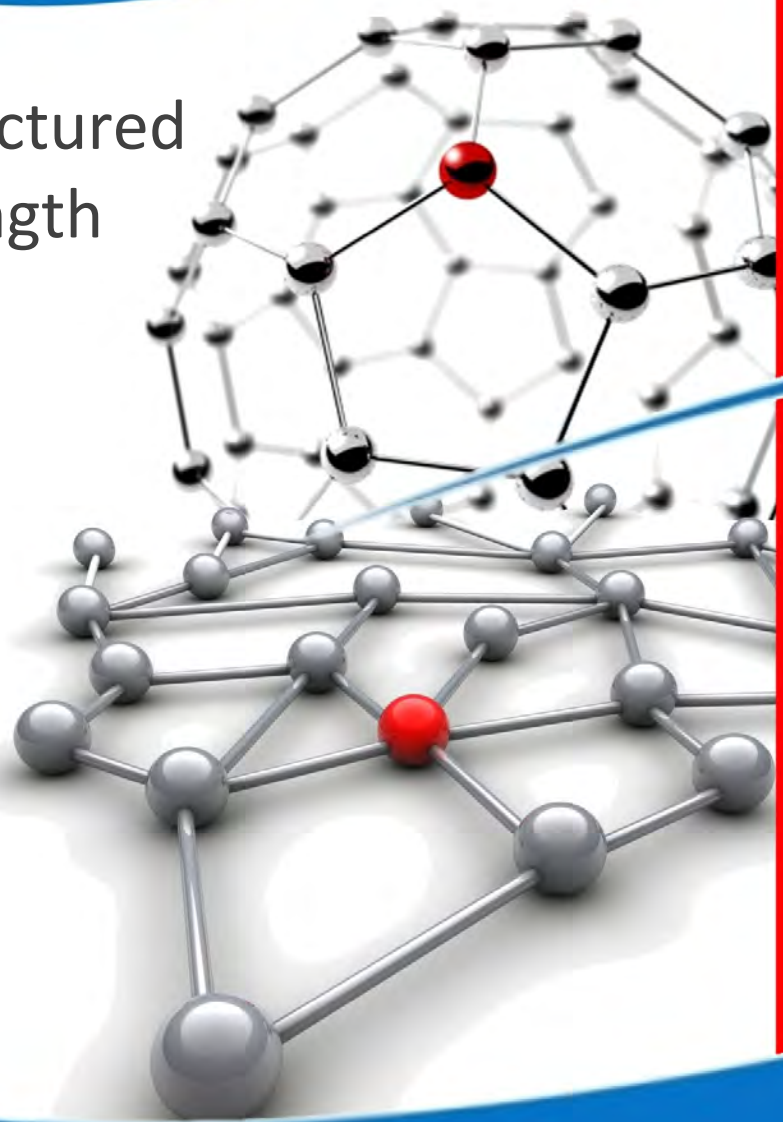
ADAMCO®

Nano-Structured High-Strength Aluminum Alloys



ALMALLOY ®

2223 Watts Street
Houston, TX 77030
1-713-701-5501
www.ADAMCO.us

rev. 2013-001

Innovative, Customer-Focused Solutions

ADAMCO INC. creates value through customer-focused innovation. We develop, manufacture, and distribute advanced, nano-structured aluminum alloys. Our unique technological solutions and know-how in making lightweight / high-strength aluminum place us in a top position of industrial nanotechnology applications. Our entrepreneurial business approach focuses on delivering leading edge solutions to our customers.
We strive to maximize sustainable value for our customers by sharing knowledge and best practices. This is our commitment to you.

Dr. Forrest "Jack" Agee, CEO of Adamco Inc., Houston, TX

US Army, Lt. Col. Ret.
Life Fellow of the IEEE
American Physical Society
American Chemical Society
American Society of Naval Engineers
Subcommittee Chair of the AIAA

ADAMCO Group
Solutions in Materials & Energy

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ALMALLOY®

A New Dimension of Strength

High Strength Aluminum Alloys

- ✓ **Strongest aluminum alloy commercially available**
- ✓ **Specific strength - superior to steel and titanium**
- ✓ **Superior thermal stability**
- ✓ **Customizable material properties**
- ✓ **Cost competitiveness**

ADAMCO's ALMALLOY offers:

All the advantages of standard aluminum, like light weight, corrosion resistance, formability,

PLUS:

- **Super Strength**
- **Super Temperature Stability**

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General Almalloy® Properties

ALMALLOY®
offers the following advantages compared to more conventional aluminum solutions:

Safety
Almalloy® is non-toxic, hygienic, physiologically harmless, and classified as a standard aluminum alloy. It has a nano structure, which contains a maximum of 2% of firmly embedded non-metallic particles and does not release any environmental-, health- or safety-related contaminants when used or machined.

Strength
Almalloy® can compete with much heavier steel and titanium solutions in strength. It is also less expensive and can be machined much more easily.

Weight
Almalloy®'s extraordinary mechanical strength allows for thinner-walled part designs resulting in extremely light weight components. Special modifications with lower specific weight enable substantial weight reduction of a given component even without any design change.

Ductility
Almalloy®'s super-fine nano- and microstructure provide for excellent formability and machining properties in relation to its top strength level.

Stiffness
Almalloy® has a higher relative modulus when compared to steel in combination with extraordinary thermal stability, which makes it extremely suitable for turbine and engine parts.

