

NOTE: MIL-STD-1627 has been redesignated as a Design Criteria Standard. The cover page has been changed for Administrative reasons. There are no other changes to this Document.

INCH-POUND

MIL-STD-1627C (SH)
30 SEPTEMBER 1994
SUPERSEDING
MIL-STD-1627B (SH)
2 SEPTEMBER 1981
(See 6.6)

DEPARTMENT OF DEFENSE
DESIGN CRITERIA

BENDING OF PIPE OR TUBE
FOR SHIP PIPING SYSTEMS



AMSC N/A

FSC 4710

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

FOREWORD

1. This Military Standard is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.
2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 03R42, 2531 Jefferson Davis Hwy, Arlington, VA 22242-5160 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.
3. This standard covers fabrication requirements and acceptance criteria for pipe bending.
4. For Naval activities, this document may be invoked upon receipt.
5. For contracts or acquisition orders which invoke MIL-STD-1627A(SH), MIL-STD-1627B or NAVSHIPS 250-582, the contractor or vendor shall not use this standard without prior contractual approval.

		<u>Page</u>
Paragraph	CONTENTS	
1.	SCOPE	1
1.1	Scope	1
2.	APPLICABLE DOCUMENTS	1
2.1	Government documents	1
2.1.1	Specifications, standards, and handbooks	1
2.2	Non-Government publications	2
2.3	Order of precedence	2
3.	DEFINITIONS	2
3.1	Activity	2
3.1.1	Authorized representative	3
3.2	Backwall	3
3.3	Bend radius	3
3.4	Bending machines	3
3.4.1	Bending machine - Ram type	3
3.4.2	Bending machine - Roll type	3
3.4.3	Bending machine - Compression type	3
3.4.4	Bending machine - Rotary type	4
3.4.5	Bending machine - Rotary type with a booster	4
3.5	Buckles and bulges	4
3.6	Cold bending	4
3.7	Crack	4
3.8	Dent	4
3.9	Flatness	4
3.10	Gouge	4
3.11	Hot bending	4
3.12	Hump	4
3.13	Minimum design wall thickness	4
3.14	Pipe	4
3.15	Qualified	4
3.16	Step	5
3.17	Wrinkles	5
4.	GENERAL REQUIREMENTS	5
4.1	Material	5
4.1.1	Base material condition	5
4.1.2	Base material cleanliness	5
4.1.3	Wall thickness	5
4.1.4	Surface condition	5
4.2	Lubricants	5
4.2.1	Unacceptable lubricant ingredients	6
4.3	Cleaning	9
4.4	Loose fillers	9
4.5	Material control	9
5.	DETAILED REQUIREMENTS	9
5.1	Bending procedures	9
5.2	Bending procedure qualification	10

CONTENTS - Continued

		<u>Page</u>
Paragraph	5.2.1	Production bends as qualification test 10
	5.2.2	Bending machine qualification 10
	5.2.3	Alternative procedures 10
	5.2.4	Qualification test approval 10
	5.2.5	Previously qualified procedures 10
	5.2.6	Vendor qualification 10
	5.2.7	Transferral of qualification 10
	5.3	Qualification test 11
	5.3.1	Sampling 11
	5.3.2	Special requirements 11
	5.3.3	Qualification bends 11
	5.4	Bending criteria 11
	5.4.1	Minimum bend radius 11
	5.4.2	Bending of longitudinally welded pipe 11
	5.4.3	Marking 11
	5.4.4	Bending temperatures 11
	5.5	Hot bending 12
	5.5.1	Heating of pipes 12
	5.5.1.1	Torch heating 12
	5.5.2	Temperature measurements during heating and bending 13
	5.6	Adjustments and corrections 13
	5.6.1	Bend angle adjustment in the closing direction 13
	5.6.2	Bend angle adjustment in the opening direction 13
	5.6.3	Reverse bending 13
	5.6.4	Corrections for out-of-round, buckles, bulges, and dents 13
	5.7	Post bending heat treatment 13
	5.7.1	General 13
	5.7.2	Cleaning prior to heat treatment 13
	5.7.3	Procedure 13
	5.8	Inspection 14
	5.8.1	Inspection procedures 14
	5.8.2	Sampling 15
	5.8.3	Inspection personnel 15
	5.9	Acceptance standards 15
	5.9.1	Surface conditions 15
	5.9.1.1	Cracks 15
	5.9.1.2	Pits, gouges, scratches and tool marks 15
	5.9.1.3	Wrinkles 15
	5.9.1.4	Buckles, bulges, humps, steps and dents 15
	5.9.1.5	Flatness 15
	5.9.2	Dimensional 15
	5.9.2.1	Out-of-roundness 16
	5.9.2.2	Wall thickness measurement 16

TABLE 3 - CONTENTS - Continued

		<u>Page</u>
Paragraph	6. NOTES	16
	6.1 Intended use	16
	6.2 Acquisition requirements	16
	6.3 Obsolete specifications referenced by this standard.	17
	6.4 Maintenance of records	17
	6.5 Subject term (key word) listing	17
	6.6 Changes from previous issue	17
FIGURES		
Figure	1. Types of bending machines	18
	2. Location of weld for welded pipe	19
	3. Calculations for buckles, bulges, humps, steps, and dents in pipe bends	20
	4. Flatness limits	21
TABLES		
Table	I. Grouping of base material	7
	II. Cold and hot bending temperatures	12
	III. Post bending heat treatment	14
	IV. Post bending heat treatment temperatures and mode of cooling	14

1. SCOPE

1.1 Scope. This standard covers pipe bending, heat treatment, and inspection requirements and acceptance criteria for piping used for ships of the United States Navy. The standard applies to pipes of 1/4 nominal pipe size (nps) and larger or tubes with 1/2 inch outside diameter (od) and larger.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

FEDERAL

QQ-N-281/3 - Nickel-Copper Alloy, Tube and Pipe, Seamless.

MILITARY

MIL-T-15005 - Tubes, Condenser and Heat Exchanger, Copper-Nickel Alloys (UNS C70600 & 71500).
 MIL-T-16286 - Tube, Steel, Seamless, Marine Boiler Application.
 MIL-T-16420 - Tube, Copper-Nickel Alloy, Seamless and Welded (Copper Alloy Numbers 715 and 706).
 MIL-T-23226 - Tube and Pipe, Corrosion-Resistant Steel, Seamless.
 MIL-T-23227 - Tube and Pipe, Nickel-Chromium-Iron Alloy.
 MIL-T-23520 - Tube and Pipe, Nickel-Copper Alloy, Seamless, Air Melted.
 MIL-T-24107 - Tube, Copper (Seamless) (Copper Alloy Numbers C10100, C10200, C10300, C10800, C12000, C12200, and C14200).
 MIL-P-24338 - Pipe, Carbon Steel, Seamless.
 MIL-P-24691/1 - Pipe and Tube, Carbon Steel, Seamless.
 MIL-P-24691/2 - Pipe and Tube, Chromium-Molybdenum Steel, Seamless.
 MIL-P-24691/3 - Pipe and Tube, Corrosion-Resistant, Stainless Steel, Seamless or Welded.

