



SURFACE VEHICLE INFORMATION REPORT

SAE**J2281 MAR2010**Issued 1997-05
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Selecting and Specifying Hot-Rolled Steel Bar Products

RATIONALE

SAE J418: Cancelled by SAE, inserted ASTM E 112 as substitute.
ASTM A 255: The title of the specification was changed by ASTM.
ASTM A 108: The title of the specification was changed by ASTM.
ASTM A 331: Withdrawn by ASTM, replaced by ASTM A 108.
ASTM A 535: Withdrawn by ASTM, no replacement.
SAE J416: Cancelled by SAE, ASTM E 8 is already listed in this spec.
4.1.3: Inserted "globular" before oxides to clarify D-types.
5.5.1: Removed reference to cancelled SAE spec. J416.
5.6: Deleted "lamps" and replaced with "laps."
5.7.1: Corrected spelling to "austenite", deleted SAE J418, corrected "ASTM E 12" to ASTM E 112.
5.7.1.1 Deleted SAE J418.

1. SCOPE

This SAE Information Report relates to hot-rolled steel bar products. It is intended as a guideline to assist in the selection and specification of hot-rolled steel bar; however, it is not to be interpreted as a material specification in itself.

1.1 Purpose

To provide general information about steel bar products and to provide a guideline for their selection and specification.

1.2 Field of Application

This document may be used as a guideline for the selection, specification, and ordering of steel bar products and as a reference and an educational document. It is intended for use by material, design, and product engineers, purchasing and material-control personnel, and educators.

2. REFERENCES

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

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2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J401	Selection and Use of Steels
SAE J403	Chemical Compositions of SAE Carbon Steels
SAE J404	Chemical Compositions of SAE Alloy Steels
SAE J406	Methods of Determining Hardenability of Steels
SAE J411	Carbon and Alloy Steels
SAE J412	General Characteristics and Heat Treatments of Steels
SAE J413	Mechanical Properties of Heat Treated Wrought Steels
SAE J416	Tensile Test Specimens
SAE J417	Hardness Tests and Hardness Number Conversions
SAE J419	Methods of Measuring Decarburization
SAE J420	Magnetic Particle Inspection
SAE J422	Microscopic Determination of Inclusions in Steels
SAE J423	Methods of Measuring Case Depth
SAE J425	Electromagnetic Testing by Eddy Current Methods
SAE J428	Ultrasonic Inspection
SAE J1081	Potential Standard Steels
SAE J1099	Technical Report on Low Cycle Fatigue Properties Ferrous and Non-Ferrous Materials
SAE J1123	Leaf Springs for Motor Vehicle Suspension—Made to Metric Units
SAE J1268	Hardenability Bands for Carbon and Alloy H Steels
SAE J1397	Estimated Mechanical Properties and Machinability of Steel Bars
SAE J1868	Restricted Hardenability Bands for Selected Alloy Steels
SAE J1975	Case Hardenability of Carburized Steels

2.1.2 ANSI Publication

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ANSI B 32.4-1980 Preferred Metric Sizes for Round, Square, Rectangle, and Hexagon Metal Products

2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM A 29/A 29M	Steel Bar, Carbon and Alloy, Hot-Wrought and Cold-Finished, General Requirements for
ASTM A 255	Methods for Determining Hardenability of Steel
ASTM A 295	High-Carbon Anti-Friction Bearing Steel
ASTM A 321	Steel Bars, Carbon, Quenched and Tempered
ASTM A 370	Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A 434	Specification for Steel Bars, Alloy, Hot-Wrought or Cold-Finished, Quenched and Tempered
ASTM A 485	High Hardenability Antifriction Bearing Steel
ASTM A 534	Carburizing Steels for Anti-Friction Bearings
ASTM A 675/A 675M	Steel Bars, Carbon, Special Quality, Mechanical Properties
ASTM E 8	Test Methods of Tension Testing of Metallic Materials
ASTM E 12	Definitions of Terms Relating to Density and Specific Gravity of Solids, Liquids, and Gases
ASTM E 112	Standard Test Methods for Determining Average Grain Size
ASTM E 45	Practice for Determining the Inclusion Content of Steel
ASTM E 381	Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings
ASTM E 399	Test Method for Plane-Strain Fracture Toughness of Metallic Materials

2.1.4 ASM Publication

Available from ASM International, 9639 Kinsman Road, Materials Park, OH 44073-0002, Tel: 440-338-5151, www.asminternational.org.

