

ZOLLERN

Solid metals. Fine solutions.

Investment Casting
Guidelines for
manufacturers
and providers



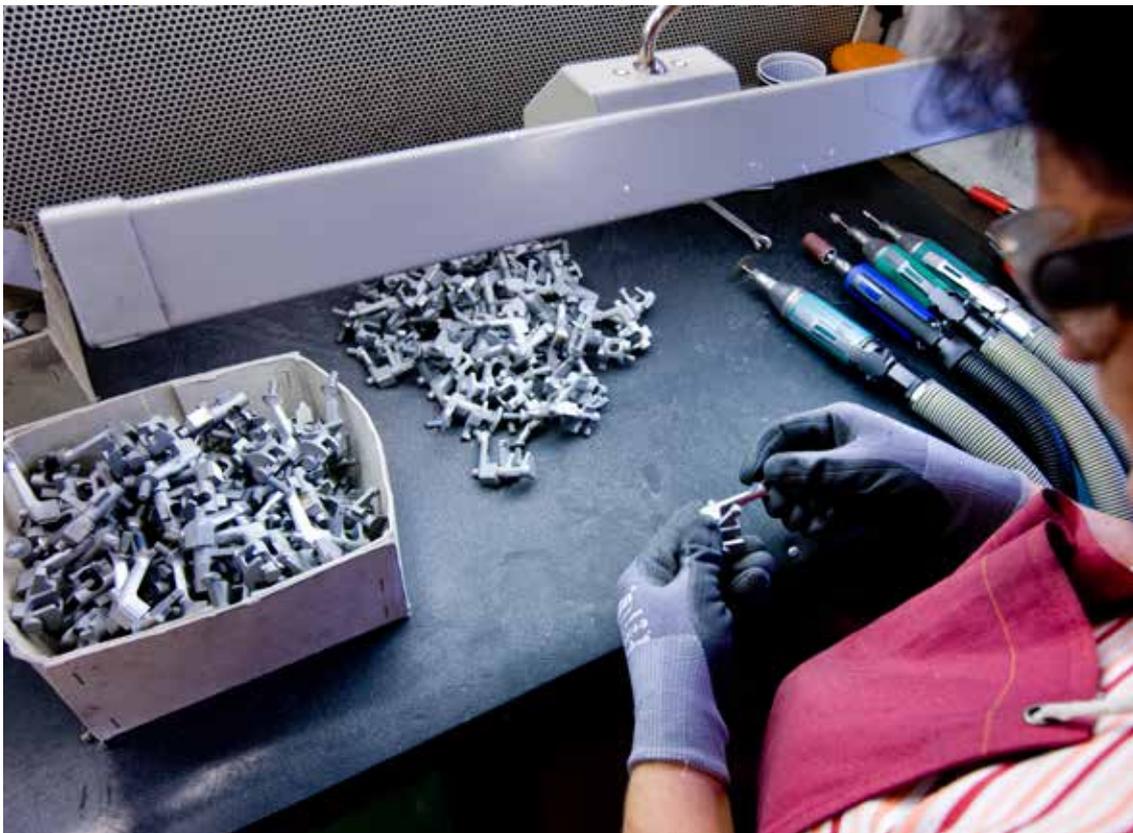
The ZOLLERN Group

ZOLLERN is one of the pioneers in the metal industry. At several locations in Europe, North America and Asia, 2,000 employees develop, produce and service a wide range of high-quality metal products. ZOLLERN supplies sophisticated solutions for a wide range of applications with its business areas of drive technology, investment casting, sand casting and forging as well as steel profiles.

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Investment casting

Dimensional tolerances, surfaces, processing allowances



The VDG specification P 695 defines the general technical terms and conditions of delivery for precision casting parts made of standardised and non-standardised metallic materials, in open, smelted and cast components produced according to the lost-wax casting process (also melting out of pattern process). In addition, for certain materials, specific requirements are defined in the specific material standards. The manufacturing process is based on industrial waxes with a calculated shrinkage.

The moulding materials used for the application are designed for moulding temperatures $> 1000^{\circ}\text{C}$.

The buyer defines the requirements for the casting part in accordance with the intended purpose. Appendix A of this specification contains a checklist for brief information on the various points that can be agreed at the time of ordering. They refer to the relevant sub-sections and paragraphs of the VDG specification.

**BDG-
Guideline
P 690**

**VDG
Information Sheet**

1. Normative References

The documents listed below are required for the application of this document. Where dated references are concerned, only the version referred to applies. With undated references, the most recent version of the document referred to (including all amendments) applies.

DIN 406-10

Technical drawings; dimension entries; terms, general principles

DIN 406-11

Technical drawings; dimension entries; principles of application

DIN 406-11

Supplementary Sheet 1 - Technical drawings - dimension entries Part 11: Principles and application; output of processing of unmachined parts

DIN 406-12

Technical drawings; dimension entries; Entry of tolerances for length and angle dimensions

DIN 1451

Part 1 - 4 Lettering - non-serif Linear Antiqua

DIN ISO 5459

Technical drawings; form and position tolerances; References and reference systems for geometrical tolerances

DIN EN ISO 1101

Geometrical product specification (GPS) - Geometrical tolerance - tolerance of form, direction, location and run-out

DIN EN ISO 1302

Geometrical product specification (GPS)
Information on surface finish in technical product documentation

DIN EN ISO 1302

Correction 1 - Geometrical product specification (GPS)
Information on surface finish in technical product documentation; Correction of DIN EN ISO 1302 (2002-06)

DIN EN ISO 5459

Draft standard - Geometrical product specification (GPS)
Geometrical tolerances - references and reference systems

DIN EN ISO 8062-2

Geometrical product specification (GPS)
Dimension, form and position tolerances for moulded parts Part 2 :Regulations

DIN EN ISO 8062-3

Geometrical product specification (GPS) Dimension, form and position tolerances for moulded parts Part 3: General dimension, form and position tolerances and processing allowances for castings

DIN ISO 19959

Visual monitoring of surface finishing for precision castings
Steel, nickel alloys and cobalt alloys

BDG Guideline P 510

Initial sampling based on 3D CAD data

VDG Information Sheet P 701

Labelling of castings

2. Definition and Scope

2.1 Definition

The precision casting process is an industrial precision casting process that in contrast to other forming processes uses a meltable model (lost model) to create an undivided ceramic mould (lost mould). In these, metals and alloys based on iron, aluminium, nickel, cobalt, titanium, copper and magnesium are cast. The castings produced by this process are distinguished by a special surface quality and dimensional accuracy. The process is also known as »Lost Mould Process«, »Investment Casting«, »Lost Wax Process« or »Fonte à Cire Perdue«.

2.2 Scope

This Information Sheet does not apply to precious metals cast according to the lost wax process, products of the jewellery industry or dental laboratories and also not to art casting.

2.3 Rapid Prototyping

Dimensional and surface tolerances for castings produced in rapid prototyping processes may deviate. They must be agreed separately with the customer for the precision castings.

3. Object

3.1 Setting of objectives

This Information Sheet defines dimensional tolerances and gives processing allowances and surface roughnesses that correspond to the current state of precision casting technology. It serves as a foundation for optimum economic co-operation between the precision casting producer and customer.

3.2 Surfaces

The technical specifications given here refer to blasted or pickled surfaces. The state as delivered may deviate, e.g. if there is additional surface finishing. Exceptions must be agreed if these involve processes that change the dimensional tolerances.

3.3 Agreement

Unless agreed otherwise, initial samples are sent with the initial order. These serve to create mutual agreement between both parties. The initial samples are to be checked by the customer. After checking, the foundry is to be informed in writing of the release for series manufacture. Deviations that have been acknowledged with the release or the approval of the initial sample are binding on production and must then be included in the (casting) drawing.

