SPECIFICATIONS

To assist our customers we have compiled the following data sheets which provide technical information frequently required by designers and fabricators.

The specifications are combined into three groups:

a) C.S.A. G40.21M 1978
b) C.S.A. G40.21 1976
c) A.S.T.M. and other specifications.

The suggested cold forming radii for the various grades of steel should, in our opinion, be attainable when using normal press brake practices. Greater care in the preparation of materials and bending practice could result in smaller radii being obtained. More generous radii may be required for rolling operations.

The establishment of specific welding techniques depends upon many factors such as temperature of the work piece and/or atmosphere, the welding process employed, the thickness and chemistry of the materials being joined, joint restraint etc. As a result only generalized welding information can be offered. In general, an electrode is employed whose strength is equal to that of the materials being joined. Suggested preheat and interpass temperatures are tabulated on the following pages:

C.S.A. G40.21M steels - page 123
C.S.A. G40.21 steels - page 134
A.S.T.M. steels -page 143

These are appreciably in agreement with those stipulated by both the C.S.A. and the AW.S. Specifications covering welded structures and should be adequate to avoid weld cracking. However, higher preheat and interpass temperatures may be required depending upon the actual welding conditions associated with specific jobs.

Guide to Structural Steel Selection

CSA G40.21M Structural Quality Steel	CSA G40.21 Designation of Similar Steel1	ASTM Designation of Similar Steel1	Max. Shape Group	Maximum Thickness			
				Plate or Bar		HSS Wall	
				mm	ins.	mm	ins.
230G	**33G**	A36; A283 Gr. D	5	300	12	-	-
350G	**50G**	A440	3	30	1 1/4	-	-
400G	**60G**	-	3	30	1 1/4	-	-
260W	**38W**	A36	4	40	1 1/2	-	-
300W	**42W*, 44W**	A572 Gr. 42 Gr. 45	3 & HSS	40	1 1/2	16	5/8
350W	**50W**	A572 Gr.50	2 & HSS	40	1 1/2	16	5/8
380W*	**55W***	A572 Gr.55	HSS	-	-	16	5/8
400W	**60W**	A572 Gr.60	1	20	3/4	-	-
480W	**70W**	A572 Gr.70	1	14	1/2	-	-
260T	**38T**	A36 KFG	5	100	4	-	-
300T	**44T**	A572 Gr.45 KFG	5	100	4	-	-
350T	**50T**	A441 K; A572 Gr.50 KFG	4 & HSS	100	4	16	5/8
380T*	**55T***	A572 Gr.55 KFG	HSS	-	-	16	5/8
400T	**60T**	A572 Gr.60 KFG	2	20	3/4	-	-
480T	**70T**	A572 Gr.70 KFG	1	20	3/4	-	-
350R	**50R**	A242	1	14	1/2	-	-
350A	**50A**	A242A; A588	5 & HSS	100	4	16	5/8
400A	**60A**	-	2	40	1 1/2	-	-
480A	**70A**	-	-	20	3/4	-	-
700Q	**100Q**	A514	-	50	2	-	-

*These grades are available in hollow structural sections only.

(1) Similarity in yield strength, description and application; not necessarily in chemical composition or test requirements; see the individual specifications for details.
(2) Assumes suitable welding technique is used.
(3) Refers to steel without paint or other protective coating.
(4) Atmospheric corrosion resistance can be enhanced to FAIR by specifying copper additions.

Weld-ability[2]	Low Temp. Toughness	Atmospheric Corrosion Resistance[3]		Description	Principal Application
G to F	-	-		Carbon-manganese steels, Semi Killed	Bolted structures
-	-	-	4		
-	-	-			
VG-G	-	-		Weldable carbon-manganese steels, Semi-Killed	General use welded construction
VG-G	-	-	4		
VG-G	-	-			
VG-G	-	-			
VG-G	-	-	4		
VG-G	-	-			
VG-G	VG	-		Welded carbon-manganese steels, Killed Fine Grain (KFG) practice, for low temperature service	Welded bridges
VG-G	VG	-	4		
VG-G	VG	-			
VG-G	VG	-			
VG-G	VG	-	4		
VG-G	VG	-			
G	-	VG		Low-alloy corrosion resisting steel, Killed	Exposed unpainted cladding and light structural members
VG-G	VG	VG		Low-alloy corrosion resisting steel, KFG for low temperature service	Exposed unpainted bridges
VG-G	VG	VG			
VG-G	VG	VG			
G with proper technique	-	-		Low-alloy, KFG, Quenched and Tempered high strength steel	Bridges and special applications

Shape Size Groupings

For Tensile Property Classification

Shape	Group 1	Group 2	Group 3	Group 4	Group 5
Wide Flange Shapes (Nominal depth in mm by Mass in Kg./m) (W Shapes)	W610 x 82, 92 W530 x 66 to 85 incl. W460 x 52 to 106 incl. W410 x 39 to 85 incl. W360 x 33 to 79 incl. W310 x 21 to 86 incl. W250 x 18 to 67 incl. W200 x 15 to 71 incl. W150 x 13 to 37 incl. W130 x 24, 28 W100 x 19	W920 x 201 to 313 incl. W840 x 176 to 226 incl. W760 x 147 to 314 incl. W690 x 125 to 265 incl. W610 x 101 to 241 incl. W530 x 92 to 219 incl. W460 x 113 to 177 incl. W410 x 100 to 149 incl. W360 x 91 to 196 incl. W310 x 97 to 158 incl. W250 x 73 to 167 incl. W200 x 86 10	W920 x 342 to 446 incl. W840 x 299 to 359 incl. W360 x 216 to 314 incl. W310 x 179 to 283 incl.	W360 x 347 to 818 incl. W310 x 313 to 500 incl.	W360 x 900 to 1086 incl.
Light Miscellaneous Beams and Columns (M Shapes)	to 56 Kg/m				
Standard I Beams (S Shapes)	to 52 Kg/m	Over 52 Kg/m			
H Bearing Piles (HP Shapes)		to 152 Kg/m	Over 152 Kg/m		
Standard Channels (C Shapes)	to 30.8 Kg/m	Over 30.8 Kg/m			
Miscellaneous Car & Shipbuilding Channels (MC Shapes)	to 42.4 Kg/m	Over 42.4 Kg/m			
Angles, Bulb Angles, Zees and Rolled Tees	to 13 mm thk.	Over 13 mm to 20 mm thk.	Over 20 mm thk.		

(1) Shape size grouping of rolled shapes is in accordance with CSA G40-20-M1978

CSA G40.21M-1978 and G40.21 (1976)

Structural Quality Steels

This Standard includes materials having a number of different types, defined as follows:

Type G - General Construction Steel. Steels of this type meet minimum strength requirements; however, the chemical control is not such that all of these steels may be welded satisfactorily under normal field conditions. They are primarily designed for applications involving bolted connections or for welding under carefully controlled shop conditions;

Type W - Weldable Steels. Steels of this type meet minimum strength requirements and are suitable for general welded construction where notch toughness at low temperatures is not a prime consideration. Applications may include buildings, compression members of bridges, etc.

Type T - Weldable Steels. Steels of this type are suitable for welded construction and may be specified when low-temperature notch toughness is a prime consideration in design. In such cases Charpy V-notch testing should be specified by the purchaser to ensure that the impact requirements are met.

Type R - Atmospheric Corrosion-Resistant Structural Steel. Steels of this type display an atmospheric corrosion resistance approximately four times that of plain carbon steels.* These steels may be readily welded up to the maximum thickness covered by this Standard. Applications include unpainted siding, unpainted light structural members, etc., where notch toughness at low temperatures is not a consideration.

Type A - Atmospheric Corrosion-Resistant Weldable Structural Steel. Steels of this type display an atmospheric corrosion resistance of approximately four times that of plain carbon steels.* These steels may be welded readily under normal conditions and are often used in structures in the unpainted condition. These steels may be specified when low-temperature notch toughness is a prime consideration in design. In such cases, Charpy V-notch testing should be specified by the purchaser to ensure that the impact requirements are met.

*Copper content not exceeding 0.02 per cent.

Type Q - Quenched and Tempered Low Alloy Steel Plate. Steels of this type display a very high yield strength and good resistance to brittle fracture and are especially suited for bridges and similar structures. While these steels may be readily welded, the welding and fabrication techniques are of fundamental importance and must not adversely affect the properties of the plate, especially the heat-affected zone.

A number of strength levels are available under this Standard, and are designated by the approximate yield strength which is incorporated in the C.S.A. Grade Number, similar to the following examples:

Metric G40.21M-1978 - Grade 230G - (Yield Strength 230 MPa- Type G).
Imperial G40.21 (1976) - Grade 33G - (Yield Strength 33 Ksi- Type G).

The grades, types, and strength levels normally available are shown on the following pages.

CSA G40.21M-1978

Formability

OLD FORMING

Plates and bars of all CSA G40.21M grades can be satisfactorily formed on a press brake or other conventional cold bending equipment There is a considerable difference in the formability of the different grades due to the strength level and chemical composition differences; because of this, care must be exercised when forming is required.

The following table summarizes the results of research and experience and is offered as a guide to the minimum bend radius that can be expected for different grades and thicknesses. These criteria apply strictly to longitudinal bends, i.e., where the bend line is transverse to the rolling direction. Transverse bends may require up to twice the indicated radius. It is assumed that the bend is not carried out on an edge that has been flame-hardened by gas cutting, on heavily burred or work hardened by shearing unless some special edge preparation, such as grinding or chipping has been carried out.

SUGGESTED MINIMUM BEND RADIUS: Longitudinal Bends

Grade	Up to 6	Over 6 to 12	Over 12 to 25	Over 25 to 40	Over 40 to 50
230G	1t	1t	2t	3t	4t
350G	2 1/2t	3 1/2t	-	-	-
400G	3t	5t	-	-	-
260W	1 1/2t	1 1/2t	2t	3t	-
300W	1 1/2t	2t	3t	4t	-
350W	2 1/2t	2 1/2t	4t	-	-
400W	3 1/2t	3 1/2t	6t	-	-
480W	5t	5t	-	-	-
260T	1 1/2t	2t	3t	4t	4t
300T	1 1/2t	2t	3t	4t	5t
350T	2 1/2t	3t	4t	-	-
400T	3 1/2t	3 1/2t	6t	-	-
480T	4t	5t	6t	-	-
350R	2t	3t	-	-	-
350A	2t	3t	5t	-	-
400A	3t	4t	6t	-	-
480A	4t	5t	6t	-	-

T = thickness in mm

HOT FORMING - is recommended for all thicknesses not showing a value. Since temperature can be a major cause of bend failure, in no case should bending be carried out at a metal temperature below 15°C.
Material of 350 MPa and higher yield strength will require greater bending and hold down force than lower strength steels and provisions must be made for a greater than usual degree of spring back.
The cold bending of structural shapes is a most difficult task and the steel producer should be consulted before cold bending of any degree of severity is carried out.

CSA G40.21M-1978

Welding

All grades of CSA G40.21M steels can be readily welded with the exception of Grades 350G and 400G which can be welded under carefully controlled conditions. It is urged that the requirements of CSA Standard W59-1977 "Welded Steel Construction (Metal Arc Welding)" be followed as a minimum.

The suggestions set forth in this guide are intended to meet these requirements. However, the applicable standard or code should be consulted before establishing any procedures.

SUGGESTED FILLER MATERIALS:

Grade	Manual Electrodes (SMAW) CSA W48.1, 48.3	Submerged Arc (SAW) CSA W48.6	Gas Metal Arc (GMAW) CSA W48.4	Flux-Cored Metal Arc (FCAW) CSA W48.5
230G	E6010, 11, 13, 20, 27	F6Z-ELXX	E70-X, E70U-X	E60T-8, E70T-X
260W, 260T	E7015, 16, 18, 28, 38	F70-EMXX	E70-X, E70U-I	E60T-8, E70T-X(a)
300W, 300T 350G, 350W	E7015, 16, 18, 28, 38	F70-EMXX	E70-X, E70U-I	E70T-X (a)
350R, 350A 400A	E8015-B4 E8016-B2, C1-3 E8018-82, C1-3	L61+ XXX10 Flux	(b)	E70T-G2
400G, 400W 400T	W8015, 16, 18	F80-EMXX	E80S	E80T
480W, 480T	E8015, 16, 18	F90-EMXX	E90E	90T
480A	E9018M	(b)	(b)	(b)

(a) Exclusive of E70T-2, E70T-3, E70T-G. (b) Consult consumable manufacturer.

EXPOSED STEEL:

When steels of Types Rand A are used in the exposed, bare, unpainted condition, the electrodes suggested or others producing a similar alloy composition in the deposited metal should be used, For applications where the material is not boldly exposed, where colour match is not important, for all but capping passes in multipass welds and for narrow single pass welds, the electrodes suggested for Grades 300T, 400T and 480T may be used.

SUGGESTED MINIMUM PREHEAT AND INTERPASS TEMPERATURES:

Welding should not be carried out when the ambient temperature is below -20°C. When the base metal temperature is below the temperature listed for the welding process and thickness it should be preheated in such a manner that the surface of the material on which the weld is to be deposited is at or above the suggested minimum temperature for a distance equal to the thickness of the material but not less than 75 mm both laterally and in advance of the welding. When the base metal temperature is below 0°C, it should be brought up to and maintained at 10°C during welding, for all grades. Temperatures higher than the minimum suggested may be required for highly restrained welds.

