UDC 669.131.7

October 1973

Cast Iron with Nodular Graphite
Unalloyed and Low Alloy Grades

DIN 1693 Part 1

Gußeisen mit Kugelgraphit; Werkstoffsorten, unlegiert und niedriglegiert

Dimensions in mm

For connection with ISO Recommendation ISO/R 1083 see Explanations. This Standard provides the basis for the quality specifications and test provisions of the Verband Güteschutz Gußeisen mit Kugelgraphit e.V. (Quality Protection Association for Cast Iron with Nodular Graphite), Düsseldorf, Sohnstraße 70 and for the DIN test and control symbol of the Deutsche Gesellschaft für Warenkennzeichnung GmbH (DGWK) (German Society for the Marking of Goods), Burggrafenstrasse 4-10, 1000 Berlin 30, see Explanations.

1. Definition

Cast iron with nodular graphite (GGG) is an iron-carbon casting material having the carbon component present as graphite which exists almost exclusively in a largely nodular form.

2. Grade classification

The grade classification (see Table 1 and Table 2) is based on tensile strength.
The characteristics for which minimum values are specified for specimens taken from separately cast test pieces (see Section 7) are, for the normal grades, apart from tensile strength, the 0.2 % proof stress and elongation, and, additionally the impact value for grades for which this is guaranteed.
The choice of grade is the concern of the purchaser. Its suitability for the intended casting from the viewpoint of casting practice shall be examined by the casting manufacturer. For castings with special properties or with guaranteed values[1]) going beyond those of Table 1 and Table 2, Sections 4, 5.1, 5.2, 6 and 8 shall be observed.

Table 1. Standard grades

Grade		Guaranteed properties determined from separately cast test pieces[3]) [4])			Reference data
Symbol	Material number	Tensile strength σ_B N/mm² min.	0,2 % proof stress[5]) $\sigma_{0,2}$ N/mm² min.	Elongation δ_5 % min.	Structure
GGG-40[2])	0.7040	400	250	15	predominantly ferritic
GGG-50	0.7050	500	320	7	ferritic/pearlitic
GGG-60	0.7060	600	380	3	pearlitic/ferritic
GGG-70	0.7070	700	440	2	predominantly pearlitic
GGG-80	0.7080	800	500	2	pearlitic

[1]) A standard dealing with guaranteed characteristic values of specimens taken from integrally cast test pieces or from the casting itself is in course of preparation.

[2]) The GGG-40 grade resulting from the combining of grades GGG-38 and GGG-42 of DIN 1693, Issue of September 1961, is interchangeable with those of the old issue of DIN 1693. The GGG-40 grade is supplied instead of the previously standardized grades GGG-38 and GGG-42.

[3]) See also Section 5.1; for section thicknesses >50 mm and compact castings in particular, agreement between manufacturer and user is urged; see also Footnote 1.

[4]) A Supplementary Sheet with a detailed exposition of the properties of the material is in course of preparation.

[5]) Instead of the 0.2 % proof stress it is permissible in the case of the ferritic grades to quote the yield point obtained from the testing machine diagram, due regard being paid to the more circumscribed test conditions - compared with DIN 50145 (new issue at present circulating as draft) - as mentioned in the Explanations.

Continued on pages 2 to 4
Explanations on pages 4 and 5

Table 2. Grades with guaranteed impact values

Grade		Guaranteed properties determined from separately cast test pieces[3) 4)]				
		Tensile strength σ_B	0.2 % proof stress[2)] $\sigma_{0.2}$	Elongation δ_5	Impact value (DVM specimens) A_V in J min.	
Symbol	Material number	N/mm^2 min.	N/mm^2 min.	% min.	Mean[6)] from 3 specimens	Individual value[6)]
GGG-35.3	0.7033	350	220	22	14 at −40 °C	11 at −40 °C
GGG-40.3	0.7043	400	250	18	14 at −20 °C	11 at −20 °C

3. Symbols

In orders and on drawings the symbols or material numbers according to Table 1 and Table 2 are to be used, e.g. GGG-60.

4. Manufacturing method

Unless agreed to the contrary, the choice of manufacturing method and chemical composition of the material is left to the casting manufacturer.

5. Requirements and service properties

5.1. Strength properties

Table 1 and Table 2 define the mechanical properties obtained from specimens taken from separately cast test pieces. Differing requirements, e.g. mechanical properties at specific locations on the casting - test pieces to be cast on or removed from the casting[1)] - or any additional requirements are to be agreed.