CTE
Almalloy®'s tunable thermal expansion coefficient makes it ideal for CTE-compensated mechanical designs for instance for lasers, housings of sensitive electronic equipment or car engine parts like con-rods, pistons, or cylinder head screws.

Hardness
Almalloy®'s customizable hardness helps minimizing wear and tear, for instance, of hydraulic components, high power engine pistons or oil & gas drilling equipment.

Thermal Stability
Almalloy®'s excellent thermal stability makes it ideal for applications at elevated temperatures like car engine parts, turbo charger components, turbine blades and nuclear power plant components.

Wear Resistance
Almalloy®'s super-high wear resistance in many cases eliminates the need for surface treatments such as hard anodizing.

Microstructure
Almalloy®'s extreme surface smoothness provides for the possibility to use it even as optical mirror material and as material in high surface quality molds.

Conductivity
Almalloy®'s customizable thermal and electrical conductivity in connection with its extreme strength makes it ideal for use in heat sinks and electrical power applications even under high mechanical stress.

Coatability
Almalloy®'s surface is protected against decomposition due to oxygen, water or chemicals by a thin, natural oxide layer.
The thickness of the protective natural oxide layer can be increased by standard electrochemical anodizing processes forming artificial, functional or decorative surfaces.

Recyclability
Almalloy® is extremely well-suited to re-melting, which requires only about 5 % of the energy initially required to produce primary aluminum. This safeguards and supplements the supply of raw materials while saving resources, protecting the environment, and conserving energy.

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How We Make Almalloy®

Rapid solidification is a method for optimizing the microstructure of aluminum alloys to achieve its maximum strength. We use melt spinning as a special form of rapid solidification in order to create nano-crystalline microstructures, which are particularly advantageous for those alloys with extreme strength in combination with excellent high temperature stability. In melt spinning, a jet of molten aluminum flows onto the moving surface of a cold, fast-spinning copper wheel. When the liquid aluminum hits the copper surface, it solidifies almost immediately and forms a solid, continuous ribbon, which is spun off from the wheel at high speed. Extremely fast cooling rates and almost instantaneous solidification during melt spinning are a result of our proprietary and highly effective heat transfer mechanism at the interface between the ribbon and the spinning wheel. We operate the system at cooling rates in excess of 10^6 Kelvin/second, virtually freezing-in the complex, but homogeneous crystalline structure of the properly alloyed liquid aluminum.

In order to create the optimum crystalline structure in the proprietary alloying cocktail of the melt, we use a high precision control mechanism for adjusting the melt temperature. By doing this we take full advantage of the different melting temperatures and solubilities of the alloying elements and their various lattice formation properties at different temperatures and in different alloy compositions. In this way, we can tune the melt to an optimum eutectic and intermetallic state for a particular desired material property of the solidified product before releasing the melt onto the wheel. We use proprietary compositions of standard alloying elements (Si, Mg, Cu, etc.), rare earth elements (Sc, Y, Nd, etc.) and, in special cases, also non-metallic ingredients for tuning the material properties. Due to the rapid solidification process, the crystalline structure in the resulting solidified ribbon is extremely fine and homogeneous. The well-defined intermetallic compounds, as well as the components with low (or in some cases even none) solubility are dispersed evenly in the metal matrix, forming an extremely homogeneous microstructural network which is essentially defining the improved properties of our alloys.

After the melt spinning process, the resulting solid ribbon is guided into a chopping station which converts it to aluminum granules with well-defined grain size distribution. The granules are then basically ready for consolidation in standard industrial hot isostatic pressing (HIP) systems. However, for further fine-tuning the material properties, we use proprietary canning, degassing and heat treatment procedures, prior to the actual hipping process, all of which are particularly optimized for our alloy compositions. The consolidated billets or blocks obtained from the hipping process have a density >99% and can directly be used in standard industrial extrusion-, rolling- or forging systems. However, because of the increased strength level, processing temperatures and speeds as well as forming parameters are different from those of standard aluminum and must match the processing specifications indicated in the respective data sheets of our alloys.

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Almalloy® in the Laboratory and R&D

Only reliable alloying and mixing processes provide for uniformity within a nanostructured and precipitation strengthened aluminum batch and replicate that same level of homogeneity also in succeeding runs. Absolute batch-to-batch reproducibility is essential for product quality. Density, hardness, strength, ductility, modulus, CTE, conductivity – these properties are all intimately influenced by the alloying and mixing processes. Any inconsistencies in the alloying and mixing operations as well as in the rapid solidification process used to form the finished, consolidated product would inevitably result in unacceptable material properties variations.

ADAMCO's automated installations allow for monitoring and controlling crucial parameters during the manufacturing process to ensure consistent product composition and mechanical quality as well as reliable batch-to-batch reproducibility. A tensile proof test is performed on every lot to increase product reliability.