Thickness of the Thickness Part at Point of Welding	Shielded Metal Arc (other than Basic Electrodes) Flux-Cored Arc Welding	Shielded Metal Arc with Basic Electrodes, Submerged Arc Welding, Gas Metal Arc Welding, Flux-Cored Arc Welding	
	230G, 300W, 300T	260W 260T 350R 300W 300T 350A 350W 350T 400A	350G 400W 400T 400G 480W 480T 480A
Up to 20 mm	none	none	10°C
Over 20 to 38 mm	65°C	10°C	65°C
Over 38 to 63 mm	110°C	65°C	110°C
Over 63 mm	150°C	110°C	150°C

CSA G40.21M-1978 and G40.21 (1976)

Type G – General Construction Steel

DISCUSSION

Type G steels are basically carbon-manganese steels, usually produced to a semi killed steel-making practice and have minimum controls placed upon the chemical composition. The steels are designed to provide the required strength levels with the lowest possible cost of materials. Steels of this type have found considerable usage in bolted structures, such as transmission towers, microwave towers, material handling equipment etc. They are not recommended for low temperature service. However, where the fabrication methods do not create notch effects and only limited thick nesses are used, satisfactory low temperature service has resulted. These steels are often welded under shop conditions where preheat and other temperatures can be carefully controlled but are not recommended for field welding where adequate control may be difficult or impossible to maintain.

AVAILABILITY

Grade 230G is readily available in plate thicknesses up to 100 mm. It is not normally produced in structural shapes. Grades 350G and 400G are not available in plate and are usually available only in the form of angles. Since these grades are not regularly rolled, the producer should be contacted prior to any commitment to their use.

CORROSION RESISTANCE

These steels have the same atmospheric corrosion resistance as plain carbon steels; however, this may be enhanced somewhat by specifying a minimum copper addition.

NOTCH TOUGHNESS

Steels of this type are not recommended for any application requiring notch toughness in the material.

WELDABILITY

While Grade 230G can be readily welded, it is recommended that Grades 350G and 400G not be used for structures involving welding in the fabrication except under very carefully controlled conditions. For suggestions of procedures to be used see page 7.

FORMABILITY

Grade 230G can be readily cold formed by the usual methods. Since Grades 350G and 400G are not available in plate, the usual forming operations do not occur. The bending of angles is a difficult operation at best and is compounded by the high strength of these grades. For minimum bend radii and other suggestions see page 6.

CUTTING

These materials can be gas cut or cold sheared using good practices, but Grades 350G and 400G are subject to moderate hardening along a gas cut edge. The degree of hardening depends largely upon the thickness of the material and its temperature.

CSA G40.21M-1978 and G40.21 (1976)

Type W – General Construction Steel

DISCUSSION

Type W steels may be categorized as the "garden variety" steel for general welded construction in Canada. They are usually produced to a semi-killed steel-making practice in thicknesses up to 40 mm. The control of carbon and manganese contents is such that normal good field welding procedures will give satisfactory results. The steels of this type may use micro-alloy grain refining elements but these are normally used only on the higher strength grades in order to attain the required strength level with minimum carbon content. This is the recommended steel type for normal building construction where shop and field welding is to be used. Although not recommended for low temperature service, these steels are widely used in compression members of bridges and similar structures and other applications where the possibility of brittle fracture is remote.

AVAILABILITY

Grade 300W has been established as the base grade for rolled structural shapes and is also one of the most commonly produced grades of structural plate. Stocks of structural shapes are generally maintained in this grade. Although grades 260W and 350W are regularly produced in plate, they are not normally produced in structural shapes. Consideration of the use of Grades 400W and 480W in plate and of any grade other than 300W in structural shapes should be discussed with the producer before any commitment is made.

CORROSION RESISTANCE

These steels have the same atmospheric corrosion resistance as plain carbon steels; this may be enhanced somewhat by specifying a minimum copper addition.

NOTCH TOUGHNESS

Steels of this type are not produced with the intention of displaying consistent notch toughness properties.

WELDABILITY

Steels of type Ware designed to be readily welded, using good shop or field practices by all of the usual methods. For suggestions of procedures to be used see page 7.

FORMABILITY

Type W steels can be readily hot or cold formed using conventional equipment and good shop practice. The higher strength grades will require greater forming pressures and allowance must be made for increased springback. For minimum suggested bend radii and other limitations see page 6.

CUTTING

These materials can be gas cut or cold sheared using good shop and field practices. Gas cutting of the lower strength grades does not require preheating but it should be considered for grades 400W and 480W and for thicker material of all grades.

CSA G40.21M-1978 and G40.21 (1976)

Type T – General Construction Steel

DISCUSSION

Type T steels may be considered as the “highest quality" carbon-manganese structural steels for welded construction. These steels are produced to a fine grain killed steel practice with control of chemical elements such that the steels are generally suitable for all types of welded structures. Type T steels are not often used for buildings, except for material having thicknesses greater than 40 mm. They are recommended for bridges and other dynamically loaded structures when they have been impact tested to the appropriate design requirements specified by the purchaser. These steels have been so used in every region in Canada.

AVAILABILITY

Type T steels are regularly produced in Grades 260T, 300T and 350T in plate; Grades 260T and 350T are not regularly produced in structural shapes. For plates to Grades 400T and 480T and for structural shapes to any of the T Grades, the producer should be consulted as to availability and minimum quantities that might be required.

CORROSION RESISTANCE

These steels have the same atmospheric corrosion resistance as plain carbon steel; this may be enhanced somewhat by specifying a minimum copper content.

NOTCH TOUGHNESS

The chemical composition of these steels has been designed to enhance the low temperature notch toughness properties. However, these steels are NOT produced with the intention of displaying consistent notch toughness properties unless impact testing has been specified by the purchaser. There is no guarantee, implied or otherwise, that these steels are suitable for applications requiring low temperature notch toughness, unless certified minimum notch toughness values are specified by the purchaser.

WELDABILITY

Steels of Type Tare specifically designed for ready weldability, using good shop and field practices by all of the usual methods. For suggestions on procedures to be used see page 7.

FORMABILITY

Type T steels can be readily hot or cold formed using conventional equipment and good shop practice. The higher strength grades will require a greater forming pressure and allowance must be made for increased springback. For minimum suggested bend radii and other limitations see page 6.

CUTTING

These steels can be gas cut and cold sheared using good shop and field practices. Gas cutting of the lower strength grades does not require preheating but it is recommended on Grade 400T and 480T and for thicker material of other grades.

CSA G40.21M-1978 and G40.21 (1976)

Type R – Atmospheric Corrosion Resistant Structural Steel

DISCUSSION

Type R steel is a high-strength low-alloy steel with a composition formulated to provide good atmospheric corrosion resistance. Up to a thickness of 14 mm it may be shop or field welded by normal procedures, but in greater thicknesses, because of the higher phosphorus content, there may be a tendency towards brittleness in the heat affected zone of welds. This type of steel is therefore normally limited to a thickness of 14 mm. The greatest application is for unpainted steel cladding and unpainted light structural members in building construction. Because of the possibility of welding problems and the availability of Type A the Type R steel is usually not specified for bridges and other dynamically loaded structures.

AVAILABILITY

Type R steel is usually available only in light plates and it is not normally produced in structural shapes.

CORROSION RESISTANCE

The long term atmospheric corrosion resistance of this steel is at least 4 times that of plain carbon steel (copper content not exceeding 0.02%). Due to its excellent corrosion resistance, this steel may be used unpainted and exposed to the atmosphere as it will develop a tight protective oxide film.

NOTCH TOUGHNESS

Steel of this type is not produced with the intention of displaying good notch toughness properties. In addition, because of the possibility of brittle welds, this steel is not recommended for any application where low temperature notch toughness is a requirement

WELDABILITY

Steel of Type R up to a maximum thickness of 14 mm may be readily welded using good shop and field practices by all of the usual methods. For suggestions on procedures to be used see page 7. Special attention should be given to electrode selection where the material is to be used in the unpainted exposed condition.

FORMABILITY

Type R steel may be readily hot or cold formed using conventional equipment and good shop practice. Since it is a high strength steel, greater than normal forming pressure will be required and allowance must be made for increased spring back. For suggestions of minimum bend radii and other limitations see page 6.

CUTTING

This steel can be gas cut or cold sheared using good shop and field practices. Since it is a low-alloy steel, some degree of preheating may be necessary for gas cutting.

CSA G40.21M-1978 and G40.21 (1976)

Type A – Atmospheric Corrosion Resistant Weldable Structural Steel

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DISCUSSION

Type A steels are high-strength low-alloy steels with a composition formulated to provide good atmospheric corrosion resistance and good weldability at high strength levels. Because of these unique combinations of properties, steels of Type A are widely used in both the painted and unpainted condition for beams and columns in building construction and for other types of construction where Type R steels are not suitable. They are recommended for bridges and other dynamically loaded structures when they have been impact tested to the appropriate design requirements specified by the purchaser.

AVAILABILITY

All Type A steels are available in plates, while only Grade 350A is available in structural shapes. The producer should be consulted as to availability and minimum quantities before commitment to the use of this type of steel in structural shapes.

CORROSION RESISTANCE

The long-term atmospheric corrosion resistance of this steel is at least 4 times that of plain carbon steel (copper content not exceeding 0.02%). Due to its excellent corrosion resistance, this steel may be used unpainted and exposed to the atmosphere as it will develop a tight protective oxide film.

NOTCH TOUGHNESS

These steels are NOT produced with the intention of displaying consistent notch toughness, unless impact testing has been specified. There is no guarantee, implied or otherwise, that these steels are suitable for applications requiring low temperature notch toughness, unless certified minimum notch toughness values are specified by the purchaser.

WELDABILITY

Steels of Type A are designed to be readily welded, using good shop or field practices, by all of the usual methods. Special attention should be given to electrode selection where the material is to be used in the unpainted, exposed condition. For suggestions on procedures to be used see page 7.

FORMABILITY

Type A steels may be readily hot or cold formed using conventional equipment and good shop practice. Since they are high-strength steels, greater than normal forming pressures will be required and allowance must be made for increased springback. For suggestions of minimum bend radii and other limitations see page 6.

CUTTING

These steels can be gas cut or cold sheared using good shop and field practices. Since they are low-alloy steels, some degree of preheating may be necessary for gas cutting.

CSA G40.21M-1978 and G40.21 (1976)

Type Q – Quenched and Tempered Low Alloy Steel Plate

DISCUSSION

Type Q steels are quenched and tempered low alloy steel plates primarily for use in welded bridges and other structures.

AVAILABILITY

Type Q steels are available in plate only to a 700 MPa (100 Ks1) Grade. Plate thickness for this steel is limited to 50 mm (2 inches).

CORROSION RESISTANCE

Some Type Q steels have a corrosion resistance that is 4 to 6 times better than plain carbon structural grade steels.

NOTCH TOUGHNESS

These steels are NOT produced with the intention of displaying consistent notch toughness, unless impact testing has been specified. There is no guarantee, implied or otherwise, that these steels are suitable for applications requiring low temperature notch toughness, unless certified minimum notch toughness values are specified by the purchaser.

WELDABILITY

Welding procedures and techniques are of prime importance. Heat input must be carefully controlled so that the properties of the adjacent plate material, the heat affected zone and the deposited weld metal, are not adversely affected.

FORMABILITY

Quenched and tempered steels have a high degree of toughness so can tolerate a fair amount of cold forming. These steels should never be hot formed because heating destroys the properties developed by quenching and tempering. Cold forming may be aided by preheating but this should not exceed 400°F. Forming this steel requires more power than for mild steel and the springback is also greater. For rolling operations, a more generous inside radius may be required and it is advisable to remove sharp edges from the tension side of the plate before forming is begun.

CUTTING

Type 0 materials can be gas cut using good shop or field practices. Generally, no preheating is required but a preheat of 100°F to 200°F may be beneficial. Steel temperature must not be lower than 65°F during cutting.

CSA G40.21M-1978 and G40.21 (1976)

Type G – General Construction Steel

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum of Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	Si(b)	Grain Refining Elements(a)
33G	0.26	1.20 (c)	0.05	0.05	0.4	0.1
50G	0.28(d)	1.65	0.04	0.05	0.4	0.1
60G	0.28(d)	1.65	0.04	0.05	0.4	0.1

a) The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated, except that if columbium is used singly or in combination with vanadium in plates thicker than 1/2 inch or shapes heavier than Group 1, the silicon content shall be 0.15 mm.
b) When fully killed steel is specified, at the purchaser's request or at the producer's option, the steel may be made with no minimum silicon content provided that the steel contains a minimum of 0.02% total aluminum content.
c) At the producer's option, material having a manganese content of 1.50% maximum may be supplied.
d) For thicknesses over 3/4 inches, carbon maximum may be 0.32%.
NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements with the prior approval of the purchaser. Copper content of 0.20% minimum may be specified by the purchaser on all grades.

STEELMAKING PRACTICE:

Not specified. Usually semi-killed, but rimmed or capped steel may be supplied for grade 33G up to 0.375" thick.

MECHANICAL PROPERTIES: Plates, Bars and Welding Shapes

Grade	Nom. Max. Thickness inches	Tensile Strength Ksi	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Up to 1-1/2"	Over 1-1/2" to 2-1/2"	Over 2-1/2"	In 8"	In 2"
33G	12	55/72	33	33	33	21	24
50G	1-1/4*	70/100	50	-	-	17	19
60G	1-1/4*	80/105	60	-	-	16	19

* Not available in plates. Bar size shapes only.

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group**	Tensile Strength Ksi	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Groups 1 & 2	Group 3 & 4	Group 5	In 8"	In 2"
33G	5	55/72	33	33	33	21	24
50G	3	70/100	50	50	-	17	19
60G	3	80/105	60	60	-	16	19

CSA G40.21M-1978

Type G – General Construction Steel

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum of Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	Si(b)	Grain Refining Elements(a)
33G	0.26	1.20 (c)	0.05	0.05	0.4	0.1
50G	0.28(d)	1.65	0.04	0.05	0.4	0.1
60G	0.28(d)	1.65	0.04	0.05	0.4	0.1

a) The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated, except that if columbium is used singly or in combination with vanadium in plates thicker than 1/2 inch or shapes heavier than Group 1, the silicon content shall be 0.15 mm.
b) When fully killed steel is specified, at the purchaser's request or at the producer's option, the steel may be made with no minimum silicon content provided that the steel contains a minimum of 0.02% total aluminum content.
c) At the producer's option, material having a manganese content of 1.50% maximum may be supplied.
d) For thicknesses over 3/4 inches, carbon maximum may be 0.32%.
NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements with the prior approval of the purchaser. Copper content of 0.20% minimum may be specified by the purchaser on all grades.

