Author **W. F. Brown, Jr.**

	Al
1.4	**Mg**
0.75	**Cu**
0.9	**Si**
0.2	**Cr**
0.2	**V**

1 GENERAL

The alloy 6069 is a new entry to the family of 6000 series of heat treatable Mg-Si-Cu aluminum alloys. The data available, while not sufficient to establish design mechanical property values for 6069, indicate that tensile ultimate and yield strengths for the T6 condition are about 40 percent higher than its sister 6061 alloy and essentially equal to the tensile properties of 6013-T6 sheet. Corrosion resistance does not appear to be inferior to 6061. Present applications are high pressure seamless gas containers formed by either hot or cold impact extrusion and tubing for light weight bicycle frames. A substantial amount of the available data was obtained from tests specified in ISO 7866 (Ref. 1) for seamless aluminum gas cylinders additional data was also obtained by the producer.

1.1 Commercial Designation.

6069

1.2 Alternate Designations.

1.3 Specifications.

No AMS, ASTM or Federal Specifications

1.4 Composition

1.4.1 *[Table]* Chemical Composition Registered with Aluminum Association.

1.5 Thermal Mechanical Treatment

1.5.1 General

The following heat treatments were established by tests on both ingots and extruded bar. Solution treatment temperature was based in part on a metallographic study of the effects of temperatures from 1025 to 1100F (Ref. 2). Eutectic melting was found to occur at 1075F. At temperatures less than 1040F, tensile strength began to decrease. The aging treatment was based on a systematic study of the effects of aging temperature and time (Figs. 1.5.3.2 to 1.5.3.7). These data indicate a wide range of tensile strength and elongations are available. The recommended heat treatment is designed to take advantage of the relatively high strength of this alloy.

Additional tests were made to explore the influence of quench and age delay as well as the effect of plastic strain before aging. Tensile specimen temperature was monitored during the delay period (Fig. 1.5.3.8). The corresponding tensile data (Fig. 1.5.3.9) indicate that if the thickest section of a part was at 700F or higher during less than a 30 second quench delay very small loss in tensile properties would be expected.

The age delay data (Fig. 1.5.3.10) show an initial decrease in tensile strengths for both 6069 and 6061. The effects of age delay have been reported previously (Ref. 6) for several 7000 series aluminum alloys with some alloys exhibiting a decrease and others an increase in strength with delay time. The same source indicates a strength loss of about 7 ksi is associated with age delay for 6061. This author is not aware of a satisfactory explanation of these effects.

1.5.2 Anneal 775F, slow cool.

1.5.3 Recommended solution treat and age for the T6 Temper: 1050F, 1.5 hr. W.Q. + 340F, 16 hr. (Ref. 2)

1.5.3.1 Alternate age: 365F, 8 hr. This age appears to give somewhat lower yield strength for the ingot material but with some improvement in elongation.(see Figs 1.5.3.2 - 1.5.3.4). For the wrought material (Figs. 1.5.3.5 - 1.5.3.7) there appears to be little difference in elongations between the recommended age and the alternate age. (Ref. 2)

1.5.3.2 *[Figure]* Effect of aging temperature and time on the tensile yield strength of specimens from homogenized ingot.

1.5.3.3 *[Figure]* Effect of aging temperature and time on the tensile ultimate strength of specimens from homogenized ingot.

1.5.3.4 *[Figure]* Effect of aging temperature and time on the elongation of specimens from homogenized ingot.

1.5.3.5 *[Figure]* Effect of aging temperature and time on the tensile yield strength of specimens from hot, extruded bar.

1.5.3.6 *[Figure]* Effect of aging temperature and time on the ultimate tensile strength of specimens from hot extruded bar.

1.5.3.7 *[Figure]* Effect of aging temperature and time on the elongation of specimens from extruded bar.

1.5.3.8 *[Figure]* Effect of quench delay on quench temperature of specimens from hot extruded tube.

1.5.3.9 *[Figure]* Effect of quench delay on tensile properties of specimens from hot extruded tube.

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1.5.3.10 *[Figure]* Effect of age delay on the tensile properties of specimens cut from cold impact extruded cylinders with tensile axis in the extrusion direction.

1.5.3.11 *[Figure]* Effect of stretching before aging on two heats with different Mg content.

1.6 Hardness

RB (HB): Anneal – 9.1 (40), T4 – 49.2 (90), T6 – 79.6 (126)

1.7 Forms and Conditions Available

Wide range of ingot diameters ranging from 2.4 to 11 inches (Ref. 7).

1.8 Melting and Casting Practice

The 6069 direct chill ingots are produced using Wagstaff Air Slip™ tooling. The ingot homogenization procedures are critical in achieving microstructural uniformity and satisfactory response to forming operations. These procedures are proprietary.

1.9 Special Considerations.

1.9.1 Directionality in tensile properties has been observed for hot extruded cylinders (see Table 3.2.1.1) with tensile strength being higher in the transverse direction (tensile axis normal to the extrusion direction) and the elongation lower than in the longitudinal or 45º direction. These effects on the tensile properties are probably associated with a combination of crystallographic and mechanical texture. The magnitude of such effects would dependent on the thermal mechanical history of the alloy.

2 Physical Properties and Environmental Effects

2.1 Thermal properties

2.1.1 Melting Range

2.1.2 Phase Changes

2.1.2.1 Liquidus 1198F, Solidus 1078F (Ref. 3)

2.1.2.2 Precipitation Hardening

The major hardening precipitate in both 6069 and 6061 is Mg_2Si (β'). Based on TEM studies (Table 2.1.2.3) the superior strength of 6069 may be associated with the higher density and closer spacing of β' precipitate as determined from specimens subjected to the same processing history.

