

PRODUCT SPECIFICATION PD103**EXPLOSION CLAD METALS FOR PRESSURE VESSELS****1.0 SCOPE**

This product specification is applicable for DETACLAD Explosion Bonded clad plates, tube sheet blanks, and formed components that are to be used in pressure vessel construction.

2.0 APPLICABLE DOCUMENTS

2.1 **Materials Specifications:** ASTM/ASME, other nationally and/or internationally accepted materials specifications, and/or proprietary specifications that are applicable.

2.2 **Testing Specifications:** ASTM/ASME, , other nationally and/or internationally accepted testing specifications, and/or proprietary specifications that are applicable.

2.3 **Construction Codes:** ASME Boiler and Pressure Vessel Code Sections II, III, V, VIII, and IX and other nationally and/or internationally accepted pressure vessel and construction codes that are applicable.

2.4 **Contract:** The Acknowledged Purchase Contract defining the product requirements as mutually agreed upon between DMC and the Customer.

Table 1. Summary of Standard Testing Options

	QA Level 1	QA Level 2	Section Reference
ASME Tensile Test	100%	100%	3.5.2.3
Ultrasonic Inspection	100%	9" Grid	3.5.1
Min. Sound Bond Area	99.0%	97.0%	3.5.1
Max. Single Nonbond Size	3-in long	9-in sq	3.5.1.2 3.5.1.3
Base Metal UT	100%	Optional	3.5.1.4
Bond Shear Test	100%	Optional	3.5.2.2 Table

Table 2. Optional, Non-standard Tests Available

Test #	Test Type	Section Reference
A-1	Testing to A263, A264, A265 or SA Equivalents	3.5.2.2 3.5.2.3 3.5.2.6
A-2	Ultrasonic Inspection to A578 S7 Level A	3.5.1.1
A-3	Ultrasonic Inspection of Cladding Metal	3.5.1.4
A-4	Shear Wave Ultrasonic Inspection to A577	3.5.1.5
A-5	Base Metal Impact Test	3.5.2.4
A-6	Surface Hardness Tests	3.5.2.5
A-7	Micro Hardness Tests	3.5.2.5
A-8	Bend Tests	3.5.2.6
A-9	Through Thickness Tensile Test	3.10
A-10	Bond Tensile Strength Test	3.10
A-11	Corrosion Testing	3.10
A-12	Penetrant Inspection	3.10
A-13	Magnetic Particle Inspection	3.10
A-14	Positive Material Identification	3.10

3.0 QUALITY REQUIREMENTS

3.1 Component Materials Specifications: Minimally, the component materials of the clad product shall comply with the following requirements of the materials specification defined in the Contract (applicable material specifications).

3.1.1 The cladding metal shall conform to the chemical composition and metallurgical requirements of the applicable material specification.

3.1.2 The base metal shall conform to the chemical composition, mechanical property, and metallurgical requirements of the applicable material specification.

3.2 Quality Assurance: Two, standard Quality Assurance Test Levels are applicable for this Specification. The

level of testing necessary to assure product quality shall be specified in the Contract. The Customer is responsible for assuring that the testing agreed upon is sufficient to ensure that the product quality is adequate for the intended purpose.

QA Level 1 is recommended where product quality is of utmost concern, such as hazardous service environments, or in applications where the bond strength and continuity are highly critical for product performance.

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QA Level 2 is recommended for general clad applications. If the Quality Assurance Level is not specified in the Contract, QA Level 2 shall be applicable.

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Standard testing for each quality level is presented in Table 1. Optional, non-standard testing is summarized in Table 2.

3.3 Product Dimensional Requirements: The product dimensional requirements shall be specified in the Contract. Tolerances on these dimensions shall be as follows:

3.3.1 Thickness:

3.3.1.1 Thickness under-gauge:

3.3.1.1.1 When thickness is specified as minimum, the under-gauge tolerance shall be zero.

3.3.1.1.2 When cladding metal thickness is specified as nominal, the under-gauge tolerance shall be .03” below that permissible in the applicable material specification for plate-gauge cladders and 0.02” below for sheet-gauge cladders.

3.3.1.1.3 When backing metal thickness is specified as nominal, the under-gauge tolerance shall be the minimum that is specified by the applicable material specification, unless stated otherwise in the contract.