5.2. Physical and technological properties

Reference data on physical and technological properties, which are to be agreed as necessary, can be taken from a Supplementary Sheet in course of preparation. Weight calculations shall be based on a density of approx. 7.2 kg/dm^3. Dimensional changes occurring in the as cast condition after cooling as a result of shrinkage amount to 0 to 2 %, being mainly concentrated in the range from 0 to 0.8 %, according to crystalline structure, shape and casting method.

6. Heat-treatment

Castings made of cast iron with nodular graphite are supplied in the as cast condition or heat-treated. Castings made of GGG-35.3 must be annealed to give a ferritic condition. Heat-treatment to relieve casting stresses shall not result in any change of structure[7)].

7. Sampling

The general principles of DIN 1605 Part 1 "Testing of materials, mechanical testing of metals; general and acceptance" apply, as appropriate, also to the sampling and testing of cast iron with nodular graphite. If the customer does not specify the shape and size of the test pieces, the decision on this will be taken by the casting manufacturer.

Separately cast test pieces shall be used for verifying the mechanical properties guaranteed in Table 1 and Table 2 for cast iron with nodular graphite.

For 1) 3) 4) and 5) see page 1

6) At room temperature the impact value as the mean for a set of 3 specimens is not less than 19 J for GGG-35.3 and not less than 16 J for GGG-40.3. The individual values are as follows: not less than 17 J for GGG-35.3 and not less than 14 J for GGG-40.3.

7) See VDG Data Sheet N1 "(Relief of residual stresses in castings made of cast iron with nodular graphite)"; obtainable through the library of the Verein Deutscher Gießereifachleute (German Foundrymen's Association), Sohnstrasse 70, 4000 Düsseldorf 1.

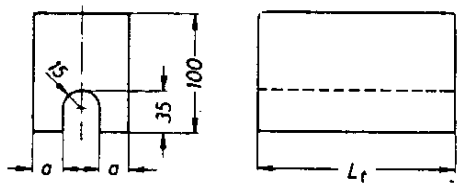

Figure 1. U test piece

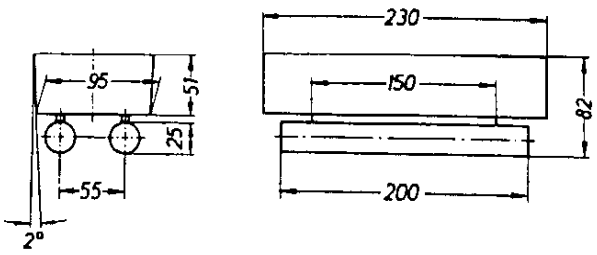

Figure 2. Simplified U test piece (Lynchburg-specimen).

These U test pieces are for making tensile specimens B 14 × 70 DIN 50125

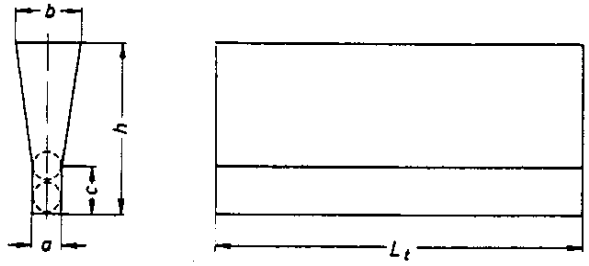

Figure 3. Y test piece

Table 3. Dimensions of U test piece and of tensile test specimens taken from it

No.	a	Overall length L_t Minimum	Test bar Tensile test specimen according to DIN 50125
U 1	25	125	B 14 x 70
U 2	30		

Table 4. Dimensions of the Y test piece and of tensile test specimens taken from it

No.	Test piece				Overall length L_t Minimum	Test bar Tensile test specimen acc. to DIN 50125
	a	b	c	h		
Y 1	10	40	20	135	60	B 6 x 30
Y 2	25	55	40	140	125	B 14 x 70
Y 3	50	100	50	150		
Y 4	75	125	65	175		

In general, U test pieces according to Figure 1, simplified U test pieces (Lynchburg specimens) according to Figure 2 od Y test pieces according to Figure 3 are used. The castings and associated test pieces are to be poured from the same ladle in direct succession as far as possible. For this purpose sand moulds shall normally be used. The thickness "a" of the U and Y type test pieces should be matched as closely as possible to the ruling section thickness of the casting. Other test piece shapes may be agreed.

When the castings are heat-treated the associated, separately cast test pieces must be jointly heat-treated with them. Integrally cast test pieces shall not be cut off until after heat-treatment.

