AM 007 GGG 40

Specification

for

cast massive impeller blades

made of

GGG 40 – sand casting

Rev.	Date	Author	Reason for revision	Checked	Approved
/	2004/10/06	J. Mennig	First edition	Dr. Hirsch	F. Kinzer
A	2005/11/29	J. Mennig	Changes of contents: Pages 4, 5, 8, 11, 15	Dr. Hirsch	F. Kinzer
B	2006/05/10	J. Mennig	Changes of contents: Page 13	Dr. Hirsch	F. Kinzer
C	2007/03/28	J. Mennig	Changes of contents: Pages 4, 5, 13	B. Floch	F. Kinzer

Table of contents:

1.0 Purpose and field of application

This specification defines the technical conditions of supply for cast massive impeller blades made of cast iron with nodular graphite (GGG 40). Any former editions and versions of AM 007 G will be invalid from now on.
The requirements and specifications fixed in the following are applicable without any restrictions both for new projects and for spare part deliveries and repair measures (for ex. within the frame of revisions).

If not otherwise agreed in this specification the standard DIN 1690-1 will still be valid.

2.0 Material and material properties

EN-GJS-400-15 (EN-JS1030) DIN EN 1563 GGG 40 (0.7040) DIN 1693-1

Chemical analysis of the melt (all values in mass-%)				
C	Si	Mn	P	Mg
3.0 ÷ 4.0	≤ 2.8	< 0.5	< 0.1	0.03 ÷ 0.1

Structure
The micro structure has to show an almost complete ferritisation [1)] (at least 80 %). The spherolithe content must not go below 90 %. Cementite (iron carbide Fe_3C) is not allowed.
[1)] Position of the polished section (micrograph) at the impeller blade see Fig. 4: Position of specimens

Mechanical porpoerties				
Tensile strength Rm [N/mm^2]	Yield strength Rp0.2 [N/mm^2]	Elongation at fracture A [%]	Brinell hardness HB 30	Density [kg/dm^3]
≥ 400	≥ 250	≥ 15	135 ÷ 185 [2)]	7.1
[2)] Values are applicable for blade foot (ref. Fig. 4: Position of specimens)				

Table 1: Material and material properties

The mechanical properties indicated in Table 1 are applicable for the entire casting.

3.0 General requirements

- Manufacturing technique: Sand casting

- Delivery condition: Cast or ferritically annealed.

- Condition of the casting:

The blades (series and type sample) have to be delivered in fettled condition (ingates, risers, edges, beads, ripplings etc. are to be removed). The complete impeller blade and the top side of the blade foot (surfaces which are subject to a surface crack examination by means of magnetic particle testing (MT)) have to be relieved from the casting skin and ground to a surface roughness of at least Ra = 6.3 µm (N9) acc. to RUBERT – refence size „sand casting". N9 acc. to RUBERT corresponds to a value of approx. Rz 40 µm (Rz 25 ÷ 60 µm). The maximum permissible limiting value is Rz 60 µm.
The required surface roughness for all other surfaces is at least Ra = 12.5 µm (N10) acc. to RUBERT.

- Design and dimensions:

Areas which won't be finished later on such as leading and tailing edge are to be ground as specified in the drawings. Possibly provided necessary thickening of the casting profile (for ex. in the area of the tailing edge) is to be ground to the dimensions indicated in the drawing.
The centering toe located at the outer diameter of the impeller blade as well as the marking located in section B must not be removed.

Permissible deviation of twist of the impeller blade:

Maximum permissible angular deviation +/- 1.0° between each section and section B – B.

Permissible casting tolerances acc. to DIN ISO 8062:

Degree of casting tolerance CT 10 for longitudinal and thickness dimensions.
Position of the tolerance field +/- 50 % of the total tolerance.
(Ref. also inspection certificate for measurement of type samples 3 GK 1764 and 3 GK 1765).

TLT will give their approval for casting of the series after measuring of the type sample.

Machining allowances

The machining allowances please find in the respective blade drawings.

- Production welds:

Production welds are allowed, however, they will have to be be carried out by qualified personnel and supervised by a welding engineer. Any production welds have to be approved by TLT. In case of doubt TLT will decide whether a defective blade can be repaired or has to be scrapped.

4.0 Internal defects

Internal defects regarding kind, size and frequency are permissible to a limited extent only. The quality of the internal condition is to be proved by ultrasonic and X-ray inspections.
The impeller blade including transition to the blade foot will be subject to X-ray inspections acc. to DIN EN 12681 (ref. also DIN EN 444). X-ray inspection is only applicable for test specimen (ref. Table 8). The blade foot and the transition to the impeller blade will be subject to ultrasonic inspection (US) (each blank).

The extent of the examinatons to be carried out is indicated in Table 8.

4.1 Permissible internal defects

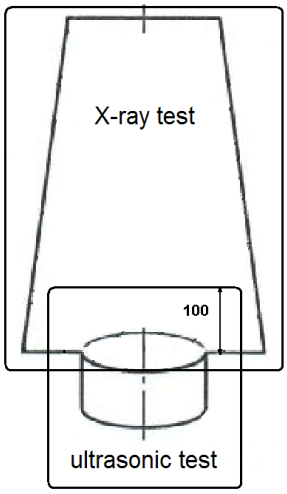

Fig. 1: Inspection areas X-ray and US examinations

X-ray examination

Required grades A3, B3, C3 acc. to ASTM E 446, cracks (D), hot cracks (E), chaplets and chills (F) are not permitted (ref. Table 2).

Ultrasonic examination (US)

The highest permissible indications are given in Table 3. It is not distinguished between core and peripheral zone. The terms “individual area” and “total area” used in Table 3 are shown in Fig. 2.

Among individual areas F are areas the distance A of which from the neighbouring area is larger than the biggest dimension L both from the one and from the other neighbouring area.
In the present example F1, F2, F3 are individual areas.
The total area is F1 + F2 + F3.
The dimensions L and B result from the connecting line of the centre points of the transciever when scanning the indication area. In case of long sound paths the real dimensions of the indication area are to be determined, if necessary, taking into consideration the geometry of the sound field and the sound propagation.

