T-1 ALUMINUM APPLICATIONS FOR BOATS AND YACHTS

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T-1 ALUMINUM APPLICATIONS FOR BOATS AND YACHTS

This technical information report provides information on the use of aluminum for constructing outboard boats using riveted construction, outboard boats using welded construction, and inboard powered boats and yachts using welded construction. The report recognizes that every design and construction problem cannot be covered or foreseen. Qualified naval architects and/or marine engineers and aluminum production technical staff should be consulted before building a boat or yacht with inboard power.

REFERENCED ORGANIZATIONS

ABYC - American Boat & Yacht Council, Inc., 3069 Solomons Island Road, Edgewater, MD 21037 Phone: (410) 956-1050. Fax: (410) 956-2737. Web site: www.abycinc.org.

Aluminum Association, 900 - 19th Street NW (#300), Washington, DC 20006-2168. Phone: (202) 862-5100. Fax: (202) 862-5164. Web site: www.aluminum.org. This association publishes the following materials:

1. Aluminum Standards and Data
2. Specifications for Aluminum Structures
3. Engineering Data for Aluminum Structures

NFPA - National Fire Protection Association, One Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101. Phone: (617) 770-3000. Fax: (617) 770-0700. Web site: www.nfpa.org.

USCG - United States Coast Guard, CFR - Obtain the Code of Federal Regulations and other government publications from the Superintendent of Documents, United States Government Information, POB 371954, Pittsburgh, PA 15250-7954. Phone: (202) 512-1800. Fax: (202) 512-2250. An excerpted edition of the CFR is available from ABYC, Inc., 3069 Solomons Island Road, Edgewater, MD 21037. Phone: (410) 956-1050. Fax: (410) 956-2737. Web site: www.abycinc.org

REQUIREMENTS - MATERIALS

The aluminum alloys listed in TABLE 1 are shown with numeric designations. These aluminum alloys are selected for their resistance to salt water corrosion, and are the only aluminum alloys recommended for building boats and yachts.

TABLE 1 – Aluminum Alloys Recommended for Building Boats and Yachts

	OUTBOARD BOATS	OUTBOARD BOATS	INBOARD BOATS
	Riveted	Welded	Welded
COMPONENTS			
1. Hull			5086-H116, H117
2. Hull stretch formed	6061-T4	• 5086-0 • 6061-T4	
3. Hull non-stretch formed	• 5050-H34, H36 • 5052-H32 to H36 • 5086-H116, H117 • 6061-T4, T6	• 5052-H32, H34 • 5086-H116, H117 • 6061-T6	
4. Transom		same as hull	same as hull
5. Transom-flat	• 5050-H36 • 5052-H32 to H36 • 5086-H116, H117 • 6061-T6		
6. Decking	• 3003, 3004 (temper depending on application) • 5005-H154 • 5050-H36 • 5052-H36 • 5086-H116, H117 • 6061-T4, T6	same as hull	same as hull

TABLE 1 – Aluminum Alloys Recommended for Building Boats and Yachts (cont.)

	OUTBOARD BOATS	OUTBOARD BOATS	INBOARD BOATS
	Riveted	Welded	Welded
7. Gunwale/extruded	• 6061-T4, T6 • 6063-T5, T6	• 6061-T4, T6 • 6063-T5, T6	
8. Gunwale/formed sheet	• 5050-H36 • 5052-H32, H34 • 5154-H34	• 5050-H34 • 5052-H32, H34 • 5086-H116, H117 • 6061-T4	
9. Keel			same as hull
10. Keel/extruded	• 6061-T4, T6 • 6062-T4, T6	• 6061-T4 • 6063-T6	
11. Keel/formed sheet	• 5082-H34 • 5086-H116, H117 • 5154-H34	• 5052-H34 • 5086-H116, H117	
12. Frames	same as keel	same as keel	• 5086-H116, H117 • 6061-T6
13. Longitudinals			same as hull
14. Splash rails	same as keel	same as keel	
15. Chine		same as keel	same as hull
16. Stem			same as hull
17. Engine beds			same as hull
18. Bulkheads			same as hull
19. Bulkhead stiffeners			same as hull
20. Struts			• 5086-H116, H117 • 6061-T6
21. Rudders			same as struts
22. Rivets	• With 5050 & 5052 sheet, use 6053-T61, 3003-F. • With 5086 sheet, use 6053-T61. • With 6061 sheet, use 6061-T6, 6053-T61		
23. Fasteners			6061-T6 bolts & nuts See Note 6.
24. Castings/for strength	• 355-T6, or • 356-T6, or • 357, sand & permanent mold	• 355-T6, or • 356-T6, or • 357, sand & permanent mold	• 355-T6, or • 356-T6, or • 357, sand & permanent mold
25. Castings/no particular strength required	• 43-F, or • F214-F, sand and permanent mold • A214-F permanent mold • 13, 43, 218, 360 die	• 43-F, or • F214-F, sand • A214-F, permanent mold • 13, 43, 218, 360 die	• 43-F, or • F214-F, sand • A214-F, permanent mold • 13, 43, 218, 360 die
26. Welding wire		• With 3003 sheet, use 1100, 4043. • With 5052 sheet, use 5356, 5154, 5052. • With 5086 sheet, use 5183, 5356. • With 6061 sheet, use 4043, 5154, 5356 See Note 1.	• With 3003 sheet, use 1100, 4043. • With 5052 sheet, use 5356, 5154, 5052. • With 5086 sheet, use 5183, 5356. • With 6061 sheet, use 4043, 5154, 5356 See Note 1.
27. Fuel tanks			See Note 2.
28. Potable water tanks			• Not recommended. See ABYC H-23.