STEELMAKING PRACTICE:

Not specified. Usually semi-killed, but rimmed or capped steel may be supplied for grade 33G up to 0.375" thick.

MECHANICAL PROPERTIES: Plates, Bars and Welding Shapes

Grade	Nom. Max. Thickness mm	Tensile Strength MPa	Yield Point, Minimum, MPa			Elongation Percent, Minimum	
			Up to 40 mm	Over 40 mm to 65 mm	Over 65 mm	In 200 mm	In 50 mm
230G	300	380/500	230	230	230	21	24
350G	30*	480/690	350	-	-	17	19
400G	30*	550/720	400	-	-	16	19

* Not available in plates. Bar size shapes only.

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group**	Tensile Strength MPa	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Groups 1 & 2	Group 3 & 4	Group 5	In 200 mm	In 50 mm
230G	5	380/520	230	230	230	21	24
350G	3	480/690	350	350	-	17	19
400G	3	550/720	400	400	-	16	19

**For section size group for Tensile Property Classification, see page 120.

CSA G40.21 (1976)

Type W – Weldable Steel

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum or Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	Si(b)	Grain Refining Elements(a)
38W	0.2	0.50/1.50	0.05	0.05	0.4	0.1
44W	0.22	0.50/1.50	0.04	0.05	0.4	0.1
50W	0.23	0.50/1.50	0.04	0.05	0.4	0.1
60W	0.23	0.50/1.50	0.04	0.05	0.4	0.1
70W	0.26	0.50/1.50	0.04	0.05	0.4	0.1

a) The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated, except that if columbium is used singly or in combination with vanadium in plates thicker than 1/2 inch or shapes heavier than Group 1, the silicon content shall be 0.15 min.
Aluminum may be used as a grain refining element without prior approval of the purchaser and when so used shall not be included in the summation of the grain refining elements in this table.
b) When fully killed steel is specified, at the purchaser's request or at the producer's option, the steel may be made with no minimum silicon content provided that the steel contains a minimum of 0.02% total aluminum content.

NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements with the prior approval of the purchaser. Copper content of 0.20% minimum may be specified by the purchaser on all grades.

STEELMAKING PRACTICE:

None specified. Normally made to semi-killed practice.

MECHANICAL PROPERTIES: Plates, Bars and Welded Shapes

Grade	Nom. Max. Thickness inches	Tensile Strength Ksi	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Up to 1-1/2"	Over 1-1/2" to 2-1/2"	Over 2-1/2"	In 8"	In 2"
38W	1 1/2	60/85	38	-	-	20	23
44W	1 1/2	65/90	44	-	-	20	23
50W	1 1/2	65/90	50	-	-	19	22
60W	3/4	75/100	60	-	-	16	-
70W	1/2	85/115	70	-	-	15	-

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group	Tensile Strength Ksi	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Group 1 & 2	Groups 3 & 4	Group 5	In 8"	In 2"
38W	4	60/85	38	38	-	20	23
44W	3	65/90	44	42	-	20	23
50W	2	65/90	50	-	-	19	-
60W	1	75/100	60	-	-	16	-
70W	1	85/115	70	-	-	15	-

CSA G40.21M - 1978

Type W – Weldable Steel

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum or Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	Si(b)	Grain Refining Elements(a)
260W	0.2	0.50/1.50	0.05	0.05	0.4	0.1
300W	0.22	0.50/1.50	0.04	0.05	0.4	0.1
350W	0.23	0.50/1.50	0.04	0.05	0.4	0.1
400W	0.23	0.50/1.50	0.04	0.05	0.4	0.1
480W	0.26	0.50/1.50	0.04	0.05	0.4	0.1

a) The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated, except that if columbium is used singly or in combination with vanadium in plates thicker than 1/2 inch or shapes heavier than Group 1, the silicon content shall be 0.15 min.
Aluminum may be used as a grain refining element without prior approval of the purchaser and when so used shall not be included in the summation of the grain refining elements in this table.
b) When fully killed steel is specified, at the purchaser's request or at the producer's option, the steel may be made with no minimum silicon content provided that the steel contains a minimum of 0.02% total aluminum content.

NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements with the prior approval of the purchaser. Copper content of 0.20% minimum may be specified by the purchaser on all grades.

STEELMAKING PRACTICE:

Normally made to semi-killed practice.

MECHANICAL PROPERTIES: Plates, Bars and Welded Shapes

Grade	Nom. Max. Thickness mm	Tensile Strength MPa	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Up to 40 mm	Over 40 mm to 65 mm	Over 65 mm	In 200 mm	In 50 mm
260W	40	410/590	260	-	-	20	23
300W	40	450/620	300	-	-	20	23
350W	40	450/620	350	-	-	19	22
400W	20	520/690	400	-	-	16	-
480W	14	590/790	480	-	-	15	-

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group	Tensile Strength MPa	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Group 1 & 2	Groups 3 & 4	Group 5	In 200 mm	In 50 mm
260W	4	410/590	260	260	-	20	23
300W	3	450/620	300	290	-	20	23
350W	2	450/620	350	-	-	19	-
400W	1	520/690	400	-	-	16	-
480W	1	590/790	480	-	-	15	-

*For section size groups for Tensile Property Classification see page 4.

CSA G40.21 (1976)

Type T – Weldable Steels

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum or Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	Si(b)	Grain Refining Elements(a)
58T	0.2	0.80/1.50	0.03	0.04	0.15/0.40	0.1
44T	0.22	0.80/1.50	0.03	0.04	0.15/0.40	0.1
50T	0.22	0.80/1.50 (c)	0.03	0.04	0.15/0.40	0.1 (d)
60T	0.22	0.80/1.50 (c)	0.03	0.04	0.15/0.40	0.1 (d)
70T	0.26	0.80/1.50 (c)	0.03	0.04	0.15/0.40	0.1 (d)

a) Aluminum may be used as a grain refining element without prior approval by the purchaser and when so used, shall not be included in the summation of grain refining elements included in this table. The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated.
b) At the purchaser's request or at the producer's option, the steel may be made with no minimum silicon content, provided that the steel contains a minimum of 0.02% total aluminum content.
c) With the prior agreement of the purchaser, the manganese content may be increased provided that the sum of the carbon content plus 1/6 of the manganese content does not exceed 0.40% for Grade 50T or 0.42% for Grades 60T or 70T.
d) A nitrogen content of 0.01 to 0.02% may be used, if the nitrogen content does not exceed 1/4 of the vanadium content.
NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements with the prior approval by the producer. A copper content of 0.20% minimum may be specified by the purchaser on all grades.

STEELMAKING PRACTICE:

Fully-killed fine grain practice specified.

MECHANICAL PROPERTIES: Plates, Bars and Welded Shapes

Grade	Nom. Max. Thickness inches	Tensile Strength Ksi	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Up to 1-1/2"	Over 1-1/2" to 2-1/2"	Over 2-1/2"	In 8"	In 2"
38T	4	60/85	38	38	36	20	23
44T	4	65/90	44	42	40	20	23
50T	4	70/95	50	48	46	19	22
60T	3/4	75/100	60	-	-	16	-
70T	3/4	85/115	70	-	-	15	-

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group	Tensile Strength Ksi	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Group 1 & 2	Groups 3 & 4	Group 5	In 8"	In 2"
38T	5	60/85	38	38	36	20	23
44T	5	65/90	44	42	40	20	23
50T	4	70/95	50	48	-	19	-
60T	2	75/100	60	-	-	16	-
70T	1	85/115	70	-	-	15	-

CSA G40.21M-1978

Type T – Weldable Steels

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum or Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	Si(b)	Grain Refining Elements(a)
260T	0.2	0.80/1.50	0.03	0.04	0.15/0.40	0.1
300T	0.22	0.80/1.50	0.03	0.04	0.15/0.40	0.1
350T	0.22	0.80/1.50 (c)	0.03	0.04	0.15/0.40	0.1 (d)
400T	0.22	0.80/1.50 (c)	0.03	0.04	0.15/0.40	0.1 (d)
480T	0.26	0.80/1.50 (c)	0.03	0.04	0.15/0.40	0.1 (d)

a) Aluminum may be used as a grain refining element without prior approval by the purchaser and when so used, shall not be included in the summation of grain refining elements included in this table. The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated.
b) At the purchaser's request or at the producer's option, the steel may be made with no minimum silicon content, provided that the steel contains a minimum of 0.02% total aluminum content.
c) With the prior agreement of the purchaser, the manganese content may be increased provided that the sum of the carbon content plus 1/6 of the manganese content does not exceed 0.40% for Grade 50T or 0.42% for Grades 60T or 70T.
d) A nitrogen content of 0.01 to 0.02% may be used, if the nitrogen content does not exceed 1/4 of the vanadium content.
NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements with the prior approval by the producer. A copper content of 0.20% minimum may be specified by the purchaser on all grades.

STEELMAKING PRACTICE:

Fully-killed fine grain practice specified.

MECHANICAL PROPERTIES: Plates, Bars and Welded Shapes

Grade	Nom. Max. Thickness mm	Tensile Strength MPa	Yield Point, Minimum, MPa			Elongation Percent, Minimum	
			Up to 40 mm	Over 40 mm to 65 mm	Over 65 mm	In 200 mm	In 50 mm
260T	100	410/590	260	260	250	20	23
300T	100	450/620	300	290	280	20	23
350T	100	480/650	350	330	320	19	22
400T	20	520/690	400	-	-	16	-
480T	20	590/790	480	-	-	15	-

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group	Tensile Strength MPa	Yield Point, Minimum, MPa			Elongation Percent, Minimum	
			Group 1 & 2	Groups 3 & 4	Group 5	In 200 mm	In 50 mm
260T	5	410/590	260	260	250	20	23
300T	5	450/620	300	290	280	20	23
350T	4	480/650	350	330	-	19	-
400T	2	520/690	400	-	-	16	-
480T	1	590/790	480	-	-	15	-

*For section size groups for Tensile Property Classification see page 4.

CSA G40.21 (1976)

Type R – Atmospheric Corrosion Resistant Structural Steel

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum or Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	S Si(b)	Grain Refining Elements(a)	Cr(c)	Ni(c)	Cu(c)
50R	0.16	0.75	0.05/0.15	0.04	0.75	0.1	0.30/1.25	0.9	0.2/0.6

a) The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated.
Aluminum may be used as a grain refining element without prior approval by the purchaser and when so used shall not be included in the summation of grain refining elements included in this table.

b) At the purchaser's request or at the producer's option, the steel may be made with no minimum silicon content, provided that the steel contains a minimum of 0.02% total aluminum content.

c) The combined contents of chromium, nickel and copper shall not be less than 1.00%.

NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements, with the prior approval of the purchaser.

STEELMAKING PRACTICE:

Fully-killed fine grain practice.

MECHANICAL PROPERTIES: Plates, Bars and Welded Shapes

Grade	Nom. Max. Thickness inches	Tensile Strength Ksi	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Up to 1-1/2"	Over 1-1/2" to 2-1/2"	Over 2-1/2"	In 8"	In 2"
50R	1/2	70/95	50	-	-	19	-

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group	Tensile Strength Ksi	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Group 1 & 2	Groups 3 & 4	Group 5	In 8"	In 2"
50R	1	70/95	50	-	-	19	-

CSA G40.21M-1978

Type R – Atmospheric Corrosion Resistant Structural Steel

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum or Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	S Si(b)	Grain Refining Elements(a)	Cr(c)	Ni(c)	Cu(c)
350R	0.16	0.75	0.05/0.15	0.04	0.75	0.1	0.30/1.25	0.9	0.2/0.6

a) The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated.
Aluminum may be used as a grain refining element without prior approval by the purchaser and when so used shall not be included in the summation of grain refining elements included in this table.

b) At the purchaser's request or at the producer's option, the steel may be made with no minimum silicon content, provided that the steel contains a minimum of 0.02% total aluminum content.

c) The combined contents of chromium, nickel and copper shall not be less than 1.00%.

NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements, with the prior approval of the purchaser.

STEELMAKING PRACTICE:

Fully-killed fine grain practice.

MECHANICAL PROPERTIES: Plates, Bars and Welded Shapes

Grade	Nom. Max. Thickness mm	Tensile Strength MPa	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Up to 40 mm	Over 40 mm to 65 mm	Over 65 mm	In 200 mm	In 50 mm
50R	14	480/650	350	-	-	19	-

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group	Tensile Strength MPa	Yield Point, Minimum, Ksi			Elongation Percent, Minimum	
			Group 1 & 2	Groups 3 & 4	Group 5	In 200 mm	In 50 mm
350R	1	480/650	350	-	-	19	-

*For section size groups for Tensile Property Classification see page 4.

CSA G40.21 (1976)

Type A – Atmospheric Corrosion Resistant Weldable Structural Steel

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum or Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	S Si(b)	Grain Refining Elements(a)	Cr(c)	Ni(c)	Cu(c)
50A	0.2	0.75/1.35	0.03	0.04	0.15/0.4	0.10	0.70(c)	0.9(c)	0.2/0.6
60A	0.2	0.75/1.35	0.03	0.04	0.15/0.4	0.10	0.70(c)	0.9(c)	0.2/0.6
70A	0.2	1.00/1.60	0.025	0.035	0.15/0.4	0.12	0.70	0.25/0.50	0.2/0.6

a) The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated.
Aluminum may be used as a grain refining element without prior approval of the purchaser and when so used shall not be included in the sumn1ation of grain refining elements included in this table.
b) At the purchaser's request, or at the producer's option, the steel may be made with no minimum silicon content, provided that the steel contains a minimum of 0.02% total aluminum content.
c) The combined total of chromium and nickel contents shall be not less than 0.40%.
NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements, with the prior approval of the purchaser.

STEELMAKING PRACTICE:
Fully-killed fine grain practice.