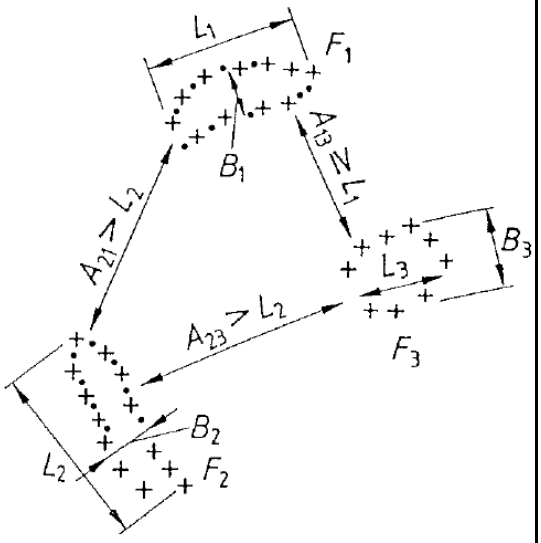

Fig. 2: Explanation of the terms „individual area“ and „total area“ in Table 3.

Maximum permissible defects found during X-ray axamination acc. to DIN 1690 part 2 (assessment acc. to ASTM E446)						
Grade	Blow holes (A)	Non-metallic inclusions (B)	Bubbles (C)	Cracks (D)	Hot cracks (E)	Chaplets and chills (F)
1	A1	B1	Ca1, Cb1, Cc1, Cd1	not permitted	not permitted	not permitted
2	A2	B2	Ca2, Cb2, Cc2, Cd2	not permitted [1)]	not permitted [1)]	not permitted
3	A3	B3	Ca3, Cb3, Cc3, Cd3	not permitted [1)]	not permitted [1)]	not permitted
4	A4	B4	Ca4, Cb4, Cc4, Cd4	not permitted [1)]	not permitted [1)]	F1 [2)]
5	A5	B5	Ca5, Cb5, Cc5, Cd5	D1 [3)]	E1 [3)]	F1

[1)] As far as the harmlessness of the cracks is not proved by fracture testing.
[2)] There may be chaplets, however, they must be welded free from cracks on the surface.
[3)] Cracks are allowed up to a length of maximum 7 mm.

Table 2: X-ray examination; maximum permissible imperfections

Maximum permissible indications found during ultrasonic examination acc. to SEP 1922 on the basis of DIN 1690 T2	
Reflectors without measurable dimension [2)]	
Maximum permissible diameter of the circular reference reflector[1)]	6 mm
Permissible number of reflectors which require to be registered on a reference area of 105 mm x 148 mm (format A6), as far as the distance [2)] A (ref. Fig. 2) between the reflectors is in any case larger than the sound beam diameter. Otherwise, even if the permissible number of reflectors which require to be registered was not exceeded, the specifications for reflectors with special features shall apply (ref. below).	5
Reflectors with measurable dimensions [2)]	
Maximum permissible diameter of the circular reference reflector [1)]	6 mm
Permissible attenuation of the back-wall echo (at 2 MHz test frequency), as far as this is not conditional on design of the casting or on the coupling.	12 dB [3)]
Maximum permissible length L at a width B (L and B ref. Fig. 2) equal or less the sound beam diameter	6 mm
Maximum permissible individual area (ref. Fig. 2)	30 mm^2
Maximum permissible total area (Fig. 2), on a reference area of 105 mm x 148 mm (format A6), i.e. on the reference area there may be maximum 5 biggest permissible individual areas	150 mm^2
Reflectors with special features	
Indications pointing to a) casting defects in unfavourable position to the sound beam or b) closely linked defects with considerable linear or depth extension or c) cracks or other defects affecting significantly the useability of the casting, are to be recorded and to be decided after consultation with TLT even if the specified limits of registratioin have not been be met or exceeded. Cracks are not permitted unless the minor nature of the cracks has been proved by fracture testing.	
Footnotes	
[1)] Circular reference reflector [2)] For the classification of the reflectors in such with and without measurable extension as well as for the determination of the distances of the reflectors without measurable extension preferably a transceiver with 24 mm diameter for longitudinal waves with a frequency of 2 MHz is to be used. [3)] Within an indicating range occasional back-wall echo attenuation of 100% is permissible (12 dB corresponds to 75 %).	

Table 3: Ultrasonic examination; maximum permissible indications

5.0 Surface defects

Size and number of surface defects are permitted to a limited extent only.

The blade surface (impeller blade and top side of blade foot) will be subject to visual examination and in addition to that subject to surface crack examination with magnetical particle testing (MT) (ref. steel-iron inspection sheet (SEP) 1935). The required surface roughness is Ra = 6.3 µm (N9) acc. to RUBERT – reference size „sand casting“. N9 acc. to RUBERT corresponds to a value of approx. Rz 40 µm (Rz 25 ÷ 60 µm). The maximum permissible limiting value is Rz 60 µm.
Magnetic particle testing is preferably made by a 4-pole-DC pulse generator (ref. QP 917), for local repairs also a yoke magnet can be used. Pay attention to sufficient magnetisation (20 ÷ 60 A/cm). Preferably use fluorescent test media. Pay attention to sufficient lighting of the surface.

The scope of surface examinations to be carried out please find in Table 8.

5.1 Permissible suface defects

For the different zones of the blade surface (ref. Fig. 3) different grades are applicable regarding the permissible surface defects.

Magnetic particle testing				
Permissible surface defects and specified grades acc. to Table 6				
Zone		A	B	C
Linear indications	horizontal	1	2	3
	vertical	2	3	4
Non-linear indications		2	3	4
		Fig. 6	Fig. 7	Fig. 8

Table 4: Magnetic particle testing; permissible surface defects

Visual inspection			
Permissible surface defects and specified grades acc. to Table 7			
Zone	A	B	C
Non-linear indications	1	2	3
	Fig. 9	Fig. 10	Fig. 11