TABLE 1 – Aluminum Alloys Recommended for Building Boats and Yachts (cont.)

	OUTBOARD BOATS	OUTBOARD BOATS	INBOARD BOATS
	Riveted	Welded	Welded
29. Fuel piping & fittings			• Alclad 3003, 3003- H18 • Alclad 6061-T6 • Alclad 6063, T6 See Note 3.
30. Potable water pipe & fittings			Not recommended. See ABYC H-23
31. Sea water pipe & fittings			same as fuel piping & fittings See Notes 3, 4, and 5.

NOTES: (1) With high silicon casting alloys such as 43, 356, and 357, use 4043 filler wire when welding to thin sheet. The 5000 series filler alloys can be used in welding to wrought alloys in heavy sheet or plate gauges. With 214 cast alloy, 5000 series fillers such as 5254, 5356, and 5183 are preferred to 4043.

(2) For gasoline fuel tanks, refer to the USCG Title 33 CFR Section 183.510, and ABYC H-24, Gasoline Fuel Systems. For diesel fuel tanks, refer to ABYC H-33, Diesel Fuel Systems. The National Fire Protection Association (NFPA) 302, Motorcraft, also contains requirements for both gasoline and diesel fuel tanks.

(3) If suitable aluminum alloy or stainless steel valves are not obtainable, use non-ferrous tubing and connect to aluminum tank by insulated flange or stainless steel nipple. For fuel systems, see ABYC H-24, Gasoline Fuel Systems. For thru-hull fittings see ABYC H-27, Seacocks, Thru-hull Fittings, and Drain Plugs.

(4) Stainless steel or plastic is recommended. Metallic sea valves or fittings should be galvanically compatible with or isolated from the hull.

(5) Refer to ABYC H-27, Seacocks, Thru-hull Fittings, and Drain Plugs.

(6) These materials are suitable for the following applications: Hardware to deck and hull; guard rails to hull; strut to hull, and water intake scoops to hull. 18-8 stainless steel fasteners can be used for above-water applications and should be used for fastening the engine to the engine bed.

PAINTING

Surface preparation, cleanliness, profile, atmospheric conditions at time of application and coat thickness should be in conformity with the printed instructions of the particular paint manufacturer. The paint manufacturer should be consulted regarding preparation and application techniques and requirements. Selection and application of anti-fouling paints on aluminum require special attention. Anti-fouling paints containing copper or mercury in any form (i.e., oxide chloride or mercuro-organic compounds) are not to be used on aluminum under any circumstances because the mercury will destroy the aluminum by forming an amalgam. If applied to aluminum hulls, anti-fouling paints containing copper may cause galvanic corrosion. A barrier coat should be applied following the paint manufacturer recommendations**.**

BI-METALLIC CONNECTIONS

Aluminum may become anodic and corrode when in contact with other metals commonly used in marine applications. This phenomenon is referred to as galvanic corrosion, and is likened to the action of a wet battery. The severity of galvanic corrosion of aluminum is potentially greater when coupled to copper or copper-bearing alloys, such as bronzes and brasses, than when coupled to steel, stainless steel, or nickel alloys. Bi-metallic connections between aluminum and other metals are undesirable, but sometimes unavoidable. Through appropriate design, galvanic corrosion of aluminum in these bi-metallic connections can be controlled. The means of control in practice depends to a certain extent upon the particular application and expected service conditions. Greater care must be taken to control galvanic corrosion of dissimilar metals under water, as compared to above-water applications, because seawater is a good conductor of corrosion current. See ABYC E-2, *Cathodic Protection*.

