



RULES FOR

MATERIALS AND WELDING 2013

PART 2 ALUMINUM and FIBER REINFORCED PLASTICS (FRP) (CHAPTERS 5-6)

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ABS Plaza
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Rule Change Notice (2013)

The effective date of each technical change since 1993 is shown in parentheses at the end of the subsection/paragraph titles within the text of each Part. Unless a particular date and month are shown, the years in parentheses refer to the following effective dates:

(2000) and after	1 January 2000 (and subsequent years)	(1996)	9 May 1996
(1999)	12 May 1999	(1995)	15 May 1995
(1998)	13 May 1998	(1994)	9 May 1994
(1997)	19 May 1997	(1993)	11 May 1993

Listing by Effective Dates of Changes from the 2006 Rules

Notice No. 1 (effective on 1 January 2007), Notice No. 2 (effective on 1 January 2008), Notice No. 3 (effective on 1 January 2009), Notice No. 4 (effective on 1 January 2010), Notice No. 5 (effective on 1 January 2011), and Notice No. 6 (effective on 1 January 2012) to the 2006 Rules, which are incorporated in the 2013 Rules, are summarized below.

EFFECTIVE DATE 1 January 2007 – shown as *(1 January 2007)* (based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
2-5-A1/Figure 9	Test No. 2 – Guided Bend Test for Root Bend and Face Bend (Plate or Pipe)	To allow bend test specimens to be machined down to 3/8" as clarified in AWS D1.2, AWS B4.0, ASME Section IX, and this PRC. (Incorporates Notice No. 1)

EFFECTIVE DATE 1 January 2008 – shown as *(1 January 2008)* (based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
2-5-8/5.3.1	Drift Expansion Tests	To add one more acceptance criteria based on current ABS practice. (Incorporates Notice No. 2)

EFFECTIVE DATE 1 January 2009 – shown as *(1 January 2009)* (based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
2-5-A2/Table 1	Consumable Grades and Base Materials for the Approval Test Drift Expansion Tests	To incorporate Rev. 1 of IACS UR W26. (Incorporates Notice No. 3)
2-5-A2/Table 3	Requirements for the Transverse Tensile and Bend Tests	To incorporate Rev. 1 of IACS UR W26. (Incorporates Notice No. 3)

EFFECTIVE DATE 1 January 2010 – shown as (1 January 2010)
(based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
2-5-5/Table 1	Mechanical Property Limits of Non-Heat-Treatable Sheet and Plate Aluminum Alloys	To reflect changes to ASTM B 928. To allow use of 5d gauge length as permitted in ASTM B 26, B 209 & B 928. (Incorporates Notice No. 4)
2-5-5/Table 2	Mechanical Property Limits of Heat-Treatable Sheet and Plate Aluminum Alloys	To allow use of 5d gauge length as permitted in ASTM B 26, B 209 & B 928. (Incorporates Notice No. 4)
2-5-5/Table 3	Mechanical Property Limits of Non-Heat-Treatable Aluminum Alloys for Extruded Bars, Rods, Shapes, and Tubes	To allow use of 5d gauge length as permitted in ASTM B 26, B 209 & B 928. (Incorporates Notice No. 4)
2-5-5/Table 4	Mechanical Property Limits of Heat-Treatable Aluminum Alloys for Extruded Products	To allow use of 5d gauge length as permitted in ASTM B 26, B 209 & B 928. (Incorporates Notice No. 4)
2-5-5/Table 5	Mechanical Property Limits of Die Forgings	To allow use of 5d gauge length as permitted in ASTM B 26, B 209 & B 928. (Incorporates Notice No. 4)
2-5-5/Table 6	Mechanical Property Limits for Hand Forgings	To allow use of 5d gauge length as permitted in ASTM B 26, B 209 & B 928. (Incorporates Notice No. 4)
2-5-5/Table 7	Mechanical Property Limits for Aluminum Alloy Castings	To allow use of 5d gauge length as permitted in ASTM B 26, B 209 & B 928. (Incorporates Notice No. 4)
2-5-6/1	General	To clarify that extruded alloys, not just rolled alloys, are to undergo corrosion testing as indicated in this paragraph. (Incorporates Notice No. 4)

EFFECTIVE DATE 1 January 2011 – shown as (1 January 2011)
(based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
2-5-1/1.1	General	To clarify that grade/temper designation of ABS grade alloys are in accordance with the established Standards. (Incorporates Notice No. 5)
2-5-1/1.9	Referenced Documents	To add additional references. (Incorporates Notice No. 5)
2-5-1/5.7 (New)	Electronic Certification System	To allow electronic certification (faster method than manual) as per the new 2-1-1/7.2. (Incorporates Notice No. 5)
2-5-1/7.3	Material Identification	To include initial “AB” in markings and references of ABS Rules. (Incorporates Notice No. 5)
2-5-2/1	General	To include active applicable ASTM standard. To provide Additional testing reference for heat treatable aluminum alloys. (Incorporates Notice No. 5)
2-5-3/Table 1	Chemical Composition Limits of Wrought Aluminum Alloys	To maintain consistency with the requirements of IACS UR W25 and ASTM B209/B221. (Incorporates Notice No. 5)
2-5-5/5.1	General	To maintain consistency with the requirements of IACS UR W25 and applicable ASTM or AA Standards. (Incorporates Notice No. 5)
2-5-5/5.9 (New)	Test Specimens Orientation and Location	To clarify references for tension test specimen orientation and location. (Incorporates Notice No. 5)
2-5-5/Table 1A	Mechanical Property Limits of Non-Heat-Treatable Sheet and Plate Aluminum Alloys	To maintain consistency with the requirements of IACS UR W25, ASTM B 209/209M and ASTM B 928/928M. (Incorporates Notice No. 5)
2-5-5/Table 1B	Longitudinal Mechanical Property Limits of Non-Heat-Treatable Marine Grade Sheet and Plate Aluminum Alloys for Hull Construction	To maintain consistency with the requirements of IACS UR W25, ASTM B 209/209M and ASTM B 928/928M. (Incorporates Notice No. 5)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
2-5-5/Table 2	Long Transverse Mechanical Property Limits of Heat-Treatable Sheet and Plate Aluminum Alloys	To maintain consistency with the requirements of IACS UR W25 and ASTM B209/209M. (Incorporates Notice No. 5)
2-5-5/Table 3	Longitudinal Mechanical Property Limits of Non-Heat-Treatable Aluminum Alloys for Extruded Bars, Rods, Shapes, and Tubes	To maintain consistency with the requirements of IACS UR W25 and ASTM B 221/221M. (Incorporates Notice No. 5)
2-5-5/Table 4	Mechanical Property Limits of Heat-Treatable Aluminum Alloys for Extruded Products	To maintain consistency with the requirements of IACS UR W25 and ASTM B221/221M. (Incorporates Notice No. 5)
2-5-5/Table 5	Mechanical Property Limits for Die Forgings	To maintain consistency with the requirements of ASTM B247/247M. (Incorporates Notice No. 5)
2-5-5/Table 6	Mechanical Property Limits for Hand Forgings	To maintain consistency with the requirements of ASTM B247/247M. (Incorporates Notice No. 5)
2-5-5/Table 7	Mechanical Property Limits for Aluminum Alloy Castings	To maintain consistency with the requirements of AA. (Incorporates Notice No. 5)
2-5-6/1	General	To add requirements for applications of 5xxx-alloys in the H116/H321 tempers in accordance with ASTM B928/928M. (Incorporates Notice No. 5)
2-5-6/3	Reference Photomicrograph	To provide reference of etchant for standard practice in accordance with ASTM B928/928M. (Incorporates Notice No. 5)
2-5-6/5	Batch Microstructural Analysis and Acceptance	To provide additional Rules for applications of 5xxx-alloys in the H116/H321 tempers and surveillance purposes in accordance with ASTM B928/928M. (Incorporates Notice No. 5)
2-5-6/7	Surveillance of Corrosion Testing	To provide additional Rules for applications of 5xxx-alloys in the H116/H321 tempers and surveillance purposes in accordance with ASTM B928/928M. (Incorporates Notice No. 5)
2-5-7/3	Selection of Tension Test Specimen	To maintain consistency with the requirements of ASTM B557/557M (Incorporates Notice No. 5)
2-5-10/1	Scope	To remove inactive designations (Incorporates Notice No. 5)
2-5-A1/Table 4	Filler Metals for Welding Aluminum Alloy – Sheet, Plate and Extrusions	To add alloy 6082, in line with 2-5-3/Table 1 and 2-5-5/Table 4. (Incorporates Notice No. 5)
2-5-A3/3.5.2	Test Data	To maintain consistency with current ABS practice. (Incorporates Notice No. 5)
2-5-A3/5 (New)	Renewal of Approval	To include renewal approval requirements in accordance with 2-A4/11. (Incorporates Notice No. 5)

