



Standard Test Methods for Tool-Resisting Steel Bars, Flats, and Shapes for Detention and Correctional Facilities¹

This standard is issued under the fixed designation A 627; 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 These test methods cover requirements for simulated service tests and testing equipment for determining the performance characteristics of various types and shapes of steels designated for use in detention and correctional facilities as fixed barriers to prevent egress and to control passage.

1.2 It is the intent of these test methods to help ensure that opening assemblies such as detention security windows, grilles, bar grating, and other physical barriers incorporating steel bars perform at or above minimum acceptable levels for control of passage to unauthorized or secure areas, for confinement of inmates and to delay or frustrate escape attempts. To meet the intent of these test methods, opening assemblies must perform to grade requirements shown in Tables X1.1 and X1.2 in Appendix X1.

1.3 These test methods apply primarily to the steels used as essential components of detention security windows, grilles, bar grating, and so forth, in opening assemblies enclosing or separating secure areas of detention/correctional facilities.

1.4 The values stated in inch-pound units are to be regarded as standard. The SI values given in parentheses are for information only.

1.5 This standard updates and combines two previous standards, ASTM Specifications A 627-95 and A 629-94, establishing new security grades and time durations.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens²

E 4 Practices for Force Verification of Testing Machines³

¹ This specification is under the jurisdiction of ASTM Committee F33 on Detention and Correctional Facilities and is the direct responsibility of Subcommittee F33.02 on Physical Barriers.

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² *Annual Book of ASTM Standards*, Vol 04.02.

³ *Annual Book of ASTM Standards*, Vol 03.01.

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials³

E 329 Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction⁴

3. Terminology

3.1 Definitions:

3.1.1 *bars, n*—round, ribbed, hexagonal, or other shaped bars that can be readily reduced to a round cross-sectional shape, $\frac{7}{8}$ -in. (22.2-mm) or 1-in. (25.4-mm) diameter (see Fig. 1). Also flat bars: $\frac{1}{4}$ by 2 in. (6.4 by 50.8 mm); $\frac{5}{16}$ by $2\frac{1}{4}$ in. (7.9 by 57.2 mm) or $\frac{3}{8}$ by $2\frac{1}{2}$ in. (9.6 by 63.5 mm).

3.1.2 *composite tool-resisting steel bar/flat, n*—a bar/flat that is a composite of a tungsten carbide or other hard material, for cutting resistance and of a high strength, low alloy steel, heat treated up to HRC 45 max. hardness for impact and deflection resistance.

3.1.3 *cutting test, n*—a simulated service test in which the rating is based on the number of a specific type of tungsten carbide rod saws required to cut through the bar.

3.1.4 *effective tool-resisting (ETR) area, n*—the cross-sectional area of the portion of the bar that is tool resistant.

3.1.5 *equipment manufacturer, n*—a manufacturer who fabricates and assembles security products, including tool-resisting steel bars, for installation in areas requiring security against ingress and egress. This manufacturer processes the semi-finished bar and fabricates finished products suitable for use in opening assemblies requiring these specified performance characteristics. This manufacturer is also responsible for heat treating, fabricating, and assembling all ancillary items so as not to impair the performance characteristics of the bar/flat.

3.1.6 *hardness, n*—indicated as HRC, refers to hardness measured according to Test Methods E 18 on the Rockwell C scale.

3.1.7 *homogeneous tool-resisting bar/flat, n*—a bar/flat that is nominally of uniform chemistry throughout, usually high strength, low alloy steel heat treated to HRC 61 min.—HRC 64 max. hardness to a case depth of 0.150 in. min. for rounds and each longitudinal edge hardened to 0.250-in. min. for flats.

⁴ *Annual Book of ASTM Standards*, Vol 04.02.

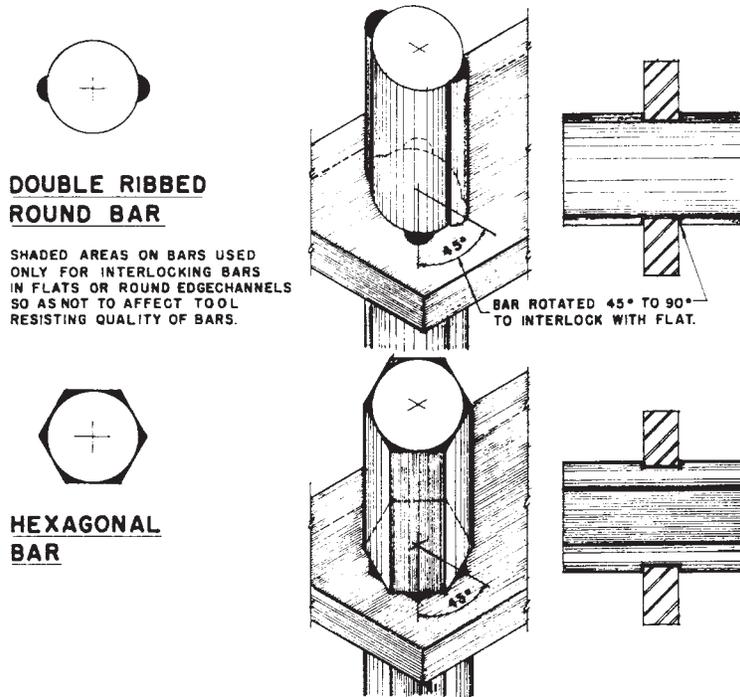


FIG. 1 Shaped Bars

3.1.8 *lot, n*—all bars/flats of the same nominal cross-sectional dimensions from the same mill heat and production lot.