The most frequently used method of preventing dissimilar metal corrosion is to separate or insulate the dissimilar metals by means of non-metallic, chemically-inert materials of high electrical resistance. Accordingly, the galvanic current flow is stifled and corrosion controlled. FIGURE 1 illustrates a means of insulating dissimilar metal joints between aluminum and steel through the use of non-metallic, inert materials. The various non-absorbent insulating materials employed include natural and synthetic rubbers, plastic tapes, caulking compounds, mastics, and mixed organic polymers. The names of some proprietary compounds of

these materials include Neoprene, Fairprene, Presstite, P.A.W. Tape, and Alumalastic. An alternative method of insulating dissimilar metals in above-water and underwater applications is to paint the surfaces of both metals with a corrosion-inhibitive paint.

Bi-metallic connections between aluminum and copper, or copper-rich alloys, such as the brasses or bronzes, should be avoided wherever possible and many parts normally made in brass or bronze alloy have been redesigned in aluminum alloy or stainless steel for this reason. Where aluminum to copper joints cannot be avoided, control of galvanic corrosion is achieved through the use of insulating materials as described above and by painting.

The use of wood treated with preservatives containing copper compounds in contact with aluminum should be avoided. In addition, surfaces of wet or unseasoned woods in contact with aluminum should be painted with aluminum-pigmented paint.

FIGURE 1 – CONNECTIONS OF DISSIMILAR METALS

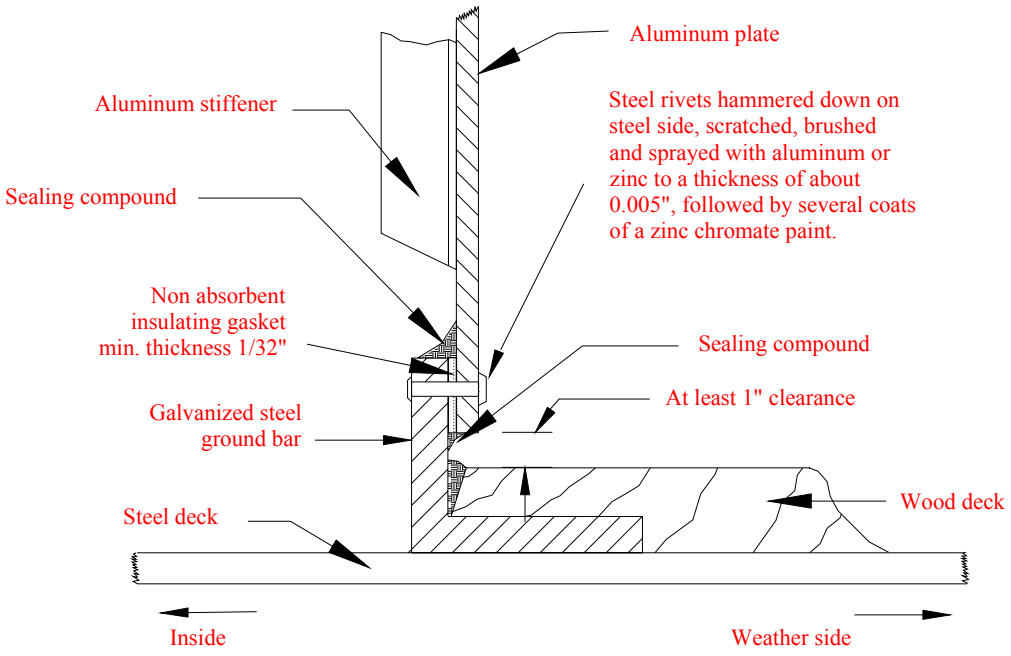

TABLE 2 – TYPICAL MECHANICAL PROPERTIES[1] FOR WROUGHT ALLOYS – For properties not listed, contact your aluminum supplier.