EFFECTIVE DATE 1 January 2012 – shown as (1 January 2012)
(based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
2-5-5/7.3	Failure to Meet Requirements	To clarify the retests requirements of sheet, plate, extrusion, forging and casting according to the guidance of IACS UR W25 and ASTM B 557/557M. (Incorporates Notice No. 6)
2-5-A1/3.5	Cleanliness	To apply due prudence to the cleaning of surfaces to be welded. (Incorporates Notice No. 6)

EFFECTIVE DATE 1 January 2013 – shown as (2013)
(based on the contract date for new construction between builder and Owner)

<i>Part/Para. No.</i>	<i>Title/Subject</i>	<i>Status/Remarks</i>
2-5-3/Table 1	Chemical Composition Limits of Wrought Aluminum Alloys	To add the chemical composition limits of 6063 alloy in accordance with ASTM B221/B221M
2-5-5/Table 1A	Mechanical Property Limits of Non-Heat-Treatable Sheet and Plate Aluminum Alloys	To correct references.
2-5-5/Table 1B	Mechanical Property Limits of Non-Heat-Treatable Marine Grade Sheet and Plate Aluminum Alloys for Hull Construction	To correct references.
2-5-9/1	Scope	To require that the manufacturer have ABS approval to supply ABS approved products.
2-5-10/1	Scope	To require that the manufacturer have ABS approval to supply ABS approved products.
2-5-A1/Figure 13	Test No. 3 – Fillet Weld Test	To remove flame cutting as it is not acceptable for aluminum.
2-5-A3/1	Scope	To cover foundries along with forges.
2-5-A3/3.5.2	Test Data	To specify the approval range within minimum and maximum thickness.

Rules for Materials and Welding – Aluminum and Fiber Reinforced Plastics (FRP)

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PART 2

CHAPTER 5 Materials for Hull Construction – Aluminum

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PART

2

CHAPTER 5 Materials for Hull Construction – Aluminum

SECTION 1 General

1 Testing and Inspection

1.1 General (2011)

All materials subject to test and inspection, intended for use in the construction of the hulls of craft classed or proposed for classification, are to be tested by the material producer and inspected by the ABS Surveyor in accordance with the following requirements or their equivalent. These requirements are not applicable to the use of aluminum alloys at low temperature for cryogenic applications. Materials, test specimens and mechanical testing procedures having characteristics differing from those prescribed herein may be approved for application, with due regard being given to established practices in the country in which the material is produced and the purpose for which the material is intended, such as the parts for which it is to be used, the type of craft and intended service, and the nature of the construction of the craft. The requirements are based on both metric and U.S. customary units. Each system of units is to be treated as separate and independent from the other. Mixing and matching of units from one system to another are not permitted. The numerical designation (grade) of aluminum alloys and the temper designation are based on those of the Aluminum Association or recognized Standards.

All materials, including semi-finished products are to be manufactured at works which are approved by ABS for the grades and maximum thickness of aluminum alloy supplied.

1.3 Witnessed Tests

All tests are to be carried out by competent personnel and conducted in the presence of the Surveyors at the place of manufacture prior to shipping. Consideration will be given to the acceptance of rolled and extruded products without witnessing of mechanical tests by the Surveyor, on the basis of compliance with ABS's Quality Assurance Program. Testing procedures are to follow established practices in international or national Standards. Test samples are to be taken from material which has undergone the same treatment as the material to be certified. Preparation of specimens is not to involve significant straining or heating. Thermally cut samples are to have excess material to allow a specimen to be machined from material that is unaffected by the cutting process.

1.5 Rejection of Previously Accepted Material

In the event of any material proving unsatisfactory in the process of being worked, it shall be rejected, notwithstanding any previous certificate of satisfactory testing.

1.7 Calibrated Testing Machines

All testing machines shall be maintained in good condition by the manufacturer and to the satisfaction of the attending Surveyor. The measuring equipment and machinery used shall be periodically calibrated by the manufacturer in accordance with ISO standards or any other recognized national/international standards requirements. The validity of calibration certificates shall be verified by the Surveyor before witnessing tests.

1.9 Referenced Documents (2011)

The following documents form a part of the overall specification to the extent they are referenced in this ABS Rules document:

ANSI H35.1	Alloy and Temper Designation Systems for Aluminum
ASTM B928/928M	Standard Specification for High Magnesium Aluminum-Alloy sheet and plate for marine Service.
ASTM B221/221M	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B247/247M	Standard Specification for Aluminum and Aluminum-Alloy Die Forgings, Hand Forgings, and Rolled Ring Forgings
ASTM B316/316M	Standard Specification for Aluminum and Aluminum – Alloy Rivet and Cold-Heading Wire and Rods
ASTM B209/209M	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B26/26M	Standard Specification for Aluminum-Alloy Sand Castings
ASTM B108	Standard Specification for Aluminum-Alloy Permanent Castings
ASTM B918	Standard Practice for Heat Treatment of Wrought Aluminum Alloys
ASTM E34	Test methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys
ASTM E1251	Test Method for optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloys by Argon Atmosphere, point-to-plane, unipolar self-initiating Capacitor Discharge.
ASTM E8/8M	Standard Test methods for Tension Testing of Metallic Materials
ASTM B557/557M	Standard Test Methods of Tension Testing Wrought and Cast Aluminum – and Magnesium-Alloy Products
ASTM B565	Method for Shear Testing of Aluminum and Aluminum – Alloy Rivet and Cold-Heading Wire and Rods
AWS D1.2/D1.2M	Structural Welding Code – Aluminum
IACS UR W25	Materials and Welding – Aluminum Alloys for Hull Construction and Marine Structure
IACS UR W26	Materials and Welding – Requirements for Welding Consumables for Aluminum Alloys

3 Defects

All materials and weldments are to be generally free from linear, planar and volumetric physical defects such as embedded and through thickness flaws, laminations and injurious surface flaws or similar forms of defects that would be detrimental to the use of the materials and weldments in the intended applications. Welding or dressing for the purpose of remedying defects is not permitted unless and until sanctioned by the Surveyor. Discoloration characteristic of proper heat treatment schedules is not cause for rejection.

5 Manufacturer's Certificates

5.1 Form of Certificate

Four copies of the mill certificates or the shipping statements of all accepted plate and shape materials indicating the aluminum alloy and temper, the purchaser and order number, the construction project number (if available), the product quantity, dimension and weight, the chemical composition, the batch number and the test results, are to be furnished to the Surveyor for his approval; one is to be forwarded to the purchaser, three are to be retained for the use of ABS. Before the mill certificates or shipping statements are distributed

by the local ABS office, the manufacturer is to furnish the Surveyor with a certificate stating that the material has been sampled, tested and inspected in accordance with these Rules and that it has met the requirements. The following form of certificate will be accepted if printed on each mill sheet or shipping statement with the name of the firm and initialed by the authorized representative of the manufacturer:

“We hereby certify that the material described herein has been made to the applicable specifications of alloy _____; temper _____, and the required samples tested in accordance with the requirements of _____ (The American Bureau of Shipping Rules or state other specification) in the presence of a Surveyor from the American Bureau of Shipping with satisfactory results.”

At the request of manufacturers, consideration may be given to modifications to the form of certificate, provided it correspondingly indicates compliance with the requirements of these Rules to no less degree than indicated in the foregoing statement.

5.3 Other Certificates

Where an aluminum alloy ingot is not produced in the plant where it is rolled, extruded or forged, a certified report is to be supplied to the Surveyor stating the name of the manufacturer, the alloy, ingot or manufacturing and inspection lot identification numbers and certification that the alloy meets the required chemical composition limits.