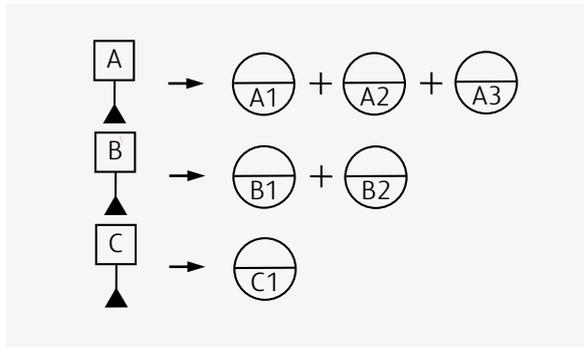
4. Dimensional Accuracy

4.1 Contraction and shrinkage

When cast metals harden and cool, the volume contracts and shrinks according to natural laws. Other influences in the production of precision casting are the results of contraction due to the lost models and expansion of the casting moulds during heating. The total sum of these influences will be correspondingly taken into account in the degrees of shrinkage by the manufacturer of the casting moulds. These are values gained by experience, dependent on the contours of the casting, the model material, the ceramics used for the mould and the casting material, but also on the particular production techniques of the individual foundries.

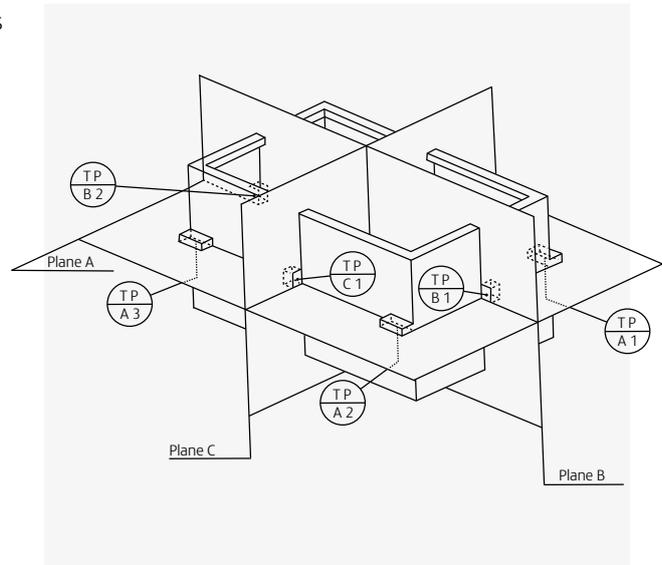
4.2 Reference planes and reference points

With castings, it is necessary to dimension the drawings or the CAD data systematically with reference planes and reference points, so-called locating points, so that dimension checks and subsequent processing are in agreement. These reference planes and reference points must be determined by the designer and agreed with the caster. The zero position of the reference planes will be defined exactly by the dimensions of the reference points.



Reference plane - Location points

The primary reference plane »A« is fixed by three reference points, A1, A2 and A3. This should correspond to the largest surface of the casting. The secondary reference plane »B« has the two reference points B1 and B2, which should if at all possible be allocated to the longitudinal axis. The tertiary reference plane »C« has only one reference point C1, which should be located in the centre of the casting or close to the centre.



Reference system (schematic example)

The reference planes are arranged to run through the symmetry axes of the casting. All reference points are to be arranged so that they cannot be removed or altered by subsequent processing. Reference points should be placed on the outer surfaces of the casting. They can also take the form of elevated or depressed surfaces. Elevated reference points have the advantage on castings with restricted form and position tolerances. When determining the reference points, care must be taken to ensure that these do not fall in a gating area. In this way, where difficult shapes are concerned, the casting can be exactly positioned by (pre-)processing of the location points.

4.3 Redundancy

In accordance with DIN 406, redundancies are to be avoided. Wall thicknesses must always be given.

4.4 Mould and draught angles

Mould and draught angles are not required as a general rule. Exceptions arising from technical mould and casting requirements must be agreed in advance by the precision casting supplier and the customer (cf. DIN EN ISO 8062-3, Supplement F (not yet published at the time of going to press)).

5. Dimensional Tolerances

5.1 Linear dimensional tolerances

Achievable dimensional tolerances for precision castings depend on the following factors:

- Casting material
- Dimensions and shape of casting

5.1.1 Casting material

In production, the different qualities of the materials influence the range of the tolerance fields. This is why, in **Table 1**, different series of tolerances apply to the different groups of materials:

Materials group	description	Degree of accuracy
D	Iron, nickel, cobalt and copper-based alloys	D1 to D3
A	Aluminium and magnesium-based alloys	A1 to A3
T	Titanium-based alloys	T1 to T3

5.1.2 Validity of the degrees of accuracy

Three degrees of accuracy are given in each of the material groups D, A and T:

- **Degree of accuracy 1**
applies to all general tolerances.
- **Degree of accuracy 2**
applies to dimensions within tolerance limits.
- **Degree of accuracy 3**
can only be complied with for individual dimensions and must be agreed with the caster, as additional production stages will be needed as well as complex tool adjustments.

Table 1a: Length dimension tolerances DCT (in mm) and dimensional tolerance degrees DCTG

Nominal dimension range	D1		D2		D3	
	DCT	DCTG	DCT	DCTG	DCT	DCTG
up to 6	0,3	5	0,24	4	0,2	4
over 6 to 10	0,36		0,28		0,22	
over 10 to 18	0,44	6	0,34	5	0,28	5
over 18 to 30	0,52		0,4		0,34	
over 30 to 50	0,8	7	0,62	6	0,5	6
over 50 to 80	0,9		0,74		0,6	
over 80 to 120	1,1	8	0,88	7	0,7	7
over 120 to 180	1,6		1,3		1,0	
over 180 to 250	2,4	9	1,9	8	1,5	8
over 250 to 315	2,6		2,2		1,6	
over 315 to 400	3,6	10	2,8	9		7
over 400 to 500	4,0		3,2			
over 500 to 630	5,4	11	4,4	10		7
over 630 to 800	6,2		5,0			
over 800 to 1000	7,2					
over 1000 to 1250						

Table 1b: Length dimension tolerances DCT (in mm) and dimensional tolerance degrees DCTG

Nominal dimension range	A1		A2		A3	
	DCT	DCTG	DCT	DCTG	DCT	DCTG
up to 6	0,3	5	0,24	4	0,2	4
over 6 to 10	0,36		0,28		0,22	
over 10 to 18	0,44	6	0,34	5	0,28	5
over 18 to 30	0,52		0,4		0,34	
over 30 to 50	0,8	7	0,62	6	0,5	6
over 50 to 80	0,9		0,74		0,6	
over 80 to 120	1,1	8	0,88	7	0,7	7
over 120 to 180	1,6		1,3		1,0	
over 180 to 250	1,9	9	1,5	8	1,2	8
over 250 to 315	2,6		2,2		1,6	
over 315 to 400	2,8	10	2,4	9	1,7	9
over 400 to 500	3,2		2,6		1,9	
over 500 to 630	4,4	10	3,4	9		10
over 630 to 800	5,0		4,0			
over 800 to 1000	5,6		4,6	10		
over 1000 to 1250	6,6					

Table 1c: Length dimension tolerances DCT (in mm) and dimensional tolerance degrees DCTG

Nominal dimension range	T1		T2		T3	
	DCT	DCTG	DCT	DCTG	DCT	DCTG
up to 6	0,5	6	0,4	6	0,4	6
over 6 to 10	0,6		0,4		0,4	
over 10 to 18	0,7	7	0,5	7	0,44	7
over 18 to 30	0,8		0,7		0,52	
over 30 to 50	1,0	8	0,8	8	0,62	8
over 50 to 80	1,5		1,2		0,9	
over 80 to 120	1,7	9	1,4	9	1,1	9
over 120 to 180	2,0		1,6		1,3	
over 180 to 250	2,4	10	1,9	10	1,5	10
over 250 to 315	3,2		2,6			
over 315 to 400	3,6	11	2,8	11		11
over 400 to 500	4,0		3,2			
over 500 to 630	5,4	11	4,4	11		11
over 630 to 800	6,2		5,0			
over 800 to 1000	7,2					
over 1000 to 1250						

5.1.3 Position of the tolerance field

The position of the tolerance field in relation to the nominal dimension can be freely selected. It is advantageous to place the tolerance field evenly around the nominal dimension. With surfaces that are machined, the sum or respectively the difference between tolerance field and processing allowance must be taken into account (see Point 7).