STANDARDS

MILITARY

MIL-STD-271 - Requirements for Nondestructive Testing Methods.
 MIL-STD-278 - Welding and Casting Standard.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, BLDG. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- A 53 - Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless.
(DoD adopted)
- A 106 - Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service. (DoD adopted)
- A 213 - Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes.
- A 269 - Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service.
- A 312 - Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipe.
- A 335 - Standard Specification for Seamless Ferritic Steel Pipe for High Temperature Service.
- B 43 - Standard Specification for Seamless Red Brass Pipe, Standard Sizes.
- B 111 - Standard Specification for Copper and Copper Alloy Seamless Condenser Tubes and Ferrule Stock.
- B 167 - Standard Specification for Nickel-Chromium-Iron Alloys (UNS N06600, N06601 and N06690) Seamless Pipe and Tube.
(DoD adopted)
- B 210 - Standard Specification for Aluminum and Aluminum Alloy Drawn Seamless Tubes.
- B 444 - Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625) Pipe and Tube.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Activity. The organization under the same quality assurance management performing work to which this standard is applicable.

3.1.1 Authorized representative. Any Government representative specifically authorized to approve equipment, material, or procedures within the scope of this document for NAVSEA. They are as follows:

- (a) For Government shipyards: The delegated representative of the Shipyard Commander.
- (b) For Commercial shipyards: The delegated representative of the Supervisor of Shipbuilding, Conversion and Repair (SUPSHIP), or the American Bureau of Shipping when specified in the Ship's Specifications for a particular ship. This includes all applicable areas in the shipyard and applicable items furnished to the shipyard by subcontractors.
- (c) For Government purchase items: The delegated representative of the Commanding Officer, NAVSSES, Philadelphia or of the Officer in Charge, NAVSSES Detachment, Mechanicsburg, or of the Officer In Charge, NAVSSES Detachment, Norfolk.
- (d) When delegated by (a), (b) or (c) above, The representative of the Defense Contract Administration Services Management Area (DCASMA).
- (e) Technical representative specifically authorized by NAVSEA.

3.2 Backwall. The outer half of the pipe or the half of the pipe undergoing tension during bending.

3.3 Bend radius. The radius from the center of curvature to the center line (axis) of the pipe, expressed as a number multiplied by the pipe or tube size. For example, bend radius of a 5D bend for 2 nominal pipe size (nps) pipe or a 2 inch tube is 10 inches.

3.4 Bending machines. Equipment used to produce bends in pipe and tube.

3.4.1 Bending machine - Ram type. Ram type bending machine consists of a bending die mounted on a ram and two pivoted pressure dies. The pipe is bent by the bending die, pushing the pipe between the pressure dies, which wraps the pipe around the bending die as shown on figure 1a. The bend in a ram type bending machine is limited to 120 degrees and the bend radius should be not less than 6D.

3.4.2 Bending machine - Roll type. Roll type bending machine consist of three properly spaced rolls. The method of bending pipe by this machine is shown on figure 1b. Bend angles of 360 degrees can be obtained on this type of bending machine with a minimum bend radius of approximately 6D on unfilled pipes.

3.4.3 Bending machine - Compression type. The compression or stationary die type bending machine consists of a stationary bending die, clamping block, and movable pressure die. The pipe is bent by clamping one end of the pipe to the bending die and the pressure die moves around the bending die, forcing the pipe into the bending die groove as shown on figure 1c. The maximum angle of bend that can be produced is 180 degrees.

3.4.4 Bending machine - Rotary type. The rotary type machine consists of a rotating bending die, clamping block, wiper die and sliding or stationary pressure die as shown on figure 1d. The clamping block holds the end of the pipe to the bending die with sufficient force to keep it from moving while it is being bent around the die. The bending die rotates around a pivot and pulls or draws the pipe around it. The bending die also supports the inner half or throat of the pipe bend. The pressure die presses the pipe into the groove of the bending die. The pressure die also supports the outer half or heel of the pipe bend. The pressure die may be stationary or slide with the pipe. The wiper die is stationary and opposite the pressure dies. The wiper die supports the inner half of the pipe and keeps the pipe throat from wrinkling. The maximum angle of bend is 180 degrees.

3.4.5 Bending machine - Rotary type with a booster. This machine is essentially the rotary type bending machine with the force being applied to the straight end of the pipe. This force reduces the pull on the pipe to bend it around the bending die as shown on figure 1e. Booster unit enables smaller radius bends to be made on the pipe.

3.5 Buckles and bulges. A wavy condition which may form on the pipe throat surface during the bending operation.

3.6 Cold bending. The bending of pipe at any temperature at which strain hardening occurs.

3.7 Crack. A crevice, fissure, rupture, or fracture of the pipe surface.

3.8 Dent. A depression in the contour of the pipe surface.

3.9 Flatness. An area on the pipe surface having no curvature.

3.10 Gouge. A groove, cavity, or scooped out area on the pipe surface produced by a sharp object or abrasive.

3.11 Hot bending. The bending of pipe at a temperature at which strain hardening does not occur (see table II).

3.12 Hump. A rounded protrusion or bulge on the backwall or heel of the pipe bend caused by the improper placement of the bending mandrel.

3.13 Minimum design wall thickness. The wall thickness specified on the fabrication drawing or computed in accordance with the applicable shipbuilding specification as the minimum acceptable for the temperature and pressure application, whichever is greater.

3.14 Pipe. The term "pipe" as used herein shall include both "pipe and tube", in accordance with the nomenclature set forth by the material specification.

3.15 Qualified. The item under consideration has been approved as required by this standard.

3.16 Step. A round bottomed crease on the throat of a pipe bend caused by the lack of, or improper spacing of the wiper die during the bending operation.

3.17 Wrinkles. Definite folds, or creases, formed on the surface of the pipe during bending operations.

4. GENERAL REQUIREMENTS

4.1 Material. Base material shall conform to the applicable contract, shipbuilding or equipment specifications. A list of generally used piping or tubing materials, arranged in groups in accordance with similarities in bending, are given in table I.

4.1.1 Base material condition. Prior to bending, the base material in the vicinity of the bend shall be in the following conditions. The pipe is usually procured to these conditions and provided no cold work has been performed on them, no additional heat treatments are required.

Material group (see table I)

Condition

S-1

Stress relieved, annealed, normalized, or normalized and tempered.

S-3, S-4, S-5

Annealed, normalized and tempered, or quenched and tempered.