In order to manufacture stable, uniform and effective products, it is essential to not only precisely know the properties and exact contents of all ingredients alone but also in combination with all other ingredients based on the specifications of the desired final alloy. Therefore ADAMCO maintains a sophisticated quality system to ensure:

- reliable sourcing of all ingredients
- in-house purification of alloying ingredients
- in-house production of standardized master alloys

Technologies for purification of molten ingredients and of the final alloy include filters, degassers and launder systems. In the final alloy, aluminum is the solvent and other ingredients are the solutes. In order to fine-tune the properties of the final product we control the following parameters and processes:

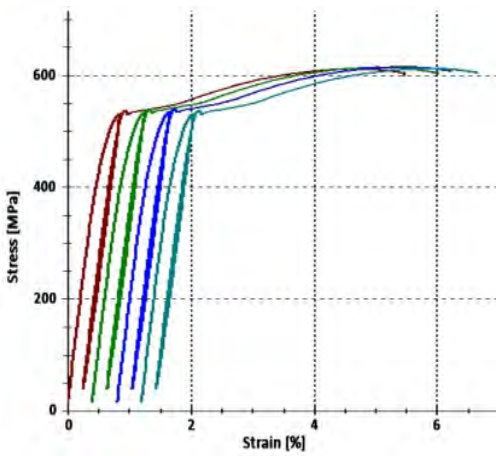
- kinetics of nucleation,
- growth and agglomeration of precipitates
- formation and distribution of metastable zones
- formation of eutectic states

The controlled formation of Intermetallics is an effective means of tuning the material properties. ADAMCO's proprietary know how comprises the well-defined addition of trace elements (this includes rare earth elements) in order to precisely control the formation of intermetallics in the melt.

Eutectic rapid solidification requires exact temperature control. Since the alloys formed in the above described processes are rather complex, proprietary multi-component phase diagrams have to be used for setting and controlling the respective melt temperatures correctly in order to create a defined effect in the melt and in the solidification process.

R&D

In an internal R&D program ADAMCO investigates possibilities for controlled crystallization of intermetallics by circulating the melt through an external cooler in order to trigger the selective formation of intermetallic precipitates.



The above picture demonstrates the excellent tensile strength reproducibility of ALMALLOY® test specimens.

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ALMALLOY® - *MS* High Strength Motor Sport Aluminum Alloys

ALMALLOY®-MS is a set of aluminum alloys optimized for motor sport applications. Almalloy® MS alloys provide the highest mechanical strength of all currently available aluminum alloys matching that of many steel- and titanium alloys. Almalloy® MS alloys combine a tensile strength of up to 840 MPa (up to over **50% better than AA7075**) and good ductility with corrosion resistance similar to AA7075. Almalloy® MS alloys are ideally suited for high performance engine component design.

Almalloy® MS alloys were originally developed in Europe for highest strength aerospace and military applications where high temperature stability is a must. Almalloy® MS alloys were recently adopted by leading German car makers for mechanical strength / temperature critical components (like pistons, connecting rods, valve parts, cylinder head screws, etc.) in leading edge high-power car engines.

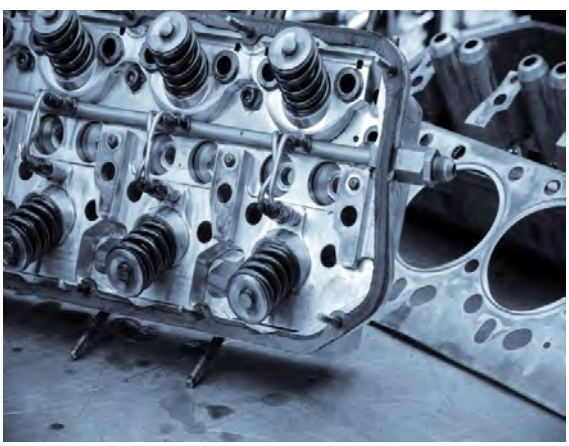
Why using softer grades?

Almalloy® MS - 900	High strength alloy. **No heat treatment.** Excellent thermal stability. Excellent formability.
Almalloy® MS - 708	Super strength alloy at T6 temper. Excellent formability.
Almalloy® MS - 707	Strongest aluminum alloy available at T6 temper. Sufficient formability for forging.

ALUMINUM ALLOY COMPARISON								
	2618 T6	2014 T6511	7075 T6511	7150 T6511	7068 T6511	**ALM-900 none**	**ALM-708 T6**	**ALM-707 T6**
UTS (MPa)	420	480	559	615	683	**710**	**760**	**840**
YTS (MPa)	340	440	496	580	655	**680**	**730**	**810**
UTS (ksi)	61	70	81	89	99	**103**	**110**	**122**
YTS (ksi)	49	64	72	84	95	**99**	**106**	**117**
Elongation (%)	7	7	7	8	5	**10**	**9**	**3**

Typical motor sports applications:

- Connecting rods
- Rocker arms
- Bearing caps
- Valve guides
- Valve spring retainers
- Cylinder head screws
- Gearbox actuators
- Shock absorbers
- Fuel pumps
- Wheel components