Metals Handbook, Volume 1 Properties and Selection: Irons, Steels and High-Performance Alloys

2.1.5 Forging Industry Association Publication

Available from Forging Industry Association, 25 West Prospect Avenue, Suite 300, Cleveland, OH 44115, Tel: 216-781-6260, www.forging.org.

FIA/ASM International Forging Handbook

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

- SAE J402 New Steel Designation System for Wrought or Rolled Steel
- SAE J409 Product Analysis—Permissible Variations from Specified Chemical Analysis of a Heat or Cast of Steel
- SAE J491 Steering Ball Studs and Socket Assemblies
- SAE J1121 Helical Compression and Extension Spring Terminology
- SAE J1442 High-Strength, Hot Rolled Steel Bars

2.2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

- ASTM A 108 Steel Bar, Carbon and Alloy, Cold Finished
- ASTM A 291 Steel Forgings, Carbon and Alloy, for Pinions, Gears and Shafts for Reduction Gears
- ASTM A 322 Steel Bars, Alloy, Standard Grades
- ASTM A 355 Steel Bars, Alloys for Nitriding
- ASTM A 400 Steel Bars, Selection Guide, Composition, and Mechanical Properties, Standard Practice for
- ASTM A 521 Steel, Closed-Impression Die Forgings for General Industrial Use
- ASTM A 576 Steel Bars, Carbon, Hot-Wrought, Special Quality
- ASTM A 688/A 688M Steel Forgings, Carbon and Alloy, for General Industrial Use
- ASTM A 689 Carbon and Alloy Steel Bars for Springs
- ASTM A 920 Steel Bars, Microalloy, Hot-Wrought, Special Quality, Mechanical Properties
- ASTM A 921 Steel Bars, Microalloy, Hot-Wrought, Special Quality, for Subsequent Hot Forging

2.2.3 American Iron and Steel Institute Publication

Available from AISI, 1140 Connecticut Ave., NW, Suite 705, Washington, DC 20036, Tel: 202-452-7100, www.steel.org.

Steel Bar Product Guidelines, Bar Steel Alloy, Carbon and Microalloy Steels: Semifinished, Hot Rolled Bars, Cold Finished Bars, Hot Rolled Deformed and Plain Concrete Reinforcing Bars

3. MANUFACTURE

As a means of introducing the product, the following briefly describes the methods of hot-rolled steel bar manufacture. Refer also to SAE J412 for a definition of some of the steel making terms. A steel bar may be derived from an ingot which is the product of a steel heat "teemed" into individual molds or from a strand casting process which involves pouring and solidifying steel heats continuously in a strand. Strand casting is the predominant method of steel bar manufacture in North America. There are two strand casting techniques associated with bar products, namely bloom casting and billet casting. A cast bloom or ingot is relatively large and requires reduction by hot rolling into a billet. Billets, whether from cast blooms or ingots, are frequently inspected and conditioned to enhance surface quality. Billets are the feedstock used in a bar mill to roll a bar product or by an open die forger to produce a forged product. Dimensional accuracy and other requirements for billets are normally subject to agreement between steel producer and purchaser. Hot-rolled steel bar is the finished product rolled from a billet, produced in lengths and coils, in numerous sections and sizes and to specific tolerances related to chemistry, dimension, surface, internal condition, mechanical properties and hardenability. Bar products may be further processed by thermal treating, descaling, and cold drawing prior to use.