MECHANICAL PROPERTIES: Plates, Bars and Welded Shapes

Grade	Nom. Max. Thickness inches	Tensile Strength Ksi	Yield Point, Minimum, MPa			Elongation Percent, Minimum	
			Up to 1-1/2"	Over 1-1/2" to 2-1/2"	Over 2-1/2"	In 8"	In 2"
50A	4	70/95	50	50	50	19	21
60A	1-1/2	75/100	60	-	-	18	21
70A	3/4	85/115	70	-	-	15	-

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group	Tensile Strength Ksi	Yield Point, Minimum, MPa			Elongation Percent, Minimum	
			Group 1 & 2	Groups 3 & 4	Group 5	In 8"	In 2"
50A	5	70/95	50	50	46	19	21
60A	2	75/100	60	-	-	18	-
70A	-	-	-	-	-	-	-

CSA G40.21 (1976)

Type A – Atmospheric Corrosion Resistant Weldable Structural Steel

CHEMICAL COMPOSITION/HEAT ANALYSIS

Percent, Maximum or Range: Plates, Bars and Shapes

Grade	C	Mn	P	S	S Si(b)	Grain Refining Elements(a)	Cr(c)	Ni(c)	Cu(c)
50A	0.2	0.75/1.35	0.03	0.04	0.15/0.4	0.10	0.70(c)	0.9(c)	0.2/0.6
60A	0.2	0.75/1.35	0.03	0.04	0.15/0.4	0.10	0.70(c)	0.9(c)	0.2/0.6
70A	0.2	1.00/1.60	0.025	0.035	0.15/0.4	0.12	0.70	0.25/0.50	0.2/0.6

a) The elements columbium and vanadium may be used singly or in combination up to the total percentage indicated.
Aluminum may be used as a grain refining element without prior approval of the purchaser and when so used shall not be included in the sumn1ation of grain refining elements included in this table.
b) At the purchaser's request, or at the producer's option, the steel may be made with no minimum silicon content, provided that the steel contains a minimum of 0.02% total aluminum content.
c) The combined total of chromium and nickel contents shall be not less than 0.40%.
NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements, with the prior approval of the purchaser.

STEELMAKING PRACTICE:
Fully-killed fine grain practice.

MECHANICAL PROPERTIES: Plates, Bars and Welded Shapes

Grade	Nom. Max. Thickness mm	Tensile Strength MPa	Yield Point, Minimum, MPa			Elongation Percent, Minimum	
			Up to 40 mm	Over 40 mm to 65 mm	Over 65 mm	In 200 mm	In 50 mm
350A	100	480/650	350	350	350	19	21
400A	40	520/690	400	-	-	18	21
480A	20	590/790	480	-	-	15	-

MECHANICAL PROPERTIES: Rolled Structural Shapes

Grade	Usual Max. Size Group	Tensile Strength MPa	Yield Point, Minimum, MPa			Elongation Percent, Minimum	
			Group 1 & 2	Groups 3 & 4	Group 5	In 200 mm	In 50 mm
350A	5	480/650	350	350	320	19	21
400A	2	520/690	400	-	-	18	-
480A	-	-	-	-	-	-	-

*For section size groups for Tensile Property Classification see page 4.

CSA G40.21 (1976)

Type Q – Quenched and Tempered Low Alloy Steel Plate

CHEMICALS COMPOSITION/HEAT ANALYSIS
Percent, Maximum or Range: Plates only

Grade	C	Mn	P	S	Si(a)	Boron	Cu(b)
100Q	0.2	1.5	0.03	0.04	0.15/0.35	0.0004/-0.005	-

a) The steel may be made with no minimum silicon content provided that the steel contains a minimum of 0.02 percent total aluminum content.
b) Copper content of 0.20 percent minimum may be specified by the purchaser.

NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements, with the prior approval of the purchaser.

STEELMAKING PRACTICE:

Fully-killed fine grain practice specified.

MECHANICAL PROPERTIES: Plates only

Grade	Nom. Max. Thickness Inches	Tensile Strength Ksi	Yield Point, Minimum, Ksi		Elongation Percent, Minimum In 2"	Remarks
			Up to 1-1/2"	Over 1-1/2" to 2-1/2"		
100Q	2	115/135	100	100	18	BHN 235-293

CSA G40.21M-1978

Type Q – Quenched and Tempered Low Alloy Steel Plate

CHEMICALS COMPOSITION/HEAT ANALYSIS
Percent, Maximum or Range: Plates only

Grade	C	Mn	P	S	Si(a)	Boron	Cu(b)
700Q	0.2	1.5	0.03	0.04	0.15/0.35	0.0005/-0.005	-

a) The steel may be made with no minimum silicon content provided that the steel contains a minimum of 0.02 percent total aluminum content.
b) Copper content of 0.20 percent minimum may be specified by the purchaser.

NOTE: In order to meet the required mechanical properties, the producer may use additional alloying elements, with the prior approval of the purchaser.

STEELMAKING PRACTICE:

Fully-killed fine grain practice specified.

MECHANICAL PROPERTIES: Plates only

Grade	**Nom. Max. Thickness mm**	**Tensile Strength MPa**	**Yield Point, Minimum, MPa**		**Elongation Percent, Minimum In 50 mm**	**Remarks**
			Up to 40 mm	**Over 40 mm to 65 mm**		
700Q	50	800/950	700	700	18	BHN 235-293

ASTM SUGGESTED WELDING PRACTICES WITH MINIMUM PREHEAT AND INTERPASS TEMPERATURES

WELDING PROCESS	ASTM SPECIFICATION	THICKNESS	PRE-HEAT TEMP.	
Shielded metal-arc with	A36 ≤ 1"	To (19 mm) 3/4" incl.	None‡	
other than low hydrogen	A283	Over (19 mm) 3/4" to (38.1 mm) 1-1/2" incl.	150°F	
electrodes*	A285	Over (38.1 mm) 1-1/2" to (63.5 mm) 2-1/2" incl.	225°F	
Flux cored-arc:		Over (63.5 mm) 2-1/2"	300°F	
Shielded metal-arc with	A36	To (19 mm) 3/4" incl.	None‡	¥70°F
low hydrogen electrodes: ŧ	A242	Over (19 mm) 3/4" to (38.1 mm) 1-1/2" incl.	70°F	150°F
	(weldable			
	grade)			
	A283**	Over (38.1 mm) 1-1/2" to (63.5 mm) 2-1/2" incl.	150°F	225°F
Submerged-arc:	A285**	Over (63.5 mm) 2-1/2"	225°F	300°F
Gas metal-arc:	A441			
	A515			
	A516			
	A572 grs			
	42, 45 & 50			
	¥A577 grs			
	55, 60 & 65			
Shielded metal-arc with	A514	To (19 mm) 3/4" incl.	50°F	
low hydrogen electrodes: ŧ	A517	Over (19 mm) 3/4" to (38.1 mm) 1-1/2" incl.	125°F	
Submerged-arc: with car-		Over (38.1 mm) 1-1/2" to (63.5 mm) 2-1/2" incl.	175°F	
bon or alloy steel wire,		Over (63.5 mm) 2-1/2"	225°F	
meutral flux:				
gas metal-arc or flux				
cored-arc.				
Submerged-arc with car-	A514	To (19 mm) 3/4" incl.	50°F	
bon steel wire, alloy flux	A517	Over (19 mm) 3/4" to (38.1 mm) 1-1/2" incl.	200°F	
		Over (38.1 mm) 1-1/2" to (63.5 mm) 2-1/2" incl.	300°F	
		Over (63.5 mm) 2-1/2"	400°F	

NOTE: Highly restrained welds may require higher preheats than the minimums shown above.

*Using E60XX or E70XX electrodes other than low hydrogen type.

**May be welded with flux cored-arc using higher preheats shown in column at extreme right.

ŧ Using low hydrogen electrodes (E7015, E7016, E7018, E7028) or process of equivalent E Electrode classification.

‡ When the base metal temperature is below 32°F it should be preheated to at least 70°F and this minimum temperature maintained during welding.

¥ These grades require higher preheat as noted in column at extreme right.

The above are recommended good practices for fabrication of structural work. For other work such as pressure vessels, etc., the appropriate codes should be consulted.

ASTM A36 General Purpose Structural Steel

(Similar to Grade 230G or 260W in CSA Standard G40.21M)
(Similar to Grade 33G or 38W in CSA Standard G40.21)

DISCUSSION

ASTM A36 steel is a widely accepted general purpose structural quality steel offering a constant 36 ksi min. yield point for all thicknesses of material. It is widely used in the construction of buildings, bridges and other structures by means of welding, bolting or riveting. This steel is useful because of its wide availability, but does not offer the equivalent allowable stress per dollar that is offered by GSA G40.230W.

NOTCH TOUGHNESS

While these steels are not normally recommended where low temperature notch toughness is critical, they have been used in many bridges and other dynamically loaded structures at temperatures at least as low as those found in the settled areas of Canada. Some improvement in the low temperature notch toughness can be obtained by specifying KILLED FINE GRAIN PRACTICE on all thicknesses.

CORROSION RESISTANCE

These steels have the same atmospheric corrosion resistance as plain carbon steels; however, this may be enhanced by specifying copper additions.

WELDABILITY

ASTM A36 steel can be easily welded, using good shop or field practices by all of the usual methods; shielded metal*arc, submerged arc, gas metal-arc, flux core and resistance welding. See table on page 27 for choice of proper electrodes together with suggested preheat temperatures to be used in various thickness ranges.

GAS CUTTING

This material can be gas cut using good shop or field practices in accordance with those suggested in the AWS Handbook. Cutting of this material generally does not require preheating, but the steel temperature should not normally be below 50°F during cutting.

FORMABILITY

ASTM A36 can be cold formed using conventional press brake equipment and good shop practices. Suggested minimum cold forming radii are given in the table.

FABRICATING PRACTICE FOR COLD FORMING

Thickness of Material	Suggested Minimum Inside Radius
Up to (6.4 mm) 1/4" incl.	1-1/2 t.
Over 6.4 mm) 1/4" to (12.7 mm) 1/2" incl.	2 t.

ASTM A36

CHEMICAL COMPOSITION, PERCENT (LADLE)

Thickness:	Plates				Shapes
	to (19 mm) 3/4" incl.	over (19 mm) 3/4" to (38.1 mm) 1-1/2" incl.	over (38.1 mm) 1-1/2" over (63.5 mm) 2-1/2"		
			to (63.5 mm) 2-1/2" incl.	to (101.6 mm) 4" incl.	all
Carbon, max.	0.25	0.25	0.26	0.27	0.26
Manganese	-	0.80/1.20	0.80/1.20	0.85/1.20	-
Phosphorus, max.	0.04	0.04	0.04	0.04	0.04
Sulphur, max.	0.05	0.05	0.05	0.05	0.05
Silicon	-	-	0.15/0.30	0.15/0.30	-

Thickness:	Bars and Bar Size Shapes		
	to (19 mm) 3/4" incl.	over (19 mm) 3/4" to (38.1 mm) 1-1/2" incl.	over (38.1) 1-1/2" to (101.6 mm) 4" incl.
Carbon, max.	0.26	0.27	0.28
Manganese	-	0.60/0.90	0.60/0.90
Phosphorus, max.	0.04	0.04	0.04
Sulphur, max.	0.05	0.05	0.05
Silicon	-	-	-

Copper – when specified 0.20 minimum all thickness.

When so specified, all thickness of material shall be produced to a fully silicon killed fine grain practice.

Our Steel Service Centres should be consulted for chemical composition of plate thickness on sizes over (101.6 mm) 4 inches.

MECHANICAL PROPERTIES – PLATES, BARS AND SHAPES

Yield point, min. (Mpa) Ksi	(248.2) 36
Tensile strength, (Mpa) Ksi	(399.9/551.6) 58/80
Elongation in (203.2 mm) 8 in., min., %	20
Elongation in (50.8 mm) 2 in., min., %	23

SUGGESTED WELDING PRACTICES – Minimum preheat and interpass temperatures

Refer to table on page 27.

ASTM A120 Black and Hot-Dipped Zinc-Coated (Galvanized) Welded or Seamless Steel Pipe For Ordinary Uses

*Read this table in conjunction with notes on page 31

Nominal Size in.	Diameters		a Type	Wall h Thickness in.	Weight per Foot i		Test Pressure	
	External in.	Internal in.			Plain Ends lbs.	T & C j lbs.	Butt Welded psi	S & ERW psi k
1/8	0.405	0.269 0.215	Std XS	0.068 0.095	0.24 0.31	0.24	700 850	700 850
1/4	0.54	0.364 0.302	Std XS	0.088 0.119	0.42 0.54	0.42	700 850	700 850
3/8	0.675	0.493 0.423	Std XS	0.091 0.126	0.57 0.74	0.57	700 850	700 8500
1/2	0.84	0.622 0.546 0.252	Std XS XXS	0.109 0.147 0.294	0.85 1.09 1.71	0.85	700 850 1000	700 850 1000
3/4	1.05	0.824 0.742 0.434	Std XS XXS	0.113 0.154 0.308	1.13 1.47 2.44	1.13	700 850 1000	700 850 1000
1	1.315	1.049 0.957 0.599	Std XS XXS	0.133 0.179 0.358	1.68 2.17 3.66	1.68	700 850 1000	700 850 1000
1 1/4	1.66	1.38 1.278 0.896	Std XS XXS	0.14 0.191 0.382	2.27 3 5.21	2.28	1000 1300 1400	1000 1500 1800
1 1/2	1.9	1.61 1.5 1.1	Std XS XXS	0.145 0.2 0.4	2.72 3.63 6.41	2.73	1000 1300 1400	1000 1500 1800
2	2.375	2.067 1.939 1.503	Std XS XXS	0.154 0.218 0.436	3.65 5.02 9.03	3.68	1000 1300 1400	1000 1500 1800
2 1/2	2.875	2.469 2.323 1.771	Std XS XXS	0.203 0.276 0.552	5.79 7.66 13.7	5.82	1000 1300 1400	1000 1500 1800
3	3.5	3.068 2.9 2.3	Std XS XXS	0.216 0.3 0.6	7.58 10.25 18.58	7.62	100 1300 1	1000 1500 1800
3 1/2	4	3.548 3.364	Std XS	0.226 0.318	9.11 12.51	9.2	1200 1700	1200 1700
4	4.5	4.026 3.826 3.152	Std XS XXS	0.237 0.337 0.674	10.79 14.98 27.54	10.89	1200 1700 1	1200 1700 2000
5	5.563	5.047 4.813 4.063	Std XS XXS	0.258 0.375 0.75	14.62 20.78 38.55	14.81	1 1 1	1200 1700 2000
6	6.625	6.065 5.761 4.897	Std XS XXS	0.28 0.432 0.864	18.97 28.57 53.16	19.18	1 1 1	1200 1700 2000
8	8.625	8.071 7.981 7.625 6.875	b Std XS XXS	0.277 0.322 0.5 0.875	24.7 28.55 43.39 72.42	25.55 29.35	1 1 1 1	1200 1300 1700 2800
10	10.75	10.192 10.136 10.02 9.75	c b Std XS d	0.279 0.307 0.365 0.5	31.2 34.24 40.48 54.74	32.75 35.75 41.85	1 1 1 1	1000 1000 1200 1600
12	12.75	12.09 12 11.75	b Std e XS f	0.33 0.375 0.5	43.77 49.56 65.42	45.45 51.15	1 1 1	1000 1100 1600
14	14	13.25 13	b c	0.375 0.5	54.57 72.09		… …	950 1300
16	16	15.25 15	b g	0.375 0.5	62.58 82.77		… …	850 1100

