TECHNICAL REPORT

ISO/TR 17671-4

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Welding — Recommendations for welding of metallic materials —

Part 4: Arc welding of aluminium and aluminium alloys

Soudage — Recommandations pour le soudage des matériaux métalliques —

Partie 4: Soudage à l'arc de l'aluminium et des alliages d'aluminium

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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is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.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 17671-4 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

This part of ISO/TR 17671 has been issued with two annexes in order to cover aluminium and the different types of its alloys in all forms which will be produced to the relevant International Standards.

In this part of ISO/TR 17671 the term aluminium stands for aluminium and its alloys.

This part of ISO/TR 17671 gives general guidance for the satisfactory design, production and control of welding and details the possible detrimental effects which may occur, together with advice on methods by which they may be avoided. Generally it is applicable to all types of aluminium materials and is appropriate regardless of the type of fabrication involved, although the application standard/contract may have additional requirements.

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 design specification.

Informative annexes give information on detrimental effects (see annex A) and choice of consumables (see annex B).

This part of ISO/TR 17671 details only welding-related matters and does not give any details of mechanical properties of the welded joint.

This part of ISO/TR 17671 identifies the main factors that affect the welding of aluminium. This will be influenced by parent metal, consumables, design, welding procedure, welding equipment, joint preparation, etc.

General requirements for fusion welding of metallic materials are detailed in ISO/TR 17671-1, in particular:

- tack welds;
- temporary attachments;
- arcing;
- inter-run cleaning and treatment;
- welding procedures;
- identification;
- inspection and testing;
- quality requirements;
- correction of non-conformity;
- distortion;
- post-weld heat treatment;
- abbreviations and symbols;
- run-on/ run-off plates.

Welding — Recommendations for welding of metallic materials —

Part 4:
Arc welding of aluminium and aluminium alloys

1 Scope

This part of ISO/TR 17671 gives general recommendations for the manual, mechanized and automatic fusion welding of wrought and cast aluminium alloys and combinations thereof.

For general guidelines, see ISO/TR 17671-1.

In this part of ISO/TR 17671 the word "pipe" alone, or in combinations, is used to mean "tube" or "hollow section", although these terms are often used by different industries for different categories of product.

2 References

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 4063:1998, *Welding and allied processes — Nomenclature of processes and reference numbers.*

ISO 6520-1, *Welding and allied processes — Classification of geometric imperfections in metallic materials — Part 1: Fusion welding*

ISO 6947:1990, *Welds — Working positions — Definitions of angles of slope and rotation*

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

ISO 9692-3, *Welding and allied processes — Recommendations for joint preparation — Part 3: Metal inert gas welding and tungsten inert gas welding of aluminium and its alloys*

ISO 9956-1, *Specification and approval of welding procedures for metallic materials — Part 1: General rules for fusion welding*

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

ISO 9956-4, *Specification and approval of welding procedures for metallic materials — Part 4: Welding procedure tests for the arc welding of aluminium and its alloys*

ISO 10042, *Arc-welded joints in aluminium and its weldable alloys — Guidance on quality levels for imperfections*

ISO 14175:1997, *Welding consumables — Shielding gases for arc welding and cutting*

ISO 14731, *Welding coordination — Tasks and responsibilities*

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

ISO/TR 15608, *Welding — Guidelines for a metallic materials grouping system*

ISO 15614-4, *Specification and approval of welding procedures for metallic materials — Welding procedure test — Part 4: Arc welding of aluminium castings*

ISO/TR 17671-1:—, *Welding — Recommendations for welding of metallic materials — Part 1: General guidance for arc welding*

EN 573-1, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 1: Numerical designation system*

EN 573-2, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 2: Chemical symbol based designation system*

EN 573-3, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 3: Chemical composition*

EN 573-4, *Aluminium and aluminium alloys — Chemical composition and form of wrought products — Part 4: Forms of products*

EN 1289, *Non-destructive examination of welds — Penetrant testing of welds — Acceptance levels*

EN 1706, *Aluminium and aluminium alloys — Castings — Chemical composition and mechanical properties*