5.2 Form and position tolerances

Form and position tolerances limit the divergence of the cast element from its theoretically exact

- form or
- direction or
- from its exact location

independently of the actual dimensions of the cast element. Form and position tolerances assume that reference planes and reference points (see Point 4.2) have been set, in accordance with DIN EN ISO 1101. If form and position tolerances have been set with the order, these are to be individually agreed between the customer and the supplier and included in the drawing in compliance with DIN EN ISO 1101.

There are three degrees of accuracy, as shown above, available. An increasing degree of accuracy is linked to an increasing degree of complexity in production. Degree of accuracy 3 (as in Table 1) can only be complied with for individual dimensions and must be agreed with the caster, as additional production stages will be required as well as complex tool adjustments.

5.3 Angle tolerances for the material groups D, A and T

Table 2: Angle tolerances

Nominal dimension range ¹⁾	Accuracy ³⁾					
	1		2		3	
	Permissible deviation in direction					
	Angular minute	mm per 100 mm	Angular minute	mm per 100 mm	Angular minute	mm per 100 mm
up to 30 mm	30 ²⁾	0,87	30 ²⁾	0,87	20 ²⁾	0,58
over 30 to 100 mm	30 ²⁾	0,87	20 ²⁾	0,58	15 ²⁾	0,44
over 100 to 200 mm	30 ²⁾	0,87	15 ²⁾	0,44	10 ²⁾	0,29
over 200 mm	30 ²⁾	0,58	15 ²⁾	0,44	10 ²⁾	0,29

1) The length of the shorter arm is the decisive length for the nominal dimension range.

2) The angle may deviate in both directions

3) In general, degree of accuracy 1 is to be applied to precision castings in titanium-based alloys.

Angle tolerances deviating from **Table 2** must be agreed with the caster and included in the drawing according to DIN EN ISO 1101.

5.4 Radius of curvature

The tolerances given apply to the material groups D, A and T.

Table 3: Radius of curvature for the material groups D, A and T

Nominal dimension range	Accuracy ¹⁾		
	1	2	3
	Radius of curvature (mm)		
up to 5 mm	± 0,30	± 0,20	± 0,15
over 5 to 10 mm	± 0,45	± 0,35	± 0,25
over 10 to 120 mm	± 0,70	± 0,50	± 0,40
over 120 mm	linear (see Table 1)		

1) In general, degree of accuracy 1 is to be applied to precision castings in titanium-based alloys.

Radii of curvature that deviate from **Table 3** must be agreed with the caster.

5.5 Dimensional tolerances for wall thicknesses

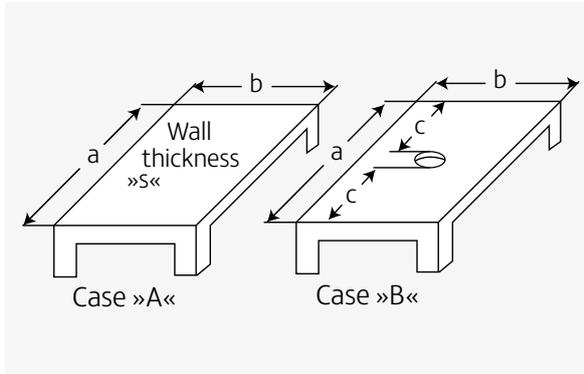
In deviation from DIN EN ISO 8062-3, the following conditions apply:

the wall thickness tolerances depend on

- the size of the (ceramic) mould that forms them
- the uninterrupted surfaces of the mould
- the possible thermal distortion of the mould
- the metallostatic pressure of the liquid metal.

The wall thickness tolerances do not therefore depend on the degree of accuracy. They are limited (or decreased) by thicker edge sections, apertures (openings, holes), connectors, ribs or similar to be cast on, which »relieve« the wall thickness. T

he tolerance area in question is to be taken from Table 4. In this table, the shortest length of a surface definitive for the wall thickness tolerance is listed according to material group. These wall thickness tolerances are valid only for unprocessed surfaces.



Examples of wall thickness tolerances

Example A

The surface formed by the dimensions a and b is not interrupted. Dimension b is smaller than dimension a. Dimension b determines the wall thickness tolerance.

Example B

The surface formed by dimensions a and b is interrupted by a drilled hole in the centre. The uninterrupted surface is therefore formed by the dimensions b and c. Dimension c is smaller than dimension b. Dimension c determines the wall thickness tolerance to be allowed.

Table 4: Wall thickness tolerance

Shortest side length of a surface (Picture left)	Material group D (mm)	Material group A (mm)	Material group T (mm)
up to 50 mm	± 0,25	± 0,25	± 0,30
over 50 to 100 mm	± 0,30	± 0,30	± 0,40
over 100 to 180 mm	± 0,40	± 0,40	± 0,50
over 180 to 315 mm	± 0,50	± 0,50	± 0,60
over 315 mm	± 0,60	± 0,60	± 0,70

5.6 Dimensional tolerances for prefabricated parts to be cast in and onto the casting

These must be agreed with the foundry.

6. Surface Finish

For cast surfaces, R_a (CLA) is to be used as in Table 5.

Tabelle 5 angewendet werden.

Table 5: Surface roughness

Surface standards	Materials group D		Materials group A		Materials group T	
	CLA (µinch)	R _a (µm)	CLA (µinch)	R _a (µm)	CLA (µinch)	R _a (µm)
N 7	63	1,6				
N 8	125	3,2	125	3,2		
N 9	250	6,3	250	6,3	250	6,3

The areas N 7, N 8 and special surface finishing must be agreed separately and included in the drawings as per DIN ISO 1302. Unless otherwise agreed, N 9 in blasted finish counts as the supplied condition.

7. Processing Allowances

Tolerance dimensions on surfaces or slight surface roughnesses that cannot be achieved by precision casting have a processing allowance. The dimensional allowance must

take into account the material-specific qualities and the least favourable computed position within the tolerance field, including the form and position tolerances.

8. Supplementary Notes

8.1 Inner radii

Radii on inside corners and inside edges (channels) help avoid casting errors and reduce notch tension in the casting during use. The minimum radius should be about 20 % of the greatest wall thickness, yet not be less than 0.5 mm. An inner radius that corresponds at least to the lowest wall thickness is desirable.

8.2 Outer radii and outside chamfering

8.2.1 Material groups D and A

Unprocessed precision castings do not have sharp edges with $R = 0$. For this reason, external radii and chamfers should always be given as maximum radii or bevels, e.g.: $R\ 0.5\ \text{max.} / L\ 0.5\ \text{max.}$

8.2.2 Material group T

For production-specific reasons, precision castings in titanium-based alloys may have sharp edges. Chamfering of the edges should be agreed between the caster and the customer.

8.3 Holes, blind holes, channels, slits and grooves

In order to be conveniently able to cast piercing holes, blind holes, channels, slits and grooves with the casting, i.e. without prefabricated ceramic cores, it is necessary to take the values listed in **Tables 6 and 7** into account.