S-8, S-21, S-22, S-31,
S-32, S-34, S-42, S-43

Annealed.

4.1.2 Base material cleanliness. Prior to bending, the pipe surfaces, inside and outside, shall be clean and free of foreign matter which may result in nicks and gouge marks on the bent pipe surface.

4.1.3 Wall thickness. Pipe selected for bending shall have sufficient wall thickness to assure that the backwall of the finished bend meets the minimum design thickness (T_m) or the minimum specified thickness.

4.1.4 Surface condition. The surfaces to be bent shall have neither dents, nicks, nor gouges in excess of that permitted by this standard (see 5.9.1).

4.2 Lubricants. Lubricants may be used in bending operations to prevent galling of the pipe material during bending and to prevent rapid wear of the die. Lubricants shall be easy to remove after bending and shall not stain the pipe. A lubricant that works effectively on one pipe material may not be effective for another. Mineral oils and organic fats, such as lanolin, are commonly used lubricants. Examples of acceptable lubricants are lanolin, lard oil, viscous oils and soap solutions. Lubricant shall have good surface adhesion and film strength at bending temperatures.

4.2.1 Unacceptable lubricant ingredients. Use of lubricants containing the following ingredients are not permitted:

- (a) Ozone depleting lubricants not meeting local volatile compound (VOC) requirements shall not be used.
- (b) Lubricants containing sulfur or chlorine shall not be used on group S-8, S-31, S-32, S-34, S-42, and S-43 materials.
- (c) Carbonaceous lubricants shall not be used on group S-8 materials.
- (d) Lubricants containing halogens, arsenic, bismuth, copper, phosphorus, sulfur, tin, lead, cadmium or zinc in excess of 250 parts per million (ppm) total halides or 250 ppm of each other individual element shall not be used on material intended for service at temperatures greater than 400 degrees Fahrenheit (°F).

TABLE I: Grouping of base material.

Material	Group number	Applicable documents	Form and grade or class
Carbon steel	S-1	ASTM A 53	Pipe, all grades
		MIL-T-16286	Tube, classes A & G
		ASTM A 106	Pipe, all grades
		MIL-P-24691/1	Pipe & tube, all grades
		MIL-T-17188	Tube, all grades
		MIL-T-20157	Tube & pipe, all grades
		MIL-P-24338	Pipe
Carbon-molybdenum steel	S-3	MIL-T-16286	Tube, class D, CMo
		MIL-T-20155	Pipe and tube, CMo
1-1/4 Chromium-1/2 molybdenum steel	S-4	ASTM A 213	Tube, grade T11
		MIL-T-16286	Tube, class F
		MIL-T-18165	Pipe & tube, class 1
		ASTM A 335	Pipe, grade P11
		MIL-P-24691/2	Pipe & tube, grades P11 or T11
2-1/2 Chromium-1 molybdenum steel	S-5	MIL-T-16286	Tube, class E
		MIL-T-18165	Pipe & tube, class 2
Austenitic corrosion resistant steel	S-8	MIL-P-1144	Pipe, grade 304, 316, 321, 347, 304L, 316L
		ASTM A 312	Pipe, grades 304, 316, 321, 347, 304L, 316L
		ASTM A 269	Tube, grades 304, 316, 321, 347, 304L, 316L
		MIL-T-16286	Tube, class C
		MIL-T-23226	Pipe & tube, grades 304, 304L, 347, & 348

TABLE I. Grouping of base material - Continued.

Material	Group number	Applicable documents	Form and grade or class
		MIL-P-24691/3	Pipe & tube, grades 304, 316, 321, 347, 304L & 316L
Aluminum	S-21	WW-T-700/1	Tube, alloy 1100
		WW-T-700/2	Tube, alloy 3003
		ASTM B 210	Tube, alloy 3003
Aluminum alloys	S-22	WW-T-700/4	Tube, alloy 5052
		WW-T-700/5	Tube, alloy 5086
		ASTM B 210	Tube, alloys 5086 & 5052
Copper	S-31	MIL-T-24107	Tube, copper
Brass	S-32	MIL-T-20168	Pipe, alloy C23000
		ASTM B 43	Pipe, alloy C23000
90/10 Copper-nickel	S-34	MIL-T-15005	Tube, alloy C70600
		ASTM B 111	Tube, alloy C70600
		MIL-T-16420	Tube, alloy C70600
70/30 Copper-nickel	S-34	MIL-T-15005	Tube, alloy C71500
		ASTM B 111	Tube, alloy C71500
		MIL-T-16420	Tube, alloy C71500
Nickel-copper	S-42	MIL-T-1368	Tube & pipe
		QQ-N-281/3	Tube & pipe
		MIL-T-23520	Tube & pipe
Ni-Cr-Fe (Inconel 600) Ni-Cr-Mo-Cb (Inconel 625)	S-43	MIL-T-23227	Tube & pipe
		ASTM B 167	Tube & pipe
		ASTM B 444	Tube & pipe

4.3 Cleaning. Piping components and assemblies of components shall be thoroughly cleaned after fabrication and before installation in the ship to remove loose particles, grease, dirt, oil, rust, and scale.

4.4 Loose fillers. Loose fillers, such as silica sand and approved low melting material (such as rosin) may be employed for internal support when mandrels are not available or practicable. Low melting rosin, melting at temperatures not to exceed 400 degrees F, shall be used for bending at ambient temperature. Removal of rosin by direct torch heating shall be limited to 400 degrees F. Silica sand used for high temperature bending shall be dry. The sand should be 91% minimum silica, containing no nonferrous contaminants and having a fineness sufficient to yield a surface which meets specification requirements. Sand previously used in nonferrous pipes shall not be used in ferrous pipes and vice versa.

4.5 Material control. The following material controls shall be required:

- (a) For corrosion resistant steel pipes: The silica sand used shall be clean and dry, and shall not be used for purposes other than filling corrosion resistant steel pipes. Hand tools that come in contact with the corrosion resistant steel pipe shall be either corrosion resistant steel or rust free ferrous tool steel and shall not be used on material other than corrosion resistant steel. Resin shall not be used for pipe filling.
- (b) For carbon and alloy steel pipes: The silica sand shall be clean and dry and shall not be used for purposes other than filling ferrous pipes. Resin shall not be used for pipe filling. Galvanized parts, bronze or lead tools shall not be used or come in contact with the pipe.
- (c) Nonferrous pipes: The silica sand shall be clean and dry and shall not be used for purposes other than filling nonferrous pipes. Galvanized parts or lead tools shall not come in contact with the pipe.

