DURA-BAR®

Continuous Cast Iron Bar Stock

Resource Guide

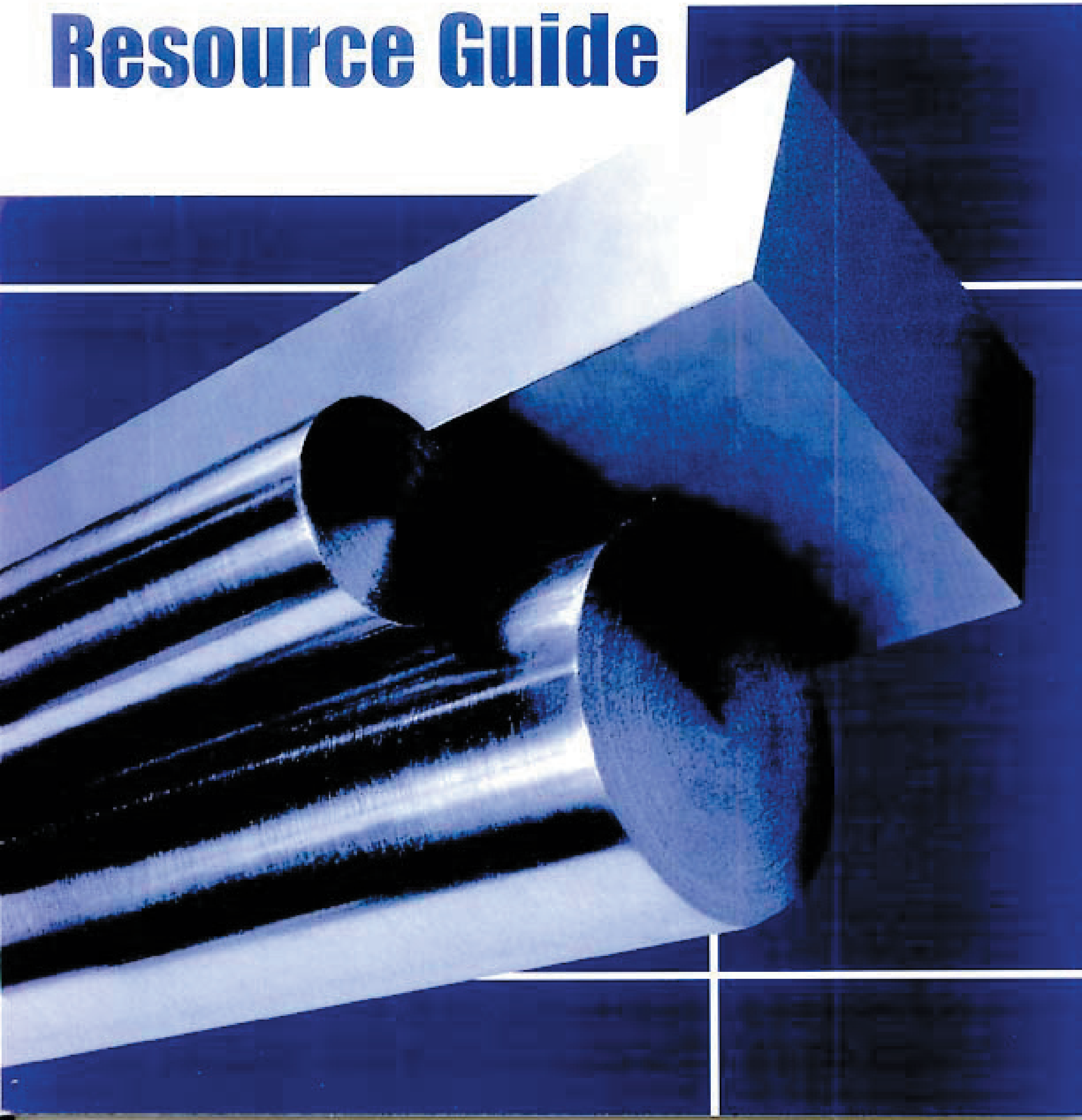


Table of Contents

Section 1 Introduction 1-1
Introduction 1-2
Cast Iron Definition...1-3
Description of Properties 1-5

