MILLTECH MARTIN BRIGHT

TECHNICAL HANDBOOK

MMB Technical Handbook

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1.0 Introduction

1.1 Scope and Purpose

The Milltech Martin Bright Technical Handbook covers all bright steel products and hard chromed bar. It is intended to fulfil several roles including:

- A training document for use by our suppliers, merchants, end users and MMB personnel.
- A guide for merchants in the purchase of MMB products.
- A reference for manufacturers in the processing of MMB products.
- A reference for design in MMB products.

1.2 Acknowledgements

Milltech Martin Bright is a key link in the chain of manufacturing and supply of finished goods. We owe our success to the continued support of the Australian and Pacific Basin manufacturing industry. Over the years, we have learnt a lot from our customers, suppliers and other industry groups. In particular we thank those customers who provided guidance on the contents of this Handbook.

1.3 References

1.3.1 Raw Materials for Bright Bar Manufacture

AS 1442 1992 "Carbon Steels and Carbon Manganese Steels – Hot Rolled Bars and Semi-finished Products".

AS 1444 1996 “Wrought Alloy Steels – Standard Hardenability (H) Series and Hardened and Tempered to Designated Mechanical Properties".

1.3.2 Bright Bar

AS 1443 - 2000 "Carbon Steels and Carbon Manganese Steels – Cold Finished Bars".
AS 1444 1996 "Wrought Alloy Steels – Standard Hardenability (H) Series and Hardened and Tempered to Designated Mechanical Properties".

1.3.3 Quality Systems

AS/NZS IS0 9001 - 2000 "Quality Management Systems – Requirements".
Milltech Martin Bright Quality Manual.

1.4 Control and Distribution of the Handbook

This handbook is included in the Document Control System of Milltech Martin Bright. The salient points are:

1.4.1 The Handbook will be provided, at MMB discretion, to customers, suppliers, end users and other interested parties.

1.4.2 The distribution of all copies will be recorded. From time to time minor changes will be incorporated in updates which will be supplied to all holders of the Handbook.

1.5 Limitation of Liability

The information contained in this handbook is not intended to be a complete statement of all relevant data applicable to MMB's products. This handbook, and the information it contains, have been designed as a guide to the range of MMB's products supplied by MMB at the date of issue of this handbook.

To the extent permitted by law, all conditions, warranties, obligations and liabilities of any kind which are, or may be implied or imposed to the contrary by any statute, rule or regulation or under the general law and whether arising from the negligence of MMB, its employees or agents, are excluded.

All information and specifications contained in this handbook may be altered, varied or modified by MMB at its discretion and without notice.

MMB is not liable for any loss or damage (including consequential loss or damage) arising from or in connection with:

1. The provision of the handbook to any party;
2. The accuracy, completeness or currency of any information in this handbook;
3. The absence or omission of any information from the handbook and
4. The reliance by any party on information contained in the handbook.

1.6 Support from Milltech Martin Bright

MMB have qualified professional staff in the areas of marketing, engineering and metallurgy. Customers and end users are encouraged to contact MMB for support in the marketing and application of our products.

2.0 Milltech Martin Bright Company Profile

2.1 The Company Today

Milltech Martin Bright is Australia's major manufacturer of cold finished bright steel bars and hard chromium plated bars, with sales over $45 million (30,000 tonnes) and 90 employees. It services local and international markets, supplying to a variety of industries including automotive, agricultural, materials handling, mining and general engineering.

Milltech Martin Bright steel products are characterised by a smooth surface, free from scale and harmful imperfections, tight dimensional tolerances, superior straightness and higher strength than hot-rolled products. They are ideally suited to machining and shafting applications.

For additional information please contact Milltech Martin Bright on + 61 2 4964 0100.

TABLE 1: HISTORY

Circa 1900	The Martin family, after establishing a small fastener manufacturing business in Sydney, NSW, ventured into the merchandising of bright bar. An agency agreement from John Vessey & Sons, England, was obtained.
1929	Bright Steels Pty Ltd formed as a result of an acquisition of a recently established bright bar manufacturer in Pyrmont, Sydney.
1953	Martin Bright Steels Limited formed to facilitate further expansion.
1956	A second plant was established in Kilburn, Adelaide.
1963	A third plant was established in Somerton, Melbourne.
1972	A new plant was built in Blacktown, Sydney, leading to the closure of the manufacturing operations at the original site in Pyrmont. During this year Martin Bright Steels acquired the last of its remaining Australian competitors.
1982	A major restructure led to the consolidation of all manufacturing operations to Somerton in Melbourne. During all of this time, distribution had grown to cover the majority of Australia plus some exports.
1986	Martin family leadership ceased, ending with an acquisition by Atlas Steels Limited. At this point Martin Bright Steels became a manufacturing operation only, with no distribution business.
1995	Email Limited acquired the entire Australian based operations of Atlas Steels.
2008	Martin Bright Steels has become a Division of Milltech as a result of that company's aquisition from OneSteel, and is now known as Milltech Martin Bright.

3.0 Manufacturing Process

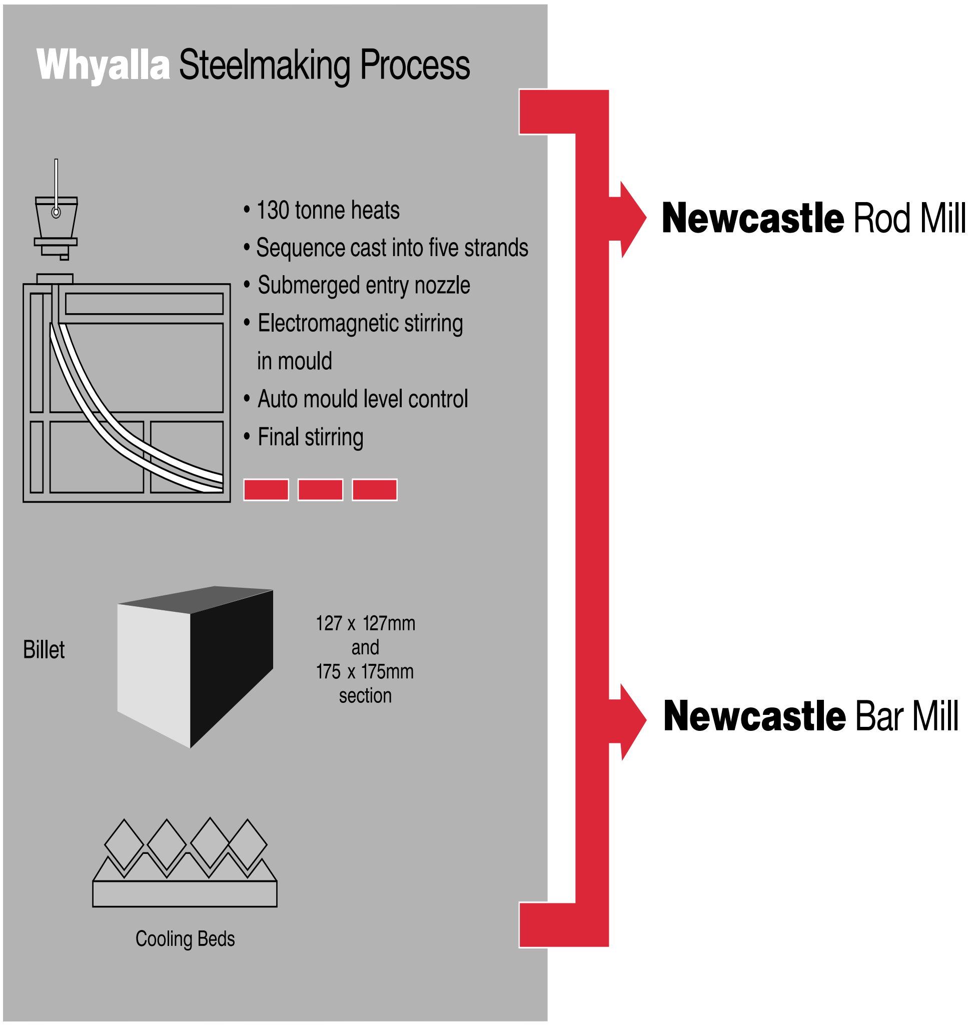
The flow charts in this section provide a basic understanding of the process of manufacture of Milltech Martin Bright's products. To put it into context, the process is shown from its beginnings as iron one.

Additional MMB processes available on request, are:

- Crack testing by eddy current or magnetic particle methods.
- Stress relieving, sub-critical annealing.
- Chamfering.
- Mechanical testing.
- Saw cutting.

All production is strictly controlled with special order requirements being covered by our Data Management System (DMS).

Manufacturing Process



Manufacturing Process

Whyalla Steel → **Newcastle Bar Mill** → **Milltech Martin Bright**

Newcastle Bar Mill

Numerous shapes, sizes and grades of bar for manufacture of bright bar, automotive components, reinforcing, grinding media, general engineering and fabrication.

Reheat Furnace
- 3-zone top and bottom natural gas fired pusher furnace

Rolling Mill
- 14 stands - roughing, 4 intermediate, 4 finishing, with high pressure water descaling and in-line laser bar gauge, producing 13-100mm bars

Cooling Beds
- 2 cooling beds

Inspection
- Off-line surface inspection for critical products

AC Surface Inspection → Internal Inspection → Bar Conditioning → Visual Inspection

- Computerised heat tracking, weighing, tagging and bundle dispatch of straight bar and coils

Manufacturing Process

Whyalla Steel →

Newcastle Rod Mill

Numerous sizes and grades of rod for manufacture of bright bar, wire, fasteners, electrodes, chain and reinforcing.

Reheat Furnace
- 3-zone top and bottom natural gas fired pusher furnace

Mill
- computer controlled no twist mill, with 2 strand operation with 7 rougher, 6 intermediate, 2 pre-finisher and 10 no twist mill stands per strand, finishing speeds up to 100m/s

- Online Laser Rod Gauge

Eddy Current Inspection
- On-line for critical products

Controlled Cooling
- 4 controlled air cooling zones and a total of 7 fans

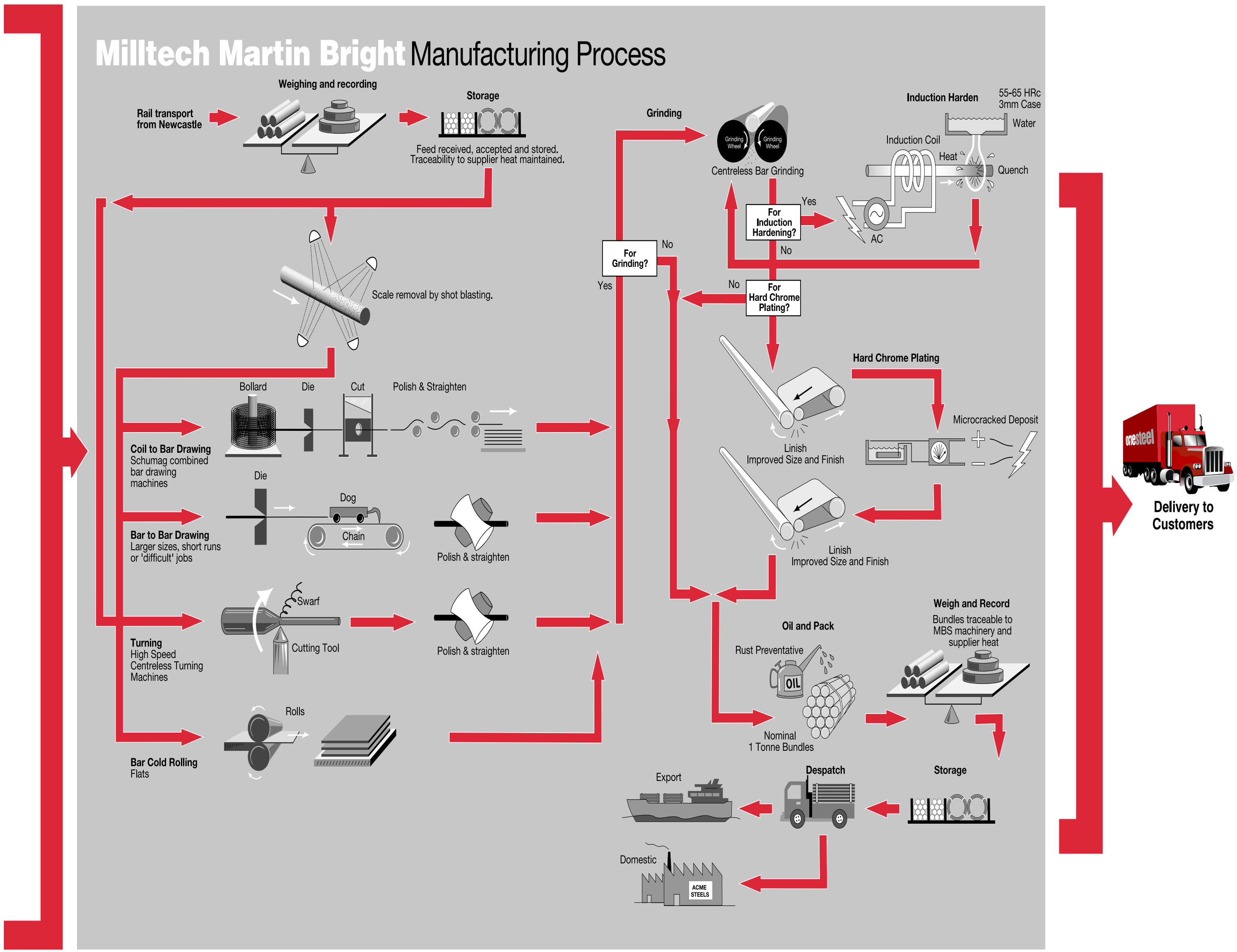
Inspection
- testing of tensile strength, elongation, carbon determination

Despatch
- 1.5 tonne coils compacted, bundled and tagged in single or double coils

→ Milltech Martin Bright

Manufacturing Process

Newcastle Rod Mill



Newcastle Bar Mill

4.0 Metallurgy of Bright Bar

The major factors which determine the properties of bright bar are:

- Chemical composition.
- Metallurgical processing (eg. casting conditions, hot rolling, cold working and/or heat treatment).
- Freedom from defects (eg. seams, laps, non metallic inclusions, etc).

The influence of each of these factors is discussed in more detail below.

4.1 Chemical Composition

TABLE 2: COMMONLY SPECIFIED ALLOYING ELEMENTS	
C	Carbon. Is the principal hardening element in all steel. As the carbon content increases, strength, hardness and hardenability increase at the expense of ductility, toughness and weldability. Carbon is prone to segregation.
Mn	Manganese. Has a similar effect to carbon but to a lesser extent. It is less severe in its detrimental influence on ductility, and weldability. It is also less prone to segregate. The use of manganese in place of carbon greatly improves impact toughness. It also strongly increases hardenability. In combination with sulphur it forms manganese sulphide inclusions which improve machinability.
Si	Silicon. One of the principal deoxiders used in steelmaking. It may be intentionally added as an alloying element too, in some spring steels. Silicon increases yield and tensile strength but its effect is less than half that of carbon. Silicon in the form of silicate inclusions can be detrimental to machinability.
P	Phosphorus. Is usually considered to be detrimental and it is restricted to a maximum limiting percentage. It has a hardening and strengthening effect but this is at the expense of a great loss in ductility and toughness. Phosphorus is added to free machining steels, despite its bad effect on mechanical properties, because it hardens and embrittles the ferrite which assists in chip breakage.
S	Sulphur. Is usually considered to be detrimental and it is kept low. It has no beneficial effect on mechanical properties and it reduces ductility and toughness particularly in the transverse direction. Sulphur has a strong tendency to segregate. During hot rolling it can lead to problems with low ductility. Steelmakers generally try to balance sulphur with manganese so that it is present as benign manganese sulphides rather than in solid solution in the ferrite. Levels of Mn:S of 5:1 are desirable for engineering steels. Sulphur is intentionally added to free machining steels to increase the level of manganese sulphide inclusions. These are known to improve machinability.

TABLE 3: SPECIAL ALLOYING ELEMENTS	
Pb	Lead. This element is virtually insoluble in steel and it is present as a dispersion within the structure. Because of this, it has no significant effect on mechanical properties. Lead improves machinability by acting as a cutting lubricant to facilitate higher surface speeds and a better surface finish.
Bi	Bismuth. Similar in effect to lead.
Se	Selenium. Acts in conjunction with manganese sulphide inclusions to improve machinability.
Te	Tellurium. Similar effect to selenium.

TABLE 4: OTHER ALLOYING ELEMENTS	
Al	Aluminium. This element is used as an alternate deoxidant to silicon. It also has the effect of refining the austenite grain size and reducing susceptibility to strain aging.
Ni	Nickel. It increases strength, toughness and hardness. It is much less potent than other elements such as C, Mn and Cr but it has none of the adverse effects on ductility. It is particularly useful in conjunction with Cr for increased hardenability in carbon steels together with a moderation of chromium's adverse effects. It retards grain growth at high temperatures. Nickel and chrome are the two major alloying elements in stainless steel.
Cr	Chromium. It increases steel's hardness and strength with a loss in ductility and toughness. Under some circumstances it forms very hard chromium carbides. It improves the hardenability of steel and it is often used in conjunction with nickel in hardenable steels.
Mo	Molybdenum. This element has a similar effect to that of chromium. It is often used in conjunction with nickel and chromium. It is particularly beneficial due to its effect in raising yield and tensile strength and reducing "temper brittleness".
V	Vanadium. Vanadium is often used as a microalloying element in high strength low alloy steels. It has a generally beneficial effect on mechanical properties and it refines austenite grain size. It has a strong tendency to form stable carbides.
Nb	Niobium (formerly known as Columbium, Cb). Niobium has a strong chemical affinity for carbon, forming exceptionally stable carbides. Like vanadium, a niobium addition to steel serves to increase the yield strength of low carbon structural steel. Such steels are fine grained and have improved low temperature impact properties in the normalised condition.
B	Boron. In very small quantities (0.0005-0.003%) boron improves the hardenability of heat treated steels.
Ti	Titanium. This is used in carbon steels principally as a deoxidising and grain refining element. It is also commonly used as a deoxidising shield when making boron steels.
N	Nitrogen. Nitrogen in small quantities increases yield and tensile strength and hardness but it is detrimental to ductility and impact toughness. It is sometimes intentionally added to improve machinability. Dissolved oxygen and nitrogen are responsible for the yield point phenomenon and cause strain aging. High nitrogen is usually associated with high scrap content in steelmaking.

TABLE 5: TRAMP ELEMENTS	
Cu	Copper. In small amounts copper can improve resistance to atmospheric corrosion but is detrimental to surface quality and hot working during hot rolling. High residual levels of copper and tin are sometimes associated with a high scrap content in steelmaking.
Sn	Tin is also detrimental in steels. It can lead to breaking up in hot working (hot shortness) and embrittlement in quench and tempered steels at certain tempering temperatures (temper embrittlement).

4.2 Metallurgical Processing

4.2.1 Steelmaking

It is at this first stage in the process that chemical composition is determined. A fully integrated iron and steelmaking process involves the smelting of iron from a charge of iron ore, coke and limestone. The carbon content of the molten iron is reduced and impurities removed by oxidation in the basic oxygen steelmaking process (BOS). Further adjustments to composition may be made in a ladle refining furnace before continuously casting.

Steels made by the integrated steelmaking route as at Milltech Whyalla Steelworks, generally have much lower residual elements and consequently more uniform properties, than mini-mill steels.

Mini-mill steels are produced by melting a charge of selected scrap and ferro-alloys in an electric arc furnace. The properties of steels made in this way can be adversely affected by tramp elements in the steel scrap.

4.2.2 Fully Deoxidised (Killed) Steels

Milltech Martin Bright uses continuously cast hot rolled feed. These types of steels are all fully deoxidised (killed) steels as necessary for the process. Semi killed rimmed and capped steels as produced previously by the ingot route are no longer produced by Milltech.

4.2.3 Merchant Quality Steels

Merchant Quality Steels eg M1020 are fully deoxidised but with wider C and Mn chemical composition ranges than AS1443 specified carbon steels like AS1443/1020. Merchant quality are not subject to limits or grain size requirements, therefore they are less uniform in properties.

4.2.4 Unspecified Deoxidation Steels

Unspecified deoxidation grades, eg. U1004 have replaced rimmed steels.

4.2.5 Austenite Grain Size

This term refers to a steel's inherent grain growth characteristics at elevated (austenitic) temperatures above 900°C. It is measured by one of several standard tests which involve heating above this temperature. Refer to Australian Standard AS 1733-1976.