ASTM A120 Black and Hot-Dipped Zinc-Coated (Galvanized) Welded or Seamless Steel Pipe For Ordinary Uses

*Read this table in conjunction with notes on page 31

Nominal Size in.	Diameters		a Type	Wall h Thickness mm	Weight per Foot i		Test Pressure	
	External mm	Internal mm			Plain Ends Kg/m	T & C j Kg/m	Butt Welded MPa	S & ERW MPa k
1/8	10.29	6.83	Std	1.73	.36	.36	4.83	4.83
		5.46	XS	2.41	.46		5.86	5.86
1/4	13.72	9.25	Std	2.24	.63	.63	4.83	4.83
		7.67	XS	3.02	.8		5.86	5.86
3/8	17.15	12.52	Std	2.31	.85	.85	4.83	4.83
		10.74	XS	3.2	1.1		5.86	5.86
1/2	21.34	15.8	Std	2.77	1.26	1.26	4.83	4.83
		13.87	XS	3.73	1.62		5.86	5.86
		6.4	XXS	7.47	2.54		6.89	6.89
3/4	26.67	20.93	Std	2.87	1.68	1.68	4.83	4.83
		18.85	XS	3.91	2.19		5.86	5.86
		11.02	XXS	7.82	3.63		6.89	6.89
1	33.4	26.64	Std	3.38	2.5	2.5	4.83	4.83
		24.31	XS	4.55	3.23		5.86	5.86
		15.21	XXS	9.09	5.45		6.89	6.89
1 1/4	42.16	35.05	Std	3.56	3.38	3.39	6.89	6.89
		32.46	XS	4.85	4.46		8.96	10.34
		22.76	XXS	9.7	7.75		9.65	12.41
1 1/2	48.26	40.89	Std	3.68	4.05	4.06	6.89	6.89
		38.1	XS	5.08	5.4		8.96	10.34
		27.94	XXS	10.16	9.54		9.65	12.41
2	60.33	52.5	Std	3.91	5.43	5.48	6.89	6.89
		49.25	XS	5.54	7.47		8.96	10.34
		38.18	XXS	11.07	13.44		9.65	12.41
2 1/2	73.03	62.71	Std	5.16	8.62	8.66	6.89	6.89
		59	XS	7.01	11.4		8.96	10.34
		44.98	XXS	14.02	20.39		9.65	12.41
3	88.9	77.93	Std	5.49	11.28	11.34	6.89	6.89
		73.66	XS	7.62	15.25		8.96	10.34
		58.42	XXS	15.24	27.65		1	12.41
3 1/2	101.6	90.12	Std	5.74	13.56	13.69	8.27	8.27
		85.45	XS	8.08	18.62		11.72	11.72
4	114.3	102.26	Std	6.02	16.06	16.21	8.27	8.27
		97.18	XS	8.56	22.29		11.72	11.72
		80.06	XXS	17.12	40.98		1	13.79
5	141.3	128.19	Std	6.55	21.76	22.04	1	8.27
		122.25	XS	9.53	30.92		1	11.72
		103.2	XXS	19.05	57.37		1	13.79
6	168.28	154.05	Std	7.11	28.23	28.54	1	8.27
		146.33	XS	10.97	42.52		1	11.72
		124.38	XXS	21.95	79.11		1	13.79
8	219.08	205	b	7.04	36.76	38.02	1	8.27
		202.72	Std	8.18	42.49	43.68	1	8.96
		193.68	XS	12.7	64.57		1	77.72
		174.63	XXS	22.23	107.77		1	19.3
10	273.05	258.88	c	7.09	46.43	48.74	1	6.89
		257.46	b	7.8	50.95	53.2	1	6.89
		254.51	Std	9.27	60.24	62.28	1	8.27
		247.65	XS d	12.7	81.46		1	11.03
12	323.85	307.09	b	9.38	65.14	67.64	1	6.89
		304.8	Std e	9.53	73.75	76.12	1	7.58
		298.45	XS f	12.7	97.36		1	11.03
14	355.6	336.55	b	9.53	81.21		…	6.55
		330.2	c	12.7	107.28		…	8.96
16	406.4	387.35	b	9.53	93.13		…	5.86
		381	g	12.7	123.18		…	7.58

ASTM A120

Black and Hot-Dipped Zinc-Coated (Galvanized) Welded or Seamless Steel Pipe for Ordinary Uses

Notes to be used in conjunction with Tables on pages 29 & 30

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a) Pipe furnished in accordance with the table on page 29 will be "Standard Pipe," which is defined in the AISI Steel Products Manual covering Steel Tubular Products as welded or seamless pipe made in three classes of wall thickness:
(1) *Standard Weight* (Std) - Schedule 40, in nominal sizes 1/8 to 6 inches, inclusive.
(2) *Extra Strong* (XS) - Schedule 80, in nominal sizes 1/8 to 12 inches, inclusive, and
(3) *Double Extra Strong* (XXS) - *, in nominal sizes 1/2 to 8 inches, inclusive.

b) Schedule 30 pipe.

c) Not covered by a schedule number.

d) Schedule 60 pipe.

e) Owing to a departure from the wall thickness for 12 in. size, Schedule 40 of the American National Standard for Wrought-Steel and Wrought-Iron Pipe (836.10), the wall thickness 0.375 may be substituted for 0.406 where agreeable to the purchaser and suitable for the service conditions.

f) Owing to a departure from the wall thickness for the 12 in. size, Schedule 60 of the American National Standard for Wrought Steel and Wrought Iron Pipe (ANSI 836.10), the wall thickness of 0.500 in. (12.70 mm) may be substituted for 0.562 in. (14.27 mm) where agreeable to the purchaser and suitable for the service conditions.

g) Schedule 40 pipe.

h) Wall thicknesses other than shown, such as covered by Schedules 10, 20, 60, etc. are a matter of agreement between the purchaser and the manufacturer.

i) As more than one weight is listed under the same size, the order must definitely specify both the weight and wall thickness required.

j) All pipe can be furnished with threads and couplings (T&C). If threads and couplings are required, the pipe is furnished with recessed couplings.

k) Seamless pipe in some of the smaller sizes of Extra Strong or Double Extra Strong may be cold drawn.

l) Butt welded pipe is not made in these sizes.

GENERAL NOTES

*The American National Standard for Wrought-Steel and Wrought-Iron Pipe (ANSI 836.10) has assigned no schedule number of "Double Extra Strong" pipe.

The taper of threads on pipe is 3/4 in. /ft. (62.5 mm/m) on the diameter for all sizes.

Sizes larger than those shown in the table are measured by their outside diameter. These larger sizes will be furnished with plain ends, unless otherwise specified. The weights will correspond to the manufacturer's published standards although it is possible to calculate the theoretical weights for any given size and wall thickness on the basis of 1 in 3 of steel weighing 0.2833 lb. For pipe over 12 in. in nominal pipe size, and for walls other than those included in the table, the test pressures should be calculated by the following equation: $P=2St/D$ where:

P = pressure, psi,
S = fiber stress, 18000 psi,
t = specified wall thickness, in., and
D = specified outside diameter, in.

High Strength Low Alloy Structural Steels

ASTM A242

(Type 1 is similar to Grade 350R in CSA Standard G40.21M).
(Type 1 is similar to Grade 50R in CSA Standard G40.21).
(Type 2 is similar to Grade 350R in CSA Standard G40.21M).
(Type 2 is similar to Grade 50R in CSA Standard G40.21).

DISCUSSION

ASTM A242 covers high strength low alloy steel shapes, plates and bars for welded, riveted or bolted construction intended primarily for use as structural members where saving in weight or added durability is important.

CORROSION RESISTANCE

These steels have enhanced atmospheric corrosion resistance of at least two times that of carbon structural steels with copper. This is due, in part, to the tightly adhering oxide coating which develops under most atmospheric conditions. The protection effect of the oxide provides greatly extended life. Under favourable conditions these steels may be used in an exposed unpainted condition in buildings and other structures.

WELDABILITY

ASTM A242 steels can be welded using good shop or field practices by all of the usual methods; shielded metal-arc, submerged-arc, gas metal-arc and resistance welding.

GAS CUTTING

These steels may be gas-cut using good shop or field practices. Use of preheat for cutting or post-heat for softening cut edges will be governed by the chemical com- position and hardening characteristics of the particular alloy steel involved.

FORMABILITY

ASTM A242 steels can be cold formed using conventional press brake equipment and good shop practices. Material (25.4 mm) 1 inch thick and over, forms best in the normalized condition though this is not mandatory.

FABRICATING PRACTICE FOR COLD FORMING

Thickness of Material	Suggested Min. inside radius
Up to (19 mm) 3/4" incl.	2 t.
Over (19 mm) 3/4" to (25.4 mm) 1" incl.	2-1/4 t.
Over (25.4 mm) 1" to (38.1 mm) 1-1/2" incl.	2-1/2 t.
Over (38.1 mm) 1-1/2" to (50.8 mm) 2" incl.	3 t.
Over (50.8 mm) 2" to (101.6 mm) 4" incl.	3-1/2 t.

ASTM A242

CHEMICAL COMPOSITION PERCENT (LADLE)

	Type 1	Type 2
Carbon, max.	0.15	0.2
Manganese, max.	1	1.35
Phosphorus, max.	0.15	0.04
Sulphur, max.	0.05	0.05
Copper, min.	0.2	.2*

*If chromium and silicon contents are each 0.50 min., then the copper 0.20 min. requirement does not apply.

MECHANICAL PROPERTIES

	Plates and Bars		
Thickness:	**Up to (19 mm) 3/4"**	**Over (19 mm) 3/4" to (38.1 mm) 1-1/2"**	**Over (38.1 mm) 1-1/2" to (101.6 mm) 4"**
Yield point, min. (Mpa) Ksi	(344.7) 50	(317.2) 46	(289.6) 42
Tensile strength, min. (Mpa) Ksi	(482.6) 70	(462) 67	(434.4) 63
Elongation in (203.2 mm) 8" mm. %	18	18	18
Elongation in (50.8 mm) 2" min. %	-	21	21
	Structural Shapes (1)		
	Groups 1 & 2	**Group 3**	**Groups 4 & 5**
Yield point, min. (Mpa) Ksi	(344.7) 50	(317.2) 46	(289.6) 42
Tensile strength, min. (Mpa) Ksi	(482.6) 70	(462) 67	(434.4) 63
Elongation in (203.2 mm) 8" mm. %	18	18	18
Elongation in (50.8 mm) 2" min. %	-	21	21

(1) See page 4.

<u>SUGGESTED WELDING PRACTICES</u> – Minimum preheat and interpass temperatures

Refer to table on page 26.

ASTM A242

SELECTION OF FILLER MATERIALS

a) On steel chosen for strength (which may later be painted) use E70 classification low hydrogen filler materials for single or multi pass welds.

b) For welds which are required to have the corrosion resistance of the base metal but not an immediate colour match, use E70 classification, low hydrogen filler materials for single pass fillets or single pass (each side) groove welds limited to 1/4" thick for manual welding and 5/16" for all other processes. Multi-pass welds or heavier deposits made with these fillers will have less corrosion resistance then the base metal.

c) When welds must have both the corrosion resistance and colour of the base metal, filler materials must be used which will provide a weld deposit of the following chemical composition:

C	Mn	P	S	Si	Cu	Ni	CR
.12 max.	.50-1.00	.030 max.	.040 max.	.35-.80	.30-.75	.40-.80	.45-.70

The weld deposit shall also have a Charpy Vee impact strength of at least 20ft. lbs. at 0°F (applies to bridge structures but not buildings).

For shielded metal arc welding, these properties can be provided by the use of E80 classification low hydrogen electrodes bearing suffixes G, 81, 82, C1, C2 or C3 in accordance with AWS specification "A5.5" or CSA specification W48.3.

For other welding processes, the filler materials must be chosen to provide not only the above weld deposit chemistry and impact strength but also minima of 60 Ksi yield; 72 Ksi ultimate and 18% elongation.

For multi-pass welds it is permitted to use E70 classification filler materials for the underlying layers of the joint provided that at least two layers on all exposed surfaces and edges are deposited with the colour matching fillers recommended above.

ASTM A283 Low and Intermediate Tensile Strength Carbon Steel Plates of Structural Quality

(Similar to Grade 230G in CSA Standard G40.21M).
(Similar to Grade 33G in CSA Standard G40.21).

DISCUSSION

ASTM A283 covers low and intermediate tensile strength carbon steel plates for general manufacturing and constructional applications. This material is normally supplied in the rimmed or semikilled types of steel and is particularly suitable for the economical production of structures requiring a considerable amount of forming. Variations in low temperature impact properties are great and these steels are not recommended for those applications requiring low temperature notch toughness.
Material supplied to ASTM A283 Grade D is similar in all aspects to material supplied to CSA G40.21M. Grade 230G.