2.1.2.3 *[Table]* Characteristics of the β' precipitate in 6069-T6 and 6061-T6

2.1.3 Thermal Conductivity

2.1.4 Thermal Expansion 13.1µ in / in / Fº (68 to 212F) (Ref. 7)

2.1.5 Specific Heat

2.1.6 Thermal Diffusivity

2.2 Other Physical Properties

2.2.1 Density 0.098 lbs / in.^{3} (Ref. 7)

2.2.2 Electrical Properties

2.2.2.1 Electrical Conductivity

2.2.2.1.1 *[Table]* Electrical conductivity and resistivity of various tempers

2.2.3 Magnetic Properties

2.2.4 Emittance

2.2.5 Damping Capacity

2.3 Chemical Environments

2.3.1 General Corrosion

The tendency for intergranular corrosion was evaluated in accordance with ISO 7866 (Ref. 1) using specimens cut from hot impact extruded cylinders (4.3 in. OD with a 0.19 in. wall) in the T6 condition and subjected to immersion in a solution contained 57g / l of NaCl + 3g / l of H_2O_2. An example of such a cylinder is shown in Fig. 2.3.1.1. Four specimens each were cut from the side wall, from the shoulder and from the bottom of the cylinders. ISO 7866 requires no evidence of intergranular corrosion during a 6 hour exposure to the NaCl + H_2O_2 solution. This requirement was met for all specimens.

2.3.1.1 *[Figure]* Example of the types of cylinders used in the ISO 78766 tests.

2.3.2 Stress Corrosion

Cyclic stressing of notched specimens (K_t=3) was used to estimate the cyclic lives of both 6069-T6 and 6061-T6 extrusions. The results (Table 2.3.2.1) show large scatter but do not indicate any significance difference between these alloys.

Stressed ring tests in accordance with ISO 7866 (Ref. 1) were made of rings cut from 6069-T6 hot impact extruded cylinders (4.3 in. O.D. x 0.91 in. wall) in the T6 condition. Three rings were bolt loaded in such a way that the external surface was in tension at the 0.2 percent yield strength. Three other rings were loaded so that the internal surface was identically stressed. The loaded rings were then subjected to cyclic exposure in “artificial sea water” consisting of 3.5 parts by mass of NaCl to 96.5 parts by mass of water with 6.4<pH<7.2. An exposure cycle was 10 minute immersion followed by 50 minute air dry. The

ISO 7866 (Ref. 1) requirement that no cracks be visible after 720 cycles (30 days) using a low magnification lens was satisfied for the six rings.

2.3.2.1 *[Table]* Results of constant stress cyclic loading in salt solution for 6069 and 6061 extrusions.

2.4 Nuclear Environments

3 Mechanical Properties

3.1 Specified Mechanical Properties

3.1.1 Producers Tentative Mechanical Properties

The producer's mechanical properties for 6069-T6 shown in Table 3.1.1.1 have been registered with the Aluminum Association and represent the properties of early runs of three sizes of extruded cylinders.

3.1.1.1 *[Table]* Producer's Tentative Mechanical Properties for 6069-T6 extrusions as registered with the Aluminum Association (AA), Aluminum Association's minimum tensile values for 6061-T6 extrusions, Mil-Hdbk-5 design tensile properties for 6061-T6 extrusions, and Mil-Hdbk-5 design tensile properties for 6013-T6 sheet.

3.2 Mechanical Properties at Room Temperature

3.2.1 Tension Stress-Strain Diagrams and Tensile Properties (See also Section 1.5)

3.2.1.1 *[Table]* Tensile properties of hot hollow extrusions from 3.5 in. dia. ingots.

3.2.1.2 *[Table]* Tensile properties of hot extruded shapes.

3.2.2 Compression Stress-Strain Diagrams and Compression Properties.

3.2.3 Impact

3.2.4 Bending

3.2.5 Torsion and Shear

3.2.6 Bearing

3.2.7 Stress Concentration

3.2.7.1 Notch Properties

3.2.7.2 Fracture Toughness

The 6061-T6 alloy exhibits very high fracture toughness in the T6 condition where the toughness is measured by a method that attempts to assess the value under plane strain conditions (e.g. K_{ic} or J_{ic}). The 6069 alloy appears to be no exception to this behavior. Attempts were made to measure K_{ic} using specimens cut from hot impact extruded cylinders 4.3 in. OD with a 0.19 in, wall in the cylindrical body and a 0.3 in. wall in the neck region (see Fig. 2.3.1.1). ASTM E399 CT specimens were removed from the shoulder section for toughness testing with the crack plane in the C-L orientation. No valid values were obtained with K_Q averaging about 31 ksi in.$^{1/2}$. Bend specimens taken from the shoulder were used for ten ASTM E813 J_{ic} tests in the C-R crack orientation. The individual values for these tests are not available but the reported average is K_{ic} = 37 ksi in$^{1/2}$ obtained using a linear elastic conversion from measured J values. It is doubtful that any of these tests gave useful information concerning crack toughness under plain strain conditions. Material behavior at the measurement points was likely associated with substantial crack tip plasticity rather than crack extension. For such very tough alloys, the fracture behavior under monatonic loading is best represented by crack growth resistance curves. If crack extension must be avoided under a specific steady load service condition (e.g. some high pressure gas storage vessels) a sustained load test containing the largest expected crack size may be used.

3.2.7.2.1 Sustained Load Crack Resistance

Two types of tests were made to evaluate the sustained load crack resistance, one for hot impact extruded cylinders and another for cold impact extruded cylinders both in the T6 condition.

<u>Tests on hot impact extruded cylinders</u>

The following tests were made in accordance with ISO 7866 (Ref. 1). Six ASTM E399 CT specimens with B=0.3 in. in the C-L crack orientation were removed from the shoulder of 4.3 in. OD cylinders having 0.91 in. cylinder body wall and a 0.3 in. thick shoulder (see Fig. 2.3.1.1). All specimens were fatigue precracked and subjected to an applied stress intensity of 15 ksi in.$^{1/2}$ at 80 F for a period of 90 days. Following the loading period, specimens were further fatigue cracked at a stress intensity not to exceed 0.6 that of the applied value and broken open. If SEM examination of the fracture surface indicated less than 0.16 mm of crack extension was produced in 90 days the test requirement was met. All specimens met this requirement.

<u>Tests on cold impact extruded cylinders</u>

These were cylinders of uniform diameter without a formed shoulder but with a closed bottom. The dimensions of the cylinders, the F_{ty} values obtained from cylinder wall specimens taken in the extrusion direction and details of the test are given in Table 3.2.7.2.1.1 which also shows the results of the same type of tests on 6061-T6 bar. Both the 6069 cylinder specimens and those from the 6061 bar gave no indication of crack extension during the hold period of 90 days.