5. DETAILED REQUIREMENTS

5.1 Bending procedures. Prior to performing production bending, each activity shall prepare detailed written bending procedures. Bending procedures shall be based on the requirements and acceptance criteria of this standard and shall include the following (see 6.2):

- (a) Base material type, pipe size and wall thickness.
- (b) Pre-bending preparations (see 4.1).
- (c) Bend radius.
- (d) Bending temperature (hot or cold).
- (e) Type of bending machine (see 5.2.2).
- (f) Type of lubricant, if any used (see 4.2).
- (g) Bend angle adjustment where applicable.
- (h) Out-of-round and buckling repair.
- (i) Post bending heat treatment, if any.
- (j) Post bending cleaning requirements.
- (k) Inspection requirements and acceptance criteria.

5.2 Bending procedure qualification. Bends to a radius of 5D or greater for materials listed in table I do not require procedure qualification. When pipe is bent to a radius of less than 5D, each activity shall qualify procedures for each of the groups (a through e) listed below. Qualification of any material in a group qualifies for all materials within that group. Qualification of a bend to a radius of less than 5D qualifies for all bends intermediate to that radius and 5D.

- (a) Carbon and alloy steels - material groups S-1, S-3, S-4, S-5.
- (b) Corrosion resistant alloys - material group S-8, S-42, S-43
(Inconel 600)
- (c) Aluminum & aluminum alloys - material groups S-21, S-22.
- (d) Copper alloys - material groups S-31, S-32, S-34.
- (e) Nickel-chromium-molybdenum-columbium alloy - Inconel 625 material group S-43.

NOTE 1: Aluminum alloy 5052 or 5086 qualifies the pipe bending of other alloys in S-21 and S-22 groups and not vice versa.

5.2.1 Production bends as qualification test. At the option of the activity, two production bends which represent the smallest radius bend for the system may be used for qualification tests. In this case, qualification applies to that particular size and wall thickness only; however, the qualification applies to all material within that group.

5.2.2 Bending machine qualification. Each type of bending machine, requires separate qualification of the bending procedure. The same procedure can be used with each machine within the type classification. Machine type classification is as follows:

- (a) Ram type.
- (b) Roll type.
- (c) Compression type.
- (d) Rotary.
- (e) Rotary with booster unit.
- (f) Portable manual type.

5.2.3 Alternative procedures. Procedures contained in NAVSEA technical manuals may be used by Naval activities without requalification.

5.2.4 Qualification test approval. The qualification test report shall be submitted to the Government inspector for approval and the bending procedure submitted for information. A copy of the qualification test report and the bending procedure shall be submitted to NAVSEA for information (see 6.2).

5.2.5 Previously qualified procedures. Procedures qualified under previous revisions of this document or predecessor documents shall not require requalification.

5.2.6 Vendor qualification. The prime contractors shall be responsible to assure that all subcontractors have procedures qualified and approved.

5.2.7 Transferral of qualification. Qualification shall not be transferred from one activity to another activity.

5.3 Qualification test. The qualification test shall include the following:

- (a) Visual inspection for cracks, wrinkles, or excessive pits, gouges, scratches, tool marks, buckles, bulges, humps, steps, dents or flatness.
- (b) Wall thickness survey.
- (c) Out-of-round measurements.
- (d) Repairs, if performed.
- (e) Post bending heat treatment, if performed.

5.3.1 Sampling. Test specimens for bending procedure qualification shall be as follows:

- (a) Qualification up to and including 6 nps: Two 90 degree bends each consisting of one thickest and one thinnest wall thickness pipe used in production, on 1 inch nps and 6 inches nps pipes (or the largest production pipe less than 6 inches nps).
- (b) Qualification over 6 nps: Two 90 degree bends for each nps size, consisting of one thickest and one thinnest wall thickness pipe used in production.
- (c) Qualification of pipe or tube with od smaller than 1 inch nps: If the ratio of the diameter/thickness (D/T) for pipe or tube is more than the ratio of D/T for the pipes tested under (a) and (b), two additional 90° bend samples shall be made. This test will qualify all the pipes or tubes with od smaller than 1 nps with D/T equal to or more than for the pipe tested.

5.3.2 Special requirements. Depending on the application of the proposed procedure or the bend radius used, additional tests may need to be performed to supplement the qualification tests.

5.3.3 Qualification bends. The test bends shall be made to the requirements of this standard and shall meet the acceptance criteria of 5.9.

5.4 Bending criteria.

5.4.1 Minimum bend radius. Piping shall not be bent to a radius less than 2D, except that S-31 and S-32 (copper and brass) materials may be bent to 1.5D.

5.4.2 Bending of longitudinally welded pipes. When bending longitudinally welded pipes, the weld shall not be located in any of the principal axes as shown on figure 2.

5.4.3 Marking. Marking of pipe for identification purposes shall not be applied to the bend area after bending.

5.4.4 Bending temperatures. Pipe bending may be accomplished "cold" or "hot", except as prohibited in table II or by fabrication drawings or specifications. The "cold" and "hot" bending temperatures shall be as specified in table II.

TABLE II. Cold and hot bending temperatures.

Material	Group number	Cold bending (°F maximum)	Hot bending (°F)
Carbon steel	S-1	1150	1650 - 1850
CMo steel	S-3	900	1650 - 1900
Cr - Mo steel	S-4, S-5	900	1700 - 1950
Corrosion-resisting steel	S-8	800	1/
Aluminum	S-21	400	500 - 800
Aluminum alloys	S-22	500	600 - 800
Copper	S-31	400	800 - 1600
Brass	S-32	500	800 - 1650
Copper-nickel	S-34	400	1/
Nickel-copper	S-42	900	1/
N06600, N06625	S-43	1000	1/

1/ These materials shall be cold bent only.

5.5 Hot bending.

5.5.1 Heating of pipes. The pipe shall be heated by furnace, induction heating, or by gas torch only long enough to obtain the desired bending temperature throughout the section to be bent. The fuel used in heating shall not contain more than 30 grains of total sulfur per 100 cubic feet of gas. The atmosphere or type of flame during heating shall be slightly reducing for all materials except corrosion-resistant steels. Corrosion-resistant steels require a slightly oxidizing atmosphere of flame.

5.5.1.1 Torch heating. Every precaution shall be taken to ensure gradual heating of the section and that it is within the temperature range specified. Sweeping motions of the torch shall be employed to avoid local overheating in any location. Heating of pipes by torch for pipes greater than 3.50 nps shall not be permitted. Uniform local heating around the circumference of pipe sizes exceeding 3.5 nps is permitted to keep the pipe at temperature during bending.

5.5.2 Temperature measurements during heating and bending. Periodically optical or contact pyrometers shall be employed to check the torch operators or induction heating equipments ability to maintain temperatures during heating, to prevent overheating, and during bending to ensure bending in the specified temperature range. Temperature indicating crayons may also be employed provided they contain neither halogens, arsenic, bismuth, copper, phosphorous, sulfur, tin, lead, cadmium, nor zinc, in excess of 250 ppm total halides or 250 ppm of each other individual element specified above.