5.5 Dual Certification

Dual certification of aluminum alloys is permitted only when alloy designations involved meet the specified chemical composition and specified minimum mechanical property requirements; provided they have the same ANSI temper designations in order to avoid any differences that may arise in welding and marine corrosion characteristics of the alloys with differing temper designations.

5.7 Electronic Certification System (2011)

An electronic certification system may be used to issue certified mill test reports, which may be electronically signed and stamped by an attending Surveyor, subject to the following conditions.

- All relevant information regarding the customer order, including the electronic certification request, is to be provided to the attending Surveyor by the manufacturer.
- Procedures are to be established to control handling and distribution of certified mill test reports among the manufacturer, ABS, and the purchaser.
- In order to implement the electronic certification system, the manufacturer is to be under mandatory ABS-QA program.

7 Identification Markings

7.1 Marine Grades

Aluminum alloys with ability to resist intergranular and exfoliation forms of corrosion when in direct contact with seawater or when used in marine environment conditions shall be treated as marine grades. Aluminum alloys with magnesium content greater than or equal to 3% are prone to these forms of corrosion and shall be tested, inspected and certified in accordance with ASTM B928 specification by the manufacturer. The acceptance criteria for corrosion tests (ASTM G66 and G67) are to follow ABS Rule requirements. The test results shall be reported on the mill certificates and are to be verified by the Surveyor. The alloy grade shall be suffixed with the letters “MG” while marking as indicated in 2-5-1/7.3.

7.3 Material Identification (2011)

All materials which have been sampled, tested and have successfully passed the requirements and have been approved by the Surveyor are to be clearly ink marked or stamped with the manufacturer’s name or trademark and material identification on each finished sheet, plate, shape, bar, rod casing or forging to signify that the material has satisfactorily complied with the tests prescribed. The material identification is to include:

- i) The initials **AB**
- ii) The aluminum alloy designation according to the Aluminum Association
- iii) The temper designation according to the Aluminum Association
- iv) The manufacturers batch number
- v) The letter “MG” is to be added after the grade and temper designation only if the material has been corrosion tested as per requirements of Section 2-5-6 of these Rules and ASTM B928. Example: AB/5083 H321 MG

7.5 Stenciled Material

In special cases, when approved, strapped or secured lifts or bundles of light sheet, plates, shapes, bars, rods or tubes of comparatively small size may be marked or stenciled on only the top piece or the marking may be shown on the tag attached to each lift or bundle.

PART

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CHAPTER 5 Materials for Hull Construction – Aluminum

SECTION 2 Standard Test Methods

1 General (2011)

The latest issue of the following test methods or specifications or their equivalents are considered acceptable:

1.1 Chemical Analysis

The chemical analyses are to be carried out in accordance with ASTM E34 or ASTM E716 or ASTM E1251 or equivalent, as may be appropriate to a specific alloy under testing and consideration for certification. The sampling practice for chemical analyses is to be carried out as indicated in 2-5-3/3 and may follow a recognized standard to the extent as may be modified or stated in this document.

1.3 Tension Testing

Refer to 2-5-5 for requirements for test specimens.

Alternative Standards ASTM E 8/8M or ASTM B557/557M or equivalent may be used.

1.5 Shear Testing

Shear tests are to be carried out in accordance with ASTM B769 or ASTM B565 or equivalent.

1.7 Hardness Testing*

Hardness tests, if applicable, are to be carried out in accordance with ASTM E18 or equivalent.

1.9 Electrical Conductivity Testing*

Electrical Conductivity tests, if applicable, are to be carried out in accordance with ASTM E1004 or equivalent.

* *Note:* Hardness and Electrical Conductivity testing are reference only for evaluation of alloys and tempers of heat treatable aluminum products.

PART

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CHAPTER 5 Materials for Hull Construction – Aluminum

SECTION 3 Chemical Composition

1 General

The chemical composition of each cast is to be determined by the aluminum manufacturer and is to conform to the applicable requirements of the alloys listed in 2-5-3/Table 1 or 2-5-3/Table 2 or such other requirements as may be specially approved.

3 Sampling

A control sample for chemical analysis is to be taken before starting to pour and one additional sample is to be taken during the pouring of each group of ingots poured simultaneously from the same source of molten metal. If not analyzed during pouring samples, it may be taken from semi-finished or finished products. When samples are taken from finished or semi-finished products, one sample is to represent each 1800 kg (4000 lb), or fraction thereof, of each alloy in an inspection lot. The manufacturer's declared analysis will be subject to occasional checks if required by the Surveyor.

Product analysis may be required where the final product chemistry is not well represented by the analysis from the cast.

When the aluminum alloys are not cast in the same works in which they are manufactured into semi-finished products, a certificate issued by the works is to be provided to the Surveyor which indicates the reference numbers and chemical composition of the heats.

5 Definition of an Inspection Lot

An inspection lot is defined as:

For non-heat treated tempers, an identifiable quantity of material of the same mill form, alloy, temper, section and size submitted for an inspection at one time before shipment. And for heat treated temper an identifiable quantity of material of the same mill form, alloy, temper, section and size traceable to a heat treated lot or lots and submitted for inspection at one time before shipment. Mill forms: sheet and plate, all material of the same thickness is considered to be of the same size.

TABLE 1
Chemical Composition Limits of Wrought Aluminum Alloys (2013)

Limits are in weight percent. Single value represents maximum limit, unless shown as a range or indicated as a minimum.

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Others ⁽¹⁾		Aluminum
									Each	Total	
5052	0.25	0.40	0.10	0.10	2.2-2.8	0.15-0.35	0.10	–	0.05	0.15	Remainder
5059	0.45	0.50	0.25	0.60-1.2	5.0-6.0	0.25	0.40-0.90	0.20	0.05 ⁽⁵⁾	0.15 ⁽⁵⁾	Remainder
5083	0.40	0.40	0.10	0.40-1.0	4.0-4.9	0.05-0.25	0.25	0.15	0.05	0.15	Remainder
5086	0.40	0.50	0.10	0.20-0.7	3.5-4.5	0.05-0.25	0.25	0.15	0.05	0.15	Remainder
5383	0.25	0.25	0.20	0.70-1.0	4.0-5.2	0.25	0.4	0.15	0.05 ⁽⁴⁾	0.15 ⁽⁴⁾	Remainder
5454	0.25	0.40	0.10	0.50-1.0	2.4-3.0	0.05-0.20	0.25	0.20	0.05	0.15	Remainder
5456	0.25	0.40	0.10	0.50-1.0	4.7-5.5	0.05-0.20	0.25	0.20	0.05	0.15	Remainder
5754	0.40	0.40	0.10	0.50 ⁽²⁾	2.6-3.6	0.30 ⁽²⁾	0.20	0.15	0.05	0.15	Remainder
6005A	0.50-0.9	0.35	0.30	0.50 ⁽³⁾	0.4-0.7	0.30 ⁽³⁾	0.20	0.10	0.05	0.15	Remainder
6061	0.40-0.8	0.70	0.15-0.40	0.15	0.8-1.2	0.04-0.35	0.25	0.15	0.05	0.15	Remainder
6063	0.20-0.6	0.35	0.10	0.10	0.45-0.9	0.10	0.10	0.10	0.05	0.15	Remainder
6082	0.70-1.3	0.50	0.10	0.40-1.0	0.6-1.2	0.25	0.20	0.10	0.05	0.15	Remainder

Notes:

- (2011) The term ‘Others’ includes any other element(s) for which no specific limit is shown in the above table. Other element(s), if added intentionally or analyzed by the alloy producer or specified by the purchaser, are to be reported and not to exceed the limit as given in the ‘Others’ column.
- Mn + Cr : 0.10 – 0.60
- Mn + Cr : 0.12 – 0.50
- Zr: maximum 0.20. The total for other elements does not include Zirconium.
- Zr: 0.05-0.25. The total for other elements does not include Zirconium.

TABLE 2
Chemical Composition Limits of Cast Aluminum Alloys

AA Aluminum Association

Limits are in weight percent. Single value represents maximum limit, unless shown as a range or indicated as a minimum.