3.2.7.2.1.1 *[Table]* Sustained load cracking resistance in air for 6069-T6 and 6061-T6 cylinders and bar.

3.2.8 Combined Loading

3.3 Mechanical Properties at Various Temperatures

3.3.1 Tension Stress-strain diagrams and Tensile Properties

3.3.2 Compression Stress-strain Diagrams and Compression Properties

3.3.3 Impact

3.3.4 Bending

3.3.5 Torsion and Shear

3.3.6 Bearing

3.3.7 Stress Concentrations (see Section 3.2.7)

3.4 Creep and Creep Rupture Properties

3.5 Fatigue Properties

3.5.1 Conventional High Cycle Fatigue

Both 6069-T6 and 6061-T6 hot and cold impact extrusions were tested at room temperature in high cycle fatigue. Data from these tests are shown in Figs. 3.5.1.1 and 3.5.1.3 and test details are shown in Tables 3.5.1.2 and 3.5.1.4. These tests show the 6069 shapes possessed a higher fatigue strength than the 6061 alloy. This difference is associated with the higher tensile strengths of the 6069 extrusions.

3.5.1.1 *[Figure]* Constant stress fatigue life for 6069 hot and cold impact extrusions and 6061 hot impact extrusions.

3.5.1.2 *[Table]* Extrusion processing and heat treatment provided to forms in fatigue study.

3.5.1.3 *[Figure]* Constant stress fatigue life for hot and cold impact extruded 6069 and cold impact extruded shapes.

3.5.1.4 *[Table]* Extrusion processing and heat treatment provided to cylinders used in fatigue study.

3.5.2 Low Cycle Fatigue

3.5.3 Fatigue Crack Propagation

3.6 Elastic Properties

The elastic properties at room temperature may be taken as equal to those for 6061.

3.6.1 Poisson’s Ratio

3.6.2 Modulus of Elasticity

3.6.3 Modulus of Rigidity

3.6.4 Tangent Modulus

3.6.5 Secant Modulus

4 Fabrication

4.1 Forming

Forming has been confined to hot and cold extrusions. Hot extrusion temperatures for seamless cylindrical shapes vary from 800 to 1000F depending on the size and shape.

4.2 Machining and Grinding (See Code 3206 - 6061)

4.3 Joining

4.4 Surface Treating (See Code 3206 - 6061)

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1. International Organization for Standardization (ISO), ISO 7866 Draft 1992 Annex A.
2. Personal Communication from S. Craig Bergsma, Northwest Aluminum Co., The Dalles, OR 97058.
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4. Bergsma, S. C., Kasner, M. E., "AA6069 A New High Strength Aluminum Alloy", *4th International Conference on Aluminum Alloys*, Atlanta, GA 1994, p.187.
5. Bergsma, S. C., Kasner, M. E., Li, X., and Wall, M. A., "Strengthening in the New Aluminum Alloy AA6069," *Automotive Alloys II,* (S. K. Das, ed.), The Minerals, Metals and Materials Society, 1998.
6. Aluminum Vol I. Properties, Physical Metallurgy and Phase Diagrams, (Kent R. Van Horn, ed.), American Society for Metals, p. 154.
7. Direct Forge 6069 Data Sheet, Northwest Aluminum Co., The Dalles, OR 97058.
8. Mil-Hdbk-5G, December 1, 1996, 6061 Alloy.
9. Mil-Hdbk-5G, November 1, 1990, 6013 Alloy.

Table 1.4.1. Chemical Composition Registered with Aluminum Association (Ref. 7)

Alloy	6069	
	Percent	
Element	Min	Max
Mg	1.2	1.6
Si	0.6	1.2
Cu	0.55	1.0
V	0.1	0.3
Cr	0.05	0.3
Ti	-	0.1
Fe	-	0.4
Mn	-	0.05
Zn	-	0.05
Sr	-	0.05

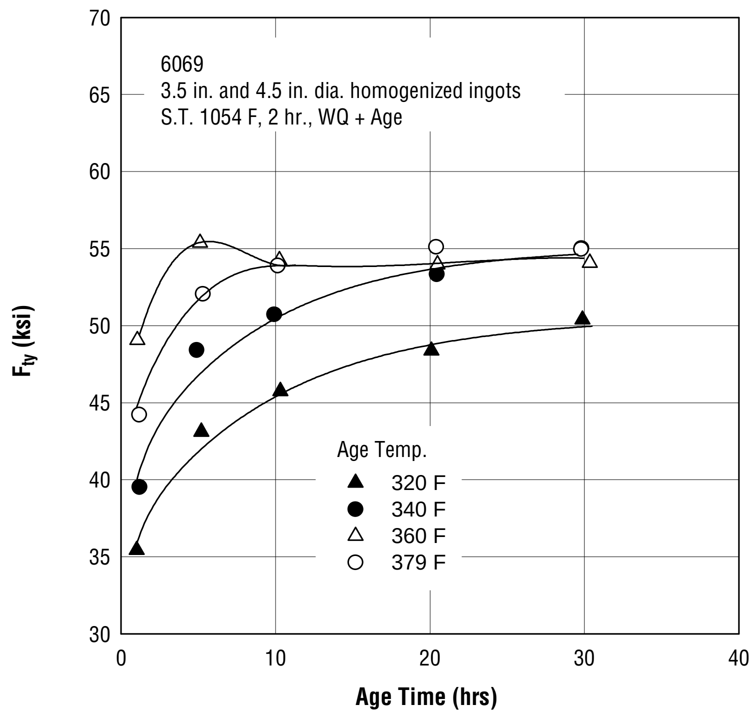

Figure 1.5.3.2 Effect of aging temperature and time on the tensile yield strength of specimens from homogenized ingot (Ref. 3)