3.1.9 *performance characteristic, n*—the response to any one test (drop-weight, cutting, or deflection) shown in Tables X1.1 and X1.2.

3.1.10 *test completion, n*—conduct one test sequence for each lot of bars.

3.1.11 *testing laboratory, n*—approved third party testing laboratory, accredited to I.S.O. Standard 17025-99, selected by the equipment manufacturer.

3.1.12 *test sequence:*

3.1.12.1 *round bars, n*—conduct drop-weight test and cutting test on one specimen bar and conduct deflection test on one additional specimen bar.

3.1.12.2 *flat bar, n*—conduct cutting test followed by hardness tests on the same flat bar.

4. Significance and Use

4.1 Security barriers used in detention/correctional facilities are a major concern for their administrative officials. These test methods are designed to identify levels of physical security for openings such as fixed and operable exterior and interior windows, bar gratings, grilles for mechanical ducts, and so forth in walls that enclose or separate secure areas.

4.2 These test methods are intended to evaluate the resistance of these barriers to violent attacks using battering devices such as benches, bunks or tables, and so forth to bend or break the steel bars and to surreptitious attacks by cutting/abrading the steel bars over prolonged periods of time using handheld grit-type cutting/abrading media such as tungsten carbide rod saws. External attacks and attacks by corrosive agents and other means not typically available to inmates are not addressed in this standard.

4.3 The primary purpose or result of these test methods is to approximate the levels of abuse to which these physical security barriers will potentially be subjected in the correctional/detention facility. The desired result of its use is to help provide a degree of assurance of protection to the public, facility personnel, and inmates.

4.4 It is recommended that detention/correctional facility administrators provide for adequate training, supervision, regular inspection, and preventive maintenance programs to enable the barriers to function as intended throughout their expected service life.

5. Ordering Information

5.1 Orders for material under this specification shall include the following information:

5.1.1 Name of material (homogeneous tool-resisting steel or composite tool resisting steel),

5.1.2 Dimensions (nominal diameter or cross section),

5.1.3 Cross section (double-ribbed, round, hexagon, square, rectangular, flat, or other shapes),

5.1.4 ASTM designation,

5.1.5 Test reports (if required),

5.1.6 Certification (if required), and

5.1.7 Special requirements (if any).

5.2 It is possible that bars of different nominal diameters/shapes are specified or shown on drawings. Each bar of the nominal diameter/cross section shape tested shall meet or exceed the minimum requirements of all tests for the diameter/shape shown in Tables X1.1 and X1.2.

5.3 The minimum levels of performance per type of steel required in Tables X1.1 and X1.2 for each bar are not independent characteristics, but are interrelated to each other

and though any one performance characteristic shall be permitted to exceed the requirements, none of the other characteristics shall be permitted to exhibit a performance lower than the minimum performance levels shown.

6. Mechanical Requirements

6.1 Drop-Weight Test:

6.1.1 *Requirements*—The specimen bar shall not crack, visibly fracture, or take a permanent set of more than 0.25 in. (6.4 mm) at the midspan between support points under the impact of 50 consecutive blows of a force as specified in Table X1.1 under “Drop-Weight Test.”

6.1.2 Number of Specimens:

6.1.2.1 The equipment manufacturer shall randomly select three bars/flats no less than 4 ft (1.22 m) in length from the lot for which the test is conducted. These 4-ft lengths shall be permanently marked after production or heat treating for easy identification of mill heat number, lot number, and individual identification of the two specimen bars taken from each of the 4-ft lengths.

6.1.2.2 Two 14-in. (356-mm) specimen bars shall be cut with a friction saw from each of the 4-ft lengths after heat treating. Each 14-in. specimen bar shall be permanently marked for easy identification as to production, mill heat number, lot number, and identity of the longer bar from which it was taken.

6.1.2.3 The testing laboratory shall, as its own choice, select two specimen bars taken from the same 4-ft length of bar for conduct of each test sequence.

6.1.2.4 It shall be the responsibility of the equipment manufacturer to determine, by visual inspection, that no unusual defects exist in the specimen bars and to determine that the specimen bars represent usual conditions, representative of all bars to be used from the lot.

6.1.2.5 In each test sequence, one specimen bar (prepared and selected as described in 6.1.2.1-6.1.2.3, inclusive) shall be used for both the drop-weight and cutting test. A second specimen bar, prepared and selected in the same manner and taken from the same 4-ft length of bar shall be used for the deflection test in each test sequence.

6.1.2.6 All specimen bars used in all test sequences shall be permanently marked for complete identification and held by the equipment manufacturer for no less than three years after the tests are completed.

6.1.3 Procedure:

6.1.3.1 Conduct the test on one specimen bar selected as required in 6.1.2.1-6.1.2.4 inclusive; stop after 50 consecutive blows, or sooner if the bar fails.

6.1.3.2 Drop the tup repeatedly so as to deliver 50 consecutive blows at the same point on the specimen bar. It shall be properly weighted and guided so as to produce the required impact in foot-pounds for each blow.

6.1.3.3 Apply each blow at the same point and on the same side of the specimen bar, perpendicular to the 14-in. (356-mm) axis and at the midpoint (± 0.250 in. (± 6.4 mm)) between the supports of the specimen bar.