4. SELECTION GUIDELINES

Hot-rolled steel bar is widely used in, but not limited to, original equipment manufacturing such as automotive, off highway, agriculture, military, railway, industrial equipment, and appliance industries. Manufacturing processing may involve forming (hot, warm, or cold forming, and cold drawing), heat treating (quench and tempering and surface hardening), machining (turning, drilling, broaching, and grinding) and surface finishing (plating and painting).

Hot-rolled bars may be selected on the basis of one or several application requirements including static, cyclic (fatigue) and dynamic (impact) load resistance, rolling contact fatigue resistance and response to various manufacturing processes. SAE J401 will assist the reader in designing parts from steel including hot-rolled bar. Further, SAE J412 is a useful selection guide showing the chemistry (grade), grain size, microstructure, cleanliness, and surface quality are important factors when selecting a hot-rolled bar product and how these factors influence processing and ultimate end use.

4.1 Mechanical Properties

Hot-rolled steel bar products can be furnished to specified minimum strengths (tensile and yield strength) or, as is more often the case, they are processed into varying hardness levels through heat treatment by the end user. SAE J413 provides mechanical properties for a range of material hardness resulting from heat treatment. It further illustrates the principle that regardless of chemical composition (grade), steels of the same cross-section hardness produced by tempering after through hardening, will have approximately the same tensile strength. Yield strength, as a percentage of tensile strength, is highest if the section is through hardened to a martensitic structure before tempering. Hot-rolled steel bar products can be furnished with certain hardenability requirements which assure the end user that minimum hardness can be achieved via proper quench and temper heat treatment (see 5.8).

4.1.1 Fatigue Properties

Parts and components made from hot-rolled steel bar are frequently subject to fatigue loading. Designing to avoid fatigue failures requires, among other factors, a knowledge of material properties existing in the finished part at the most critically stressed location. SAE J1099 contains fatigue properties of several steel bar grades (carbon and alloy steels).

4.1.2 Fracture Toughness

Parts are frequently subjected to impact loads and their constituent material should possess sufficient fracture toughness to withstand the load at service temperature without failing. Parts made from steel and steel bar generally have good fracture toughness and resistance. Steels are frequently tested using impact loading on specimens with prepared notches to examine the nature of the fracture (ductile or brittle) and the energy absorption. Charpy V Notch testing, as specified in ASTM A 370 is a popular method, however, it and similar tests are comparative and can only show relative performance. Fracture mechanics provides a more engineered prediction of fracture resistance. Fracture mechanics treats fracture toughness as the resistance to crack growth. Cracks are frequently present, either introduced during manufacture or initiated early in the life of the component. Resistance offered by the material to crack growth is as significant as the type of loading and environment in predicting crack growth resistance. Fracture mechanics uses a parameter called the plane strain fracture toughness, K_{Ic} , a type of stress intensity factor. The property K_{Ic} determined by the test method outlined in ASTM E 399 characterizes material fracture resistance in a non-corrosive environment in the presence of a sharp crack under severe tensile constraint. A K_{Ic} value is believed to represent the lower limiting value of fracture toughness and can be used to estimate the relationship between failure stress and defect size in a material in service.

4.1.3 Rolling Contact Fatigue

Contact stress resistance is often defined as rolling contact fatigue resistance in bearing applications. Rolling contact fatigue strength measures the Hertzian contact stress between two rotating surfaces. This fatigue strength is measured by the resistance to failure from pitting or spalling when constant load is applied under controlled lubricant conditions. Bearing steel cleanliness strongly influences the rolling contact fatigue strength of a component since pitting or spalling sites are often initiated from subsurface nonmetallic inclusions. The oxide type inclusion has the most deleterious effect on rolling contact fatigue. Oxide type nonmetallic inclusions form a poor interface with the steel matrix due to their very hard and brittle properties. They tend to be grouped in small clusters that increase the stress concentration critical for initiating fatigue failures. Bar steels intended for rolling contact applications are frequently specified to have certain cleanliness levels or ratings.