	TENSION			HARDNESS	SHEAR	BEARING	FATIGUE	MODULUS
Alloy and Temper	Strength (psi)		Elongation in 2 inches (percent) 1/16 inch thick specimen	Brinell Number (500 kg load; 10 mm ball)	Ultimate Shearing Strength (psi)	Ultimate Bearing Strength[2] (psi)	Endurance Limit[3] (psi)	Modulus of Elasticity[4] (psi)
	ultimate	yield						
3003-B14	22,000	21,000	8	40	14,000	38,000	9,000	10.0×10^6
5005-H154*	-	-	-	-	-	-	-	-
5050-0	21,000	8,000	24	36	15,000	39,000	12,000	10.0×10^6
5050- H-32	25,000	21,000	9	46	17,000	47,000	13,000	10.0×10^6
5050-H34	28,000	24,000	8	53	18,000	52,000	13,000	10.0×10^6
5050-H36	30,000	26,000	7	58	19,000	56,000	14,000	10.0×10^6
5052-0	28,000	13,000	25	47	18,000	61,000	16,000	10.2×10^6
5052-H32	33,000	28,000	12	60	20,000	71,000	17,000	10.0×10^6
5052-H34	38,000	31,000	10	68	21,000	78,000	18,000	10.2×10^6
5052-H36	40,000	35,000	8	73	23,000	82,000	19,000	10.2×10^6
5086-0	38,000	17,000	22	65	23,000	-	-	10.3×10^6
5086-H116	42,000	30,000	12	77	25,000	-	-	10.3×10^6
5086-H117	47,000	37,000	10	86	27,000	-	15,000	10.3×10^6
5154-0	35,000	17,000	27	58	22,000	-	17,000	10.2×10^6
5154-H32	39,000	30,000	15	67	22,000	-	18,000	10.2×10^6
5154-H34	42,000	33,000	13	73	24,000	-	19,000	10.2×10^6
5154-H36	45,000	36,000	12	78	26,000	-	20,000	10.2×10^6
5154-H112	35,000	17,000	25	63	-	-	17,000	10.2×10^6
5454-0	36,000	17,000	22	62	-	-	18,000	10.2×10^6
5454-H32	40,000	30,000	10	73	-	-	18,000	10.2×10^6
5454-H34	44,000	35,000	10	81	-	-	18,000	10.2×10^6
5454-H36	-	-	-	-	-	-	-	-
5454-H112	36,000	18,000	18	62	-	-	18,000	10.2×10^6
6061-T4	35,000	21,000	22	65	-	-	14,000	10.0×10^6
6061-T6	45,000	40,000	12	95	-	-	14,000	10.0×10^6
6063-T6	35,000	31,000	12	73	-	-	10,000	10.0×10^6

*Pattern sheet

NOTES: (1) Properties listed are for information only and are not guaranteed.

(2) Ultimate bearing strength with edge distance 2.0 times rivet diameter.

(3) Based on 500,000,000 cycles of completely reversed stress using the R.R. Moore type of machine and specimen.

(4) Average of tension and compression moduli; compression modulus about two percent greater than tension modulus.

TABLE 3 – MECHANICAL PROPERTY LIMITS FOR EXTRUSIONS – For properties not listed, contact your aluminum supplier.

Alloy and Temper	Thickness[1] (inches)	Area (square inches)	Ultimate Strength Minimum (psi)	Yield Strength Minimum (psi)	Elongation[2] in 2 inches or 4D[3] (percent minimum)
6061-T4	All	All	26,000	16,000	16
6061-T6	Up thru 0.249	All	38,000	35,000	8
6061-T6	0.250 and over	All	38,000	35,000	10
6063-T5	Up to 1.000	All	22,000	16,000	8
6063-T6	Up thru 0.124	All	30,000	25,000	8
6063-T6	0.125-1.000	All	30,000	25,000	10
5083-H112	Up thru 5	Up thru 32	39,000	15,000	12
5086-H112	Up thru 5	All	35,000	14,000	12
5154-H112	All	All	30,000	11,000	-
5454-H112	Up thru 5	Up thru 32	31,000	12,000	12

NOTES: (1) The thickness of the cross section from which the tension test specimen is taken determines the applicable mechanical properties. For material 1-1/2 inches or less in thickness, when not tested in full section, the tension test

specimen is taken from the center of the section. For material over 1-1/2 inches in thickness, the specimen is taken midway between the center and the surface. Specimens are taken parallel to the direction of extrusion.

(2) For material of such dimensions that a standard test specimen cannot be taken, or for material thinner than 0.062 inch, the test for elongation is not required.

(3) "D" represents specimen diameter.

TABLE 4 - TYPICAL MECHANICAL PROPERTIES FOR DIE-CASTING ALLOYS - For properties not listed, contact your aluminum supplier.

Alloy	Tensile Strength (psi)	Yield Strength (offset = 0.2%) (psi)	Elongation percent in 2 inches	Endurance Limit R.R. Moore type specimen 500,000,000 cycles (psi)	Shearing Strength (psi)
13	39,000	21,000	2.0	19,000	25,000
43	30,000	16,000	9.0	19,000	17,000
218	45,000	27,000	8.0	28,000	23,000
360	44,000	27,000	3.0	20,000	28,000

TABLE 5 - TYPICAL MECHANICAL PROPERTIES FOR PERMANENT MOLD ALLOYS - For properties not listed, contact your aluminum supplier.