Table 6: Dimensions for holes, blind holes and channels

Diameter d (mm)	greatest length or depth	
	piercing hole (l)	blind hole (t)
2 to 4	$\approx 1 \times d$	$\approx 0,6 \times d$
over 4 to 6	$\approx 2 \times d$	$\approx 1,0 \times d$
over 6 to 10	$\approx 3 \times d$	$\approx 1,6 \times d$
over 10	$\approx 4 \times d$	$\approx 2,0 \times d$

Table 7: Dimensions for slits and grooves

Width b (mm)	greatest depth at bottom	
	open (l)	closed (t)
2 to 4	$\approx 1 \times b$	$\approx 1,0 \times b$
over 4 to 6	$\approx 2 \times b$	$\approx 1,0 \times b$
over 6 to 10	$\approx 3 \times b$	$\approx 1,6 \times b$
over 10	$\approx 4 \times b$	$\approx 2,0 \times b$

8.4 Labelling of the Castings

If the castings are to be labelled, the size of the lettering (»medium« according to DIN 1451) and the location on the casting must be agreed. VDG Information Sheet P 701 »Labelling of Castings« is to be applied correspondingly.

The labelling can be cast on raised or depressed: the best form is raised in a depressed field. If no instructions for this exist in the drawings, the type of labelling will be determined by the supplier.

9. Further Information

In the brochure »Feingießen Herstellung Eigenschaften Anwendung«, a special print by the periodical »konstruieren + gießen« 33 (2008) Issue 1 by the Zentrale für Gussverwendung (ZGV, Centre for Casting Applications) in Düsseldorf, the entire procedure is described in detail. This

text contains practical notes on materials and design plus numerous examples of the high profitability of precision casting. Company brochures and material information sheets from the German precision casting foundries within the BDG (Bundesverband der Deutschen Gießerei-Industrie, German Casting Industry Association) contain information on the manufacturing programs of individual precision casting foundries.

**BDG-
Guideline
P 695**

**VDG
Information
Sheet**

1. Normative references

This VDG specification contains provisions from other publications by means of dated or undated references. These normative references are quoted at the relevant points in the text and the publications are listed in the following. In the case of fixed references, subsequent changes or revisions of these publications belong to this specification only if they are incorporated by means of changes or revisions.

In the case of undated references, the last edition of the publication referred to is valid.

DIN EN 1559-1

Casting Technical terms and conditions of delivery
Part 1: General

DIN EN 1559-2

Casting Technical terms and conditions of delivery
Part 2: Additional requirements for steel cast parts

DIN EN 10204

Metal products Types of test certificates

DIN EN 10027-1

Designation systems for steel types Part 1: Abbreviation

DIN EN 10027-2

Designation system for steel types Part 2: Numerical system

DIN EN ISO 9001

Quality management systems requirements

DIN EN ISO 6506-1

Hardness test according to Brinell Part 1: Test method

DIN EN ISO 6507-1

Hardness test according to Vickers Part 1: Test method

DIN EN ISO 6508-1

Hardness test according to Rockwell Part 1: Test method

DIN 29531

Aerospace - Technical terms and conditions of delivery

SAE AMS 2175

Classification and inspection of castings

DIN EN 2076 Part 3

Aerospace - Technical terms and conditions of delivery

DIN EN 2103 Part 3

Aviation - Technical terms and conditions of delivery

DIN EN 1559-3

Casting Technical terms and conditions of delivery
Part 3: Additional requirements for iron cast parts

DIN EN 1559-4

Casting Technical terms and conditions of delivery
Part 4: Additional requirements for aluminium cast parts

DIN EN 1371-2

Casting penetrant test Part 2: Precision casting parts

DIN EN 1369

Casting Magnetic particle inspection

DIN EN 12681

Radiography test

ASTM E 155

Standard Reference Radiographs Aluminium and magnesium castings

ASTM E 192

Standard Reference Radiographs Investment steel casting of aerospace applications

EN 1370

Casting Test of surface roughness with the aid of reference samples

DIN ISO 2859

Acceptance sampling inspection based on the number of defective units or faults (attribute test)

DIN ISO 3951

Sampling procedure based on quantitative properties (variable inspection)

DIN EN 10213

Cast steel for pressure vessels

DIN EN 10295

Heat-resistant cast steel

ISO 19959

Visual inspection of the surface qualities of precision cast parts steel, nickel alloys and cobalt alloys

DIN EN 1706

Cast parts made of aluminium and aluminium alloys

DIN EN 10293

Cast steel for general applications

DIN EN 10283

Corrosion-resistant cast steel

2. Definitions

The following definitions apply to the use of this specification P 695 as a correction of or addition to EN 1559-1:

2.1 Melt/cast charge

A melt/cast charge comprises the total quantity of metal originating from the same furnace or crucible furnaces or from several furnaces and mixed before casting in the crucible.

2.2 Master melt

A master alloy is the product of a single furnace charge for the production of one or more melts.

2.3 Remelt

Remelt refers to the total quantity of material resmelted in a melting vessel.

2.4 Batch/inspection batch

Unless otherwise defined, a batch/inspection batch consists of cast parts of the same dimensions and material from one melt or remelt which are produced, treated and jointly presented for inspection.

If more than one melt is included in one heat treatment batch, this can be defined as one batch/inspection batch by agreement between the manufacturer and the customer.

2.5 Rough casting part

A rough casting part is a casting part which was not subjected to machining after casting (removal of sprues, gates, burrs and removal of moulding material residue can be agreed).

2.6 Sample

A cast part produced under the same production conditions as the cast parts to be provided to the customer for inspection before production release is issued.

NOTE: With the sample, proof is to be furnished that the manufacturer is capable of meeting the quality requirements (dimensions, material, function etc.).

2.7 Welds

The terms and definitions in the relevant European standards for welding apply. Production welding includes finishing welding and joint welding as well as welding of small area surfaces.

2.8 Inspection

Activities such as measuring, inspection, determination of test results, measurement (with gauges) of one or more characteristics of a product or service and comparison of the results with defined requirements in order to ascertain compliance.

2.9 Continuous monitoring

Regular inspection of the characteristics and/or production conditions of a casting part produced in general over a long period, in large quantities and in each case in accordance with the same regulations. The inspection is carried out in accordance with an agreed procedure and may also include agreed statistical methods.

2.10 Non-specific inspection

Inspections carried out on casting parts or inspection units which are not necessarily supplied to the customer, in accordance with processes which appear appropriate to the manufacturer, which are to determine whether casting parts produced in accordance with a certain process comply with the requirements specified in the order.

2.11 Specific inspection

Inspections carried out before delivery on the casting parts or on inspection units representing the delivered casting part in accordance with the technical conditions defined in the order to ensure that these casting parts meet the requirements specified in the order.

2.12 Inspection unit

The number or amount of casting parts which are jointly accepted or rejected based on the inspections carried out on the samples in accordance with the requirements of the relevant specification, material standard or order.

2.13 Sample casting part

A casting part selected from an inspection unit for the purpose of taking samples.

2.14 Sample

Part of a sample piece with defined dimensions, machined or unmachined, placed in a state required for carrying out a certain inspection.

NOTE: In certain cases, the sample may be the sample casting part itself.

3. Information to be provided by the customer

3.1 Binding information

(see also checklist in Appendix A (informative))

The customer must provide clear information with the order, in particular on

- a) the number of casting pieces to be supplied, the permissible deviations from these numbers and the delivery schedule. Unless otherwise stated, the terms and conditions of the manufacturer apply.
- b) the definition of the casting material,
 - the number of the applicable material standard,
 - the material symbol (material designation) and/or the material number of the casting material,
- c) the drawings, standards, technical rules, directives etc. applicable to the order,
- d) the requirements regarding the external and internal casting piece qualities in so far as they diverge from the details given in this specification.

