Designation: B432 – 14

Standard Specification for Copper and Copper Alloy Clad Steel Plate[1]

This standard is issued under the fixed designation B432; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification establishes the requirements for plate of a carbon steel or low-alloy steel base to which is integrally and continuously bonded on one or both sides a layer of copper or copper-base alloy. The material is generally intended for pressure vessel use but may be used in other structural applications where corrosion resistance or conductivity of the alloy is of prime importance.

1.2 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A6/A6M Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

B96/B96M Specification for Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes and Pressure Vessels

B152/B152M Specification for Copper Sheet, Strip, Plate, and Rolled Bar

B171/B171M Specification for Copper-Alloy Plate and Sheet for Pressure Vessels, Condensers, and Heat Exchangers

B846 Terminology for Copper and Copper Alloys

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *ASME Code:*[3]

Boiler and Pressure Vessel Code, Section VIII

Boiler and Pressure Vessel Code, Section IX

3. Terminology

3.1 For definitions of terms related to copper and copper alloys, refer to Terminology B846.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *base metal (backing steel), n*—component to which the cladding metal is applied, usually the greater percentage of the composite plate and usually consisting of carbon or low-alloy steel.

3.2.2 *blind flange, n*—same as a cover.

3.2.3 *bonding, n*—adhesion of one surface to another without the use of an adhesive as a bonding agent.

3.2.4 *cladding metal, n*—the copper or copper-base alloy component of the composite plate.

3.2.5 *cover, n*—a component with similar features to a tubesheet which is used as a closure and which typically requires surface machining over part of the face while maintaining minimum specified minimum thickness.

3.2.6 *double-clad, n*—material is considered as double-clad when both sides of the steel base metal are covered with copper cladding.

3.2.7 *interface, n—of the clad product*, is that region of the thickness in which the product transitions from essentially 100 % base metal to 100 % cladding metal, also referred to as the bond or bondzone.

3.2.8 *integrally and continuously bonded, adv*—a condition in which the cladding metal and base metal are brought together to form a metallurgical bond at essentially the entire interface of the two metals by means other than those processes that do not produce a homogeneous composite plate.

3.2.9 *plate, n*—the term plate as used in this specification applies to material 0.188 in. (4.78 mm) and over in thickness, and over 10 in. (254 mm) in width.

[1] This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.01 on Plate, Sheet, and Strip.

Current edition approved Sept. 1, 2014. Published November 2014. Originally approved in 1966. Last previous edition approved in 2009 as B432 – 09a. DOI: 10.1520/B0432-14.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

***A Summary of Changes section appears at the end of this standard**

3.2.10 *single-clad, n*—material is considered as single-clad when only one side of the steel base metal is covered with copper cladding.

3.2.11 *tubesheet, n*—the term tubesheet as used in this specification applies to a clad plate, which is used in a heat exchanger to separate the tubeside and shell side components. Typically, but not necessarily, tubesheets are round, relatively thick, and require that the cladding and/or base be machined flat over part or all of the face while maintaining specified minimum thicknesses.

4. Ordering Information

4.1 Include the following specified choices when placing orders for product under this specification, as applicable:

4.1.1 ASTM designation and year of issue,

4.1.2 Dimensions, including the thickness of the cladding alloy and the backing steel, or of the total composite plate, and if more or less restrictive thickness tolerances apply,

4.1.3 Quantity—total weight or number of pieces of each size.

4.1.4 Cladding metal specification (see Section 6),

4.1.5 Base metal specification (see Section 6),

4.1.6 Advise if the part is to be used as a tubesheet, cover, or blind flange,

4.1.7 Restrictions, if required, on repair by welding (see Section 11).

4.2 The following options are available but may not be included unless specified at the time of placing of the order when required:

4.2.1 Shear testing requirements if any (see Sections 7 and 8).

4.2.2 Certification,

4.2.3 Test Report,

4.2.4 Options presented in the Supplementary Requirements Section of this specification,

4.2.5 Additions to the specification or special requirements,

4.2.6 The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specifications A20/A20M or A6/A6M as applicable. If the requirements of this specification are in conflict with the requirements of Specifications A20/A20M or A6/A6M, the requirements of this specification shall prevail.

5. Materials and Manufacture

5.1 *Materials:*

5.1.1 The base metal shall be manufactured in accordance with all applicable requirements of the base metal specifications (see 4.1.5).

5.1.2 The cladding metal shall be manufactured in accordance with all applicable requirements of the cladding metal specifications (see 4.1.4).