Austenite grain growth is reduced by the presence of aluminium nitride in sub microscopic particles which obstruct the movement of grain boundaries. The introduction of aluminium during casting at the time of deoxidation is used to refine austenite grain size.

The preference for coarse or fine grained austenite varies with the application. Each condition has its advantages. Fine grained austenite is of course, resistant to the deterioration in mechanical properties when held at forging, welding or carburising temperatures. It is therefore less prone to cracking or distortion on quenching or forging. Fine grained austenite steels are also less affected by strain aging.

Coarse grained austenite steels, on the other hand, are more hardenable and carburise more readily. They are easier to machine.

It should be emphasised that austenite grain size is a measure of grain size at elevated temperatures. It bears no direct relationship to the steel's grain size at room temperature.

4.2.6 Hot Rolling

Steel, as cast, has comparatively poor mechanical properties. The hot rolling process greatly improves the properties by:

1. Grain refining due to the continual recrystallisation which occurs when hot working.
2. Elimination of the oriented cast structure (ingotism).
3. Promotion of homogeneity by physically breaking up the constituents and allowing the opportunity for diffusion to occur.
4. Blow holes and other defects can weld up in rolling.

The result of these improvements is better mechanical properties, particularly ductility and toughness. The ratio of reduction of cross-sectional area of the original casting to that of the final hot rolled product is a measure of the amount of reduction and level of improvement which can be expected from hot rolling.

Another factor of great importance is the finishing conditions in hot rolling because they will determine the grain size and level of cold work (if any) in the material. Parameters such as finishing temperature and cooling rate are therefore important. In general, fine grained steels have superior mechanical properties.

4.2.7 Cold Work

Any deformation of steel below its recrystallisation temperature (about 500°C) is called cold work. It increases steel's yield point, hardness and tensile strength at the expense of ductility and impact toughness. In lower carbon steels, the loss of ductility is beneficial to machining because it promotes chip breaking.

In bright drawing, the usual measure of the degree of cold work is called "draft" or "reduction of area". This is a measure of the reduction of cross-sectional area in the drawing process.

Turned product does not involve significant cold work. The mechanical properties of turned bar are the same as hot rolled.

The effect of cold work can be removed by annealing. Even at raised temperatures, below the recrystallisation temperature, there is some softening ("recovery") which can occur. This is called stress relieving.

4.2.8 Strain Aging

Over extended periods (eg. 6 months) there can be a change in the properties of cold worked steel. This is due to the slow migration of carbon and nitrogen back to dislocations which were previously moved by cold work. The yield point, previously made indistinguishable by cold work, returns. Hardness, yield and tensile strength increase and ductility and impact toughness are reduced.

Strain aging can be induced by heating to around 250°C. (This is sometimes called strain annealing). For this reason, heating of cold drawn bar first results in an increase in hardness, followed by a sharp reduction as the recrystallisation temperature is approached.

Strain aging has been used to improve machinability in some grades.

4.2.9 Heat Treatment

Full Annealing

This process is rarely utilised for softening bright steel. Full annealing involves a slow furnace cool and is therefore expensive. (It is more applicable to steel castings where undesirable structures must be removed.)

Normalising utilises similar working temperatures but it involves an air cool. The mechanical properties of normalised steel are generally superior to those of a full anneal.

Sub-Critical Anneal (or Stress Relieving)

This is the process frequently employed to remove the effects of cold work. It is sometimes also called "interpass annealing" or "stress relieving". In practice, a wide range of temperatures and times can be selected, depending on the desired properties. At one extreme, a very slight softening can be achieved, at the other, the softest condition possible, "spheroidise annealed".

Induction Hardening

Induction hardening is a heating and quenching operation which is restricted to the outer layers of the material, leaving the core softer and more ductile. Heat is provided through the effect of an electromagnetic field which induces electric currents on the bar surface. Resistance to this current causes heating. Only hardenable grades can be induction hardened.

In the quenched condition the surface can sometimes be too hard and brittle to straighten. A tempering operation is usually necessary to soften and improve toughness.

Post Heat Treatment Processes
Steel during heat treatment can form scale on the surface and distort. For this reason a shot blast and straightening operation is generally required after heat treatment.

4.3 Freedom From Defects

4.3.1 Steel Mill Defects

With the advent of continuous casting many of the previously common ingot route defects have disappeared eg pipe and/or lamination. Steel mill defects sometimes found today are steel laps, handling damage (abrasion), sub surface non metallic inclusions, seams and occasionally segregation.

Scrappy lap is a surface defect which can have a variety of causes but, in recent times, most have their origin in the hot rolling mill. They are not removed by cold drawing but, turning or grinding can remove them. End users can find that scrappy lap may cause rejectable parts because of the poor 'visual' appearance, reduced ability to hold fluid pressure and/or the possibility of acting as a stress raiser.

Handling damage (abrasion) and seams may raise similar concerns to scrappy lap. Non-metallic inclusions and segregation may cause embrittlement or machining difficulties. In the case of lead segregation, visual appearance may be impaired and there may be an adverse effect on the ability of the part to hold fluid pressure, particularly if the component has been heated, allowing the lead to "sweat out".

Beyond what could be classed as defects, there are inherent features which can influence processing and end use. For example, machinability is sensitive to variations in grain size, cold work, shape and distribution of manganese sulphides, composition and distribution of other non-metallic inclusions. Material ideal for one application may not suit another.

Decarburisation is another of the inherent metallurgical features in hot rolled products. It is caused by oxidation of the surface layers of the feed billet during pre-heating for hot rolling. As a guide, decarburisation depth is expected to not normally exceed 1% of hot rolled diameter for most engineering steels. It is sometimes much less. Note that decarburisation can also be introduced by heating to above red heat, in operations subsequent to Milltech manufacture. If necessary this can be removed by turning or grinding, as it can adversely affect the hardenability of heat treated components, particularly the surface hardness.

4.3.2 Bright Bar Defects

There are a wide variety of potential mechanical defects in bright bar, but if we restrict ourselves to those of a metallurgical nature, the level of cold work in drawn bar and type of heat treatment (if applicable) may cause concern. For most commercial product these characteristics are not specified. On occasions where mechanical properties are specified, inappropriate draft and heat treatment can lead to testing failures.

The level of cold work also influences machinability and ductility.

4.3.3 Removal of Surface Defects by Inspection

MMB do not know of any steel mill which is capable, from a statistical process control viewpoint, of producing totally surface defect free hot rolled steel. If the presence of an occasional defect is unacceptable then non-destructive eddy current testing should be specified.

4.4 Steel Grade Names

4.4.1 Carbon Steels – Supplied to Chemical Composition Only

The system adopted in Australian Standards is based on the American Iron and Steel Institute - Society of Automotive Engineers (AISI-SAE) system. It consists of 4 digits to which further prefixes and suffixes may be added. The first two digits indicate the alloy family name. For plain carbon steels it is "10..." followed by two digits which indicate the nominal carbon content. eg. 1020 is a plain carbon steel with a nominal 0.20% carbon content. The table following shows the families applicable to MMB product.

To be strictly correct, the grade designation should be preceded by the number of the applicable Australian Standard. For bright steel this is AS 1443 for most grades, and AS 1444 for alloy steels.

TABLE 6: BRIGHT STEEL GRADES

Digits	Type of Steel & Average Chemical Content Carbon Steels
10XX	Plain carbon (Mn 1.00% max.)
11XX	Resulphurised
12XX	Resulphurised and Rephosphorised
13XX	MANGANESE STEELS Mn 1.75%
41XX	CHROMIUM-MOLYBDENUM STEELS Cr 0.5,0.8 & 0.95; Mo 0.12,0.20,0.25,0.30
86XX	NICKEL-CHROMIUM-MOLYBDENUM STEELS Ni 0.55; Cr 0.50; Mo 0.20

TABLE 7: OLD STEELMAKING PRACTICES – DEGREE OF DEOXIDISATION

Old Prefix	Practice
R	"Rimming" – a low carbon rim is present on the outside of the steel; no longer made in Australia.
S	"Semi-Killed" – standard grades of steel but with restricted carbon content ranges.
CS	"Commercial Semi-Killed" – standard grades of steel. Wide (0.10%) carbon content ranges.
K	"Fully Killed" – steel made with a high degree of internal cleanliness and chemical uniformity.

TABLE 8: CURRENT STEELMAKING PRACTICES

Old Prefix	New Prefix	Practice	Example of Old Prefix	Example of New Prefix
R	U	Steel with unspecified deoxidation	R1008	U1004
S	U	(no minimum % Si specified)	S1010	S1010
CS	M	Merchant Quality. Similar to 'U' with wider composition range	CS1020	CS1020
K	No Prefix	As per relevant table in Standard	K1040	K1040
X	X	A major deviation in chemical composition from AISI-SAE grades	XK1320	XK1320

Note: Free machining grades are an exception. The S has been dropped with no prefix to replace it, eg. S1214 has become 1214.

Modification Symbols

i) For lead-bearing steels, the letter "L" is used to indicate that the steel contains lead, and is placed between the second and third characters of the four-digit series designation.

ii) For aluminium-killed steels, the letter "A" is placed between the second and third characters of the four-digit series designation.

iii) For boron-treated steels, the letter "B" is placed between the second and third characters of the four-digit series designation.

iv) For micro-alloyed steels, the letter "M" is placed between the second and third characters of the four-digit series designation.

Examples of designation: AS 1443/12L14, AS 1443/10A10, AS 1443/10B22, AS 1443/10M40, AS 1443/X1038.

Surface Finish

The Surface Condition or maximum allowable surface defect depth is designated by the suffix in the full grade name.

Commercial Finish	- No suffix e.g. M1020
'B' Condition	- B suffix S1214B
'F' Condition	- F suffix AS 1443/1045F

Austenite Grain Size

The following designations consisting of suffix letters 'CG' or 'FG' indicate the austenitic grain size of the steel as defined in AS 1733:

a) CG: Coarse grained
b) FG: Fine

Examples of designation: AS 1443/1030FFG

Note: The absence of these suffix letters indicates that the steel may be coarse-grained or fine-grained at the supplier's option.

Steels with prefix 'U' or 'M' are not subject to austenite grain size specification.

4.4.2 Carbon Steels Supplied to Chemical Composition and Mechanical Properties

In practice, most steels supplied to mechanical properties are covered by an individually negotiated specification for a particular customer. There are, however, standard grades in AS 1443, to which MMB can supply eg. AS 1443 D4.

TABLE 9: NEAREST GRADE EQUIVALENTS CARBON & ALLOY STEELS							
Australian	**USA**		**British**		**German**		**Japanese**
	AISI-SAE ASTM	**UNS NO.**	**BS970**	**Old En Series**	**Werkstoff Nr.**	**DIN**	**JIS**
1004	1005	G10050	040A04	En2A	-	-	-
1010	1010	G10100	045M10	En32A	1.0301 1.1121	C10 Ck10	S10C
1020	1020	G10200	070M20	En3B	1.0402	C22	S220C
1030	1030	G10300	080M30	En5,6,6A	1.0528 1.1178	C30 Ck30	S30C
1040	1040	G10400	080M40	En8	1.1186	Ck40	S40C
1045	1045	G10450	080A47	En43B	1.0503 1.1191	C45 Ck45	S45C
1050	1050	G10500	080M50	En43C	1.0540 1.1206	C50 Ck50	S50C
12L14	12L14	G12144	230M07 leaded	En1A leaded	1.0718	9SMnPb28	SUM22L
1214	1215, 1213*	G12130	220M07	En1A	1.0715	9SMn28	SUM22
1137	1137	G1370	216M36	-	1.0726	35S20	SUM41
1146	1146	G11460	212A42	-	1.0727	45S20	SUM42
X1320	1320	-	150M19	En14A	1.0499	21Mn6Al	SMn420
X1340	1340	G13400	150M36	En15B	-	-	SMn438 SMn443
1022	1022	G10220	080A20	-	1.1133	GS-20Mn5	SMnC420
8620	8620	G86200	805H20	En325	1.6523	21NiCrMo2	SNCM220(H)
4140	4140	41400	708M40	En19A	1.7225	42CrMo4	SCM440(H)

* GRADE 1214 DOES NOT EXIST UNDER THE AISI-SAE SYSTEM

5.0 Bright Bar Product Range – Sections, Tolerances & Grades

5.1 Marbrite® Carbon and Low Alloy Bright Steel Bars and Marcrome® Hard Chrome Bar Size Range

TABLE 10: SIZE RANGE

Production Method	Shapes	Sizes (mm)		Standard Nominal Lengths
Cold Drawn	Rounds ●	Diameter	4.76 to 63.5	3.5m or 6.0m
	Hexagons ⬣	Across Flat (AF)	7.46 to 70	3.5m
	Squares ■	Across Flat (AF)	4.76 to 150	3.5m
Turned & Polished	Rounds ●	Diameter	25 to 260	3.5m or 6.0m
Cold Finished	Flats ▬	Width	10 to 152	3.5m
		Thickness	3 to 50	
Chromed	Rounds ●	Diameter	19.05 to 152.4	5.6m

Note: Generally, carbon steels are manufactured in nominal 6m lengths and free machining steels in nominal 3.5 m lengths. Other sizes, shapes, grades and lengths may be available upon enquiry. eg. Round with flats, triangle, fluted square, trapezium, bevelled flat, rounded hexagon, octagon, etc.

5.2 Marbrite® Preferred Standard Size and Grades

MMB products are manufactured in a wide range of both hard and soft metric sizes.
Non-standard sizes' availability depends on tooling (dies) and economically viable order quantity.

Some combinations of standard size and grade are not readily available. Enquires for sizes not listed should be made through our Sales Department.

SIZE 11A: MARBRITE® BRIGHT STEEL STANDARD SIZES – ROUNDS

Rounds (mm)		1020	1030	1045	1214	12L14
7.94	5/16″	✓	✓		✓	✓
8.00		✓	✓		✓	✓
9.52	3/8″	✓	✓		✓	✓
10.00		✓	✓	✓	✓	✓
11.11	7/16″				✓	✓
12.00		✓	✓		✓	✓
12.70	1/2″	✓	✓	✓	✓	✓
14.00					✓	✓
14.29	9/16″	✓	✓		✓	✓
15.00					✓	✓
15.87	5/8″	✓	✓	✓	✓	✓
16.00		✓	✓	✓	✓	✓
17.00						✓
17.46	11/16″				✓	✓
18.00					✓	✓
19.00						✓
19.05	3/4″	✓	✓	✓	✓	✓
20.00		✓	✓	✓	✓	✓
20.64	13/16″				✓	✓
22.00					✓	✓
22.22	7/8″	✓	✓	✓	✓	✓
23.81	15/16″				✓	✓
24.00						✓
25.00		✓	✓	✓	✓	✓
25.40	1″	✓	✓	✓	✓	✓
27.00					✓	✓
28.57	1 1/8″	✓	✓	✓	✓	✓
30.00		✓	✓	✓	✓	✓
31.75	1 1/4″	✓	✓	✓	✓	✓

EFFECTIVE 01.10.02 – All material available ex stock in standard lengths only.

TABLE 11B: MARBRITE® BRIGHT STEEL STANDARD SIZES – ROUNDS

Rounds (mm)		1020	1030	1045	1214	12L14
32.00					✓	
34.92	1⅜″	✓	✓	✓	✓	✓
35.00		✓	✓	✓	✓	✓
36.00					✓	✓
38.10	1½″	✓	✓	✓	✓	✓
39.00					✓	✓
40.00		✓	✓	✓	✓	✓
41.27	1⅝″				✓	✓
44.45	1¾″	✓	✓	✓	✓	✓
45.00		✓	✓	✓	✓	
47.62	1⅞″				✓	✓
50.00		✓	✓	✓	✓	✓
50.80	2″	✓	✓	✓	✓	✓
53.97	2⅛″				✓	✓
55.00					✓	✓
57.15	2¼″		✓		✓	✓
60.00		✓	✓	✓	✓	✓
60.32	2⅜″					✓
63.50	2½″	✓	✓	✓	✓	✓
65.00		✓	✓	✓	✓	
69.85	2¾″				✓	
70.00		✓	✓	✓	✓	
75.00		✓	✓	✓	✓	
76.20	3″	✓	✓	✓	✓	
80.00		✓	✓	✓	✓	
88.90	3½″	✓	✓	✓	✓	
90.00		✓	✓	✓	✓	
100.00		✓	✓	✓	✓	
101.60	4″	✓	✓	✓	✓	
114.30	4½″	✓				
127.00	5″	✓			✓	
152.40	6″	✓			✓	
160.00*		✓				
165.10*	6½″	✓				
177.80*	7″	✓				
190.50*	7½″	✓				
200.00*		✓				
203.20	8″	✓				

TABLE 12: MARBRITE® BRIGHT STEEL STANDARD SIZES – HEXAGONS			
Hexagons		1214	12L14
11.11	7/16″	✓	✓
12.70	½″		✓
13.00			✓
14.29	9/16″		✓
15.87	⅝″	✓	✓
17.00			✓
17.46	11/16″	✓	✓
19.00			✓
19.05	¾″	✓	✓
20.64	13/16″	✓	✓
22.00			✓
22.22	⅞″	✓	✓
23.81	15/16″		✓
24.00			✓
25.40	1″	✓	✓
26.99	1 1/16″	✓	✓
28.57	1⅛″	✓	✓
30.00		✓	✓
31.75	1¼″	✓	✓
34.92	1⅜″	✓	✓
36.00		✓	✓
38.10	1½″	✓	✓
42.42		✓	✓
44.45	1¾″	✓	✓
50.80	2″	✓	✓
52.07			✓
55.00		✓	
61.21		✓	✓

TABLE13: MARBRITE® BRIGHT STEEL STANDARD SIZES – SQUARES			
Squares (mm)		1020	1214
6.35	¼″		
7.94	5/16″		✓
9.52			✓
12.70	½″		✓
15.87	⅝″		✓
16.00			✓
19.05	¾″		✓
22.22	⅞″		✓
25.00			✓
25.40	1″		✓
28.57	1⅛″		✓
31.75	1¼″	✓	✓
38.10	1½″		✓
50.00		✓	✓
50.80	2″	✓	✓
63.50	2½″		✓
46.20	3″	✓	✓
101.60	4″	✓	

TABLE 14: MARBRITE® BRIGHT STEEL STANDARD SIZES – FLATS							
Flats	Thickness (mm)						
Width (mm)	3	5	7	10	15	20	25
12		✓					
16	✓	✓					
20	✓	✓		✓			
25		✓	✓	✓	✓		
32		✓	✓	✓	✓	✓	✓
40		✓	✓	✓	✓	✓	✓
50		✓	✓	✓	✓	✓	✓
75		✓		✓	✓	✓	✓
100				✓	✓	✓	✓

TABLE 15: MARBRITE® BRIGHT STEEL STANDARD SIZES – FLATS							
Flats		Thickness (mm)					
Width (mm)		6.35 ¼"	12.70 ½"	25.40 1"	31.75 1¼"	38.10 1½"	50.80 2"
25.40	1″	✓	✓				
31.75	1¼″	✓	✓				
38.10	1½″	✓	✓	✓			
44.45	1¾″	✓			✓		
50.80	2″		✓	✓	✓	✓	
76.20	3″		✓	✓	✓	✓	✓
101.60	4"			✓	✓	✓	✓
152.40	5"			✓			

3mm, 5mm and 7mm thickness – available in 1004 grade.
10mm thickness and above – available in 1020 grade.

5.3 Marcrome® Hard Chrome and Induction Hardened Round Bar Preferred Sizes

Any of the above standard sizes in the range 19.05–152.4 mm diameter (127 mm max for induction hardened bar) includes 25 minimum thickness chrome layer.

5.4 Dimensional Tolerances

Tolerances in this section are derived from Australian Standards AS 1443 and AS 1444.