Where applicable, enquiries and orders must contain further details, such as:

- e) the delivery condition, such as heat treatment, surface treatment
- f) type and scope of machining to be carried out by the manufacturer
- g) type and scope of the specific inspections to be carried out by the manufacturer and their test conditions
- h) type of certificates as per DIN EN 10 204 with the inspections carried out
- i) type of surface protection and packaging
- j) the composition of a charge (e.g. cast charge, heat treatment charge) in so far as this is not defined in the material specification

k) agreements on production weldings in so far as they diverge from the details of this specification

l) any other special requirements such as joint structures, corrosion-resistance and machineability

3.2 Drawings, dimensions and tolerances

The customer is to provide the manufacturer with a sufficient number of the necessary drawings. The surfaces to be machined and the working faces for machining as well as the datum surfaces for the dimensional inspection are to be defined in the drawings. Precision casting tolerances are given in the VDG specification P 690. If no degree of accuracy was agreed with the order, a degree of accuracy of 1 applies to linear, non-tolerated dimensions and a degree of accuracy of 2 for tolerated dimensions. Divergent tolerances or degrees of accuracy require separate agreement. In so far as the customer provides the manufacturer with a model tool or models, the dimensional risk for the precision cast parts produced therefrom lies with the customer.

3.2.1 Initial sample inspection and initial sample test report

It is usual with precision cast parts to produce a certain number of initial samples before beginning serial production. Number of initial samples and scope of the initial sample inspections is to be agreed between the manufacturer and the customer.

It is recommended to draw up an initial sample inspection report (e.g. as per VDA), but this is to be agreed between the manufacturer and the customer.

3.2.2 Preliminary samples

Supply of preliminary samples can be agreed. In the case of preliminary samples, it is to be clearly stated whether they are intended as dimensional samples or material samples.

3.2.3 Release for serial production

Release for serial production is given appropriately on the initial sample inspection report or in another written form.

4. Designations and material standards

Selection of the materials for the precision cast parts should be based on the current national or international casting standards.

If no casting standard exists for the material, standards of other production processes can be applied. In this case, however, only the chemical composition for the selected material is binding. Other properties to be assured are to be agreed.

5. Manufacture

5.1 Manufacturing process

The manufacturing process comprises all production processes up to the delivery of the cast part, such as

- production of the casting mould
- casting process
- smelting of the casing material and smelting treatment

The customer is to be informed of the smelting and moulding process if an appropriate enquiry was included with the order.

5.2 Production welding

Production weldings are permitted in so far as nothing else was agreed at the time of the order.

Taking appropriate account of the material and of the form of the casting parts, production weldings are to be carried out in such a way that the quality values relevant in the welded material and in the welding zone sufficiently meet the requirements of the properties of the basic materials or the properties of the product.

Agreements can be reached with regard to the filler materials to be used. Otherwise, the manufacturer must take a decision in accordance with the recommendations of the material standard or according to his experience. The areas on which the product weldings are to be carried out are to be prepared and inspected in such a way that perfect welding is ensured. Documentation of areas of product weldings can be agreed. If necessary, the precision cast parts with product weldings are to undergo heat treatment. The definitions of the material standards are to be observed for this purpose.

Production weldings are to be reworked in such a way that they are as similar as possible to neighbouring surfaces.

6. Requirements

6.1 Chemical composition

Unless otherwise defined in the order, the requirements in the relevant casting material standards apply in terms of the chemical composition of the casting material. The same applies to materials which are standardised but not yet listed as casting materials unless otherwise stated by the manufacturer.

For material analyses on the cast part, the permissible deviations in the material standard or agreements between the manufacturer and the customer apply.

If neither the relevant material standards nor the order contain information on the chemical composition of the material, e.g. if the material is only defined by the mechanical properties, the manufacturer is free to select a suitable chemical composition.

6.2 Mechanical properties, hardness test/tensile strength

Unless otherwise defined in the order, the requirements in the relevant casting material standard apply in terms of the material properties. Unless standardised casting materials are involved, the mechanical properties are to be agreed on ordering. If the relevant wall thickness or sampling method is not defined, the requirements defined for samples in the material standard apply in terms of material properties.

In cases where special properties such as yield strength, tensile strength and hardness apply to certain areas of the cast part or to the complete cast part, these properties must be agreed at the time of the order.

Unless otherwise agreed with the order, the tensile strength test can be replaced with a hardness test in accordance with DIN EN ISO 6506-1/6507-1/6508-1. The hardness values are to be converted if necessary in accordance with DIN EN ISO 18265.

6.3 General cast part quality

Unless otherwise agreed with the order, the cast parts are supplied as unmachined cast parts according to 3.5.

6.3.1 Non-destructive test

If requirements for the external or internal properties are agreed, these must define:

- the non-destructive test procedure to be applied;
- the scope (area and/or frequency) of the test characteristics to be determined;
- the acceptance criteria.

In such areas in which a non-destructive inspection has been agreed, the required surface quality is to be ensured by applying a suitable process.

6.3.2 Quality levels

6.3.2.1 Classification of the quality levels

The quality levels for the external quality are classified according to tests according to the magnetic leakage flux process or the dye method.

The quality levels for internal properties are classified on the basis of a radiography test (radioscopic) and/or an x-ray test (radiographic).

An ultrasound inspection of precision cast parts is to be agreed separately.

6.3.2.2 Selection of quality levels

Permissibility of external and internal flaws in precision cast parts can be defined in the material standards or in the order. Here the following is to be taken into account according to the height, type and distribution (critical or non-critical zone):

Different quality levels can be agreed for different areas of the precision cast part. In such cases, the relevant areas are to be clearly specified and defined in the drawing.

In addition to equivalent quality levels, different quality levels can also be agreed for internal and external properties.

If no quality level is agreed on ordering and unless otherwise defined in the material standard, the requirements of quality level 4 apply to the external and internal properties.

For **production weldings**, the same requirements generally apply with regard to the quality level as for the basic material unless otherwise agreed when ordering.

6.3.2.3 Standard designation

The standard designations for quality levels 1 to 4 as per table 1 is composed according to the following example:

- designation of the quality level 1,2,3 or 4
- the I/S mark (Investment casting surface) for the quality level of the external quality
- the I/V mark (Investment casting volume) for the quality level of the internal quality

Example 1:

VDG specification P 695 I/S 2 I/V 4

If selection of the testing process is not to remain at the discretion of the manufacturer, the following code letters are to be used for the quality level according to example 2

- Magnetic particle inspection - M
- Dye penetrant test - P
- Radiographic X-ray test - R
- Fluoroscopy - D
- Ultrasound testing - U

Example 2:

VDG specification P 695 - I/S P2 - I/V R4

Inspections

Agreements on inspections. If one of the quality levels is ordered for the external and/or internal quality is ordered, proof of the observance of the quality level is to be agreed with the customer.

Scope of inspection

The scope of inspection (e.g.100 % of the component per piece or 10 % of the parts to 100%) surface and volume inspection is to be defined in the enquiry.

Test procedure and assessment criteria

The tests are to be carried out in accordance with the current EN or DIN test standards in each case. The evaluation is carried out in accordance with tables 1 to 3 on pages 26 to 29.

Magnetic particle inspection

Carried out and assessed in accordance with DIN EN 1369.

Dye penetrant test

The test is carried out in accordance with DIN EN 1371-2. Assessment is carried out in accordance with table 1a. Reference surface for the assessment, square frame, dimensions 25 x 25 mm².