6.1.3.4 To prevent an unmeasured secondary impact after each drop from the test height, make provisions in the testing

procedure to prevent the weighted tup from rebounding and again striking the test specimen.

6.1.3.5 The drop-weight machine is of simple design constructed from readily available rolled and shaped structural steel products. Raise the weight by any mechanical or electrical hoisting equipment or, alternatively, by hand. Provide a mechanical or electrical mechanism to achieve quick release of the weight. This testing machine shall conform to the requirements of Sections 16 and 18 of Practices E 4 as modified by the requirements of this specification or the manufacturer of the testing machine, provided that modifications of this equipment or assembly details provide a functionally acceptable drop-weight machine.

6.1.3.6 For $\frac{7}{8}$ -in. (22.2-mm) diameter bar, the drop-weight machine shall drop a weight of 50 lb. (22.7 kg) from a height of 2 ft (611 mm). For 1-in. (25.4-mm) diameter bar, the drop-weight machine shall drop a weight of 50 lb. (22.7 kg) from a height of 3 ft (916 mm).

6.1.3.7 The hardened tup that strikes the specimen bar shall be rounded initially to 0.250-in. (6.35-mm) radius and shall be heat treated to a minimum hardness of HRC 50.

6.1.3.8 The entire tup and weight shall fall freely by gravity when released and shall be inspected after each five blows to determine that the original shape of the tup has not been seriously deformed through repeated impact. If the 0.250-in. radius is flattened to more than 0.312-in. radius, the test shall be interrupted and the tup shall be restored to the 0.250-in. radius before testing is continued.

6.1.3.9 The fixed anvil-type supports for the 14-in. specimen bar shall be located no less than 2 in. (51 mm) above the bed of the testing machine and spaced 12 in. (305 mm) apart $\pm \frac{1}{16}$ in. (± 1.59 mm). They shall be so constructed as to hold the same point of the specimen bar underneath the tup for each drop of the weight by preventing significant rotation or lateral movement of the specimen bar during the conduct of the 50 blows required for a test (see Fig. 2 for a typical example).

6.1.3.10 The part of the machine in which the specimen bar is placed for drop-weight testing shall be surrounded by a metal guard screen for protection, as the breaking into two halves of the bar has the potential to cause them to be ejected laterally from the machine with projectile-like velocities (see Fig. 2 for a typical example).

6.1.3.11 The addition of other safety devices or features are permitted provided that a functionally equivalent drop-weight machine is maintained.

6.1.3.12 The entire test machine shall be securely bolted to a rigid foundation, such as a concrete floor, so as to eliminate any possible cushioning effect that would diminish the force of the impact generated by the falling top.

6.1.3.13 In addition to initial markings required for preparation of specimens, all specimen bars shall be given a durable marking, before beginning the drop-weight test, showing the side of the bar and the point at which the top contacted the bar.

6.2 Cutting Test:

6.2.1 *Requirements*—Performance characteristics shall be such that the bar tested is not severed with the number of rod saws required in Tables X1.1 and X1.2 under “Cutting Test.”

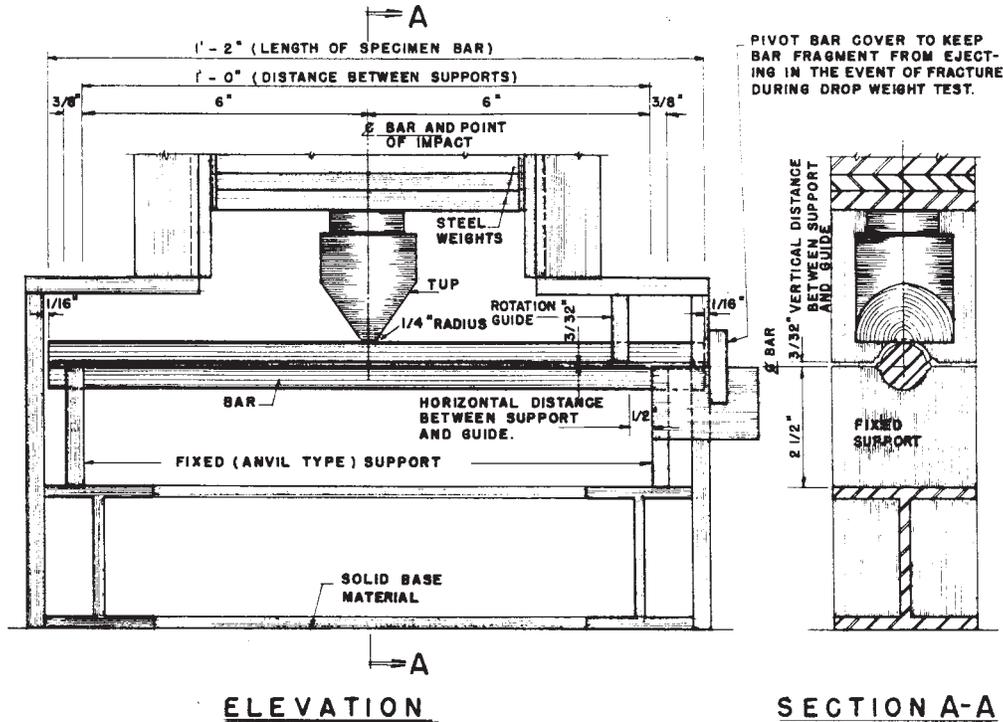


FIG. 2 Typical Example of Drop-Weight Test Apparatus

6.2.1.1 Interpretation of Cutting Test Results Based Upon Effective Tool-Resisting (ETR) Area—Composite Steel—The equation for computing the theoretical number of rod saws required to cut through a composite T.R. bar/flat is:

$$E = (A_{T.R.} / a_{T.R.}) \times 60 \quad (1)$$

where:

- E = calculated number of rod saws to sever the E.T.R. area within the steel bars/shapes,
- $A_{T.R.}$ = tool-resisting area that fits within the steel bar/shape cross-sectional area, in.²,
- $a_{T.R.}$ = tool-resistant area of the segment cut in 18 000 cutting cycles, in.², and
- 60 = number of rod saws used in 18 000 cutting cycles (300 cycles/rod saw).