Alloy and Temper	Tensile Strength (psi)	Tensile Yield Strength (offset = 0.2%) (psi)	Elongation percent in 2 inches	Compressive Yield Strength (offset = 0.2%) (psi)	Brinell Hardness (500 kg load 10 mm ball)	Shearing Strength (psi)	Endurance Limit R.R. Moore type specimen 500,000,000 (psi)
356	52,000	43,000	5.0	-	-	-	-
43 F	23,000	9,000	10.9	9,000	45	16,000	8,000
A214F	27,000	16,000	7.0	17,000	60	22,000	-
356-T6	38,000	27,000	5.0	27,000	85	30,000	13,000
355-T6	42,000	27,000	4.0	27,000	90	34,000	10,000
Almag 35	42,000	23,000	10.0	-	75	-	-

TABLE 6 - TYPICAL MECHANICAL PROPERTIES FOR SAND CASTING ALLOYS - For properties not listed, contact your aluminum supplier.

Alloy and Temper	Tensile Strength (psi)	Tensile Yield Strength (offset = 0.2%) (psi)	Elongation percent in 2 inches	Compressive Yield Strength (offset = 0.2%) (psi)	Brinell Hardness (500 kg load 10 mm ball)	Shearing Strength (psi)	Endurance Limit R.R. Moore type specimen 500,000,000 cycles (psi)
357	50,000	43,000	2.0	-	-	-	-
43 F	19,000	8,000	8.0	9,000	40	14,000	8,000
F214F	21,000	12,000	3.0	13,000	50	17,000	8,000
356-T6	33,000	24,000	3.5	25,000	70	26,000	8,500
356-T51	25,000	20,000	2.0	21,000	60	20,000	8,000
355-T6	35,000	25,000	3.0	26,000	80	28,000	9,000
Almag 35	40,000	21,000	13.0	-	70	-	10,000
351-T51	28,000	23,000	1.5	24,000	65	22,000	8,000

TABLE 7 - MECHANICAL PROPERTY LIMITS[1] FOR PIPE - For properties not listed, contact your aluminum supplier.

Alloy and Temper	Pipe Size in inches	Ultimate Strength Minimum (psi)	Yield Strength Minimum (psi)	Elongation in 2 inches or 4D[2] (percent minimum)
6061-T6	under 1"	42,000	35,000	12
6061-T6	1" and over	38,000	35,000	10
6063-T6	All	30,000	25,000	8
3003-H18	under 1"	27,000	24,000	-

NOTES: (1) Specimens tested parallel to the direction of working.

(2) "D" represents diameter of cut-out specimen.

(3) Mechanical property limits are shown for un-clad pipe. Clad pipe properties are slightly lower.

TABLE 8 - MECHANICAL PROPERTY LIMITS FOR RIVETS AND WELDING WIRE

For Rivets[1]
3003 – F
6053 - T61
6061 - T6

For Welding Wire[2]
1100
4043
5052
5154
5183
5356
5554
5556
5654

NOTES: (1) Mechanical property limits can be obtained directly from manufacturer or through handbooks.

(2) For weld properties, contact the various aluminum producers as many factors determine efficiency.

TABLE 9 - RECOMMENDED RIVET DIAMETERS

Material Thickness[1] in inches	Rivet Diameter in inches
0.028 to 0.036	1/16
Over 0.036 to 0.048	3/32
Over 0.048 to 0.064	1/8
Over 0.064 to 0.080	5/32
Over 0.080 to 0.104	3/16
Over 0.104 to 0.128	1/4
Over 0.128 to 0.188	5/16
Over 0.188 to 0.20	3/8
Over 0.20 to 0.25	7/16
Over 0.25 to 0.30	1/2
Over 0.30 to 0.35	9/16
Over 0.35 to 0.40	5/8
Over 0.40 to 0.55	3/4
Over 0.55 to 0.70	7/8

NOTES: (1) Thickness referred to is that of thinnest component.

(2) The edge distance for riveting should normally be 2D (where D = rivet diameter) and never less than 1-1/2D. With these edge distances, the bearing strength of aluminum alloys may be taken as 1.8 times the tensile strength. The rivet pitch should not be less than 3D. For water-tightness, the maximum is 4D or 10T (i.e., the thickness of thinnest material in the joint), whichever is smaller.

(3) Check with rivet manufacturers for special conditions and problems.

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Origin and Development of ABYC T-1, Aluminum Applications for Boats and Yachts.

ABYC T-1, originally issued as ABYC S-1, was approved for publication in the late 1960's. An update was issued in 1973. In 1998, the designation of the document was changed from S-1 to T-1. The July 2001 update is the work of the Technical Information Project Technical Committee.

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