8. Testing of material

When verification of the guaranteed values according to Table 1 and Table 2 or of values in respect of other properties is required, and when other testings (e.g. testing of chemical composition) are specified, agreement to this effect shall be reached. For assessment of the graphite formation the VDG Data Sheet P 441[8]), August 1962 "Code for identifying graphite formation" may be used.

8.1. Tensile test

The values generally determined are tensile strength, 0.2 % proof stress and elongation, use being made of the test bars indicated in Tables 3 and 4.

The testing is covered by:

DIN 50125 Testing of metallic materials; tensile test specimens, directions for their preparation

DIN 50145 Testing of metallic materials; tensile test (new issue at present circulating as draft)

[8]) Obtainable through the library of the Verein Deutscher Gießereifachleute, Sohnstrasse 70, 4000 Düsseldorf 1

8.2. Notched bar impact bending test

The notched bar impact bending test shall be performed according to DIN 50115 "Testing of steel and cast steel; notched bar impact bending test" on 3 specimens taken from test pieces according to Section 7.

8.3. Number of specimens and nominal dimensions of specimens

The number of specimens and their nominal dimensions according to DIN 50125 shall be agreed. In the absence of any agreement the manufacturer shall decide.

8.4. Retestings

If, in the first testing, the specimens taken in agreed number from the test piece fail to meet the requirements, substitute specimens shall be taken from the test piece and tested. If these substitute specimens also fail to meet the requirements, or if no substitute specimens can be taken from the test piece, an agreed number of specimens shall be taken from a second test piece or from a casting from the same batch of metal and tested. If these specimens also fail, the associated castings may be rejected (see also DIN 1605 Part 1).

In the case of spot tests on runs of castings, specimens which have failed through defects of material may be replaced - up to an agreed percentage of the sampling quantity - by other specimens taken from the same batch.

9. Certificates concerning testings and acceptance

Certificates regarding testings are to be agreed in the form of statements of compliance with the order, works reports or test certificates according to DIN 50049 "Certificates concerning tests of materials". The type of certificate and the nature and extent of testing must be specified at the time of ordering.

Explanations

The first issue of DIN 1693 was prepared in the years from 1955 to 1959 and it appeared in September 1961. In the meantime both the manufacture and the applications of the material have undergone considerable further development making revision of the Standard necessary. The classification of grades of the unalloyed and low alloy material has been modified as follows to bring it into line with the present state of the art as regards manufacture and use.

The GGG-45 grade, which is listed in the September 1961 Issue of DIN 1693 with the low elongation of 5 % has proved to be of no significance and has been deleted.

The ferritic grades GGG-38 and GGG-42, which were formerly segregated because they were based on different manufacturing technologies, have been combined to form a single grade GGG-40. The two ferritic/pearlitic grades GGG-50 and GGG-60 have been retained although, because of differences in the proportions of ferrite and pearlite in the structure, the first-mentioned grade exhibits a comparatively wide scatter in regard to its mechanical properties in the as cast condition, depending on section thickness casting shape.

The range of high tensile strength grades has been enlarged by inclusion of the GGG-80 grade with a purely pearlitic structure in the non-heat-treated condition. ISO/TC 25 "Cast iron" is also concerned with following up this development. Corresponding proposals are under discussion.

The grades GGG-50, GGG-60 and GGG-70 are approximately in agreement with ISO Recommendation ISO/R 1083. Although the GGG-38 and GGG-42 grades are still contained in ISO/R 1083, their interchangeability with the new grade GGG-40 according to DIN 1693 Part 1 is assured, so that agreement between ISO and DIN exists here also.

In GINA work has been proceeding for some time on the preparation of a DIN standard giving general technical conditions of delivery for castings and it is intended that this shall contain all the general conditions relating to castings. This development has been taken into account and DIN 1693 divided into Part 1 (grades of material) and Part 14 (castings).

With the adoption of this arrangement the work on standards for cast iron with nodular graphite is also in harmony with ISO/R 1083, since this only specifies grades of material. It is proposed to withdraw DIN 1693 Part 14 as soon as the DIN standard dealing with general technical conditions of delivery for castings appears.

Since the mechanical properties of ductile cast iron as a material for centrifugally cast pressure pipes are to be determined on test bars removed from the cast pipe, and not on separately or integrally cast specimens, this grade has not been covered by DIN 1693 Part 1, but instead is dealt with in DIN 28600 "Pressure pipes and fittings of ductile cast iron for gas and water mains".

The increasing importance of the ferritic grades with guaranteed impact values has led to the inclusion in this Standard of the GGG-35.3 and GGG-40.3 grades (Table 2). Manufacture of the GGG-35.3 grade in particular normally calls for the use of special grades of pig iron with the lowest possible content of carbon-stabilizing elements. With regard to content of accompanying elements, the aim is to achieve levels of Si $\leqq$ 2.1 %, Mn $\leqq$ 0.1 % and P $\leqq$ 0.05 %. The guaranteed impact value can usually only be secured by way of heat-treatment.