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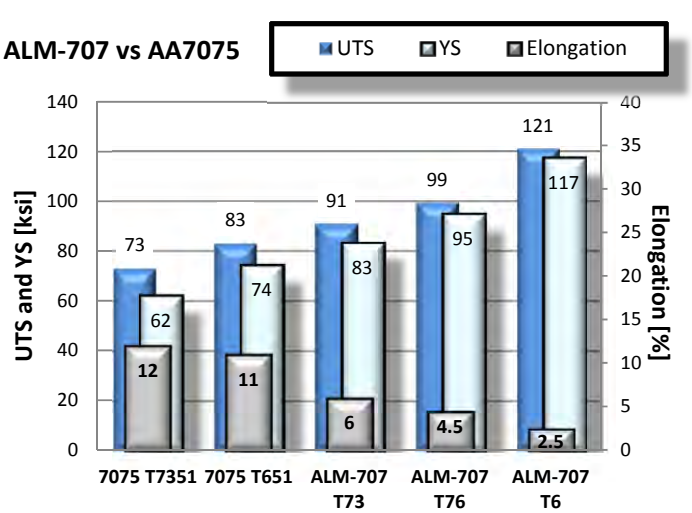
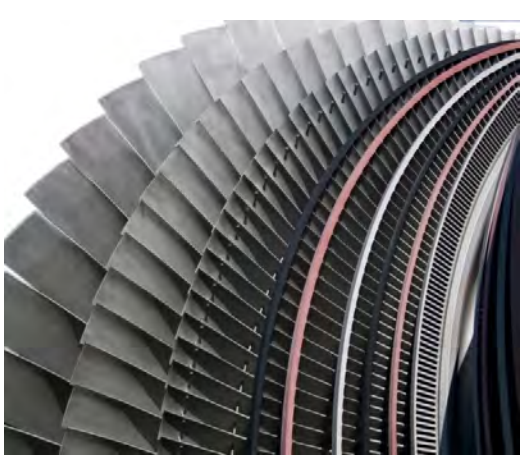
Super High Strength Aluminum: ALMALLOY®-707

ALMALLOY®-707 is a high performance Aluminum alloy, manufactured by powder metallurgical techniques. It shows extreme strength levels in combination with an increased stiffness. The alloy has excellent microstructure stability. Compared to conventional 7xxx alloys, ALM-707 offers superior strength levels in the T76 and T73 temper.

Chemical Composition (nominal)						
Element		Al	Zn	Mg	Cu	others
Content	[weight %]	bal	9.5	3.0	1.5	2.35
Physical Properties (typical values)						
Density	[g/cm^3] ¦ [lb/in^3]	2.91	0.1051			
Hardness	[HV30]		T6: 230±10	T76: 200±10	T73:180±10	
Mechanical Properties (typical values)						
Property		**Unit**				
Heat Treatment			T6	T76	T73	
UTS	R_m	MPa	835	685	625	
UTS	R_m	ksi	121	99	91	
Yield Strength	$R_{p0.2}$	MPa	810	685	625	
Yield Strength	$R_{p0.2}$	ksi	117	99	91	
Elongation	A_5	%	2.5±0.5	4.5±0.5	6.5 ± 0.5	
Young's Modulus	E	GPa	81	80	81	
Young's Modulus	E	10^3 ksi	12	12	12	
Remarks: All data were obtained from extruded rods with 15 mm diameter. Samples from rods or bars with different dimensions may show slightly different mechanical properties.						

ALM-707 vs AA7075





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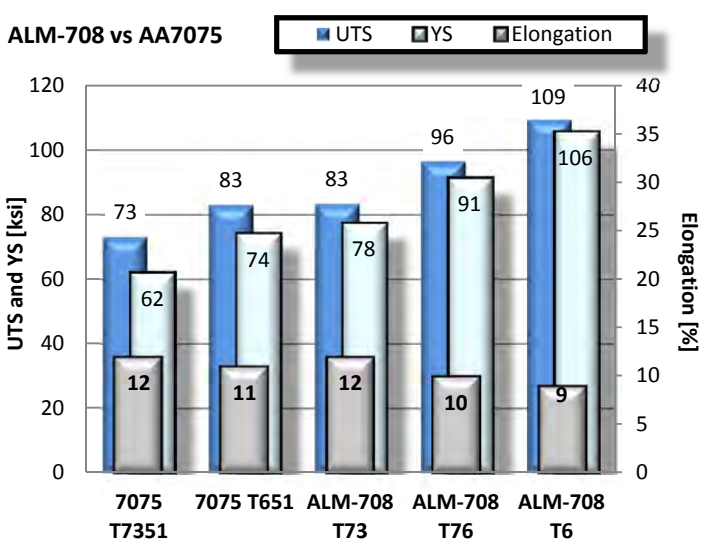
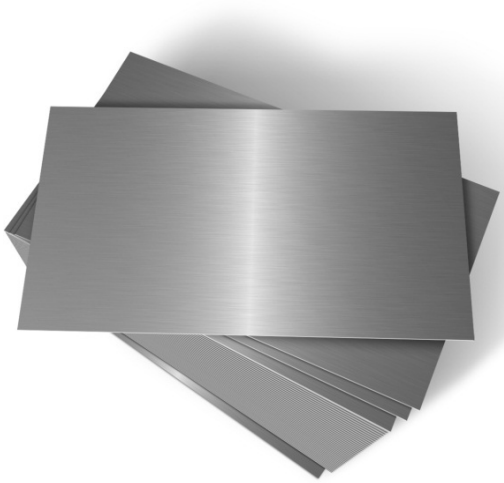
High Strength, Fracture Toughness, and High Ductility: ALMALLOY®-708

ALMALLOY®-708 is a high performance aluminum alloy manufactured by powder metallurgical processing. It shows high strength in combination with a very good elongation and fracture toughness. ALM-708 is a superior replacement for conventional 7xxx alloys such as AA7075 or AA7050. Forging and/or machining can be done using standard equipment. Standard coating or anodizing technologies can be used for surface finishing.