3.3.1.2 Thickness over-gauge:

3.3.1.2.1 For cladding metals the thickness over-gauge tolerance shall be 0.125” greater than that permissible for the specified nominal thickness in the applicable material specification.

3.3.1.2.2 For base metals the thickness over-gauge tolerance shall be 0.25” greater than that permissible for the specified nominal thickness in the applicable material specification.

3.3.1.2.3 When the Contract specifies manufacture to the requirements of ASTM/ASME A-263, A-264, or A-265, the over-gauge tolerances of 3.3.1.2.1 and 3.3.1.2.2 shall take precedence over the over-gauge tolerances of the referenced specification shall apply.

3.3.1.3 When the bond zone exhibits a wavy morphology, component metal thickness shall be determined by measurements from the median line of the wavy interface.

3.3.2 Length, width, and diametrical tolerances shall be in accordance with tables 3, 4, and 5. For products not covered in these tables, the tolerances shall be mutually agreed upon.

Table 3. Allowable Variations in Length and Width of Thermally Cut Rectangular Clad Plate

Total Thickness (inches)	Permissible Variation from Specified Length or Width (inches)
<2.0	+0.8, -0.0
≥ 2.0 < 4.0	+1.0, -0.0
≥ 4.0 < 8.0	+1.5, -0.0
≥ 8.0	Tolerance Per Agreement

Table 4. Allowable Variations in Diameter for Clad Tubesheet Blanks with Machined O.D.

Specified Diameter (inches)	Permissible Variation from Specified Diameter (inches)
< 12.0	+0.04, -0.0
≥ 12.0 < 24.0	+0.06, -0.0
≥ 24.0 < 72.0	+0.12, -0.0
≥ 72.0	+0.25, -0.0

Table 5. Allowable Variation in Diameter for Thermally Cut, Circular Tubesheet Blanks.

Total Thickness (inches)	Permissible Variation from Specified Diameter (inches)
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≤ 4.0	+0.8, -0.0
$>4.0, \leq 6.0$	+1.3, -0.0
$>6.0, \leq 8.0$	+1.5, -0.0
>8.0	Tolerance Per Agreement

3.4 Flatness:

3.4.1 Tubesheet blanks:

3.4.1.1. The permissible out-of-flatness shall be in accordance with Table 6 except as noted in 3.4.1.2. Non-circular parts shall be treated as circles of the smallest diameter fully encompassing the part.

3.4.1.2. When it is specified in the Contract that the product shall be suitable for subsequent machining to specified minimum thicknesses, the out-of-flatness of the product plus the thickness provided shall permit machining of the cladder and/or backer face flat without reducing thickness below the minimum specified.

Table 6. Allowable Flatness Variations for Clad Tube Sheet Blanks

Diameter (inches)	Total Nominal Thickness (inches)									
	$\geq 0.375,$ < 1.0	$\geq 1.0,$ < 2.0	$\geq 2.0,$ < 3.0	$\geq 3.0,$ 4.0	$< \geq 4.0,$ < 5.0	$\geq 5.0,$ 6.0	$< \geq 6.0,$ 7.0	$< \geq 7.0,$ 8.0	<	≥ 8.0
< 24	0.125	0.060	0.060	0.125	0.250	0.188	0.188	0.125		*
$\geq 24, < 48$	0.125	0.125	0.125	0.125	0.125	0.250	0.250	0.188		*
$\geq 48, < 60$	0.250	0.125	0.125	0.125	0.125	0.250	0.250	0.250		*
$\geq 60, < 72$	0.250	0.125	0.125	0.125	0.125	0.250	0.375	0.312		*
$\geq 72, < 84$	0.312	0.188	0.125	0.125	0.188	0.375	0.375	0.438		*
$\geq 84, < 96$	0.375	0.250	0.188	0.188	0.250	0.375	0.500	0.625		*
$\geq 96, < 108$	0.500	0.250	0.250	0.250	0.375	0.500	0.500	*		*
$\geq 108, < 120$	0.750	0.250	0.250	0.250	0.438	0.625	*	*		*
$\geq 120, < 132$	0.875	0.312	0.312	0.312	0.500	*	*	*		*
$\geq 132, < 144$	1.000	0.375	0.375	0.375	*	*	*	*		*
$\geq 144, < 156$	1.250	0.375	0.375	0.375	*	*	*	*		*
≥ 156	*	*	*	*	*	*	*	*		*

* To be Agreed between DMC and Customer

Note 1: When circular tube sheet blanks are supplied with machined faces, the out-of-flatness shall not deviate

from a straight edge by more than 0.020" for parts of 60" diameter or less and shall not exceed 0.020" over any 60" span for larger diameters.