EN 1780-1, *Aluminium and aluminium alloys — Designation of unalloyed and alloyed aluminium ingots for remelting, master alloys and castings — Part 1: Numerical designation system*

EN 1780-2, *Aluminium and aluminium alloys — Designation of unalloyed and alloyed aluminium ingots for remelting, master alloys and casting — Part 2: Chemical symbol based designation system*

EN 1780-3, *Aluminium and aluminium alloys — Designation of unalloyed and alloyed aluminium ingots for remelting, master alloys and castings — Part 3: Writing rules for chemical composition*

3 Terms and definitions

For the purposes of this part of ISO/TR 17671, the terms and definitions of ISO/TR 17671-1 apply.

4 Provision of quality requirements

In order to ensure the quality of work, it should be performed by approved personnel in accordance with e.g. ISO 9606-2, ISO 14732 and ISO 14731 using approved procedures, e.g. ISO 9956-1, ISO 9956-2, ISO 9956-4 and ISO 15614-4.

5 Parent metal

5.1 General

This part of ISO/TR 17671 applies to wrought, cast and combinations of aluminium, e.g. in accordance with ISO 9606-2, ISO 14732, ISO 9956-4 and ISO 15614-4. The principles of this part of ISO/TR 17671 can be applied to other non-standard or proprietary aluminium alloys, which can include the advanced superplastic alloys and metal matrix composites, provided the composition of the alloy falls within the parent metal groups listed in annex B. In such cases, the use of this part of ISO/TR 17671 shall be in accordance with the design specification.

Material standards do not fully take into account welding requirements. For this reason, it is sometimes necessary to specify additional requirements for the material when placing the order. This can include selection/restriction of composition/mechanical properties (within certain additional limits to the basic standard requirements) and additional cleanliness of the components.

Permanent backing material and temporary attachments should be compatible with the parent metal.

5.2 Storage and handling

Contact with ferritic materials and copper should be avoided, in order to prevent corrosion.

To avoid the use of incorrect materials, they should be stored so that the alloy type is known (see warning on hard stamping in ISO/TR 17671-1:—).

6 Factors affecting properties of welded structures and assemblies

A short list of possible detrimental effects that can occur as a result of welding, is given in annex A. The list is not exhaustive but features those metallurgical and technological influences that are specific to, or more prevalent with, aluminium. Potential causes and counter measures are also listed.

Consideration shall be given, e.g. in the design of welded structures, to the mechanical properties of the heat affected zone (HAZ) and the weld deposit which can be influenced by the welding procedure. For instance, the weld deposit and the HAZ can have lower mechanical properties than the parent material.

Care should be taken to avoid the creation of any HAZ that has not been considered in the design, e.g. the welding of a temporary attachment.

7 Fusion welding processes

This part of ISO/TR 17671 applies to the following processes in accordance with ISO 4063:1998, and may be used singly or in combination.

— 131 Metal arc inert gas welding (MIG);

— 141 Tungsten inert gas arc welding (TIG);

— 15 Plasma arc welding.

Other fusion welding processes may be considered by agreement.

8 Welding consumables

8.1 Filler metal

The filler metal should be compatible with the parent metal, see annex B.

Filler metals should be stored in their original packaging in a dry place adequately protected from the effects of the weather and in accordance with relevant standards and/or the supplier's recommendation.

Particular attention shall be paid to the storage and identification of partly used reels of wire and packages of rods located in fabricating shops or on site. This is necessary to ensure that they do not become moist or contaminated, e.g. by dust or oil.

8.2 Shielding gases and gas backing

Argon is most commonly used for MIG, TIG and plasma arc welding of aluminium, but some advantage can be obtained by the use of helium and helium/argon mixtures. They produce improved penetration and/or an increase in the welding speed. They can also reduce imperfections. Shielding gases and gas backing of the following categories in accordance with ISO 14175:1997 shall normally be used.

— I1 (argon);

— I2 (helium);

— I3 (argon/helium mixtures).

Other gas mixtures should only be used in accordance with the design specification (see annex B).

