

## ■ Aluminum

Pure aluminum is soft and ductile and most commercial uses require greater strength than pure aluminum affords. So, strength is achieved by the addition of other elements to produce alloys. Further strengthening is possible by means which classify the alloys into roughly two categories, non-heat-treatable (alloyed with manganese, silicon, iron, and magnesium) and heat-treatable (alloyed with copper, magnesium, zinc, and silicon).

Aluminum is available in a wide variety of alloys to meet specific applications. This article focuses on the alloys commonly used by DSM in precision sheet metal.

### 1100-H14 (QQ-A-250/1d)

Commercially pure aluminum, highly resistant to chemical attack and weathering. Excellent for chemical processing equipment and other uses where product purity is important. Easily worked and welded, ductile enough for deep draws, but the lowest strength aluminum alloy. Uses include light reflectors, decorative and jewelry parts, name plates. Seldom used in precision sheet metal -- see 5052-H32.

### 3003-H14 (QQ-A-250/2c)

General purpose manganese alloy. Stronger than 1100 with same good formability and low cost. Fine corrosion resistance and weldability. Used in stampings, spun and drawn parts, mail boxes, cabinets, tanks, fan blades. For higher strength, consider 5052-H32.

### 5052-H32 (QQ-A-250/8d)

Main alloy is magnesium. Far stronger than any of the alloys described above, yet forms well with reasonable inside bend radii. Corrosion resistance and weldability is very good. Better salt water corrosion resistance than 1100. Used for electronic chassis, tanks, pressure vessels and any number of parts requiring considerable strength and formability at reasonable cost. Anodizing may be slightly yellowish.

### 6061-T6 (QQ-A-250/11d)

Alloyed with magnesium & silicon. Heat treatable to improve strength. A widely used structural alloy for light to medium strength applications. Requires much larger inside bend radii than 5052-H32, but can be formed. Combines good weldability, corrosion resistance, and strength after heat treatment. Since it loses appreciable strength when welded, the 5000 series alloys replace it in dump body and some marine applications.

## ■ Quick comparison chart

Alloy	Yield	Formable	Weldable	Corrosion	Color code
1100-H14	17000	A	A	A+	WHITE
3003-H14	21000	B	A	A	GREEN
5052-H32	28000	B	A	A	PURPLE
6061-T6	40000	C	A	B+	BLUE

■ **Minimum bend radius**

When aluminum is bent around too small of an inside radius, cracking will occur. Cracking is most pronounced when the bend runs parallel to the natural grain of the material (formed as the sheet is rolled from molten ingot). It is generally a good idea to keep the inside radius at least equal to the material thickness. The more the merrier!

Min bend radii for thickness (in 1/32nds of inch):

ALLOY	.032	.040	.050	.063	.090	.125	.190	.250
1100-H14	0	0	0	0	0	0	3	6
3003-H14	0	0	0	0	1	2	4	8
5052-H32	0	1	1	2	3	4	8	12
6061-T6	2	2	3	4	6	8	18	32

■ **Aluminum sheet vs steel sheet**

The following table gives a quick point of reference when you need the approximate thickness of aluminum sheet to use in replacing steel sheet. The designated aluminum thickness will give you about the same stiffness. Or, putting it another way, the deflection will be about equal. **As a rule of thumb, plan on using an aluminum sheet about 40% thicker than steel.** Since aluminum weighs only 1/3 as much as steel, this means that the equivalent aluminum sheet will weigh only half as much as the steel sheet it replaces.

Approximate stiffness equivalence:

Steel LB/SF	Steel Thick	Alu Thick	Alu LB/SF
.975	.024	.032	.452
1.22	.029	.040	.564
1.47	.035	.050	.705
1.80	.044	.063	.890
2.44	.059	.080	1.13
2.56	.062	.090	1.27
2.86	.070	.100	1.41
3.66	.089	.125	1.76
4.88	.119	.160	2.25
5.49	.134	.190	2.68
7.33	.179	.250	3.53

**Aluminum sheet thickness tolerances**

During the rolling process that produces the sheet stock, a certain amount of "bowing" occurs in the rollers. This results in the sheet being slightly thinner at the edges than at the center of the sheet.

Aluminum thickness tolerances:

Thickness	36" Sheet	48" Sheet
.018-.028	.002	.0025
.029-.036	.002	.0025
.037-.045	.0025	.003
.046-.068	.003	.004
.069-.076	.003	.004
.077-.096	.0035	.004
.097-.108	.004	.005
.109-.125	.0045	.005
.126-.140	.0045	.005
.141-.172	.006	.008
.173-.203	.007	.010
.204-.249	.009	.011

### ■ Aluminum temper designation

Aluminum is specified with a 4 digit alloy followed by a temper designation. For example, 5052-H32 indicates an aluminum/magnesium alloy that has been strain hardened and stabilized by low temperature heating and is 1/4 hard.

-H	Strain hardened (cold worked) with or without thermal treatment.
-H1	Strain hardened without thermal treatment.
-H2	Strain hardened and partially annealed.
-H3	Strain hardened and stabilized by low temperature heating.
2nd Digit	A second digit denotes the degree of hardness. -Hx2 = 1/4 hard. -Hx4 = 1/2 hard. -Hx6 = 3/4 hard. -Hx8 = full hard.
-O	Full Soft (annealed).
-T	Heat treated to produce stable tempers.
-T1	Partially solution heat treated and naturally aged.
-T3	Solution heat treated and cold worked.
-T4	Solution heat treated and naturally aged.
-T5	Partially solution heat treated and artificially aged. -T51 Stress relieved by stretching. -T510 No further straightening after stretching. -T511 Minor straightening after stretching. -T52 Stress relieved by thermal treatment.
-T6	Solution heat treated and artificially aged.
-T7	Solution heat treated and stabilized.
-T8	Solution heat treated, cold worked, and artificially aged.
-T9	Solution heat treated, artificially aged, and cold worked.