CORROSION RESISTANCE

This material has the same atmospheric corrosion resistance as plain carbon steel, but this may be enhanced by the use of copper additions.

WELDABILITY

ASTM A283 steels can be readily welded, using good shop or field practices by all of the usual methods; shielded metal-arc, submerged-arc, gas metal-arc, flux-core and resistance welding. See table on page 26 for choice of proper electrodes together with suggested preheat temperatures to be used in various thickness ranges.

GAS CUTTING

ASTM A283 plates may be gas cut using good shop or field practices in accordance with those suggested in the AWS Handbook. Cutting of this material generally does not require preheating.

FORMABILITY

These steels can be readily cold formed using conventional press brake equipment and good shop practices. Grade A material will provide the greatest cold formability with grades B, C and D providing progressively less formability in that order.

FABRICATING PRACTICE FOR COLD FORMING

Thickness of Material	Suggested Minimum Inside Radius			
	Grade A	Grade B	Grade C	Grade D
Up to (6.4 mm) 1/4" incl.	1 t.	1 t.	1 t.	1 t.
Over (6.4 mm) 1/4" to (12.7 mm) 1/2" incl.	1 t.	2t.	2·1121.	3 t.
Over (12.7 mm) 1/2" to (25.4 mm) 1" incl.	21.	41.	Hot Form	Hot Form
Over (25.4 mm) 1" to (50.8 mm) 2" incl.	4t.	Hot Form	Hot Form	Hot Form
Over (50.8 mm) 2"	Hot Form	Hot Form	Hot Form	Hot Form

ASTM A283

CHEMICAL COMPOSITION, PERCENT (LADLE) – ALL GRADES		
Phosphorus	**Sulphur**	**Copper**
0.04 max.	0.05 max.	0.20 min. (when specified)

MECHANICAL PROPERTIES – PLATES

	Grade A	**Grade B**
Yield point, min., (Mpa) Ksi	(165.5) 24	(186.2) 27
Tensile strength, (Mpa) Ksi	(310.3/379.2) 45/55	(344.7/413.7) 50/60
Elongation in (203.2 mm) 8" min., %	27	25
Elongation in (50.8 mm) 2" min., %	30	28
	Grade C	**Grade D**
Yield point, min., (Mpa) Ksi	(206.8) 30	(227.5) 33
Tensile strength, (Mpa) Ksi	(379.2/448.2) 55/65	(413.7/496.4*) 60/72*
Elongation in (203.2 mm) 8" min., %	23	21
Elongation in (50.8 mm) 2" min., %	27	23

*The upper limit of (496.4 MPa) 72 Ksi may be increased to (517.1 MPa) 75 Ksi for material over (38.1 mm) 1-1/2” in thickness.

SUGGESTED WELDING PRACTICES – Minimum preheat and interpass temperatures

Refer to table on page 26.

ASTM A285 Low and Intermediate Tensile Strength Carbon Steel Plates for Pressure Vessels

DISCUSSION

ASTM A285 covers low and intermediate tensile strength carbon steel plates for pressure vessels up to a maximum of (50.8 mm) 2" thick. This material is normally supplied in the rimmed or semi-killed types and is particularly suitable for economic production of low-pressure vessels coming under the jurisdiction of the ASME Pressure Vessel Code.

CORROSION RESISTANCE

This material has the same atmospheric corrosion resistance as plain carbon steel, but this may be enhanced by the use of copper additions.

WELDABILITY

ASTM A285 steels can be readily welded, using good shop or field practices, by all of the usual methods; shielded metal-arc, submerged-arc, gas metal-arc, flux core and resistance welding. This material conforms to welding category P1 of the ASME Pressure Vessel Code. See table on page 26 for choice of proper electrodes together with suggested preheat temperatures to be used in various thickness ranges. Welded vessels under the ASME Code will normally require post weld that treatment of 1100°F for 1 hour per inch of thickness.

GAS CUTIING

ASTM A285 steels can be gas cut using good shop or field practices in accordance with those suggested in the AWS Handbook. Cutting of this material generally does not require preheating.

FORMABILITY

ASTM A285 steels can be readily cold formed using conventional press brake equipment and good shop practices. Grade A material will provide the greatest cold formability, with Grade B and Grade C providing progressively poorer formability in that order. Suggested minimum cold forming radii are shown in the table below.

FABRICATING PRACTICE FOR COLD FORMING

Thickness of Material	Suggested Minimum Inside Radius		
	Grade A	Grade B	Grade C
Up to (6.4 mm) 1/4" incl.	1 t.	1 t.	1 t.
Over (6.4 mm) 1/4" to (12.7 mm) 1/2" incl.	1 t.	2 t.	2-1/2 t.
Over (12.7 mm) 1/2" to (25.4 mm) 1" incl.	2 t.	4 t.	Hot Form
Over (25.4 mm) 1" to (50.8 mm) 2" incl.	4 t.	Hot Form	Hot Form

ASTM A285

CHEMICAL COMPOSITION, PERCENT (LADLE)

	Grade A	Grade B	Grade C
Carbon, max. (19 mm) 3/4" and under	0.15	0.2	0.25
Over (19 mm) 3/4" to (50.8 mm) 2" incl.	0.17	0.22	0.28
Manganese, max.	0.9	0.9	0.9
Phosphorus, max.	0.035	0.035	0.035
Sulphur, max.	0.04	0.04	0.04
Copper, when specified	0.20/0.35	0.20/0.35	0.20/0.35

When plates (12.7 mm) ½" and under in thickness are rolled and coiled and sheared to length or hot piled on a continuous mill, the maximum carbon content will be 0.18, 0.23 and 0.28% for grades A, B and C respectively.

MECHANICAL PROPERTIES – PLATES

	Grade A	Grade B	Grade C
Yield point, min., (Mpa) Ksi	(165.5) 24	(186.2) 27	(206.8) 30
Tensile strength, (Mpa) Ksi	(310.3/379.2) 45/65	(344.7/413.7) 50/70	(379.2/448.2) 55/75
Elongation in (203.2 mm) 8" min., %	27	25	23
Elongation in (50.8 mm) 2" min., %	30	28	27

SUGGESTED WELDING PRACTICES – Minimum preheat and interpass temperatures.
Refer to table on page 26.

ASTM A441 High-Strength Low-Alloy Structural Manganese Vanadium Steel

DISCUSSION

ASTM A441 specification covers a high strength low-alloy steel which possesses a combination of high strength and toughness, good fabricating and welding characteristics together with resistance to abrasion and fatigue, all at a relatively low cost. It is intended primarily for use in welded bridges and buildings where savings in weight or added durability are important.

CORROSION RESISTANCE

The atmospheric corrosion resistance of this material is twice that of plain carbon steel.

WELDABILITY

ASTM A441 steel can be easily welded, using good shop or field practices by all of the usual methods; shielded metal-arc, submerged-arc, gas metal-arc and resistance welding. See table on page 26 for choice of proper electrodes together with suggested preheat temperatures to be used in various thickness ranges.

GAS CUTIING

This material can be gas cut using good shop or field practices in accordance with those suggested in the AWS Handbook. Cutting of this material generally does not require preheating, but the steel temperature should never be lower than 50°F during cutting.

FORMABILITY

ASTM A441 steel can be cold formed using conventional press brake equipment and good shop practices. Slightly greater forming pressures and more liberal bending radii are required than are normally used for carbon steel. Suggested minimum cold forming radii are given in the table below.

FABRICATING PRACTICE FOR COLD FORMING

Thickness of Material	Suggested inside Radius
Up to (6.4 mm) 1/4" incl.	2 t.
Over (6.4 mm) 1/4" to (12.7 mm) 1/2" incl.	3 t.

Hot forming is recommended for angle bending material over (12.7 mm) ½” in thickness.

ASTM A441

CHEMICAL COMPOSITION, PERCENT (LADLE)

C	Mn	P	S	Si	Cu	V
0.22 max.	0.85/1.25	0.04 max.	0.05 max.	0.30 max.	0.20 min.	0.02 min.

MECHANICAL PROPERTIES

	Plates and Bars		
Thickness:	**Up to (19 mm) 3/4"**	**Over (19 mm) 3/4" to (38.1 mm) 1-1/2"**	**Over (38.1 mm) 1-1/2" to (101.6 mm) 4"**
Yield point, min. (Mpa) Ksi	(344.7) 50	(317.2) 46	(289.6) 42
Tensile strength, min. (Mpa) Ksi	(482.6) 70	(462) 67	(434.4) 63
Elongation in (203.2 mm) 8" min., %	18	18	18
Elongation in (50.8 mm) 2" min., %	-	21	21
	Structural Shapes (1)		
	Groups 1 & 2		**Group 3**
Yield point, min. (Mpa) Ksi	(344.7) 50		(317.2) 46
Tensile strength, min. (Mpa) Ksi	(482.6) 70		(462) 67
Elongation in (203.2 mm) 8" min., %	18		18
Elongation in (50.8 mm) 2" min., %	-		-

When the material is normalized the minimum yield point and minimum tensile strength shall be reduced by (34.5 MPa) 5 Ksi.

(1) See page 4.

<u>SUGGESTED WELDING PRACTICING</u> – Minimum preheat and interpass temperatures.
Refer to table on page 26.

ASTM A514 Quenched and Tempered Alloy
Steel Plates of Structural Quality
(Similar to Grade 700Q in CSA Standard G40.21M).
(Similar to Grade 100Q in CSA Standard G40.21).

DISCUSSION
ASTM A514 specification covers quenched and tempered alloy steel plates primarily for use in welded bridges and other structures.

CORROSION RESISTANCE
Some A514 steels have a corrosion resistance that is 4 to 6 times better than plain carbon structural grade steels.

WELDABILITY
Welding procedures and techniques are of prime importance. Heat input must be carefully controlled so that properties of the adjacent plate material, the heat affected zone and the deposited weld metal, are not adversely affected.

GAS CUTTING
A514 material can be gas cut using good shop or field practices. Generally, no preheating is required but a preheat of 100" to 200" may be beneficial. Steel temperature must not be lower than 65°F during cutting.

FORMABILITY
Quenched and tempered steels have a high degree of toughness so can tolerate a fair amount of cold forming. These steels should never be hot formed because heating destroys the properties developed by quenching and tempering. Cold forming may be aided by pre-heating but this should not exceed 400°F. Forming this steel requires more power than for mild steel and the springback is also greater. For rolling operations, a more generous inside radius may be required and it is advisable to remove sharp edges from the tension side of the plate before forming is begun.

FABRICATING PRACTICE FOR COLD FORMING – by press brake

Thickness of Material	Suggested inside Radius
Up to (25.4 mm) 1” incl.	3-1/2 t.
Over (25.4 mm) 1" to (50.8 mm) 2" incl.	4 t.

ASTM A514

CHEMICAL COMPOSITION, PERCENT (LADLE)

Grade	C	Mn	P max.	S max.	Si	Ni	Cr	Mo	V	B	Cu
C	.10 - .20	1.10 - 1.50	0.035	0.04	.15 - .30			.20 - .30		.001 - .005	
F	.10 - .20	.60 - 1.00	0.035	0.04	.15 - .35	.70 - 1.00	.40 - .65	.40 - .60	.03 - .08	.002 - .006	.15 - .50

MECHANICAL PROPERTIES

	Thickness		
	to (19 mm) 3/4"	**Over (19 mm) 3/.4" to (63.5 mm) 2-1/2"**	**Over (63.5 mm) 2-1/2" to (101.6 mm) 4"**
Yield strength, min., (Mpa) Ksi	(689.5) 100	(689.5) 100	(620.5) 90
Tensile strength (Mpa) Ksi	(792.9/930.8) 115/135	(792.9/930.8) 115/135	(724/930.8) 105/135
Elongation in (50.8 mm) 2" min., %	18	18	17

SUGGESTED WELDING PRACTICING – Minimum preheat and interpass temperatures.

a) **Refer to table on page 26.**
b) **Interpass temperature should not exceed 400^{o}F.**
c) **Heat input must not exceed the values given in the following tabulation:**

Maximum Welding Heat Input in joules/inch

Preheat and Interpass Temperature, F	Plate Thickness, inches							
	3/16	**1/4**	**3/8**	**12**	**5/8**	**3/4**	**1**	**1 1/4**
70	17500	23700	35000	47400	64500	88600	any	any
150	15300	20900	30700	41900	57400	77400	120000	any
200	14000	19200	28000	35500	53000	69900	110300	154000
300	11500	15800	23500	31900	42500	55700	86000	120000
400	9000	12300	18500	25900	33500	41900	65600	94000

$$\text{Joules/inch of weld} = \frac{\text{Amperes X volts X 60}}{\text{Speed in inches per minute}}$$

Note: Heat-input limits for temperatures and thicknesses included, but not shown, in this table may be obtained by interpolation.

d) **If the weldment is to be stress relieved the welding electrodes must not contain more than 0.05% Vanadium.**

ASTM A515 Carbon Steel Plates for Pressure Vessels for Intermediate and Higher Temperature Service

DISCUSSION

ASTM A515 covers steel plates of intermediate tensile strength for pressure vessels to be operated at intermediate or higher temperatures. The four grades offer excellent combinations of strength, weldability and toughness to permit designers flexibility in the design of pressure vessels coming under the jurisdiction of the ASME Pressure Vessel Code.

The plates are produced from fully killed steels and may be ordered to have an austenitic grain size of from 1 to 5 for improved creep resistance and added resistance to graphitization at elevated temperatures.

This material cannot be expected to provide adequate notch toughness, even in the normalized condition, to perform satisfactorily on low temperature pressure vessels.

CORROSION RESISTANCE

This material has the same atmospheric corrosion resistance as plain carbon steels.