6.2.1.2 Interpretation of Cutting Test Results—Homogeneous Tool-Resisting Bars/Flats—The cutting test shall be performed with number of rod saws as required for total severance.

6.2.1.3 Interpretation of Cutting Test Results--Composite Tool-Resisting Bars/Flats—The cutting test shall be performed with min. 60 rod saws.

6.2.2 Number of Specimens:

6.2.2.1 The same specimen bar that has acceptably passed the drop-weight test shall be subjected to the cutting test to determine its cutting-test performance characteristic.

6.2.2.2 It shall not be permissible to change, by heat treating or any other method, any of the qualities for characteristics of the specimen bar as tested under the requirements of the drop-weight test before the specimen being subjected to the cutting test.

6.2.2.3 Ribs on double-ribbed bars or points on hexagonal bars or any other configuration shall be permitted to be used to lock and counterlock bars in various security applications. However, only the round circumference that fits within the cross section of the shape shall be used to compute the cross-sectional area of the bar being tested in the cutting test (see Fig. 1).

6.2.3 Test Method:

6.2.3.1 The testing laboratory shall be responsible for determining that all rod saws used for testing comply with the specifications for tungsten carbide rod saws, which are as follows: 0.090-in. (2.1-mm) diameter, standard grit, 12-in. (304-mm) approximate length.

6.2.3.2 The test shall be conducted on a 6- by 6-in. (150- by 150-mm) gravity-feed, power-hacksaw machine under the following conditions:

Rod saw tension	200 lbf (890 N)
Static gravity feed pressure (ctr. of stroke)	26 ± 1 lbf (116 ± 4 N)
Dynamic feed pressure	21-37 (93-165 N)
Maximum lift on return strokes	0 in. (0 mm)
Speed	60 strokes/min.
Length of stroke	6 in. (152 mm)
Cutting fluid	none

6.2.3.3 The cutting resistance of the specimen bar shall be determined by placing it firmly in a vice underneath the rod saw in the power hacksaw and causing 18 000 cutting cycles of the rod saw to be made on the bar at one point. The point at which the cutting test is conducted shall be more than 2 in. (51 mm) from either end of the specimen bar and not closer than ½ in. (12.7 mm) to the midpoint of the specimen bar. The

direction of the cut shall be perpendicular to the 14-in. (356-mm) axis of the bar (see Fig. 3).

6.2.3.4 To assure uniform cutting action with no significant variations as a result of unusual rod saw wear in any of the 18 000 cycles, a new rod saw shall be used for every 300 cutting cycles.

6.2.3.5 One cutting cycle of the power hacksaw shall be a complete forward motion and return motion of the saw to the position from which the cycle began.

6.3 Deflection Test:

6.3.1 Requirements—The specimen shall not fracture or take a permanent set of more than 1/4 in. (6.4 mm) at the midspan between the 12-in. (305-mm) support points when a specimen bar of nominal diameter shown in Table X1.1 is subjected to a load as required under 6.3.3.

6.3.2 Number of Specimens—The other specimen bar (see 6.1.2.5) taken from the same 4-ft (1.22-m) length of bar as the specimen used for the drop-weight and cutting tests shall be used in conducting the deflection test.

6.3.3 Test Method:

6.3.3.1 The testing machine shall conform to the requirements of Test Method C 39 and shall be permitted to be of any type that is of sufficient capacity to provide the rate of loading required.

6.3.3.2 Fixed supports spaced 12 in. (305 mm) apart ($\pm 1/16$ in. (± 1.59 mm) supporting the specimen bar no less than 2 in. (51 mm) above the bed plate of the testing machine shall be

provided beneath the pressure ram. The machine shall be so constructed as to prevent the specimen bar from turning under pressure, providing such construction shall not restrict deflection in any manner (see Fig. 4 for a typical example).

6.3.3.3 A tup, rounded to a 0.250-in. (6.35-mm) radius, hardened to a HRC 50, minimum, shall be mounted on the ram of the testing machine and used to transmit pressure from the ram to the bar. The contact of the tup with the specimen bar shall be midway between the supports and at right angles to the 14-in. (356-mm) axis of the bar (see Fig. 4 for a typical example).

6.3.3.4 The measured load shall be applied to the bar consistently and uniformly over a period of not less than 2 s, nor more than 30 s, from zero to the maximum load corresponding to the level of deflection resistance required in Table X1.1.

6.3.3.5 The specified maximum load shall be applied to the bar and held continuously at maximum load level for not less than 3 min.

7. Hardness Test

7.1 The flat bar specimen tested for cutting resistance shall be used for hardness tests.

7.2 Location of Tests:

7.2.1 For plain flats, the test shall be made on both top and bottom of the flat within 0.040 in. (1 mm) of the midpoint between the longitudinal centerline and the edge of the flat.