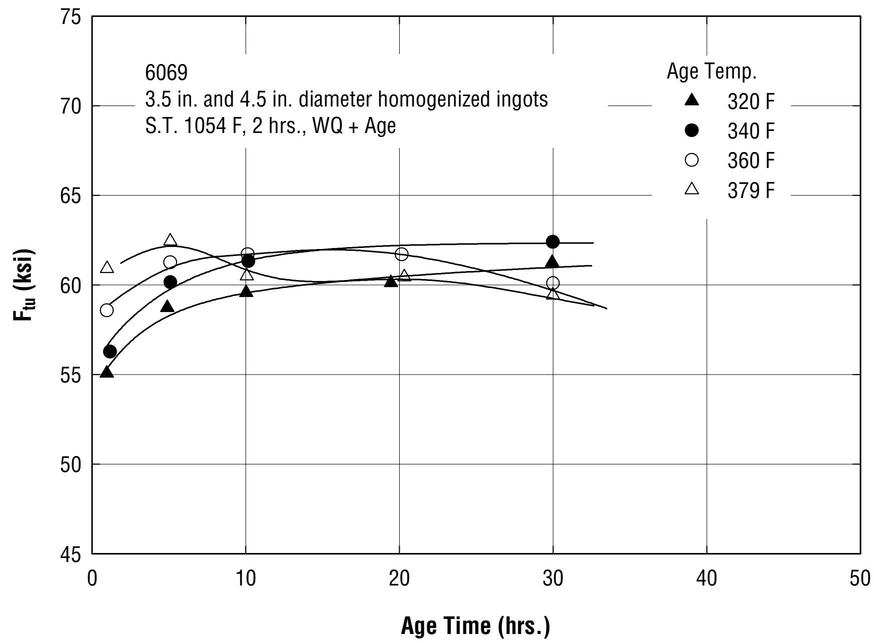

Figure 1.5.3.3 Effect of age temperature and time on the tensile ultimate strength of specimens from homogenized ingot (Ref. 3)

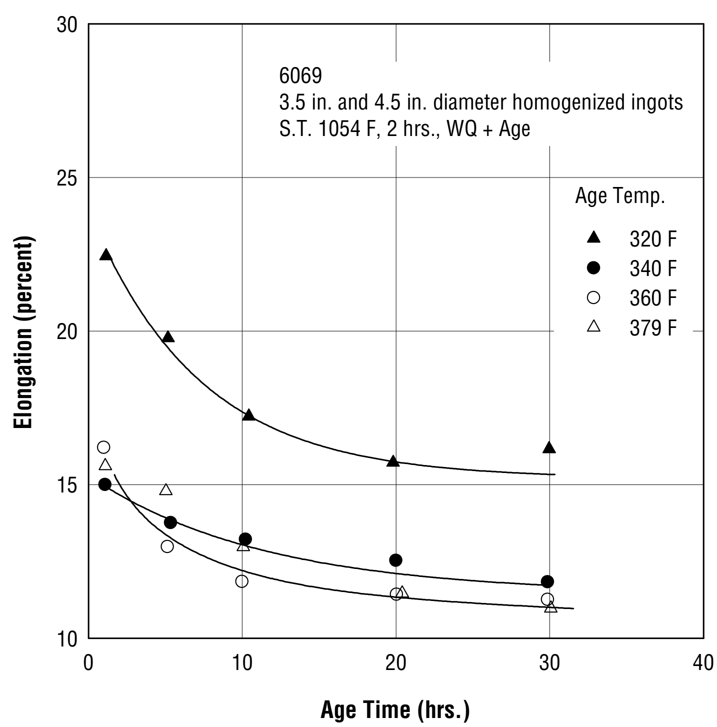

Figure 1.5.3.4 Effect of age temperature and time on the elongation of specimens from homogenized ingot (Ref. 3)

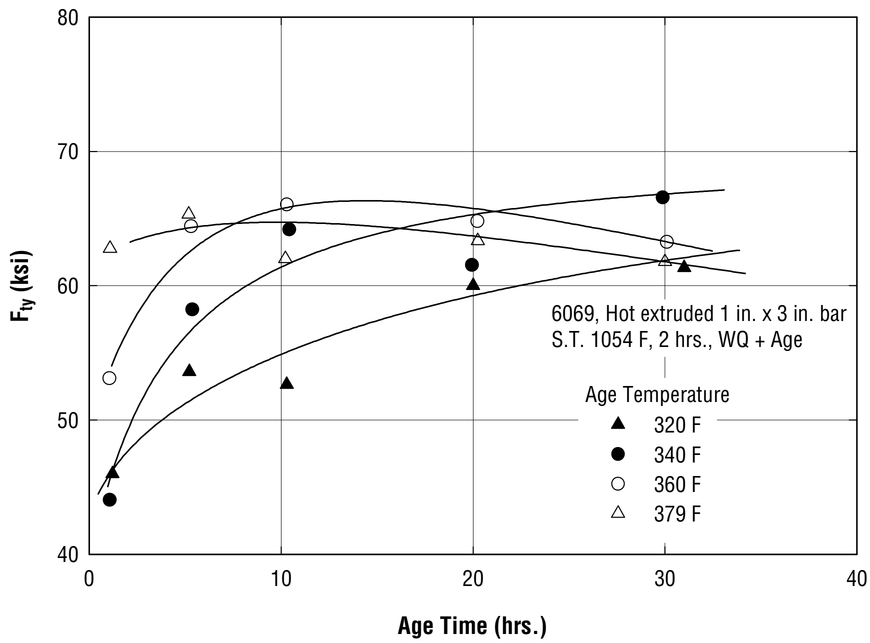

Figure 1.5.3.5 Effect of aging temperature and time on tensile yield strength of specimens from hot extruded bar (Ref. 3)