9 Equipment

Further information is given in ISO 3834-2 and ISO 3834-3. Return cables should be of the same or greater cross-sectional area as the welding leads. When quality assurance in accordance with ISO 3834-2 is required, monitoring systems should be calibrated and welding equipment should be validated.

10 Joint types

10.1 General

General guidance is given in ISO 9692-3. Gaps between fusion faces can cause problems, e.g. burn-through, distortion and imperfections. Attempts should therefore be made to minimize them.

10.2 Butt joints

10.2.1 General

Butt joints includes all joints between plates, pipes or combinations including “T” butt joints.

10.2.2 Full penetration

10.2.2.1 Single-sided welding

The following methods should be used for welding the joint:

a) without backing;

b) with temporary backing;

c) with permanent backing;

d) other suitable method.

10.2.2.2 Double-sided welding

The following methods should be used for welding the joint:

a) fully weld the first side, then complete the weld from the second side;

b) partially weld from both sides, completing the weld in a balanced sequence. This method will minimize distortion;

c) root run placed from the first side (instead of backing), then complete the weld from the second side;

d) other suitable method.

10.2.3 Partial penetration

10.2.3.1 Single-sided welding

The following methods should be used for welding the joint:

a) weld to achieve the required weld depth without penetrating to the second side;

b) other suitable method.

10.2.3.2 Double-sided welding

The following methods should be used for welding the joint:

a) weld to achieve the required weld depth, then weld from the second side to achieve that required weld depth;

b) partially weld from both sides, completing welds to the required weld depths utilizing a balanced sequence. This method will minimize distortion;

c) weld to achieve the required weld depth then finish the weld from the second side by placement of a sealing run;

d) other suitable method.

10.3 Fillet welds

The root gap between contacting surfaces should be as small as possible.

11 Backing material

11.1 Permanent backing material

For further information on material types see ISO/TR 15608.

11.2 Temporary backing material

Stainless steel, aluminium, copper or ceramics can be used. Precautions should be taken to avoid copper or other material pick-up or overheating of backing material. For the purposes of this part of ISO/TR 17671 stainless steel refers only to austenitic stainless steel.

12 Branch connections

12.1 General

This type of joint is applicable to either full penetration and/or fillet welds in pipe, e.g. circular or elliptical. The details for all types of branch connections, e.g. form of joint, angle between sections, angle between fusion faces, root gap between parts, should be arranged to permit the use of a satisfactory welding procedure.

12.2 Butt welded joints

By their nature branch connections are usually of a single-sided form, utilizing a varying weld geometry. This depends on the respective dimensions of the pipe and branches, together with their alignment angles. Welding may be performed with or without backing material to suitable methods. The branch connection should be prepared in accordance with 10.2.

Branch connections in pipes that are “set on” should be welded so as to provide the required weld thickness completely around the branch or as otherwise shown on suitable drawings. For “set in” or “set through” branch connections, welding normally should be performed so as to provide the required weld thickness through the main pipe.

12.3 Fillet welded joints

Branch connections in tubular sections should be fillet welded such that the size of the completed joint fully meets design requirements. Where possible, the surfaces of the pipe and branch should be in as close contact as possible with the gap in order to avoid detrimental phenomena (e.g. excessive penetration and excessive porosity).

13 Gouging

In full penetration butt welds, welded from both sides, the back of the first run can be removed, by suitable means, down to clean, sound weld metal before welding is started on the second side. Mechanical methods should be used, e.g. milling, chiselling, sawing or grinding. The preferred methods are milling and sawing. No oil based lubricants should be used. If grinding is used, the discs should be special types intended for aluminium only. Plasma gouging is permitted. After gouging all contaminants should be removed from the joint fusion faces. In certain cases it will be desirable to check the surface for imperfections, e.g. by the use of penetrant testing in accordance with EN 1289.

14 Preparation of joint

For the preparation of the joint, general guidance is given in ISO 9692-3. Particular attention is drawn to the need to minimize the sizes of root gaps, where appropriate.

The joint should be prepared by mechanical means or by laser, plasma, water jet cutting or other suitable method.