TABLE 16: STANDARD CROSS-SECTIONAL TOLERANCE FOR BRIGHT STEELS

Form and Condition – Bright Bars					
Rounds			Square	Hexagonal	Flat (see Note 4)
Precision Ground	Cold Drawn	Turned & Polished			
h8	h10	h11	h11	h11	h11

TABLE 17: CROSS-SECTIONAL DIMENSION TOLERANCES

Specified Diameter or Cross-Sectional Dimension		Tolerance Grade (mm)											
		h7		h8		h9		h10		h11		h12	
	≤ 3	+0,	-0.010	+0,	-0.014	+0,	-0.025	+0,	-0.040	+0,	-0.060	+0,	-0.100
>3	≤ 6	+0,	-0.012	+0,	-0.018	+0,	-0.030	+0,	-0.048	+0,	-0.075	+0,	-0.120
>6	≤ 10	+0,	-0.015	+0,	-0.022	+0,	-0.036	+0,	-0.058	+0,	-0.090	+0,	-0.150
>10	≤ 18	+0,	-0.018	+0,	-0.027	+0,	-0.043	+0,	-0.070	+0,	-0.110	+0,	-0.180
>18	≤ 30	+0,	-0.021	+0,	-0.033	+0,	-0.052	+0,	-0.084	+0,	-0.130	+0,	-0.210
>30	≤ 50	+0,	-0.025	+0,	-0.039	+0,	-0.062	+0,	-0.100	+0,	-0.160	+0,	-0.250
>50	≤ 80	+0,	-0.030	+0,	-0.046	+0,	-0.074	+0,	-0.120	+0,	-0.190	+0,	-0.300
>80	≤ 120	+0,	-0.035	+0,	-0.054	+0,	-0.087	+0,	-0.140	+0,	-0.220	+0,	-0.350
>120	≤ 180	+0,	-0.040	+0,	-0.063	+0,	-0.100	+0,	-0.160	+0,	-0.250	+0,	-0.400
>180	≤ 250	+0,	-0.046	+0,	-0.072	+0,	-0.115	+0,	-0.185	+0,	-0.290	+0,	-0.460
>250	≤ 315	+0,	-0.052	+0,	-0.081	+0,	-0.130	+0,	-0.210	+0,	-0.320	+0,	-0.520

* These tolerance values have been derived from AS 1654

Notes:

1. Out-of-round, out-of-hexagon and out-of-square bars have tolerances equal to one half of the tolerance band.
2. The diameter should be measured at a distance of at least 150 mm from the end of the product (as per AS 1443).
3. Cross-sectional dimensions may be checked using instruments such as limit gap gauges, micrometers, callipers and three-point measuring devices. Measurement is carried out at room temperature.
4. Width tolerances are generally not applied to Bar Cold Rolled Flats up to 7 mm thick.
   Indicative width variations for bar cold rolled flats are:
   up to 25mm ± 0.4mm, over 25 to 50mm ± 0.8mm, over 50mm to 100mm + 1.6/ -0.8mm
5. For applications requiring greater precision, h7 may be specified for precision ground, h9 for cold drawn and/or h10 for turned and polished, but this is subject to negotiation prior to order placement.

5.5 Length Tolerances

Bars may be in the cropped, saw cut or chamfered form.

TABLE 18: LENGTH TOLERANCE

Length Category	Length		Length Details to be Specified
	Nominal range (m)	Tolerance (mm)	
Mill length	3.5 or 6.0	±250	nominal length
Set length	3.0 to 7.0	-0, +50	nominal length

Note: For mill length, bars having a total mass of up to 10% of the quantity supplied may be shorter but no less that 3.0 metres.

5.6 Straightness Tolerances

TABLE 19: STRAIGHTNESS TOLERANCE FOR BARS FOR COMMERCIAL APPLICATIONS

Section	Steel Type	Maximum permissible deviation from Straight Line (mm)
Rounds	Grades with < 0.25% carbon Grades with ≥ 0.25% carbon, alloys and all heat treated grades	1 in 1000 1 in 500
Squares & Hexagons	All grades	1 in 375
Flats	All grades	1 in 375

Commercial straightness is satisfactory for common, automatic machining applications. Higher levels of straightness usually involve extra operations and additional cost.

Straightness tolerances for critical applications

For round bars less than 25mm in diameter, the maximum deviation from straightness shall be less than 0.1 mm in 300mm (1:3000).

For precision ground and hard chromed bar, the maximum straightness deviation shall be less than 0.30mm over one (1) metre. Other tolerances may be agreed, subject to enquiry.

Notes:

1. Total indicator readings with T.I.R. Gauges are considered to measure twice the amount of deviation from a straight line.
2. All straightness measurements should be taken at least 50mm from the end of the bar.
3. Cold drawn bar can exhibit "memory", particularly in harder grades, drawn from coiled feed. It can tend to slowly curl up at the ends, in storage. In addition, machining operations can upset the balance of residual stress in bright bar and cause distortion, particularly machining processes which do not remove material evenly around the circumference eg. Machining of key ways.

5.7 Surface Quality

5.7.1 Cold Drawn and Cold Rolled Bars

The maximum permissible depth of surface imperfections for these bars is shown under 'B' condition in the following table. Due account should be taken of this in subsequent machining of components. Where specific assurance of maximum surface defect levels and relative freedom from defects is required, material can be supplied crack tested, subject to negotiation. Other conditions may be available upon enquiry.

5.7.2 Turned and Polished or Precision Ground Bars

The metal removed from the surface during the manufacture of turned and polished or precision ground bars should be sufficient to ensure freedom from surface defects of steel making or hot rolling origin.

5.7.3 Surface Roughness

Australian Standards do not specify a surface roughness value.
The following figures are given as a guide only:

Cold drawn bars	0.1–0.8 microns Ra
Turned and polished bars	0.2–0.7 microns Ra
Precision ground bars	0.2–0.7 microns Ra
Hard chromed bars	0.1–0.3 microns Ra

5.8 Hard Chrome Marcrome®

5.8.1 1045, 1045 Induction Hardened or 4140

Base material with a microcracked chromium deposit of a minimum thickness of 25 microns (0.025mm or 0.001").
As chromed surface hardness 1,000–1,150 HV.

5.8.2 Induction Hardened Chrome Bar – 1045 Base Material

Case depth 3mm approx.
Case Hardness 55–65 HRc

5.8.3 Diameter Tolerances

Over 19.05mm to 50.8mm	+ Nil, - 0.03mm
Over 50.8mm to 101.6mm	+ Nil, -0.05mm
Over 101.6mm to 152.0mm	+ Nil, -0.07mm

TABLE 20: MAXIMUM ALLOWABLE SURFACE DEFECT DEPTH (MM)

Diameter (mm) *		Thickness of Flats	Surface Condition/Maximum Depth		
Rods	Rounds		Commercial	B	F
-		3	0.40	0.20	0.10
-		5	0.40	0.20	0.10
5.5		-	0.40	0.20	0.10
-		-	0.40	0.20	0.10
6.5		-	0.40	0.21	0.11
7.0		-	0.40	0.21	0.11
7.5		-	0.40	0.22	0.12
8.0		8	0.40	0.22	0.12
9.0		-	0.40	0.23	0.13
10.0	10	10	0.40	0.23	0.13
11.2	-	-	0.45	0.24	0.14
-	12	12	0.40	0.25	0.15
12.5	-	-	0.50	0.25	0.15
	14	-	0.56	0.26	0.16
	16	16	0.64	0.27	0.17
	18	-	0.72	0.29	0.19
	20	20	0.80	0.30	0.20
	22	-	0.96	0.33	0.21
	24	-	1.00	0.36	0.22
		25	1.08	0.37	0.22
	27	-	1.20	0.42	0.23
	30	-	1.28	0.45	0.24
	-	32	1.32	0.48	0.24
	33	-	1.44	0.49	0.25
	36	-	1.56	0.54	0.26
	39	-	1.60	0.59	0.27
	-	40	1.60	0.60	0.27
	42	-	1.60	0.63	0.28
	45	-	1.60	0.68	0.29
	48	-	1.60	0.72	0.39
	50	50	1.60	0.75	0.30
	56	-	1.60	0.84	0.32
	60	-	1.60	0.90	0.34
	65	-	1.60	0.98	0.35
	70	-	1.60	1.05	0.37
	75	-	1.60	1.13	0.38
	80	-	1.60	1.20	0.40
	90	-	1.60	1.20	0.40
	100	-	1.60	1.20	0.40

* Diameter of hot rolled feed from which the cold finished bar is manufactured

The maximum allowable surface defect in squares and hexagons is the same as for the equivalent cross-section eg: 24mm square corresponds to 24mm diameter round.

5.9 Steel Grades – Chemical Composition

TABLE 21: FREE MACHINING GRADES

Grade Designation AS 1443	Chemical Composition (cast analysis), %									
	Carbon		Silicon		Manganese		Phosphorus		Sulphur	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1137	0.32	0.39	0.10	0.35	1.35	1.65	-	0.040	0.08	0.13
1146	0.42	0.49	0.10	0.35	0.70	1.00	-	0.040	0.08	0.13
1214	-	0.15	-	0.10	0.80	1.20	0.04	0.09	0.25	0.35
12L14*	-	0.15	-	0.10	0.80	1.20	0.04	0.09	0.25	0.35

* For lead-bearing steels, the lead content is 0.15% to 0.35%.

TABLE 22: MERCHANT QUALITY STEELS

Grade Designation AS 1443	Chemical Composition (cast analysis), %						
	Carbon		Silicon	Manganese		Phosphorus	Sulphur
	Min	Max	Max	Min	Max	Max	Max
M1020	0.15	0.25	0.35	0.30	0.90	0.050	0.050
M1030	0.25	0.35	0.35	0.30	0.90	0.050	0.050

Note: These grades are not subject to product analysis or grain size requirements.

TABLE 23: CARBON STEELS

Grade Designation AS 1443	Chemical Composition (cast analysis), %							
	Carbon		Silicon		Manganese		Phosphorus	Sulphur
	Min	Max	Min	Max	Min	Max	Max	Max
1004	-	0.06	0.10	0.35	0.25	0.50	0.040	0.040
1010	0.08	0.13	0.10	0.35	0.30	0.60	0.040	0.040
1020	0.18	0.23	0.10	0.35	0.30	0.60	0.040	0.040
1022	0.18	0.23	0.10	0.35	0.70	1.00	0.040	0.040
1030	0.28	0.34	0.10	0.35	0.60	0.90	0.040	0.040
1035	0.32	0.38	0.10	0.35	0.60	0.90	0.040	0.040
1040	0.37	0.44	0.10	0.35	0.60	0.90	0.040	0.040
1045	0.43	0.50	0.10	0.35	0.60	0.90	0.040	0.040
1050	0.48	0.55	0.10	0.35	0.60	0.90	0.040	0.040

TABLE 24: CARBON MANGANESE STEELS

Grade Designation AS 1443	Chemical Composition (cast analysis), %							
	Carbon		Silicon		Manganese		Phosphorus	Sulphur
	Min	Max	Min	Max	Min	Max	Max	Max
X1320	0.18	0.23	0.10	0.35	1.40	1.70	0.040	0.040
X1340	0.38	0.43	0.10	0.35	1.40	1.70	0.040	0.040

TABLE 25: LOW ALLOY STEELS

Grade AS 1444	Chemical Composition (cast analysis), %													
	Carbon		Silicon		Manganese		Phosphorus	Sulphur	Chromium		Molybdenum		Nickel	
	Min	Max	Min	Max	Min	Max	Max	Max	Min	Max	Min	Max	Min	Max
4140	0.38	0.43	0.10	0.35	0.75	1.00	0.040	0.040	0.80	1.10	0.15	0.25	-	-
8620	0.18	0.23	0.10	0.35	0.70	0.90	0.040	0.040	0.40	0.60	0.15	0.25	0.40	0.70

5.10 Mechanical Properties

The preceding grades are supplied to "Chemistry only" specifications. Indicative minimum mechanical properties are shown in the relevant grade data sheets in Appendix 1.

The mechanical properties for a particular chemical composition are dependent on:

- The condition of the steel prior to cold finishing. Is it hot rolled, annealed or hardened and tempered?
- The amount of reduction (draft) during cold drawing. The greater the reduction the higher the strength and lower the ductility.
- Turned and polished and/or precision ground, bar will exhibit the same mechanical properties as the feed used prior to cold finishing.

The sheer strength of bright bar is not usually specified. It is generally analogous with tensile strength and so as a "rule of thumb" is considered to be to 75% of the tensile strength.

4140 is a low alloy steel usually supplied quenched and tempered to condition "T".

5.11 Steel Specification Summary

TABLE 26: STEEL SPECIFICATION SUMMARY

Classification	Grade Name	Chemical Composition							Indicative Minimum Mechanical Properties							
									Tensile Strength (MPa)				Elongation (%)			
									Cold Drawn			Turned	Cold Drawn			Turned
		% C	% Mn	% Si	% P	% S	% Cr	% Mo	<16mm	16 to <38mm	38 to 63.5mm	≤250mm	<16mm	16 to <38mm	38 to 63.5mm	≤250mm
Plain Low Carbon Cold Forming Steels	U1004	0.06 max.	0.25 /0.50	0.35 max.	0.04 max.	0.04 max.	0.30 max.	0.10 max.	Mechanical Properties not usually specified							
	U1010	0.08 /0.13	0.30 /0.60	0.35 max.	0.04 max.	0.04 max.	0.30 max.	0.10 max.	385	370	355	325	13	17	17	22
Plain Carbon Merchant Quality Steels	M1020	0.15 /0.25	0.30 /0.90	0.35 max.	0.05 max.	0.05 max.	0.30 max.	0.10 max.	480	460	430	410	12	12	13	22
	M1030	0.25 /0.35	0.30 /0.90	0.35 max.	0.05 max.	0.05 max.	0.30 max.	0.10 max.	560	540	520	500	10	11	12	20
Fully Killed Plain Carbon Steel	1045	0.43 /0.50	0.60 /0.90	0.10 /0.35	0.04 max.	0.04 max.	0.30 max.	0.10 max.	690	650	640	600	7	8	14	
Free Machining Steels	1214	0.15 max.	0.80 /1.20	0.10 max.	0.04 /0.09	0.25 /0.35	0.30 max.	0.10 max.	480	430	400	370	7	8	9	17
	12L14	0.15 max.	0.80 /1.20	0.10 max.	0.04 /0.09	0.25 /0.35	0.30 max.	0.10 max.	480	430	400	370	7	8	9	17
Medium Carbon Free Machining Steels	1137	0.32 /0.39	1.35 /1.65	0.10 /0.35	0.04 max.	0.08 /0.13	0.30 max.	0.10 max.	660	640	620	600	7	7	8	14
	1146	0.42 /0.49	0.70 /1.00	0.10 /0.35	0.04 max.	0.08 /0.13	0.30 max.	0.10 max.	680	650	620	585	7	7	8	13
Carbon Manganese Steels	X1320	0.18 /0.23	1.40 /1.70	0.10 /0.35	0.04 max.	0.04 max.	0.30 max.	0.10 max.	620	590	555	525	10	12	12	18
	X1340	0.38 /0.43	1.40 /1.70	0.10 /0.35	0.04 max.	0.04 max.	0.30 max.	0.10 max.	770	740	710	680	9	9	9	18
Low Alloy Chrome-Moly	4140T	0.37 /0.44	0.65 /1.10	0.10 /0.35	0.04 max.	0.04 max.	0.75 /1.20	0.15 /0.30	850	850	850	850	9	9	9	13

OTHER GRADES MAY BE AVAILABLE SUBJECT TO ENQUIRY.

Please ring Milltech Martin Bright Customer Service on 1800 333 163 for further information.

5.12 Product Identification – Grade Colour Codes

These are painted on the ends of bars.

TABLE 27 : MARBRITE®	
DESIGNATION GRADE	COLOUR ONE END
1010	Black (BS5252 00E53)
1020	Custard (AS2700 Y22)
1030	White (BS5252 00E55)
1040	Golden Tan (AS2700 X53)
1045	No paint Grade not allocated a colour
1214	Rose Pink (AS2700 R25)
12L14	Violet (AS2700 P13)
1146	Marigold (AS 2700 X13)

Standard Referenced – AS700 – 1985, BS5252 – 1976

TABLE 28 : MARCROME®	
DESIGNATION GRADE	COLOUR ONE END
1045	Red
4140 HARDENED & TEMPERED	Green
1045 INDUCTIONED HARDENED	Yellow

Hard chrome bars have coloured end plugs on the tubular cardboard packaging.

6.0 Selection of Bright Bars

6.1 Selection of Marbrite®

The responsibility for the selection of a suitable MMB product remains with the purchaser. However, this document contains some information which may assist this process.

In addition, our qualified technical staff are available to provide assistance.

6.1.1 Selection of Size and Shape

The specification of relatively common sizes and shapes facilitates continuity of supply and low cost. "Marbrite® – Product Range" contains information on sizes and shapes but we also strongly recommend that a MMB merchant is contacted in the early stages of design so that the specification of products not normally carried in stock can be avoided, where possible.

Sometimes costly machining operations can be reduced by utilising the excellent finish and close tolerances of bright bar together with the ability to produce special shapes.

The maximum permissible imperfection depth should be considered when calculating the bright bar size to suit a particular machined finished size.

6.1.2 Selection of Grades

This decision can have extensive ramifications and it should not be made lightly, especially where issues of safety are involved.

The checklist below may be useful.

1. Rules and regulations. Are any applicable to the decision of grade selection? eg. products covered by industry codes, standards, Government regulations etc.
2. Previous experience. Has the product been manufactured before by this method? If so, what grade was used and how did it perform? Is there a traditional grade for this product? See the documents on the application of Bright Steel for more information.
3. Specifications. Is there a drawing for the product with a material specification?
4. Performance Criteria. The following issues should be addressed:
   - Mechanical Properties. Are these critical to processing or end use? Is the expense of mechanical testing justified? eg. ductility is needed for thread rolling or crimping.
   - Machinability. How much machining is involved and can mechanical properties be compromised for the sake of machinability, by the use of free-cutting grades?
   - Weldability. Is this required?
   - Hardenability. Is the heat treatment to a specification required? MMB can advise on heat treatment data for particular grades.
   - Case Hardenable. Generally, material of over 0.30% carbon is not suitable for carburising. There are a wide variety of alternative hardening processes eg. nitriding or carbo-nitriding may be considered. MMB can assist with advice on this subject.

- Corrosion resistance and special environments. Is this an issue? Is there any special environment?

5. Physical Properties. For some products the following properties may be important:
   - Magnetic
   - Electrical
6. Availability and cost. The availability of a grade in a particular size can vary greatly, from supply in single bars ex-merchant stock, to a minimum order quantity of 120 tonnes and a 6 month lead time. MMB recommend that our merchants are contacted regarding availability and cost of grades.

6.1.3 Other Requirements

Straightness Critical

Commercial straightness may not be adequate for applications such as pump shafts and electric motor spindles, and is therefore subject to negotiation prior to placement of order.

Electroplating

To achieve a premium quality electroplated finish MMB recommend the use of ground bar, or bright bar which has been further prepared by polishing, grinding or linishing. It is acknowledged, however, that a large number of electroplating jobs do not require a premium quality and cannot tolerate additional preparation costs.

MMB request that, in such cases, the order is endorsed "suitable for electroplating" and we will endeavour to produce a bright drawn bar fit for the purpose of plating, as received. However, we are not able to guarantee performance in plating.

Decarburisation

Decarburisation can influence surface hardness. Where appropriate, a specification can be negotiated for decarburisation.

Austenite Grain Size

For some grades of carbon and low alloy steel, austenite grain size is specifiable although it is generally not necessary for commercial bright bar.

Condition of the Steel

The hardness and ductility of bright steel can be varied by altering the level of cold work (draft) or by the use of heat treatment. For some applications, where these properties are critical, feed size may be stipulated or heat treatment may be requested. MMB can stress relieve, sub-critically anneal, strain age or induction harden but we do not have quench and temper facilities.

7.0 Purchasing Guidelines

7.1 Information Required for Ordering Milltech Martin Bright Products

7.1.1 Carbon, Low Alloy Steels and Stainless Steels for Commercial Products as per MMB Price List

Order No.	(eg. ON44980)
Size	(eg. 25.4 mm)
Shape	(eg. Round)
Grade	(eg. M1020)
Condition	(eg. Cold Drawn)
Length	(eg. 3.5 m mill lengths)
Quantity	(eg. 1 tonne) (MMB standard bundles are 1 tonne)
Delivery Details	(eg. Week 36)
Chamfering	(eg. Yes or No)
Packaging	see section 7.2

In addition other requirements can be invoked by:

1. Specifying the MMB DMS or Route Sheet No., or
2. Identifying the end user (eg. ACC, ACME ENG.)

Our DMS Systems contains instructions such as:

- Grade check
- Non destructive Eddy current testing
- Heat treatment
- Special packing
- Saw cutting
- Additional measurements
- Mechanical testing

7.1.2 Hard Chrome Bar 1045 as per MMB Price List

Order	(eg. ON44980)
Size	(eg. 25.4 mm)
Length	(eg. 6.0 m) (allow 100 mm at each end unchromed)
Quantity	(eg. 1 tonne)
Delivery Details	(eg. Week 36)

Alternatives to be considered are:

- Other grades (eg. 4140)
- Induction hardening
- Thickness of chrome other than 25 micron (0.001")

Milltech Martin Bright is a manufacturer of bright steel products, not a merchant. Domestic sales enquiries for MMB product should be directed through one of our merchants. Should assistance be required in locating a merchant, our Sales Department is available to help.

