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# F

## SECTION F

### HIGH STRENGTH LOW ALLOY STEELS HEAT TREATED CONSTRUCTIONAL ALLOY STEELS ABRASION RESISTING STEELS

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## **HIGH STRENGTH LOW ALLOY STEELS**

### **SHEETS—PLATES**

High strength low alloy (HSLA) steels are essentially low carbon steels to which have been added small amounts of such alloying elements as chromium, nickel, molybdenum, vanadium, zirconium, copper, and columbium. The effect of the alloy addition is to raise the yield point of the steel in the as-rolled condition to a level substantially higher than that of the structural carbon grades, and at the same time provide weldability and formability. Thus, they offer the advantages of higher strength-to-weight ratios, increased resistance to wear and abrasion, and in some cases improved resistance to atmospheric corrosion.

These steels are produced under dozens of different trade names and are covered by a number to ASTM, SAE, and military specifications. General characteristics are similar, but the various grades may be categorized in a general way according to their resistance to atmospheric corrosion.

#### **Resistance to Atmospheric Corrosion** **Equivalent to that of Carbon Steels**

**Color Marking:** Brown and Orange

Specifications: ASTM A 572 Grade 50 (Plates)  
SAE J410 Grade 950X (Sheets, Plates)

#### **Resistance to Atmospheric Corrosion** **Two times that of Carbon Steels**

**Color Marking:** Red and White

Specifications: ASTM A 606 Type 2 (Sheets)  
SAE J410 Grade 950B (Sheets, Plates)

#### **Resistance to Atmospheric Corrosion** **Four Times that of Carbon Steels**

**Color Marking:** Gold and Red

Specifications: ASTM A 242 Type 1 (Plates)  
A588 (Plates)  
A606 Type 4 (Sheets)  
SAE J410 Grade 950D (Sheets, Plates)

**MECHANICAL PROPERTIES** — The following minimums generally apply depending upon applicable thickness and specification:

|                                  |        |
|----------------------------------|--------|
| Tensile Strength, min, psi       | 70,000 |
| Yield Strength, min, psi         | 50,000 |
| Elongation, min, % in 2" (Sheet) | 22     |
| % in 8" (Plate)                  | 18     |

**WELDABILITY** — High Strength Low Alloy grades are weldable with welding techniques suitable for the grade and intended service.

# **HIGH STRENGTH LOW ALLOY STEEL (Continued)**



## **HIGH STRENGTH SHEETS**

**Thick-  
ness**      **Width  
and  
Length**      **Est. Wt.  
Lbs. Per  
Sheet**

### **Cold Rolled**

**20 Ga. 1.50 Lbs. Sq. Ft.**  
.0359"  
36 x 120      45.00

**18 Ga. 2.0 Lbs. Sq. Ft.**  
.0478"  
48x120      80.00  
144      96.00

**16 Ga. 2.5 Lbs. Sq. Ft.**  
.0598"  
36x120      75.00  
48x120      100.00  
144      120.00

**14 Ga. 3.125 Lbs. Sq. Ft.**  
.0747"  
60x120      156.25  
144      187.50

### **Hot Rolled**

**14 Ga. 3.125 Lbs. Sq. Ft.**  
.0747"  
36x120      93.75  
120      175.00  
144      112.50  
48x96      100.00  
120      125.00  
144      150.00  
240      250.00

**13 Ga. 3.75 Lbs. Sq. Ft.**  
.0897"  
60x240      375.00

**12 Ga. 4.375 Lbs. Sq. Ft.**  
.1046"  
36x120      131.25  
48x96      140.00  
120      175.0  
144      210.00  
192      280.00  
240      350.00  
60x96      175.00  
120      218.75  
144      262.50  
192      350.00  
240      437.50



## **HIGH STRENGTH PLATES**

**Thick-  
ness**      **Width  
and  
Length**      **Est.Wt.  
Lbs. Per  
Sheet**

### **Hot Rolled**

**12 Ga. (Cont.)**  
72x120      262.50  
144      315.00  
192      420.00  
240      525.00

**11 Ga. 5.0 Lbs. Sq. Ft.**  
.1196"  
48x120      200.00  
144      240.00  
192      320.00  
240      400.00  
60x144      300.00  
192      400.00  
240      500.00  
72x120      300.00  
144      360.00  
192      480.00  
240      600.00

**10 Ga. 5.625 Lbs. Sq. Ft.**  
.1345"  
36x96      135.00  
120      168.75  
48x96      180.00  
120      225.00  
144      270.00  
240      450.00  
60x96      225.00  
120      281.25  
144      337.50  
192      450.00  
240      562.00  
72x96      270.05  
120      337.50  
144      405.07  
192      540.00  
240      675.00

**7 Ga. 7.5 Lbs. Sq. Ft.**  
.1793"  
48x120      300.00  
144      360.00  
192      480.00  
240      600.00

High Strength

Low Alloy

Plates

are stocked in

thicknesses

from 3/16" to 3 1/2",

widths up to 96",

and

lengths up to 360".