5.6 Adjustments and corrections. Bend angles, out-of-round, and correctable buckling or other surface irregularities may be adjusted or corrected at the original bending temperature or at any temperature within the range of "cold" or "hot" bending as applicable (see table II). When post bending heat treatment is required, and adjustments and corrections are performed on the bend area after posting bending heat treatment, the bend shall be reheat treated to the requirements specified in table III except as allowed in paragraph 5.6.1.

5.6.1 Bend angle adjustment in the closing direction. Bend angle may be adjusted in the closing direction to any degree. Adjustment made after post bending heat treatment need not be re-heat treated if the adjustment did not exceed 10 degrees.

5.6.2 Bend angle adjustment in the opening direction. Bend angle may be adjusted once in the opening direction. The adjustment shall be not greater than 10 degrees. For adjustments greater than 10 degrees, the pipe shall be restored to the pre-bending condition in accordance with 4.1.1 before the adjustment.

5.6.3 Reverse bending. Reverse bending, after the pipe has been adjusted in the opening direction, is not permitted unless the pipe is removed from the bending machine and restored to its pre-bending condition in accordance with 4.1.1.

5.6.4 Corrections for out-of-round, buckles, bulges, and dents. Excessive out-of-round may be corrected. Correction of buckles, bulges and dents may be accomplished cold provided the corrections do not produce dents or tool marks in excess of those permitted by 5.9.1.2 and 5.9.1.4.

5.7 Post bending heat treatment.

5.7.1 General. If a post bending heat treatment other than that required in this section is specified in an applicable system or component specification, it shall apply.

5.7.2 Cleaning prior to heat treatment. The bent pipe shall be cleaned to remove all of the lubricants and filler material prior to heat treating in accordance with 4.3.

5.7.3 Procedure. When post bend heat treatment is required by table III, for groups S-1, S-3, S-4 or S-5, it shall be performed as required for post weld heat treatment as specified in MIL-STD-278. Group S-22 shall be post bend heat treated, when required by table III, as specified in table IV. Temperature monitoring and cleanliness controls shall be as specified in MIL-STD-278.

TABLE III. Post bending heat treatment.

Material group	Bend radii	Bending temperature	Post bending heat treatment
S-1, S-3, S-4, S-5	2D and over	Cold	Required for some sizes 1/, 2/
	2D and over	Hot	None
S-8, S-34	2D and over	Cold	None
S-21, S-22, 3/ S-42, S-43	3D and over	Cold	None
	2D to 3D	Cold	Anneal 4/
	2D and over	Hot 5/	None
S-31, S-32	1-1/2D and over	Cold	None
		Hot	None

- 1/ Carbon steel with wall thickness greater than 3/4 inch shall be stress relieved.
- 2/ Alloy steel with wall thickness 1/2 inch and greater or pipe sizes 4 nps or greater shall be stress relieved.
- 3/ Bending shall be performed only on O temper material.
- 4/ S-42, S-43, and S-22 (alloy 5086) shall be post bend heat treated per table IV. No post bend heat treatment is required for other S-21 and S-22 alloys listed in table I.
- 5/ Aluminum alloys (S-21 & S-22) only may be hot bent. Alloys S-42 & S-43 shall be cold bent.

TABLE IV. Post bending heat treatment temperatures and mode of cooling.

Material group	Anneal (°F)
S-22 (alloy 5086)	650 - AC
S-42	1450 - AC
S-43	1850 - AC

AC - Air cool

5.8 Inspection.

5.8.1 Inspection procedures. Production bends shall be visually and dimensionally inspected on a sampling basis to the requirements of 5.9.

5.8.2 Sampling. This sample shall include representative pipe sizes, bend radii, and angles that the activity has bent during a specified period of time. A sampling plan having a statistical basis in published criteria shall be prepared by the quality assurance function of the activity and submitted to the Government inspector for approval (see 6.2). The acceptable plan will basically exhibit equivalence to a 95 percent confidence level based on statistical analysis of actual test data, that not less than 95% of the bends from each sample will meet the acceptance standards cited herein.

5.8.3 Inspection personnel. Visual examination and nondestructive inspection personnel shall be required to pass a vision test in accordance with MIL-STD-271. Nondestructive inspection personnel for ultrasonic measurement, inspection shall also be qualified in accordance with MIL-STD-271.

5.9 Acceptance standards. Acceptance criteria shall be in accordance with 5.9.1 through 5.9.2.2.

5.9.1 Surface condition.

5.9.1.1 Cracks. The bent pipe shall be free of cracks.

5.9.1.2 Pits, gouges, scratches and tool marks. The pipe surface shall be examined for pits, gouges, scratches, and tool marks. Randomly distributed round bottomed discontinuities are acceptable provided they do not exceed a depth of 0.010 inch or 5 percent of the nominal thickness, whichever is greater, and provided this depth does not reduce the wall thickness below its minimum requirement. Discontinuities exceeding this limit shall be removed by fairing in either by grinding or buffing to a radius of three times the depth. The final wall thickness after defect removal shall meet the minimum thickness requirement.

5.9.1.3 Wrinkles. Pipe surface shall be free of wrinkles.

5.9.1.4 Buckles, bulges, humps, steps, and dents. The bent pipe shall be examined for excessive buckles, bulges, humps, steps, and dents. Buckles, bulges, humps, steps, and dents will be acceptable provided the following conditions (see figure 3) are met:

- (a) Buckles, bulges, humps, steps, and dents shall blend smoothly in a gradual manner.
- (b) The maximum vertical height of any buckle, bulge, hump, step, or dent shall be not greater than 3 percent of the nominal pipe outside diameter.
- (c) The distance to height ratio (D/h) as shown on figure 3, shall be not less than 12:1.

5.9.1.5 Flatness. Flatness on the pipe surface shall be acceptable if it meets the requirements shown on figure 4.

5.9.2 Dimensional.

~~5.9.2.1~~ Out-of-roundness. Bent pipe shall be measured for out-of-roundness and shall meet the following requirements:

- (a) For pipe working pressure not less than 600 pounds per square inch (psi): 5 percent (maximum).
- (b) For pipe working pressure less than 600 psi: 8 percent (maximum).

5.9.2.1.1 Out-of-roundness calculation. Out-of-roundness shall be calculated as follows:

$$\text{Out-of-round (percent)} = \frac{D_{\text{max.}} - D_{\text{min.}}}{D_{\text{nom.}}} \times 100$$

Where: D max. - Maximum measured diameter (D) at the bend.