Section 2 Gray Iron 2-1
Gray Iron Description of Grades.................................2-2
G1 Partially Ferritic Gray Iron....................................2-3
G1A Ferritic Gray Iron 2-6
G2 Highly Pearlitic Gray Iron 2-8
G2A Highly Pearlitic High-Strength Gray Iron..............2-11
Stock Listings 2-13

Section 3 Ductile Iron.................................... 3-1
Ductile Iron Description of Grades 3-2
65-45-12 Ferritic Ductile Iron 3-3
80-55-06 Partially Pearlitic Ductile Iron........................3-6
100-70-02 Pearlitic Ductile Iron 3-9
4512 HRDS Heat Resistant Ductile Iron 3-12
Stock Listings 3-14

Section 4 Ni-Resist 4-1
Ni-Resist Description of Grades..................................4-2
201 Type 1 Ni-Resist...4-3
202 Type 2 Ni-Resist...4-6
Stock Listings 4-9

Section 5 Heat Treating 5-1
Stress Relieving 5-3
Annealing..5-4
Hardening 5-6
Surface Hardening 5-9
Austempering...5-9
Hardness Measurements...5-9
Growth 5-9

Section 6 Appendices.................................... 6-1
Tolerances...6-2
ASTM References...6-8
Glossary 6-13
Useful Formulas & Sample Calculations......................6-21
Hardness Conversions...6-24
Mechanical Properties 6-25

Quality Policy

DURA-BAR®
Continuous Cast Iron Bar Stock
A division of
WELLS MANUFACTURING COMPANY

We will provide competitive products and services, to our customers and each other, that will meet or exceed their requirements.

We will understand and agree upon the requirements of the customer and our quality system.

We will commit to doing the job right the first time, measuring performance, and striving for

Introduction

- Introduction to Dura-Bar 1-2
- Cast Iron Definition 1-3
- Description of Properties 1-5

Scope: This book is intended to be an informational reference guide to explain the typical characteristics of continuous cast iron bar stock.

For more specific information, contact Dura-Bar Sales at 800-227-6455.

Introduction to Dura-Bar

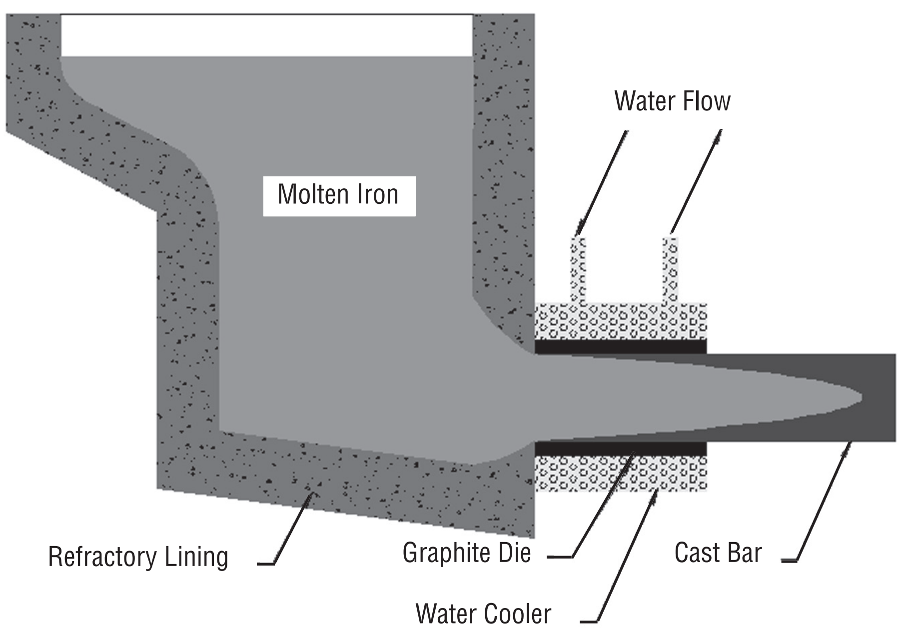
In 1961, Wells Manufacturing Company introduced the process of continuous iron casting into North America. The process was originally developed in Europe after World War II as an alternate method of producing cast iron bar stock without patterns and conventional molding methods. A water-cooled graphite die that is machined to form the shape of the bar is mounted on a bar machine crucible. As the bar is pulled horizontally from the crucible, the ferrostatic head pressure feeds molten iron into the die, producing a fine-grained cast iron bar. *(See Fig. 1 below.)*

The only part of the bar that is solidified when it exits the die is an outer skin; the core is molten iron. Heat from the molten iron core reheats the rapidly chilled outer skin above the critical temperature. The entire bar cools in air until it is notched and broken off in standard lengths. The rim has a finer graphite structure in a matrix that is more ferritic than that in the center.