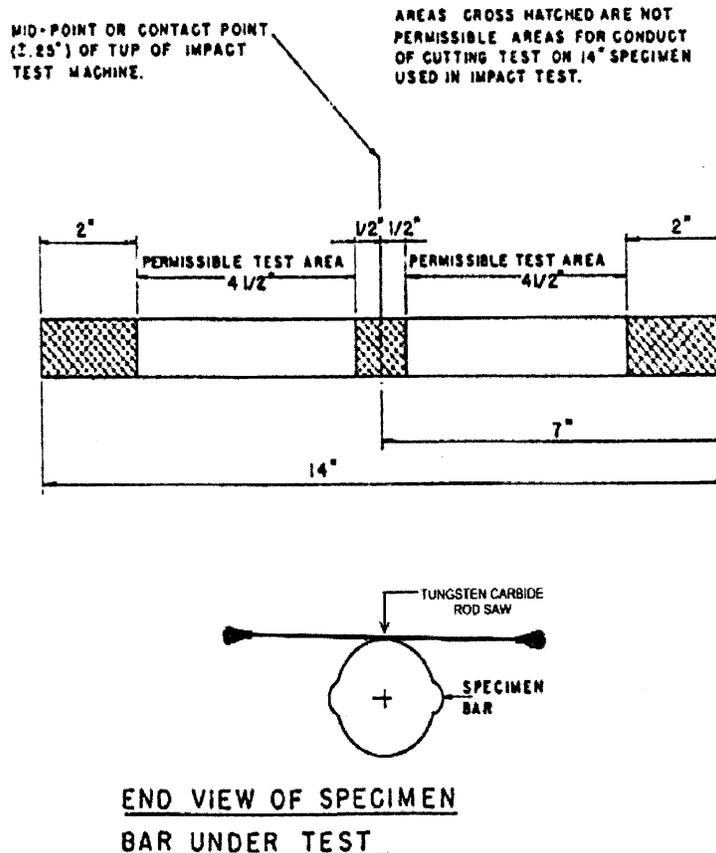


FIG. 3 Permissible Rod Saw-Testing Area on Specimen Bar

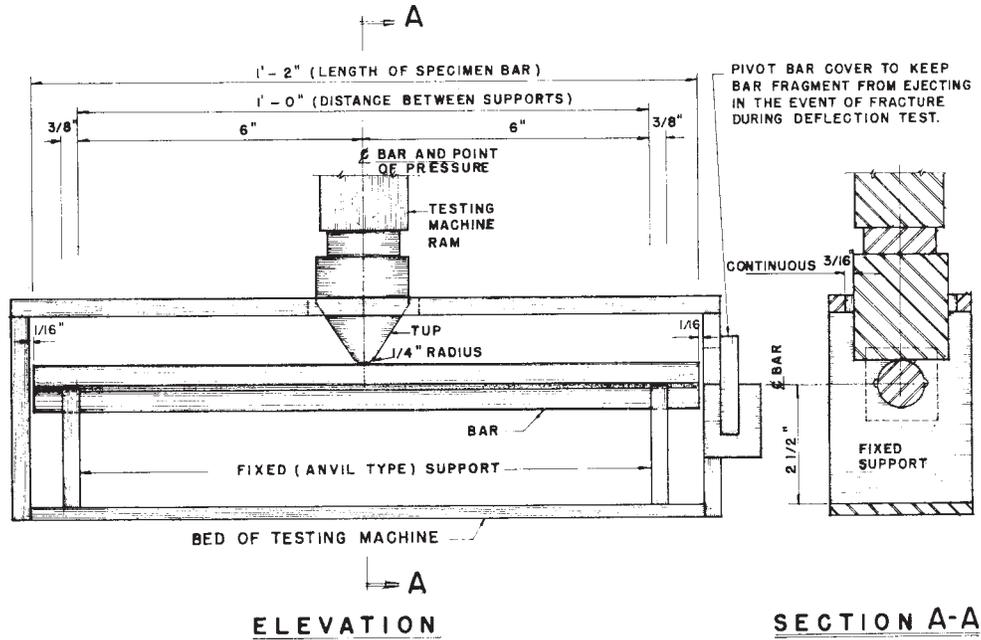


FIG. 4 Typical Example of Deflection Test Apparatus

7.2.2 For flats having holes, hardness tests shall be made on both top and bottom of the flats at points located on the transverse centerline of the hole and positioned within 0.125 ± 0.040 in. (3.2 ± 1 mm) from the edges of the hole.

7.2.3 For squares, the bar shall be cut at right angles to the longitudinal centerline and the hardness test shall be made within 0.040 in. (1 mm) of the center of the transverse sectional area thus obtained.

7.2.4 The hardness measurements shall not exceed HRC 45.

7.2.5 There shall be no evidence of cracks in the specimen. See Appendix.

8. Retests

8.1 In the event of a specimen-bar failure in one or more of the drop-weight, cutting, or deflection tests, the laboratory shall use the four additional specimen bars (prepared as required in 6.1.2.1-6.1.2.4) for the conduct of two additional test sequences. To be acceptable, all the additional specimen bars tested must meet satisfactorily all test requirements in the two additional test sequences.

9. Inspection

9.1 All tests and inspection shall be made before shipment, unless otherwise specified or agreed upon by the purchaser and seller as a part of the purchase contract.