Table 5: Visual inspection; permissible surface defetcs

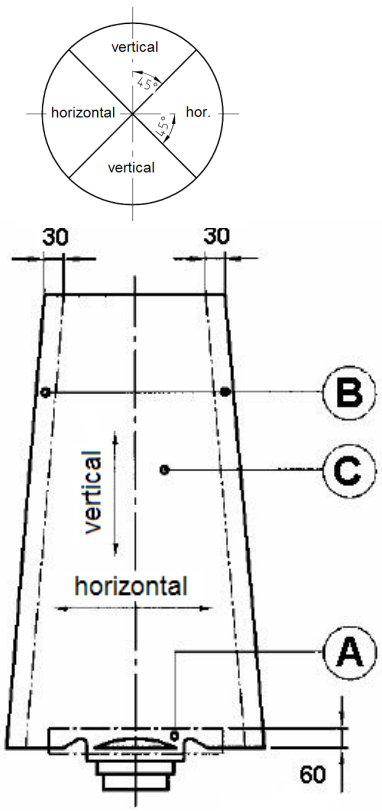

Fig. 3: Division of zones blade surface

Maximum permissible indications during magnetic particle testing acc. to SEP 1935 acc. to DIN 1690 T2 on a reference area of 105 mm x 148 mm (acc. to format A6).					
Grade	Diameter or length of the smallest indication to be considered [mm]	Non-linear indications [1] (except aligned indications [2])		Linear indications [1] or aligned indications [2]	
		Total area [mm^2]	Length of a single indication [3] [mm]	Maximum permissible length [4] of a single linear aligned indication [mm]	Maximum permissible length [4] of all linear indications and aligned indications [mm]
1	1.5	10	2	3	6
2	2	35	4	6	12
3	3	70	6	9	18
4	5	200	10	18	27
5	5	500	16	27	40

[1] Indications whose lengths are greater and equal to or smaller respectively than three times their width are kown as linear or non-linear indications (see also footnote 2).
[2] If at least 3 linear or non-linear indications are arranged one behind the other at a distance of 2 mm they are regarded as aligned indicationis
[3] Within the reference area there must not be more than 2 indications of the maximum permissible length.
[4] The length of one group of aligned indications shall be taken as the distance between the start of the first and the opposite end of the last indication of the group.

Table 6: Magnetic particle testing; maximum permissible indications

Maximum permissible indications during visual examinations of the surface acc. to DIN 1690 T2 on a reference area of 105 mm x 148 mm (acc. to format A6).					
Grade	Diameter or length of the smallest indication to be considered [mm]	Non-linear indications [1] (except aligned indications [2])		Linear indications [1] or aligned indications [2]	
		Number	Diameter of a single indication [mm]	Maximum permissible length [4] of a single linear indication or aligned indication [mm]	Maximum permissible length [4] of all linear indications and aligned indications [mm]
1	1.5	8	3	3	6
2	2	8	6 [5]	6	12
3	3	12	9 [5]	9	18
4	5	20	14 [5]	18	27
5	5	32	21 [5]	27	40

[1] Indications whose lengths are greater than and equal or smaller respectively than three times their width are known as linear and non-linear indications (see also footnote 2).
[2] If at least 3 lineare or non-lineare indications are arranged behind the other at a distance of maximum 2 mm they shall be regarded as aligned indications.
[3] Not applicable.
[4] The length of one group of aligned indications shall be taken as the distance between the start of the first and the opposite end of the last indication of the group.
[5] The frequency distributions of the size of the isolated indications shall approximately meet the specifications in the figures of chapter 8.0, however, none of the indications may be bigger than the value indicated in the above table. If in the reference areas lineare indications appear beside non-linear indications, the linear conditions have to fullfill the conditions for linear indications of the same grade (unless specified otherwise); in addition to that they are to be considered for the number of non-linear indications.

Table 7: Visual examination of the surface; maximum permissible indications

5.2 Remediation of surface defects

Unacceptable surface defects have to be remedied by grinding or welding. Therefore the proceedings described in the following have to be observed. This applies both for new blades and for blades which will be examined within the frame of a revision.

- Preparation of a testable surface

Cleaning, brushing, sandblasting, grinding (as required), until a testable surface has been achieved. The required surface roughness is Ra = 6.3 µm (N9) acc. to RUBERT – reference size „sand casting. N9 acc. to RUBERT corresponds to a value of approx. 40 µm (Rz 25 ÷ 60 µm). The maximum permissible limiting value is Rz 60 µm.

- Determination of the defects to be remedied

The blade surface (impeller blade and top side of blade foot) will be examined visually and in addition to that they will be subject to MT-testing (magnetic particle procedure, see 5.1) in order to determine the defects which have to be remedied.

- Correction of defects

Unacceptable surface defects up to a maximum depth of approx. 10 % of the respective blade thickness (however, not more than approx. 1 mm per blade side) may be remedied by grinding and reduced to the acceptable length respectively.
Further defects (if not deeper than approx. 50 % of the respective blade thickness and on one side only) may be worked by grinding (or milling) up to the perfect base material and repaired by means of welding. By means of MT-testing it is to be proved that the welding groove is free from cracks in order to assure perfect welding.
If the correction of defects won't be possible taking into consideration aforementioned limiting values further proceeding has to be defined together with TLT. In case of doubt TLT will decide whether a defective blade can be repaired or has to be scrapped.

- Surface crack examination

Finally the condition of the blade surface (acc. to specification?) has to be proved by MT-testing. In addition to that the welded areas will be examined by PT-testing (dye penetration testing, FE) after a period of approx. 7 days.

6.0 Examinations to be carried out

To be examined	Type of examination	Test standard	Scope of testing	Requirements	Certificates
chem. composition	chemical analysis	----	per melting heat	AM 007 GGG 40 Table 1	3.1 EN 10204
microstructure	micrograph		1 micrograph per test specimen (position of specimen see Fig. 4)	AM 007 GGG 40 Table 1	3.1 EN 10204
mech. properties	tensile test	DIN EN 10002-1	2 tensile tests per test specimen (position see Fig. 4)	AM 007 GGG 40 Table 1	3.1 EN 10204
	hardness test acc. to Brinell	DIN EN ISO 6506-1	each blade blank (see Fig. 4)	AM 007 GGG 40 Table 1	3.1 EN 10204
internal defects	ultrasonic examination (US)	SEP 1922	each blade blank (only foot and blade transition; Fig. 1)	AM 007 GGG 40 Table 3	3.1 EN 10204
	X-ray examination	DIN EN 12681	1 examination per test specimen (only impeller blade and blade transition; Fig. 1)	ASTM E 446 A3, B3, C3, D3, E3, F3	3.1 EN 10204
surface defects	magnetic particle testing (MT)	SEP 1935	each blade blank (except test specimen) (only impeller blade and blade transition Fig. 3)	AM 007 GGG 40 Table 4 DIN 1690 part 2	3.1 EN 10204
	visual inspection [1)]	----	each blade blank (except test specimen) (only impeller blade and blade tranistion, Fig. 3)	AM 007 GGG 40 Table 5 dye penetrant testing; non-linear indications DIN 1690 part 2	3.1 EN 10204
dimensions [1)]	dimensional check	----	type sample acc. to 3 GK 1764 and 3 GK 1765	AM 007 GGG 40 impeller blade drawing	----
	dimensional check (reduced scope of testing)	----	thickness of impeller blade after grinding 5 % of the blade blanks (at least 1 blade) sections B, D, F, H, K at 10, 30, 70, 90 % of the chord length	AM 007 GGG 40 impeller blade drawing	3.1 EN 10204

[1)] In case of welded blades pay attention to possible distortion

Table 8: Examinations to be carried out (overview)

The number of test specimen (and thus the scope of testing) has been defined as follows: Per TLT-order and per cast blade model (e.g. Model-No. 11.360) at least one test specimen will be necessary, independent of the number of blades to be delivered. If a TLT-order (related to one blade model) comprises more than 100 blades two test specimen will be necessary (from 200 blades 3 a.s.o.) If the whole delivery does not come from the same melting heat the test specimen have to be from different heats.