Maximum bearing steel inclusion cleanliness ratings are specified in ASTM A 295 for high carbon grades, ASTM A 485 for high carbon/high hardenability steel grades, and ASTM A 534 for carburized grades. The nonmetallic inclusion rating scales used in any of the previous specifications are shown in the Jernkontoret ("J") charts described in ASTM E 45. The nonmetallic inclusion field rating charts include sulfides (A type), aluminates (B types), silicates (C types), and globular oxides (D types).

4.2 Processing

4.2.1 Forming

Bulk forming of hot-rolled bars is employed in the manufacture of numerous parts and components. Hot forging is a widely used method as is cold forming. Warm forming is an increasing popular technique which takes advantage of reduced metal flow resistance through an intermediate temperature warming of the material. Warm and cold forming are near net shape techniques which reduce the amount of machining for the final part. The primary feature of forming is the enhancement of mechanical properties in the direction of major metal flow during forming. Microalloyed forging steels take advantage of the heat of hot forging and, by control of cooling, achieve desirable mechanical properties without subsequent heat treatment. Many steel bar products are suitable for forming. Steel bars in the 10XX, 11XX, and 15XX Carbon series and the 13XX, 40XX, 41XX, and 43XX Alloy series are popular. Products with relatively low carbon content, for example SAE 1020, 1038, 4137, 5140, and 8620 are commonly cold formed. Detailed information about bulk forming may be found in the FIA/ASM International Forging Handbook.

4.2.2 Machining

Machining can be a major and therefore important factor in overall processing cost when considering steel bar selection. Machinability is the relative measure of the ease of machining in a given set of circumstances. This may mean the amount of tool force and wear, required cycle time, ease of chip formation, and surface finish. The material selection has a major impact on machinability and certain steel bar grades produced with machining in mind. Cold drawing markedly improves consistency of machining. An interpretation widely used in the industry is SAE J1397 which provides a machinability rating for various SAE grades of steel bar in hot-rolled and cold-drawn condition.

4.2.3 Heat Treating

Hot-rolled steel bars and parts made from hot-rolled bars are heat treated in order to attain the hardness and microstructure required in the final product or to make them suitable for further processing. Heat treating can consist of annealing, stress relieving, quench and tempering, and surface hardening. The various types of annealing are performed to soften the material and to alter the microstructure. A frequently employed method of increasing hardness and strength of the higher carbon and alloy steel grades, particularly after forming of the part, is quench and tempering. This involves heating and holding above the critical temperature, rapid cooling by quenching followed by a subcritical heating called tempering to restore ductility. Surface hardening describes techniques that selectively harden the surface of the bar or part to increase surface strength and wear resistance. Reference may be made to the ASM Handbook for further information about these heat treatment methods.

5. SPECIFICATION GUIDELINES

Hot-rolled steel bars are normally specified on the basis of the following:

5.1 Carbon, Alloy, and Microalloy Steel

The designations carbon steel and alloy steel, which are defined in SAE J411, are frequently used when specifying hot-rolled steel bars. The common practice is to designate "C" for carbon steel and "Alloy" for alloy steel. Microalloy steels (sometimes referred to as high strength low alloy) are intended for use in the as-rolled condition or in hot forging where the desired mechanical properties are developed during the forge process.

5.2 Grade

Steel grade or chemical composition determines strength, hardness, and response to thermal treatment in steel products. Hot-rolled steel bars are produced in the standard grades shown in SAE J403, J404, and J1081 and in many modified versions of these SAE chemical compositions. The SAE grade designation should be used when specifying hot-rolled bars.