7.2 Packaging

Unless otherwise specified, all Marbrite® is packed in oiled bundles and strap tied.

All Marcrome® is packed in individually wrapped cardboard tubes and boxed in non-returnable timber cases lines with a water resistant polyvinyl sheet.

Unless otherwise specified, all Precision Ground product is individually bar wrapped (paper), then enveloped in a sheet of water resistant material, with timber battens strapped to the outside of the bundle.

8.0 Application of Bright Steel Products

8.1 Marbrite® Advantages

Smooth, Clean, Scale Free Surface

This is important in machining operations because scale is hard and abrasive and blunts cutting tools. Bright bar's smooth surface also makes it suitable for metal finishing processes with minimal preparation. eg. painting, phosphating, electroplating.

Close Tolerance on Section

Compared with Hot Rolled Steel, the tolerance band is reduced by over 50%. This characteristic is often advantageous in component manufacture where a portion of the original bright bar surface may be an integral part of the component. In precision ground bright bar, bearings may be fitted directly onto the bar.

Superior Straightness

Commercial quality bright bar is straight enough for use as feed for multi spindle and CNC machines. In addition, bright bar can be produced for straightness critical applications such as pump shafting and electric motor spindles.

Control of Surface Defects

Steel in the hot rolled condition is difficult to inspect for surface defects. When converted to bright bar, inspection is facilitated. In addition to visual techniques, eddy current, ultrasonic and magnetic particle methods are used.

Increased Hardness, Strength and Springiness (in cold drawn and cold rolled bar)

Work hardening, which occurs during cold drawing or cold rolling, improves mechanical properties. This factor can be exploited to achieve economy in engineering design.

Improved Machinability (in cold drawn and cold rolled bar)

The work hardening of the matrix in low carbon, free machining grades improves machinability because chip breakage is encouraged. This can have significant economic benefits, in terms of reduced component production cycle times.

Wide Variety of Shapes

Bright bar, can be produced in a huge range of shapes from the common geometric shapes such as circles, triangles, squares, hexagons and octagons to special variations such as rounds with flats, D sections and fluted sections.

Removal of Surface Defects and Decarburisation (Turned Bar only)

In some components the absence of surface defects is absolutely critical. Because turning removes the hot rolled skin, surface defects and decarburisation can be effectively eliminated. Surface hardness can be adversely influenced by decarburisation.

8.2 Marbrite® Handling and Storage

Milltech Martin Bright takes all reasonable precautions to preserve product quality. All Marbrite® carbon steel products, including Marcrome® hard chrome bar, are supplied with a protective coating of waxy oil corrosion preventative. This will provide up to 6 months protection against corrosion when the product is kept dry and away from corrosive fumes.

Guidelines

1. Always ensure that lifting equipment is suitable, safe, capable of lifting the weight and operated by qualified and competent people.
2. Sling the product with material which will not damage the surface. For bright bars with standard packaging, textile slings are preferable, provided there is no cutting hazard. Do not use chains.
3. Take care not to accidentally tear off identification tags and maintain identification and traceability of part bundles.
4. Store in an area protected from weather and corrosive fumes eg. warehouse racking with dunnage on all surfaces to avoid metal to metal contact. Premature rusting can result from rubbing or scuffing of the oil coating; contact with wet or "green" timber dunnage; wetting from roof leaks, driving rain and condensation.
5. Standard (1 Tonne) bundles may be stacked up to 6 high, separated with dunnage provided that the bearers are vertically aligned so that distortion of the bundle is minimised. 3.5m bars need a minimum of 2 supports and 6 m bars need 3 supports.
6. Inspect bright stock for deterioration at least every month. Advice on corrosion protection is available from MMB.
7. Precision ground and hard chrome bars should be handled carefully and not allowed to "clash". Plastic rings or other inserts are a useful precaution against clashing. Where the product is tubed, do not allow the tube to be heated or wet as this can lead to corrosion.
8. All transport for bright bar should have substantial "end boards" to protect from "spearing" in a sudden stop or crash. Packing should be used under chains. All transport should also have weather protection.
9. Skewing of bars in bundles sometimes causes customers and users some concern. Our experience has been that this has minimal influence on straightness once the bar is removed. Snagging of the product, however, is a common source of bent bars.

8.3 Surface finishing

8.3.1 Electroplating

For a premium quality electroplate finish on Marbrite®, it is recommended that ground material is used or, alternatively, bright bar which has been further prepared by grinding, linishing, buffing or polishing.

8.3.2 Phosphating

All Marbrite® is suitable for phosphate coating. The process of phosphating involves complex surface chemistry. Care must be taken to thoroughly clean the steel and avoid contamination.

8.3.3 Hot Dip Galvanizing

Both silicon and phosphorus contents of steels can have major effects on the structure, appearance and properties of galvanised coatings.

As recommended by the Galvanizers Association of Australia, for a smooth bright galvanized coating, the following criteria should be applied:

% Si < 0.04%
and
%Si + (2.5 x %P) < 0.09%

Marbrite® Plain Carbon Grades like U1004 and U1010 are eminently suitable for hot dip galvanizing. M1020 may be suitable, provided the %Si is in the range 0.15 to 0.22%. Re-phosphurised grades like S1214 and S12L14 are not considered suitable for galvanizing.

Because Hot Dip Galvanizing involves heating to approx. 460°C it may affect the hardness and ductility of cold worked bars.

8.4 Machining

Machinability can be measured by one or any combination of the following attributes:

- Tool life
- Tool wear (part growth)
- Surface (roughness)
- Feeds and speeds achievable
- Swarf type

12L14 is MMB's premium free machining steel. It is a resulphurised, rephosphorised, leaded grade of low carbon steel. The reasons for its improved machinability over other low carbon grades are:

1. Manganese sulphide inclusions. The increased sulphur levels promote the formation of these inclusions. They improve machinability by acting as stress concentrators to initiate chip fracture. In addition, they provide a lubricating effect on the tool surface.
2. Phosphorus. This is present in solid solution in the steel. It embrittles the ferrite matrix which also assists in chip fracture.
3. Lead is present as discrete particles which attach themselves to the tails of the manganese sulphides. It then acts as a lubricant to the cutting process.

In addition, the embrittlement induced by cold drawing can be beneficial to chip breakage.

Although the higher phosphorus and sulphur levels are beneficial to machinability, they can be detrimental to mechanical properties – particularly ductility, impact toughness and fatigue resistance.

The additions of sulphur, phosphorus and lead do not preclude free cutting steels from the processes of case hardening and electroplating but welding of leaded steels is not recommended because of health concerns relating to toxic lead fumes.

Carbon levels of approximately 0.30% are thought to provide the most optimum machinability in plain carbon grades.

In plain low carbon steels the main factor influencing machinability is the reduced chip fracture. These steels are said to be "gummy". As the carbon level increases machinability is adversely affected by excessive abrasion in the harder steels.

Information on recommended machining parameters follows. This is derived from information previously supplied by BHP, and MMB acknowledge that many machinists see these guidelines as being very conservative, because better tools and lubricants are available today.

MMB have the resources of their metallurgical laboratory, should assistance be required in resolving machining difficulties. Attention to the following checklist will assist.

1. Where possible obtain samples of both "good" and "bad" machining:
   a) components
   b) original bright bar ends
   c) swarf.

2. Maintain traceability of "good" and "bad" material, preferably by MMB bundle number, or else by heat number.

Cutting Speeds and Feed for Standard High Speed Steel Tools
These tables are based on the use of high speed steel and are intended as a general guide only. When selecting speeds and feed the width and depth of cut, rigidity of machine, finish, tolerance and final diameter must be taken into consideration. Percentage Mean Relative Machinability Rating is based on AISI B 1112 as 100%.

TABLE 29: CUTTING DATA FOR TURNING, FORMING, PARTING OFF, CHASING AND THREADING

Grade	Mean Relative machina-bility %	Cutting Speed Surface m/min		Feed – mm/rev.					
		Turning Forming Part Off Chasing	Threading with Die or Tap	Forming	Parting Off: With Previous Breaking Down	Parting Off: Without Previous Breaking Down	Centring or Chamfering	Turning: Rough	Turning: Finish
Free Machining Steels									
1214	136	63–77	18–20	.04–.08	.08–.13	.04–.06	.20–.25	.15–.23	.08–.15
12L14	158	72–87	18–20	.04–.09	.08–.14	.07–.07	.23–.28	.17–.24	.08–.15
1137	61	27–36	3–15+	.02–.05	.04–.06	.02–.03	.10–.15	.08–.13	.04–.08
1146	70	26–34	3–15+	.02–.04	.04–.06	.02–.03	.10–.15	.08–.13	.04–.08
Carbon Steels									
1010	70	30–40	15-17	.02–.04	.05–.08	.02–.04	.10–.15	.10–.15	.08–.12
1020	72	31–42	10-13	.02–.04	.05–.08	.02–.04	.10–.15	.10–.15	.08–.12
1030	70	30–40	3–14+	.01–.03	.05–.08	.02–.04	.09–.13	.10–.15	.05–.10
1035	70	30–40	3–14+	.01–.03	.05–.08	.02–.04	.09–.13	.10–.15	.05–.10
1040	64	27–37	3–14+	.01–.03	.04–.08	.02–.04	.08–.10	.09–.14	.05–.10
1045	57	26–33	3–14+	.01–.03	.04–.06	.02–.03	.08–.10	.09–.14	.03–.08
Carbon Manganese Steels									
X1320	54	23–31	9–12	.01–.03	.04–.06	.02–.03	.09–.13	.08–.13	.08–.10
X1340 *	50	21–30	3–9+	.01–.02	.03–.05	.01–.02	.07–.11	.08–.10	.03–.08

* Annealed

TABLE 30: CUTTING DATA FOR DRILLING							
Grade	Mean Relative Machinability %	Cutting Speed Surface M/mm at Drill Periphery	Feed - mm / rev.				
			Drill Diam 1–3mm	Drill Diam 3–6mm	Drill Diam 6–12mm	Drill Diam 12–19mm	Drill Diam 19–25mm
Free Machining Steels							
1214	136	52–62	.02–.08	.08–.13	.13-.15	.15–.18	.18–.20
12L14	158	58–69	.03–.09	.09–.15	.15-.19	.20–.22	.22–.25
1137	61	22–29	.02–.04	.04–.08	.10-.12	.10–.13	.12–.14
1146	58	21–27	.02–.04	.04–.08	.08-.10	.09–.11	.11–.13
Carbon Steels							
1010	70	25–32	.03–.06	.06–.10	.10-.12	.12–.14	.11–.14
1020	72	26–33	.03–.06	.06–.10	.10-.12	.12–.14	.11–.14
1030	70	25–32	.03–.05	.05–.09	.09-.11	.11–.13	.11–.13
1035	70	25–32	.02–.04	.04–.08	.08-.10	.11–.13	.10–.12
1040	64	25–30	.02–.04	.04–.08	.08-.10	.11–.13	.10–.12
1045	57	20–26	.02–.04	.04–.08	.07-.09	.10–.12	.08–.10
Carbon Manganese Steels							
X1320	54	19-25	.02–.04	.04–.08	.08-.10	.10–.13	.09–.11
X1340*	50	18-23	.02–.03	.03–.06	.06-.08	.09–.12	.08–.10

* Annealed
Extracted from BHP Free Machining Steels Brochure May 1970.

8.5 Cold Forming

The degree to which bright bar can be cold formed by processes such as bending, flattening, crimping or swaging is mainly determined by the ductility of the material. The higher the carbon the less ductile. Cold drawn is generally less ductile than hot rolled.

Ductility is influenced by:

- Chemical composition (grade).
- Metallurgical history (steel mill finishing conditions, prior cold work, heat treatment, strain aging).
- Freedom from defects and imperfections (especially surface laps, scratches, burrs). These can initiate cracks on the outside of bends.

If fracture is a problem in cold forming the checklist below provides some possible remedies.

- Check tooling for unnecessary scoring, nicking, snagging, tearing and for lack of lubrication.
- Decrease extension of material by increasing inside bend radius.

- Metallurgical investigation of material for possible cause of low ductility.
- Change grade or condition of the material.
- Hot or warm form.

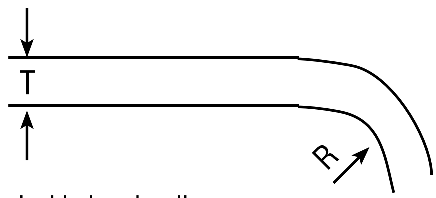
For low carbon lightly drawn ductile materials with reduction of area greater than 50%

$R_{min} = 0.33T$

For harder drawn material with reduction of area 40 to 50%

$R_{min} = 0.56T$

Where



R = inside bend radius
T = thickness of material

*Dieter "Mechanical Metallurgy" 2nd edition 1981 McGraw Hill.

8.6 Thread Rolling

The success of thread rolling is dependent upon the thread rolling machinery and the ductility of the bright bar. In general, all Marbrite® is capable of thread rolling but the lower carbon, softer grades are the most suitable.

There are formulae for calculating the blank diameter but actual performance may vary due to factors such as the hardness and toughness of the material and the nature of the thread rolling process.

Pitch Diam (mm)	Blank Diam (mm)	
	Normal Fit	Free Fit
6–13mm	+0.05	-0.05 to -0.08
Over 13mm	+0.08	-0.08 to -0.13

TABLE 31: APPROXIMATE BRIGHT BAR DIAMETERS FOR THREAD ROLLING

Metric (course pitch)		Imperial	
Nom. Size (mm)	Bar Diam. (mm)	No. Size (inch)	Bar Diam (mm)
6	5.4	1/8 BSW	2.69
8	7.24	3/16 BSW	3.99
10	9.07	1/4 BSW / UNC / UNF	5.69
12	10.93	5/16 BSW / UNC	6.93
16	14.76	5/16 UNF	7.19
20	18.43	3/8 BSW / UNC	8.41
24	22.12	3/8 UNF	8.76
30	27.79	7/16 BSW / UNC	9.83
		1/2 BSW / UNC	11.23
		1/2 UNF	11.79
		9/16 BSW / UNC	12.80
		9/16 UNF	13.28
		5/8 BSW / UNC	14.25
		5/8 UNF	14.88
		3/4 BSW / UNC	17.27
		3/4 UNF	17.91
		7/8 BSW / UNC	20.27
		7/8 UNF	20.93
		1 BSW / UNC	23.16
		1 UNF	23.88

8.7 Welding

The information contained in this section has been produced with the assistance of the Welding Technology Institute of Australia (WTIA) Ph. (02) 9748 4443.

Welding is a process, which has many variables that affect the quality of the outcome. Successful welding requires trained and competent operators, suitable consumable items and welding equipment together with correct joint design and welding procedures. MMB believes that this information may be useful to those developing their own procedures for the fabrication of equipment incorporating MMB products. Success will be dependent on the proper management of all the elements mentioned above. Many of the requirements, including design aspects such as assessment of service stress levels to be encountered, are beyond the control of MMB and therefore no responsibility can be taken for the overall performance of a particular weldment or welding procedure. Variations to the guidelines may be appropriate in the light of engineering considerations or previous experience.

8.7.1 Metallurgical Effects of Arc Welding

The process of arc welding involves localised melting of the parent metal in an electric arc while surrounded by an inert gas atmosphere, usually with the addition of filler material (welding consumable) melted by the arc, resulting in the formation of what can be considered as a small casting. The weld zone is subject to intense local heating followed by relatively rapid cooling by heat transfer to the surrounding metal. If either the parent material or the weld-pool is of a hardenable chemistry, this rapid cooling or quenching can result in the formation of undesirable hard and brittle phases in the weld zone, which may then lead to "cold cracking". In most cases hardening and embrittlement can be avoided by well-designed and implemented welding procedures.

Contamination by elements such as sulphur and phosphorus may lead to formation of low strength, low melting point phases that result in "hot cracking", which occurs as the weldment is cooling down. Sources of contamination are surface coatings, hydraulic fluids, cutting fluids, lubricants and in some cases undesirable chemistries (for welding) of parent metals.

Higher strength and higher hardenability materials may be susceptible to cracking after the weldment cools due to excessive hydrogen absorbed into the molten metal during welding. This is known as hydrogen assisted cold cracking (HACC) and is dependent on material chemistry, material thickness, weld zone cooling rates and residual stress levels in the weld area.

8.7.2 Welding of Carbon and Low Alloy Steels

Hardenability is the chief determining factor in the weldability of carbon and low alloy steels. A system has been devised which relates the hardening potential of other elements to that of carbon. The resultant parameter is called "carbon equivalent" (CE).

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

Weldability Group Numbers have been assigned to particular CE bands.

TABLE 32: RELATIONSHIP BETWEEN CARBON EQUIVALENT AND GROUP NUMBER

Carbon Equivalent	Group Number
Below 0.30	1
0.30 to below 0.35	2
0.35 to below 0.40	3
0.40 to below 0.45	4
0.45 to below 0.50	5
0.50 to below 0.55	6
0.55 to below 0.60	7
0.60 to below 0.65	8
0.65 to below 0.70	9
0.70 to below 0.75	10
0.75 to below 0.80	11
0.80 and above	12

Other metallurgical influences from welding which must be considered are:

- The effect of welding on prior heat treatment condition.
- The loss of work hardening in the vicinity of the weld.
- Possible inducement of strain aging adjacent to the weld.

Joint geometry, especially factors such as restraint and the presence of notches can also affect the performance of welds.

The following information gives recommendations for welding steels supplied by MMB. Recommendations are based primarily on steel composition and they assume moderate conditions of restraint and joint complexity. Where low hydrogen or hydrogen-controlled conditions are nominated, consumable care, joint preparation, job preparation, welding environment and welding procedures must be adequate to achieve low hydrogen conditions. Particular care is required for welding consumables to prevent deterioration in storage or after exposure to the atmosphere.

8.7.3 Preheat and Heat Input

Guidelines for preheating steels supplied by MMB are given in the Weldability of Marbrite® Grades Table 33, Page 47. These preheats are based on a welding heat input of 1.0 to 1.5 kJ/mm of deposit (See Note Table 33, Page 47). With higher heat inputs the recommended preheat will be reduced.

Information required to determine preheat temperature includes:

- Material composition to determine weldability group.
- Joint configuration to determine the combined joint thickness (CJT).
- Joint weldability index (refer AS/NZS 1554.1 or WTIA TN 1).
- Arc energy input – calculated from welding procedure parameters (current, voltage and travel speed).
- Hydrogen control level achievable based on process, consumables and welding environment.

The above are used to determine preheat from charts in AS/NZS 1554.1 or WTIA TN 1.

Further information on the method for determination of preheat temperature can be referenced in AS/NZS 1554.1 "Welding of steel structures", WTIA Technical Note 1 "The Weldability of Steels" and WTIA Technical Note 11 "Commentary on the structural steel welding standard AS/NZS 1554.
Note: This heat input is achieved with MNAW using:

- Non-iron powder – 3.25 electrodes at 2mm to 3mm of electrode per mm of deposit, 4.0mm electrodes at 1.3 mm to 2 mm of electrode per mm of deposit (EXX10, EXX11, EXX12, EXX13, EXX15, EXX16 and EXX20).
- Low iron powder – 3.25 electrodes at 1.5mm to 2.4mm of electrode per mm of deposit, 4.0mm electrodes at 1mm to 1.5mm of electrode per mm of deposit (EXX14, EXX18).
- Medium iron powder – 3.25 electrodes at 1.2mm to 1.9mm of electrode per mm of deposit, 4.0mm electrodes at 0.8 mm to 1.2mm of electrode per mm of deposit (EXX24, EXX27, EXX28).

8.7.4 Hydrogen Control

The term "low hydrogen" or more correctly "hydrogen controlled" is indicative of products or processes that have controlled maximum limits on moisture content or hydrogen producing materials. Achieving the level of hydrogen control required involves a combination of factors, which may include:

- Selection of a suitable low hydrogen welding process.
- Selection of a suitable low hydrogen welding consumable.
- Adequate preparation and cleanliness of the weld area.
- Appropriate preheat and interpass temperature control.
- Adequate welding heat input during welding.
- Post weld heating (preheat level) or post weld heat treatment (stress relieving or tempering).

