TECHNICAL REPORT

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Cast irons —

Part 1: Materials and properties for design

Fontes —

Partie 1: Matériaux et propriétés pour la conception

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Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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

ISO/TR 10809-1 was prepared by Technical Committee ISO/TC 25, *Cast irons and pig irons*.

ISO/TR 10809 consists of the following parts, under the general title *Cast irons*:

— *Part 1: Materials and properties for design*

— *Part 2: Welding*

Introduction

Worldwide cast iron production is in excess of 60 000 000 tonnes per annum. It is manufactured in a wide range of alloys and has applications in all sectors of world production and manufacture. Its use spans many industries, including automotive, oil, mining, etc.

The technology of cast irons is not widely taught or understood around the globe. This part of ISO/TR 10809 is intended to provide information about cast iron materials so that users and designers are better able to understand cast iron as a design material in its own right and correctly specify cast iron for suitable applications.

Cast irons —

Part 1: Materials and properties for design

1 Scope

The purpose of this part of ISO/TR 10809 is to assist the designer and engineer in understanding the family of cast iron materials and to utilize them with a more complete knowledge of their potential, among the wide range of other engineering materials and fabrication methods now available. A considerable amount of the data provided are metallurgical, but it is usually the metallurgical aspects of the cast irons that create misunderstandings when these materials are specified. This is because metallurgy is not one of the scientific disciplines taught to engineering students. Thus, such students often have a lack of knowledge regarding the fundamentals underpinning the material properties of cast irons. This part of ISO/TR 10809 suggests what can be achieved, what cannot be achieved and why, if and when cast irons are specified. It is not designed to be a textbook of metallurgy. It is intended to help people to choose the correct material for the right reasons and also to help to obviate the specification or expectation of unrealistic additional requirements, which are unlikely to be met and which can be detrimental to the intended application.

2 Why use cast irons as an engineering material?

The first questions that the designer and engineer will probably ask are:

— Can I use a cast iron?

— Should I use a cast iron?

— Which type and grade are applicable?

— What are the advantages?

The following sub-clauses give general information on the cast iron types currently standardized in International Standards.

2.1 Why use grey cast iron?

Grey cast iron provides the largest worldwide tonnage of all cast irons produced, mainly because of its wide range of uses within general engineering, its ease of machining, and its cost advantage. The material has the highest thermal conductivity among the range of cast irons, which is why it is used in applications where this property is important. Typical examples are automotive parts such as brake drums, discs, clutch plates, and cylinder blocks and heads. Grey cast iron lacks ductility, but for parts where requirements for ductility and impact strength are low or unimportant, a huge range of applications can be found. These include, for example, the manufacture of machine tools such as lathe beds, where slideways can easily be surface hardened and the “self-lubricating” properties of the material are advantageous. This highly versatile material should be considered for a potential application unless there are ductility issues, or the design requires ultimate strengths in excess of 300 N/mm^2.

2.2 Why use spheroidal graphite cast iron?

Spheroidal graphite cast iron has the benefit of ductility as well as strength, which is why it is often considered to be a material superior to grey cast iron. Its main disadvantage in this respect is that it does not have the thermal conductivity provided by grey cast iron and is not normally used where this property is important. A large number of grades of spheroidal graphite cast iron are available to the designer, based on the fact that as tensile strength increases, ductility decreases. Thus the designer has the opportunity to utilize different combinations of tensile/ductility properties, depending upon the application. The lower-strength grades with high ductility also have good impact properties and, for this reason, spheroidal graphite cast iron is increasingly being used to produce cast parts to replace steel fabrications. Large tonnages of spheroidal graphite cast iron are used to produce centrifugally cast pipe for water and sometimes gas transportation, but the majority is used in general engineering applications where its considerably higher tensile properties compared with grey cast iron are of advantage.

2.3 Why use compacted cast iron?

Compacted graphite cast irons have applications as components which require additional strength, stiffness, and ductility over and above that offered by grey cast iron. Typical applications include cylinder blocks and heads, brake drums and brake discs, pump housings, hydraulic components, and cylinder liners. The benefits of the material are that it provides higher tensile strengths and some ductility in conjunction with thermal conductivity properties similar to those found in grey cast irons.

