/TR 17671 covers welds made by one of the following welding processes in accordance with ISO 4063 or by a combination of those processes:

111 manual metal-arc welding with covered electrode;

114 flux-cored wire metal-arc welding without gas shield;

12 submerged arc welding;

131 metal-arc inert gas welding; MIG welding;

135 metal-arc active gas welding; MAG welding;

136 flux-cored wire metal-arc welding with active gas shield;

137 flux-cored wire metal-arc welding with inert gas shield;

138 metal-cored wire metal-arc welding with active gas shield;

139 metal-cored wire metal-arc welding with inert gas shield;

141 tungsten inert gas arc welding; TIG welding;

15 plasma arc welding;

other fusion welding processes by agreement.

## 8 Welding consumables

### 8.1 General

Welding consumables should be designated in accordance with the relevant International Standard. Consumables are selected with regard to the particular application, e.g. joint design, welding position and the properties required to meet the service conditions. Any special recommendations given by the manufacturer/supplier should be observed.

In some cases it may be possible to weld without the addition of filler metal.

### 8.2 Supply, storage and handling

All consumables should be stored and handled with care and in accordance with the relevant standards and/or the manufacturer's/supplier's recommendations.

Covered electrodes, wire electrodes, rods and fluxes, etc., as well as their packaging, that show signs of damage or deterioration should not be used.

Examples of damage or deterioration are cracked or flaked coatings on covered electrodes, rusty or dirty wire electrodes and wire with flaked or damaged protective coatings.

Consumables returned to the stores should be treated in accordance with the manufacturer's/supplier's recommendations before re-issue.

# 9 Equipment

The manufacturer carrying out the fabrication is responsible for ensuring that the capacity of the welding plant and ancillary equipment is adequate for the welding procedure to be used. The welding plant should be regularly checked and maintained.

All electrical plant used in connection with the welding operation should be adequately earthed. The welding return cable from the workpiece should be of adequate cross-section, connected as close as possible to the point of welding.

Means of measuring the welding parameters should be available, either as part of the welding equipment, or by the provision of portable instruments. Such parameters may include arc voltage, welding current, wire feed rate, welding speed, shielding/purging gas flow rates and temperature of parent/weld metal.

# 10 Fabrication

## 10.1 General

Fabrication facilities should be protected from adverse weather, e.g. wind, rain, snow, draughts, etc. and should be kept dry. Facilities should be suitable for the work and adequate precautions be taken to ensure that contamination from other materials does not occur.

Surfaces should be dry and free from condensation and any other material that would adversely affect the quality of the welds. If necessary, forming tools, welding fixtures, clamps or manipulators should be cleaned before use.

When using gas-shielded welding processes, the weld zone should be protected from the effects of draughts or other air movements. Air currents even at low speed can remove the shielding gas and therefore welding zones should be protected.

When inert gas backing is necessary to prevent oxidation of the reverse side of a weld, purging using a suitable gas supply in accordance with ISO 14175 should be carried out.

## 10.2 Butt weld

The details of all butt welds, e.g. type of joint (which may include partial penetration joints), included angle and root gap between parts, should be arranged to permit the use of a satisfactory welding technique and the combination of weld detail and welding technique should be such that the resultant joint will comply with the requirements of the design.

The ends of butt joints should be welded to provide the full weld thickness. This may be achieved by the use of run-off and/or run-on plates.

The material for the permanent weld pool backing should be metallurgically compatible with the filler and parent metal. The backing may be either an integral part of a section or a separate component. The thickness of the backing material should be such as to support the weld without burning through.

The material for the temporary weld pool backing, where appropriate, should be chosen so that contamination of the parent/weld metal is avoided. See clauses 15 and 16 for further details.

In all full penetration butt welds where these are to be welded from both sides, certain welding procedures allow this to be done without back gouging, grinding or chipping, but where complete interpenetration cannot be achieved, the back of the first run shall be removed by suitable means to clean sound metal before welding is started on the second side.

In some cases it may be desirable to check that clean sound metal exists by application of a suitable non-destructive crack detection method.

### 10.3 Fillet weld

Unless otherwise specified, the fusion faces to be joined by fillet welds should be in as close contact as possible.

A fillet weld, as deposited, should be of not less than the specified dimensions which are clearly indicated as throat thickness and/or leg length, as appropriate, taking into account the use of deep penetration processes or partial preparations.

## 11 Preparation of joint

The preparation of the fusion faces is such that the limits of accuracy required by the appropriate welding procedure can be achieved.

Surfaces and edges should be free from cracks and notches.

Any imperfection in the preparation of the joint may be corrected by methods detailed in the design specification.

NOTE See also the relevant International Standard for joint preparation.

## 12 Assembly for welding

Parts to be welded should be assembled such that the joints are accessible and visible to the welders and/or operators involved. Jigs and manipulators should be used, where practicable, so that the welding can be carried out in the most suitable welding position.

The sequence of assembly and welding should be such that all welds can be examined in accordance with the relevant requirements. See annex A.

To minimize distortion and/or residual stresses it may be necessary to pre-set joints or pre-bend parts of the structure prior to welding and/or to specify the weld sequence to assist in the control of distortion and shrinkage.