In certain situations there may be upper limits on preheat temperatures and welding heat inputs to avoid having a detrimental effect on parent material properties, e.g. quenched and tempered steels.

8.7.5 Control of Hot Cracking

Free-cutting steels such as X1112, 1137, 1146 with high sulphur contents and 1214 with high phosphorus content are prone to hot cracking and are unsuitable for welding except in very low stress non-critical applications. Cracking may occur either in the weld deposit or in the heat affected zone adjacent to the weld.

12L14 contains lead in addition to high sulphur and phosphorus and presents a health hazard. DO NOT WELD.

Hot cracking may occur on other materials and may be prevented by:

- Cleaning off all traces of cutting oils or other surface contaminants.
- Avoiding parent steels containing more than 0.06% total of sulphur and phosphorus.
- Planning welding parameters to reduce thermally induced strains.
- Adjusting parameters to obtain weld width between 0.8 and 1.2 weld depth.
- Controlling joint fit up to reduce excessive gaps.
- Reducing parent metal dilution into weld metal.

8.7.6 Weldability of Marbrite®

The following table lists the grades of steel in the Marbrite® range with Group numbers, welding notes, preheats and comments. The preheat recommendations are based on welding heat inputs in the range of 1.0 to 1.5 kJ/mm. If higher heat input is used preheat temperature may be reduced. If lower heat input is used then higher preheat temperatures will be necessary. If hydrogen controlled conditions cannot be established on materials where it is required, it is recommended that preheat temperatures be increased by at least 25°C.

TABLE 33: WELDING OF MARBRITE® GRADES

Grade	Group No.	Notes (see below)	Preheat °C				Comments
			CJT ≤20	CJT 20–40	CJT 40–80	CJT ≥80	
1137	7	NR H F	25	75	125	150	Welding should only be considered in low load non-critical applications.
1146	9	NR H F	75	125	175	200	
1214	3	NR H F	Nil	Nil	Nil	Nil	
12L14 *	3	NR H F	Nil	Nil	Nil	Nil	DO NOT WELD *
M1020	2	O	Nil	Nil	Nil	Nil	No special precautions
M1030	5	H/O	Nil	25	75	100	Hydrogen control processes recommended
1004	1	O	Nil	Nil	Nil	Nil	No special precautions
1010	1	O	Nil	Nil	Nil	Nil	No special precautions
1020	2	O	Nil	Nil	Nil	Nil	No special precautions
1022	3	O	Nil	Nil	Nil	Nil	No special precautions
1030	5	H/O	Nil	25	75	100	Hydrogen control processes recommended
1035	6	H	Nil	50	100	150	Lightly alloyed consumable for matching strength
1040	8	H SC SR	50	100	150	200	Alloyed consumable for strength matching maybe required in multiple layer welds. Butter welding with an unalloyed consumable
1045 ≠	9	H SC SR	75	125	175	200	
1050	10	H SC SR	100	150	200	250	
X1320	5	H/O	Nil	25	75	100	Hydrogen control processes recommended
X1340	10	H SC SR	100	150	200	250	As for 1050
4140	12	H SC SR	150	200	250	250	Closely controlled procedures necessary
8620	6	H/O	Nil	50	100	150	Lightly alloyed consumable for matching strength

Notes:
- * – The presence of lead in 12L14 causes a health hazard in arc welding.
- ≠ – Further information is available for Marcrome® in CD No. SP30.
- O – Any electrode type or welding process is satisfactory.
- H/O – Hydrogen controlled electrodes or semi-automatic processes are recommended, but rutile or other electrodes may be used.
- H – Hydrogen controlled electrodes or semi-automatic or automatic processes are essential for good welding.
- SC – Slow cooling from welding or preheat temperature is recommended.
- SR – Postweld heat treatment (stress relief) is suggested for high quality work, particularly where severe service conditions apply to the component.
- NR – Welding is generally not recommended.
- F – If welding has to be carried out on free-cutting steels, basic coated MMAW or specially formulated electrodes for welding sulphurised steels should be used. Butter layers on each part to be joined are recommended before making a joining weld.

8.8 Brazing

All Marbrite® carbon and bright bar is suitable for brazing. The elevated temperatures associated with brazing will have an effect on the metallurgical properties of the bar. The work hardening from cold drawing will be lost and the new properties will be dependent upon the temperatures involved, the hardenability of the material and the cooling rate after brazing.

Leaded steels such as 12L14 are suitable for brazing. Some users have concerns about "lead sweat" leaving voids in the product but considerable quantities have been successfully brazed. In good quality leaded steel, the lead is very finely dispersed and not prone to "sweating out". All known cases of "lead sweat" have been associated with steel rejectable on the basis of lead segregation ie. lead colonies of excessive size. Appropriate precautions should be taken to avoid exposure of personnel to any lead fumes generated during brazing.

8.9 Heat Treatment

8.9.1 Full Annealing

The heating of steel into the austenite range followed by a slow furnace cool. Not commonly used for softening bright bar or relieving the stresses of cold working, as the process involves a long furnace time and as such can be quite expensive.

8.9.2 Normalising

The heating of steel into the austenite range followed by cooling in still air. Removes the effects of cold working and refines the grain structure, resulting in hardness and tensile properties similar to hot rolled but more uniform and less directional in nature.

8.9.3 Sub-critical (or spherodised) Annealing

Annealing at temperatures, 650°C to 700°C, ie. into the recrystallisation range, but below the lower critical temperature 723°C, at which austenite begins to form.

8.9.4 Stress Relieving

Can result from any annealing or normalising heat treatment, but is usually carried out, at temperatures below that necessary for full recrystallisation.
A typical stress relieving, process annealing is 4 hours at 650°C. Process annealing results in softening and complete relief of internal stresses. Often used to restore ductility between cold drawing operations or to eliminate possible distortion on machining.

Typically, stress relieving at relatively low temperatures eg. 500°C will partially relieve cold drawing stresses, and thereby increase the hardness and tensile strength of cold drawn steels. At higher temperatures the cold drawing stresses are completely removed such that hardness, tensile strength and yield strength are reduced.

The choice of a specific stress relieving temperature and time is dependent on chemical composition, amount of draft in cold drawing and final properties required in the bar.

8.9.5 Strain Aging

A change in mechanical properties which occurs over time after cold working. The principal changes are an increase in hardness and a reduction in ductility and impact toughness. It can be accelerated by heating of steel to approx. 250°C.

8.9.6 Quench and Tempering (also known as hardening and tempering)

This is applicable to those steels which have sufficient carbon and alloying elements to render them hardenable. The process exploits the fact that when these steels are rapidly cooled the usual phase transformation, which occurs at around 720°C, is thwarted and hard, meta-stable phases are formed instead, such as martensite or bainite. In most cases the material ''as quenched" is too hard and brittle and a further heating (tempering) to a lower temperature must be employed to achieve a better balance of mechanical properties.

8.9.7 Induction or Flame Hardening

By selectively heating the surface only, hardenable steels can be hardened on the outer skin without significantly altering the properties of the core. 1040 and 1045 are grades often used for this process. The same principles apply to this process as for "through hardening" by quench and tempering.

8.9.8 Case Hardening

There are many case hardening processes available today. The traditional one is carburising which can be achieved by heating to approx 900°C in a carbon rich atmosphere or a fused cyanide salt. Carbon diffuses into the steel raising the carbon content near the surface to approx 0.9%C.

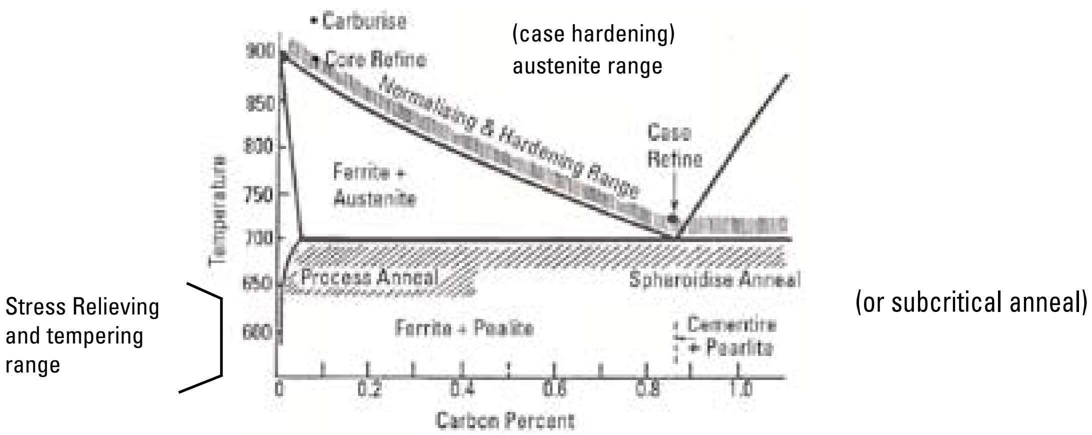
Carburising involves growth and distortion. For good performance of the case it is critical that it is under compression. Surface growth will achieve this objective unless the core also grows. It is this problem with core growth that precludes material above 0.30%C from case hardening. (At levels of over 0.30%C there is some growth in the core due to martensitic transformation). If superior core properties are required then alloy steels such as 8620 are used rather than steels of higher carbon.

For the case hardening of higher carbon steels (0.2–0.5%C), nitriding is an option. Steels suitable for nitriding generally contain aluminium, chromium and molybdenum. Vanadium and tungsten also assist in nitriding. Nitriding is performed by heating to approx. 500°C in an atmosphere of cracked ammonia.

Carbo-nitriding is a further variation, where ammonia is added to a carburising atmosphere.

The diagram below depicts the temperature ranges for various heat treatment processes for carbon steels.

Heat Treatment Ranges of Carbon Steels



8.9.9 Heat Treatment Tips and Traps

The most frequent sources of trouble in heat treatment are:

- Cooling rate too slow in quenching ie. "slack quenching"; or
- Cooling rate too fast causing "quench cracks".

Decarburisation, the removal of carbon from the surface during heating for quenching, or prior hot rolling can also be a problem in some cases. It can result in reduced surface hardenability. Because turned bar has the hot rolled surface removed, it is less subject to decarburisation concerns.

8.10 MARCROME® – HARD CHROME BAR

8.10.1 Handling and Storage of Marcrome®

Marcrome® hard chrome bar is supplied in a cardboard tube with plastic end caps. The tube is designed to provide maximum impact resistance protection for the bar during handling and transportation. For ease of identification of steel grade used in the manufacture of Marcrome®, the end plugs of the cardboard tube are colour coded.

For added protection during transport, Marcrome® leaves the manufacturing plant packed in sturdy wooden crates lined with water resistant plastic. Crates are identified with a numbered tag showing details of contents including size, product, heat number, customer, order number, gross and net weight.

Because of the end use applications of hard chrome bar it is essential that due care be particularly taken in the handling and storage of the product during component manufacture.

Soft web slings should be used in the handling of hard chrome bar and where possible the bar should be carried in the Marcrome® cardboard tube during component manufacture.

Storage of hard chrome bar can be in the original crates or in racks made with brackets protected with rubber to ensure the chromium surface of the bar is not scored or damaged by the metal surface of the bracket. The preference is to store the bar in the cardboard tube, but if this is not possible, it is recommended that a distance be maintained between bars using rubber rings or inserts slipped over each bar. To prevent bending of bars during storage it is recommended that they be supported in at least three places. Storage should be in a dry area, as water can react with the chemicals in the cardboard tube, thus causing corrosion on the surface of the hard chrome bar.

8.10.2 Weldability of Marcrome®

The weldability of hard chrome bar is governed by the chemistry and heat treatment condition of the base metal. Marcrome® base material steel grades are usually 1045 or 4140, as ordered. Both grades have a high carbon equivalent and are subject to quench hardening and hydrogen assisted cold cracking unless carefully controlled welding procedures are followed.

Preheat should be applied to heat through the full section to be welded and the recommended preheat temperature maintained throughout the welding operation. Preheat reduces the cooling rates and allows extended time for hydrogen diffusion from the weld zone.

The presence of the deposited chromium layer on the steel surface need not be considered as a source of detrimental chromium; the layer is too thin compared with the large volume of steel. If Marcrome® bar is supplied in an induction-hardened condition, welding is generally not recommended.

Marcrome® – 1045

For manual metal-arc welding (MMAW) of 1045 use "hydrogen controlled" electrodes conforming to AS 1553.1 E 4816-3 or E4818-3. Based on a welding heat input of 1.2 kJ/mm a minimum preheat is recommended of 90°C for combined joint thickness (CJT) of 20mm, 140°C for CJTs of 40mm and 200°C for CJTs of 80mm and greater.

For semi-automatic welding with solid wires (GMAW) an electrode conforming to AS/NZS 2717.1 ES6-GC-W503AH or ES6-GM-W503AH is recommended. Based on a welding heat input of 2.2KJ/mm, a minimum preheat of 50°C is recommended for CJTs of 20mm, 120°C for CJTs of 40mm and 180°C for CJTs of 80mm and greater.

For semiautomatic welding with flux-cored wires (FCAW) an electrode conforming to AS 2203.1 ETP-GMp-W503A.CM1 H5 is recommended. Based on a welding heat input of 2.2KJ/mm, a minimum preheat of 50°C is recommended for CJTs of 20mm, 120°C for CJTs of 40mm and 180°C for CJTs of 80mm and greater.

Marcrome® – 4140
For manual metal-arc welding (MMAW) of 4140 use "hydrogen controlled" electrodes conforming to AS 1553.1 E 4816-3 or E4818-3. Based on a welding heat input of 1.2 kJ/mm a minimum preheat is recommended of 150°C for a combined joint thickness (CJT) of 20mm, 200°C for CJTs of 40mm and 200°C for CJTs of 80mm and greater.

For semi-automatic welding with solid wires (GMAW) an electrode conforming to AS/NZS 2717.1 ES6-GC-W503AH or ES6-GM-W503AH is recommended. Based on a welding heat input of 2.2KJ/mm, a minimum preheat of 150°C is recommended for CJTs of 20mm, 190°C for CJTs of 40mm and 200°C for CJTs of 80mm and greater.

For semi-automatic welding with flux-cored wires (FCAW) an electrode conforming to AS 2203.1 ETP-GMp-W503A.CM1 H5 is recommended. Based on a welding heat input of 2.2KJ/mm, a minimum preheat of 150°C is recommended for CJTs of 20mm, 190°C for CJTs of 40mm and 200°C for CJTs of 80mm and greater.

Post weld heat treatment (PWHT)
For optimum performance of welds in critical applications it is recommended that a post weld heat treatment (PWHT) be carried out to reduce heat affected zone (HAZ) hardness, improve HAZ toughness and reduce weld zone hydrogen levels. Maximum PWHT temperatures should be 50°C below tempering temperatures for the base material.

It is recommended that the protective cardboard tube housing Marcrome® bar be removed prior to welding. The heat of welding can cause the cardboard to emit fumes and residue, which may corrode the Marcrome® surface.

If further technical assistance is required please contact MMB or the Welding Technology Institute of Australia.

8.10.3 Machinability of Marcrome®
Marcrome® can be machined in the same manner as the base metal. It is recommended that machining begin under the chromium deposit or at a point without chrome, preferably starting at the end of a bar.

Clamping materials should be of aluminium, copper or mild steel and care must be taken to remove hard particles, such as chromium, away from the bright polished chrome surface, particularly on rolling and conveying machinery.

The parting of Marcrome® can be achieved by bandsaw or hacksaw using blades suitable to the grade of steel from which the Marcrome® bar has been manufactured. For induction hardened bar it will be necessary to use a specially treated blade (eg. Titanium nitride coated) or high speed abrasive saw.

8.11 Typical Applications of Marbrite® and Marcrome®

TABLE 34: TYPICAL APPLICATIONS – AUTOMOTIVE

Grade	Application
1137	Tow balls (high quality)
1214, 12L14	Brake hose ends , pulleys, disc brake pistons, wheel nuts and inserts, control linkages, gear box components (case hardened)
M1020	Head rest struts, jack handle
U1010	Seat belt anchors
1022	Steering column
1045	Shock absorber struts
X1320	Carburised gears
X1340	Park brake pin
8620	Pitman arm stud

TABLE 35: TYPICAL APPLICATIONS – WHITE GOODS

Grade	Application
1214	Egg beater shafts
M1030, 1045	Motor shafts
1146, 1214	Washing machine spindles

TABLE 36: TYPICAL APPLICATIONS – AGRICULTURAL

Grade	Application
1214	Pulley inserts
M1030	Sugar mill roller shaft
1045	Power take off shaft, pump shafts

TABLE 37: TYPICAL APPLICATIONS – GENERAL ENGINEERING

Grade	Application
1214, 12L14	Domestic garage bin axles, concrete anchors, padlock shackles (case hardened), hydraulic fittings, vice jaws (case hardened)
U1004	Roller door tracks, shop fittings, storage racks
M1020	Threaded bar
1022	Pressure vessel fittings
M1030	Gate hinges
1045	Medium/high tensile bolts or shafting
4140	Hydraulic rams, High tensile bolts
1340	High strength fasteners

9.0 Quality Assurance

9.1 Accreditations

9.1.1 Quality Systems

Milltech Martin Bright Quality System conforms to ISO 9001 2000. The system has been accredited by an independent auditing authority, Standards Australia's SRI Global, Licence No QEC530.

9.1.2 Laboratory Testing

The Milltech Martin Bright Laboratory is accredited by the National Association of Testing Authorities (NATA) for Mechanical Testing. Reg. No. 71.

9.2 Products Standards

Milltech Martin Bright products are manufactured in accordance with the following standards (as applicable).

AS 1443-2004 "Carbon Steels and Carbon-manganese Steels – Cold Finished Bars".
AS 1444-1996 "Wrought Alloy Steels – AISI-SAE Standard, Hardenability (H) and Hardened and Tempered to Designated Mechanical Properties".

9.3 Traceability

It is in the interests of all parties involved in manufacture to maintain traceability. Should a problem arise with the product, traceability makes it much easier to isolate the suspect material, verify its origin, and diagnose the cause of the problem.

From a one tonne bundle's individual bundle number, the original heat number and all details of manufacture can be traced, down to the machines and the operators involved. The bundle number can be found on the plastic tag attached to every bundle or on the delivery documents.

9.4 Customer Complaints

Milltech Martin Bright has a formal system for responding to customer complaints, as described in the Standard Operating Procedure SYS-SOP-015 in the Milltech Martin Bright Quality Manual. It is MMB's policy to respond promptly to customer complaints and to take all reasonable action to quickly resolve the problem in a mutually satisfactory manner.

As a result of a customer complaint, a written explanation of the problem and details of any appropriate corrective action will be supplied to the customer. Should material need to be returned, a Goods Return Authority (GRA) will be raised to facilitate this.

Complaints should be raised and responded to through the appropriate Sales Account Manager.

Below is a checklist which may help the customer complaint process.

1. Isolate and identify the suspect batch preferably by bundle number, if not, heat number.
2. Find out the "full story"
    - What is the problem?
    - When did it start?
    - How frequent is it and how much product is affected?
    - What performance is normally expected?
    - Who is involved?
    - Where is the affected product now?
    - Has there been any major financial loss?
3. Arrange samples of "good" and "bad" components, and bar ends (if possible).
4. All complaints are given a "CCA number". Please quote this in correspondence.

9.5 New Products

The Milltech Martin Bright Quality (DMS) System incorporates a "step by step" approach for the introduction of new products.

To gain maximum benefit from the planning process, close liaison with the customer is necessary.

10.0 Appendices

APPENDIX 1 – GRADE DATA SHEETS
Carbon Steels
U1004
U1010
M1020
M1030
1045
1214
12L14
1137
1146
X1320
X1340
AS 1444-4140-T

Carbon Steels – Data Sheet U1004

Grade

AS 1443 / U1004	Approx. Equivalents: AISI / SAE 1005; UNS G10050; BS970 040A04; En2A	Steel Type: Plain Low Carbon

Chemical Composition (% by weight)

C	Si	Mn	P	S
0.06 max	0.35 max	0.25–0.50	0.04 max	0.04 max

Mechanical Properties

Cold Drawn	Not covered by mechanical properties tables in AS1443
Turned & Polished	

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.87	12.6×10^{-6}	200,000	Ferromagnetic

Heat Treatment

Forging	Normalise	Full Anneal	Sub-critical Anneal
1300°C	910–950°C	900–930°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
45	Not hardenable	Not hardenable	Yes

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Readily weldable with Low carbon Consumables	Yes	Yes

Summary

A very soft grade with excellent cold forming properties provided adequate internal bending radius is used. Tends to be "gummy" in machining. Suitable for general purpose low strength applications, eg. roller door tracks, shop fittings, storage racks and pressings, racking, pressings.