6.1 Proceeding of the examinations to be carried out

Heat	Test specimen	Type samples	Series
chem. composition (chemical analysis)			
	microstructure ferrit portion (polished section, micrograph)		
	examination of the internal condition X-ray examination of impeller blade and blade transition		
	mechanical properties tensile test, hardness test acc. to Brinell		
		dimensional check	
		approval for series casting	
		hardness test acc. to Brinell	hardness test acc. to Brinell
		examination of the internal condition US examination impeller blade foot	examination of the internal condition US examination impeller blade foot
		Grinding of impeller blade incl. top side of blade foot	Grinding of impeller blade incl. top side of blade foot
		MT-testing impeller blade incl. top side of blade foot	MT-testing impeller blade incl. top side of blade foot
		visual check of impeller blade incl. top side of blade foot	visual check impeller blade incl. top side of blade foot
		remediation of surface defects (if necessary)	remediation of surface defects (if necessary)
		dimensional check of impeller blade (reduced scope of testing)	dimensional check of impeller blade (reduced scope of testing)

Table 9: Proceeding of the examinations to be carried out (incl. necessary intermediate steps)

6.2 Position of the specimens

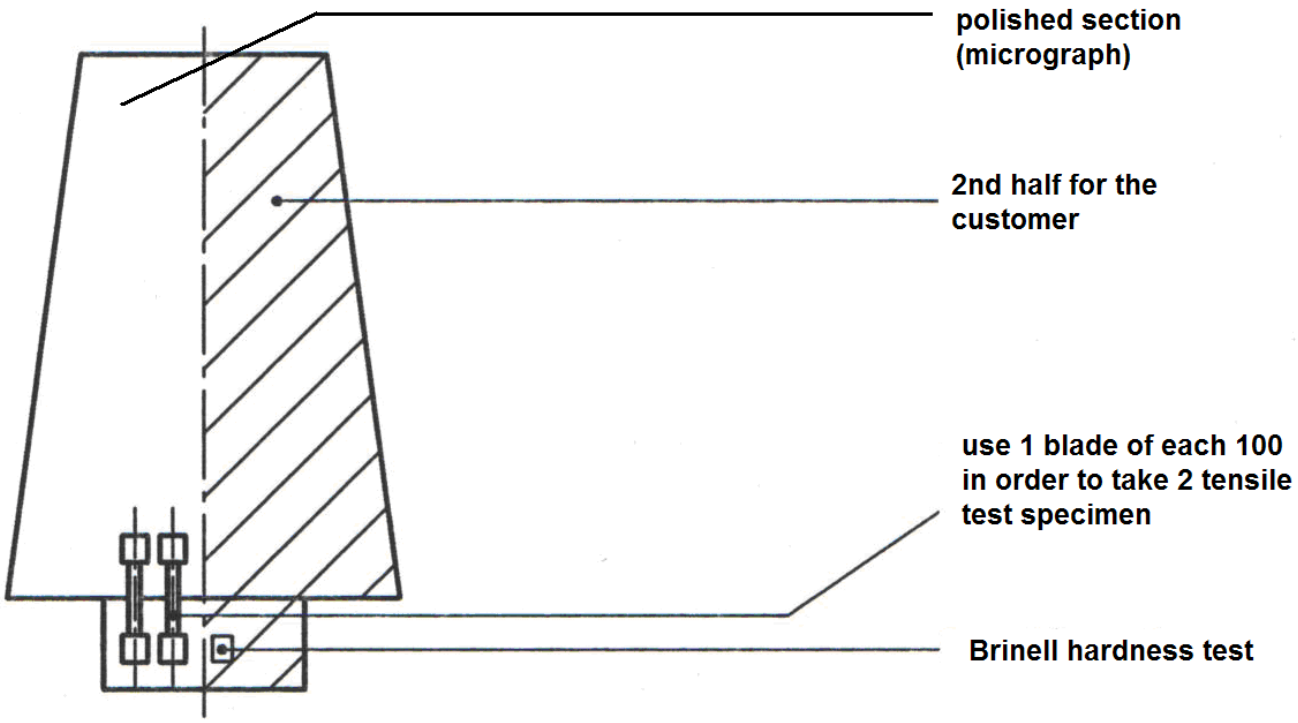

Fig. 4: Position of specimens

6.3 Qualification of the test personnel

The personnel authorized for the execution of all non-destructive material tests defined within the frame of this specification has to be at least qualified and certified acc. to DIN EN 473 grade 2. In case of doubt DIN EN 473 will show which tests will be affected.

7.0 Examinations after receipt

In the future the blades delivered by the caster (series, not type samples) are to be examined as follows after receipt of goods (before machining in any case):

- Visual check:

Rounding of the leading and trailing edges acc. to drawing specifications (all blades).
Surface roughness impeller blade and blade transition Ra = 6.3 µm (N9) acc. to RUBERT – reference size „sand casting“. The maximum permissible limiting value is Rz 60 µm (all blades).
Other conspicuities: Damages, distortion, position of the cams for machining.

- Surface crack examination acc. to MT-procedure:

One examination per 30 delivered blades, at least, however, one blade per order (independent of the total number of delivered blades). Basic principles of this examination are the datas in this specification (see 5.0). If the requirements won't be fullfilled the entire delivery is to be examined.