3.4.2 Plates: Flatness of clad plates shall be in accordance with Table 7. If ASTM/ASME A-263, A-264, or A-265 is specified in the Contract, flatness shall

be covered by this section in place of the flatness tables of ASTM/ASME A-20.

3.5 Quality Testing:

3.5.1 Ultrasonic Inspection: All DETACLAD products, intended for pressure vessel applications shall be inspected for bond continuity by ultrasonic inspection.

Table 7. Allowable Variations from Flatness for Clad Plate

Specified Total Nominal Thickness (inches)	Maximum Variation from Straight Edge for Specified Widths (inches)										
	≥ 8, < 36	≥ 36, < 48	≥ 48, < 60	≥ 60, < 72	≥ 72, < 84	≥ 84, < 96	≥ 96, < 108	≥ 108, < 120	≥ 120, < 144	≥ 144, < 168	≥ 168
>0.375, ≥0.5	0.75	0.84	0.94	0.94	1.13	1.31	1.50	1.69	1.88	2.81	3.19
>0.5, ≥0.75	0.66	0.75	0.84	0.94	0.94	1.13	1.50	1.50	1.69	2.25	3.00
>0.75, ≥ 1.0	0.66	0.75	0.84	0.94	0.94	0.94	1.13	1.31	1.50	2.06	2.63
>1.0, ≥ 2.0	0.56	0.75	0.75	0.84	0.84	0.94	0.94	0.94	1.03	1.69	2.25
>2.0, ≥ 4.0	0.47	0.56	0.66	0.75	0.75	0.75	0.75	0.84	0.94	1.31	1.69
>4.0, ≥ 6.0	0.56	0.66	0.75	0.75	0.84	0.84	0.94	1.13	1.31	1.31	1.50
>6.0, ≥ 8.0	0.66	0.75	0.75	0.84	1.03	1.13	1.31	1.31	1.50	1.50	1.50
>8.0	To be agreed between DMC and customer										

3.5.1.1 Ultrasonic Inspection Method: The ultrasonic inspection shall be performed using the applicable procedures of ASTM A578. Inspection shall be performed using a 1-1/8" diameter or smaller transducer positioned perpendicular to the material surface being inspected and shall be by direct contact using a suitable fluid couplant. Any condition which causes complete loss of back reflection accompanied by a reflection from the bond interface shall be considered as a recordable non-bond indication.

3.5.1.2 Material produced to QA Level 1, and materials specifically defined as heat exchanger tubesheet blanks in the Contract, shall be inspected over 100% of the product area. No single non-bond indication shall exceed 3" in its longest dimension. The summation of recordable non-bond areas shall not exceed 1% of the specified product area (99% minimum sound bond area). When mutually agreed upon and specified in the Contract, ultrasonic inspection of QA Level 1 material will be in accordance with the additional requirements of ASTM/ASME A-578

Supplementary Requirement S-7 (no single non-bond indication shall exceed 1" long).

3.5.1.3 Material produced to Level 2 shall be inspected on a 9" minimum spacing square grid pattern. Additionally, the product shall be inspected over a 2" wide band adjacent to its periphery. In the event that any recordable non-bond indications are observed, the grid squares containing the indication shall be inspected over 100% of their area. No single indication shall exceed 9 square inches in area. The summation of recordable non-bond indications shall not exceed 3% of the defined product area (97% minimum sound bond area).

3.5.1.4 When specified in the Contract, component metals (clad metal, base metal, or both) shall be ultrasonically inspected for laminations. Inspection procedures and acceptance criteria are to be in accordance with ASTM A-578 Level I or II, or other specifications, as mutually established. When QA Level 1 is specified in the contract, the base metal is to be tested for compliance to ASTM A-578 Level I.