For

weights

refer to

Section D,

Pages 6 and 7.

## HEAT TREATED CONSTRUCTIONAL ALLOY STEELS

### PLATES — ASTM A 514

**Color Marking:** Blue and Brown

Heat Treated Constructional Alloy Steels are low carbon alloy steels that have been heat treated by conventional liquid quenching and tempering to a strength level substantially higher than that of the high strength low alloy grades. The alloying elements and amount of alloy content vary among the grades depending upon the section thickness and desired properties. The low carbon content improves their general weldability.

ASTM Specification A 514 covers this material in "Structural" Quality. The specification provides for a number of grades, which correspond to trade names of various steel producers.

#### ANALYSIS

| ASTM Grade | "F"        | "B"        | "H"        | "Q"       | "C"       |
|------------|------------|------------|------------|-----------|-----------|
| C          | .10/.20    | .12/.21    | .12/.21    | .14/.21   | .10/.20   |
| Mn         | .60/1.00   | .70/1.00   | .95/1.30   | .95/1.30  | 1.10/1.50 |
| P Max.     | .035       | .035       | .035       | .035      | .035      |
| S Max.     | .040       | .040       | .040       | .040      | .040      |
| Si         | .15/.35    | .20/.35    | .20/.35    | .15/.35   | .15/.30   |
| Cr         | .40/.65    | .40/.65    | .40/.65    | 1.00/1.50 | —         |
| Ni         | .70/1.00   | —          | .30/.70    | 1.20/1.50 | —         |
| Mo         | .40/.60    | .15/.25    | .20/.30    | .40/.60   | .20/.30   |
| V          | .03/.08    | .03/.08    | .03/.08    | .03/.08   | —         |
| Ti         | —          | .01/.03    | —          | —         | —         |
| Cu         | .15/.50    | —          | —          | —         | —         |
| B          | .0005/.006 | .0005/.005 | .0005/.005 | —         | .001/.005 |

**APPLICATIONS** — "Structural" Quality is used in general structural applications where its greater strength permits reduction in weight by using smaller cross-sectional areas. It is intended for welded construction where welding procedures are suitable to maintain the properties of the plate. Such applications include bridge and building members, body and frame members for earth-moving and transportation equipment, and components for heavy machinery.

## HEAT TREATED CONSTRUCTIONAL ALLOY STEELS (Continued)

**MECHANICAL PROPERTIES** — Applicable to “Structural” Quality.

| ASTM<br>A 514<br>Grade | Thickness                | Yield<br>Strength<br>(psi)<br>Minimum | Tensile<br>Strength<br>(psi) | Elongation<br>in 2”<br>Min. | Reduction of<br>Area Min. |                       |
|------------------------|--------------------------|---------------------------------------|------------------------------|-----------------------------|---------------------------|-----------------------|
|                        |                          |                                       |                              |                             | 3/4” &<br>Under           | Over<br>3/4”<br>Thick |
| <b>B &amp; C</b>       | Up to 1 1/4” incl.       | 100,000                               | 110/130,000                  | 18%                         | 40%                       | 50%                   |
| <b>H</b>               | Up to 2” incl.           | 100,000                               | 110/130,000                  | 18%                         | 40%                       | 50%                   |
| <b>F</b>               | Up to 2 1/2” incl.       | 100,000                               | 110/130,000                  | 18%                         | 40%                       | 50%                   |
| <b>Q</b>               | Up to 2 1/2”<br>6” incl. | 90,000                                | 100/130,000                  | 16%                         | —                         | 50%                   |

**FORMING** — “Structural” Quality material is readily cold formed, provided sufficient power is available and allowance is made for greater spring back than with mild steel.

| Thickness of Material | Minimum Radius |
|-----------------------|----------------|
| Up to 1” incl.        | 2 x thickness  |
| Over 1” to 2” incl.   | 3 x thickness  |

Warm forming may be done at temperatures below 1100°F without destroying the mechanical properties or toughness. Hot forming may be done at 1600° - 1800°F, but the formed part must be heat treated to restore its original properties.

**MACHINABILITY** — Cutting speed of “Structural” Quality is approximately 40% of that of 1212, or 65 surface feet per minute.

**WELDABILITY** — Techniques similar to those used in structural carbon steels apply, but precautions must be exercised. Hydrogen must be kept out of the welding operation. Large sections or those under high restraint should be preheated to temperatures not exceeding 400°F.