AA	Silicon	Iron	Copper	Manganese	Magnesium	Zinc	Titanium	Others		Aluminum
								Each	Total	
356.0	6.5–7.5	0.6 ⁽¹⁾	0.25	0.35 ⁽¹⁾	0.20–0.45	0.35	0.25	0.05	0.15	Remainder
A356.0	6.5–7.5	0.20	0.20	0.10	0.20–0.45	0.10	0.20	0.05	0.15	Remainder
357.0	6.5–7.5	0.15	0.05	0.03	0.45–0.6	0.05	0.20	0.05	0.15	Remainder

Note:

- If the iron content exceeds 0.45%, manganese content shall not be less than one half of the iron.

PART

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CHAPTER 5 Materials for Hull Construction – Aluminum

SECTION 4 Heat Treatment

Alloys 6005A, 6061 and 6082 products are to be suitably **heat** treated to develop the mechanical properties specified in 2-5-5/Tables 2, 4, 5 and 6 for the various tempers. Alternative heat treatments will be specially considered.

- T4 Solution heat treated and then naturally aged.
- T451 For sheet and plate that are stress relieved by stretching after solution heat treatment.
- T4511 For extruded bars, rods or shapes that are stress relieved by stretching after solution heat treatment.
- T5 Cooled from an elevated temperature shaping process and then artificially aged. Usually associated with extruded products.
- T6 Solution heat treated and then artificially aged.
- T651 For sheet and plate that are stress relieved by stretching after solution heat treatment and then artificially aged.
- T6511 For extruded bars, rods or shapes that are stress relieved by stretching after solution heat treatment and then artificially aged.

PART

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CHAPTER 5 Materials for Hull Construction – Aluminum

SECTION 5 Tensile Properties

1 General

Tensile properties are to conform to the applicable requirements of the alloys and tempers listed in 2-5-5/Tables 1 through 7. Mechanical properties for welded joints are lower for strain hardened or heat treated alloys. For as welded properties refer to Appendix 2-5-A1.

3 Yield Strength

The yield strength is defined as that determined at 0.2% offset.

5 Standard Test Specimens

5.1 General (2011)

Tension test specimens may be the full cross section of the material being tested or they may be machined as indicated for specific product forms. Test specimens in accordance with other recognized standards may be accepted subject to special approval.

5.3 Full-Section Specimens

Tension test specimens of the full cross section of the material may be used for wire, rod, bar, shapes and tubular products. It is permissible to reduce the section slightly throughout the section to insure fracture within the gauge marks.

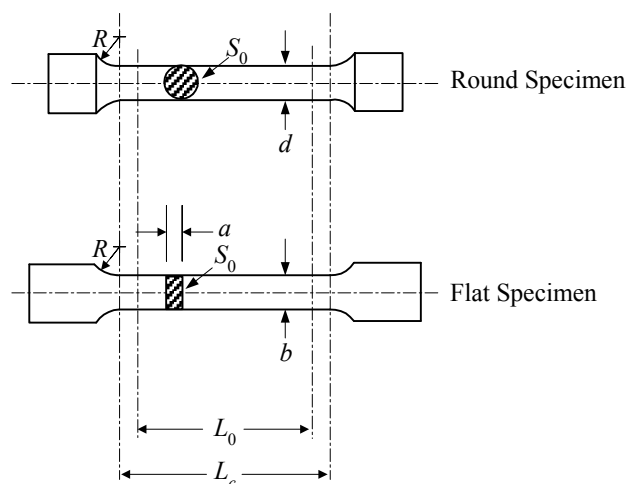
5.5 Machined Specimens

Standard tension test specimens' requirements are indicated in 2-5-5/Figure 1.

The following designations are used:

d	=	diameter
a	=	thickness
b	=	width
L_0	=	original gauge length
L_c	=	parallel length
S_0	=	original cross sectional area
R	=	transition radius
D	=	external tube diameter
t	=	plate thickness

FIGURE 1
Standard Tension Test Specimen



5.7 Dimensions

Proportional test specimens with a gauge length:

$$L_0 = 5.65 \sqrt{S_0}$$

can be used or preferably $5d$ can be used as the gauge length, L_0 should preferably be greater than 20 mm. The gauge length may be rounded off to the nearest 5 mm provided that the difference between this length and L_0 is less than 10% of L_0 .

Flat tensile test specimens shall be used for specified thicknesses up to and including 12.5 mm. The tensile test specimen shall be prepared so that both rolled surfaces are maintained. For thicknesses exceeding 12.5 mm, round tensile test specimens will be used. For thicknesses up to and including 40 mm, the longitudinal axis of the round tensile test specimen shall be located at a distance from the surface equal to half of the thickness. For thicknesses over 40 mm, the longitudinal axis of the round tensile test specimen shall be located at a distance from one of the surfaces equal to one quarter of the thickness.

5.7.1 Plates Strips and Sections

Flat specimens are usually to be used with dimensions as specified below

- *Proportional flat specimen*

$$\begin{aligned} a &= t \\ b &= 25 \text{ mm} \\ L_0 &= 5.65 \sqrt{S_0} \\ L_c &= L_0 + 2 \sqrt{S_0} \\ R &= 25 \text{ mm} \end{aligned}$$

- *Non-proportional flat specimen*

$$\begin{aligned} a &= t \\ b &= 25 \text{ mm} \\ L_0 &= 200 \text{ mm} \\ L_c &> 212.5 \text{ mm} \\ R &= 25 \text{ mm} \end{aligned}$$

When the capacity of the available testing machine is insufficient to allow the use of test specimen of full thickness, this may be reduced by machining one of the rolled surfaces.

Alternatively, for materials over 40 mm thick, proportional round test specimens with dimensions as specified below may be used.

- *Round specimen*

$$d \geq 10 \text{ mm to } 20 \text{ mm, preferably } 14 \text{ mm}$$

$$L_0 = 5d$$

$$L_c \geq L_0 + \frac{d}{2}$$

$$R = 10 \text{ mm (for materials with a specified elongation less than } 10\%, R \geq 1.5d)$$

The axes of the round test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.

5.7.2 Forgings and Castings

Proportional round test specimens with dimensions as specified above in 2-5-5/5.7.1 are usually to be used. For small size bars and similar products the test specimens may consist of a suitable length of bar or other product tested in the full cross-section.

5.9 Test Specimens Orientation and Location (2011)

The practice for orientation and location of tension test specimens is to be followed as per ASTM B557/557M or equivalent standard and to the extent as may be modified or stated in this document. The orientation and location of tension test specimens are to be indicated in the test report.

7 Retests

7.1 Defective Test specimen

If the percentage elongation of a tension test specimen is less than that specified, and if any part of the fracture is outside of the middle half of the gauge length or in a punched or scribed mark within the reduced section, another test specimen may be selected.

7.3 Failure to Meet Requirements (2012)

If any tension test specimen selected in accordance with 2-5-7/5, 2-5-8/5 or 2-5-9/5 fails to conform to the requirements, two additional specimens, for each specimen that failed, may be selected from the area that is adjacent to the area represented by the failure or failures. In the case of separately cast test specimens, for each specimen that failed, two additional cast specimens from the same batch may be selected for retest. If both of these additional tests are satisfactory, the remaining piece and/or the remaining material from the same batch may be accepted.

If one or both of the additional tests referred to above are unsatisfactory, the piece is to be rejected. If the rejected piece is from a batch, the remaining material from the same batch may be accepted provided that two of the remaining pieces in the batch are tested and conform to the requirements. If tension test specimens from either of these two pieces fail to conform to the requirements, the whole batch of material is to be rejected.

If the failure to conform to the requirements is the result of an inadequate thermal treatment, additional aging treatment, as applicable to the material, may be permitted at the discretion of the attending ABS Surveyor. However, no re-solution heat treatment of the alloys and tempers listed in this section is allowed.

In the event of material failing to comply with the test requirements the Classification brand stamp is to be unmistakably defaced by the manufacturer.

TABLE 1A
Mechanical Property Limits of Non-Heat-Treatable Sheet
and Plate Aluminum Alloys ^(2, 3) (2013)

Mechanical test specimens are taken as detailed in 2-5-5/5 or as specified in ASTM B 557/557M.