Radiography/fluoroscopy

Carried out in accordance with DIN EN 12681, evaluation as per ASTM E 192 or E 155, see table 2 and 3.

Ultrasound test

A US test and the necessary evaluation criteria for this are to be defined in the enquiry.

6.3.3 Surface faults

If minor surface faults do not impair the application or if the surface of the cast part corresponds with the initial sample, they do not need to be removed with production weldings. If necessary, such surface faults are to be removed by cleaning within the dimensional tolerances.

NOTE: Examples of minor surface faults are small moulding material or slag marks, small cold weld marks, small scabs, small cavities, accumulations of small pores, unevenness, burr.

Major external and internal faults may be repaired by **production welding** where this is applicable. Other methods of repair (e.g. impregnating) are to be agreed between the manufacturer and the customer.

In the case of unmachined casting parts, it is recommended that the customer discusses with the manufacturer the selection of a non-destructive test procedure and acceptance criteria for subsequent surface machining. If not agreed in more detail, faults appearing on machined surfaces are not to be considered to be grounds for rejection.

6.3.4 Surface quality

If requested, the surface quality is to be agreed and stated on the drawing.

If the surface quality is not defined, the specifications of the VDG specification P 690 pt. 6, »Surface quality« apply.

6.4 Special requirements for the cast part properties

Special requirements for the cast part properties, e.g. pressure-tightness against certain media, with defined pressures and temperatures, or the joint, are to be defined in the enquiry.

7. Tests and certificates

7.1 General

The manufacturer is to take the necessary measures to meet the agreed requirements, e.g. by supervising the production conditions and/or testing samples or the cast parts.

The customer can agree suitable quality assurance measures with the manufacturer by which the test procedures and scope of testing are defined. The tests carried out at the manufacturer's site do not exempt the customer from carrying out his own incoming goods inspections.

7.2 Certificates

If a certificate as per DIN EN 10 204 or a declaration of conformity is to be issued due to internal monitoring and inspection of the manufacturer, this is to be agreed when ordering. This applies in particular to non-destructive tests, where additional agreements are to be reached on the type and verification of the test results.

In general, the tests are carried out by experts of the manufacturer, by special agreement or also by external persons appointed by the customer.

7.2.1 Inspections of the delivery

Generally, the cast parts are tested in the manufacturer's works. Here the inspections are to be carried out and the requirements applied as specified in the relevant material standard and/or agreed at the time of the order. With this agreement, the required type of inspection is also to be specified non-specific, specific or continual.

If non-specific inspection is required, see 7.2.2. If specific inspection is required, see 7.2.3. If continual monitoring is to be carried out, see 7.2.4.

7.2.2 Non-specific inspection

If requested, the manufacturer can issue a factory certificate of compliance based on non-specific inspections (see 3.1 in EN 10204) or a test report (see 3.2 in EN 10204) for the customer.

If the customer orders a test report, he must also state, if required, for which characteristics of the cast part test results are to be listed in the certificate.

7.2.3 Specific inspection

If the customer requests specific tests to prove that the cast part of the delivery complies with the requirements of the order, the enquiry and order must contain the following information:

- the type of certificate required:

In addition, the enquiry and order must contain the following information if the product or material standard does not contain any corresponding information:

- the inspection unit and the number of sample parts per inspection unit; -
- the conditions for sampling and for preparation of the sample pieces and samples; -
- if applicable the marking of the inspection units;
- the inspection method;
- and, in the case of acceptance test certificates and acceptance reports which are to be signed by external acceptance officers, the address of the inspection company.

7.2.4 Continual monitoring

In special cases, the specific inspection of a cast part can be replaced by agreement by continual monitoring of its characteristics and/or of production by the manufacturer. The features to be demonstrated and their values, the frequency of inspection and, if necessary, the requested certificates are to be agreed at the time of order. Where necessary, this agreement must also define the right of the purchaser to have this inspection verified.

7.2.5 Statistical sample inspection

If statistical sample inspections are agreed, the basic rules of the sample inspection as per DIN ISO 2859 and DIN ISO 3951 are to be observed.

The following can be agreed for the sample instructions:

- a) the acceptance quality limit (AQL) and the minimum value of the associated probability of acceptance or
- b) the sample system and the acceptance quality limit or
- c) the sample system and the inspection level.

If no special agreements are reached, inspection according to sampling scheme as per DIN ISO 2859, inspection level II applies.

7.3 Acceptance officer

7.3.1 Inspection by an acceptance officer

Presentation of part or all of the delivery for specific inspection is to be reported to the acceptance officer by the manufacturer or his authorised representative in a suitable manner. Reference is to be made to the order.

To avoid interruptions in the normal production process, the date or dates for the inspection/determination of inspection results are to be agreed between the manufacturer and the acceptance officer.

If an external acceptance officer does not appear on the agreed date, the acceptance officer of the manufacturer may carry out the acceptance test himself in order to avoid interruptions in the production process and submit the acceptance certificate to the customer, unless this is expressly excluded.

7.3.2 Rights and obligations of the acceptance officer

In order to carry out the agreed inspection, the acceptance officer must have free access at all suitable times to the points at which the cast parts are inspected.

He may state the sample cast parts of the inspection unit from which sample cast parts are to be taken in accordance with the regulations. He is entitled to track the sampling, preparation (machining and treatment) of the samples and execution of the inspections. He is to comply with all instructions, in particular the safety instructions of the works. The manufacturer is entitled to appoint a member of the factory to supervise him. The inspections are to be carried out in such a way that normal operations are interrupted as little as possible.

7.4 Sample parts

7.4.1 Production/taking of sample parts

If required, sample parts are to be produced as defined in the corresponding material standard or at the time of ordering. These may be

- cast separately,
- cast on or
- taken from the cast part.

Unless described in more detail in the order, separately cast samples are inspected which come from the same smelting and were subjected to the same heat as the inspection batch.

7.4.2 Number/size of sample parts

The number and size of sample parts are based on the defined number of samples for the agreed inspections including the recurrent inspections.

7.4.3 Separation of sample parts

Unless otherwise defined, cast on sample parts may only be separated after marking and where appropriate after heat treatment.

Separately cast sample parts and those that have to be separated for machining are to be marked.

7.5 Test method

If applicable, tests are to be carried out in accordance with the EN or DIN standards. This also applies to the presentation of results. If there are no such European standards, other test methods may be used, which are then agreed at the time of ordering.

7.5.1 Chemical composition

The chemical composition is tested in accordance with the specifications of the material specification.

7.5.2 Visual inspection

The precision cast parts are visually inspected before delivery to the customer in order to sort out surface faults, inclusions and damage which exceed an acceptable degree (see pt. 6.3.3). Unless otherwise agreed, this visual inspection can be carried out during production.

7.6 Invalid inspections

An inspection is invalid if its results were insufficient for the following reasons:

- defective production of a sample (workpiece fault, machining fault), but not material faults
- defective inspection (installation of the sample, performance, test equipment).

It is irrelevant whether the fault emerges during or after the inspection. In either case, only the individual inspection must be carried out.

7.7 Repeat inspections

7.7.1 General

Unless otherwise specified in the material standard, the standard for specific technical delivery conditions or in the product standard, the following applies:

If initial calculations of test results of a inspection unit do not comply with the defined requirements, the manufacturer may either withdraw the inspection unit concerned or carry out a repeat inspection in accordance with the procedures described in 7.7.2 and 7.7.3.

7.7.2 Individual values

If inspections produce an insufficient result, for which no mean value but only individual values are defined (e.g. tensile test, bending test or face quenching), the procedure is as follows:

7.7.2.1 The inspection unit is an individual piece

Two repeat inspections of the same type as the inspection whose results do not meet the requirements are to be carried out. The results of both new repeat inspections must meet the defined requirements. If this is not the case, the inspection unit is to be rejected or the treatment repeated (see 7.8).