8.0 Pictures for the evaluation of non-linear indications

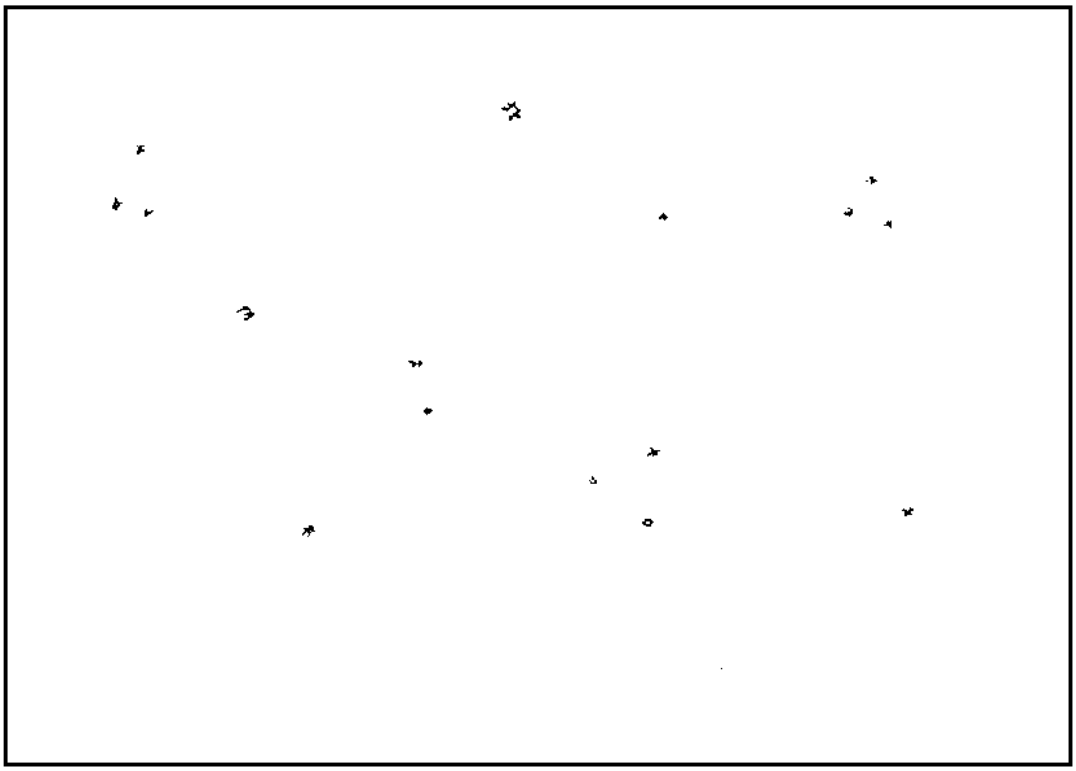

Fig. 5: Grade 1 – magnetic particle testing

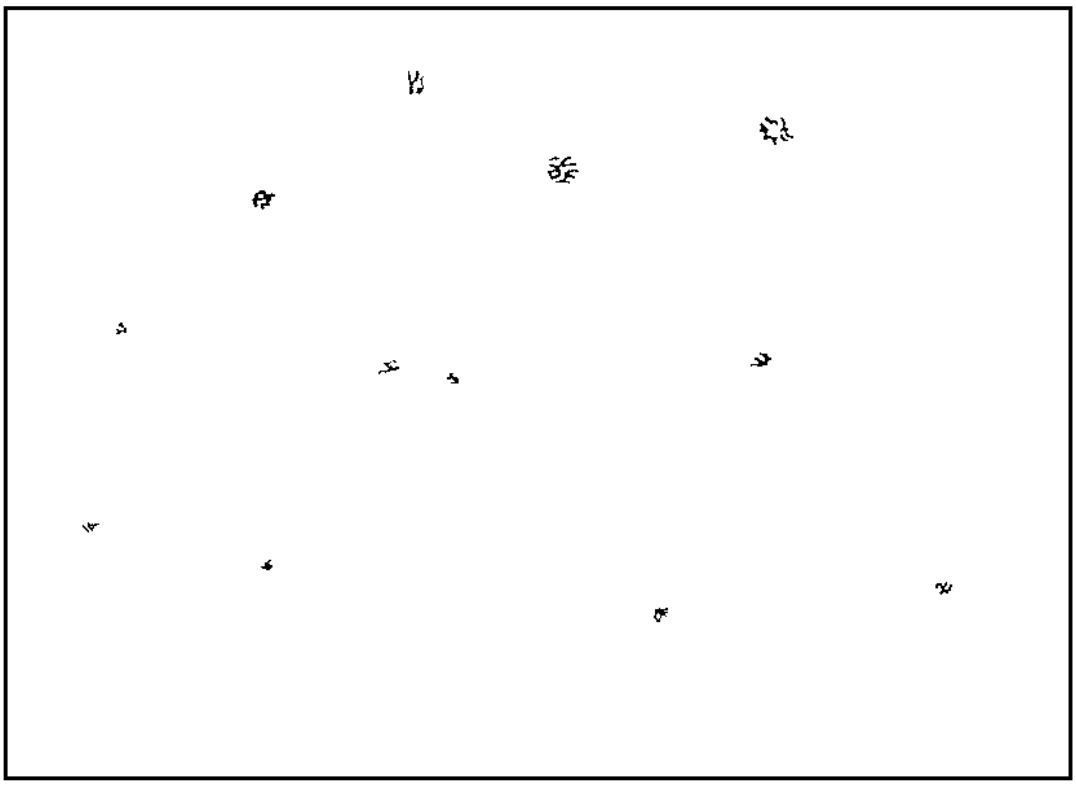

Fig. 6: Grade 2 – magnetic particle testing

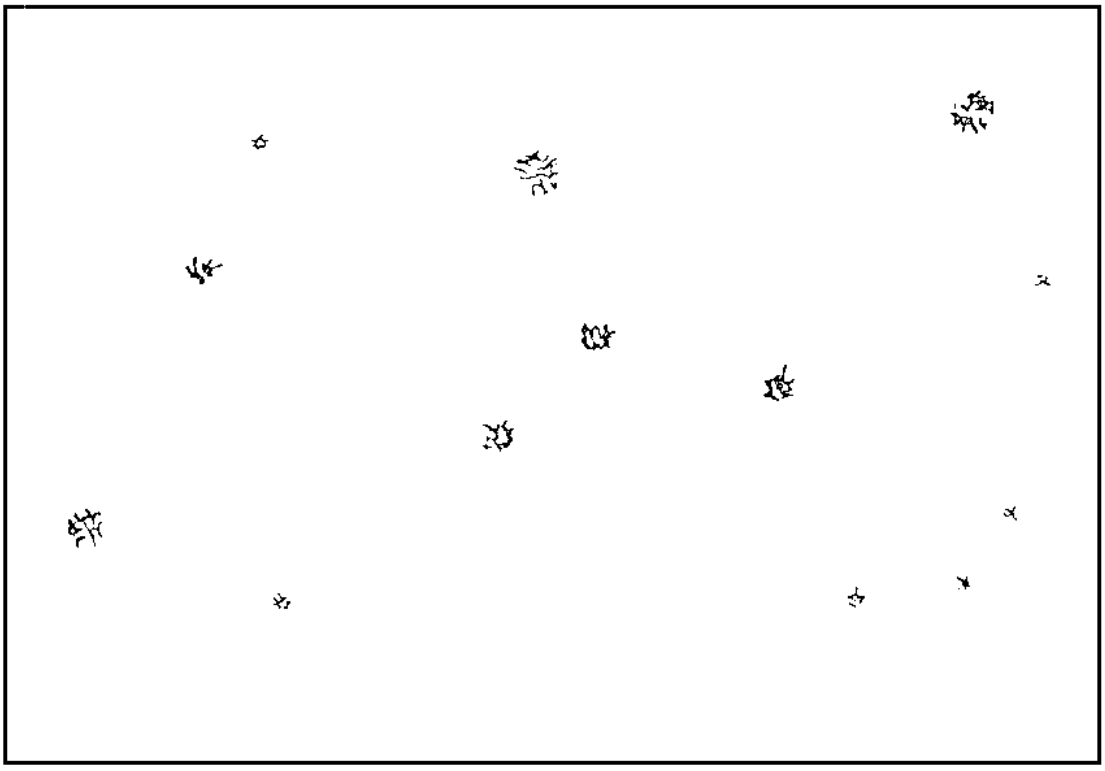

Fig. 7: Grade 3 – magnetic particle testing

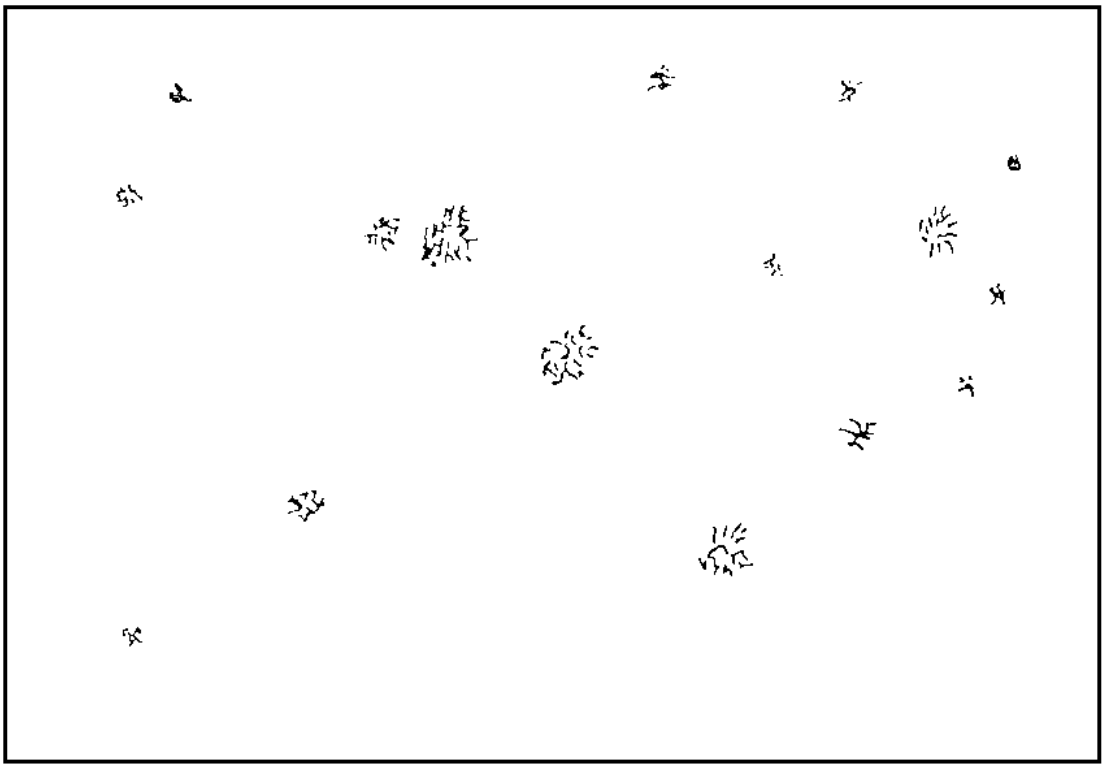

Fig. 8: Grade 4 – magnetic particle testing

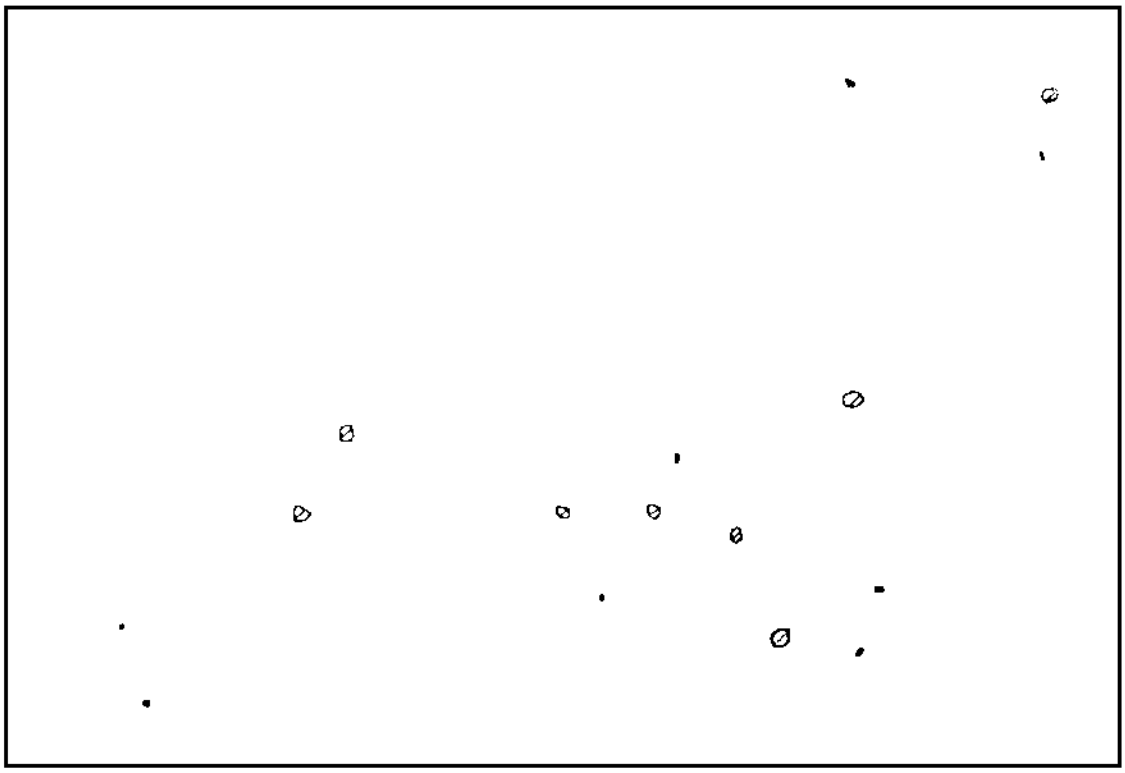

Fig. 9: Grade 1 – dye penetration test

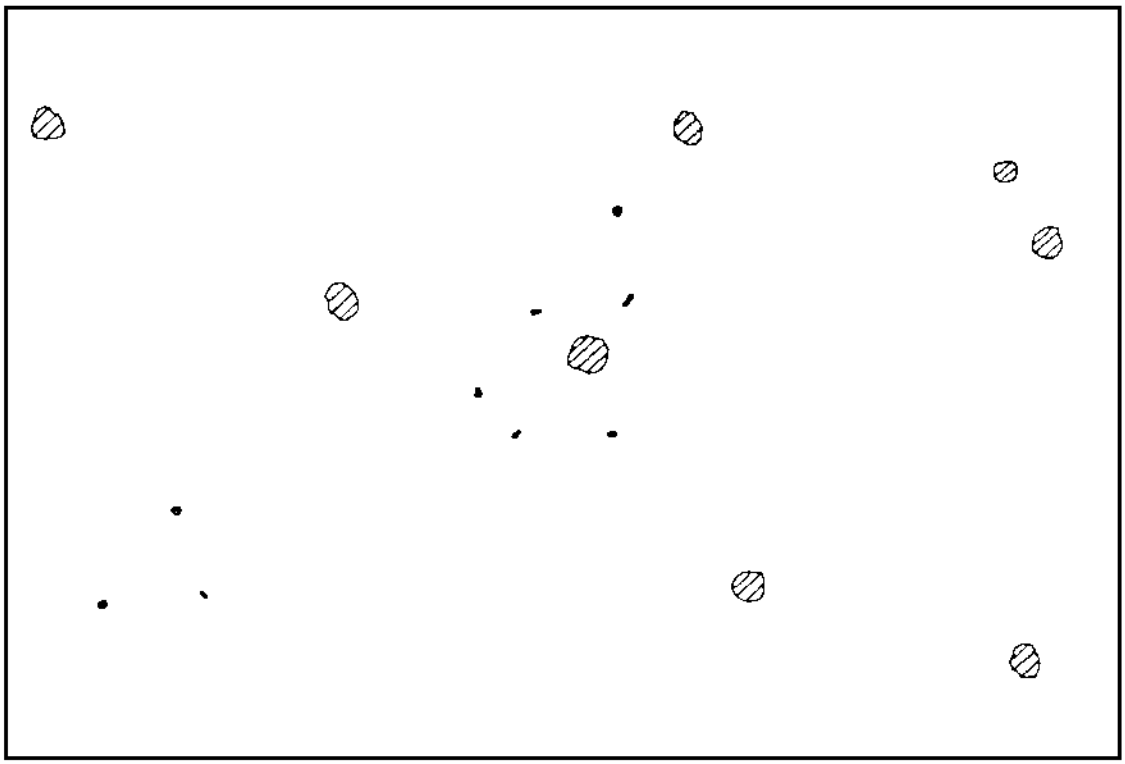

Fig. 10: Grade 2 – dye penetration test

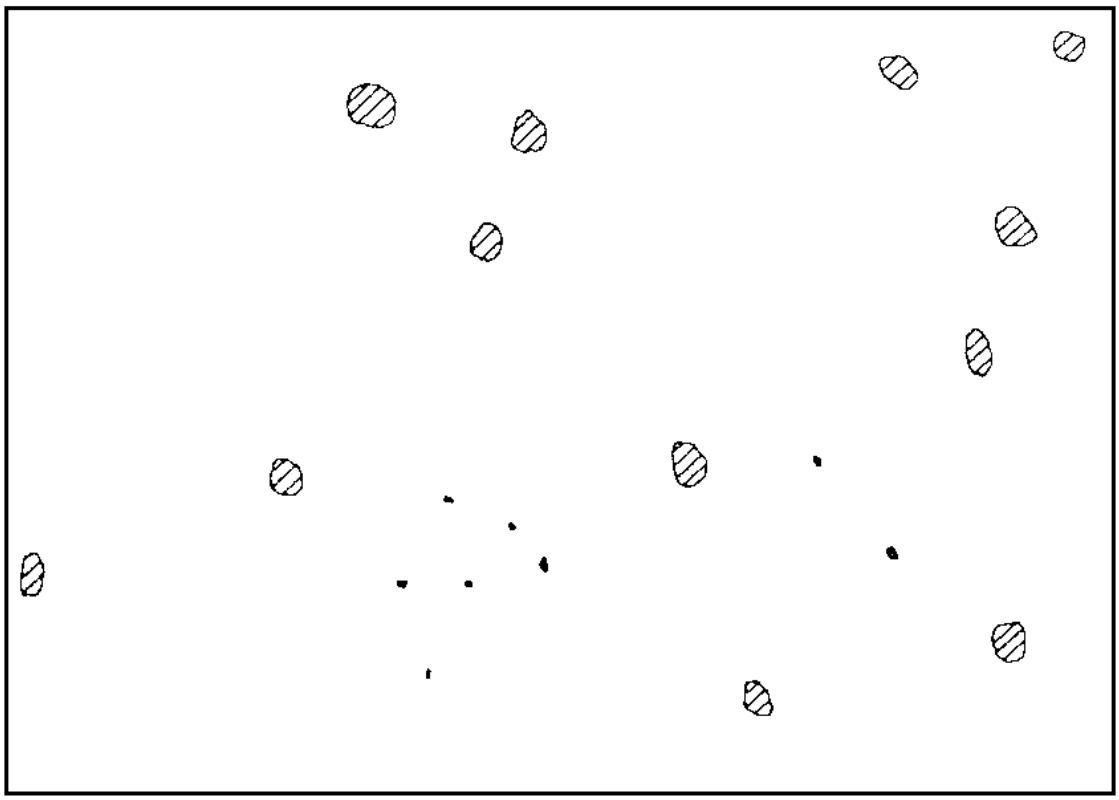

Fig. 11: Grade 3 – dye penetration test

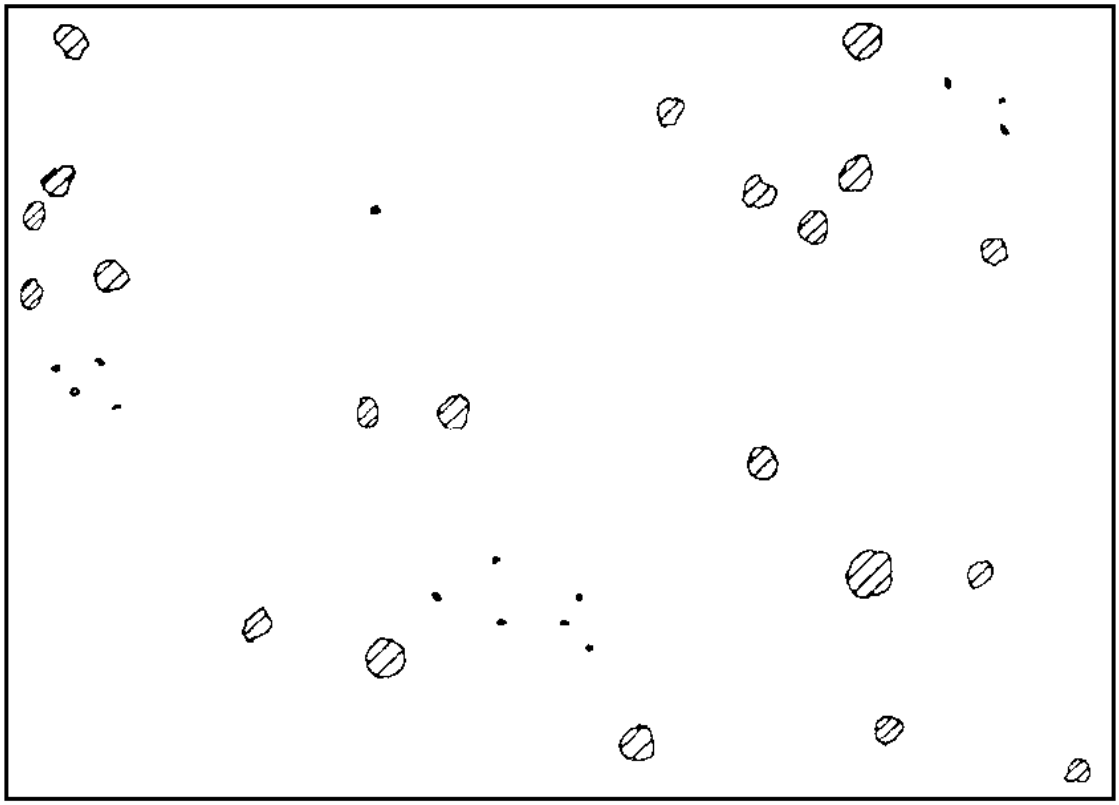

Fig. 12: Grade 4 – dye penetration test