5.2 *Manufacture:*

5.2.1 The cladding metal shall be bonded to the base metal by any cladding operation that will produce a clad product which will conform to the requirements of this specification. Cladding methods are, but not limited to, explosion bonding, roll bonding, and weld overlay.

5.2.2 The cladding metal may be fabricated from multiple sheets or plates by edge butt welding prior to the cladding operation.

5.2.3 The cladding thickness may consist of multiple layers of the cladding metal.

5.3 *Heat Treatment*—Unless otherwise specified or agreed between the purchaser and the manufacturer, all heat treatments shall be performed as needed in the cladding operation to assure the following:

5.3.1 The cladding metal conforms to the applicable requirements of the cladding metal specification.

5.3.2 The base metal conforms to the applicable requirements of the base metal specification, and

5.3.3 The clad bond exhibits optimum resistance to disbonding during common fabrication processes.

6. Chemical Composition

6.1 The clad plate shall conform to any combination of base metal and cladding metal as described in 6.2 and 6.3, and as agreed upon between the purchaser and the manufacturer.

6.2 *Base Metal*—The base metal may be carbon steel or low-alloy steel conforming to the ASTM specifications for steels for either pressure vessels or general structural applications, or other, as agreed upon by the purchaser and manufacturer. The base metal shall conform to the chemical requirements of the specification to which it is ordered.

6.3 *Cladding Metal*—The copper or copper alloy cladding metal specified shall conform to the requirements as to chemical composition prescribed in the respective cladding metal Specifications B96/B96M, B152/B152M, or B171/B171M, or other copper-base alloy specification as agreed upon by the purchaser and manufacturer.

7. Mechanical Requirements

7.1 *Tensile Property Requirements:*

7.1.1 Tensile tests shall be performed on the base metal only.

7.1.2 Tensile tests shall conform to the requirements of the Base Metal Specification.

8. Performance Requirements

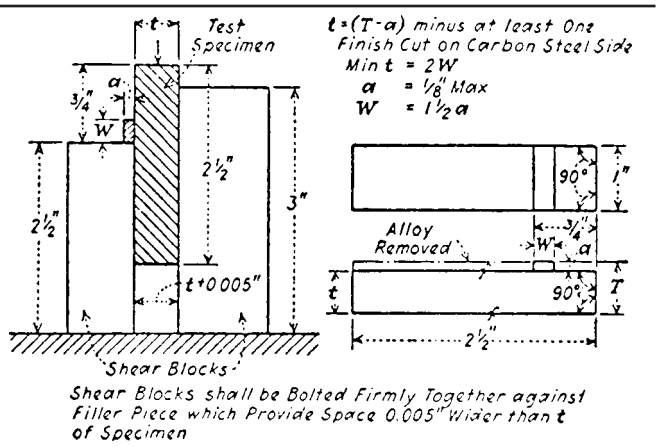
8.1 *Bond Strength Requirements:*

8.1.1 *Shear Strength Test:*

8.1.1.1 When specified in the contract or purchase order, the minimum shear strength of the interface shall be 12 000 psi (84 MPa). The shear test shall be made in the manner indicated in Fig. 1. The shear test is not applicable when the specified minimum cladding thickness is 0.075 in. (1.9 mm) or less.

8.1.2 *Alternate Bond Strength Test:*

8.1.2.1 As an alternative to the shear strength test provided in 8.1.1 or when agreed upon by the purchaser and the manufacturer, three bend tests shall be made with the alloy cladding in compression to determine the quality of the bond. These bend tests shall be made using 1.5 in (38 mm) wide by full thickness specimens and shall be bent through an angle of 180° to the bend diameters provided for in either Specification A6/A6M or Specification A20/A20M, in Appendix X4 or



SI Equivalents

in.	mm	in.	mm
0.005	0.127	1	25.4
⅛	3.18	2½	63.5
¾	19.1	3	76.2

FIG. 1 Test Specimen and Method of Making Shear Test of Clad Plate

equivalent, as applicable. At least two of the three tests shall show not more than 50 % separation on both edges of the bent portion. Greater separation shall be cause for rejection. The bond strength bend test is generally not recommended for cladding thicknesses where the shear test is applicable.

8.2 Additional mechanical tests may be performed. See Supplementary Requirements.

9. Dimensions and Permissible Variations

9.1 Unless otherwise specified herein, permissible variations except for thickness shall be in accordance with Specifications A20/A20M or A6/A6M as applicable based on the base metal specification.

9.2 Minimum thickness of the alloy cladding metal and of the backing steel, or of the total composite plate, shall be as required by purchase order documents when ordered to minimum thickness.