### ■ Effects of alloying elements

Series	Main Alloy	Effect of Alloying Element
1000	none (99% alu)	Unalloyed aluminum is highly corrosion resistant, low strength, workable, conductive. Non-heat-treatable.
2000	Copper	Gives strength, hardness, machinability. Heat-treatable.
3000	Manganese	Adds moderate strength, good workability. Non-heat-treatable.
5000	Magnesium	Moderate to high strength. Corrosion resistant. Non-heat-treatable.
6000	Magnesium & Silicon	Increases strength, formability, corrosion resistance. Heat-treatable.
7000	Zinc	For greatest strength. Heat treatable.

## ■ Steel

Steel sheet is commonly categorized as either "hot rolled" or "cold rolled" and by varying the amount of carbon, the manufacturer can produce a wide range of material characteristics. Tool steels have a much higher carbon content than the mild steels used in sheet metal work.

The hot rolling process is generally less expensive, but results in a surface slag that is not always acceptable. Pickled and Oiled Hot Roll Steel has had most of the mill oxide removed and has a better surface appearance.

Cold roll steel is commonly used in precision sheet metal applications due to its excellent surface condition, material consistency, and accuracy in thickness.

ASTM-A366 specifies a cold roll steel with a maximum carbon content of .10 for improved welding and forming. It is soft enough to bend back on itself in any direction without cracking. Typical applications include refrigerators, ranges, washing machines, auto and truck bodies, signs, panels, shelving, furniture, and stamped parts.

One main advantage of steel over aluminum is the ease of resistance spot welding. Steel also has a lower cost per pound than aluminum, although adding corrosion protection (plating and painting) may consume a great deal of the cost savings over aluminum.

Steel sheet is available in a wide range of pre-finished products, including galvanized, paint primed, and fully painted. DSM generally works with bare steel sheet and plates the finished part to assure that all perforations and bends are adequately covered.

## ■ Steel sheet tolerances

The following table shows the commercial quality gauge thicknesses. DSM generally purchases "HCQ" (Half Commercial Quality) which tightens the tolerance range on each gauge by approximately 50%. Note that some gauge thicknesses actually overlap in decimal range. Steel sheet thickness tolerances:

gauge	Nominal	Max	Min	LB/SF
10	.1345	.1405	.1285	5.625
11	.1196	.1256	.1136	5.000
12	.1046	.1106	.0986	4.375
14	.0747	.0797	.0697	3.125
16	.0598	.0648	.0548	2.500
18	.0478	.0518	.0438	2.000
20	.0359	.0389	.0329	1.500
22	.0299	.0329	.0269	1.250
24	.0239	.0269	.0209	1.000
26	.0179	.0199	.0159	0.750
28	.0149	.0169	.0129	0.625

## Stainless Steel

Stainless steel does rust, but in a minuscule amount compared to steel sheet. This is accomplished by alloying elements like nickel to reduce the amount of iron exposed on the surface. There is a variety of stainless steel alloys. This article focuses on those alloys commonly used in sheet metal applications.

### Stainless steel alloys

Alloy	Characteristics
303	NOT FOR SHEET METAL. For use in automatic machining applications (screws). Corrosion resistant to atmospheric exposures, sterilizing solutions, most organic and many inorganic chemicals; most dyes, nitric acid and foods.
304	The most widely used of the stainless steel and heat resisting steels. Offers good corrosion resistance to many chemical corrodents as well as industrial atmospheres. Has very good formability and can be readily welded by all common methods. ASTM A240 Cold rolled, annealed and pickled. Finishes: 2B, #3, and #4.
316	Better corrosion and pitting resistance as well as higher strength at elevated temperatures than T304. Used for pumps, valves, textile and chemical equipment, pulp & paper and marine applications. ASTM A240 Cold rolled, annealed and pickled. Finishes: 2B, #3, and #4.
410	Heat-treatable stainless used widely where corrosion resistance is not severe (air, fresh water, some chemicals). Frequently used in cutlery. This series is martensitic (magnetic). ASTM A240 Hot rolled, annealed and pickled. Finishes: Dull

### Stainless sheet thickness tolerances

During the rolling process that produces the sheet stock, a certain amount of "bowing" occurs in the rollers. This results in the sheet being slightly thinner at the edges than at the center of the sheet.

Stainless thickness tolerances:

Thickness	36" Sheet	48" Sheet
.017-.030	.0015	.002
.031-.041	.002	.003
.042-.059	.003	.004
.060-.073	.003	.0045
.074-.084	.004	.0055
.085-.099	.004	.006
.100-.115	.005	.007
.116-.131	.005	.0075
.132-.146	.006	.009
.147-.187	.007	.0105

■ **Stainless sheet surface finishes**

Sheet stock from the rolling mill is available in several finishes. To protect the finish, a static adhering PVC film may be applied. DSM normally handles "2B bare" and grains or polishes the part after all perforation is completed.

Stainless sheet finishes:

<b>Finish</b>	<b>Description</b>
#1	Hot rolled, annealed and pickled.
#2D	Dull cold rolled, annealed, and pickled.
#2B	Bright cold rolled, annealed, and pickled.
#3	Grained 100-120 grit.
#4	Grained 150-180 grit
BA	Bright Annealed -- highly reflective.