2.4 Why use malleable cast iron?

There are two different types of malleable cast iron, blackheart and whiteheart. The blackheart grades have properties similar to the spheroidal graphite cast irons and the materials have traditionally been considered interchangeable in most general engineering applications. The main advantage of blackheart malleable iron, compared with spheroidal graphite cast iron, is that it is easier to machine, because of the different metal composition. The whiteheart malleable grades are still used to produce traditional thin section castings, particularly fittings such as hinges and locks. Now, however, their uses are more usually confined to the production of thin section castings where the heat treatment process involved can be adjusted to completely decarburize the material. This is of considerable advantage to designers; it allows malleable whiteheart castings to be welded to steels as part of a fabrication process, because the whiteheart material possesses properties that are not dissimilar to the steel to which it is welded.

2.5 Why use ausferritic cast iron?

The austempering heat treatment carried out on a normal spheroidal graphite cast iron enhances its properties to produce a range of grades with exceptionally high tensile strengths. The highest tensile strength grade also has a high hardness that allows it to be used in abrasion-resisting applications, the most common one being as digger teeth on earth-moving equipment. As with all spheroidal graphite cast iron materials, increases in tensile strength and hardness are accompanied by decreases in ductility. This allows for a wide range of properties that can be exploited, provided that their combination is applicable to the component design. Tensile strengths up to 1 400 N/mm^2, hardness greater than 400 HBW, and tensile elongation up to 10 % are possible (although not all three simultaneously in the same grade of material). These mechanical properties also generate a high fatigue strength that is useful in gears and other components for use in a rotating/bending application.

2.6 Why use abrasion-resistant cast iron?

The abrasion-resisting cast irons are a range of hard and tough materials that compete with other alloys such as manganese steel, mainly in the mining and extraction industries, in wear-resistant applications such as slurry pumps and in more generalized applications such as in the operation of shot-cleaning plants. Thus they are rightly considered to be a consumable item where the rate of wear, or operational life, is important in the decision-making process regarding the choice of material. Generally speaking, they tend to be less expensive and easier to manufacture than the abrasion-resisting steels with which they are usually compared. They perform well in a variety of applications and should not be casually dismissed as the material of choice in any application that requires abrasion resistance. The effectiveness of any abrasion-resisting material is highly dependent upon the materials which it is in contact with and the circumstances under which it performs. For example, slight changes in the composition of an ore in an extraction application, and even its water content, can significantly influence the wear rate. The 13 grades of abrasion-resisting irons specified in ISO 21988 offer a wide choice of alloys for matching the material against the intended application.

2.7 Why use austenitic cast iron?

The austenitic cast irons (sometimes called Ni-resists) are a range of materials that provide corrosion resistance, heat resistance or a combination of both. Austenitic cast irons are often compared with stainless steels when a design is being considered. One specific application for which the austenitic cast iron grades are considered is where the component to be produced needs to be non-magnetizable and other properties are of secondary importance. Both flake graphite and spheroidal graphite iron grades are produced: the spheroidal graphite iron grades exhibit superior tensile properties to those of the flake graphite grades. These materials vary widely in their metal composition in order to meet a broad range of applications; in general, the most arduous applications are met by those grades containing the highest nickel content. The 12 grades of austenitic cast iron cover the spectrum of applications where highly alloyed materials are required in order to meet arduous conditions in service.

3 Commentary

Cast irons have particular and peculiar metallurgical and other properties which are unique to the material and which give it specific valuable attributes that make it a useful material in certain applications.

3.1 Recent changes in standardization

ISO/TC 25 is the International Technical Committee responsible for the development of International Standards for cast irons. Since 1998, when it was reactivated after a dormancy of 14 years, ISO/TC 25 has been working through a programme of creation, revision, assessment and publication of cast iron material and related standards. These International Standards include annexes of additional information about material properties, which are not requirements of the standards, but which provide helpful technical and application information to designers and engineers.

The International Standards that have been reviewed, created, published or retained in their current form are shown in Table 1.

Table 1 — International Standards for cast iron materials and microstructure

Scope	Standard number
Grey cast irons	ISO 185
Spheroidal graphite cast irons	ISO 1083
Compacted (vermicular) graphite cast irons	ISO 16112
Malleable cast irons	ISO 5922
Ausferritic spheroidal graphite cast irons	ISO 17804
Abrasion-resistant cast irons	ISO 21988
Austenitic cast irons	ISO 2892
Designation of microstructure of cast irons – visual analysis	ISO 945-1

The seven International Standards for cast iron materials (see Table 1) encompass a huge international tonnage. In 1999, reported world production reached 49,3 million tonnes/annum, and this figure had increased to 61,6 million tonnes/annum by 2006 (the last available statistics). The trend is continuing for cast irons utilized in the manufacture of a wide range of different components ranging in mass from a few grams to more than 100 tonnes.