When cutting has a detrimental effect on the properties of the zone adjacent to the cut, allowance should be made to remove the damaged material following cutting. Crack detection is advantageous following cutting.

To avoid adverse effects on the quality of the weld, the surfaces and edges should be suitable for the welding process. They should be free from cracks and notches, dry and free from excessive oxide, oil, grease, paint, moisture, etc. Prior to welding and before assembly of the joint, fusion faces and adjacent surfaces shall be degreased and the oxide layer refreshed. The period between cleaning and welding should be as short as possible in order to avoid recontamination.

Degreasing by solvents or other suitable methods should be followed by the removal of surface oxide by mechanical means. Degreasing by chemical etching may remove the original surface oxide layer.

NOTE In this context, the term “refreshed” applies to the removal of the contaminated oxide layer followed by reoxidation in a dry environment.

15 Assembly for welding

The preferred welding positions in accordance with ISO 6947:1990 are PA, PB, PC and PF.

16 Alignment of joints

The acceptance criteria for misalignment shall be in accordance with the appropriate quality level selected from ISO 10042. For certain applications closer tolerances might be necessary.

17 Pre-heating

Pre-heating may be applied for the following reasons:

- to remove moisture prior to welding, e.g. when site welding;
- to avoid cold-start imperfections;
- to achieve heat balance when welding extremely dissimilar thicknesses;
- to reduce heat sink effects when welding thick sections.

The pre-heat temperature is given in Table 1. The time at temperature is important and shall be for as short a time as possible in order to avoid detrimental effects. See annex A.

Excessive pre-heating beyond the values given in Table 1 will affect the mechanical properties in work hardened or fully heat treated materials (i.e. partial annealing or overageing). It can also alter the metallurgical structure of the HAZ by causing grain growth and/or the precipitation of second phases.

In some circumstances the use of argon-helium mixtures or helium instead of argon may eliminate the need for preheating.

18 Interpass temperature

The interpass temperature should be controlled for the following reasons:

- to prevent reduction of mechanical properties by overheating;
- to reduce the size of HAZ softening;
- to reduce the extent of HAZ segregation, e.g. overaging.

It is recommended that the temperature of the joint at the commencement of each successive weld run does not exceed the appropriate value given in Table 1.

Table 1 — Recommended maximum preheat and interpass temperatures

Parent metal	Preheat temperature ºC max.	Interpass temperature ºC max.
Non-heat treatable alloys		
1xxx		
3xxx		
5xxx	120 [a]	120 [a]
AlSi cast		
AlMg cast		
Heat treated alloys		
6xxx		
AlSiMg cast	120 [a]	100
AlSiCu cast		
7xxx	100 [a]	80

NOTE 1 The temperatures in this table are intended for guidance. They can be changed to other values by contract and should be stated in the welding procedure specification.

NOTE 2 In group 22.4 (5XXX) alloys containing $>$ 3,5 % Mg and in group 23.2 (7XXX) alloys, precipitation of such phases can produce sensitization to exfoliation corrosion and stress corrosion cracking in certain service environments.

[a] Prolonged heating can produce partial annealing in work-hardened alloys and overaging in fully heat treated alloys.

19 Methods of temperature measurement

When preheat and/or interpass temperature control is required, the temperature should be measured, e.g. by means of contact pyrometers, thermo-indicating paints or crayons, and recorded as required.

For interpass temperature control, the temperature should be measured at a point as close as is practical to the weld metal.

20 Additional recommendations

20.1 Inter-run cleaning and treatment

The surface of each weld run should be cleaned by stainless steel wire brushing or mechanical means before it is covered by the next run.

20.2 Inspection and testing

It is recommended that welds are not dressed, painted or otherwise treated until they have been inspected.

20.3 Quality requirements

Acceptance levels, in accordance with ISO 10042, should also be in accordance with the design specification.

20.4 Correction of non-conformity

Corrections of non-conformity should be based on ISO 10042.

20.5 Temporary attachments

See clauses 6 and 7.