Chemical Composition (nominal)						
Element		Al	Zn	Mg	Cu	others
Content	[weight %]	bal	11.0	2.0	1.1	0.45
Physical Properties (typical values)						
Density	[g/cm^3] ¦ [lb/in^3]	2.91	0.1051			
Hardness	[HV30]		T6: 210±10		T73: 170±10	
Electrical Conductivity	[% IACS]		28.6		37.2	
Mechanical Properties (typical values)						
Property		**Unit**				
Heat Treatment			**T6**	**T76**	**T73**	
UTS	R_m	MPa	755		575	
UTS	R_m	ksi	110		83	
Yield Strength	$R_{p0.2}$	MPa	730		535	
Yield Strength	$R_{p0.2}$	ksi	106		78	
Elongation	A_5	%	9±0.5		13±0.5	
Young's Modulus	E	GPa	86			
Young's Modulus	E	10^3 ksi	13			
Fracture Toughness		MPa*m$^{0.5}$	14.5			
Remarks: All data were obtained from extruded rods with 15 mm diameter. Samples from rods or bars with different dimensions may show slightly different mechanical properties.						





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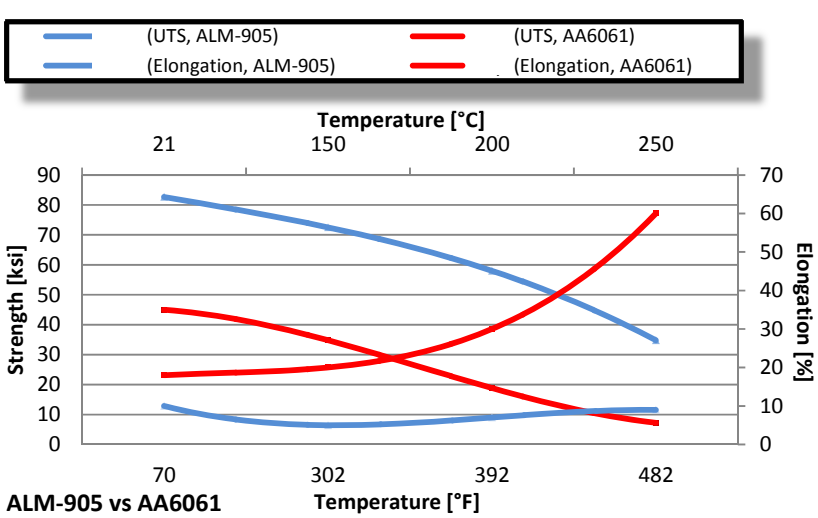
Excellent Heat Resistance and Fatigue Properties: ALMALLOY®-905

ALMALLOY®-905 is a heat resistant, high performance aluminum alloy, which is manufactured by powder metallurgy. In terms of strength, fatigue, and Young's Modulus the alloy is a superior replacement for the conventional alloy AA2618 over the entire temperature range up to 350 °C. ALM-905 does not need any heat treatment. The alloy shows extremely high microstructure stability. Conventional equipment can be used for machining and standard cutting parameters can be used. Standard coating or anodizing technologies can be used for surface finishing.

Chemical Composition (nominal)					
Element	Al	Ni	Fe		others
Content, nominal [weight %]	bal	5.0	2.5		6.7
Content, minimum [weight %]	bal	5.2	2.7		7.2
Content, maximum [weight %]	bal	4.7	2.2		6.2
Physical Properties (typical values)					
Density [g/cm^3] ¦ [lb/in^3]	2.96	0.1069			
Hardness [HV30]	>170				
Thermal Expansion [10^{-6} /K]	20				
Mechanical Properties (typical values)					
Property	**Unit**				
Test Temperature	°C	21	150	200	250
Test Temperature	°F	70	302	392	482
UTS R_m	MPa	570	500	400	240
UTS R_m	ksi	83	73	58	35
Yield Strength $R_{p0.2}$	MPa	480	460	360	225
Yield Strength $R_{p0.2}$	ksi	70	67	52	33
Fatigue Strength R=-1	MPa	213	200		190
Fatigue Strength R=-1	ksi	31	29		28
Fatigue Strength R=-0	MPa	166	164		156
Fatigue Strength R=-0	ksi	24	24		23
Fatigue Strength R=-2.3	MPa	253			205
Fatigue Strength R=-2.3	ksi	37			30
Remarks: All data were obtained from extruded rods with 15 mm diameter. Samples from rods or bars with different dimensions may show slightly different mechanical properties. All test specimens have been annealed at test temperature for 200 hours.					