10. Certification and Reports

10.1 *Certification*—Upon request of the purchaser in the contract or order, a manufacturer’s certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished by the equipment manufacturer at the time of shipment.

10.2 *Laboratory Summary Certification*—The following statement, upon request of the purchaser in the contract or order, shall be permitted to be substituted for 9.1: “Specimen bars of _____ in. nominal diameter marked _____ (type of steel) met the specified performance characteristics for complete test sequence for _____ nominal diameter bars, Table X1.1, and flat bar dimensions _____ Table X1.2, ASTM Standard Test Methods A 627, for Tool-Resisting Steel Bars for Detention Facilities, Grade _____.”

10.3 *Reports*—When required in the contract or order, reports shall be submitted containing the following information:

- 10.3.1 Name and address of laboratory,
- 10.3.2 Date laboratory completed tests,
- 10.3.3 Name and address of equipment manufacturer,
- 10.3.4 Mill heat and production lot number and description of identifying marking,
- 10.3.5 Location of testing equipment,
- 10.3.6 Dimensions (nominal diameter),
- 10.3.7 Cross section (double-ribbed round, hexagon, other shapes),
- 10.3.8 All test data, and
- 10.3.9 Effective tool-resisting area (A_{TR}) and area of segment cut (a_{TR}).

11. Keywords

11.1 correctional facility; cutting test; deflection test; detention facility; drop-weight test; physical security; security; security grades; steel bars; tool resistance; tool-resisting steel bars

APPENDIXES
(Nonmandatory Information)
X1. MINIMUM ACCEPTABLE PERFORMANCE CHARACTERISTICS FOR COMPOSITE AND HOMOGENEOUS TOOL-RESISTING STEELS

NOTE X1.1—The steel types below reflect the currently available technology and this standard is not meant to restrict in any way the future development of alternate or emerging technologies, or both, of steels or other composite materials that could meet the performance criteria for the grades in Tables X1.1 and X1.2.

TABLE X1.1 Round, Tool-Resisting Steel Bars—Security Grades

Minimum Acceptable Performance Characteristics										
Grade No.	Steel Type	Nominal Bar Diameter		Drop Weight Test, 50 Blows		Deflection Test, Permanent Set		Cutting Test Minimum to Sever the Bar	Time Duration	
		in.	(mm)	ft-lb	(J)	lbf	(N)		h	min
1	Composite T.R. Steel	1	(25.4)	150	(203)	8500	(37810)	144	12	720
2	Composite T.R. Steel	1	(25.4)	150	(203)	8500	(37810)	72	6	360
3	Homogeneous T.R. Steel	1	(25.4)	150	(203)	8500	(37810)	6	0.5	30
4	Homogeneous T.R. Steel	7/8	(22.2)	100	(136)	6000	(26690)	2	0.2	10

TABLE X1.2 Flat, Tool-Resisting Steel Bars—Security Grades

Minimum Acceptable Performance Characteristics								
Grade No.	Steel Type	Dimensions		Hardness Test Rockwell C	Cutting Test Minimum Number	Time Minimum		
		in.	(mm)					
1	Composite T. R. Steel	3/8 by 2 1/2	(9.5 by 63.5)	Maximum HRC-45	72	6	360	
2	Composite T. R. Steel	3/8 by 2 1/2	(9.5 by 63.5)	Maximum HRC-45	36	3	180	
3	Homogeneous T. R. Steel	5/16 by 2 1/4	(7.9 by 57.2)	Maximum HRC-45	3	0.25	15	
4	Homogeneous T. R. Steel	1/4 by 2	(6.4 by 50.8)	Maximum HRC-45	2	0.17	10	

X2. ROD SAW TESTING

X2.1 It is the purpose of these test methods to provide systematic basis for obtaining comparable values of various steels in resistance to cutting by tungsten carbide rod saw. The T.C. rod saw is as available as its predecessor, the steel hack saw blade, however, the T.C. rod saw is much more concealable for contraband, thus, on the basis of its cutting effectiveness and its geometry, it has become the most potent and dangerous tool.

X2.2 The T.C. rod saw is tremendously more effective in cutting the steel bars and flats than the steel hack saw blade.

X2.3 The previous ASTM designations A 627 and A 629, test methods for tool resisting steel, have dealt only with homogeneous class material, tested for cutting resistance by

steel hack saw blade. With the advent of the T.C. rod saw, the above tests are no longer sufficient to meet the potential threat. As an illustration, 1 in. dia. T.R. steel bar could resist 3000 steel hack saw blades while the same bar could be severed by a single tungsten carbide rod saw.

X2.4 The test method involving both homogeneous and composite steels for cutting by T.C. rod saw and the concurrent measurement of resistive values allows the specifier to choose the appropriate steel type and security grade for the intended purpose. See Appendix X1, Tables X1.1 and X1.2.

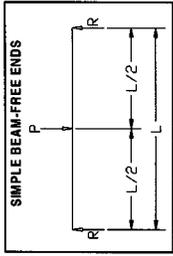
X2.5 Note that composite tool resisting steel is also available that can exceed 12 h resistance to cutting by T.C. rod saw.

X3. ROUND STEEL BAR-DEFLECTION AND PERMANENT SET OVER VARIOUS SPANS/LOADS

X3.1 See Fig. X3.1.

X4. ROUND STEEL BAR-DEFLECTION OVER VARIOUS SPANS/LOADS

X4.1 See Fig. X4.1.