9.3 Permissible variation in thickness when ordered to nominal thicknesses shall be 0.01 in. (0.25 mm) under each for backing steel or total composite, and 0.03 in. (0.76 mm) under for the alloy cladding.

9.4 Permissible variations for excess thickness of the total composite shall be the greater of 0.125 in. (3.2 mm) or 10 % of the total composite thickness ordered and may occur in either backing steel, cladding, or both, provided the minimum for each is met.

9.5 When the product is specified for use as tubesheets, covers, or blind flanges in the ordering information, the flatness tolerances of Table 1 shall apply, otherwise flatness shall be in accordance with Specifications A20/A20M or A6/A6M as applicable based on the base metal specification.

9.6 When the product is specified for use as tubesheets, covers, or blind flanges in the ordering information and a machined edge condition is specified, the diameter tolerances of Table 2 shall apply.

9.7 More restrictive or less restrictive permissible variations may be agreed upon by the purchaser and the manufacturer.

10. Workmanship, Finish and Appearance

10.1 The product shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable.

10.2 Unless otherwise specified, the clad surface may be supplied as-rolled, ground, blasted (descaled by means of sand, grit, shot or wire followed by pickling), or 100 % conditioned.

10.3 The cladding metal shall be integrally and continuously bonded to the base metal.

11. Sampling

11.1 The lot size, portion size, and selection of sample pieces shall be taken according to the base metal specifications.

11.2 *Chemical Analysis*—A sample for chemical analysis from the finished clad product shall not be taken unless specified in the contract or purchase order. The copper sheet or strip that is used as the cladding for this product is to be sampled and tested as prescribed in its product specification (See 6.3). The steel plate that is used as the base metal in this product is to be sampled and tested as prescribed in either Specifications A20/A20M or A6/A6M.

12. Number of Tests and Retests

12.1 *Test:*

12.1.1 *Chemical Analysis*—When specified in the contract or purchase order that a chemical analysis shall be performed on the cladding metal, the base metal, or both, the tests shall be

TABLE 1 Flatness Tolerances for Tube Sheets, Clad One Side Only[A]

Total Thickness, in. (mm)	Maximum Deviation from True Flatness[B] for a Given Diameter, Width, or Length, in. (mm)				
	To 48 (1219)	Over 48 (1219) to 72 (1829)	Over 72 (1829) to 96 (2438)	Over 96 (2438) to 120 (3048)	Over 120 (3048)
To 2½ (63.5)	⅛ (3.18)	⅛ (3.18)	3/16 (4.76)	¼ (6.35)	½ (12.7)
Over 2½ (63.5) to 4 (102)	⅛ (3.18)	⅛ (3.18)	¼ (6.35)	½ (12.7)	½ (12.7)
Over 4 (102) to 6 (152)	⅛ (3.18)	¼ (6.35)	⅜ (9.52)	½ (12.7)	½ (12.7)
Over 6 (152) to 8 (203)	3/16 (4.76)	⅜ (9.52)	½ (12.7)	½ (12.7)	½ (12.7)

[A] Two side clads by special arrangement.

[B] Measured distance from an imaginary plane representing the best fit to the part surface. Measurement methods may include, but are not limited to, planar grids, planar redial wheels, setup on a machining table, or laser surveying.

TABLE 2 Outside Diameter Tolerances for Tubesheets, Covers, or Blind Flanges when a Machined OD is Specified

Diameter	Tolerance, ±
Under 60 in. (1.52 m)	0.06 in. (1.5 mm)
60.0 to 84.0 in. (1.52 to 2.14 m)	0.12 in. (3.2 mm)
>84.0 in. (>2.13 m)	0.25 in. (6.4 mm)

performed in accordance with the applicable requirements of the Cladding Metal or Base Metal Specifications, or both.

12.2 *Other Tests:*

12.2.1 *Tensile Test*—One or more tension tests, as required by the base metal specification, and when specified, one shear test or three bond strength bend tests, as applicable, shall be made, representing each manufacturing lot. Each specimen shall be in the final condition of heat treatment required for the plate, including any SPWHT (Simulated Post Weld Heat Treatment) if required, Supplementary Requirement S3.

12.3 *Retests:*

12.3.1 When requested by the manufacturer or supplier, a retest shall be permitted when results of test obtained by the purchaser or supplier fail to conform to the requirements of the product specification.

12.3.2 The retest shall be as directed in the product specification for the initial test except that the number of test specimens shall be twice that normally required for the specified test.