The International Standards for cast irons detail the properties of seven individual types of cast iron material which together specify 84 different grades. It is recommended that these standards and the associated annexes of supporting information be carefully consulted, in order to allow the most appropriate material to be chosen for the application. Table 2 provides a short résumé of properties that will lead the user to the relevant International Standard. It also compares one cast iron material type with another, but does not compare the cast irons with other materials. For example, if a cast iron with high strength and ductility were required then an examination of ISO 1083 or ISO 17804 would be beneficial. The individual grades within these two International Standards can then be consulted to find the most appropriate one and to determine whether the other, unspecified properties in the annexes are beneficial or detrimental to the application.

Table 2 — General properties for the range of International Standards for cast iron

Property	ISO 185 Grey	ISO 1083 Spheroidal	ISO 16112 Compacted (vermicular)	ISO 5922 Malleable	ISO 17804 Ausferritic spheroidal	ISO 21988 Abrasion-resistant	ISO 2892 Austenitic
Tensile strength	√√	√√√√	√√√	√√√√	√√√√√	0	√√√
Proof strength	√	√√√√	√√	√√√	√√√√√	0	√√√
Elongation	√	√√√√√	√	√√√	√√√	0	√√√
Impact resistance	√	√√√	√	√√√	√√	√√√	√√√
Low-temperature properties	√√	√√√	√√	√√√	√√	√	√√√
Thermal conductivity	√√√√√	√√√	√√√√	√√√	√√√	√	√√√
Thermal expansion	√√	√√	√√	√√	√√	√	√√√√
Abrasion resistance	√√	√√	√√	√	√√√	√√√√√	√√
Corrosion resistance	√√	√√	√√	√√	√√	√√√√√	√√√√√
Heat resistance	√√√	√√	√√	√√	√√	√	√√√√
Machinability	√√√√√	√√√	√√√	√√√	√√	√	√√√
Weldability	√√	√√√	√√	√√√	√	0	√√

0 Not applicable
√ Low
√√ Average
√√√ High
√√√√ Very high
√√√√√ Highest

Ausferritic spheroidal graphite cast irons should only be welded prior to austempering.

NOTE ISO 5922 JMB grades = √√√, JMW grades = √√√√, JMW-S grade = √√√√√.

Table 3 provides data on typical applications (the list is not exhaustive). Table 3 should also help the designer and engineer to select the most appropriate International Standard, and ultimately the choice of the grade within it.

Table 3 — Typical mechanical property ranges and applications for cast irons

ISO 185 **Grey**	**Minimum tensile strength range 100 N/mm^2 to 350 N/mm^2, elongation < 1 %** Wide range of general engineering parts: pumps, valves, compressor bodies, machine tools, cylinder blocks, brake drums and discs, clutch plates, press tools, street furniture.
ISO 1083 **Spheroidal**	**Minimum tensile strength range 350 N/mm^2 to 900 N/mm^2, elongation range 2 % to 22 %** Wide range of general engineering parts requiring higher strength, elongation, and fatigue properties than grey cast iron: crankshafts, valves, pumps, steering knuckles, suspension components, axle boxes.
ISO 16112 **Compacted** **(vermicular)**	**Minimum tensile strength range 300 N/mm^2 to 500 N/mm^2, elongation range 0,5 % to 2 %** Components requiring good thermal conductivity in conjunction with higher strength than grey cast iron: ingot moulds, cylinder blocks, brake drums and discs, cylinder liners, hydraulic parts.
ISO 17804 **Ausferritic**	**Minimum tensile strength range 800 N/mm^2 to 1 400 N/mm^2, elongation range 2 % to 11 %** Castings requiring very high strengths with good elongation, fatigue, and abrasion resistance properties: gears and cams, crankshafts, differentials, digger teeth, wear shoes, track guides.
ISO 5922 **Malleable**	**Minimum tensile strength range 270 N/mm^2 to 800 N/mm^2, elongation range 1 % to 16 %** Wide range of general engineering parts requiring higher strength, elongation, and fatigue resistance with some grades weldable: pipe fittings, suspension components, gear cases, universal joints.
ISO 2892 **Austenitic**	**Minimum tensile strength range 140 N/mm^2 to 440 N/mm^2, elongation range 1 % to 25 %** Parts requiring corrosion and heat resistance, some grades being non-magnetizable: pumps, manifolds, gas turbine housings, turbochargers, refrigeration components, compressors.
ISO 21988 **Abrasion-** **resistant**	**Minimum hardness range 340 HBW to 630 HBW** Castings requiring high abrasion and impact resistance: rock crushers, grinding balls, digger teeth, shot-cleaning wear-plates, pumps and valves carrying abrasive liquids.