D min. - Minimum measured (D) at the bend.

$$D_{\text{nom.}} = \frac{D_{\text{max.}} + D_{\text{min.}}}{2}$$

5.9.2.2 Wall thickness measurement. The wall thickness throughout the length of the bent pipe shall meet the minimum specified design wall thickness requirement. In addition, backwall thinning shall not be greater than 25 percent from the actual prebent pipe wall thickness. The 25 percent backwall thinning limit does not apply to copper and brass tubes. Measurements shall be made with a micrometer or calibrated ultrasonic instrument in accordance with MIL-STD-271. Measurements shall be made on the backwall of pipe bent to a radius of less than 5D and on those locations where defects have been removed. Each wall thickness determination shall meet the above criteria.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful but is not mandatory.)

6.1 Intended use. This standard covers fabrication requirements for pipe bending intended for shipboard fluid systems.

6.2 Acquisition requirements. The following Data Item Descriptions (DID's) must be listed, as applicable, on the Contract Data Requirements List (DD Form 1423) when this standard is applied on a contract, in order to obtain the data, except where DoD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

<u>Reference Paragraph</u>	<u>DID Number</u>	<u>DID Title</u>	<u>Suggested Tailoring</u>
5.1, 6.4	UDI-T-23732	Procedures, test	----
5.2.4	DI-T-2072	Reports, test	10.1.b

The above DID's were those cleared as of the date of this standard. The current issue of DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

6.3 Obsolete specifications referenced by this standard.

FEDERAL

- WW-T-700 - Tube, Aluminum and Aluminum Alloy, Drawn, Seamless, General Specification for.
- WW-T-700/1 - Tube, Aluminum, Drawn, Seamless, 1100.
- WW-T-700/2 - Tube, Aluminum Alloy, Drawn, Seamless, 3003.
- WW-T-700/4 - Tube, Aluminum Alloy, Drawn, Seamless, 5052.
- WW-T-700/5 - Tube, Aluminum Alloy, Drawn, Seamless, 5086.

MILITARY

- MIL-P-1144 - Pipe, Corrosion Resistant, Stainless Steel, Seamless and Welded.
- MIL-T-1368 - Tube and Pipe, Nickel-Copper Alloy, Seamless and Welded.
- MIL-T-17188 - Tubes, Carbon Steel, Electric Resistance Welded, Marine Boiler.
- MIL-T-18165 - Tube and Pipe, Chromium - Molybdenum Alloy Steel, Seamless.
- MIL-T-20155 - Tubing, Steel Alloy, Molybdenum, Seamless.
- MIL-T-20157 - Tube and Pipe, Carbon Steel, Seamless.
- MIL-T-20168 - Tubes, Brass, Seamless.

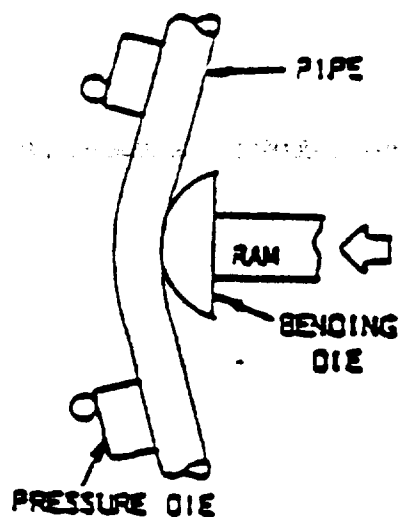
6.4 Maintenance of records. Unless otherwise specified by NAVSEA, required records shall be maintained by the organization performing the work and be available to the authorized representative throughout the life of the contract and for a period of 3 years after delivery. At the expiration of the record retention period, NAVSEA or its authorized representative shall be furnished written notification. Disposition of records shall be as agreed upon by NAVSEA and the contractor.

6.5 Subject term (key word) listing.

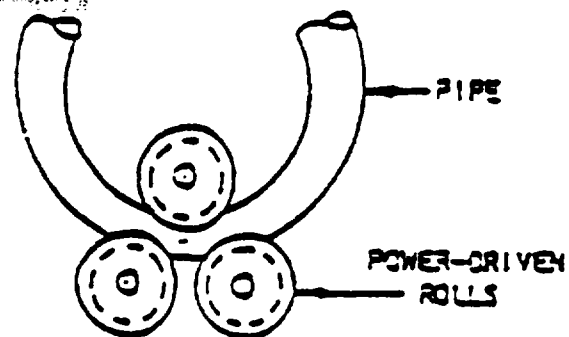
Die
Mandrel
Material base
Support, internal

6.6 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

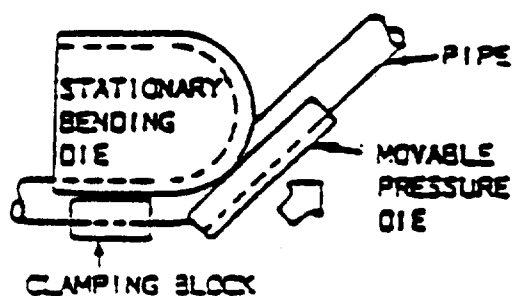
Preparing activity:
Navy - SH
(Project 4710-N008)