ALM-905 vs AA6061

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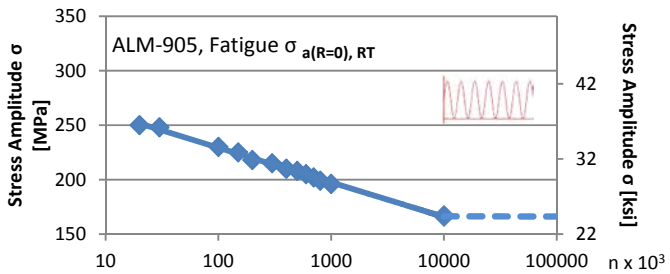
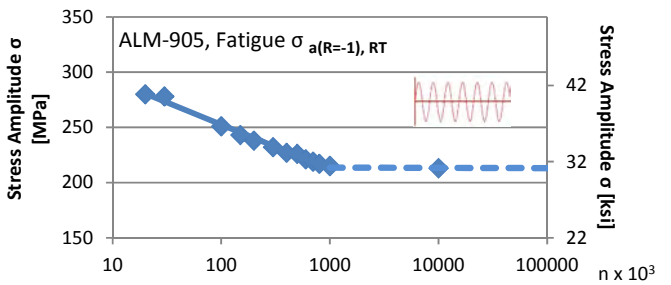
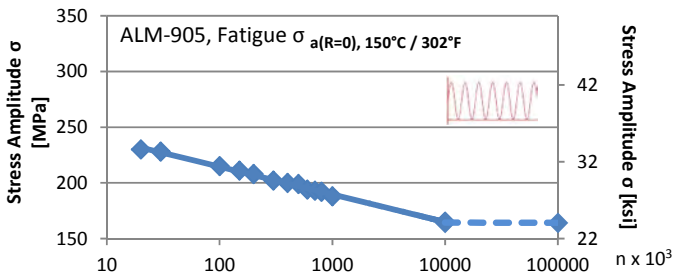
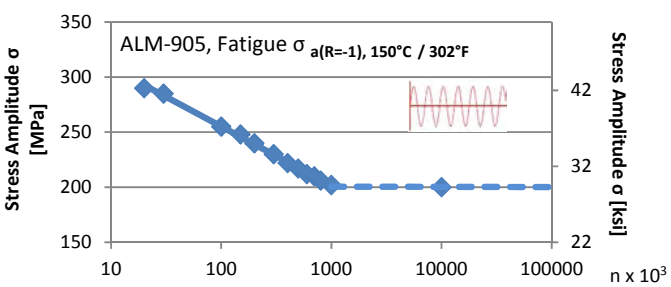
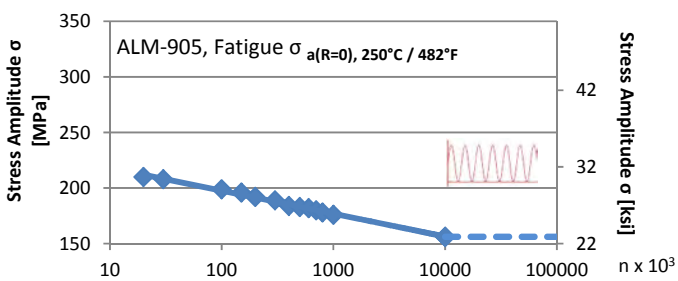
ALMALLOY®-905 Fatigue Properties

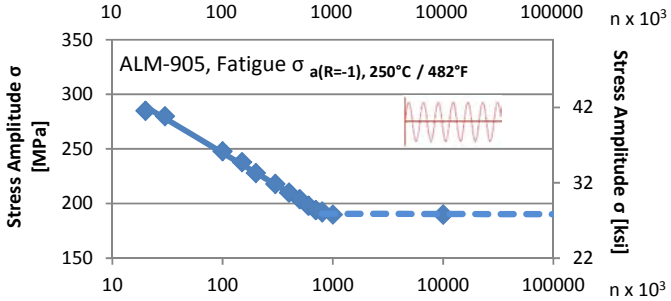


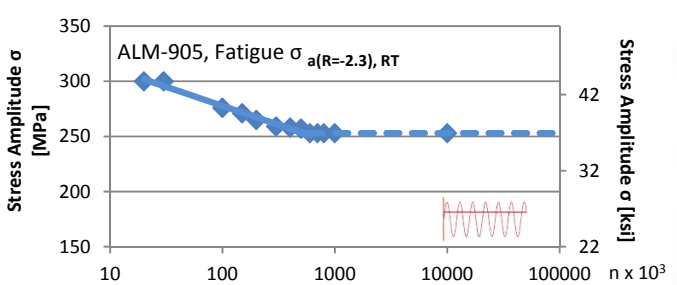


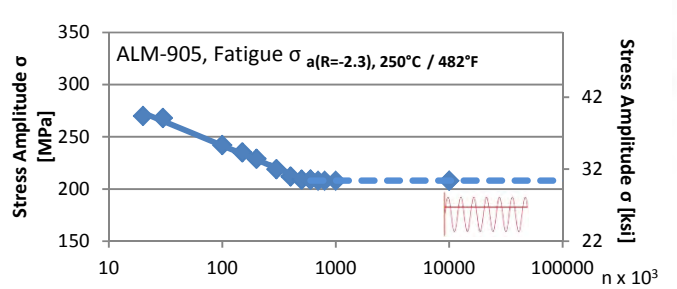


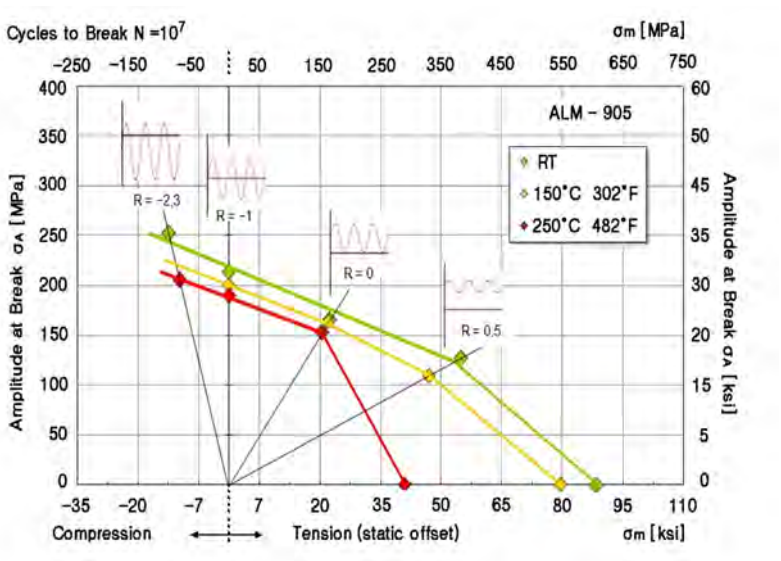












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ALMALLOY® - 4xx Low CTE Aluminum Alloys / Application Examples