There is often a communication difficulty between casting producers and the engineers and designers employed by their customers over the understanding of the cast iron material properties beyond those of the normative requirements of the specific International Standard. This can lead to confusion, a good example of which is the phenomenon of section sensitivity in grey cast irons, where, depending on the section thickness, the mechanical properties in the casting may be either lower or higher than those in separately cast test pieces. Even experienced engineers are sometimes unfamiliar with the properties of the cast irons, leading to either an underestimation of the true potential of the material or unrealistic expectations of it.

The cast irons have a complex metallurgy and a wide range of different material properties or specific property requirements can be obtained through the correct choice of material.

3.2 General metallurgy of the cast irons

The glossary of terms relating to International Standards for cast irons (see Annex A) explains the meaning of the metallurgical terms given below.

The plain carbon steels are iron-carbon alloys where the carbon content dictates the main properties and other elements are generally at too low a level to be of major significance. At 0 % carbon content, the material is soft pure iron, or ferrite. As the carbon content is increased, increasing amounts of pearlite are formed, which is harder and stronger, such that at about 0,9 % carbon content the structure is fully pearlitic. This range of carbon content is where the majority of plain carbon steels exist. Raising the carbon content results in the formation of iron carbide in increasing amounts (sometimes called cementite), which is hard and brittle. Above about 1,7 % carbon content, the material is called white cast iron and comprises a mixture of pearlite and iron carbide.

It is this structure (a mixture of pearlite and iron carbide) that forms the basis of the manufacture of the abrasion-resistant cast irons and malleable cast irons, although refinements to metal composition and the use of heat treatment are required to meet the specified requirements of their respective International Standards. The International Standards for the other cast irons require the majority of the carbon content to be present in the form of graphite, and this is achieved by the addition of silicon, which promotes the formation of graphite instead of carbide. Grey cast irons contain flake (lamellar) graphite, which is the normal graphite form that occurs during solidification. Spheroidal and compacted graphite cast irons are produced by deliberate modification of the solidification mechanism, usually by an addition of magnesium. In the case of the austenitic cast irons, high levels of other elements are also added to produce the required material properties. Ausferritic cast irons are both alloyed and subjected to heat treatment, in order to meet the requirements of the appropriate International Standard. Heat treatments are applied to all of these materials, either as part of the production route, or to enhance properties, or to obtain stress relief in complex components.

Summarizing, therefore, there are seven material types each broadly described as follows.

Grey cast iron — cast iron with a flake graphite form, usually in a pearlitic matrix except for the very lowest grades where ferrite is present. The material does not normally require heat treatment, unless stress relief is applied to ensure dimensional stability.

Spheroidal graphite cast iron — cast iron with the solidification mode modified to produce graphite in spheroids as opposed to flakes. The grades range from those containing fully ferritic to fully pearlitic matrices including a recently developed high silicon grade. Heat treatment is sometimes used to produce the ferritic grades, particularly those requiring high impact values at low temperature. The highest-strength grade can be produced by an oil quench and temper heat treatment. Stress relief can be applied if necessary.

Compacted (vermicular) graphite cast iron — cast iron with the solidification mode modified to produce stubby, or compacted graphite flakes, usually with a small percentage of spheroidal graphite present. The grades range from those containing mainly ferritic to fully pearlitic matrices. The material is not normally heat treated unless stress relief is required.

Malleable cast iron — two types of cast iron called separately blackheart and whiteheart. They are deliberately produced with a low silicon level to produce iron carbide and are then heat treated to break down the carbide and form graphite, as ragged spheroids usually known as temper carbon nodules. The grades range from fully ferritic to fully pearlitic. The material can be oil quenched and tempered to produce the highest grade.