## 13 Preheat and interpass temperature

For measurement of temperature and further information, see ISO 13916.

Details of preheat and interpass temperatures depend on material specifications and are specified in the relevant parts of ISO 13916.

## 14 Tack welds

When required, tack welds should be applied to keep the components in alignment during welding. The length of the individual tack weld and the frequency of such welds should be specified in the relevant weld procedure specification (WPS) or elsewhere. In joints welded by fully-mechanized or automatic processes, the condition for deposition of tack welds should be included in the WPS. The tack welds should be applied in a balanced sequence in order to minimize the risk of distortion and maintain good fit-up.

Where a tack weld is incorporated in a welded joint, the shape of the tack weld should be suitable for incorporation in the finished weld and should only be carried out by approved welders. The tack weld should be free from cracks and other unpermitted imperfections in the weld deposit and should be cleaned thoroughly before final welding. Tack welds which have cracked and other imperfections such as cold starts and crater cracks should be removed prior to welding. All tack welds not incorporated in the final weld should be removed.

## 15 Temporary attachments

Where the assembly or erection procedure requires the use of temporary welded attachments, they should be such that they can be easily removed without damage to the structure. Consideration should be given to the location of temporary attachments. The material of attachment and consumables used should be compatible with the parent metal.

When written weld procedure specifications are required, all welds for temporary attachments should be made in accordance with them. Care should be taken to ensure that such welding is carried out only if permitted by the design specification and that unintended detrimental effects are avoided, e.g. stress raisers and/or shrinkage stresses.

The surface of the parent metal should be carefully ground smooth after removing the temporary attachment.

If necessary, surface inspection of the parent metal may be carried out to demonstrate that the material is free from unpermitted imperfections.

## 16 Run-on and run-off plates

Run-on and run-off plates, when required, should be manufactured from a grade of metal compatible with that used for the fabrication, and have a thickness and edge preparation similar to those used for the joint. The length of the run-on and run-off plates depends on the thickness of the parent material and the weld procedure. The run-on and run-off plates should be of sufficient length to ensure that start/stop imperfections are contained within them.

## 17 Arcing

All initial striking of the arc should be within the fusion faces or on run-on plates. Precautions should be taken to avoid unintentional arcing.

Unintentional arcing between the workpiece and the welding earth return lead or any part at earth potential can be avoided by a firm earth connection located close to the weld joint. Good insulation of the cable and cable joints is essential. In the event of an accidental arc, the surface of the metal should be lightly dressed and, if necessary, checked visually and/or by a crack detection method.

## 18 Inter-run cleaning and treatment

Where a process generates a slag that protects the weld metal, this slag should be removed from each run of weld metal before a further run is superimposed unless otherwise permitted by the WPS. Attention should also be paid to the junction between the weld metal and the fusion faces. Visible imperfections such as cracks, cavities and other unpermitted imperfections should be removed before the deposition of further weld metal.

For welding processes using a shielding gas it may be necessary to remove adherent oxides before the deposition of further runs.

Appropriate tools should be used for inter-run cleaning.

## 19 Heat input

Heat input during welding can be a main influencing factor on the properties of welds. It effects the temperature-time-cycles occurring during welding.

Where appropriate, the heat input value $Q$ may be calculated as follows (see also Table 1):

$$Q = k \frac{U \times I}{v} \times 10^{-3} \text{ in kJ/mm}$$

**Table 2 — Thermal efficiency factor, $k$, of welding process**

| Process No. | Process | Factor $k$ |
|---|---|---|
| 121 | Submerged arc welding with wire electrode | 1,0 |
| 111 | Metal-arc welding with covered electrode | 0,8 |
| 131 | MIG welding | 0,8 |
| 135 | MAG welding | 0,8 |
| 114 | Flux-cored wire metal-arc welding without gas shield | 0,8 |
| 136 | Flux-cored wire metal-arc welding with active gas shield | 0,8 |
| 137 | Flux-cored wire metal-arc welding with inert gas shield | 0,8 |
| 138 | Metal-cored wire metal-arc welding with active gas shield | 0,8 |
| 139 | Metal-cored wire metal-arc welding with inert gas shield | 0,8 |
| 141 | TIG welding | 0,6 |
| 15 | Plasma arc welding | 0,6 |



## 20 Welding procedures

When written welding procedure specifications are required they should cover all welding operations including temporary attachments and correction of non-conformities. The contents of the procedures should comply with ISO 9956-2. Where applicable, the welding procedure approval should be in accordance with the appropriate International Standard.

Welders/welding operators should be provided with information to enable the welding procedure to be carried out in accordance with the requirements. Where appropriate, they should be approved to the relevant part of ISO 9606 or ISO 14732.

## 21 Traceability

Adequate means of identification, either by an identification mark or other methods, should be provided to enable each weld to be traced to the welder/welders or welding operator/operators by whom it was made. Hard stamping should be avoided, but when it has to be used attention is drawn to its use in highly stressed areas and areas susceptible to corrosion.

## 22 Peening

Peening of welds should be carried out only in accordance with the application standard or design specification.