Alloy and Temper	Thickness ⁽¹⁾		Ultimate Tensile Strength N/mm ² (ksi)		Yield Strength 0.2% Offset N/mm ² (ksi)		Minimum Elongation Percent in		
	millimeters over - through	(inches)	minimum	maximum	minimum	maximum	50 mm	5d	2 in. /4d
5052-O	3.0–6.3	(0.118–0.249)	170 (25.0)	215 (31.0)	65 (9.5)		19	-	20
	6.3–80.0	(0.250–3.000)	170 (25.0)	215 (31.0)	65 (9.5)		18	16	18
5052-H32 ⁽⁴⁾	3.0–6.3	(0.118–0.249)	215 (31.0)	265 (38.0)	160 (23.0)		7	-	9
	6.3–12.5	(0.250–0.499)	215 (31.0)	265 (38.0)	160 (23.0)		11	-	11
	12.5–50.0	(0.500–2.000)	215 (31.0)	265 (38.0)	160 (23.0)		11	10	12
5052-H34 ⁽⁴⁾	3.0–6.3	(0.118–0.249)	235 (34.0)	285 (41.0)	180 (26.0)		6	-	7
	6.3–25.0	(0.250–1.000)	235 (34.0)	285 (41.0)	180 (26.0)		10	9	10
5052-H112	6.3–12.5	(0.250–0.499)	190 (28.0)		110 (16.0)		7	-	7
	12.5–40.0	(0.500–2.000)	170 (25.0)		65 (9.5)		-	10	12
	40.0–80.0	(2.001–3.000)	170 (25.0)		65 (9.5)		-	14	16
5059-O	3.0–50.0	(0.118–2.000)	330 (48.0)		160 (23.0)		24	24	24
5059-H111	3.0–20.0	(0.118–0.787)	330 (48.0)		160 (23.0)		24	24	24
	20.0–40.0	(0.788–1.575)	330 (48.0)		160 (23.0)		-	20	20
5083-O	3.0–50.0	(0.118–2.000)	275 (40.0)	350 (51.0)	125 (18.0)	200 (29.0)	16	14	16
5083-H112	3.0–50.0	(0.118–2.000)	275 (40.0)		125 (18.0)		12	10	12
5086-O	3.0–6.3	(0.118–0.249)	240 (35.0)	305 (44.0)	95 (14.0)		18	-	18
	6.3–50.0	(0.250–2.000)	240 (35.0)	305 (44.0)	95 (14.0)		16	14	16
5086-H112	3.0–12.5	(0.118–0.499)	250 (36.0)		125 (18.0)		8	-	8
	12.5–40.0	(0.500–1.000)	240 (35.0)		105 (16.0)		-	9	10
	40.0–80.0	(1.001–2.000)	235 (35.0)		105 (16)		-	12	14
5383-O	3.0–50	(0.118–2.000)	290 (42.0)		145 (21.0)		-	17	17
5454-O	3.0–6.3	(0.118–0.249)	215 (31.0)	285 (41.0)	85 (12.0)		16	-	18
	6.3–80.0	(0.250–3.000)	215 (31.0)	285 (41.0)	85 (12.0)		18	16	18
5454-H32 ^(4,5)	3.0–6.3	(0.118–0.249)	250 (36.0)	305 (44.0)	180 (26.0)		8	-	8
	6.3–50.0	(0.250–2.000)	250 (36.0)	305 (44.0)	180 (26.0)		12	10	12
5454-H34 ^(4,5)	3.0–6.3	(0.118–0.249)	270 (39.0)	325 (47.0)	200 (29.0)		6	-	7
	6.3–25.0	(0.250–1.000)	270 (39.0)	325 (47.0)	200 (29.0)		10	9	10
5454-H112 ⁽⁵⁾	6.3–12.5	(0.250–0.499)	220 (32.0)		125 (18.0)		8	-	8
	12.5–40.0	(0.500–2.000)	215 (31.0)		85 (12.0)		-	9	11
	40.0–80.0	(2.001–3.000)	215 (31.0)		85 (12.0)		-	13	15
5456-O	3.0–6.3	(0.118–1.500)	290 (42.0)	365 (53.0)	130 (19.0)	205 (30.0)	16	-	16
	6.3–80.0	(1.501–3.000)	285 (41.0)	360 (52.0)	125 (18.0)	205 (30.0)	16	14	16
5456-H112	6.3–40.0	(0.250–1.500)	290 (42.0)		130 (19.0)		12	10	12
	40.1–80.0	(1.501–3.000)	285 (41.0)		125 (18.0)		-	10	12
5754-O	3.0–12.5	(0.118–0.138)	200 (29.0)	270 (39.0)	80 (12.0)		19	-	19
	12.6–50.0	(0.139–2.000)	190 (27.5)	240 (34.8)	80 (12.0)		18	17	18

Notes:

- 1 Type of test specimen used depends on thickness of material: (See 2-5-5/5.)
- 2 (2011) Values applicable to longitudinal test specimens.
- 3 (2011) Use of the latest ASTM B209/209M specification may be approved upon application.
- 4 (2011) For the corresponding H2x temper, the maximum tensile strength and minimum yield strength do not apply.
- 5 (2013) 5454 is recommended for service applications where exposed to temperatures exceeding 65°C (150°F).

TABLE 1B
Mechanical Property Limits of Non-Heat-Treatable Marine Grade Sheet and Plate
Aluminum Alloys for Hull Construction (2, 3, 4) (2013)

Alloy and Temper	Thickness ⁽¹⁾		Ultimate Tensile Strength N/mm ² (ksi)		Yield Strength 0.2% Offset N/mm ² (ksi)		Minimum Elongation Percent in		
	millimeters over - through	(inches)	minimum	maximum	minimum	maximum	50 mm	5d	2 in. /4d
5059-H116	3.0–20.0	(0.118–0.787)	370 (54.0)		270 (39.0)		10	10	10
	20.0–40.0	(0.788–1.575)	360 (52.0)		260 (38.0)		-	10	10
5059-H321	3.0–20.0	(0.118–0.787)	370 (54.0)		270 (39.0)		10	10	10
	20.0–40.0	(0.788–1.575)	360 (52.0)		260 (38.0)		-	10	10
5083-H116	3.0–12.5	(0.118–0.499)	305 (44.0)		215 (31.0)		10	-	10
	12.5–40.0	(0.500–1.500)	305 (44.0)		215 (31.0)		-	10	12
	40.0–80.0	(1.501–3.000)	285 (41.0)		200 (29.0)		-	10	12
5083-H321	3.2–5.0	(0.125–0.187)	305 (44.0)	385 (56.0)	215 (31.0)		10	-	10
	5.0–12.5	(0.188–0.499)	305 (44.0)	385 (56.0)	215 (31.0)		12	-	12
	12.5–40.0	(0.500–1.500)	305 (44.0)	385 (56.0)	215 (31.0)		-	10	12
	40.0–80.0	(1.501–3.000)	285 (41.0)	385 (56.0)	200 (29.0)		-	10	12
5086-H116	3.0–6.3	(0.118–0.249)	275 (40.0)		195 (28.0)		8	-	8
	6.3–50.0	(0.250–2.000)	275 (40.0)		195 (28.0)		10	9	10
5086-H321	3.0–6.3	(0.118–0.249)	275 (40.0)	355 (52.0)	195 (28.0)		8	-	8
	6.3–8.0	(0.250–0.320)	275 (40.0)	355 (52.0)	195 (28.0)		9	-	9
5383-H116	3.0–50.0	(0.118–2.000)	330 (48.0)		230 (33.0)		10	10	10
5383-H321	3.0–50.0	(0.118–2.000)	330 (48.0)		230 (33.0)		10	10	10
5456-H116	3.0–12.5	(0.118–0.499)	315 (46.0)		230 (33.0)		10	-	10
	12.5–30.0	(0.500–1.250)	315 (46.0)		230 (33.0)		-	10	12
	30.0–40.0	(1.251–1.500)	305 (44.0)		215 (31.0)		-	10	12
	40.0–80.0	(1.501–3.000)	285 (41.0)		200 (29.0)		-	10	12
5456-H321	3.0–4.0	0.118–0.187	330 (48.0)	405 (59.0)	235 (34.0)		10	-	10
	4.0–12.5	0.188–0.499	315 (46.0)	405 (59.0)	230 (33.0)	315 (46.0)	12	10	12
	12.5–40.0	0.500–1.500	305 (44.0)	385 (56.0)	215 (31.0)	305 (44.0)	-	10	12
	40.0–80.0	(1.501–3.000)	285 (41.0)	370 (54.0)	200 (29.0)	295 (43.0)	-	10	12

Notes:

- 1 Type of test specimen used depends on thickness of material: (See 2-5-5/5.)
- 2 (2011) Values applicable to longitudinal test specimens.
- 3 (2011) Marine Grade sheet and plate as shown in 2-5-5/Table 1B are to be capable of passing an appropriate test for resistance to exfoliation and intergranular corrosion. Refer to Section 2-5-6 for full details of corrosion test requirements.
- 4 (2013) Use of the latest **ASTM B 928/928M** specification may be approved upon application.