7.7.2.2 The inspection unit consists of more than one piece

Unless otherwise agreed, the manufacturer may leave the sample cast part from which the results that do not meet the requirements originate in the inspection unit or withdraw them at his discretion.

If the sample cast part is withdrawn from the inspection unit, the acceptance officer is to select two other sample cast parts from the same inspection unit. Two further inspections of the same type are then to be carried out on the samples from these two sample cast parts under the same conditions as for the first inspections; both repeat inspections must comply with the defined requirements.

If the sample cast part is left in the inspection unit, proceed as described under a), whereby one of the new samples is to be taken from the sample cast part left in the inspection unit; both repeat inspections must meet the defined requirements.

7.8 Sorting and repeat treatment

The manufacturer is entitled to sort out the cast parts which do not comply with the requirements and/or subject them to repeat treatment (e.g. heat treatment, machining etc.), either before or after the repeat inspections, and to submit these cast parts as a new inspection unit in accordance with 2.4.

The manufacturer is to inform the acceptance officer of the sorting out method and/ or repeat treatments used.

8. Marking

The manufacturer is to mark the delivery, if asked to, in compliance with the relevant standards or by agreements at the time of order with

- Manufacturer's marks;
- Information on traceability;
- Marking of the alloy;
- other marks requested by the customer.

9. Packaging and surface protection

If no specific agreements are reached and if no specific agreements have been reached and no regulations exist with regard to the specification, the manufacturer is free to select the type of packaging.

However, the selection is to be made in such a way that the quality of the products is not damaged by transport or possible intermediate storage.

If cast parts have to be subjected to an acceptance inspection, surface protection and/or packaging may only be carried out after such an inspection.

10. Complaints

In the case of a complaint, the manufacturer must be able to convince himself of the justification for the complaint within a reasonable time.

Complaints may only be made against defective cast parts if the defects significantly impair further processing or use of the parts.

This applies if no other agreement has been reached at the time of ordering.

The buyer has to give the manufacturer the opportunity to assess whether the complaints are justified.

Table 1a: Assessment criteria quality levels (related to an area 25 x 25 mm²) based on DIN EN 1371-2 (penetrant test)

Non-linear (round) indications (SP and CP) in mm		Quality level			
		1	2	3	4
Diameter of the smallest indication to be taken into account (SP or CP)		1,5	2	3	5
Highest number of non-linear indication (SP+CP)		2	2	2	1
Highest permissible dimension of the indications A, B, C, F, N in mm	SP	3	5	7	10
	CP	5	6	9	15

Linear indications (LP) in mm	Quality level											
	1			2			3			4		
	L	I	C	L	I	C	L	I	C	L	I	C
Wall thickness $t \leq 16$ mm	0,5	1	1,5	1	1,5	2,5	1,5	2	4	2	2,5	5
Wall thickness $16 \text{ mm} < t \leq 50$ mm	0,5	2	4	1	3	6	1,5	4	8	2	5	14

Explanation of abbreviations:

- L = Length of the smallest indication
- I = longest length of the isolated indications
- C = longest length of the cumulative indications
- SP = non-linear isolated indication
- CP = non-linear clustered indication
- LP = linear indications (length 3x > width)

Table 1b: Assessment criteria for quality levels based on DIN EN 1369 (Magnetic particle inspection)

Linear (LM) and series connected (AM) indications ¹⁾		LM 1		LM 2		LM 3		LM 4		LM 5	
		AM 1	AM 2	AM 3	AM 4	AM 5					
Length L ₁ of the smallest indication in mm to be taken into account Arrangement of the indications Wall thickness: Longest length L ₂ in relation to wall thickness t in mm	individual I cumulative C	I C	I C	I C	I C	I C	I C	I C	I C	I C	
	Wall thickness: t ≤ 16 mm	2 4	4 6	6 10	10 18	18 25					
	Wall thickness: 16 mm < t ≤ 50 in mm	3 6	6 12	9 18	18 27	27 40					

Non-linear sporadic indications (SM) ¹⁾		SM 1		SM 2		SM 3		SM 4		SM 5	
		Length L ₁ of the smallest indication in mm to be taken into account	1,5	2	3	5	5				
Non-linear indications (SM)	largest permissible total area in mm ²	10	35	70	200	500					
	longest permissible individual length L ₂ in mm	2 ²⁾	4 ²⁾	6 ²⁾	10 ²⁾	16 ²⁾					

¹⁾ Enlargement factor 1 (eye)

²⁾ Maximum 2 indications with the specified largest dimension are permitted.

Table 2: X-ray reference images for the acceptance of precision cast parts (Steel, nickel, cobalt alloys)

Evaluation as per ASTM E 192

Category	Fault type (Illustration)	Comparison table	Wall thickness (tested cast part)	Number of maximum permissible comparative images (1 to 8)			
				mm (inch)	mm	1	2
1.1	Gas pores	3,2 (1/8)	≤ 6,4	2	4	3	7
		9,5 (3/8)	more than 6,4 to 12,7	2	4	6	7 ²⁾
		19 (3/4)	more than 12,7 to 25,4	2	4	6	7
2.1	Shrinkage pores ³⁾	19 (3/4)	all wall thicknesses	2	3	4	5
2.2	Shrinkage pores, spongy	3,2 (1/8)	≤ 6,4	2	4	6	7
		9,5 (3/8)	more than 6,4 to 12,7	2	3	5	6
		19 (3/4)	more than 12,7 to 25,4	2	3	5	7
2.4	Shrinkage pores, dendritic	3,2 (1/8)	≤ 6,4	2	4	6	7
		9,5 (3/8)	more than 6,4 to 12,7	2	4	6	7
		19 (3/4)	more than 12,7 to 25,4	2	3	5	6
3.5	Shrinkage pores, filamentary ³⁾	19 (3/4)	all wall thicknesses	1	2	3	3
3.11	Non-metallic inclusions of lower density	3,2 (1/8)	≤ 6,4	2	4	5	6
		9,5 (3/8)	more than 6,4 to 12,7	2	4	6	7
		19 (3/4)	more than 12,7 to 25,4	2	4	6	7
3.12	Non-metallic inclusions of higher density	9,5 (3/8)	all wall thicknesses	not permitted ⁵⁾			
4.1	Hot tears	9,5 (3/8)	all wall thicknesses	not permitted			
4.2	Cold cracks	9,5 (3/8)	all wall thicknesses				
4.3	Cold shuts	9,5 (3/8)	all wall thicknesses				
6.2	Run-out fault	9,5 (3/8)	all wall thicknesses	must not exceed the drawing tolerance			
5.3	Core shift	9,5 (3/8)	all wall thicknesses				
6.12	Mould buckle, positive	9,5 (3/8)	all wall thicknesses				
	Mould buckle, negative	9,5 (3/8)	all wall thicknesses				
5.11	Mould ridge	9,5 (3/8)	all wall thicknesses				
5.5	Excess metal in cracked core	9,5 (3/8)	all wall thicknesses				

²⁾ Cracks emanating from gas inclusions, not permitted

³⁾ For wall thicknesses < 12.7 mm, requirements for maximum permissible fault indication can be defined in the test instructions by separate agreement.

⁵⁾ Inclusions of higher density are acceptable up to the size of the largest individual gas bubbles of the corresponding comparative image. The number is limited to 2 units per 50 mm x 60 mm area. The minimum distance between two inclusions must be greater or equal to twice the diameter of the larger indication.

Signs of diffraction mottling phenomena are permitted in so far as they are sufficiently known to the X-ray tester, either by additional X-ray images from various angles or with a micro-section of representative cast parts.