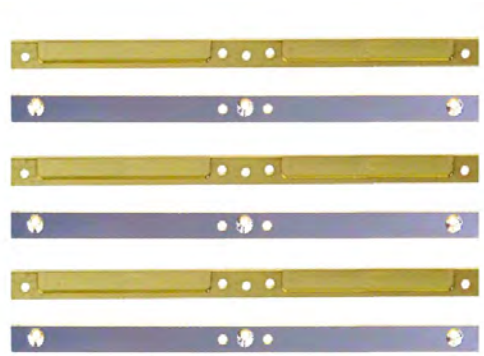
RF and microwave products

ADAMCO Low CTE Alloys have a typical CTE of 8 to 18 ppm/°K and are three to six times lighter than conventional packaging and baseplate materials used in RF and microwave products like Kovar®, copper-molybdenum, and copper-tungsten. ADAMCO CE Alloys have a much better thermal conductivity compared to Kovar® making them ideal for high electrical power applications. At the same time ADAMCO Low CTE Alloys can be easily machined, plated, and coated.

The combination of low CTE, high thermal conductivity, low density, and dimensional stability makes ADAMCO Low CTE ALLOYS ideal for microwave packaging in space and aerospace applications at high frequencies.

PCB guide-bars

ADAMCO Low CTE Alloys are also used for PCB guide-bars in aircraft and in other electronic applications where the material is exposed to temperature variations and mechanical load. On one side of the guide-bars particular areas are gold plated providing an optimum fit to the corresponding copper-clad areas on the PCBs where they are soldered to. The other side of the guide-bars is hard nickel plated for good wear resistance when the boards are slid into racks and fastened down.



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AlSi Low CTE Alloys: ALMALLOY®-4xx

ALMALLOY®-4xx Low CTE alloys are light-weight, non-toxic, nano-structured silicon-aluminum alloys which are designed for use in the electronics and optics industries. Their coefficient of thermal expansion (CTE) can be tuned to any value between 8 and 18 ppm/°C.

Almalloy® Low CTE alloys can be precisely machined and plated (Ni, Au, Ag, etc.) using standard processes. ADAMCO Low CTE alloys have a high thermal conductivity, excellent dimensional stability, extreme stiffness and good bending strength. ADAMCO Low CTE alloys are available as plates and blocks, or machined and plated to customer specification, ready for system integration.

Remarks:
(1): properties of extruded material
(2): properties of material after HIP

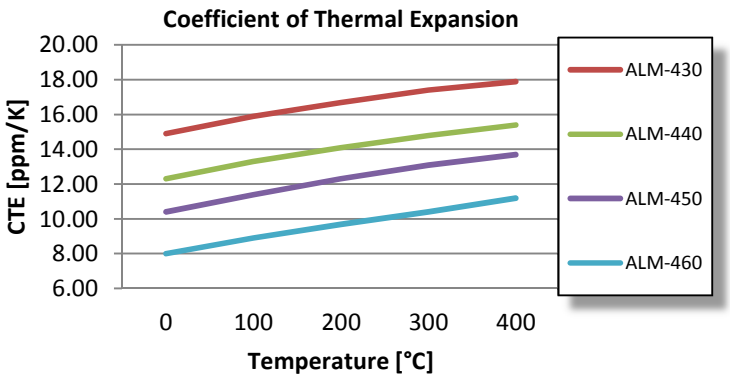
Alloy designation		**ALM-430** (1)	**ALM-440** (1)	**ALM-450** (2)	**ALM-460** (2)
Si content:	%	30 ± 1.5	40 ± 2	50 ± 2.5	60 ± 3
Density:	g/cm^3	2.59	2.55	2.5	2.46
Hardness:	HV30	82	100	140	182
Tensile Strength:	MPa	270	230	170	164
	ksi	39.16	33.36	24.66	23.78
Yield Strength (0.1%):	MPa	110	120	152	157
	ksi	15.95	17.40	22.04	22.77
Young's Modulus:	GPa	93	98	109	117.4
	10^3 ksi	13.49	14.21	15.81	17.02
Shear Modulus:	GPa	35.9	37.9	42.3	45.9
	10^3 ksi	5.21	5.50	6.13	6.66
Poisson's Ratio:		0.295	0.292	0.289	0.278

Elastic Properties							
Alloy designation		**ALM-450**			**ALM-460**		
Test temperature: °C		25	100	150	25	100	150
Young's Modulus:	GPa	109	107.1	105.2	117.4	115.3	113.2
	10^3 ksi	15.81	15.53	15.25	17.02	16.72	16.41
Shear Modulus:	GPa	42.3	41.5	40.7	45.9	45.4	44.2
	10^3 ksi	6.13	6.02	5.90	6.66	6.58	6.41
Poisson's Ratio:		0.289	0.291	0.292	0.278	0.27	0.28