TABLE 2
Long Transverse Mechanical Property Limits of Heat-Treatable Sheet and Plate Aluminum Alloys ^(2, 6) (2011)

Mechanical test specimens are taken as detailed in 2-5-5/5 or as specified in ASTM B 557/557M.

Alloy and Temper	Type	Thickness ⁽¹⁾		Minimum Tensile Strength	Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in		
		millimeters over - through	(inches)			50 mm	5d	2 in. /4d
6061-T4	Sheet	3.0–6.3	(0.118–0.249)	205 (30.0)	110 (16.0)	16	-	16
6061-T451 ^(4,5)	Plate	6.3–25.0	(0.250–1.000)	205 (30.0)	110 (16.0)	18	16	18
		25.0–80.0	(1.001–3.000)	205 (30.0)	110 (16.0)	-	14	16
6061-T6 and -T62 ⁽³⁾	Sheet	3.0–6.3	(0.118–0.249)	290 (42.0)	240 (35.0)	10	-	10
6061-T62 ⁽³⁾ and -T651 ^(4,5)	Plate	6.3–12.5	(0.250–0.499)	290 (42.0)	240 (35.0)	10	-	10
		12.5–25.0	(0.500–1.000)	290 (42.0)	240 (35.0)	-	8	9
		25.0–50.0	(1.001–2.000)	290 (42.0)	240 (35.0)	-	7	8
		50.0–80.0	(2.001–3.000)	290 (42.0)	240 (35.0)	-	5	6

Notes:

- 1 Type of test specimen used depends on thickness of material; (See 2-5-5/5).
- 2 (2011) Values applicable to long transverse test specimens.
- 3 (2011) These properties apply to samples of material, which are solution heat treated or solution and precipitation treated from O or F temper by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.
- 4 For stress-relieved tempers, characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.
- 5 Upon artificial aging, T451 temper material is to be capable of developing the mechanical properties applicable to the T651 temper.
- 6 (2011) Use of the latest ASTM B209/209M specification may be approved upon application.

TABLE 3
Longitudinal Mechanical Property Limits of Non-Heat-Treatable Aluminum Alloys
for Extruded Bars, Rods, Shapes, and Tubes ^(2, 3) (2011)

Mechanical test specimens are taken as detailed in 2-5-5/5 or as specified in ASTM B 557/557M.

Alloy and Temper	Maximum Diameter or Thickness ⁽¹⁾		Maximum Area		Ultimate Tensile Strength N/mm ² (ksi)		Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in		
	mm	(in.)	mm ²	(in ²)	minimum	maximum	N/mm ² (ksi)	50 mm	5d	2 in. /4d
5059-H112	50	(2.0)	---	---	330 (48.0)	---	200 (29.0)	-	10	10
5083-O ⁽⁴⁾	130.0	(5.0)	20000	(32)	270 (39.0)	350 (51.0)	110 (16.0)	14	12	14
5083-H111 ⁽⁴⁾	130.0	(5.0)	20000	(32)	275 (40.0)		165 (24.0)	12	10	12
5083-H112 ⁽⁴⁾	130.0	(5.0)	20000	(32)	270 (39.0)		110 (16.0)	12	10	12
5086-O ⁽⁴⁾	130.0	(5.0)	20000	(32)	240 (35.0)	315 (46.0)	95 (14.0)	14	12	14
5086-H111 ⁽⁴⁾	130.0	(5.0)	20000	(32)	250 (36.0)		145 (21.0)	12	10	12
5086-H112 ⁽⁴⁾	130.0	(5.0)	20000	(32)	240 (35.0)		95 (14.0)	12	10	12
5383-O	50	(2.0)	---	---	290 (42.0)	---	145 (21.0)	17	17	17
5383-H111	50	(2.0)	---	---	290 (42.0)		145 (21.0)	17	17	17
5383-H112	50	(2.0)	---	---	310 (45.0)		190 (27.5)	-	13	13
5456-O ⁽⁴⁾	130.0	(5.0)	20000	(32)	285 (41.0)	365 (53.0)	130 (19.0)	14	12	14
5456-H111 ⁽⁴⁾	130.0	(5.0)	20000	(32)	290 (42.0)		180 (26.0)	12	10	12
5456-H112 ⁽⁴⁾	130.0	(5.0)	20000	(32)	285 (41.0)		130 (19.0)	12	10	12

Notes:

- 1 Type of test specimen used depends on thickness of material; (see 2-5-5/5.)
- 2 (2011) Values applicable to longitudinal test specimens.
- 3 (2011) Use of the latest ASTM B221/221M specification may be approved upon application.
- 4 (2011) Properties not applicable to extruded tube over 70 mm (2.999 inch) wall thickness.

TABLE 4
Mechanical Property Limits of Heat-Treatable Aluminum Alloys
for Extruded Products ^(2, 6) (2011)

Mechanical test specimens are taken as detailed in 2-5-5/5 as specified in ASTM B 557/557M.

Alloy and Temper	Diameter or Thickness ⁽¹⁾		Area	Ultimate Tensile Strength N/mm ² (ksi)	Yield Strength 0.2% Offset N/mm ² (ksi)	Minimum Elongation Percent in		
	millimeters over - through	(inches)	mm ² /in ²	minimum	minimum	50 mm	5d	2 in. /4d
6005A-T5	3.0–6.3 6.3–50.0	(0.118–0.249) (0.250–2.000)	All	260 (38.0) 260 (38.0)	215 (31.0) 215 (31.0)	7 9	- 8	7 9
6005A-T6	3.0–10.0 10.0–50.0	(0.118–0.400) (0.401–2.000)	All	260 (38.0) 260 (38.0)	215 (31.0) 200 (29.0)	8 8	- 6	8 8
6005A-T61	3.0–6.3 6.4–25.0	(0.118–0.249) (0.250–0.999)	All	260 (38.0) 260 (38.0)	240 (35.0) 240 (35.0)	8 10	- 9	8 10
6061-T4/T4511 ^(4,5)	All	All	All	180 (26.0)	110 (16.0)	16	14	16
6061-T6 ^(4,5) , -T62 ⁽³⁾ and -T6511 ^(4,5)	3.0–6.3 6.3 and over	(0.118–0.249) (0.250 and over)	All	260 (38.0) 260 (38.0)	240 (35.0) 240 (35.0)	8 10	- 9	8 10
6063-T6, -T62 ⁽³⁾	3.0–3.2 3.2–25.0	(0.118–0.124) (0.125–1.000)	All	205 (30.0) 205 (30.0)	170 (25.0) 170 (25.0)	8 10	- 9	8 10
6082-T5	3.0–50.0	(0.118–2.000)	All	270 (39.0)	230 (33.0)	8	6	8
6082-T6, -T6511	3.0–5.0 5.0–50.0 50.0–150.0	(0.118–0.199) (0.200–2.000) (2.001–6.000)	All	290 (42.0) 310 (45.0) 310 (45.0)	250 (36.0) 260 (38.0) 260 (38.0)	6 10 -	- 8 8	6 10 8

TABLE 4 (continued)
Mechanical Property Limits of Heat-Treatable Aluminum Alloys
for Extruded Products ^(2, 6) (2011)

Notes:

- 1 Type of test specimen used depends on thickness of material; (see 2-5-5/5.)
- 2 (2011) Values applicable to longitudinal test specimens.
- 3 (2011) These properties apply to samples of material, which are solution heat treated or solution and precipitation treated from O or F temper by the producer to determine that the material will respond to proper heat treatment. Properties attained by the user, however, may be lower than those listed if the material has been formed or otherwise cold or hot worked, particularly in the annealed temper, prior to solution heat treatment.
- 4 For stress-relieved tempers, characteristics and properties other than those specified may differ somewhat from the corresponding characteristics and properties of material in the basic temper.
- 5 Upon artificial aging, T4 and T4511 temper material are to be capable of developing the mechanical properties applicable to the T6 and T6511 tempers, respectively.
- 6 (2011) Use of the latest ASTM B221/221M specification may be approved upon application.