For denoting the ductility of the material the absolute level of the impact value is of less significance than the level of the transition temperature from the region of ductile fracture to the region of brittle fracture. Impact values at minus temperatures are quoted primarily with a view to allow the level of the transition temperature to be estimated.

Since a natural pronounced yield point occurs only with the ferritic grade, and since an increasing proportion of pearlite in the structure of the higher strength grades precludes its determination from the testing machine diagram with an adequate degree of confidence, the 0.2 % proof stress has been introduced as standard for all grades. With the ferritic grade there is the option of substituting the easier yield point measurement subject to the error limit of the 0.2 % proof stress determination, provided that the following conditions circumscribing the method compared with DIN 50145 (new issue at present circulating as draft) are observed:

- yield point is measured on test bar without preloading
- rate of loading when using method applying load continuously between 0.5 times yield point and 1.2 times yield point to be 2 N/(mm^2 s) max., and beyond this point until fracture occure at 10 N/(mm^2 s) max.
- when using the method with stepwise unloading, a hold of 0.5 min./load level to be observed.

Mathematical-statistical studies of the relationship between the mechanical properties have confirmed the empirical finding that the guaranteed yield point values in DIN 1693, Issue of September 1961, are only achievable by sacrificing toughness and establishing a tensile strength considerably above the minimum value. In conformity with the natural behaviour of the material, therefore, the minimum values of 0.2 % proof stress habe been reduced by an insignificant amount whilst retaining the interchangeability of grades.

In general, the mechanical properties of metal castings are dependent on section thickness, i.e. they are influenced to a greater or lesser extent by the rate of cooling which in turn depends largely on the geometrical proportions of the casting shape. Moreover, the critical rate of cooling is also influenced by the chemical composition of the molten metal in so far as graphitizing elements such as silicon tend to slow the cooling rate, whereas carbide-stabilizing elements tend to increase it.

With separately cast test pieces the cooling rate depends solely on the section thickness and in this case there are connections between the chemical composition and the cooling rate on the one hand and the mechanical properties on the other.

To identify the values associated with particular properties of cast iron with nodular graphite, therefore, the thicknesses of the U and Y type test pieces must be matched as closely as possible to the ruling thicknesses of the casting. By "ruling thickness" is understood that thickness of section of a casting which is stated by the customer as being the one principally stressed.

After heat-treatment, however, the mechanical properties of castings made of cast iron with nodular graphite are largely independent of differences in section thickness up to a thickness of about 50 mm. The material symbol GGG, formed from the initial letters of the terms "gegossen" (cast), "Gußeisen" (cast iron) and "globular" (nodular) has been specified in the light of the directions in DIN 17006 Part 4. There is a whole range of other terms for the material in the literature and daily usage, e.g. "spheroidal graphite cast iron", "ductile cast iron", "nodular iron", "spherolitic cast iron", "spheroidal cast iron" etc., which certainly do not denote special grades, but instead designate the same material group. In international usage the term "ductile cast iron" normally denotes cast iron with nodular graphite for making centrifugally cast pipes. The term "spheroidal cast iron" ("Sphäroguß") is a protected trade name.

The Verband Güteschutz Gußeisen mit Kugelgraphit e.V. can grant a quality symbol for the use in this connection. The quality symbol consists of a rounded capital letter "G" with the legend "Quality symbol - RAL" "Cast iron with nodular graphite" enclosing the Arabic numeral "4". The symbol is read as "4 G cast iron" (meaning quality protection (Güteschutz), cast iron (Gußeisen), cast (gegossen) and nodular (globular); the last "3 Gs" stand for the symbol "GGG" of DIN 1693 Part 1). On castings the quality symbol is used without legend. The object of the Association is to guarantee to purchasers of castings that the products marked with this quality symbol comply with the quality specifications and DIN standards in regard to the material.

Provided that the material and the casting satisfy the requirements of DIN 1693 and any special agreements reached, and provided also that this is verified by external and internal quality control, the castings concerned may be marked with the DIN test and control symbol (see Section 10 of DIN 1693 Part 14, Issue of October 1973).

As supplementary information on the range of applications of cast iron with nodular graphite, particulars of mechanical and physical properties are to be given in a Supplementary Sheet in course of preparation; the values given will be re-examined, supplemented and if necessary corrected from time to time in the light of further test results as these become available.