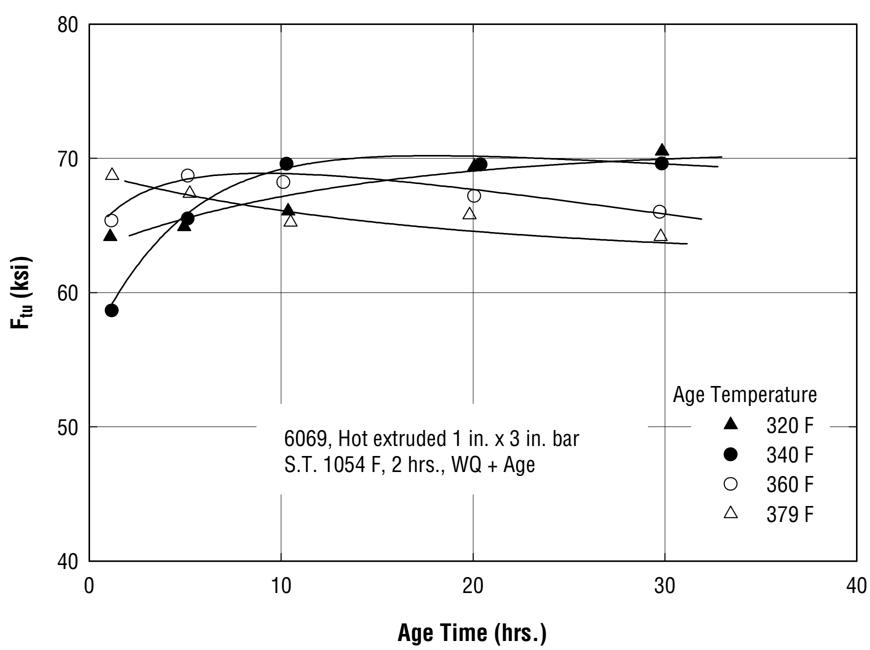

Figure 1.5.3.6 Effect of aging temperature and time on the ultimate tensile strength of specimens from hot extruded bar (Ref. 3)

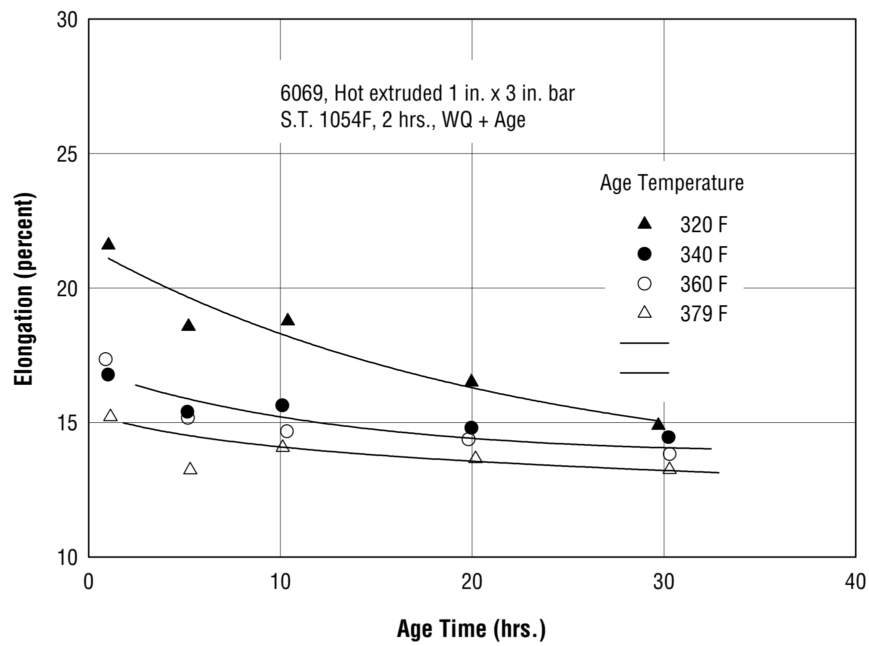

Figure 1.5.3.7 Effect of aging temperature and time on the elongation of specime from hot extruded bar (Ref. 3)

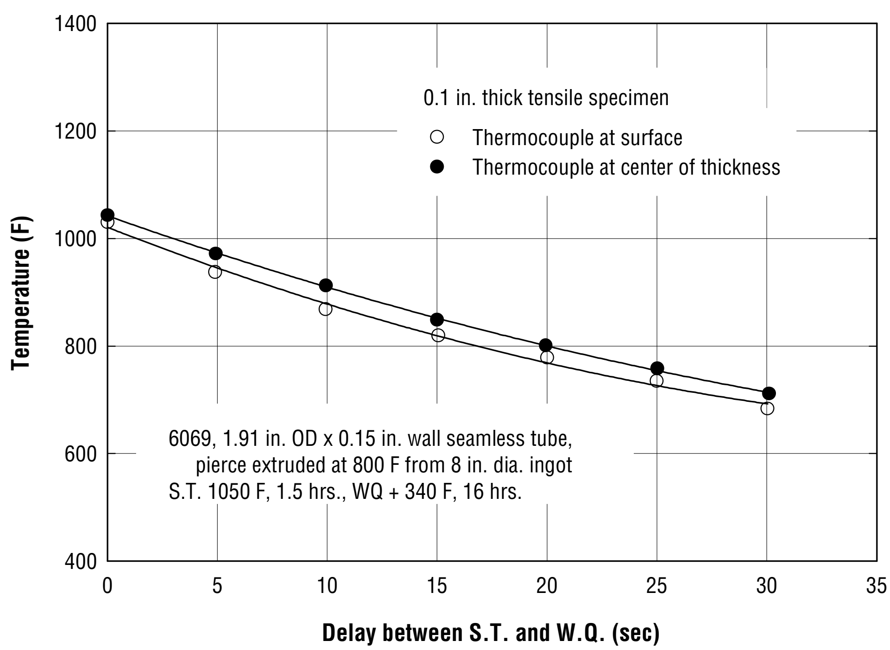

Figure 1.5.3.8 Effect of quench delay on the quench temperature of specimens cut from a hot extruded tube (Ref. 2)