Table 3: X-ray reference images for the acceptance of precision cast parts made of aluminium alloys**Evaluation as per ASTM E 155**

Fault	Thickness reference part ¹⁾		Thickness test cast part		Acceptance of reference images			
	inch	mm	inch	mm	1	2	3	4
Gas inclusions	1/4"	6,35	≤ 1/2	≤ 12,7	1	3	5	6
	3/4"	19,1	1/2 – 2	12,7 – 51	1	3	5	6
Gas pores (round)	1/4"	6,35	≤ 1/2	≤ 12,7	2	3	5	7
	3/4"	19,1	1/2 – 2	12,7 – 51	2	3	5	7
Gas pores (elongated)	1/4"	6,35	≤ 1/2	≤ 12,7	2	4	5	6
	3/4"	19,1	1/2 – 2	12,7 – 51	2	4	5	6
Shrinkage porosity	1/4"	6,35	all wall thicknesses		1	2	3	4
Shrinkage porosity, spongy	1/4"	6,35	≤ 1/2	≤ 12,7	2	3	5	6
	3/4"	19,1	1/2 – 2	12,7 – 51	1	2	4	5
Foreign inclusions (lower density)	1/4"	6,35	≤ 1/2	≤ 12,7	1	2	4	5
	3/4"	19,1	1/2 – 2	12,7 – 51	1	2	4	5
Foreign inclusions (higher density)	1/4"	6,35	≤ 1/2	≤ 12,7	1	2	4	5
	3/4"	19,1	1/2 – 2	12,7 – 51	1	2	3	4

¹⁾ Cracks, cold welding points and segregates are not permitted.

Signs of diffraction mottling phenomena are permitted in so far as they are sufficiently known to the X-ray tester, either by additional X-ray images from various angles or with a micro-section of representative cast parts.

Comment: the acceptance conditions for cast parts of more than 19 mm wall thickness are to be specified in the order, drawing or test instructions.

Appendix A (informative)

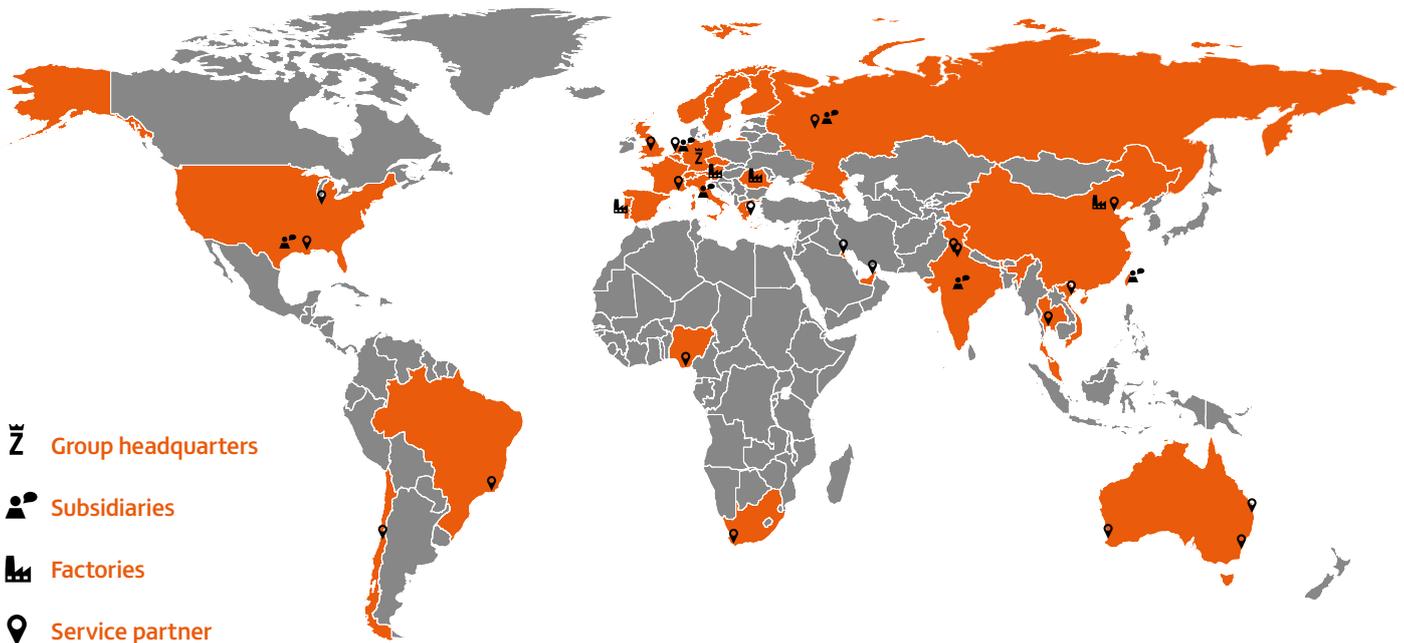
Checklist with the binding and/or optional information

Note: This appendix A contains a checklist for brief information on the various points that can be agreed at the time of ordering. They refer to the relevant sub-sections and paragraphs of the VDG specification P 695.

Table A (checklist)

Section	Title (example)	Agreement	Comments
3.	Information to be given by the customer		
3.1	Binding information		
	a) number of cast parts		
	b) applicable drawings, standards etc.		
	c) casting material (e.g. G-X 6 CrNi 18 9)		
	with standardised materials		
	• Material standard (DIN 17 445)		
	• Material number (1.4308)		
	d) cast part property, if different to 6.3.1		
	further information (if applicable)		
	e) condition as delivered (heat treatment; surface treatment)		
	f) machining		
	g) special tests		
	h) certificate as per EN 10 204 (acceptance test certificate 3.1.B)		
	i) surface protection/packaging		
	j) batch definition, cast batch, heat treatment lot		
	k) production welding		
	l) special requirements (joint structure)		
3.2	Drawings, dimensions and tolerances (as per VDG P 690) (binding)		
	Number of initial samples (binding)		
3.2.1	Initial sample report (as per VDA)		
3.2.2	Preliminary sample		
5.2	Production welding (documentation, welding additive)		
6.	Requirements		
6.1	Chemical composition		
	Batch analysis		
	Analysis of cast parts		

Section	Title (example)	Agreement	Comments
6.2	Mechanical properties (tensile test)		
	Hardness test (HV, HB, HRC)		
6.3	Non-destructive test (X-ray, crack test)		
6.3.1	Surface property (visible surface, surface roughness)		
6.3.3	Non-destructive test (X-ray, crack test)		
6.3.4	Surface property (visible surface, surface roughness)		
7.2	Certificate (as per EN 10204)		
7.2.1	Test on the delivery		
7.2.2	Non-specific inspection		
7.2.3	Specific inspection		
7.2.4	Continual monitoring		
7.2.5	Statistical sampling (as per DIN ISO 3859)		
7.3	Acceptance officer		
7.3.1	Inspection by an acceptance officer (TÜV, BWB etc.)		
7.4	Sample part		
7.4.1	Separately cast sample parts		
7.4.1	Cast sample parts		
7.4.1	Samples taken from the cast part		
	Position of the samples		
7.4.2	Number and size		
7.4.3	Marking of the samples		
7.5	Test method, see also 6.3.2 and P 695 Part 2		
7.5.2	Visual inspection		
8	Marking (cast on, punched)		
9	Packaging and surface protection (special corrosion protection)		



ZOLLERN

ZOLLERN GmbH & Co. KG

Hitzkofer Strasse 1
 72517 Sigmaringendorf-Laucherthal
 Germany
 T +49 7571 70-0
 F +49 7571 70-602
 info@zollern.com
 www.zollern.com