TABLE 5
Mechanical Property Limits for Die Forgings ⁽³⁾ (2011)

Alloy and Temper	Thickness	Specimen Axis Parallel to Direction of Grain Flow						Specimen Axis Not Parallel to Direction of Grain Flow					
		Minimum Ultimate Tensile Strength	Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in ⁽⁴⁾			Minimum Ultimate Tensile Strength	Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in ⁽⁴⁾				
		N/mm ² (ksi)	N/mm ² (ksi)	50 mm	5d	2 in. /4d	N/mm ² (ksi)	N/mm ² (ksi)	50 mm	5d	2 in. /4d		
5083-H111	to 100 (4)	290 (42.0)	150 (22.0)	14	12	14	270 (39.0)	140 (20.0)	12	10	12		
5083-H112	to 100 (4)	275 (40.0)	125 (18.0)	16	14	16	270 (39.0)	110 (16.0)	14	12	14		
5456-H112 ⁽¹⁾	to 100 (4)	303 (44.0)	140 (20.0)	16	16	16							
6061-T6	to 100 (4)	260 (38.0)	240 (35.0)	7 ⁽²⁾	6 ⁽²⁾	7 ⁽²⁾	260 (38.0)	240 (35.0)	5	4	5		

Notes:

- 1 (2011) Alloy 5456 is not covered in ASTM B247/247M, but use of such forgings meeting these requirements may be considered.
- 2 (2010) When sample is selected from a separately-forged test coupon, an elongation minimum of 10% applies.
- 3 (2011) Use of the latest ASTM B247/247M Specification may be approved upon application.
- 4 (2011) Elongation values apply to test specimens taken from an actual forging or its prolongation.

TABLE 6
Mechanical Property Limits for Hand Forgings ^(2, 3) (2011)

Alloy and Temper	Thickness	Axis of Test Specimen	Minimum Ultimate Tensile Strength	Minimum Yield Strength 0.2% Offset	Minimum Elongation Percent in	
	mm (in.)		N/mm ² (ksi)	N/mm ² (ksi)	5d	4d
5083-H111	to 100 (4)	Longitudinal Long transverse	290 (42.0) 270 (39.0)	150 (22.0) 140 (20.0)	12 10	14 12
5083-H112	to 100 (4)	Longitudinal Long transverse	275 (40.0) 270 (39.0)	125 (18.0) 110 (16.0)	14 12	16 14
5456-H112 ⁽¹⁾	to 75 (3)	Longitudinal Long transverse	305 (44.0) 290 (42.0)	140 (20.0) 125 (18.0)	16 14	16 14
6061-T6/-T652	to 100 (4)	Longitudinal	260 (38.0)	240 (35.0)	9	10
		Long transverse	260 (38.0)	240 (35.0)	7	8
		Short transverse ⁽²⁾	255 (37.0)	230 (33.0)	4	5
6061-T6/-T652	over 100 (4) to 200 (8)	Longitudinal	255 (37.0)	235 (34.0)	7	8
		Long transverse	255 (37.0)	235 (34.0)	5	6
		Short transverse	240 (35.0)	220 (32.0)	3	4

Notes:

- (2011) Alloy 5456 is not covered in ASTM B247/247M, but use of such forgings meeting these requirements may be considered.
- Requirement applicable to thicknesses of 50 mm (2 in.) and greater.
- (2011) Use of the latest ASTM B247/247M Specification may be approved upon application.

TABLE 7
Mechanical Property Limits for Aluminum Alloy Castings (2011)

AA Aluminum Association

Alloy	Temper	Casting	Minimum Ultimate Tensile Strength	Minimum Yield Strength 0.20% Offset	Minimum Elongation in 50 mm (2 in.)
AA			N/mm ² (ksi)	N/mm ² (ksi)	percent
356.0	T6	Sand	205 (30.0)	140 (20.0)	3
		Permanent mold	228 (33.3)	152 (22.0)	3
A356.0	T6 T61	Sand	235 (34.0)	165 (24.0)	3.5
			245 (35.0)	180 (26.0)	1.0
A356.0	T61 Separately cast coupons	Permanent mold	262 (38.0)	179 (26.0)	5
	T61 Integral coupons		230 (33.3)	179 (26.0)	5
357.0	T6	Permanent mold	310 (45.0)		3

TABLE 8
Aluminum Alloy Equivalents

AA	Aluminum Association	BS	British Standard
ASTM	American Society for Testing and Material	UNI	Unificazione Nazionale Italiana
CSA	Canadian Standards Association	JIS	Japanese Industrial Standard
NF	Normes Francaises	ISO	International Organization for Standardization

The equivalents are approximate based on the best available information. The actual specification or standard should be consulted for full information.

<i>U.S. ASTM, AA</i>	<i>Canada CSA</i>	<i>France NF</i>	<i>U.K. BS</i>	<i>Italy UNI</i>	<i>Japan JIS</i>	<i>ISO</i>
5052	GR20		2L, 55, 2L, 56, L80, L81	PA1Mg2.5	A2-1	A1Mg2.5Mn
5083	GM41, E54S*		N8		A2-7	A1Mg4.5Mn
5086		AG4MC				A1Mg4
5454	GM31N, 55330*					A1Mg3Mn
5456			N61			
6061	GS11N		H20		A2-4	A1Mg1SiCu

Note:

* Commercial designations.

PART

2

CHAPTER 5 Materials for Hull Construction – Aluminum

SECTION 6 Corrosion Testing

1 General (2011)

Rolled 5xxx-alloys delivered in H116 and H321 tempers (as listed in 2-5-5/Table 1B) intended for use in marine hull construction or in marine applications where frequent direct contact with seawater is expected are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance as per requirements of this Section and ASTM B 928/928M. These alloys should not be used for service which provides prolonged exposure (continuous or discontinuous) to temperatures exceeding 65°C (150°F) because of the risk of sensitization and the resulting susceptibility to intergranular corrosion and stress corrosion cracking.

The alloy grades of the 6000 series should not be used in direct contact with seawater unless protected by anodes and/or paint system.

3 Reference Photomicrograph (2011)

The manufacturers shall establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500× [using 40% phosphoric acid etch for 3 minutes at 35°C (50°F)], shall be established for each of the alloy-tempers and thickness ranges relevant. The reference photographs shall be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET). The samples shall also have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm², when subjected to the test described in ASTM G67 (NAMLT). Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by ABS. Production practices shall not be changed after approval of the reference micrographs.

Other recognized test methods may also be accepted at ABS's discretion.

5 Batch Microstructural Analysis and Acceptance (2011)

For batch acceptance of 5xxx-alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate may be carried out, provided that surveillance testing as stated in 2-5-6/7 is performed. The microstructure of the sample is to be compared to the reference photomicrograph [taken at 500× after 3 minutes etch in phosphoric acid at 35°C (50°F)] of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface shall be prepared for metallographic examination. If the microstructure shows evidence of continuous grain boundary network of aluminum-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation-corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. If the results from testing satisfy the acceptance criteria stated in 2-5-6/3 the batch is accepted, else it is to be rejected.

As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 or equivalent standards and accepted if the results satisfy the acceptance criteria stated in 2-5-6/3.

7 Surveillance of Corrosion Testing (2011)

The manufacturer shall perform, each quarter or after any process change, at least one test for exfoliation corrosion resistance and one test for intergranular corrosion resistance, in accordance with ASTM G66 and G67 or equivalent standards for each approved alloy grade. The manufacturer shall maintain records of all surveillance test results and make them available to the Surveyor for product certification.