9.0 Revision service

The department VTB Kit construction deisgn/standard documentation is responsible for the revision service of this specification.

10.0 Further valid documents

ASTM E446:	Reference Radiographs for Steel Castings up to 2 in. (51 mm) Thickness
DIN 1690-1:	Technische Lieferbedingungen für Gußstücke aus metallischen Werkstoffen; Teil 1: Allgemeine Lieferbedingungen; August 1981
DIN 1690-2:	Technische Lieferbedingungen für Gußstücke aus metallischen Werkstoffen;Teil 2: Stahlguß; Einteilung nach Gütestufen aufgrund zerstörungsfreier Prüfungen; Ausgabe Juni 1985
DIN 1693-1:	Gußeisen mit Kugelgraphit:: Werkstoffsorten; unlegiert und niedriglegiert; Ausgabe Oktober 1973
DIN 8573-1:	Schweißzusätze zum Schweißen unlegierter und niedriglegierter Gußeisenwerkstoffe; Teil 1: Bezeichnungen; Technische Lieferbedingungen; Ausgabe Jan. 1983
DIN EN 444:	Grundlagen für die Durchstrahlungsprüfung von metallischen Werkstoffen mit Röntgen- und Gammastrahlen; Ausgabe April 1994
DIN EN 473:	Qualifizierung und Zertifizierung von Personal der zerstörungsfreien Prüfung; Allgemeine Grundlagen; Ausgabe März 2001
DIN EN 1563:	Gießereiwesen - Gußeisen mit Kugelgraphit; Ausgabe Feb. 2003
DIN EN 10002-1:	Metallische Werkstoffe - Zugversuch - Teil 1: Prüfverfahren bei Raumtemperatur; Ausgabe: Dez. 2001
DIN EN 10204:	Metallische Erzeugnisse – Arten von Prüfbescheinigungen; Ausgabe Januar 2005
DIN EN 12681:	Durchstrahlungsprüfung; Ausgabe Juni 2003
DIN EN 13068-3:	Zerstörungsfreie Prüfung - Radioskopische Prüfung - Teil 3: Allgemeine Grundlagen für die radioskopische Prüfung von metallischen Werkstoffen mit Röntgen- und Gammastrahlen; Ausgabe: Dez. 2001
DIN EN ISO 6506-1:	Metallische Werkstoffe – Härteprüfung nach Brinell; Teil 1: Prüfverfahren; Ausgabe: Okt. 1999
DIN ISO 8062:	Gußstücke: System für Maßtoleranzen und Bearbeitungszugaben; Ausgabe August 1998
SEP 1922:	Ultraschallprüfung von Gußstücken aus ferritischem Stahl; Ausgabe Juli 1985
SEP 1935:	Oberflächenrißprüfung von Gußstücken aus Stahl: Magnetpulverprüfung; Ausgabe Juni 1982
QP 917:	Oberflächenrißprüfung nach dem Magnetpulververfahren (MT-Prüfung) mit 4-Pol-Gleichstromimpulstechnik