12.3.3 Test results for all specimens shall conform to the product specification requirements in retest. Failure to conform shall be cause for rejection.

13. Specimen Preparation

13.1 *Chemical Analysis:*

13.1.1 Chemical Analysis may be performed on the cladding metal, the base metal, or both, as specified in the contract or purchase order.

13.1.2 When chemical analysis is specified for the cladding alloy on finished product, the analysis may be accomplished by wet chemical or instrumental procedures. If wet chemical procedures are used, millings may be taken only when the composite plate thickness is sufficient to permit obtaining millings without danger of contamination from the adjacent layer. If spectrometric procedures are used, the sample shall be exposed on the center line of the cladding when there is sufficient cladding thickness available so that there is no contamination from the adjacent base metal.

13.1.3 If chemical analysis is specified by the purchaser for the cladding alloy, it shall be made on a sample taken from the finished product or a broken test specimen. For wet chemical analysis, in order to avoid contamination by the base plate metal, millings of cladding samples shall be taken from the test coupon by removal and discard of all the base metal plus 40 % of the cladding thickness from the bonded side, not to exceed 0.063 in. (1.6 mm). The material shall be cleaned and sufficient millings taken to represent the full cross-section of the remainder.

13.1.4 The results of the chemical analysis shall conform to the requirements of the cladding metal and base metal specifications, as applicable.

13.2 *Tensile Strength:*

13.2.1 The test specimen shall be prepared in accordance with the requirements prescribed in the specifications for the base metal.

13.2.2 When required by the purchaser, the shear test specimen shall be taken near a top or bottom corner of the plate as rolled, parallel to its longitudinal axis, or other location that is representative of the final product.

13.2.3 Bend test specimens for the alternative bond strength tests shall be taken at right angles to its longitudinal axis.

14. Test Method

14.1 *Shear Test:*

When specified in the contract or purchase order the product furnished shall conform to the shear test requirements in accordance with 8.1 or 8.2.

15. Significance of Numerical Limits

15.1 For purposes of determining compliance with the specified limits for requirements listed in the following table and for dimensional tolerances, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E29.

Property	Rounded Unit for Observed or Calculated Value
Shear Strength	Nearest ksi [5 MPa]

16. Inspection

16.1 All plates shall be inspected for bond integrity prior to shipment,

16.1.1 When mutually agreed upon between the purchaser and the manufacturer, either visual or ultrasonic inspection shall be used when the total plate thickness is less than 0.375 in. (9.525 mm). When plate total thickness is 0.375 in. (9.525 mm) or greater, the ultrasonic inspection method shall be performed. Ultrasonic inspection shall be in accordance with 16.2. The extent of examination shall be at the discretion of the manufacturer and sufficient to provide the quality level in 16.2 specified by the purchaser.

16.1.2 Ultrasonic inspection shall be in accordance with the procedures and methods of Specification A578/A578M. For purposes of defining non-bond, the cladding shall be interpreted to be non-bonded when there is complete loss of back reflection accompanied by an echo indication from the plane of the interface of the clad and backing steel. Areas within 1 in. (25.4 mm) of a cut edge on the plate that contain indications exceeding 50 % of the back reflection at the bond interface shall be considered to be non-bonded.

16.1.3 The extent of ultrasonic examination shall be at the discretion of the manufacturer and sufficient to provide the quality level in 16.2 specified by the purchaser. Plates shall be examined with 100 % coverage when Supplementary Requirement S1 is specified.

16.2 *Quality Levels:*

16.2.1 *Class A*—No single unbonded area exceeding 1 in. (25.4 mm) in its longest dimension with total unbonded area not to exceed 1 % of the total clad surface area.

16.2.2 *Class B*—No single unbonded area exceeding 3 in. (76.2 mm) in its longest dimension with total unbonded area not to exceed 3 % of the total clad surface area.

16.2.3 *Class C*—No single unbonded area exceeding 9 $in.^2$ (58 cm^2) with total unbonded area not to exceed 5 % of the total clad surface area.

16.2.4 The Class to be supplied shall be listed on the purchase order. When none has been specified, plates shall be furnished as Class C.

17. Rework of Cladding by Welding

17.1 The material manufacturer may rework defects in cladding by welding provided the following requirements are met:

17.1.1 When specified in the purchase order, prior approval shall be obtained from the purchaser.

17.1.2 The welding procedure and the welders or welding operators shall be qualified in accordance with ASME BPV Code Section IX, as applies to overlays.