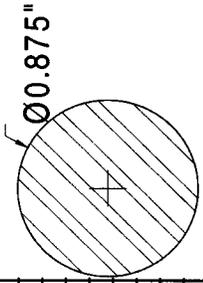
HOMOGENEOUS TOOL-RESISTING STEEL BARS / SECURITY APPLICATIONS

CONCENTRATED LOAD AT CENTER
SIMPLE BEAM - FREE ENDS

SINGLE HOMOGENEOUS TOOL-RESISTING STEEL ROUND BAR 7/8" DIA.

DEFLECTION

LOAD P LBS	SPAN @ (inches)																	
	12"		18"		24"		30"		36"		42"		48"		54"		60"	
	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max
1	500	0.025"	0.086"	0.210"	0.383"	0.662"	1.029"	1.502"	2.091"	2.802"								
2	1000	0.050"	0.164"	0.380"	0.746"	1.240"	1.969"											
3	1500	0.075"	0.243"	0.557"	1.190"	1.852"												
4	2000	0.097"	0.329"	0.782"	1.516"													
5	2500	0.123"	0.425"	1.036"	1.914"													
6	3000	0.150"	0.558"	1.445"														
7	3500	0.174"	0.651"															
8	4000	0.199"	0.744"															
9	4500	0.226"																
10	5000	0.255"																
11	5500	0.284"																
12	6000	0.320"																



SINGLE HOMOGENEOUS TOOL-RESISTING STEEL ROUND BAR 1" DIA.

DEFLECTION

LOAD P LBS	SPAN @ (inches)																	
	12"		18"		24"		30"		36"		42"		48"		54"		60"	
	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max
1	500	0.011"	0.039"	0.096"	0.191"	0.336"	0.541"	0.818"	1.177"	1.630"								
2	1000	0.024"	0.084"	0.203"	0.400"	0.698"	1.116"	1.678"	2.403"	3.313"								
3	1500	0.035"	0.125"	0.304"	0.607"	1.068"	1.723"	2.606"	3.754"									
4	2000	0.047"	0.165"	0.401"	0.797"	1.398"	2.248"	3.392"										
5	2500	0.061"	0.213"	0.520"	1.040"	1.829"	2.950"											
6	3000	0.075"	0.261"	0.632"	1.254"	2.194"	3.523"											
7	3500	0.084"	0.315"	0.805"	1.667"	3.021"												
8	4000	0.096"	0.365"	0.943"	1.970"	3.595"												
9	4500	0.110"	0.424"	1.101"	2.309"													
10	5000	0.121"	0.472"	1.241"	2.627"													
11	5500	0.136"	0.542"	1.445"	3.092"													
12	6000	0.149"	0.598"	1.605"	3.450"													
13	6500	0.165"	0.687"	1.891"														
14	7000	0.180"	0.767"	2.148"														
15	7500	0.198"	0.870"	2.487"														
16	8000	0.217"	0.981"	2.862"														
17	8500	0.235"	1.093"															
18	9000	0.254"	1.218"															

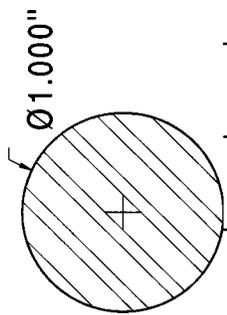


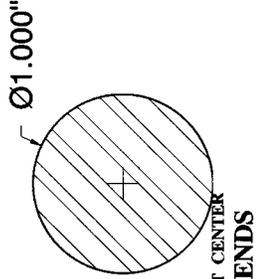
FIG. X3.1 Round Steel Bar-Deflection and Permanent Set Over Various Spans/Loads

PERMANENT SET

LOAD P LBS	SPAN @ (inches)													
	12"		18"		24"		30"		36"		48"		60"	
	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max
1	500	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"
2	1000	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"
3	1500	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"	0.001"
4	2000	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"
5	2500	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"
6	3000	0.007"	0.007"	0.007"	0.007"	0.007"	0.007"	0.007"	0.007"	0.007"	0.007"	0.007"	0.007"	0.007"
7	3500	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"
8	4000	0.012"	0.012"	0.012"	0.012"	0.012"	0.012"	0.012"	0.012"	0.012"	0.012"	0.012"	0.012"	0.012"
9	4500	0.016"	0.016"	0.016"	0.016"	0.016"	0.016"	0.016"	0.016"	0.016"	0.016"	0.016"	0.016"	0.016"
10	5000	0.021"	0.021"	0.021"	0.021"	0.021"	0.021"	0.021"	0.021"	0.021"	0.021"	0.021"	0.021"	0.021"
11	5500	0.029"	0.029"	0.029"	0.029"	0.029"	0.029"	0.029"	0.029"	0.029"	0.029"	0.029"	0.029"	0.029"
12	6000	0.041"	0.041"	0.041"	0.041"	0.041"	0.041"	0.041"	0.041"	0.041"	0.041"	0.041"	0.041"	0.041"

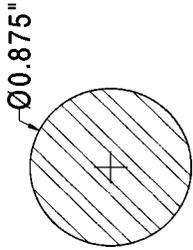
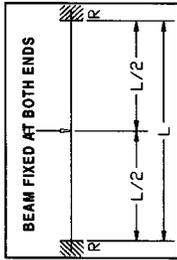
PERMANENT SET