Ausferritic cast iron — spheroidal graphite cast iron deliberately subjected to an austempering heat treatment that enhances material properties, producing an ausferritic matrix containing graphite spheroids. It sometimes requires special alloying to ensure structural uniformity of the matrix in thick sections. It rarely requires further heat treatment following production.

Abrasion-resistant cast iron — cast iron, usually with a martensitic matrix, resulting from heat treatment, that contains complex carbides to provide good abrasion resistance.

Austenitic cast iron — cast iron with an austenitic matrix that is stable down to sub-zero temperatures. It contains grades with either graphite flakes or spheroids, and is highly alloyed and used in special-purpose applications. It can be stress relieved and stabilized for high-temperature applications.

3.3 Section sensitivity and its effects on material properties

Section sensitivity is one of the most important phenomena to be understood with regard to cast iron material properties.

Most engineers expect that the same properties will be obtained in both the castings and the test pieces poured with them. This is largely the case with steels and many other alloys, but is not the case with cast irons, for reasons related to the section sensitivity.

The expression "section sensitivity" is used to explain the relationship between the results from the separately cast test piece used to confirm the tensile properties of cast iron materials and the tensile properties in the casting. These properties usually differ. This is a very important aspect of design with cast iron materials and is related to the effects produced on material structure, resulting from different speeds of solidification in varying casting sections.

In thin section castings the solidification will be rapid, whereas in thick sections solidification will be slow. Thus, depending on the section thickness, there will be differences in the graphite form and size, and also possibly in the matrix. These effects result in differing mechanical properties within the various casting sections. In ISO 185, for grey cast irons, where the effects of section sensitivity are most pronounced, a separately cast test piece of uniform dimensions is used to determine the precise mechanical properties of the material and the properties in the casting can be obtained empirically to ratify design strengths. Much research has been conducted to derive data on the properties in different sections and this research has resulted in the collection of data such as that detailed in ISO 185:2005, Table 1, an extract from which is shown in Table 4.

Table 4 — Extract from Table 1 of ISO 185:2005 relating to section sensitivity

Material designation	Tensile strength (mandatory values in separately cast samples) N/mm² minimum	Relevant wall thickness mm		Tensile strength (anticipated values in castings) N/mm² minimum
		over	up to and including	
ISO 185/JL/150	150	2,5	5	180
		5	10	155
		10	20	130
		20	40	110
		40	80	95
		80	150	80
		150	300	—
ISO 185/JL/250	250	5	10	250
		10	20	225
		20	40	195
		40	80	170
		80	150	155
		150	300	—
ISO 185/JL/350	350	10	20	315
		20	40	280
		40	80	250
		80	150	225
		150	300	—

Section sensitivity of whiteheart and weldable blackheart malleable cast irons is affected by the decarburization process (see 6.3 and 6.7).

Section sensitivity is less pronounced in the compacted graphite cast irons, even less pronounced in the range of cast irons containing graphite spheroids, and least pronounced in the grades of blackheart malleable cast irons and the abrasion-resistant cast irons. In the International Standards for compacted graphite cast irons, spheroidal graphite cast irons, and ausferritic spheroidal graphite cast irons, separately cast test pieces are also required, but with the option of utilizing a cast-on test piece. This arrangement more closely replicates the properties of the wall thickness to which it is attached, provided that the correct test piece is used. Tables in the various International Standards for cast iron dictate the required mechanical properties, depending upon the relevant wall thickness.

The terminology “relevant wall thickness” was deliberately chosen for inclusion in the International Standards concerned, so that the manufacturer and the producer can agree on the section of the casting where the cast-on sample, from which the test piece is taken, is placed. The relevant wall thickness would normally be construed to be the wall thickness that is the most important for the purposes of design; this is often the most highly stressed area. Where precision is required in the determination of material properties, the International Standards allow for the option of cutting samples from the casting at an agreed location. Obviously this destroys the casting and is invariably carried out according to agreed routine sampling plans, or as initial validation during first-off sampling.

3.4 Understanding hardness

National standards do not always specify hardness, although informative data are sometimes provided for the various grades. Customers, on the other hand, commonly specify hardness ranges for the materials that are required. ISO 185 contains special hardness-only grades which are normative and which do not require tensile strength validation. Therefore, it is now possible to specify castings according to a mandatory hardness grade, but they might also be produced according to a tensile strength grade where, in addition, the customer demands a hardness range to be met.