Carbon Steels – Data Sheet U1010 (formerly S1010)

Grade

AS 1443 / U1010	Approx. Equivalents: AISI / SAE 1010;UNS UNS G10100; BS970 045M10; En32A; Werkstoff No. 1.0301, 1.1121; DIN C10, Ck10; JIS S10C	Steel Type: Plain Low Carbon

Chemical Composition (% by weight)

C	Si	Mn	P	S
0.08–0.13	0.35 max	0.30–0.60	0.04 max	0.04 max

Mechanical Properties

Cold Drawn	Not covered by mechanical properties tables in AS1443
Turned & Polished	

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.87	12.2×10^{-6}	200,000	Ferromagnetic

Heat Treatment

Forging	Normalise	Full Anneal	Sub-critical Anneal
1300°C	910–950°C	900–930°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
55	Not hardenable	Not hardenable	Yes

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Readily weldable with Low carbon Consumables	Yes	Yes

Summary

A soft, ductile material with reasonably good cold bending properties. Suitable for general purpose "mild steel" applications, eg. automotive seat belt anchors etc.

Carbon Steels – Data Sheet M1020 (formerly CS1020)

Grade

AS 1443 / U1020 AS 1443 / D3* AS 1443 / T3* *Mechanical Test	Approx. Equivalents: AISI / SAE 1020; UNS G10200; BS970 070M20; En38; Werkstoff No. 1.0402; DIN C22; JIS 20C	Steel Type: Plain Carbon Mild Steel

Chemical Composition (% by weight)

C	Si	Mn	P	S
015–0.25	0.35 max	0.30–0.90	0.05 max	0.05 max

Indicative Mechanical Properties

Cold Drawn Size mm	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
≤ 16	380	480	12	142
> 16 ≤ 38	370	460	12	135
> 38 ≤ 63	340	430	13	126
Turned & Polished Size mm				
≤ 50	250	410	22	119
> 50 ≤250	230	410	22	119

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.86	11.7×10^{-6}	207,000	Ferromagnetic

Heat Treatment

Forging	Normalise	Full Anneal	Sub-critical Anneal
1280°C	890–940°C	870–910°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
65	Not hardenable	Not hardenable	Yes

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Readily weldable with low carbon consumables. Preheat heavy sections	Yes	Yes, provided %Si is below 0.05%

Summary

A frequently used, economical grade for general purpose “mild steel” applications. Good balance of strength, ductility, toughness and weldability. Examples of applications: jack handles, threaded bar, shafts.

Carbon Steels – Data Sheet M1030 (formerly CS1030)

Grade

AS 1443 / U1030 AS 1443 / D4* AS 1443 / T4* *Mechanical Test	Approx. Equivalents: AISI / SAE 1030; UNS G10300; BS970 080M30; En5,6,6A; Werkstoff No. 1.0528, 1:1178; DIN C30, Ck30; JIS S30C	Steel Type: Plain Carbon Mild Steel

Chemical Composition (% by weight)

C	Si	Mn	P	S
0.25–0.35	0.35 max	0.30–0.90	0.05 max	0.05 max

Indicative Mechanical Properties

Cold Drawn Size mm	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
≤ 16	440	560	10	164
> 16 ≤ 38	430	540	11	160
> 38 ≤ 63	410	520	12	154
Turned & Polished Size mm				
All sizes to 260mm	250	500	20	147

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.86	11.5×10^{-6}	207,000	Ferromagnetic

Heat Treatment

Forging	Quench	Normalise	Full Anneal	Sub-critical Anneal
1250°C	870–710°C Water or Brine	870–920°C	850–920°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
70	Low hardenable	Low hardenable	Not recommended

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Readily weldable with low carbon consumables. Preheat heavy sections	Limited ductility	Not generally recommended. Refer to Section 8.3.3

Summary
Slightly higher strength and lower ductility than “mild steel”. Provides more strength than M1020 while remaining reasonably ductile and weldable. Typical applications: Architectural fittings, shafts.

Carbon Steels – Data Sheet 1045 (formerly K1045)

Grade

AS 1443 / 1045 AS 1443 / D6* AS 1443 / T6* *Mechanical Test	Approx. Equivalents: AISI / SAE 1045; UNS G10450; BS70 080A47; En43B; Werkstoff No. 1.0503, 1:1191; DIN C45, Ck45; JIS S45C	Steel Type: Plain Medium Carbon Steel

Chemical Composition (% by weight)

C	Si	Mn	P	S
0.43–0.50	0.10–0.35	0.60–0.90	0.04 max	0.04 max

Indicative Mechanical Properties

Cold Drawn Size mm	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
≤ 16	540	690	8	207
> 16 ≤ 38	510	650	8	195
> 38 ≤ 63	500	640	9	190
Turned & Polished Size mm				
All sizes to 260mm	300	600	14	179

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.84	11.5×10^{-6}	207,000	Ferromagnetic

Heat Treatment

Forging	Quench	Normalise	Full Anneal	Sub-critical Anneal
1250°C	810–850°C Water or Brine	870–920°C	800–850°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
55	Yes	Yes	No

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Yes, with appropriate procedures	No	Not generally recommended. Refer to Section 8.3.3

Summary
The base metal grade for hard chrome plated bar used for hydraulic and pneumatic rams. High strength with reasonable ductility and weldability. Examples of applications: hard chromed bar, shafting.

Carbon Steels – Data Sheet 1214 (formerly S1214)

Grade

AS 1443 / 1214 AS 1443 / D12* AS 1443 / T12* *Mechanical Test	Approx. Equivalents: SAE J403, AISI/SAE 1213, 1215; UNS G12130; BS970 230M07 En1a; Werkstoff no. 1.0715; DIN 95Mn28; JIS SUM22	Steel Type: Re-Sulphurised and Re-Phosphorised Free Machining Steel

Chemical Composition (% by weight)

C	Si	Mn	P	S
0.15 max	0.10 max	0.80–1.20	0.04–0.09	0.25–0.35

Indicative Mechanical Properties

Cold Drawn Size mm	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
$\leq$ 16	350	480	7	142
> 16 $\leq$ 38	330	430	8	126
> 38 $\leq$ 63	290	400	9	115
Turned & Polished Size mm				
All sizes to 260mm	230	370	17	105

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.87	12.2 x 10^{-6}	207,000	Ferromagnetic

Heat Treatment

Forging	Normalise	Full Anneal	Sub-critical Anneal
1300°C	900–940°C	890–920°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
136	Not hardenable	Not hardenable	Yes

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Yes, precautions required because of sulphur content	Limited ductility	Not generally recommended. Refer to Section 8.3.3

Summary

A widely used free machining steel which has reasonable ductility and weldability; less expensive than 12L14. Examples of applications: shafts which require considerable machining, concrete ferrules (case hardened).

Carbon Steels – Data Sheet 12L14 (formerly S12L14)

Grade

AS 1443 / 12L14 AS 1443 / D13* AS 1443 / T13* *Mechanical Test	Approx. Equivalents: AISI / SAE 12L14; UNS G12144; SAE J403; BS970 230M07 leaded En1A leaded; Werkstoff No. 1.07185; DIN 95MnPb28; JIS SUM22L	Steel Type: Re-Sulphurised and Re-Phosphorised Free Machining Steel

Chemical Composition (% by weight)

C	Si	Mn	P	S	Pb
0.15 max	0.10 max	0.80–1.20	0.04–0.09	0.25–0.35	0.15–0.35

Indicative Mechanical Properties

Cold Drawn Size mm	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
≤ 16	350	480	7	142
> 16 ≤ 38	330	430	8	126
> 38 ≤ 63	290	400	9	115
Turned & Polished Size mm				
All sizes to 260mm	230	370	17	105

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.87	12.2×10^{-6}	207,000	Ferromagnetic

Heat Treatment

Forging	Normalise	Full Anneal	Sub-critical Anneal
1300°C	900–940°C	890–920°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
158	Not hardenable	Not hardenable	Yes

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	No. Lead fumes are a health hazard	Limited ductility	Not generally recommended. Refer to Section 8.3.3

Summary

The premium grade of free cutting steel used by repetition engineers for a wide variety of applications. Excellent machinability and suitable for case hardening and electroplating. Examples of applications: brake components, gear box components, hydraulic fittings.

Carbon Steels – Data Sheet 1137 (formerly K1137)

Grade

AS 1443 / 1137 AS 1443 / D14* AS 1443 / T14* *Mechanical Test	Approx. Equivalents: AISI / SAE 1137; UNS G11370; BS970 216M36; Werkstoff No. 1.0726; DIN 35S20; JIS SUM41	Steel Type: Medium Carbon Re-Sulphurised Steel

Chemical Composition (% by weight)

C	Si	Mn	P	S
0.32–0.39	0.10–0.35	1.35–1.65	0.04 max	0.08–0.13

Indicative Mechanical Properties

Cold Drawn Size mm	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
≤ 16	510	660	7	197
> 16 ≤ 38	480	640	7	190
> 38 ≤ 63	460	620	8	185
Turned & Polished Size mm				
All sizes to 260mm	300	600	14	179

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.84	11.3×10^{-6}	207,000	Ferromagnetic

Heat Treatment

Forging	Quench	Normalise	Full Anneal	Sub-critical Anneal
1250°C	830–860°C Water or Brine	870–920°C	790–830°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
70	Yes	Yes	No

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Yes, with appropriate procedures. Precautions required because of sulphur content	No	Not generally recommended. Refer to Section 8.3.3

Summary

A tough high strength free machining steel. It is used where other free machining steels have insufficient tensile / impact strength. Examples of applications: tow balls, automotive clutch boss.

Carbon Steels – Data Sheet 1146 (formerly K1146)

Grade

AS 1443 / 1146	Approx. Equivalents: AISI / SAE 1146; UNS G11460; BS970 212A42; Werkstoff No. 1.0727; DIN 45S20; JIS SUM42	Steel Type: Medium Carbon Re-Sulphurised Steel

Chemical Composition (% by weight)

C	Si	Mn	P	S
0.42–0.49	0.10–0.35	0.70–1.00	0.04 max	0.08–0.13

Indicative Mechanical Properties

Cold Drawn Size mm	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
Turned & Polished Size mm	Not covered by mechanical properties table in AS1443. Expected results similar to 1045 but with lower elongation figures.			

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.84	11.2×10^{-6}	207,000	Ferromagnetic

Heat Treatment

Forging	Quench	Normalise	Full Anneal	Sub-critical Anneal
1250°C	800–840°C Water or Brine	850–930°C	790–830°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
70	Yes	Yes	No

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Yes, with appropriate procedures. Precautions required because of sulphur content	No	Not generally recommended. Refer to Section 8.3.3

Summary
A high strength heat treatable steel with improved machinability. It is used where other free machining steels have insufficient strength. Examples of applications: ball joint housings.

Carbon Steels – Data Sheet **X1320** (formerly XK1320)

Grade

AS 1443 / 1320	Approx. Equivalents: AISI / SAE 1320; BS970 150M19; En1A; Werkstoff no. 1.0499; DIN 21Mn6A1; JIS SMn420	Steel Type: Low Carbon Manganese Steel

Chemical Composition (% by weight)

C	Si	Mn	P	S
0.18–0.23	0.10–0.35	1.40–1.70	0.04 max	0.04 max

Indicative Mechanical Properties

Cold Drawn Size mm	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
Turned & Polished Size mm	Not covered by mechanical properties table in AS1443. Expected elongation results similar to M1020. Yield and tensile results approximately 90 MPa higher.			
Note: More precise information is available from MMB.				

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.86	11.7 x 10^{-6}	207,000	Ferromagnetic

Heat Treatment

Forging	Quench	Normalise	Full Anneal	Sub-critical Anneal
1280°C	850–890°C	850–930°C	840–880°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
54	Low hardenability	Low hardenability	Yes

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Yes, with appropriate procedures.	Yes, Tough material	Not generally recommended. Refer to Section 8.3.3

Summary

A very tough steel which offers a good combination of strength and ductility, and is well suited to case hardening. Examples of applications: convertible roof frame, gears and splined shafts in carburised condition.

Carbon Steels – Data Sheet X1340 (formerly XK1340)

Grade

AS 1443 / 1340	Approx. Equivalents: AISI / SAE 1340; UNS G13400; BS970 150M36; EN15B; JIS SMn438; SMn443	Steel Type: Medium Carbon Manganese Steel

Chemical Composition (% by weight)

C	Si	Mn	P	S
0.38–0.43	0.10–0.35	1.40–1.70	0.04 max	0.04 max

Indicative Mechanical Properties

Cold Drawn Size mm	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
Turned & Polished Size mm	Not covered by mechanical properties table in AS1443. Expected yield, tensile and elongation results to be superior to M1045.			

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.84	11.7×10^{-6}	207,000	Ferromagnetic

Heat Treatment

Forging	Quench	Normalise	Full Anneal	Sub-critical Anneal
1250°C	820–850°C	870–920°C	800–850°C	500–700°C

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening	Case Hardening (Carburise)
50	Yes	Yes	No

Electroplate	Welding	Cold Forming	Hot Dip Galvanising
Yes	Yes, with appropriate procedures.	No	Not generally recommended. Refer to Section 8.3.3

Summary

A high strength, tough, heat treatable grade used for more critical engineering applications.
Examples of applications: park brake pin, gear box components, high strength bolts and fasteners.

Carbon Steels – Data Sheet AS 1444-4140-T

Grade

AS 1444-4140-T	Approx. Equivalents: AISI / SAE 4140; BS970; Part 1 708M40 (En19A); ASTM A434; 42CrM04; Wnr 1.7225; JISG4105; SCM440	Steel Type: Hardened and Tempered Alloy Steel

Chemical Composition (% by weight)

C	Si	Mn	Cr	Mo	P&S
0.37–0.44	0.10–0.35	0.65–1.10	0.75–1.20	0.15–0.30	0.040 max

Indicative Mechanical Properties

	Yield Strength (MPa) min	Tensile Strength (MPa) min	Elong (5d) % min	Hardness HB Min
Cold Drawn Condition T	680	850–1000	9	248–302
Turned & Polished Condition T	665	850–1000	13	248–302
Note: Cold drawn generally higher in strength and less ductile than Turned and Polished.				

Physical Properties

Specific Gravity (SG)	Thermal Expansion cm / cm / °C 100°C	Modulus of Elasticity In Tension (MPa 20°C)	Magnetic Permeability
7.8	12.3×10^{-6}	200,000	Ferromagnetic

Heat Treatment

Forging	Quench	Temper (Stress Relieve)	Full Anneal
980–1205°C	820–880°C Oil and Water	500–680°C	815–870°C Slow furnace cool

Applications

Machinability Rating %	Through Hardening	Induction / Flame Hardening
< 50	Yes, depends on ruling section	Yes

Welding	Cold Forming
With caution pre and post heat required. Refer WTIA Technical Note No.1. Group No. 12	No, low ductility

Summary
A medium carbon chromium molybdenum high tensile steel supplied in the hardened and tempered condition. Suitable for high tensile bolts and shafts.

APPENDIX 2 – PHYSICAL PROPERTIES OF STEEL

	SG	Thermal Expansion cm/cm/°C 0–100°C	Modules of Elasticity in Tension + MPa (20°C)	Magnetic* Permeability (Annealed) 20°C
Pure Iron	7.87	11.75×10^{-6}	200,000	Ferromagnetic
1020	7.86	11.70×10^{-6}	207,000	Ferromagnetic
1040	7.84	11.30×10^{-6}	207,000	Ferromagnetic
1080	7.84	10.80×10^{-6}	207,000	Ferromagnetic

* Also known as Young's Modules

APPENDIX 3 – CONVERSION FACTORS

Imperial – Metric			
Multiplication Factor Imperial (UK/USA) to Metric	**Imperial (UK/USA)**	**Metric**	**Multiplication Factor Metric to Imperial (UK/USA)**
Length			
25.400	Inches	Millimetres	0.03937
0.3048	Feet	Metres	3.2808
0.9144	Yards	Metres	1.0936
1.6093	Miles	Kilometres	0.6214
0.0254	Micro inches (0.000001")	Microns (0.001mm)	39.37
Area			
645.16	Square inches	Square millimetres	0.00155
0.0929	Square feet	Square metres	10.7639
0.8361	Square yards	Square metres	1.960
Volume			
16.387	Cubic inches	Cubic centimetres	0.06102
0.02832	Cubic feet	Cubic metres	35.3147
0.7645	Cubic yards	Cubic metres	1.3080
4.546	Gallons (UK)	Litre	0.2200
Mass			
0.4536	Pounds (avoirdupois)	Kilogram	2.2046
1016.0475	Ton (UK 2,240 lbs)	Kilogram	0.00009842
1.01605	Ton (UK 2,240 lbs)	Tonne	0.9842
0.9072	Ton (USA net or Short 2,000 lbs)	Tonne	1,1023
Stress			
15.4443	UK tons force per sq inch	Megapascal (Mpa) or N/mm^2*	0.064749
0.006895	Pounds per sq inch	Megapascal (Mpa) or N/mm^2*	145.04
Miscellaneous			
1.35582	Foot pound	Joule (Newton metre)	0.73756
4.44822	Pound force	Newton	0.224809
0.7457	Horsepower	Kilowatt	1.34102
1.488	Pounds per foot	Kilogram per metre	0.6720
0.3048	Feet per minute	Metres per minute	3.2808

* 1 kilogram force = 9.807 Newton   1kgf/mm² = 9.807 Mpa (N/mm^2)

APPENDIX 4 – METRIC EQUIVALENTS

mm		Inches		mm		Inches		mm		Inches	
	0.794	1/32	.0313		15.081	19/32	.5938	45			1.7717
1			.0394		15.875	5/8	.625		47.625	1 7/8	1.875
	1.588	1/16	.0625	16			.6299	50			1.9685
2			0.787		16.669	21/32	.6563		50.8	2	2
	2.381	3/32	0.938	17			.6693	55			2.1654
3			.1181		17.463	11/16	.6875		57.15	2 1/4	2.5
	3.175	1/8	.125	18			.7087	60			2.3622
	3.969	5/32	.1563		18.256	23/32	.7188		63.5	2 1/2	2.5
4			.1575	19			.748	65			2.5591
	4.763	3/16	.1875		19.05	3/4	.75		69.85	2 3/4	2.75
5			.1969		19.844	25/32	.7813	70			2.7559
	5.556	7/32	.2188	20			.7874		76.2	3	3
6			.2362		20.638	13/16	.8125	80			3.1496
	6.35	1/4	.25	21			.8268		82.55	3 1/4	3.25
7			.2756		21.431	27/32	.8438		88.9	3 1/2	3.5
	7.144	9/32	.2813	22			.8661	90			3.5433
	7.938	5/16	.3125		22.225	7/8	.875		95.25	3 3/4	3.75
8			.315	23			.9055	100			3.937
	8.731	11/32	.3438		23.019	29/32	.9063		101.6	4	4
9			.354		23.813	15/16	.9375	110			4.3307
	9.525	3/8	.375	24			.9449		114.3	4 1/2	4.5
10			.3937		24.606	31/32	.9688	120			4.7244
	10.319	13/32	.4063	25			.9843		127	5	5
11			.4331		25.4	1	1	130			5.1181
	11.113	7/16	.4375		28.575	1 1/8	1.125		139.7	5 1/2	5.5
	11.906	15/32	.4688	30			1.1811	140			5.5118
12			.4724		31.75	1 1/4	1.25	150			5.9055
	12.7	1/2	.5		34.925	1 3/8	1.375		152.4	6	6
13			.5118	35			1.378		165.1	6 1/2	6.5
	13.494	17/32	.5313		38.1	1 1/2	1.5		1.778	7	7
14			.5512	40			1.5748		203.2	8	8
	14.288	9/16	.5625		41.275	1 5/8	1.625		228.6	9	9
15			.5906		44.45	1 3/4	1.75		254	10	10

(Rounded off to – mm to 3 decimal places, Inches to 4 decimal places)