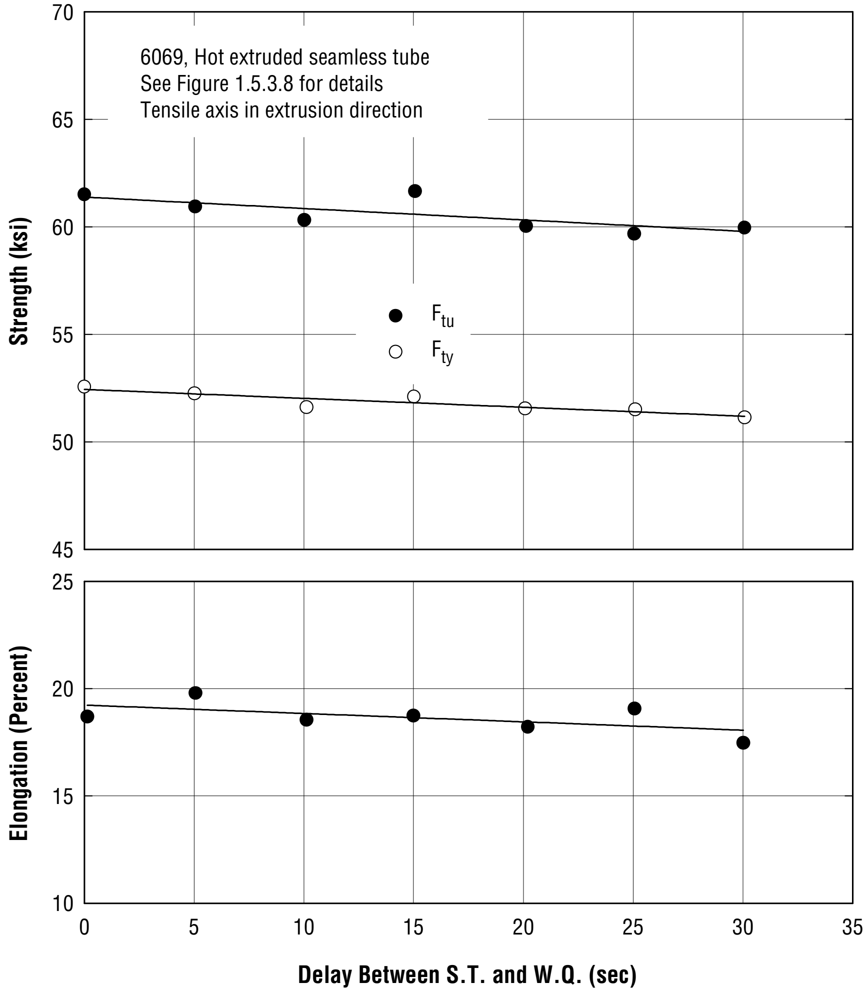

Figure 1.5.3.9 Effect of quench delay on tensile properties of specimens from hot extruded tube (Ref. 2)

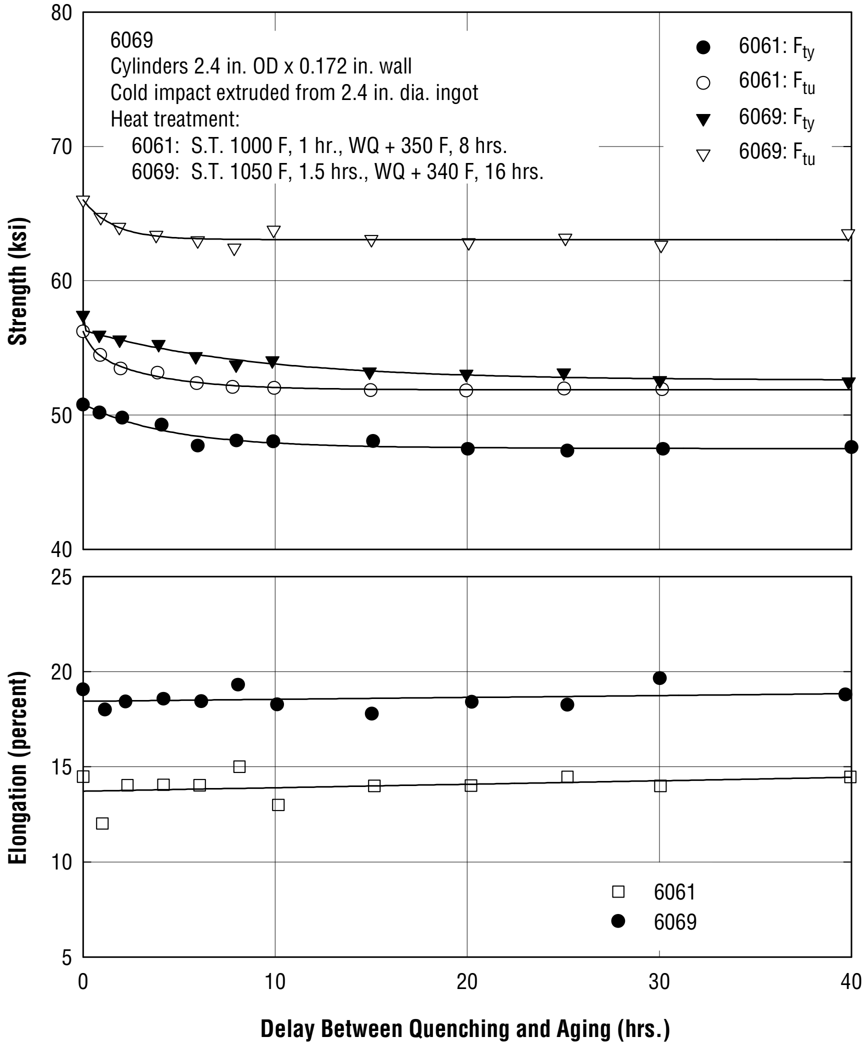

Figure 1.5.3.10 Effect of age delay on the tensile properties of specimens cut from cold impact extruded cylinders with tensile axis in extrusion direction (Ref. 2)

Table 2.1.2.3 Characteristics of b' precipitate in 6069-T6 and 6061-T6 (Ref. 5)

Alloy	6069-T6	6061-T6
Density (β' µm^{-3})	1.85x10^{5}	1.5x10^{5}
Length (nm)	22.5	24.5
Width (nm)	2.1	2.1
Spacing (nm)	17.8	18.5

Table 2.2.2.1.1 Electrical Conductivity and Resistivity of Various Tempers (Ref. 6)

Alloy	6069		
Temper	O	T4	T6
Conductivity (percent IACS)	44	35	38
Resisitivity (µohm in)	1.55	1.94	1.79