PART

2

CHAPTER 5 Materials for Hull Construction – Aluminum

SECTION 7 Sheet, Plate and Rolled Products

1 Scope

The following requirements cover non-heat-treatable and heat-treatable aluminum alloys for sheet plate, and rolled products intended to be used in hull construction.

3 Selection of Tension Test Specimen (2011)

For rolled products, test samples are taken at one-third of the width from the longitudinal edge. Tension test specimens for non-heat-treatable rolled products are to be taken in the longitudinal direction. For heat-treatable rolled products, generally tests in the long transverse direction are required. If the width is insufficient to obtain long transverse test specimens, and when specified, tests in the longitudinal direction may be permitted. Short transverse testing, when specified, is only applicable to plate having a specified thickness of 40 mm (1.500 in.) or greater. The standard rectangular tension test specimen shown in 2-5-5/Figure 1 is to be used for sheet and plate less than 12.5 mm (0.5 in.) in thickness. For plate 12.5 mm (0.5 in.) and greater in thickness, the round tension test specimen shown in 2-5-5/Figure 1 is to be used. The tension test specimen is to be taken midway between the two plate surfaces for plate in thicknesses of 12.5 mm (0.5 in.) up to 40 mm (1.57 in.). For plate over 40 mm (1.57 in.) in thickness, the specimen shall be taken midway between the center and surface of the plate.

After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation is maintained.

5 Number of Tension Tests

Tension test specimens are to be selected as follows.

5.1 Sheet

For sheet under 6.3 mm (0.25 in.) in thickness, one tensile test specimen is to be taken from one random sheet representative of 900 kg (2000 pounds) or fraction thereof in each batch.

5.3 Plate and Rolled Products

For plate and rolled products 6.3 mm (0.25 in.) and over in thicknesses, one tensile test specimen is to be taken from each batch of the product. If the weight of one batch exceeds 2000 kg (4410 lb), or fraction thereof, one extra tensile test specimen is to be taken from every 2000 kg (4410 lb) or fraction thereof, in each batch.

For single plates or coils weighing more than 2000 kg (4410 lb) each, only one tensile test specimen per plate or coil is to be taken.

5.5 Definition of a Batch

The term batch applies to products if they are all:

- The same alloy grade from the same cast;
- The same product form and similar dimensions (for plates, the same thickness);
- Manufactured by the same process, and;
- Submitted simultaneously to the same temper condition.

7 Surface Finish

The material is to be free from injurious defects and have a workmanlike finish. It is to be surface inspected at the mill by the Surveyors only when specifically requested and so ordered by the purchaser.

9 Nondestructive Examination (NDE)

In general NDE of material is not required for acceptance purposes.

However, the manufacturer is expected to employ suitable methods of NDE for maintaining compliance with quality standards.

11 Dimensions and Tolerance

It is the Manufacturer's responsibility to check dimensions and to comply with the following tolerance requirements.

Under-thickness for rolled products are given in 2-5-7/Table 1. Dimensional tolerances other than under-thickness tolerance are to comply with a recognized national or international standard.

TABLE 1
Under-thickness Tolerance for Rolled Products

Nominal Thickness (<i>t</i>), mm	Thickness Tolerances for Nominal Width (<i>w</i>), mm		
	$w \leq 1500$	$1500 < w \leq 2000$	$2000 < w \leq 3500$
$3.0 \leq t < 4.0$	0.10	0.15	0.15
$4.0 \leq t < 8.0$	0.20	0.20	0.25
$8.0 \leq t < 12.0$	0.25	0.25	0.25
$12.0 \leq t < 20.0$	0.35	0.40	0.50
$20.0 \leq t < 30.0$	0.45	0.50	0.65

PART

2

CHAPTER 5 Materials for Hull Construction – Aluminum

SECTION 8 Extrusions

1 Scope

The following requirements cover extruded non-heat-treatable and heat-treatable aluminum alloy products intended to be used in hull construction.

3 Selection of Specimens

For extruded products tension test specimens are to be taken in the range $\frac{1}{3}$ to $\frac{1}{2}$ of the distance from the longitudinal edge to the centre of the thickest part.

Tension test specimens are to be taken in the longitudinal direction and are to be of the full section of the material where practicable. Otherwise, the specimens shown in 2-5-5/Figure 1 are to be used. For material 40 mm (1.57 in.) and less in diameter or thickness, the specimen is to be taken from the center of the section. For material greater than 40 mm (1.57 in.) in thickness or diameter the specimen is to be located midway between the center and an edge.

After removal of test samples, each test specimen is to be marked in order that its original identity, location and orientation are maintained.

5 Number of Tests

5.1 Tension Tests

For the products with a nominal weight of less than 1 kg/m (0.7 lb/ft), one tensile test specimen is to be taken from each 1000 kg, (2205 lb) or fraction thereof, in each batch. For nominal weights between 1 and 5 kg/m (0.7 and 3.5 lb/ft), one tensile test specimen is to be taken from each 2000 kg (4410 lb) or fraction hereof, in each batch. If the nominal weight exceeds 5 kg/m (3.5 lb/ft), one tensile test specimen is to be taken for each 3000 kg (6615 lb) of the product or fraction thereof, in each batch.

5.3 Drift Expansion Tests

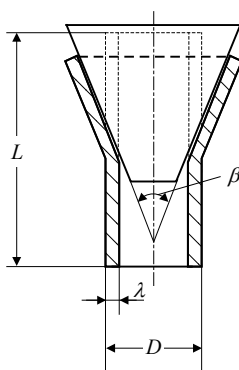
The Manufacturer is to demonstrate by macrosection tests or drift expansion tests of closed profiles performed on each batch of closed profiles that there is no lack of fusion at the press welds.

5.3.1 Drift Expansion Tests (2008)

- Every fifth profile shall be sampled after final heat treatment.
- Batches of five profiles or less shall be sampled one profile.
- Profiles with lengths exceeding 6 m shall be sampled every profile in the start of the production.
- The number of tests may be reduced to every fifth profile if the results from the first 3-5 profiles are found acceptable.
- Each profile sampled will have two samples cut from the front and back end of the production profile.
- The test specimens are to be cut with the ends perpendicular to the axis of the profile.

- The edges of the end may be rounded by filing.
- The length of the specimen is to be in accordance with 2-5-8/Figure 1 or recognized standard such as ISO 8493.
- Testing is to be carried out at ambient temperature and is to consist of expanding the end of the profile by means of a hardened conical steel mandrel having an included angle of at least 60°.
- The sample is considered to be unacceptable if the sample fails with a clean split along the weld line, which confirms lack of fusion.
- The entire batch of closed profiles (press welded) being tested is to be rejected if the sampled profile fails during drift expansion test. However, each profile in the rejected batch may be tested individually and accepted if it passes the test.

FIGURE 1
Drift Expansion Test



Notes

- 1 L equal to twice the external diameter D of the tube if the angle of the drift is 30°, and L equal to $1.5D$ if the angle of the drift is 45° or 60°.
- 2 The test piece may be shorter provided that after testing the remaining cylindrical portion is not less than $0.5D$.
- 3 The rate of penetration of the mandrel shall not exceed 50 mm/min.

5.5 Definition of a Batch

The term batch applies to products if they are all:

- The same alloy grade from the same cast;
- The same product form and similar dimensions (for plates, the same thickness);
- Manufactured by the same process, and;
- Submitted simultaneously to the same temper condition.

7 Surface Finish

The material is to be free from injurious defects and have a workmanlike finish. It is to be surface inspected at the mill only when specifically requested and so ordered by the purchaser.

9 Nondestructive Examination (NDE)

In general NDE of material is not required for acceptance purposes.

However, the manufacturer is expected to employ suitable methods of NDE for maintaining compliance with quality standards.

11 Dimensions and Tolerance

It is the Manufacturer's responsibility to check dimensions and to comply with the following tolerance requirements:

Under-thickness tolerances for extruded products are to be in accordance with recognized national or international standards.

Dimensional tolerances other than under-thickness tolerance are to comply with recognized national or international standards.