The most notable characteristic of continuous cast iron is its fine-grained, dense, as-cast structure. Since the bar is being pulled from the bottom of the holding crucible, dross, slag and other impurities float to the top, away from the opening of the die.

Commitment to continuous quality improvement has qualified Dura-Bar as an engineering material for applications that require close conformance to tolerances, excellent machinability and high strength.

Fig. 1
The Dura-Bar continuous casting process results in a fine-grained cast iron.



Cast Iron Definition

Cast iron is a ferrous metal that has been alloyed with carbon and silicon. Carbon is added to the base melt in amounts that exceed the solubility limits in iron and precipitates out as a graphite particle. Silicon is added to the molten bath to nucleate the graphite which optimizes the properties of the cast iron. Small additions of other alloys can be used to produce the desired shape of the graphite and to achieve the desired matrix structure.

The type and distribution of precipitated graphite influences most of the properties of cast iron. Graphite is the reason for the free machining characteristics, which is why cast iron is often a suitable replacement for leaded and other free-machining steels. Excellent noise and vibration damping, thermal conductivity and resistance to wear are inherent to cast iron because of the presence of graphite.

The graphite shapes available in Dura-Bar grades are described in Table 1.

Table 1
Dura-Bar graphite shapes

Shape	ASTM Designation*	Characteristics	Dura-Bar Grades
Flake	Type VII A 4-5	Lowest Strength Best Machinability	G1, G2
Fine Flake	Type VII D 6-8	Medium Strength Good Surface Finish	G1A, G2A
Nodules	Types I & II	Highest Strength	4512, 5506, 7002

** Evaluated in accordance with ASTM A247, "Evaluating the Microstructure of Graphite in Iron Castings."*

The matrix structure in a non-alloyed cast iron will range from all ferrite to all pearlite. Ferrite is softer and lower in strength, as compared to pearlite, and a wide range of properties can be obtained by varying the ferrite-to-pearlite ratio.

The matrix structures available in the Dura-Bar grades are described in Table 2 on the next page.

Table 2
Dura-Bar matrix structures

Matrix	Characteristics	Grades
Ferrite	Soft, Easily Machined	None - Must Be Annealed
Ferrite & Pearlite	Medium Hardness and Strength	G1, G1A, All Ductiles
Pearlite	Hardest, Readily Machinable	G2, G2A

Material Selection

Selecting the proper grade of cast iron depends on the application. Combinations of graphite structures with the different matrix structures will result in a wide variety of grades each having its own unique properties.

Special grades of bar stock may also be produced by alloy additions. These alloys are used to enhance specific properties, such as strength and hardness.

Additions of nickel and copper will stabilize austenite at room temperatures. These alloys, known as Ni-Resist, are suitable for use in moderately corrosive atmospheres and at temperatures around -300^{o}F (-185^{o}F). Ni-Resist grades are soft and readily machinable but are not normally used in applications requiring high strength and wear resistance.

Grade selection depends upon the desired machining characteristics and on the necessary properties of the finished part. This section contains descriptions of selected properties that will pertain to Dura-Bar continuous cast iron bar stock.

Corrosion Resistance

Corrosion resistance is not a specific property of a metal but is a characteristic that depends upon the conditions of exposure and upon the quality of performance that is required. All cast irons have two constituents in their microstructures--graphite and the matrix. Graphite will withstand a wide variety of chemical and atmospheric conditions, and the matrix structure will behave similar to nonalloyed steel under the same conditions.

Ni-Resist irons having an austenitic matrix will be the most corrosion resistant grade, although even standard grades of iron may be suitable depending on the environment. Selection of the proper grade depends on the application, and each case should be reviewed independently.