CONVERSION FACTORS: mm = Inches x 25.4 Inches = mm x .03937

APPENDIX 5 – TABLE OF MASS IN KILOGRAMS PER METRE OF MARBRITE® STEEL

● ROUND

Size mm	Mass kg per metre	Metres per 1 tonne	Approx. No. of bars per tonne: 3.5 metres	Approx. No. of bars per tonne: 6.0 metres
3	0.056	17857	5102	2976
4	0.099	10101	2886	1683
5	0.154	6494	1855	1082
6	0.222	4504	1287	751
7	0.302	3311	946	552
8	0.395	2532	723	422
9	0.499	2204	573	334
10	0.617	1621	463	270
11	0.746	1340	383	223
12	0.888	1126	322	188
13	1.042	960	274	160
14	1.209	827	236	137
15	1.387	721	206	120
16	1.578	634	181	107
17	1.782	561	160	93
18	1.998	500	143	83
19	2.226	450	128	75
20	2.466	406	116	67
21	2.719	368	105	61
22	2.984	335	96	56
23	3.262	307	87	51
24	3.551	282	80	47
25	3.853	260	74	43
26	4.168	240	68	40
27	4.495	223	63	37
28	4.834	207	59	34
30	5.549	180	51	30
32	6.312	159	45	26
33	6.714	149	42.5	24.8
35	7.553	132	37.8	22.0
36	7.990	125	35.7	20.8
38	8.903	112	32.1	18.7
39	9.378	107	30.4	17.8
40	9.865	101	29.0	16.9
42	10.876	92	26.3	15.3
45	12.485	80	22.9	13.3
46	13.046	77	21.9	12.8
48	14.205	70	20.1	11.7
50	15.413	65	18.5	10.8
52	16.671	60	17.1	10.0
55	18.650	53.6	15.3	8.9
56	19.335	51.7	14.8	8.6
60	22.195	45.0	12.8	7.5
65	26.049	38.4	10.9	6.4

● ROUND

Size mm	Mass kg per metre	Metres per 1 tonne	Approx. No. of bars per tonne: 3.5 metres	Approx. No. of bars per tonne: 6.0 metres
70	30.210	33.1	9.5	5.5
75	34.680	28.8	8.2	4.8
80	39.458	25.3	7.2	4.2
85	44.545	22.4	6.4	3.7
90	49.939	20.0	5.7	3.3
95	55.642	17.9	5.1	3.0
100	61.654	16.2	4.6	2.7
110	74.601	13.4	3.8	2.2
120	88.781	11.3	3.2	1.9
130	104.19	9.6	2.7	1.6
140	120.84	8.3	2.3	1.3
150	138.72	7.2	2.1	1.2

⬢ HEXAGON

Size mm a/f	Mass kg per metre	Approx. No. of: Metres per 1 tonne	Approx. No. of: Bars 3.5m per 1 tonne
3.2	0.069	14492	4140
4.0	0.109	9174	2621
5.0	0.170	5882	1680
5.5	0.206	4854	1386
6.0	0.245	4061	1166
7.0	0.333	3003	858
8.0	0.435	2299	657
10.0	0.680	1470	420
11.0	0.823	1215	347
13.0	1.149	870	248
14.0	1.332	750	214
15.0	1.530	653	187
16.0	1.740	575	164
17.0	1.965	509	145
19.0	2.454	407	116
21.0	2.998	333	95
22.0	3.290	304	87
24.0	3.916	255	73
25.0	4.249	235	67
27.0	4.956	202	58
30.0	6.118	163	46.7
32.0	6.961	144	41.0
36.0	8.811	113	32.4
38.0	9.817	102	29.1
46.0	14.385	69	19.8
55.0	20.565	48.6	13.9

■ SQUARE

Size mm a/f	Mass kg per metre	Approx. No. of: Metres per 1 tonne	Approx. No. of: Bars 3.5m per 1 tonne
3	0.071	14084	4024
4	0.126	7936	2267
5	0.196	5102	1458
6	0.283	3533	1009
8	0.502	1992	569
10	0.785	1274	364
12	1.130	885	253
13	1.327	753	215
14	1.539	650	185
16	2.010	497	142
18	2.543	393	112
20	3.140	318	91
25	4.906	204	58
28	6.154	162	46
32	8.038	124	35.5
35	9.616	104	29.7

CONVERSION FACTORS

To calculate the mass of steel bars:

ROUND - dia. mm^2 x .006165
= Mass in kilograms per metre

ROUND - dia. mm^2 x .004143
= Mass in lbs per foot

HEXAGON - size mm^2 x .006798
= Mass in kilograms per metre

HEXAGON - size mm^2 x .00457
= Mass in lbs per foot

SQUARE - section mm^2 x .00785
= Mass in kilograms per metre

SQUARE - section mm^2 x .00527
= Mass in lbs per foot

FLAT - width in mm x Thickness in mm x .00785 = Mass in kilograms per metre

FLAT - Width in mm x Thickness in mm x .00527 = Mass in lbs per foot

Lbs per foot x 1.4880 = kilograms per metre

Kilograms per metre x 0.6720 = lbs per foot

Feet to metres x 0.3048

Metres to feet x 3.2809

UK tons per sq inch (tons f/in^2) x 15.4443
= Mega Pascals (MPa)

Mega Pascals (MPa) x .064749
= UK tons f per square inch

Newton per sq millimetre (N/mm^2) x 0.064749 = UK tons f per square inch

MASS IN KILOGRAMS PER METRE OF BRIGHT STEEL – SQUARE EDGE FLAT BARS, METRIC SIZES

Width mm	Thickness – mm: 2	3	4	5	6	7	8	9	10	12	15	20	25	30
6	0.094	0.141	0.188	0.235										
7	0.110	0.165	0.220	0.275	0.330									
8	0.125	0.188	0.251	0.314	0.377	0.440								
9	0.141	0.212	0.283	0.353	0.424	0.495	0.565							
10	0.157	0.236	0.314	0.393	0.471	0.550	0.628	0.707						
12	0.188	0.283	0.377	0.471	0.565	0.659	0.754	0.848	0.942					
16	0.251	0.377	0.502	0.628	0.754	0.879	1.005	1.130	1.256	1.507	1.884			
20	0.314	0.471	0.628	0.785	0.942	1.099	1.256	1.413	1.570	1.884	2.355			
25	0.393	0.589	0.785	0.981	1.178	1.374	1.570	1.766	1.963	2.355	2.944	3.925		
32	0.502	0.754	1.005	1.256	1.507	1.758	2.010	2.261	2.512	3.014	3.768	5.024	6.280	7.536
40	0.628	0.942	1.256	1.570	1.884	2.198	2.512	2.826	3.140	3.768	4.710	6.280	7.850	9.420
45	0.707	1.060	1.413	1.766	2.120	2.473	2.826	3.179	3.533	4.239	5.299	7.065	8.831	10.60
50	0.785	1.178	1.570	1.963	2.355	2.748	3.140	3.533	3.925	4.710	5.888	7.850	9.813	11.77
55	0.864	1.295	1.727	2.159	2.591	3.022	3.454	3.886	4.318	5.181	6.476	8.635	10.79	12.95
65	1.021	1.531	2.041	2.551	3.062	3.572	4.082	4.592	5.103	6.123	7.654	10.20	12.76	15.31
75	1.178	1.766	2.355	2.944	3.533	4.121	4.710	5.299	5.888	7.065	8.831	11.77	14.72	17.66
90	1.413	2.120	2.826	3.533	4.239	4.946	5.652	6.359	7.065	8.478	10.60	14.13	17.66	21.19
100	1.570	2.355	3.140	3.925	4.710	5.495	6.280	7.065	7.850	9.420	11.77	15.70	19.62	23.55

APPENDIX 6 – APPROXIMATE EQUIVALENT HARDNESS NUMBERS AND TENSILE STRENGTH FOR BRINELL HARDNESS NUMBERS FOR CARBON STEEL

Brinell Identification Dia. mm	Brinell Hardness Number 10mm Ball 3000kg Load	Diamond Pyramid hardness No.	Rockwell Hardness No. B-Scale 100 kg Load 1/16″ Dia. Ball	Rockwell Hardness No. C-Scale 150g Load Brale Penetrator	Shore Scleroscope Hardness No.	Tensile Strength in MPa
–	–	940	–	68.0	97	–
–	–	840	–	65.3	91	–
–	–	780	–	63.3	87	–
2.35	682	737	–	61.7	84	–
2.40	653	697	–	60.0	81	–
2.45	627	667	–	58.7	79	2392
2.50	601	640	–	57.3	77	2261
2.55	578	615	–	56.0	75	2158
2.60	555	591	–	54.7	73	2058
2.65	534	569	–	53.5	71	1962
2.70	514	547	–	52.1	70	1893
2.75	495	528	–	51.0	68	1817
2.80	477	508	–	49.6	66	1738
2.85	461	491	–	48.5	65	1665
2.90	444	472	–	47.1	63	1586
2.95	429	455	–	45.7	61	1513
3.00	415	440	–	44.5	59	1461
3.05	401	424	–	43.1	58	1391
3.10	388	410	–	41.8	56	1330
3.15	375	396	–	40.4	54	1271
3.20	363	383	–	39.1	52	1220
3.25	352	372	(110.0)	37.9	51	1175
3.30	341	360	(109.0)	36.6	50	1133
3.35	331	349	(108.5)	35.5	48	1097
3.40	321	339	(108.0)	34.3	47	1062
3.45	311	328	(107.5)	33.1	46	1029
3.50	302	319	(107.0)	32.1	45	1001
3.55	293	309	(106.0)	30.9	43	975
3.60	285	301	(105.5)	29.9	42	949
3.65	277	292	(104.5)	28.8	41	923
3.70	269	284	(104.0)	27.6	40	896
3.75	262	276	(103.0)	26.6	39	873
3.80	255	269	(102.0)	25.4	38	849
3.85	248	261	(101.0)	24.2	37	826
3.90	241	253	100.0	22.8	36	803
3.95	235	247	99.0	21.7	35	783
4.00	229	241	98.2	20.5	34	764
4.05	223	234	97.3	(18.8)	–	742
4.10	217	228	96.4	(17.5)	33	722
4.15	212	222	95.5	(16.0)	–	706
4.20	207	218	94.6	(15.2)	32	691
4.25	201	212	93.8	(13.8)	31	672
4.30	197	207	92.9	(12.7)	30	658
4.35	192	202	91.8	(11.5)	29	642

Cautions

1. Conversions must only be made from hardness values measured in accordance with the relevant standards and all the precautions observed therein.
2. Indentation hardness is not a single fundamental property but is an empirical measure dependent upon a combination of properties and the contribution of each to the hardness number varies with the type of test. No single conversion relationship can thus fit all metals or even a single metal in all its various structural conditions.

Below 240 HB the effects of strain hardening characteristics of the material on the test results increase significantly depending on preliminary and test loads applied as well as the type of indentor, making the conversion numbers subject to increasing unreliability as the hardness decreases. While the values from A.S.T.M. E140-88 have been found reliable for steel following a wide range of heat treatments, the remainder of the values should be treated with particular caution.

Values in parentheses are beyond the standard range and are given for information only.

APPENDIX 6 – APPROXIMATE EQUIVALENT HARDNESS NUMBERS AND TENSILE STRENGTH FOR BRINELL HARDNESS NUMBERS FOR CARBON STEEL (CONT'D)

Brinell Identification Dia. mm	Brinell Hardness Number 10mm Ball 3000kg Load	Diamond Pyramid hardness No.	Rockwell Hardness No.		Shore Scleroscope Hardness No.	Tensile Strength in MPa
			B-Scale 100 kg Load ¹⁄₁₆" Dia. Ball	C-Scale 150g Load Brale Penetrator		
4.40	187	196	90.7	(10.0)	–	625
4.45	183	192	90.0	(9.0)	28	612
4.50	179	188	89.1	(8.0)	27	599
4.55	174	182	87.8	(6.4)	–	583
4.60	170	178	86.8	(5.4)	26	570
4.65	167	175	86.0	(4.4)	–	560
4.70	163	171	85.0	(3.3)	25	546
4.75	159	167	83.8	(2.1)	–	535
4.80	156	163	82.9	(0.9)	24	526
4.85	152	159	81.7	–	–	514
4.90	149	156	80.8	–	23	504
4.95	146	153	79.8	–	–	495
5.00	143	150	78.7	–	22	485
5.05	140	146	77.6	–	–	475
5.10	137	143	76.4	–	21	464
5.15	134	140	75.2	–	–	455
5.20	131	137	74.0	–	–	446
5.25	128	134	72.7	–	–	437
5.30	126	132	72.0	–	20	431
5.35	123	129	70.6	–	–	422
5.40	121	127	69.8	–	19	416
5.45	118	124	68.5	–	–	407
5.50	116	122	67.6	–	18	401
5.55	114	120	66.8	–	–	395
5.60	111	117	65.7	–	15	386
5.65	109	115	64.6	–	–	380
5.70	107	112	63.5	–	–	374
5.75	105	110	62.3	–	–	368
5.80	103	108	61.1	–	–	362
5.85	101	106	59.9	–	–	356
5.90	99.2	104	58.8	–	–	350
5.95	97.3	102	57.7	–	–	344
6.00	95.5	100	56.5	–	–	339
6.05	93.7	98.6	55.4	–	–	334
6.10	92.0	96.8	53.5	–	–	328
6.15	90.3	95.0	52.2	–	–	323
6.20	88.7	93.3	50.9	–	–	318
6.25	87.1	91.7	49.2	–	–	314
6.30	85.5	90.0	47.4	–	–	309
6.35	84.0	88.4	45.5	–	–	304
6.40	82.5	86.9	43.3	–	–	300
6.45	81.0	85.3	41.0	–	–	295
6.50	79.6	83.8	38.6	–	–	291
6.55	78.2	82.4	36.1	–	–	287

Cautions

1. Conversions must only be made from hardness values measured in accordance with the relevant standards and all the precautions observed therein.
2. Indentation hardness is not a single fundamental property but is an empirical measure dependent upon a combination of properties and the contribution of each to the hardness number varies with the type of test. No single conversion relationship can thus fit all metals or even a single metal in all its various structural conditions.

Below 240 HB the effects of strain hardening characteristics of the material on the test results increase significantly depending on preliminary and test loads applied as well as the type of indentor, making the conversion numbers subject to increasing unreliability as the hardness decreases. While the values from A.S.T.M. E140-88 have been found reliable for steel following a wide range of heat treatments, the remainder of the values should be treated with particular caution.

Values in parentheses are beyond the standard range and are given for information only.

APPENDIX 7 – STRESS CONVERSION TABLE

1 ton f/in² = 15.444 MPa
1 psi lbf/in² = 0.006895 MPa
1 kg/mm² = 9.807 MPa

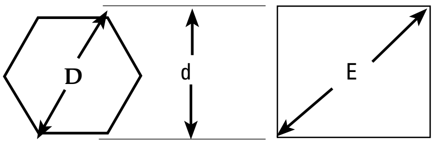
MPa (N/mm^2)	Imperial (UK) ton f/in²	Pound f/in² psi	MPa (N/mm^2)	Imperial (UK) ton f/in²	Pound f/in² psi
200	12.95	29000	820	53.09	118930
220	14.24	31900	840	54.39	121830
240	15.54	34810	860	55.68	124730
260	16.83	37710	880	56.98	127630
280	18.13	40610	900	58.27	130530
300	19.42	43510	920	59.57	133430
320	20.72	46410	940	60.86	136340
340	22.01	49310	960	62.16	139240
360	23.31	52210	980	63.45	142140
380	24.60	55110	1000	64.75	145040
400	25.90	58020	1020	66.04	147940
420	27.19	60920	1040	67.34	150840
440	28.49	63820	1060	68.63	153740
460	29.78	66720	1080	69.93	156640
480	31.08	69620	1100	71.22	159540
500	32.37	72520	1120	72.52	162440
520	33.67	75420	1140	73.81	165340
540	34.96	78320	1160	75.11	168240
560	36.26	81220	1180	76.40	171140
580	37.55	84120	1200	77.70	174050
600	38.85	87020	1220	78.99	176950
620	40.14	89920	1240	80.29	179850
640	41.43	92820	1260	81.58	182750
660	42.73	95720	1280	82.88	185650
680	44.03	98630	1300	84.17	188550
700	45.32	101530	1320	85.47	191450
720	46.62	104430	1340	86.76	194350
740	47.91	107330	1360	88.06	197250
760	49.21	110230	1380	89.35	200150
780	50.50	113130	1400	90.65	203050
800	51.80	116030			

APPENDIX 8 – TEMPERATURE CONVERSION TABLE

$(^{o}C \times 1.8) + 32 = {}^{o}F$ $\frac{^{o}F - 32}{1.8} = {}^{o}C$

ºC	ºF	ºC	ºF	ºC	ºF	ºC	ºF
0	32	310	590	610	1130	910	1670
10	50	320	608	620	1148	920	1688
20	68	330	626	630	1166	930	1706
30	86	340	644	640	1184	940	1724
40	104	350	662	650	1202	950	1742
50	122	360	680	660	1220	960	1760
60	140	370	698	670	1238	970	1778
70	158	380	716	680	1256	980	1796
80	176	390	734	690	1274	990	1814
90	194	400	752	700	1292	1000	1832
100	212	410	770	710	1310	1010	1850
110	230	420	788	720	1328	1020	1868
120	248	430	806	730	1346	1030	1886
130	266	440	824	740	1364	1040	1904
140	284	450	842	750	1382	1050	1922
150	302	460	860	760	1400	1060	1940
160	320	470	878	770	1418	1070	1958
170	338	480	896	780	1436	1080	1976
180	356	490	914	790	1454	1090	1994
190	374	500	932	800	1472	1100	2012
200	392	510	950	810	1490	1110	2030
210	410	520	968	820	1508	1120	2048
220	428	530	986	830	1526	1130	2066
230	446	540	1004	840	1544	1140	2084
240	464	550	1022	850	1562	1150	2102
250	482	560	1040	860	1580	1160	2120
260	500	570	1058	870	1598	1170	2138
270	518	580	1076	880	1616	1180	2156
280	536	590	1094	890	1634	1190	2174
290	554	600	1112	900	1652	1200	2192
300	572						

APPENDIX 9 – DISTANCE ACROSS CORNERS OF HEXAGONS AND SQUARES



D = 1.1547 d
E = 1.4142 d

METRIC SIZES

d mm	D mm	E mm	d mm	D mm	E mm	d mm	D mm	E mm
3	3.464	4.243	34	39.260	48.083	68	78.520	96.166
3.5	4.041	4.950	35	40.415	49.497	69	79.674	97.580
4	4.619	5.657	36	41.569	50.911	70	80.829	98.994
4.5	5.196	6.364	37	42.724	52.325	71	81.984	100.408
5	5.774	7.071	38	43.879	53.740	72	83.138	101.822
5.5	6.351	7.778	39	45.033	55.154	73	84.293	103.237
6	6.928	8.485	40	46.188	56.568	74	85.448	104.651
7	8.083	9.899	41	47.343	57.982	75	86.603	106.065
8	9.238	11.314	42	48.497	59.396	76	87.757	107.479
9	10.392	12.728	43	49.652	60.811	77	88.912	108.893
10	11.547	14.142	44	50.807	62.225	78	90.067	110.308
11	12.702	15.556	45	51.962	63.639	79	91.221	111.722
12	13.856	16.970	46	53.116	65.053	80	92.376	113.136
13	15.011	18.385	47	54.271	66.467	81	93.531	114.550
14	16.166	19.799	48	55.426	67.882	82	94.685	115.964
15	17.321	21.213	49	56.580	69.296	83	95.840	117.379
16	18.475	22.627	50	57.735	70.710	84	96.995	118.793
17	19.630	24.041	51	58.890	72.124	85	98.150	120.207
18	20.785	25.456	52	60.044	73.538	86	99.304	121.621
19	21.939	26.870	53	61.199	74.953	87	100.459	123.035
20	23.094	28.284	54	62.354	76.367	88	101.614	124.450
21	24.249	29.698	55	63.509	77.781	89	102.768	125.864
22	25.403	31.112	56	64.663	79.195	90	103.923	127.278
23	26.558	32.527	57	65.818	80.609	91	105.078	128.692
24	27.713	33.941	58	66.973	82.024	92	106.232	130.106
25	28.868	35.355	59	68.127	83.438	93	107.387	131.521
26	30.022	36.769	60	69.282	84.852	94	108.542	132.935
27	31.177	38.183	61	70.437	86.266	95	109.697	134.349
28	32.332	39.598	62	71.591	87.680	96	110.851	135.763
29	33.486	41.012	63	72.746	89.095	97	112.006	137.177
30	34.641	42.426	64	73.901	90.509	98	113.161	138.592
31	35.796	43.840	65	75.056	91.923	99	114.315	140.006
32	36.950	45.254	66	76.210	93.337	100	115.470	141.420
33	38.105	46.669	67	77.365	94.751			

I.S.O METRIC BOLTS & NUTS

Diameter of bolt – mm	Width across flats of hexagon – mm	Diameter of bolt – mm	Width across flats of hexagon – mm	Diameter of bolt – mm	Width across flats of hexagon – mm
3.0	5.5	8.0	13.0	20.0	30.0
4.0	7.0	10.0	17.0	24.0	36.0
5.0	8.0	12.0	19.0	30.0	46.0
6.0	10.0	16.0	24.0	36.0	55.0

11.0 Glossary

A

accreditation:	Certification by a duly recognised body of the suitability of a group or an individual to provide the specific service or operation needed.
air hardening steel:	Steels which will harden by air cooling rather than quenching.
Al:	Chemical symbol for aluminium.
alloy steel:	All steels which contain specified minimum contents of alloying elements (other than carbon, manganese up to 1.65%, and silicon up to 0.6%); eg. 4140 is an alloy steel because of its specified minimum levels of chromium and molybdenum.
anisotropic:	Of different properties in different directions eg. in direction of rolling compared with across direction of rolling.
annealing (full):	The heating of a steel into the austenitic range followed by slow (furnace) cooling. This heat treatment may be for the purpose of softening, relief of internal stresses or grain refining.
austenite:	Steel with the iron atoms arranged in a face centred cubic pattern. (Found at high temperature in carbon steels but at room temperature in some alloy steels eg. austenitic stainless steel.)
austenite grain size:	The grain size of steel when heated to the austenitic region. This is generally measured by a standardised testing procedure; eg McQuaid-Ehn test.