5.3 Quality

A quality designation is often used in specifying steel bar. The designation implies material characteristics that are important for the intended end use. Characteristics such as surface and internal condition, and the steps taken during manufacture to assure their adequate level, are associated with a quality designation. Special Bar Quality, Special Quality, or "SQ" are carbon steel bar designations. Similarly, Regular Quality Alloy or simply "Alloy," as shown in 5.1, implies an alloy steel bar product. Sometimes more specific designations are used: for example Axle Shaft, Bearing, Cold Heading, Aircraft, and Magnaflux Qualities identifying a very specific end use. Merchant Quality is the base quality for hot-rolled carbon steel bars intended for non-critical end uses.

5.4 Dimensional Characteristics

Bar products are produced to specified shape (or section), dimension, and tolerances commonly available as follows:

5.4.1 Sections and Size Ranges

Rounds¹ (RDS): 12 mm to 320 mm

Squares¹ (SQS): from 12 mm to 150 mm across flat

Hexagons¹ (HEX): 12 mm to 100 mm across flat

Flats and Rectangles¹: Over 5.0 mm thick and up to 150 mm width

Round Edge Flats²: 5.0 mm thick and over and up to 150 mm width

¹ Based on American National Standard B32.4M-1980, Reaffirmed 1994, Preferred Metric Sizes for Round, Square, Rectangle and Hexagon Metal Products, published by the American Society of Mechanical Engineers.

² SAE J1123, Leaf Springs for Motor Vehicle Suspension - Made to Metric Units.

Producers should be consulted to determine availability of sizes of Round Corner Squares (RCS) or of a particular section and size within or outside the ranges shown previously.

5.4.2 Lengths and Coils

Bars are rolled and cut to specified length (order length) by shearing and sawing or are rolled and coiled. Bar lengths, coil weights, and their dimensions vary by producer.

5.4.3 Dimensional Tolerances

Applicable section and size tolerances are shown in ASTM A 29/A 29M. Straightness and length tolerances for length products are also defined in ASTM A 29/A29M. More restrictive tolerances than are shown in ASTM A 29/A 29M may be agreed upon between supplier and purchaser.

5.5 Mechanical Properties

Hot-rolled carbon steel bars can be produced to meet mechanical properties with associated limited chemical requirements. Mechanical property requirements for Carbon and Microalloy steel bars are found in ASTM A 675/A 675M and ASTM A 920 respectively. Somewhat higher properties for Carbon and Alloy bars are obtained by quench and tempering as shown in ASTM A 321 and ASTM A 434, respectively. Mechanical properties can also be subject to agreement between producer and user.

5.5.1 Tensile Testing

Tensile testing is a requirement for products produced to minimum tensile requirements. Tensile tests measure strength, elongation, and reduction of area in a prepared sample obtained from a product. Tensile test methods are described in ASTM A 370 and ASTM E 8.

5.6 Surface Characteristics

Users should recognize that hot-rolled steel bars are the product of hot rolling with inherent surface characteristics. Although great care is taken during steelmaking and bar rolling, the surface may contain certain discontinuities. Seams, laps, and slivers are types of physical discontinuities that can have an impact in forming operations and where cyclic stress is present. Decarburization which is the absence of base carbon on and below the bar surface, is a concern for applications involving surface hardening, quench and tempering and peening. In the interest of simplicity and cost, the supplier and purchaser should determine limits on acceptable surface discontinuities. Non-destructive, sophisticated methods of inspection, particularly for physical discontinuities can be employed during or after the hot bar rolling to detect and limit them. Also, several surface metal removal processes can be employed to improve surface quality in terms of level, frequency, and smoothness. Decarburization can result from both rolling and post rolling processes. The user should consider the level of decarburization generally allowed for the bar (up to 1.6% of diameter) prior to ordering. Some grades are more prone to decarburization and, prior to further processing, may require some degree of surface metal removal.

5.6.1 Surface Decarburization Testing

SAE J419 describes a method for rating the types and level of decarburization on and below the bar surface.

5.6.2 Magnetic Particle Inspection

Refer to Section 6 and 6.3.