It is important to make clear that the section-sensitivity phenomenon affects hardness. For example, the graphite in graphitic materials is coarser in thick sections than in thin sections and the matrix may also be affected by the different cooling rates; thus thick sections will be softer than thin sections. An illustration is given in ISO 185:2005, Table 2, which takes this situation into account by specifying the hardness range of 40 mm to 80 mm sections and providing anticipated values in other, thinner sections. Additional information regarding the section sensitivity in relation to hardness is given in ISO 185:2005, Annex C.

An important point to note for all cast irons is that they are metallic materials with graphite, or in the case of the abrasion-resistant cast iron grades, carbides, in a steel-like matrix. For this reason it is inappropriate to use a hardness tester with an indenter smaller than 5 mm in diameter. The usually specified test apparatus is a Brinell hardness-testing machine fitted with a 10 mm ball and 3 000 kg load (10/3 000) as this provides the most accurate reading. For thinner sections, a 5 mm ball and 750 kg load (5/750) are applicable. Rockwell, Vickers and other hardness-testing apparatus with small indenters and light loads give variable results and usually cause confusion.

When hardness is specified, the hardness range needs to be realistic to take into account normal variations in the material. A typical hardness variation for a grey cast iron would be about 50 HBW. For example, a JL/250 grey cast iron material would typically have a hardness range of 187 HBW to 241 HBW. For a spheroidal graphite cast iron, the hardness variation will be between 10 HBW and 70 HBW depending upon the grade and matrix. For abrasion-resistant cast iron materials, the situation is somewhat different because the hardness minimum is specified. It must be appreciated, however, that there will still be a hardness variation between thin and thick sections, even though the minimum specified value is met.

The most important point of all is that, if castings are specified to be hardness tested, then the hardness range and the locations of the hardness test on the castings should be agreed between the manufacturer and purchaser.

3.5 Heat treatment

Some of the materials specified in the International Standards for cast irons require special heat treatment operations as part of the production process; the manufacture of malleable and ausferritic irons require heat treatment according to 6.3 and 7.2, respectively. Other cast iron types can require heat treatment processes for remedial reasons, as is allowed in the relevant International Standards, or to help achieve the requirements of the grade. Examples of common heat treatments are given in Table 5.

Table 5 — Examples of common heat treatments applied to cast irons

Process	Temperature °C	Time	Subsequent process
Annealing	900	1 h + 1 h per 25 mm of casting section[a]	Slow furnace cooling to below 200 °C
Normalizing	900	1 h + 1 h per 25 mm of casting section[a]	Air quench outside the furnace, sometimes using cooling fans for larger castings
Oil quench and temper	900	1 h + 1 h per 25 mm of casting section[a]	Quench in oil and then temper at the temperature for the desired hardness, usually ~300 °C
Stress relief	550	1 h + 1 h per 25 mm of casting section[a]	Slow furnace cool to below 200 °C

[a] Time at temperature depends on the size of the castings and their packing density. The times are for individual castings or small numbers in a batch. Where large numbers of small castings are packed together in a furnace, it is essential that the complete batch is raised to the desired temperature before process commences.

3.6 Welding

There is a common misconception that cast irons cannot be welded and, in many internal company specifications, or in requirements additional to those demanded in International Standards and other standards, it is specifically disallowed as a result of the belief that a weld will act as a stress-raiser, promoting failure of the part.

It has been accepted that some cast irons do not respond well to welding, whilst others need special considerations regarding acceptable techniques. With the exception of the weldable cast irons, manual arc welding using steel rods typically employed for steel welding purposes should never be used, as the weldment will have no long-term integrity and may cause catastrophic failure of the casting. Engineers and designers would be wrong, however, to dismiss a welding operation as out of hand without consideration of the reliable possibilities. These fall into two categories, namely: finishing welding to remove unwanted defects and joint welding of cast irons to other materials as part of a fabrication. As with all repair or finishing welding, the question arises as to whether welding is cost effective or whether it is more sensible to produce a replacement casting. This is particularly the case in the manufacture of large numbers of small castings.

The welding processes for cast irons are fully described in ISO/TR 10809-2.

4 ISO 185 Grey cast irons

4.1 Overview

Grey cast irons are sometimes called flake graphite cast irons or lamellar graphite cast irons. Their properties are specified in ISO 185:2005, Tables 1 and 2. The structure of grey cast irons contains graphite flakes in a mainly pearlitic matrix as shown in Figure 1.