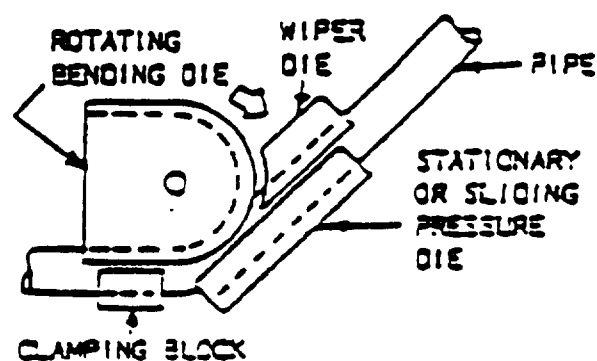
a. RAM TYPE



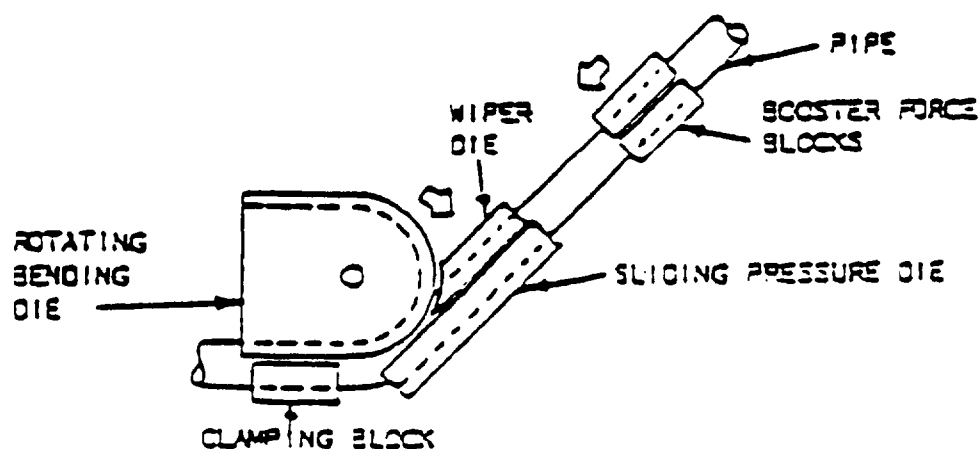
b. ROLL TYPE



c. COMPRESSION TYPE

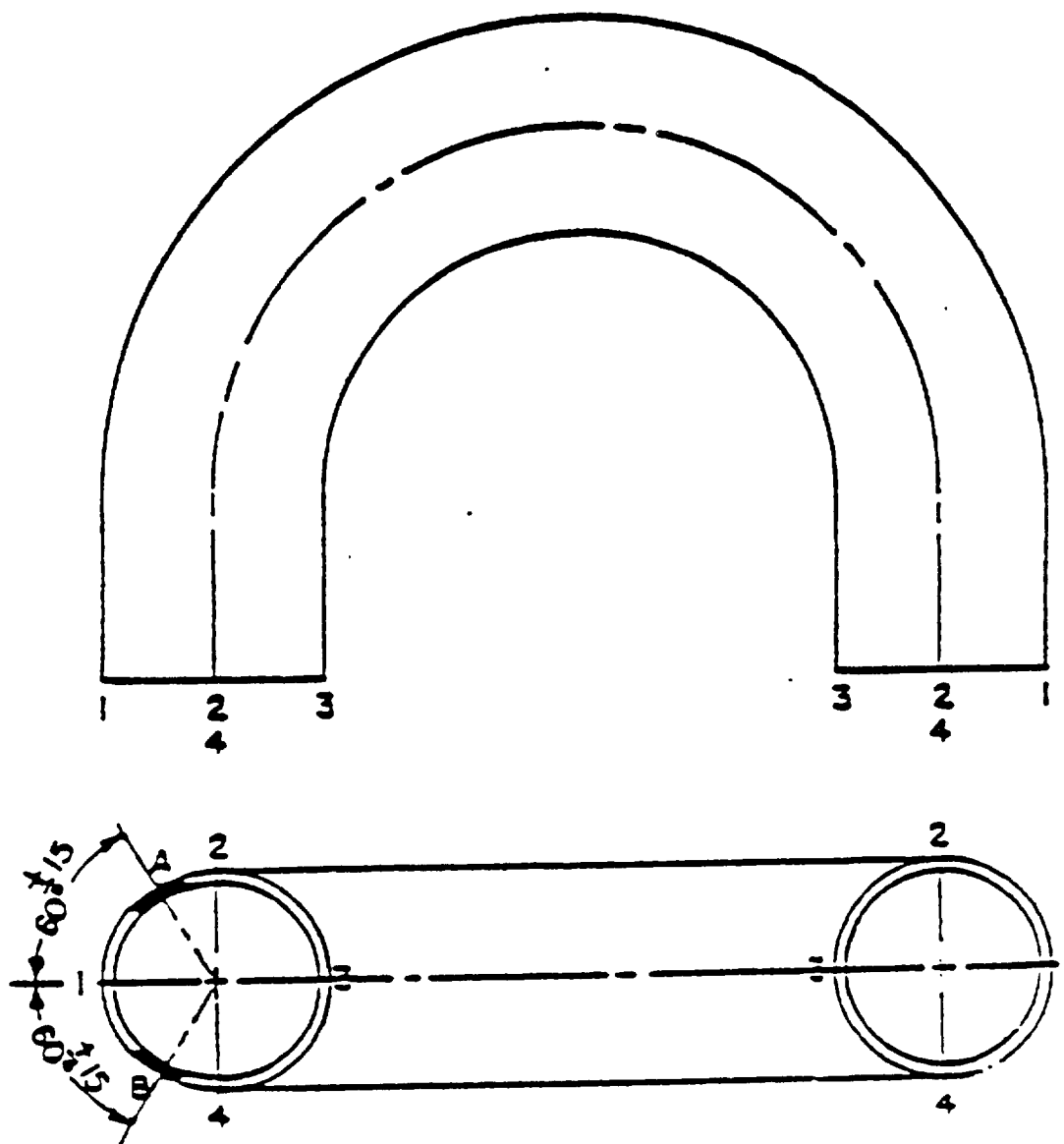


d. ROTARY OR CRAW TYPE



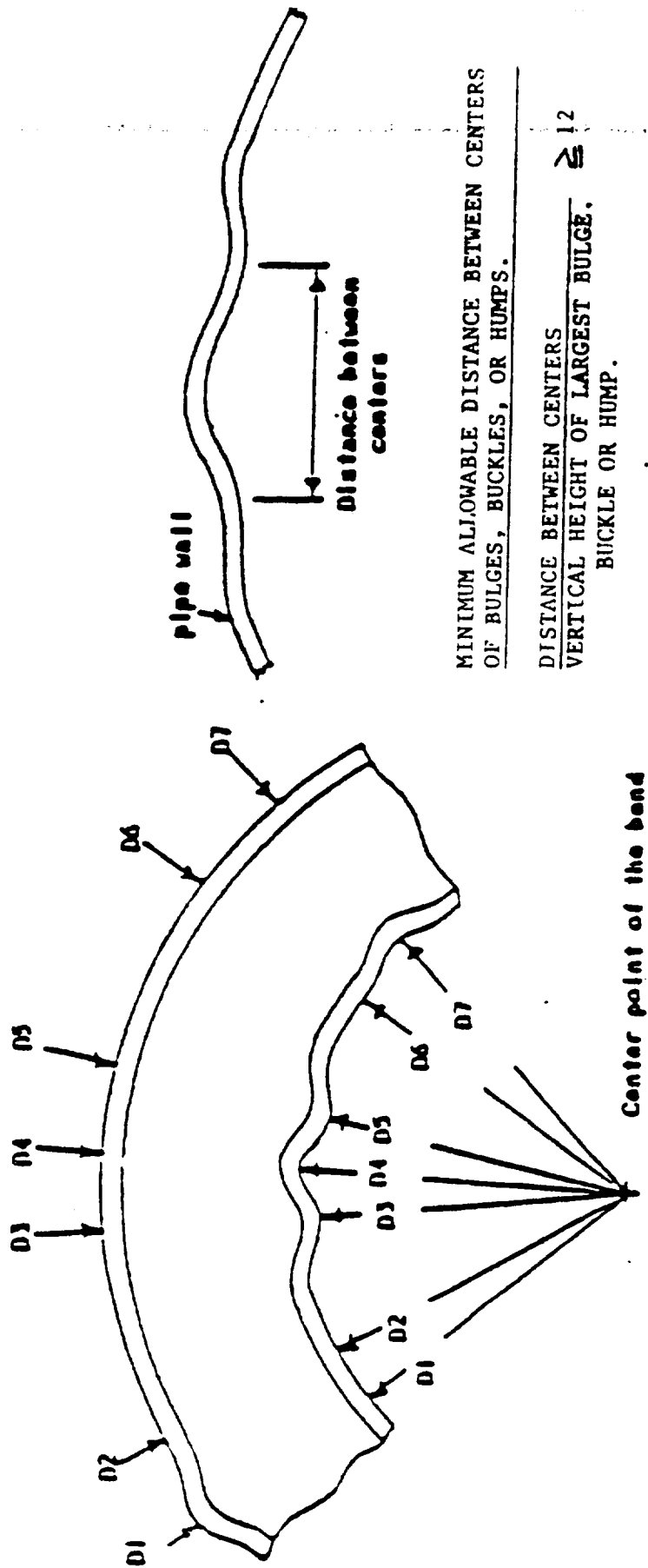
e. ROTARY TYPE WITH BOOSTER UNIT

FIGURE 1. Types of bending machines.