LOAD P LBS	SPAN @ (inches)													
	12"		18"		24"		30"		36"		48"		60"	
	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max
1	500	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"
2	1000	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"
3	1500	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"
4	2000	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"
5	2500	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"	0.000"
6	3000	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"
7	3500	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"	0.002"
8	4000	0.003"	0.003"	0.003"	0.003"	0.003"	0.003"	0.003"	0.003"	0.003"	0.003"	0.003"	0.003"	0.003"
9	4500	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"	0.005"
10	5000	0.006"	0.006"	0.006"	0.006"	0.006"	0.006"	0.006"	0.006"	0.006"	0.006"	0.006"	0.006"	0.006"
11	5500	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"	0.009"
12	6000	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"	0.014"
13	6500	0.015"	0.015"	0.015"	0.015"	0.015"	0.015"	0.015"	0.015"	0.015"	0.015"	0.015"	0.015"	0.015"
14	7000	0.020"	0.020"	0.020"	0.020"	0.020"	0.020"	0.020"	0.020"	0.020"	0.020"	0.020"	0.020"	0.020"
15	7500	0.024"	0.024"	0.024"	0.024"	0.024"	0.024"	0.024"	0.024"	0.024"	0.024"	0.024"	0.024"	0.024"
16	8000	0.028"	0.028"	0.028"	0.028"	0.028"	0.028"	0.028"	0.028"	0.028"	0.028"	0.028"	0.028"	0.028"
17	8500	0.030"	0.030"	0.030"	0.030"	0.030"	0.030"	0.030"	0.030"	0.030"	0.030"	0.030"	0.030"	0.030"
18	9000	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"	0.037"



CONCENTRATED LOAD AT CENTER
SIMPLE BEAM - FIXED ENDS

SINGLE HOMOGENEOUS TOOL-RESISTING STEEL ROUND BAR 1" DIA.



HOMOGENEOUS TOOL-RESISTING STEEL BARS /
SECURITY APPLICATIONS

CONCENTRATED LOAD AT CENTER
SIMPLE BEAM - FIXED ENDS

SINGLE HOMOGENEOUS TOOL-RESISTING STEEL ROUND BAR 7/8" DIA.

DEFLECTION

LOAD P LBS	SPAN @ (inches)											
	12"		18"		24"		30"		36"		60"	
	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max
1	0.003	0.010	0.024	0.048	0.084	0.135	0.205	0.294	0.408			
2	0.006	0.021	0.051	0.100	0.175	0.279	0.420	0.601	0.828			
3	0.009	0.031	0.076	0.152	0.267	0.431	0.652	0.939				
4	0.012	0.041	0.100	0.199	0.350	0.562	0.848					
5	0.015	0.053	0.130	0.260	0.457	0.738						
6	0.019	0.065	0.158	0.314	0.549	0.881						
7	0.021	0.079	0.201	0.417	0.755							
8	0.024	0.091	0.236	0.493	0.899							
9	0.028	0.106	0.275	0.577								
10	0.030	0.118	0.310	0.657								
11	0.034	0.136	0.361	0.773								
12	0.037	0.150	0.401	0.863								
13	0.041	0.172	0.473									
14	0.045	0.192	0.537									
15	0.050	0.218	0.622									
16	0.054	0.245	0.716									
17	0.059	0.273										
18	0.064	0.303										

DEFLECTION

LOAD P LBS	SPAN @ (inches)											
	12"		18"		24"		30"		36"		60"	
	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max	f max
1	0.006	0.021	0.053	0.096	0.166	0.257	0.376	0.523	0.701			
2	0.012	0.041	0.095	0.186	0.310	0.492						
3	0.019	0.061	0.139	0.297	0.463							
4	0.024	0.082	0.196	0.379								
5	0.031	0.106	0.259	0.479								
6	0.038	0.139	0.361									
7	0.044	0.163										
8	0.050	0.186										
9	0.057											
10	0.064											
11	0.071											
12	0.080											

FIG. X4.1 Round Stel Bar-Deflection Over Various Spans/Loads

X5. EXAMPLE APPLICATION OF GRADE NUMBERS BY LOCATION AND CUSTODY LEVEL

X5.1 See Table X5.1.

TABLE X5.1 Example Application of Grade Numbers by Location and Custody Level^A

Location/Access/Observation	Custody Level			
	Super-Max	Max	Med	Min
A. Openings used in separating inmates from freedom. Possible applications include openings in exterior walls, or at primary security interior walls such as at visiting.				
1. Accessible to attack and never observed.	1	1 or 2	2	2 or 3
2. Accessible to attack and only intermittently observed.	1 or 2	2	2 or 3	3
3. Accessible to attack but continuously observed.	2	2 or 3	3	3 or 4
4. Not accessible to attack.	2 or 3	3	3 or 4	4
B. Openings used in separating classifications of inmates. Possible applications include openings between cells, dayrooms, or corridors.				
1. Accessible to attack and never observed.	2	2 or 3	3	3 or 4
2. Accessible to attack and only intermittently observed.	2 or 3	3	3 or 4	4
3. Accessible to attack but continuously observed.	3	3 or 4	4	Not TR
4. Not accessible to attack.	3 or 4	4	Not TR	Not TR

^A Although four grades of tool resistant material are available, it may not be cost effective to use all four grades on a single project. Fabrication labor costs including different setups, jigs, templates and coordination of different materials may exceed the material savings of using the lower grades, particularly for smaller projects.

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