B

B:	Chemical symbol for boron.
bainite:	Microstructure of carbide dispersed in ferrite, usually obtained by interrupted quenching of steel.
banding:	(banded structure). A segregated structure of parallel layers, usually in the direction of rolling.
Bi:	Chemical symbol for bismuth.
billet:	A semi-finished forged, rolled or continuously cast product, usually rectangular, intended for further processing by rolling or forging. Cross-section generally less than 165mm square and width to thickness ratio less than 4:1.
black bar:	Steel in the hot rolled condition with its characteristic grey to black surface scale.
bloom:	Same definition as billet except that cross-section is generally greater than 165mm square. (Blooms are usually rolled into billets.)
brazing:	Joining of metals above 425°C but below the melting point of the joined metals, by the fusion of a "filler metal".

bright bars:	Bars produced by cold drawing, cold rolling, turning and polishing, precision grinding, or a combination of these processes and which have a smooth surface free of scale and harmful imperfections.
Brinell hardness:	A specific type of hardness test which determines hardness by the diameter of the impression left by ball indentor to which a controlled load is applied, eg. "HBW 10/3000" signifies Brinell hardness, 10mm tungsten carbide ball indentor, 3000kg load.

C

C:	Chemical symbol for carbon.
camber:	Bend or curve when a section is laid flat and viewed from above.
capability:	(production). The product range and speed of production of a particular machine or process.
capability:	(statistical). The ability of a process within statistical control to conform to specification. (Usually expressed as values of Cp or Cpk.)
carbo-nitriding:	Case hardening of a steel object by heating in a gaseous atmosphere rich in both carbon and nitrogen. The hardening is through the diffusion of both carbon and nitrogen to the steel surface.
carbon steel:	Steels in which carbon is the chief alloying element and the specified minimum of other elements does not exceed 1.65% manganese, 0.6% silicon and 0.4% for all other elements.
carburising:	The raising of the carbon content of the surface of a steel object (usually by heating in the presence of a source of carbon). Traditional method of case hardening.
case hardening:	The use of metallurgical processes (carburising, cyaniding, nitriding or other heat treatment) to harden the surface of a metal object leaving the core relatively soft.
cast analysis:	See heat analysis.
cast certificate:	See heat certificate.
Cd:	Chemical symbol for cadmium.
certificate of compliance:	A certificate signed by an authorised party affirming that the supplier of a product or service has met the requirements of the relevant specifications, contract or regulation.
certificate of conformance:	A certificate signed by an authorised party affirming that a product or service has met the requirements of the relevant specifications, contract or regulation.
Charpy:	See impact test.
C.L.A.:	Centre line Average. See Ra
Co:	Chemical symbol for cobalt.
coarse grained (austenite):	A steel prone to grain growth at elevated temperatures. This is usually measured by a standardised testing procedure; eg. McQuaid-Ehn test.

cold draw:	Drawing below the re-crystallisation temperature through a die. (Usually results in work hardening of the material.) This is a method of producing "bright bar".
cold roll:	Rolling below the re-crystallisation temperature. (Usually results in work hardening of the material.) This is a method of producing "bright bar".
cold sized bars:	Bars which are sized by cold drawing or cold rolling to provide closer dimensional tolerances than occur for hot rolled bars, but which may contain some surface imperfections. (Not classified as "bright bar".)
cold work:	Deformation below the re-crystallisation temperature. (Usually results in hardening of the material, ie. Work hardening.)
Continuous casting:	A technique of casting molten metal into blooms, slabs and billets which continually solidify while being poured, thus by-passing the ingot stage.
Cr:	Chemical symbol for chromium.
Cu:	Chemical symbol for copper.
cyaniding:	Case hardening of a steel object by immersion in a molten cyanide salt bath followed by quenching. The hardening is through the diffusion of both carbon and nitrogen to the steel surface.

D

decarburisation:	Removal of carbon from the surface of steel. (Usually by heating in a oxidising environment.)
die:	A block or plate with a conical hole through which the bar is drawn.
diffusion:	The gradual permeation of atoms or molecules through a material, caused by thermal agitation.
dislocation:	A fault in the regular stacking pattern of atoms in a crystal or grain.
draft:	The reduction of cross-section area which occurs when a bar is drawn through a die.
ductility:	A measure of the amount of deformation a metal can withstand before fracture.
dunnage:	Loose material laid between or wedged amongst cargo for protection from transit damage.

E

electrolyte:	A liquid which conducts electricity through the movement of salts in solution.
elongation:	The increase in length of a tensile test piece when stressed. (Elongation at fracture is usually expressed as a percentage of the original length.)

etching:	Controlled application of aggressive chemicals to the surface of a sample, usually for the purpose of revealing its structure.
eutectic:	An alloy whose melting point is lower than any other mixture of its constituents and which solidifies as a dispersion of two distinct solids. Eutectic dispersions usually have a characteristic pattern.
eutectoid:	A solid alloy analogous to a eutectic which on cooling decomposes to form a dispersion of two new and distinct solids.

F

Fe:	Chemical symbol for iron.
ferrite:	Iron with atoms arranged in a body centred cubic pattern (found in carbon steels at room temperature).
ferromagnetic:	A substance which possesses magnetic properties in the absence of an external field (eg. iron and steel).
fine grained (austenite):	A steel whose tendency to grain growth at elevated temperatures has been reduced (eg. by addition of aluminium). This is usually measured by a standardised testing procedure: eg. McQuaid-Ehn test.
flame hardening:	A surface hardening process which uses a gas flame to heat the surface prior to quenching. Similar to induction hardening with a different heat source.
fracture toughness:	See impact test.
free cutting steel:	Steel which has been metallurgically altered to improve machinability (eg. by addition of S,P,Pb).
fretting corrosion:	Damage caused by a combination of mutual abrasion and corrosion between two contacting metal surfaces subject to vibration.

G

galling:	Damage caused by the chafing of metal surfaces in contact.
galvanic cell (corrosion):	Two dissimilar metals in the presence of an electrolyte causing corrosion of one (the anode) through the passage of a self generated electric current.
grain:	Individual crystals in a metal.
gummy:	Where the chip formation is poor, and the metal is torn from the surface like chewing gum.

H

H:	Chemical symbol for hydrogen.
hardenability:	The depth and level of hardness which can be achieved in a metal under a standard heat treatment test, ie. A metal's potential ability to be hardened. Not to be confused with hardness, eg. an annealed material may be low in hardness but it may have a high potential to be further hardened (hardenability).

hard drawn:	Cold drawing with a relatively high draft resulting in a high degree of work hardening.
hard metric:	Full and complete metrication without cognisance of other measurement systems.
hardness:	Resistance to penetration.
heat affected zone (HAZ):	In a process involving localised heating (eg. welding), that area of the surrounding metal which has not been melted but is nevertheless metallurgically affected by the heat.
heat analysis:	The chemical analysis of a sample usually taken from the molten steel before casting. Refer to AS 1213.
heat certificate:	A certificate signed by an authorised party which demonstrates that the heat or cast conforms to the chemical specification.
heat treatment:	A controlled cycle of heating and cooling of solid metals for the purpose of obtaining the desired properties.
hot roll:	Rolling above the re-crystallisation temperature. (This does not result in work hardening.)
hot work:	Deformation above the re-crystallisation temperature. (This does not result in work hardening.)

I

impact test:	A test of toughness which measures the energy absorbed when a specimen is struck with a controlled blow. Common types of test are Izod and Charpy.
inclusions:	Particles of impurities contained in a material.
Induction hardening:	A surface hardening process which uses an electromagnetic field to heat the steel prior to quenching.
ingotism:	Grain structure characteristic of a cast ingot with pronounced variation from the surface to the core and with inherent planes of weakness.
internal stress:	Stresses which are retained within a metal following thermal or mechanical straining.
Izod:	See impact test.

J

Jominy (end quench):	A test for determining hardenability.

K

killed:	A steel which is fully deoxidised before casting. This has the effect of eliminating lively gas evolution from the molten steel hence the name "killed". Killed steels are known for their high degree of chemical homegeneity (lack of segregation).

L

lay: The direction of the predominant pattern on a machined surface.

longitudinal: In the direction of rolling or metal flow.

low alloy steel: Steel containing up to 10% of alloying elements.

M

machinability: The ease with which a material can be machined can be measured in terms of eg. tool life, tool wear (part growth), surface finish, surface type.

Macroscopic examination: Visual examination at magnification of less than X 10.

macrostructure: The structure of a material under macroscopic examination.

Magnetic permeability: The ability of a material to become magnetised. High permeability materials are easily magnetised.

martensite: Steel with the atoms arranged in a body centred tetragonal pattern and supersaturated with carbon. (Produced by rapid quenching of austenite).

mass effect: The variation in mechanical properties caused by the influence of the size of the material.

matrix: The enveloping phase (background) in which another phase is embedded.

mean: Arithmetic average.

Mechanical properties: Those properties associated with stress and strain; eg. yield stress, tensile stress, elongation, hardness.

Merchant bar: A finished product of solid section which may have rectangular, square, round or hexagonal cross-section. Used as raw material for bright bar production. Fully described in AS 1442.

Mg: Chemical symbol for magnesium.

Microcracked (chrome plating): Containing microscopic cracks which do not provide a continuous path through the plating.

micrometre: See micron (not to be confused with the common measuring instrument called "micrometer").

micron: 0.001 mm or 0.00004".

microstructure: The structure of a material as viewed by the microscope (magnification above l0 X).

mid radial: A point equidistant from the centre and the circumference of a circular section.

Mn: Chemical symbol for manganese.

Mo: Chemical symbol for molybdenum.

modulus of elasticity: Elastic stress per unit of elastic strain. 207,000 MPa for carbon steels.

morphology: The form, structure and distribution of a phase.

N

N:	Chemical symbol for nitrogen.
Nb:	Chemical symbol for niobium. Also known as Columbium (USA).
Ni:	Chemical symbol for nickel.
nitriding:	A steel case hardening process in which nitrogen is introduced to the steel surface by means of heating in a nitrogen rich environment, eg. Ammonia. The nitrogen forms hard nitrides particularly in steels containing Al, Cr, V, Wand Mo.
normalising:	The heating of a steel into the austenitic range followed by cooling in still air. This heat treatment may be for the purpose of softening, relief of internal stresses or grain refining. Normalised steel is harder than annealed steel.
nucleation:	The start of growth of a new phase.

O

O:	Chemical symbol for oxygen.
oxide inclusions:	Particles of oxide impurities within a material. Usually regarded as undesirable.

P

P:	Chemical symbol for phosphorus.
Pb:	Chemical symbol for lead.
pearlite:	An iron/iron carbide eutectoid of approx. 0.8%C which is characterised by a lamellar structure (similar to the appearance of a fingerprint).
peeled bar:	Bars which are finished by rough machining. (Not classified as "bright bar".)
phase:	A physically distinct, homogenous component of a microstructure eg. ferrite, cementite.
phase diagram:	A graph of phase relationships with chemical composition and other factors, eg. temperature.
pickle:	Removal of scale by immersion in a dilute acid bath.
Powder metallurgy:	The production of metal components by compacting powder in a die followed by sintering (bonding).
Precision ground bar:	Bright bar which has been subsequently ground to improve dimensional tolerances and surface finish.
process anneal:	See sub-critical anneal.
product analysis:	Chemical analysis of the finished product from the steel mill (not analysis of the molten steel).
product audit:	An additional inspection of the product over and above routine inspection in order to assess the effectiveness of routine inspection.
proof stress:	Used as a substitute for yield point in materials which show no well defined yield. It is generally the stress which corresponds to 0.2% permanent extension of the sample under tensile test.

proportional limit:	The stress at which a tensile sample ceases to behave as an ideal spring according to Hooke's Law, ie. Extension ceases to be proportional to load. This is usually close to the yield point in carbon steels.

Q

quality assurance:	Planned and systematic actions to provide confidence that goods or services will satisfy the requirements.
quality audit:	A systematic and independent examination of the Quality System to determine whether it is suitable and effective.
quality control:	The operational techniques and activities that are used to ensure that quality requirements will be fulfilled, eg. inspection.
quality management:	That aspect of management activity that determines and implements Quality Policy.
quality plan:	A document setting out quality practices, records and activities specific to a particular job. Eg. A Route Sheet.
quality policy:	A statement made by management of the overall quality intentions and directions of an organisation.
quality systems:	The entire organisation, procedures and resources for implementation of quality management.
quench:	Rapid cooling from an elevated temperature, eg. by immersion of red hot steel in water.

R

Ra:	A measurement of surface roughness which is calculated by taking the arithmetic mean of the deviations from the centre line. This is also known as "Centre Line Average" or "C.L.A."
radial:	Arranged like radii, eg. spokes of a wheel.
recovery:	See Stress Relieve.
recrystallisation:	The formation of new, annealed grains from previously work hardened grains.
reduction of area (R of A):	In drawing – see "draft".
	In tensile testing. The decrease in area at the point of fracture, usually expressed as a percentage of the original area.
reeling:	The straightening and smoothing of a round bar by feeding through a set of skewed, contoured rolls.
residual stress:	See "internal stress".
Rockwell hardness:	A method of hardness testing which utilises an indentor under a fixed load. The depth of indentation is a measure of the hardness, eg. "HRB" signifies Rockwell Hardness, "B" scale.
rod:	A semi finished or finished product of approximately circular cross-section produced in coils. It may be used as feed for bright bar manufacture. Fully described in AS 1442. (Rod generally has wider tolerances than the equivalent merchant bar.)

S

S:	Chemical symbol for sulphur.
scale:	An oxide layer on metals formed during exposure to high temperature. Also known as "mill scale".
Se:	Chemical symbol for selenium.
segregation:	lack of uniformity in composition within an object.
semi-killed:	A steel which is partially deoxidised (killed) before casting so that shrinkage during solidification is approximately balanced by expansion due to gas evolution. These steels are more prone to segregation than fully killed steels. They are also referred to as "balanced steels".
sensitisation:	Heat induced (550°C–850°C) precipitation of chromium carbides at grain boundaries in austenitic stainless steels. This leaves the steel prone to corrosion because of depletion of chromium in the surrounding matrix.
shear strength:	A property analogous to tensile strength but measured with the specimen in shear loading rather than stretching. As a "rule of thumb" – shear strength = 0.75 tensile strength.
shot blasting:	Blasting with metal shot, usually to remove "mill scale".
Si:	Chemical symbol for silicon.
six sigma:	A statistical measure of the extent of variation of a process. The range is generally regarded as encompassing the full extent of variation of a process.
Sn:	Chemical symbol for tin.
soft metric:	Partial metrication in which old imperial sizes are converted to their direct equivalents in the metric system. c.f. hard metric, eg.]" = 25.4mm soft metric, 25mm hard metric.
soldering:	Joining of metals with a liquid filler metal at temperatures below 425°C. The joined metals are not melted themselves.
solid solution:	A solid phase which contains foreign (different) atoms as an integral part of the phase, eg. carbon in ferrite (iron).
spark test:	A quick method for the approximate determination of the chemical composition of carbon steels. It utilises the appearance of sparks from a grinding wheel as compared with reference samples.
specification:	The document which describes the requirements with which the product or service has to conform.
spectrometer:	(vacuum emission or atomic absorption). Instruments which provide a quantitative determination of analysis by utilising the characteristic emission or absorption of light by each element.
Spheroidise (anneal):	An extended heat treatment process which results in steel with iron carbide in spheroidal form. This is the softest condition obtainable by annealing.
stainless steel:	A family of alloy steels containing chromium approx. 8–25%. They are characterised by their resistance to corrosion.

Standard deviation:	A statistical measure of the variation of a set of data.
statistical process control: (SPC)	The application of statistical techniques to the control of processes. This traditionally involves the use of control charts where data is assessed against the known inherent variation of the process.
strain:	Change in length under load (usually expressed as a fraction or percentage of the original length).
strain aging:	A change in mechanical properties which occurs over time after cold working. The principal changes are an increase in hardness and a reduction in ductility and impact toughness. It can be accelerated by heating of steel to approx. 250^{o}C.
strain-harden:	See cold work.
stress:	Force (load) per unit of cross-sectional area. Unit MPa.
stress relieve:	Removal of residual stresses by heating below the recrystallisation temperature (typical stress relief 500^{o}C).
stress-strain curve:	A graphical representation of the results of tensile testing with strain (extension) shown on the horizontal axis and stress (load) shown on the vertical axis.
sub-critical anneal: (process anneal)	Annealing above the recrystallisation temperature but below the temperature required to form austenite (typical sub-critical anneal 650^{o}C). This results in softening and relief of internal stresses.
sulphur print test:	A spot test which reveals the presence of sulphides in steel. (Used to detect re-sulphurised free machining steels.)
sweep:	Bend or curve when a section is laid on edge and viewed from above.

T

Te:	Chemical symbol for tellurium.
temper:	Reheating after quenching to reduce hardness and brittleness.
temper brittleness:	Brittleness in some alloys, associated with tempering in a particular temperature range.
tensile strength:	The maximum stress achieved in a tensile test (based on original cross-section area).
tensile test:	The controlled stretching of a specimen until fracture occurs. A stress-strain curve is usually produced. Properties such as proof stress, yield and tensile strength, elongation and reduction of area are determined by this test.
Ti:	Chemical symbol for titanium.
tolerance:	The permitted variation in a process or characteristic of an item.
total quality management:	(Also known as total quality control, TQM or TQC). The application of statistical principles and techniques in all stages of design, production, service, marketing and administration to achieve the desired result.

toughness:	The property of absorbing energy before fracture. (Not to be confused with hardness or strength, eg. glass is hard and strong but not tough.) See "Impact Test".
traceability:	The ability to trace the history of an item by means of recorded identification. This may be either upstream or downstream, ie. to go backwards in time from a point or to go forwards from a previous point.
transverse:	Perpendicular to the direction of rolling or metal flow.
turned and polished:	A bright bar produced by removal of the hot rolled surface by a cutting (turning) operation followed by polishing. This should not be confused with a peeled bar which is not bright bar.

U

ultimate tensile strength (UTS):	See tensile strength.
ultrasonic testing:	A non-destructive testing method which utilises sound waves, of higher than audible frequency, to detect the presence of internal discontinuities (defects).

V

V:	Chemical symbol for vanadium.
variance:	A statistical measure of a variation of a set of data. The square root of variance equals standard deviation.
Vickers hardness:	A method of hardness testing which utilises pyramid shaped indentation under a fixed load. The point to point width of the indentation is a measure of hardness, eg. "HV30" signifies Vickers Hardness, 30kg load.

W

W:	Chemical symbol for tungsten. Also known as Wolfram.
weld:	A joining operation involving melting of the joined metals.
work hardening:	See cold work.

Y

yield point:	A property usually measured in a tensile test. It is the stress (based on original area) at which there is a marked increase in extension of the sample (strain) without an increase in load. (Cold worked material generally does not exhibit a well defined yield point and 0.2% proof stress is used as a substitute for yield.)
Young's Modulus:	See modulus of elasticity.

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