WELDABILITY

ASTM A515 steels can be readily welded using good shop or field practices by all of the usual methods; shielded metal-arc, submerged-arc, gas metal-arc and resistance welding. This material conforms to welding category P1 of the ASME Pressure Vessel Code. See table on page 26 for choice of proper electrodes together with suggested preheat temperatures to be used in various thickness ranges. Since many plates may exceed 0.30% carbon content and 1 inch in thickness, special preheat requirements should be carefully checked. Welded vessels under the ASME Code normally will require post weld heat treatment of 1100°F for 1 hour per inch of thickness.

GAS CUTTING

ASTM A515 plates can be gas cut using good shop or field practices in accordance with those suggested in the AWS Handbook. Plates over 0.30% carbon content and over 1 inch in thickness may display some edge hardening; if this is a problem, preheat to 200°F is suggested. Cutting of this material should not normally be carried out at a metal temperature below 50°F.

FORMABILITY

This material can be readily cold formed using conventional press brake equipment and good shop practices. Grade 55 material provides the greatest degree of formability, with progressively decreasing formability for grades 60, 65 and 70. Suggested minimum cold forming radii are given in the table below.

FABRICATING PRACTICE FOR COLD FORMING

	Suggested Minimum Inside Radius			
Thickness of Material	**Grade 55**	**Grade 60**	**Grade 65**	**Grade 70**
Up to (6.4 mm) 1/4" incl.	1 t.	1 1/2 t.	2 t.	2 1/2 t.
Over (6.4 mm) 1/4" to (12.7 mm) 1/2"	2 1/2 t.	3 t.	3 t.	4 t.
Over (12.7 mm) 1/2" to (25.4 mm) 1"	Hot Form	Hot Form	Hot Form	Hot Form

ASTM A515

CHEMICAL COMPOSITION, PERCENT (LADLE)

	Grade 55	Grade 60	Grade 65	Grade 70
Carbon, max.				
(25.4 mm) 1" and under	0.2	0.24	0.28	0.31
over (25.4 mm) 1" to				
(50.8 mm) 2" incl.	0.22	0.27	0.31	0.33
over (50.8 mm) 2" to				
(101.6 mm) 4" incl.	0.24	0.29	0.33	0.35
Manganese, max.	0.9	0.9	0.9	0.9
Phosphorus, max.	0.035	0.035	0.035	0.035
Sulphur, max.	0.04	0.04	0.04	0.04
Silicon	0.15/0.30	0.15/0.30	0.15/0.30	0.15/0.30

When so specified the steel shall have an austenitic grain of 1 to 5.

MECHANICAL PROPERTIES – PLATES

	Grade 55	Grade 60
Yield point, min., (Mpa) Ksi	(206.8) 30	(220.6) 32
Tensile strength, (Mpa) Ksi	(379.2/448.2) 55/65	(413.7/448.2) 60/72
Elongation in (203.2 mm) 8" min., %	23	21
Elongation in (50.8 mm) 2" min., %	27	25
Yield point, min., (Mpa) Ksi	(241.3) 35	(262.0) 38
Tensile strength, (Mpa) Ksi	(448.2/530.9) 65/77	(482.6/586.1) 70/85
Elongation in (203.2 mm) 8" min., %	19	17
Elongation in (50.8 mm) 2" min., %	23	21

HEAT TREATMENT

All plates over (50.8 mm) 2” shall either be normalized or hot formed. When so specified tensile test specimens shall be stress relieved at 1100-1200^{o}F.

SUGGESTED WELDING PRACTICES – Minimum preheat and interpass temperatures.
Refer to table on page 26.

ASTM A516 Carbon Steel Plates for Pressure Vessels for Moderate and Lower Temperature Service

DISCUSSION

ASTM A516 covers steel plates of intermediate tensile strength for pressure vessels to be operated at atmospheric or lower temperature. The four grades offer excellent combinations of strength, weldability and toughness to permit designers flexibility in the design of pressure vessels coming under the jurisdiction of the ASME Pressure Vessel Code.

The plates are produced from fully killed fine grained steels and in the normalized condition will meet the requirements of ASTM A300: 15 ft.-lbs. energy at -50°F on Charpy U-notch specimens. Since A516 plates are made to a silicon-aluminum deoxidation practice they are not approved for elevated service temperatures above 850°F.

CORROSION RESISTANCE

This material has the same atmospheric corrosion resistance as plain carbon steel.

WELDABILITY

ASTM A516 steels can be readily welded, using good shop or field practices by all of the usual methods; shielded metal arc, submerged arc, gas metal-arc and resistance welding. This material conforms to Welding Category P1 of the ASME Pressure Vessel Code. See table on page 143 for choice of proper electrodes together with suggested preheat temperatures to be used in various thickness ranges. Welded vessels under the ASME Code normally will require post weld heat treatment of 1100°F for 1 hour per inch of thickness.

GASCUTIING

ASTM A516 plates can be gas cut using good shop or field practices in accordance with those suggested in the AWS Handbook. Cutting of this material should not normally be carried out at a metal temperature below 50°F.

FORMABILITY

This material can be readily cold formed using conventional press brake equipment and good shop practices. Grade 55 material provides the greatest degree of formability, with progressively decreasing formability for grades 60, 65 and 70. Suggested minimum cold forming radii are given in the table.

FABRICATING PRACTICE FOR COLD FORMING

	Suggested Minimum Inside Radius			
Thickness of Material	**Grade 55**	**Grade 60**	**Grade 65**	**Grade 70**
Up to (6.4 mm) 1/4" incl.	1 t.	1 1/2 t.	2 t.	2 1/2 t.
Over (6.4 mm) 1/4" to (12.7 mm) 1/2"	2 1/2 t.	3 t.	3 t.	4 t.
Over (12.7 mm) 1/2" to (25.4 mm) 1"	Hot Form	Hot Form	Hot Form	Hot Form

ASTM A516

CHEMICAL COMPOSITION, PERCENT (LADLE)

	Grade 55	Grade 60	Grade 65	Grade 70
Carbon, max. (12.7 mm) ½ " and under	0.18	0.21	0.24	0.27
over (12.7 mm) ½ " to (50.8 mm) 2" incl.	0.20	0.23	0.26	0.28
over (50.8 mm) 2" to (101.6 mm) 4" incl.	0.22	0.25	0.28	0.30
Manganese* (12.7 mm) ½" and under	0.60/0.90	0.60/0.90	0.85/1.20	0.85/1.20
Phosphorus, max.	0.035	0.035	0.035	0.035
Sulphur, max.	0.04	0.04	0.04	0.04
Silicon	0.15/0.30	0.15/0.30	0.15/0.30	0.15/0.30

All grades are to be produced to fine grained practice and shall have an austenitic grain size of 5 or finer.
*When specified in accordance with ASTM A300, the Manganese content for all thicknesses shall be 0.85/1.20.

MECHANICAL PROPERTIES – PLATES

	Grade 55	Grade 60
Yield point, min., (Mpa) Ksi	(206.8) 30	(220.6) 32
Tensile strength, (Mpa) Ksi	(379.2/448.2) 55/65	(413.7/448.2) 60/72
Elongation in (203.2 mm) 8" min., %	23	21
Elongation in (50.8 mm) 2" min., %	27	25
Yield point, min., (Mpa) Ksi	(241.3) 35	(262.0) 38
Tensile strength, (Mpa) Ksi	(448.2/530.9) 65/77	(482.6/586.1) 70/85
Elongation in (203.2 mm) 8" min., %	19	17
Elongation in (50.8 mm) 2" min., %	23	21

HEAT TREATMENT
All plates over (38.1 mm) 1 ½" shall either be normalized of hot formed. When improved notch toughness is required all plates shall be normalized.
Note: ASTM A300 specifies all material in the normalized condition.

<u>SUGGESTED WELDING PRACTICES</u> – Minimum preheat and interpass temperatures.
Refer to table on page 26.

ASTM A517 Quenched and Tempered

Alloy Steel Plates

(Similar to Grade 700Q in CSA Standard G40.21M).
(Similar to Grade 100Q in CSA Standard G40.21).

DISCUSSION

ASTM A517 Specification covers quenched and tempered alloy steel plates primarily for use in fusion welded boilers and other pressure vessels.

CORROSION RESISTANCE

The corrosion resistance of A517 steel is 4 to 6 times better than plain carbon structural grade steels.

WELDABILITY

Welding procedures and techniques are of prime importance. Heat input must be carefully controlled so that properties of the adjacent plate material, the heat affected zone and the deposited weld metal, are not adversely affected.

GAS CUTIING

A517 material can be gas cut using good shop or field practices.- Generally, no preheating is required but a preheat of 100° to 200° may be beneficial. Steel temperature must not be lower than 65^{o}F during cutting.

FORMABILITY

Quenched and tempered steels have a high degree of toughness so can tolerate a fair amount of cold forming. These steels should never be hot formed because heating destroys the properties developed by quenching and tempering. Cold forming may be aided by pre-heating but this should not exceed 400^{o}F. Forming this steel requires more power than for mild steel and the springback is also greater. For rolling operations, a more generous inside radius may be required and it is advisable to remove sharp edges from the tension side of the plate before rolling is begun.

FABRICATING PRACTICE FOR COLD FORMING

Thickness of Material	Suggested minimum inside Radius
Up to (25.4 mm) 1” incl.	3-1/2 t.
Over (25.4 mm) 1" to (50.8 mm) 2" incl.	4 t.

ASTM A517

CHEMICAL COMPOSITION, PERCENT (LADLE)

Grade	C	Mn	P max.	S max.	Si	Ni	Cr	Mo	V	B	Cu
C	.10 - .20	1.10 - 1.50	0.035	0.04	.15 - .30			.20 - .30		.001 - .005	
F	.10 - .20	.60 - 1.00	0.035	0.04	.15 - .35	.70 - 1.00	.40 - .65	.40 - .60	.03 - .08	.002 - .006	.15 - .50

MECHANICAL PROPERTIES

	Thickness	
	to (19 mm) 3/4"	over (19 mm) 3/4" to (63.5 mm) 2·112"
Yield point, min., (MPa) Ksi	(689.5) 100	(689.5) 100
Tensile strength, (MPa) Ksi	(792.9/930.8) 115/135	(792.9/930.8) 115/135
Elongation in (50.8 mm) 2" min.,%	16	16

SUGGESTED WELDING PRACTICES – Minimum preheat and interpass temperatures.

a) Refer to table on page 26.
b) Interpass temperature should not exceed 400°F.
c) Heat input must not exceed the values given in the following tabulation:

Maximum Welding Heat Input in joules/inch

Preheat and Interpass Temperature, F	Plate Thickness, inches							
	3/16	1/4	3/8	12	5/8	3/4	1	1 1/4
70	17500	23700	35000	47400	64500	88600	any	any
150	15300	20900	30700	41900	57400	77400	120000	any
200	14000	19200	28000	35500	53000	69900	110300	154000
300	11500	15800	23500	31900	42500	55700	86000	120000
400	9000	12300	18500	25900	33500	41900	65600	94000

$$\text{Joules/inch of weld} = \frac{\text{Amperes X volts X 60}}{\text{Speed in inches per minute}}$$

Note: Heat-input limits for temperatures and thicknesses included, but not shown, in this table may be obtained by interpolation.

d) If the weldment is to be stress relieved the welding electrodes must not contain more than 0.05% Vanadium.

ASTM A572 High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality

(Similar to Grade 300W to 400W in CSA Standard G40.21M).
(Similar to Grade 44W to 60W in CSA Standard G40.21).

DISCUSSION

ASTM A572 steels offer a good balance of strength, weldability and formability to permit designers a considerable degree of flexibility in reducing weight and costs by using thinner sections.

ASTM A572 steels are available up to the maximum thicknesses shown in the following table:

Grade 42	Plate & bars to (101.6 mm) 4"	maximum, all shapes
Grade 45	Plate & bars to (38.1 mm) 1-1/2"	maximum, all shapes
Grade 50	Plate & bars to (38.1 mm) 1-1/2"	maximum, all shapes
Grade 55	Plate & bars to (38.1 mm) 1-1/2"	maximum, all shapes
Grade 60	Plate & bars to (25.4 mm) 1"	maximum, group 1 & 2 shapes
Grade 65	Plate & bars to (12.7 mm) 1/2"	maximum, group 1 shapes

These steels may be specified as Type 1 (Columbium) or Type 11 (Vanadium). Unless otherwise specified, Type 1 will normally be supplied in thicknesses up to (9.5 mm) 3/8" maximum and group 1 shapes.

NOTCH TOUGHNESS

While these steels, because of their low carbon contents and high manganese contents, generally do show good notch toughness properties and since they are semikilled or balanced steels, such properties are not consistent and these steels are not recommended for such service where low temperature notch toughness is critical.

CORROSION RESISTANCE

These ·steels have the same atmospheric corrosion resistance as plain carbon steels, however, this may be enhanced by specifying copper additions.

WELDABILITY

ASTM A572 steels can be easily welded using good shop or field practices by all of the usual methods; shielded metal-arc, submerged-arc, gas metal-arc and resistance welding. See table on page 143 for choice of proper electrodes together with suggested preheat temperatures to be used in various thickness ranges.

GAS CUTTING

This material can be gas cut using good shop or field practices in accordance with those suggested in the AWS Handbook. Cutting of these steels generally does not require preheating, but the steel temperature should never- be lower than 50^{o}F during cutting.

FORMABILITY

ASTM A572 steels can be cold formed with ease using conventional press brake equipment and good shop practices; grade 42 material will provide the greatest cold formability with grades 45, 50, 55 and 60 providing progressively less formability in that order. Suggested minimum radii are given in the table below.

Thickness of Material	Suggested Minimum Inside Radius					
	Grade 42	Grade 45	Grade 50	Grade 55	Grade 60	Grade 65
Up to (6.4 mm) 1/4" incl.	1 t.	1 t.	1 1/2 t.	1 1/2 t.	2 t.	3 t.
Over (6.4 mm) 1/4" to (12.7 mm) 1/2"	2 t.	2 t.	2 t.	2 1/2 t.	3 t.	4 t.

Hot forming is recommended for plates over (12.7 mm) 1/2” in thickness.