Annex A

Detrimental effects on weld properties and measures for their avoidance

Although most aluminium alloys are readily welded via the correct selection of process and consumable, it is possible, under certain circumstances, for a number of imperfections to occur. These may be a function of the consumable selected, the operating parameters chosen for the welding process, or metallurgical effects associated with the combinations of parent/consumable materials. However, the imperfections can be minimized or eradicated by selecting the appropriate welding parameters or consumables. Typical detrimental effects that are more prevalent to aluminium are given in Table A.1, together with the principal reasons for their occurrence and methods for their avoidance. These effects should be avoided especially in the case of dynamically loaded structures that have underlying safety aspects.

Notwithstanding the quality of the weld, there are detrimental influences on the good performance of the weld which result from inadequate design. These may include stress concentrations due to sharp transitions in material thickness and high residual stresses induced by the close proximity and accumulations of welded joints.

In the case of work-hardened or heat-treated alloys, the fact that the HAZ of the weld suffers a reduction in mechanical properties should be taken into account when making design calculations. However, during welding, care should be taken to avoid excessive heat input which could increase the softening and extent of the HAZ.

The avoidance of some detrimental effects is dependent on the maintenance of the correct angle and distance between the welding torch and the work piece. For the feed system use materials adapted to aluminium to avoid contamination and damage of the filler metal. The torches used for welding of aluminium, together with their cables and conduits, are quite bulky and can be difficult to manoeuvre in tight corners. Designers of welded structures should ensure that there is adequate access for torch and welder to all joints. In some instances, it may be necessary to weld from one side only with a suitable edge preparation and permanent or temporary backing.

Table A.1 — Detrimental effects on weld properties and measures to be taken for their avoidance

Detrimental effect [a]	Principal reasons	Prevention and/or counter-measure
Porosity e.g. linear porosity (2014) or pore clusters (2013)	Contaminated filler metal. Moisture on the surface of the filler metal.	Improve cleanliness of filler metal. Store in a clean environment above the dew point of the working area.
	Contaminated joint area. Moisture on the surface of the joint.	Clean and dry joint area prior to welding, e.g. preheating. Ensure material is at ambient temperature prior to welding.
	Unacceptably high H_2 content in the filler metal and/or parent metal.	If necessary contact supplier and/or producer of filler metal and/or parent metal.
	Formation of pores due to a too narrow gap in the joint area.	Optimize gaps preventing air escaping through the weld pool.
	Unfavourable welding positions PC, PD, PE, PG.	If possible, use welding positions PA, PB, PF.
	Time for gas evolution too short.	Increase heat input and/or preheat, change joint preparation.
	Impure shielding gas, due to leaking cooling water or gas supply system.	Eliminate leakage.
	Impure shielding gas, e.g. due to moisture penetration. Unsuitable hose quality.	Use shielding gas complying with ISO 14175. Ensure suitable hose quality, replace perished hoses, hose length to be short as possible, if possible use metallic hoses.
	Non-laminar gas flow due to too high or too low flow rate or draught.	Optimize the adjustment of the gas flow, avoid draught.
	Arc voltage too high.	Optimize arc voltage.
	Torch angle too small.	Use correct torch angle.
Oxide inclusions (303)	Formation of oxide in the arc or weld pool area by entry of oxygen due to interrupted or insufficient gas flow.	See porosity. Optimize the adjustment of the gas flow, avoid draught.
	Inadequate cleaning of the joint area and/or previous runs.	Ensure cleanliness of the joint area/previous runs is correct. Optimize arc condition.
	Surplus oxygen in pre-heating flame.	Optimize flame.
	Incorrect manipulation of TIG filler rods.	Do not remove the rod end from the protective gas shield.