**HEAT TREATING** — Stress relieving may be performed, if necessary, by heating at temperatures up to 1100°F. If “Structural” Quality material is heated over 1100°F, it must be re-heat treated to restore the original strength.

Austenitize — 1650° - 1700°F

Quench — Agitated Water

Temper — 1150° - 1250°F



## HEAT TREATED CONSTRUCTIONAL ALLOY PLATES

### STOCK SIZES

Stocked in thicknesses from 3/16” to 6” and lengths up to 30’.  
Stock widths are 72”, 84”, or 96”, depending on thickness.

For weights, refer to Page 7 of Section D.

## AR 235 ABRASION RESISTING STEEL

### Plates — Sheets

**Color Marking:** Gray and Orange

Abrasion Resisting Steel AR 235 is a medium-carbon, high-manganese, product. It is a hard, tough, wear-resistant steel which is ductile enough to permit certain machining. The chemical composition of this grade provides a Brinell hardness of approximately 235 in the as-rolled condition, along with a tensile strength of approximately 115,000 psi.

### ANALYSIS (Typical)

| Carbon | Manganese | Phosphorus | Sulphur | Silicon |
|--------|-----------|------------|---------|---------|
| .40    | 1.50      | .021       | .028    | .20     |

**APPLICATIONS** — Abrasion Resisting Steel will give two to ten times the life of Mild Steel when used in mixers, loaders, conveyors, scraper blades, dirt-moving equipment, dipper teeth, drag conveyor bottoms, mine screens, troughs, spouts, shovels, hoppers, dump truck bodies, concrete buckets, fan blades, ore skips, tail sluices, bucket lips, rock screens, loading chutes, agitator paddles, dredge pump liners, grinding pans, liner plates, tipple sluices, etc.

**MECHANICAL PROPERTIES** — Typical properties for 1/2" plate in the as-rolled conditions are:

| Tensile<br>Strength<br>(psi) | Yield<br>Strength<br>(psi) | Elongation<br>in<br>8" | Reduction<br>of<br>Area | Brinell<br>Hardness |
|------------------------------|----------------------------|------------------------|-------------------------|---------------------|
| 115,000                      | 70,000                     | 16%                    | 35%                     | 235                 |

**SHEARING and FLAME CUTTING** — In shear cutting, the capacity rating of the shear should be discounted about 40%. Abrasion Resisting Steel can be readily cut with a gas torch but the extreme heat of the torch coming in contact with this hard metal has a tendency to harden the steel at point of contact, leaving an edge which is more difficult to machine. If flame cutting is necessary, it is recommended that an allowance of about 3/8" be made on all burned edges, followed by machine cutting inside the burned edges. Another method is to burn full to the size required and then grind off the oxidized edge. Either of these methods should eliminate the necessity of machine cutting through the burned edge. Some users prefer to preheat the edge that is to be flame cut to about 650°F and normalize afterward. This eliminates grinding or machining the burned edge.

**PUNCHING** — Holes may be punched in thicknesses up to about 3/8". The capacity of the punch should be discounted about 40%. Holes in plates 3/8" and thicker should be drilled.

**BENDING and FORMING** — This steel, if not extremely cold, will take a 90° bend to a reasonable radius in thicknesses up to about 3/8" without fracture, providing it is bent slowly (by degree) until the forming has been completed. For more difficult forming and for all forming of heavier gauges, it should be heated and formed while hot. Hot forming should be done at about 1500°F. If steel is allowed to cool slowly it will not lose its abrasive resisting qualities, nor should there be any cracking or distortion. High carbon steel such as this grade should not be worked by any method while extremely cold.

**MACHINABILITY** — This grade, due to its high hardness and toughness, is rather difficult to machine. However, the usual high-speed tools are more than capable of doing machine cutting when necessary.

## AR 360 ABRASION RESISTING STEEL PLATES

**Color Marking:** Brown

Abrasion Resisting Steel is a medium-carbon, low-alloy steel that has been heat treated by quenching and tempering to develop high abrasion and impact resistance and high yield strength. Resistance to wear and abrasion is to a large degree a function of carbon content and hardness. This grade has a composition that is balanced to combine the desired properties with good welding and fabrication characteristics.

### ANALYSIS (Typical Range)

| C       | Mn      | P         | S        | Si      | Cr       | Mo      |
|---------|---------|-----------|----------|---------|----------|---------|
| .25/.32 | .40/.65 | .035 Max. | .04 Max. | .20/.35 | .80/1.15 | .15/.25 |

**APPLICATIONS** — AR 360 is designed to provide the best in abrasion and impact resistance. Toughness is maintained while the high hardness contributes to excellent abrasion resistance.