3.5.1.5 When specified in the Contract, the component metals shall be inspected for nonlaminar internal or bond defects using shear wave ultrasonic inspection. The procedure and acceptance/rejection criteria shall be per ASTM A-577 and as mutually established.

3.5.1.6 When the product is supplied as a formed head, ultrasonic inspection is to be performed after the completion of all forming and heat treatment operations.

3.5.1.7 When the product is supplied as a rolled cylinder, full ultrasonic inspection is to be performed prior to rolling only. Only areas of recordable UT conditions are to be re-examined after rolling.

3.5.2 Mechanical Testing:

3.5.2.1 Material Condition for Mechanical Testing:

3.5.2.1.1 Unless specified in the Contract or other invoked specifications, mechanical property certification of the base metal shall be based upon testing performed without bonding, preferably upon testing performed by the producing steel mill at the time of manufacture.

3.5.2.1.2 In the event that post-bonding heat treatments are required for DMC processing, post heat-treatment mechanical testing may be required for compliance with ASME Section VIII Subsection USC-85. This testing shall be performed on test coupons which have been given simulated heat treatments as applicable and mechanical properties shall be certified based upon these tests.

3.5.2.1.3 When simulated heat treatments are specified by the customer in the Contract, testing is to be performed on test coupons which have been given the specified heat treatments and mechanical properties shall be certified

based upon these tests. These heat treatments shall be additive to any required by 3.5.2.1.2.

3.5.2.2 Bond Shear Strength: DETACLAD produced to this Specification shall be capable of producing the minimum bond shear strength listed in Table 8. When QA Level 1 is specified, or when additionally specified in the Contract, bond shear strength testing shall be performed on each bonded plate and the test values shall be reported on the Certificate of Conformance. Bond shear strength is to be determined using specimens of the design presented in ASTM/ASME A-263, A-264, or A-265. For materials not covered by these specifications, specimens shall be of the same configuration, but dimensions may be modified as defined in DMC Standard Procedures.

Table 8. Minimum Bond Shear Strength Values

Type of Cladder	Minimum Bond Shear Strength (lb/in-sq)
Metal	
Stainless Steel	35,000
Nickel & Nickel Alloys	35,000
Titanium & Zirconium	20,000
Copper & Copper Alloys	15,000
Aluminum	8,000

3.5.2.3 Tensile Test: Tensile tests are performed on all DETACLAD products produced for pressure vessel applications. When ASTM/ASME A-263, A-264, or A-265 is invoked by the Contract, tensile testing shall be in accordance with the invoked specification. Otherwise, the tensile testing is to be performed on the base metal only in accordance with the requirements of the applicable material specification.

3.5.2.4 Impact Tests: When required by the applicable material specification or when specified in the Contract, impact tests are to be performed. Test type, temperature, orientation, and acceptance criteria shall be specified in the Contract.

3.5.2.5 Hardness Tests: When required by the applicable material specification or when specified in the Contract, hardness tests shall be performed. Unless specified otherwise, these tests are to be performed on the cladder or base metal exposed planar surface. When specifically agreed upon, bondzone microhardness tests may be performed.

3.5.2.6 Bend Tests: When required by the applicable material specification or when specified in the Contract, bend tests are to be performed. Bend test type (tension, compression, side), bend radius, and acceptance criteria,

are to conform to the referenced specifications. Bend tests shall be performed on material in the as-supplied condition except, when material is supplied as formed heads, the bend tests shall be performed on specimens representative of the forming blank.

3.6 Cladder Metal Construction: Unless otherwise specified in the Contract, DMC may fabricate the cladder metal by butt seam welding of multiple smaller sheets or plates prior to explosion bonding. All welding shall be performed in accordance with the applicable requirements of ASME Code Section IX. The cladder metal seam welds shall be 100% inspected before and after bonding using dye penetrant inspection. When specified in the Contract, the welds shall be radiographed, either spot or 100% as specified, prior to bonding. NDE procedures and acceptance criteria shall be in accordance with ASME Section VIII. Certification of NDE inspections and Code Compliance shall be included in the Certificate of Conformance, Para. 5.0.