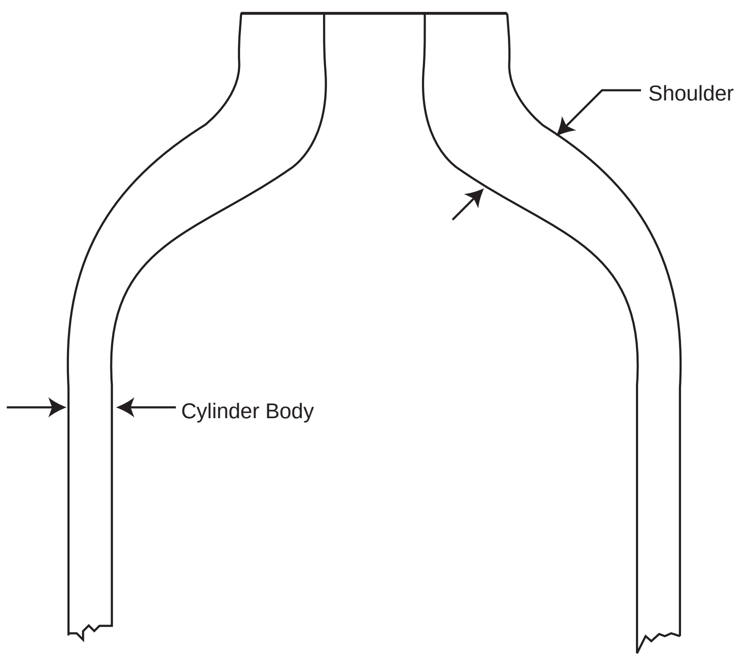

Fig. 2.3.1.1 Example of the types of cylinders used in the ISO 7866 tests

Table 2.3.2.1 Results of Constant Stress Cyclic Loading in Salt Solution for 6069 and 6061 extrusions

Type of Test	Notch specimens (K_t = 3) subjected to cyclic stressing in the extrusion direction between 1.47 and 14.7 ksi in aerated 3.5 percent NaCl solution.	
Alloys	6069	6061
Form	Hot Extrusion t=0.75 in. x W=2.2 in.	Solid Circular Extrusion
Heat Treatment	S.T 1054F, 2 hrs., WQ + 340F, 24 hrs.	S.T. 1000F, 1 hr., WQ + 351, 8 hrs.
Number of Tests	7	6
	Cycles to Failure x 10^{-5}	
Mean	1.04316	0.61478
Sdev	1.19116	0.34678
Statistics	Normality test failed: Mann-Whitney Rank Sum Test shows no significant difference between the performance of the two alloys (P = 0.945).	

Table 3.1.1.1 Producer's tentative tensile properties for 6069-T6 extrusions as registered with the aluminum association (AA), Aluminum Association's minimum tensile values for 6061-T6 extrusions, Mil-Hdbk-5 design tensile properties for 6061-T6 extrusions and 6013-T6 sheet

Alloy	6069-T6		6061-T6	6061-T6	6013-T6
Form	Extruded cylinders, 4.3 in. OD x 0.19 in. wall		Extrusions	Extrusions	Sheet
Source	Producer's AA values (Ref. 2)		Producer's AA values (Ref. 2)	Mil Hdbk-5 (Ref. 8)	Mil Hdbk-5 (Ref. 9)
Heat Treat	S.T. 1050F, 1.5 hrs., WQ + 340 F, 16 hrs.		S.T. 1000 F, 1 hr., WQ + 350 F, 8 hrs.	S.T. 1000 F, 1 hr., WQ + 350 F, 8 hrs.	S.T. 1050 F, 0.5 hrs., WQ + 375 F, 4 hrs.
Extrusion Method	Cold impact (a)	Hot impact (a)			
Size	8 in. OD x 0.5 in. wall 4.3 in. OD x 0.19 in. wall 2.4 in. OD x 0.17 in. wall	4.3 in. x 0.19 wall		t < 6.5 in. B basis values L	0.126 in. < t < 0.249 S basis values L
Ftu (ksi)	60	58	38	41	52
Fty (ksi)	53	49	35	38	48
Elongation (4D, percent)	10	9	8	-	8

(a) All properties measured in the extrusion direction.

Table 3.2.1.1 Tensile Properties of Hot Hollow Extrusions from 3.5 in. dia. Ingot (Ref. 3)

Alloy	6069		
Form	1.25 X 1.25 in. X 1/8 in. Wall Hollow Hot Extrusion		
Condition	S.T. 1060F, 2hr. W.Q. + 351F,16 hr.		
Direction	L	T	45°
Ftu-ksi (a)	57.4	65.4	59.7
Fty-ksi	50.1	59	52.4
e-percent	20	9.6	21.5

(a) Tensile properties are averages of 2 to 5 tests per direction

Table 3.2.1.2 Tensile Properties of Hot Extruded Shapes in T6 Condition (Ref. 3)

Alloy	6069-T6			
Form (a)	1.25 in. dia. Round Bar		0.5 in. Thick x 3 in. Wide	0.75 in. Thick x 2.2 in. Wide
Condition	1054F, 2hr W.Q. + 351F, 16 hr.		1054F, 2 hr. W.Q. + 340F, 24 hr.	1054F, 2hr. W.Q. + 340F, 18 hr.
Direction	L	T	L	L
F_{tu} (ksi)	69.3	64.1	65	68
F_{ty} (ksi)	64.8	57.6	60	64
e (percent)	14.4	13	15	14.5

(a) Extruded from 3.5 in. dia. ingot.

Table 3.2.7.2.1.1 Sustained Load Cracking Resistance in Air for 6069-T6 and 6061-T6 Cylinders and Bars (Ref. 3)

Type of Test	2.3 in. dia. X 0.3 in. thick disks with a sawed notch extending from a tapered center hole. Specimens precracked using a tapered pin forced into the hole. The indicated strains were produced by forcing the tapered pin to various depths and measured with strain gauges near the notch tip.				
Form	Cold Impacted Cylinders 2.4 in. OD x 0.172 in. Wall				Solid Bar 2.4 in. dia.
Heat Treatment	6069: S.T. 1050 F, 1.5 hrs., WQ + 340F, 16 hrs. 6061: S.T. 1000 F, 1 hr., WQ + 350F, 8 hrs.				
Location	Bottom of Cylinders				Bar
Specimen ID	RD0556	RD0560	RD0555	RD0557	RD0591
Alloy	6069	6069	6069	6061	6069
F_{ty} (ksi)	55.3	56.3	55.4	49.9	56
Test Temp. (F)	185	185	68	68	68
Strain at Notch (m in./in.)	3760	2830	4460	3170	2820
Duration	Ninety days without indication of crack growth as indicated by no change in strain and by metallographic examination.				