**MECHANICAL PROPERTIES** — The following are typical properties that may be considered as representative:

**Tensile Strength**  
(psi)

177,000

**Brinell Hardness**

360

**FORMING** — Cold forming of AR 360 may be performed with the bending done at right angles to the direction of rolling. A generous forming radius should be used, preferably 10 times the plate thickness or greater. Allowance should be made for more springback. The edges should be ground to remove notches and the effects of burning.

Warm forming of this grade is not satisfactory because of the low temperature at which the tempering has been performed. Hot forming is easily accomplished in the 1600° - 1800°F temperature range, but the formed part must be re-heat treated to restore its original properties.

**WELDABILITY** — This material may be welded with the usual production welding techniques. Hydrogen must be kept out of the welding operation. Low hydrogen electrodes such as E-100XX, E-110XX, or E-120XX are recommended. Preheating between 200°F and 400°F may be considered if a unique stress distribution pattern exists.

**HEAT TREATING** — This grade is water quenched from 1600° - 1650°F. Tempering is usually performed between 700°F and 1000°F to obtain the required hardness.



### AR 360 ABRASION RESISTING HEAT TREATED PLATES

Stocked in thicknesses from 1/4" to 1 1/2", widths up to 84", and lengths to 20'. For weights, refer to Pages 6 and 7 of Section D.

## ABRASION RESISTING STEEL (Continued)

### AR 400 ABRASION RESISTING STEEL PLATES

Abrasion Resisting Steel is a low-carbon, low-alloy steel that has been heat treated by quench and tempering to develop high abrasion resistance and high yield strength. Resistance to wear and abrasion is to a large degree a function of alloy content and hardness.

This grade has a composition balanced to combine the desired properties with good welding and fabrication characteristics.

#### ANALYSIS (Maximum % of Elements)

| C   | Mn   | Si  | Cr  | Ni   | B          |
|-----|------|-----|-----|------|------------|
| .17 | 1.55 | .55 | .55 | 1.00 | .0005/.005 |

**MECHANICAL PROPERTIES** — The following properties may be considered typical:

**Tensile Strength**  
(psi)

200,000

**Brinell Hardness**

400

**FORMING** — Cold forming of AR 400 may be performed with the bending radius done at right angles to the direction of rolling. A generous forming radius should be used, preferably 10 times the plate thickness or greater. Allowance should be made for more spring back. The edges should be ground to remove notches and the effects of burning.

Warm forming is not recommended due to the low tempering temperature used at heat treat. Hot forming at 1600° - 1800°F is easily accomplished, however, material must be re-heat treated to restore properties.

**WELDABILITY** — This material is relatively weldable using standard welding techniques. Pre and post heating are recommended.

**HEAT TREATING** — This material is furnished in the water quench and tempered condition. Generally, this material is austenitized at 1600° - 1650°F and water quenched followed by tempering between 700° and 1000°F to obtain the desired hardness.

Other Hardness levels available upon request.

## ABRASION RESISTING STEEL (Continued)



**WELDABILITY** — Abrasion Resisting Steel may be welded with proper precautions. Preheating is recommended, and after welding it is good practice to stress relieve or normalize. To normalize, heat to 1650°F and allow to cool slowly in air. Normalizing is sometimes omitted when the welded part is not subject to severe vibration and stress. However, normalizing will prevent cracks, give uniform structure, and will not reduce the abrasive-resisting qualities. The grade of welding rod to be used depends upon the thickness of section, design, service requirements, etc.



### ABRASION RESISTING PLATES

Abrasion Resisting Plates are stocked in thicknesses from  $\frac{3}{16}$ " to  $1\frac{1}{2}$ ", widths up to 96", and lengths up to 360".

For weights refer to Section D, Pages 6 and 7.



### ABRASION RESISTING SHEETS

|                |                        | Est. Weight, Lbs. |                |                |                        | Est. Weight, Lbs. |                |
|----------------|------------------------|-------------------|----------------|----------------|------------------------|-------------------|----------------|
| Thick-<br>ness | Width<br>and<br>Length | Per<br>Sheet      | Per<br>Sq. Ft. | Thick-<br>ness | Width<br>and<br>Length | Per<br>Sheet      | Per<br>Sq. Ft. |
| <b>14 Ga.</b>  |                        |                   |                | <b>11 Ga.</b>  |                        |                   |                |
| .0747"         | 36 x 144               | 112.50            | 3.125          | .1196"         | 48 x 144               | 240.00            | 5.000          |
|                | 48 x 144               | 150.00            | "              |                |                        |                   |                |
| <b>12 Ga.</b>  |                        |                   |                | <b>10 Ga.</b>  |                        |                   |                |
| .1046"         | 48 x 144               | 210.00            | 4.375          | .1345"         | 48 x 120               | 225.00            | 5.625          |
|                |                        |                   |                |                | 144                    | 270.00            | "              |



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### **NOTE TO ALLOY STEEL USERS**

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