3.7 Formed Heads and Cylinders: When clad material produced to this specification is supplied as a formed head or cylinder, the bonded material shall conform to all of the quality requirements of this specification after forming, except for thickness over-gauge. The size, configuration, and any special finish conditions shall be defined in the Contract. The forming procedures, heat treatments, and contour tolerances shall be in accordance with the applicable requirements of the ASME Code Section VIII. When mutually agreed upon, head blanks may be fabricated by butt seam welding of multiple smaller explosion bonded plates. All welding shall be performed in accordance with the applicable requirements of ASME Code Section VIII and IX. Steel welds shall be 100% radiographed prior to forming. The cladder metal restoration welds shall be 100% penetrant inspected before and after forming. NDE procedures and acceptance criteria shall be in accordance with ASME Section VIII. Certification of NDE inspection and Code Compliance shall be included in the Certificate Package, Para. 5.0.

3.8 Repair of Rejectable Conditions: Unless stated otherwise in the Contract, DMC shall have the option to perform weld repair of rejectable non-bond and defects in the component metals. All weld repairs are to be performed in accordance with the applicable requirements of ASME Code Section IX. Upon Buyer request, copies of the applicable welding procedures and welder qualifications will be provided. All repair welds are to be inspected over 100% of the exposed surface using the dye penetrant procedures of ASME Section V. Weld repairs of non-bonds shall be ultrasonically inspected in accordance with the applicable requirements of Section 3.5.1. Weld repairs of pressure boundary components shall be in accordance with the applicable requirements of ASME Section VIII.

3.9 When DETACLAD is supplied with a specified sound bond area that is smaller than the as-supplied product size, the quality requirements for cladding metal and bonding shall apply exclusively to the specified sound bond area. When DETACLAD is supplied oversize, with a defined product size that is smaller than the as-supplied size, all quality requirements shall apply exclusively to the defined product size.

3.10 Optional Tests: When required by the applicable material specification or when specified in the Contract, additional mechanical or non-destructive tests shall be performed. These may include, but are not limited to through-thickness tensile tests, bond tensile strength tests, penetrant inspections, magnetic particle inspections, corrosion testing, and positive material identification. The design of these tests, the material condition, and the applicable test specifications are to be mutually agreed upon and specified in the Contract.

3.11 General Quality: All DETACLAD materials produced to this specification shall be shipped with a workman-like finish that is free from injurious defects in accordance with DMC Quality Standard WS-1-2.

3.12 Metric Conversions: Conversion of values in this specification to metric equivalents shall be in accordance with the standards of ASTM E380.

3.13 Rounding of Numerical Values: Rounding of numerical values shall comply with ASTM E29, using the Rounding-Off Method.

3.14 Non-Standard Quality Requirements: When mutually agreed upon and specified in the Contract, DYNACLAD products shall be produced to requirements other than those presented in this Specification.

4.0 MARKING

4.1 All DETACLAD products manufactured under this specification shall be marked with the following on the base metal surface using low stress metal stamps:

4.1.1 DMC letters

4.1.2 DMC's traceability number

4.1.3 Cladding Metal Specification Number and appropriate designator

4.1.4 Backing Metal Specification Number and appropriate designator

4.1.5 Minimum permissible tensile strength of the base metal

5.0 CERTIFICATION

DMC shall provide a Certificate of Compliance for DETACLAD produced to this Specification. The Certificate of Compliance shall certify that the cladding metal complies with the specified chemical composition, that the backing metal complies with the specified chemical composition and mechanical test requirements, and shall present the results of nondestructive examinations and mechanical testing performed on the bonded product.

When specified by the Contract, copies of the certified material test reports for the component metals and/or any other specified inspection reports and documents shall be provided with the Certificate of Compliance.

Footnote: This specification follows the guidelines mutually established by the membership of the International

Explosion Metalworking Association (IEMA) presented in IEMA Guidenote 100.

DETA CLAD products are manufactured under the following US and Canadian patents:

US: 3,024,526; 3,744,119; 3,761,004; 3,137,937; 3,233,312

Canadian: 950,242

DETA CLAD Products are manufactured by DMC- Clad Metal Division of Dynamic Materials Corp.

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