Coefficient of Thermal Expansion (ppm/K)				
Alloy designation	**ALM-430**	**ALM-440**	**ALM-450**	**ALM-460**
Temperature range: °C				
25 - 100	15.9	13.3	11.4	9
25 - 200	16.8	14.1	12.4	10
25 - 300	17.4	14.8	13.2	10.7
25 - 400	17.9	15.4	13.9	11

Typical applications:

- Matching CTE of ceramic circuit boards
- RF/microwave components
- Heat sinks (spreaders)
- Optical and opto-electronic housings
- Lens holders
- Laser components
- Carrier plates for laminate PCBs
- Guide bars for circuit boards



NEW! ALM-470: CTE < 7 ppm/K

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ALM-450 LOW CTE AlSi ALLOY

ALMALLOY®-450 is a pure binary, high performance, low CTE aluminum alloy especially designed for applications where complex machinability, plating, lightweight, high thermal conductivity, and hermeticity are required. The alloy is manufactured from the melt by rapid solidification via melt spinning. Since the mechanical properties are generated by dispersion strengthening there is no need for any heat treatment. Due to the high content of silicon and the very homogeneous distribution of small silicon primary particles, the alloy shows excellent wear resistance. Furthermore, the silicon provides for low thermal expansion (CTE) of the alloy. The alloy shows extreme stability in microstructure and geometry. Typical applications range from housings for RF and microwave receivers, amplifiers, converters over MMC- and MMIC- packagings to optical and laser components. Standard equipment can be used for machining with standard machining parameters for high strength aluminum alloys.

Chemical Composition (nominal)						
Element		Al	Si			
Content	[weight %]	50.0	50.0			
Physical Properties (typical values)						
		Unit				
Density		g/cm3	2.50			
Electrical Conductivity		%IACS	21.0			
Hardness		HV30	140			
CTE (25°C)		ppm/K	11.4			
Thermal Conductivity		W/m*K	148			
Mechanical Properties (typical values)						
Property		**Unit**				
Machinability (please call for machining guidelines (PDF))			good			
Plating (optional, additional corrosion protection)			Zn			
Brazing (interface: >1µm pure hard gold (Au99/Co1) on >15µm Ni)			good			
Hermeticity (RGA tested at hermetically sealed housings)						
Isothermal storage (residual gas analysis (RGA))		175°C / one week	passed*			
Thermal shocks (200)		-55°C / +125°C	passed*			
Vibrations and mechanical shocks		MIL Std 88, 2002	ongoing			
Temperature		°C / °F	21 / 70			
UTS	R_m	MPa	170			
UTS	R_m	ksi	24.66			
Yield Strength	$R_{p0.2}$	MPa	152			
Yield Strength	$R_{p0.2}$	ksi	22.04			
Elongation	A_5	%	1.3 ±0.3			
Young's Modulus	E	GPa	109			
Young's Modulus	E	10^3 ksi	15.81			

Remarks: All data were obtained from hipped samples (hot isostatic pressing). The samples showed 100% density and no porosity after hipping.

*hermetic with 99.9% N2, trace levels of H2 were detected.

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Rev 2013-12-26

ADAMCO® Light Metal Alloys (ALMALLOY®) – Available Geometries

ADAMCO's **A**dvanced **L**ight **M**etal alloys (ALM-XXX) are available in standard dimensions shown in the below table. In addition, near net shape forgings can be produced and other sizes can be custom-made in any other shape.

Available Geometries									
(different for mm and inches)	**ALM-426**	**ALM-432**	**ALM-450**	**ALM-460**	**ALM-470**	**ALM-707**	**ALM-708**	**ALM-905**	**Remarks**
Round Bars, Extruded									
dia 20 mm / 0.75"	X	X	X	X	X	X	X	X	
dia 30 mm / 1"	X	X	X	X	X	X	X	X	
dia 50 mm / 2"	X	X	X	X	X	X	X	X	tbd: to be developed
dia 65 mm / 2.5"	X	X	X	X	X	X	X	X	
dia 75 mm / 3"	X	X	X	X	X	X	X	X	
dia 85 mm / 3.5"	X	X	X	X	tbd	X	X	tbd	
dia 100 mm / 4"	X	X	X	X	tbd	X	X	tbd	
Flat Bars, Extruded									The possible combinations of width and thickness depend on extrusion ratio and press configuration as well as on the extrusion mode. Please ask for offer.
min / max width: 20 / 460 mm 0.75" / 11"	X	X	X	X	tbd	X	X	X	
min / max thickn.: 10 / 60 mm 0.4" / 2.5"	X	X	X	X	tbd	X	X	X	
Blocks for Rolling									The maximum size is limited by the size of the degassing furnace. Larger sizes are possible for high volumes.
max length: 900 mm / 35"	X	X				X	X		
max width: 650 mm / 25"	X	X				X	X		
max thickness: 350 mm / 14"	X	X				X	X		
Blocks for 3D-Forging									The maximum size is limited by the size of the degassing furnace. Larger sizes are possible for high volumes.
max dia: 350 mm / 14"	X	X				X	X	X	
max length: 900 mm / 35"	X	X				X	X	X	
Flat Sheets, Rolled									The maximum size is limited by the size of the rolling mill. Larger sizes are possible for high volumes.
max width: 500 mm / 20"	X	X				X	X		
max length: 500 mm / 20"	X	X				X	X		
min thickness: .9mm / .035	X	X				X	X		

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Our products are exclusively available from our main service center in Houston and from authorized, independent metal service centers across North America.

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to see how we can help your business.