Table A.1 (*continued*)

Detrimental effect [a]	Principal reasons	Prevention and/or counter-measure
Cracks (100)		
Solidification cracking e.g. Crater crack (104)	Solidification characteristic of the weld pool.	Select a filler metal to ensure optimum weldability. Place the end crater on the run out plate or work with a programme for filling craters.
	Internal stress.	Choose a welding sequence that reduces self restraint and distortion.
e.g. Liquidation cracking	Remelting of low melting point constituents segregating on the grain boundaries of the HAZ.	Reduce heat input and interpass temperature. Reduce crack susceptibility by using a single run technique. Reduce internal stress. Select a suitable filler metal (e.g. 4xxx series).
Metallic inclusions (304) Tungsten inclusions (3041)	Tungsten inclusions (TIG: 141 and plasma arc welding: 15) due to excessive current for the tungsten electrode or for touching into the weld pool.	Reduce the current for the tungsten electrode type and diameter. Do not dip the tip of the tungsten electrode into the weld pool.
Copper inclusions (3042)	Copper inclusions (MIG: 131) due to overheating/burn out of contact tip.	Choose a torch and contact tip appropriate to current. Work with a short arc length.
	Pick up from copper backing bars.	Replace copper backing bars with stainless steel, aluminium or ceramics if necessary.

[a] See ISO 6520-1.

Annex B

Recommendations for the choice of consumables

B.1 Filler metals

The choice of the filler metal depends on several factors including the following:

- the compatibility to the chemical composition of the parent metal(s), e.g. the propensity for weld cracking;
- the mechanical properties required of the joint (taking into account both the HAZ and weld metal properties);
- the subsequent treatment of the welded part or construction, e.g. surface treatment, anodizing and decorative finishes;
- the corrosion resistance required of the joint;
- optimum weldability.

The ultimate selection will be dependent on the application and may involve a value judgement of such factors.

Table B.1 details a filler metal grouping system.

Table B.2 gives recommendations for the selection of filler metal for welding joints in similar and dissimilar parent metal alloys under working temperatures up to + 50 °C. Parent metals shown include wrought alloys in accordance with EN 573-1, EN 573-2, EN 573-3 and EN 573-4, and cast alloys in accordance with EN 1780-1, EN 1780-2, EN 1780-3 and EN 1706.

The recommendations given in these tables are included purely for guidance. In some circumstances a different choice of filler metals may be used, but this should be in accordance with the design specification.

Table B.1 — Filler metal grouping system

Type	Alloy designation	Chemical designation	Remarks
Type 1	R-1450 R-1080A	Al 99,5Ti Al 99,8	Ti decreases the cracking susceptibility in the weld metal by means of grain reinforcement.
Type 3	R-3103	Al Mn1	
Type 4	R-4043A R-4046 R-4047A R-4018	Al Si5 Al Si10Mg Al Si12(A) Al Si7Mg	Type 4 filler alloys will oxidize by anodizing or atmospheric exposure to give a dark grey colour, the intensity of which increases with increase in Si content. Thus these filler metals will not provide a good colour match with wrought parent metal alloys. These alloys are specifically used to prevent solidification cracking in joints involving high dilution and high restraint.
Type 5	R-5249 R-5754	Al Mg2Mn0,8Zr Al Mg3	If good corrosion resistance and colour matching are important considerations, then the Mg content of the filler metal should be matched to that of the parent metal. If high proof and rupture weld metal strengths are the important considerations, then a filler metal with a Mg content of 4,5 % to 5 % should be used.
	R-5556A R-5183 R-5087 R-5356	AlMg5,2Mn AlMg4,5Mn0,7(A) AlMg4,5MnZr AlMg5Cr(A)	Cr and Zr decrease the cracking susceptibility in the weld metal by means of grain reinforcement. Zr reduces the risk of hot cracking.

NOTE 1 The type numbers 1, 3, 4 and 5 correspond to the first number of the alloy designation.

NOTE 2 This table will be valid until a new filler metal standard is issued.