ASTM A572

CHEMICAL COMPOSITION, PERCENT (LADLE)

	Grade 42	Grade 45	Grade 50	Grade 55	Grade 60	Grade 65
Carbon max.	0.21	0.22	0.23	0.25	0.26	0.26
Manganese, max. (see note)	1.35	1.35	1.35	1.35	1.35	1.35
Phosphorus, max.	0.04	0.04	0.04	0,04	0.04	0.04
Sulphur, max.	0.05	0.05	0.05	0.05	0.05	0.05
Silicon, max.	0.30	0.30	0.30	0.30	0.30	0.30
*Columbium or Vanadium, min.	0.01	0.01	0.01	0.01	0.01	0.01
Copper, when specified, min.	0.20	0.20	0.20	0.20	0.20	0.20

Note: For plates over (9.5 mm) 3/8", minimum manganese content 0.80%.
For plates (9.5 mm) 3/8" and under, minimum manganese content 0.50%.
For all other products, the manganese to carbon ratio shall not be less than 2:1.
*Columbium additions restricted to plate or bar thicknesses of (12.7 mm) 1/2" max. or group 1 shapes.

MECHANICAL PROPERTIES- PLATES, BARS, STRUCTURALS

	Grade 42	Grade 45	Grade 50
Yield point, in., (MPa) Ksi	(289.6) 42	(310.3) 45	(344.7) 50
Tensile strength, in., (MPa) Ksi	(413.7) 60	(413.7) 60	(498.2) 65
Elongation in (203.2 mm) 8" min., %	20	19	18
Elongation in (50.8 mm) 2" min., %	24	22	21
	Grade 55	Grade 60	Grade 65
Yield point, min., (MPa) Ksi	(379.2) 55	(413.7) 60	(448.2) 65
Tensile strength, min., (MPa) Ksi	(482.6) 70	(517.1) 75	(551.6) 80
Elongation in {203.2 mm) 8" min., %	17	16	15
Elongation in {50.8 mm) 2" min., %	20	18	-

SUGGESTED WELDING PRACTICES - Minimum preheat and interpass temperatures.
Refer to table on page 26.

Abrasion Resistant Plate Steels

GENERAL

These steels are primarily intended to provide resistance to abrasive wear superior to that of ordinary structural quality steels. The “AR” material is intermediate carbon manganese steel with improved workability over carbon steel of the same hardness level.

The CHT-360 and Wei-Ten 8OC-360 plates are quenched and tempered steels that provide great tensile strength, hardness and abrasion resistance, yet are readily fabricated when appropriate precautions are employed.

All are proprietary steels that are furnished to the chemical composition shown in the following table. Mechanical properties for each steel are shown for information purposes only.

ABRASION RESISTANCE

Service and laboratory tests indicate that the abrasion resistance of these steels is expected to be substantially as shown in the following tables. However, the values cannot be guaranteed because of unpredictable variations in service conditions.

GAS CUTTING

These steels can be gas cut satisfactorily but the cut surfaces will have a hardened skin that should be removed by grinding or machining if subsequent forming is to be done. To prevent excessive hardening, "AR" Plate should be preheated to 500°F but the CHT-360 or Wei-Ten BOC-360 need not be preheated beyond 225°F.

FORMING

These steels are tough and can be cold formed satisfactorily if extreme care is taken. The bending force and spring back will be about 3 to 4 times that encountered for ordinary carbon steel.

The edges on the tension side should be ground to a radius of not less than 1/16"; the bottom die spacing should be at least 12 to 16 times the plate thickness; the plate temperature should never be less than 100°F and the inside bend radius should be at least 6 times the plate thickness.

More severe forming can be done "hot"-ie 1500°F for "AR" Plate or 400°F for CHT- 360 and Wel-Ten 8OC-360. If higher temperatures are used for the quenched and tempered steels, re-quenching and tempering will be required to restore the original properties of the steel.

WELDABILITY

In welding these steels, certain precautions must be taken to avoid cracking. Suggested welding practices are shown in the table. Where maximum toughness in the weld zone is required, the entire weldment should be stress relieved. If however, quenched and tempered steels are heated above 400°F the entire weldment will require re-quenching and tempering to restore the original properties of the steel.

Abrasion Resistant Plate Steels

CHEMICAL COMPOSITION, TYPICAL PERCENT (LADLE)

Plate Material	C	Mn	P	S	Si	CR	Mo	V	Ti	B	CU
"AR" Plate	.30/.45	1.30/1.65	0.04	0.05	.15/.35	.30/.50	-	-	-	-	.20/.50
CHT-360	0.16	1.3	0.015	0.02	0.28	-	0.23	0.04	0.02	0.001	-
Wel-Ten 80C-360	0.17	0.89	0.018	0.008	0.24	1.04	0.43	-	-	0.001	0.28

MECHANICAL PROPERTIES (TYPICAL)

Plate Material:	"AR" Plate as rolled (12 mm) 1/2" plate	CHT-360 (Q & T)	Wel-Ten 80C-360 (Q & T) (25 mm) 1" plate
Yield point, min., (Mpa) Ksi	(413.7) 60	(1137.6) 165	(999.7) 145
Tensile strength, min., (Mpa) Ksi	(689.5) 100	(1241.1) 180	(1275.5) 185
Elongation in (50.8 mm) 2" min. %	Not Available	11	14
Charpy Vee, (Joules) Ft. lbs.	Not Available	(27.1) 20 @ + 70°F (20.3) 15 @ - 50°F	(39.3) 29 @ + 68°F (20.3) 20 @ - 40°F

SUGGESTED WELDING PRACTICES

Plate Material	Thickness	Min. Preheat (1) & Interpass Temp.	L.H. Electrode Classification (2)
"AR" Plate	Up to (12.7 mm) 1/2"	300°F	E90XX or E100XX
	(14.3 to 50.8 mm) 9/16 to 2"	400°F	
CHT-360	Up to (19 mm) 3/4"	70°F	E110XX(3)
	(20.6 to 50.8 mm) 13/16 to 2"	175°F	
Wel-Ten 80C-360	Up to (12.7 mm) 1/2"	70°F	E110XX(3)
	(14.3 to 38.1 mm) 9/16 to 1 1/2"	225°F	

Note: (1) Preheat temperatures greater than the minimum shown above may be required for highly restrained welds.

(2) If the weldment is to be stress-relieved, the electrodes must not contain more than 0.05% Vanadium

(3) The weld metal deposit will be somewhat softer than the plate. Higher strength electrodes, with suitable preheat, can provide greater weld metal hardness, if required.

Cold Finished Leaded Steel Bars C12L14

CHEMICAL COMPOSITION, PERCENT (LADLE)

C	Mn	P	S	Pb
0.09	0.75 -	0.04 -	0.26 -	0.15 -
Max.	1.05	0.09	0.35	0.35

In order to obtain maximum machinability nitrogen is being added although not shown in the A.I.S.I. Specification. If the part is to be severely coined, crimped or cold formed after machining, C.O.S-12L15 should be ordered without nitrogen. These cases will be few.

MACHINABILITY

Free machining steels, without lead, contain sulphides in the form of hard microscopic particles which impart a degree of brittleness and promote efficient separation of the chip, improving the machining characteristics of the steel.

In leaded steels the hard sulphide particles accept the lead as a coating or envelope so that the lead becomes a lubricating agent within the work piece itself, acting as a lubricant between the tool edge and the hard brittle sulphide. A decrease in machining time of 20% to 75% has been a common experience of users changing from a standard to leaded steel.

HEAT TREATMENT

Leaded steels respond to heat treatment in exactly the same way as non-leaded steels, the same temperature can be used for treatments such as hardening and tempering. In case hardening lead has no effect upon the depth of carbon penetration or the hardness of the resulting case.

TEST FOR LEAD CONTENT

Clean the portion to be tested with sand paper and put two or three drops of sodium hydroxide on the cleaned area. Allow the solution to sit for one minute then soak up with blotting paper. One drop of sodium sulphide on the wet portion of the blotter will turn brown if the material is leaded.

CONCLUSION

Leaded steels are not a panacea for all machining problems but they are a proven help when used in high speed machining operations.

Precision Shafting or High Strength, Distortion Free, Precision Ground Shafting

DISCUSSION

This specialty product was developed for application requiring high strength, wear resistance, tight straightness tolerance and micro finish. Uses include water pump shafts, hydraulic and pneumatic cylinder piston rods and high speed and heavy duty shafts.

CHEMICAL COMPOSITION, PERCENT (LADLE). AISI – 1045

*C	Mn	P	S	Si
.43/.50	.60/.90	.035 max.	.045 max.	.15/.30

*Under (74.6 mm) 2-15/16” dia. – 1045 carbon, (74.6 mm) 2-15/16” and over – 1050 carbon.

MECHANICAL PROPERTIES

Yield strength, (Mpa) Ksi		(310.3 to 413.7) 45 to 60
Tensile strength, (Mpa) Ksi		(551.6 to 689.5) 80 to 100
Elongation in (50.8 mm) 2", %	to (74.6 mm) 2-15/16"	15
	over (74.6 mm) 2-15/16"	16
Reduction of area, %	to (74.6 mm) 2-15/16"	40
	over (74.6 mm) 2-15/16"	35

TOLERANCES

SIZE	
(38.1 mm) 1-1/2" dia. and under	(+ .000 - .025 mm) + .000 - .001"
Over (38.1 mm) 1-1/2" to less than (63.5 mm) 2-1/2"	(+ .000 - .038 mm) + .000 - .0015"
(63.5 mm) 2-1/2" to (76.2 mm) 3" inclusive	(+ .000 - .051 mm) + .000 - .002"
Over (76.2 mm) 3" to (101.6 mm) 4"	(+ .000 - .076 mm) + .000 - .003"

DESCRIPTION

(12.7 mm)	½” to less than (41.3 mm) 1-5/8” dia.	– Cold drawn and ground.
(41.3 mm)	1-5/8” to less than (74.6 mm) 2-15/16” dia.	– Turned, cold drawn and ground.
(74.6 mm)	2-15/16” to less than (165.1 mm) 6-1/2” dia.	– Rough turned then ground.

C1144 Cold Finished Stressproof or Century Series Steel Bars

DISCUSSION

C1144 Stress proof or Century Series is designed to meet, in one bar, the need for greater strength elimination of heat treatment, better machinability and wearability. The manufacturing process consists of drawing the bar with heavy draft, followed by stress relieving under controlled furnace conditions. It is widely used for keyed shafts, arbors, gears, pinions, pins and lead screws.

MACHINABILITY

Although a high strength material, the product has excellent machining qualities. It is rated at 83% of B1112 and will machine 50% to 100% faster than heat treated materials of equivalent hardness.
It is ideal for automatic screw machines and with its high strength; parts are ready for use as machined, without the necessity of heat treating.

WELDABILITY

The material can be welded satisfactorily if proper precautions are taken. Like other steels in its sulphur and carbon range, it cannot be considered readily weldable steel and should not be welded in a highly stressed area.
When welding, use a low hydrogen, coated rod. The rod manufacturer will recommend what to use when welding high sulphur, medium carbon steel.

INDUCTION HARDENING

This product is an excellent induction hardening steel. Its hardenability when quenched is between that of alloy steels and carbon steels in the 1045 and 1050 class.
Although having fine induction hardening qualities the material should not be quenched at above Rc 62 and Rc 58 might be considered the limit. Severe cracking could ensue at Rc 58/62 if the section is not uniform. No attempt should he made to induction harden keyways or cross-drilled holes.

GRADES

Other grades of higher strength are also available.

C1144

CHEMICAL COMPOSITION, PERCENT (LADLE)

C	Mn	P	S	Si	Cu	N
.40 - .48	1.35 - 1.65	0.40 max.	.24 - .33	.15 - .30	.15 - .25	.006 - .009

MECHANICAL PROPERTIES

Yield strength, min., (Mpa) Ksi	(689.5) 100
Tensile strength, (Mpa) Ksi	(861.8) 125
Machining charasteristics	83% of B1112
Elongation in (50.8 mm) 2", min. %	10/15
Reduction of area, %	15/30

TOLERANCES

Rounds	
(38.1 mm) 1-1/4" to (38.1 mm) 1-1/2" incl.	(+ .000 - .102 mm) + .000 - .004"
Over (38.1 mm) 1-1/2" to (63.5 mm) 2-1/2" incl.	(+ .000 - .127 mm) + .000 - .005"
Over (63.5 mm) 2-1/2" to (101.6 mm) 4" incl.	(+ .000 - .152 mm) + .000 - .006"
Over (101.6 mm) 4" to (114.3 mm) 4-1/2" incl.	(+ .000 - .178 mm) + .000 - .007"
Hexagons	
(6.4 mm) 1/4" to (19 mm) ¾" incl.	(+ .000 - .102 mm) + .000 - .004"
Over (19 mm) ¾ " to (38.1 mm) 1-1/2" incl.	(+ .000 - .127 mm) + .000 - .005"
Over (38.1 mm) 1-1/2" to (50.8 mm) 2" incl.	(+ .000 - .152 mm) + .000 - .006"

GROUND AND POLISHED

When parts require an extremely smooth finish, measured in micro-inches the ground and polished offers a mirror like finish. Its smooth surface minimizes wear on parts that are subject to friction. The bars in this finish are true to shape, straight and to close standard tolerances. This makes further finishing operations unnecessary.

TOLERANCES (Cold Drawn, Ground and Polished Rounds)

(6.4 mm) 1/4" to (38.1 mm) 1-1/2" incl.	(+ .000 - .025 mm) + .000 - .001"
Over (38.1 mm) 1-1/2" to less than (63.5 mm) 2-1/2" incl.	(+ .000 - .038 mm) + .000 - .0015"
(63.5 mm) 2-1/2" to (76.2 mm) 3" incl.	(+ .000 - .051 mm) + .000 - .002"
Over (76.2 mm) 3" to (101.6 mm) 4" incl.	(+ .000 - .076 mm) + .000 - .003"
Over (101.6 mm) 4" to (114.3 mm) 4-1/2" incl.	(+ .000 - .127 mm) + .000 - .005"