17.1.3 The defective area shall be removed, and the area prepared for rework shall be examined by a liquid penetrant method compliant with ASME Code Section VIII, Division 1, Appendix 8, to ensure all defective area has been removed.

17.1.4 The rework weld shall be deposited in accordance with a welding procedure and welding materials suitable for the cladding material. The surface condition of the reworked area shall be restored to a condition similar to the rest of the cladding.

17.1.5 The reworked area shall be examined by a liquid penetrant method in accordance with ASME Code Section VIII, Division 1, Appendix 8.

17.1.6 The location and extent of the weld rework together with the rework procedure and examination results shall be transmitted as a part of the certification.

17.2 The material manufacturer may repair defects in the base metal by welding provided repairs are permitted in the base metal specification and are made in accordance with that specification.

18. Rejection and Rehearing

18.1 *Rejection:*

18.1.1 Product that fails to conform to the specification requirements when tested by the purchaser, or purchaser's agent, shall be subject to rejection.

18.1.2 Rejection shall be reported to the manufacturer, or supplier, promptly. In addition, a written notification of rejection shall follow.

18.1.3 In case of dissatisfaction with results of the test upon which rejection was based, the manufacturer, or supplier, shall have the option to make claim for a rehearing.

18.2 *Rehearing:*

18.2.1 As a result of product rejection, the manufacturer or supplier, shall have the option to make claim for a retest to be conducted by the manufacturer, or supplier, and the purchaser.

18.2.2 Samples of the rejected product shall be taken in accordance with this product specification and subjected to test by both parties using the test method(s) specified in this product specification, or alternately, upon agreement of both parties, an independent laboratory may be selected for the test(s) using the test method(s) specified in this product specification.

19. General Requirements for Delivery

19.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specifications A6/A6M or A20/A20M as appropriate for the backing metal.

19.2 In the event of conflicts between this specification and the general delivery requirement specification for the backing steel, this specification shall apply.

20. Certification

20.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met.

20.2 When specified in the purchase order or contract that product is purchased for ASME Boiler and Pressure Vessel Code applications, certification to this specification is mandatory.

21. Test Report

21.1 When specified in the contract or purchase order, a report of the test results shall be furnished.

22. Product Marking

22.1 Except as specified in 22.2, plates shall be marked in accordance with the requirements of Specifications A6/A6M or A20/A20M for the backing steel as applicable, the cladding alloy designation, and this specification number.

22.2 For double-clad material or for material under 0.375 in. (9.5 mm) nominal in thickness or for clad plates provided with conditioned surfaces, the marking specified in 22.1 shall be legibly stenciled instead of stamped.

23. Keywords

23.1 bond strength; clad; cladding; clad steel plate; copper; copper-base alloy; steel; tubesheet

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified on the order.

S1. Ultrasonic Inspection of 100 % of Surface

S1.1 Ultrasonic inspection shall be performed with scanning over 100 % of the plate surface.

S2. Product Analysis

S2.1 A product analysis shall be made on either the cladding metal, base metal, or both as specified in the purchase order.

S2.2 Testing shall be in accordance with 12.1.1 unless S2.4 applies.

S2.3 The testing frequency shall be agreed upon between purchaser and manufacturer.

S2.4 Product verification by Positive Metal Identification (PMI) techniques may be used as an alternate to the requirements of 12.1.1 when mutually agreed upon.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons

S3.1 Prior to testing, the test specimens representing the plate for acceptance purposes for mechanical properties shall be thermally treated to simulate a post-weld heat treatment, using the heat treatment parameters (such as temperature range, time, and cooling rates) specified in the order. The test results for such heat-treated test specimens shall meet the applicable product specification requirements.

S4. Charpy V-Notch Impact Test

S4.1 Charpy V-notch impact tests shall be conducted in accordance with Supplementary Requirement S5 of Specifications A6/A6M or A20/A20M, as applicable for the base metal specification.

S5. Ultrasonic Examination of Base Metal for Soundness in Accordance with Specification A578/A578M

S5.1 All plates shall be ultrasonically examined for base metal soundness in accordance with the requirements of Specification A578/A578M. The acceptance level shall be specified in the order.

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which, when applied to a body having a mass of one kilogram, gives it an acceleration of one metre per second squared ($N = kg \cdot m/s^2$). The derived SI unit for pressure or stress is the newton per square metre (N/m^2) which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since 1 ksi = 6 894 757 Pa, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2.

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue (B432 – 09a) that may impact the use of this standard. (Approved Sept. 1, 2014.)

(1) The specification was revised in few sections to comply with the selected wording in Guide B950.