Table B.2 — Selection of filler metal (for filler types see Table B.2)

Choice of filler metal within each box (the numbers in the Table B.2 refers to the type numbers in accordance with Table B.1)

First line — optimum mechanical properties
Second line — optimum corrosion resistance
Third line — optimum weldability

Parent metal											
Al	4 1 4										
AlMn	4 or 5 1 4	3 or 4 3 4									
AlMg <1%[a]	4 or 5 1 4	4 4 4	4 4 4								
AlMg 3%	4 or 5 5[b] 4 or 5	5 5[b]or 3 4	5 5[b] 4	5 5[b] 5							
AlMg 5%[c]	5 5 5	5 5 5	5 5 5	5 5 5	5 5 5						
AlMgSi[d]	4 or 5 5 4	4 or 5 5 4	4 or 5 5 4	5 5 4	5 5 4	5 or 4 5 4					
AlZnMg	5 5 5	5 5 5	5 5 5	5 5 5	5 5 5	5 5 5	5 5 5				
AlSiCu <1%[e, f]	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4			
AlSiMg[e]	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4		
AlSiCu[e, f]	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	
AlCu[c]	NR[g]	NR[g]	NR[g]	NR[g]	NR[g]	4 4 4	4 4 4	4 4 4	4 4 4	4 4 4	NR[g] NR[g] 4
Parent metal	Al	AlMn	AlMg<1%	AlMg3%	AlMg5%	AlMgSi	AlZnMg	AlSiCu<1%	AlSiMg	AlSiCu	AlCu

Notes to Table B.2.

NOTE 1 When welding parent metal alloys containing ⩾ 2 % Mg with AlSi5 or AlSi10 type filler metal (or when welding parent metals containing ⩾ 2 % Si with AlMg5 type fillers) sufficient Mg_2Si precipitate may be formed at the fusion line to embrittle the joint. These combinations are not recommended for dynamic or impact loaded structures. When this alloy combination is unavoidable AlMg5 or AlSi5 type fillers can be used.

NOTE 2 Parent metal is according to the chemical composition without relation to wrought or cast material.

[a] When welded autogenously, these alloys are prone to solidification cracking. This may be prevented by applying compressive jigging or by increasing the Mg content of the weld pool to above 3 %.

[b] The intergranular corrosion and/or stress corrosion resistance of type 5 in Table B.1 is enhanced when the Mg content does not exceed approximately 3 %. For service environments which are potentially inducive to intergranular corrosion and/or stress corrosion the Mg content of the weld metal should be similar to and not significantly greater than that of the parent metal. Thus it is preferable to weld parent metals with corresponding filler metal alloys.

[c] Under certain environmental conditions, e.g. service at a temperature ⩾ 65 °C, alloys containing > 3 % Mg may be susceptible to intergranular corrosion and/or stress corrosion. The susceptibility will increase with increasing Mg content and/or work hardened condition. Allowance should be made for the effect of weld metal dilution.

[d] These alloys are not recommended to be welded autogenously as they are susceptible to solidification cracking.

[e] The silicon content of the filler metal should be selected to provide the closest match to that of the parent metal casting alloy.

[f] When cast alloys are pressure die cast they are not weldable due to gas content.

[g] Not recommended – incompatibility of the parent metal.

B.2 Shielding gases

When welding aluminium the choice of shielding gas can have an important effect on the productivity and quality of the finished joint.

Due to the sensitivity of aluminium to oxidation, inert gases such as argon and helium have to be used. Although argon is the most widely used shielding gas, there can be advantages in using helium and mixtures of argon and helium. (Pure helium is limited to DC TIG welding.)

The advantages can include:

- improved penetration and weld run shape;
- increased welding speed;
- welding a greater range of thicknesses;
- reduction in preheat temperature;
- reduced level of imperfections such as porosity.

As the level of helium in the mixture increases, the penetration profile changes from a narrow finger-like profile to a more rounded shape. The user will also see a reduction in the level of reinforcement and an increase in the depth of penetration.

For any material thickness, an increase in welding speed can be achieved by the addition of helium to argon. This is because helium transfers heat more effectively from the arc than does argon. Increasing the welding speed can also lead to a reduction in the size of the heat affected zone.

The higher heat input associated with the helium rich mixtures also facilitates the welding of thicker section joints. However, high helium mixtures are not normally recommended for material thicknesses less than about 3 mm, other than in automatic applications.

The additional heat generated from the use of helium-containing mixtures can also reduce the occurrence of weld imperfections such as porosity and lack of fusion face.

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