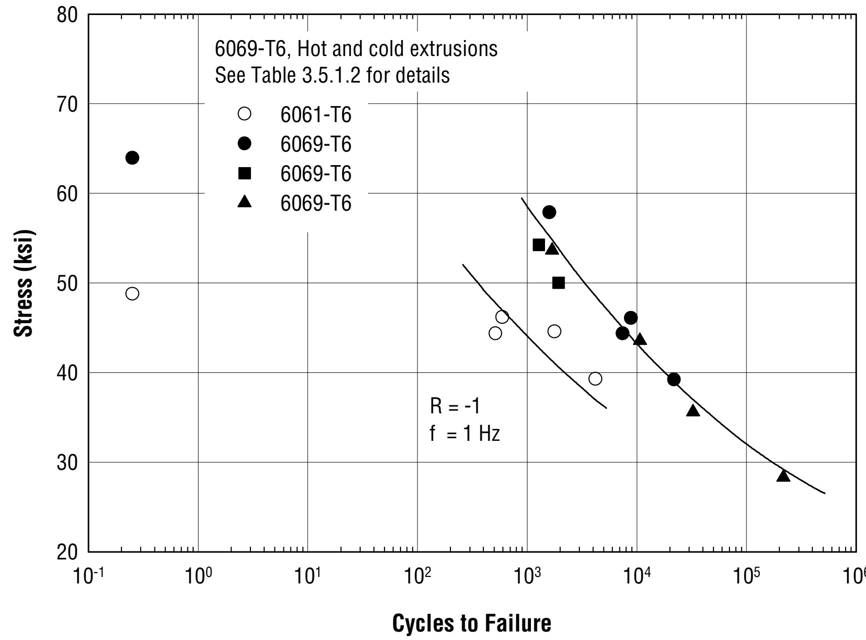

Figure 3.5.1.1 Constant stress fatigue life for 6069 hot and cold extrusions and 6061 hot extrusions (Ref. 3)

Table 3.5.1.2 Extrusion Processing and Heat Treatment Provided to Forms in Fatigue Study (Ref. 2)

Alloy	6061	6069		
Processing	3.5 in. dia. Ingot hot extruded to 1.125 in. solid round	3.5 in. dia. Ingot hot extruded to 3 in. wid. x 0.5 in. thick bar	4.3 in. dia ingot + anneal + cold impact extruded to 4.3 in. OD cylinder with 0.2 in. wall	
Specimen Direction	L(a)	L	Cylinder L	Base normal to wall
Data Code for Figure 3.5.1.1	○	●	■	▲
Anneal	None	None	775F, Slow Cool	
S.T. + Age for all Forms	6069: 1050F, 2 hrs., WQ + 340F, 24 hrs. 6061: 990F, 2 hrs., WQ + 350F, 8 hrs.			

(a) Longitudinal = in the extruded direction

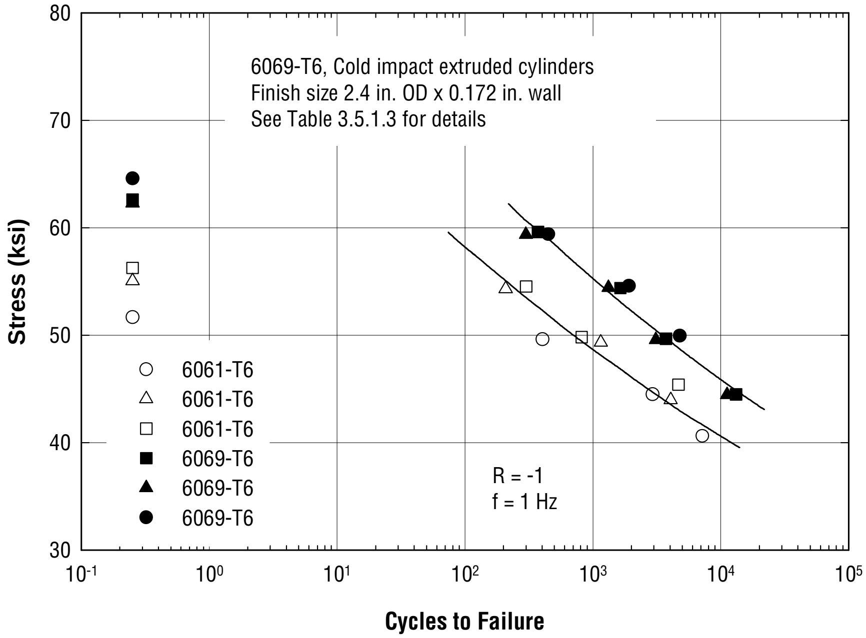

Figure 3.5.1.3 Constant stress fatigue life for hot and cold impact extruded 6069 and cold impact extruded 6061 shapes (Ref. 2)

Table 3.5.1.4 Extrusion processing and heat treatment provided to cylinders used in fatigue study (Ref. 2)

Alloys	6069			6061		
Data Code for Figure 3.5.1.3	●	■	▲	□	△	○
Processing	8 in. dia. Ingot hot extruded to 2.4 in. bar + anneal + cold extruded to finished shape		Cast to 2.4 in. dia. Bar + anneal + cold extruded to finished shape			2.4 in. bar stock + anneal + cold extruded to finished shape
Anneal	775F, Slow Cool					
Solution Treat + Age	6069: 1050F, 1.5 hrs., WQ + 340F, 16 hrs. 6061: 1000F, 1 hr., WQ + 350F, 8 hrs.					
Specimen Direction	Longitudinal (in extrusion direction) for all specimens					