Fatigue Strength

Any part that is subjected to repeated loading may fail under a load that is less than the ultimate strength of the material. The maximum load that can be applied for an infinite number of cycles defines the fatigue strength of the material. Geometry of the part and type of loading will also influence the fatigue strength, and testing should be done in order to determine whether or not a particular material is suitable for the application.

Fatigue strength is influenced primarily by the graphite size and shape but will also be affected by the matrix structure. The endurance ratio is the fraction by which ultimate strengths are reduced under fatigue loading. Endurance ratios will range from .35 to .60, depending on the particular grade of iron. The continuous casting process ensures optimum endurance ratios by eliminating slag, porosity and inclusions in the bars which can severely lower fatigue life. Ductile irons having nodular graphite will have the highest endurance ratio; gray irons with coarse flake graphite will have the lowest.

Hardness

Hardness is a measure of the strength of the material as well as the resistance to wear and the machining characteristics. Material hardness of cast iron will usually be measured by Brinell Hardness Testing, and that value can easily be converted to any other hardness value for comparisons. It is important to use hardness as a measure of strength, wear and machinability only within a particular grade. Different grades of iron or steel with the same hardness values may not be comparable in strength, wear and machinability. The softest grade of Dura-Bar will have a hardness of 131 BHN. The maximum hardness value will be 329 BHN.

Heat Treat Response

Dura-Bar cast iron has excellent response to heat treat, with achievable matrix hardness of 60 Rc and average hardnesses of 50 Rc possible. Severity of quench rate must be controlled in order to reduce the possibility of cracking. Stress relieving may be necessary, depending on the nature of the heat treat. *(See the section on Heat Treating, page 5-2.)*

Impact Strength

Cast iron is usually not recommended for applications that are under severe impact loading. Nodular graphite in a ferritic matrix will maximize impact strength in cast iron parts, and coarse flake graphite in a pearlitic matrix will result in the lowest impact strength. Typical unnotched Charpy values will range from 5 to 25 ft. lbs.

Machinability

The matrix structure will be the most significant contributing factor that affects ease of cutting and tool life. Dura-Bar 65-45-12 ductile iron has the highest ferrite percentage in the ductile grades and is most commonly referred to as being the easiest to machine. The G1 and G1A gray iron grades will contain ferrite and therefore will be easier to machine than the G2 or G2A grades that have a fully pearlitic matrix.

Dimensional stability will depend on the machining conditions and on the amount of residual stresses in the as-cast bar. Stress relieving may be necessary if extremely close tolerances are required in the machined part. Material grades by themselves will not adversely affect the ability to hold tight dimensional tolerances, although more residual stresses result in a part when machining harder materials.

Strength

Strength is influenced primarily by the size and shape of the graphite of the cast iron. Nodular shaped graphite in the ductile irons will yield higher strengths than the flake graphite in the gray irons. Strength increases with decreasing flake size but is not significantly affected by varying nodule size. The tensile strength will range from a minimum of 25,000 psi to a maximum of 100,000 psi. Graphite is not a significant factor when cast iron is subjected to compressive loading. Compressive strengths for cast irons will be as high as 150,000 psi.

Surface Finish

Optimal surface finishes will be achieved with fine flake size. Coarse graphite flakes can lead to tearing of the material during machining and will result in a poor finish. Usually, slight modifications in tooling and machining conditions will correct this condition. Machined finishes of 32 RMS will be typical; however, single-digit values are readily obtainable.

Thermal Conductivity

Cast irons have excellent thermal conductivity because of the presence of graphite. Coarse flake graphite in a ferritic matrix will have a thermal conductivity value of approximately 1.5 times that of low carbon steel.

Vibration Damping

Because graphite acts as a cushion, the vibration damping characteristics of Dura-Bar are excellent. Gray iron will have at least 10 times the damping capacities of low carbon steel; ductile iron will have three times.

Wear Resistance

Wear resistance is usually directly related to hardness but inversely related to machinability. The matrix structure of the iron has the most significant impact on wear characteristics, although the presence of graphite dramatically reduces the likelihood that galling will occur in sliding wear applications. Alloy additions, such as chrome, will stabilize carbides and improve wear properties if necessary.