NOTE: The weld shall not be located at the axes 1-3 or 2-4.
It is preferred that the weld be located at locations
A or B.

FIGURE 2. Location of weld for welded pipe.



CALCULATION OF VERTICAL HEIGHT (3 percent of o.d. maximum)

1. Vertical height of the largest hump - $D1 - D2$.
2. Vertical height of the largest bulge or buckle - $\frac{D3 + D5 - D4}{2}$
3. Vertical height of the largest step or dent - $D6 - D7$.

FIGURE 3. Calculations for buckles, bulges, humps, steps, and dents in pipe bends.

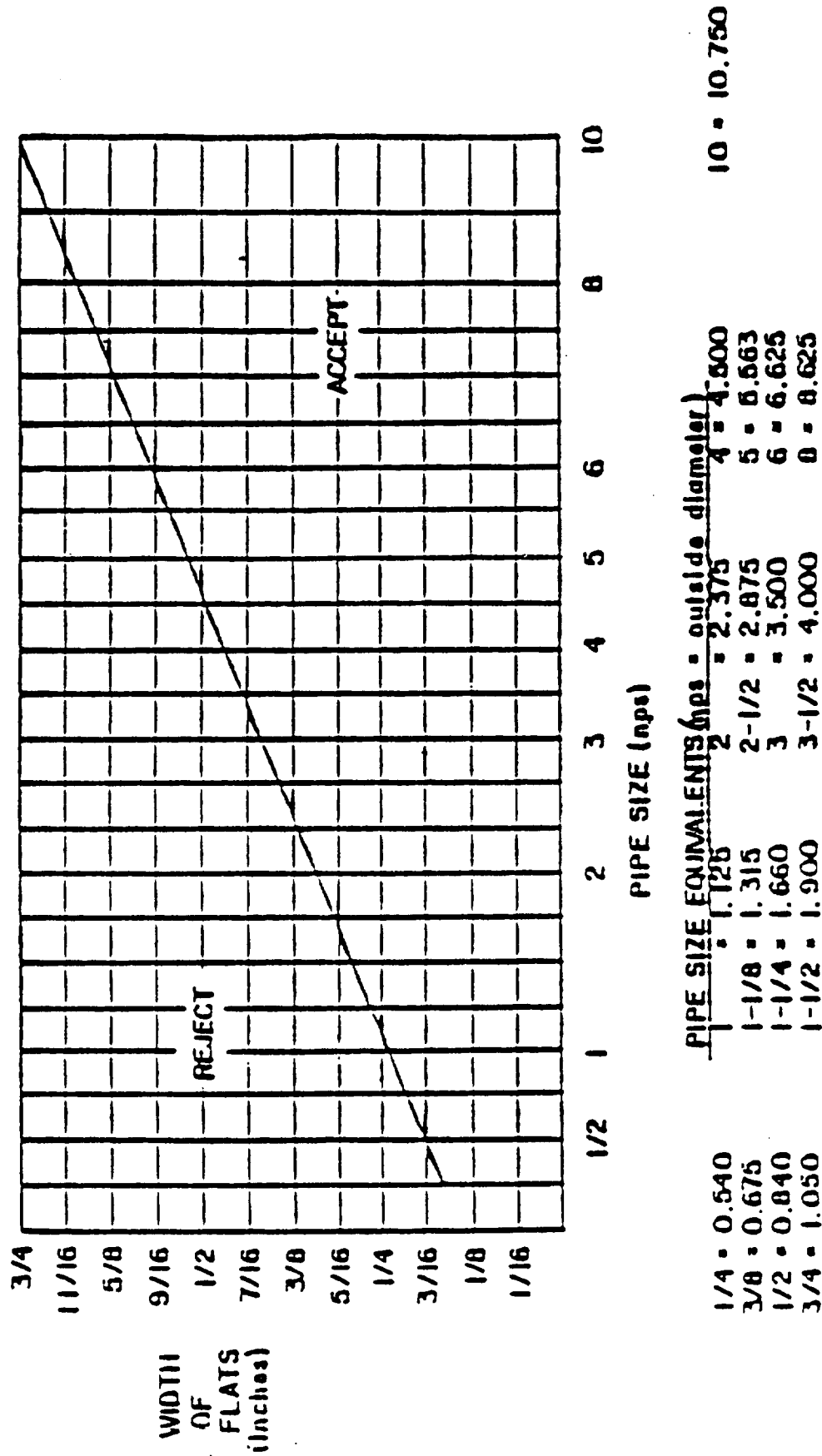


FIGURE 4. Flatness limits.

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the comment number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of this form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER

MIL-STD-1627C(SH)

2. DOCUMENT DATE (YYMMDD)

940930

3. DOCUMENT TITLE

BENDING OF PIPE OR TUBE FOR SHIP PIPING SYSTEMS.

4. NATURE OF CHANGE (identity paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle Initial)

b. ORGANIZATION

c. ADDRESS (Include Zip Code)

d. TELEPHONE (Include Area Code)

7. DATE SUBMITTED (YYMMDD)

(1) Commercial

(2) DSN

(if applicable)

8. PREPARING ACTIVITY

A. NAME Technical Point of Contact (TPOC)

MR. AL GRUBOWSKI, SEA 03M2

ADDRESS ALL CORRESPONDENCE AS FOLLOWS:

b. TELEPHONE (Include Area Code)

(1) Commercial:

DSN:

TPOC: 703-602-0205

8-332-0205

c. ADDRESS (Include Zip Code)

COMMANDER, NAVAL SEA SYSTEMS COMMAND

ATTN: SEA 03R42

2531 JEFFERSON DAVIS HIGHWAY

ARLINGTON, VA 22242-5160

IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT:

Defense Quality and Standardization Office

5203 Leesburg Pike, Suite 1403

Falls Church, VA 22041-3466

Telephone 703-756-2340 DSN 289-2340