



Designation: B649 – 21

Standard Specification for Ni-Fe-Cr-Mo-Cu-N Low-Carbon Alloy and Cr-Ni-Fe-N Low-Carbon Alloy Bar and Wire, Ni-Cr-Fe-Mo-N Alloy Wire, and Ni-Fe-Cr-Mo-N Alloy Bar¹

This standard is issued under the fixed designation B649; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers nickel-iron-chromium-molybdenum-copper-nitrogen alloy and chromium-nickel-iron-nitrogen low-carbon alloy bar and wire, nickel-chromium-iron-molybdenum-nitrogen alloy wire, and nickel-iron-chromium-molybdenum-nitrogen alloy bar.

1.2 ASTM International has adopted definitions whereby some grades, such as UNS N08904,² previously in this specification were recognized as stainless steels, because those grades have iron as the largest element by mass percent. Such grades are under the oversight of ASTM Committee A01 and its subcommittees. The products of N08904 previously covered in this specification are now covered by Specifications [A479/A479M](#) and [A484/A484M](#).

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

1.4 *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 become familiar with all hazards including those identified in the appropriate Safety Data Sheet (SDS) for this product/material as provided by the manufacturer, to establish appropriate safety, health, and environmental practices, and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

¹ This specification is under the jurisdiction of ASTM Committee B02 on Nonferrous Metals and Alloys and is the direct responsibility of Subcommittee B02.07 on Refined Nickel and Cobalt and Their Alloys.

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² New designation established in accordance with Practice E527 and SAE J1086, Practice for Numbering Metals and Alloys (UNS).

2. Referenced Documents

2.1 ASTM Standards:³

[A479/A479M](#) Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

[A484/A484M](#) Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

[B880](#) Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys

[E8](#) Test Methods for Tension Testing of Metallic Materials [Metric] E0008_E0008M

[E29](#) Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

[E55](#) Practice for Sampling Wrought Nonferrous Metals and Alloys for Determination of Chemical Composition

[E527](#) Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

[E1473](#) Test Methods for Chemical Analysis of Nickel, Cobalt and High-Temperature Alloys

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *bars, n*—hot-finished rounds, squares, octagons, and hexagons: $\frac{1}{4}$ in. (6.35 mm) and over in diameter or size; Hot-finished flats: $\frac{1}{4}$ in. to 10 in. (254 mm) inclusive in width, $\frac{1}{8}$ in. (3.18 mm) and over in thickness; Cold-finished rounds, squares, octagons, hexagons, and shapes: over $\frac{1}{2}$ in. (12.70 mm) in diameter or size; Cold-finished flats: $\frac{3}{8}$ in. (9.52 mm) and over in width (see 3.1.1.1) and $\frac{1}{8}$ in. and over in thickness (see 3.1.1.2).

3.1.1.1 *Discussion*—Widths less than $\frac{3}{8}$ in. (9.52 mm) and thicknesses less than $\frac{3}{16}$ in. (4.76 mm) are described generally as flat wire.

3.1.1.2 *Discussion*—Thickness $\frac{1}{8}$ in. to under $\frac{3}{16}$ in. (3.18 mm to under 4.76 mm) can be cold-rolled strip as well as bar.

³ For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

TABLE 1 Chemical Requirements

Element	UNS N08935	UNS N08936	UNS N08925	UNS N08031	UNS N08034	UNS N08354	UNS N08926	UNS R20033
Carbon, max	0.030	0.020	0.020	0.015	0.01	0.030	0.020	0.015
Manganese ^A	1.2	4.00–6.00	1.00	2.0	1.0–4.0	1.00	2.00	2.0
Phosphorus, max	0.030	0.025	0.045	0.020	0.020	0.030	0.03	0.02
Sulfur, max	0.020	0.010	0.030	0.010	0.010	0.010	0.01	0.01
Silicon, max	0.5	0.50	0.50	0.3	0.1	1.00	0.5	0.50
Nickel	34.0–36.0	33.00–35.00	24.00–26.00	30.0–32.0	33.5–35.0	34.0–36.0	24.00–26.00	30.0–33.0
Chromium	26.0–28.0	26.00–28.00	19.00–21.00	26.0–28.0	26.0–27.0	22.0–24.0	19.00–21.00	31.0–35.0
Molybdenum	6.1–7.1	5.00–6.00	6.0–7.0	6.0–7.0	6.0–7.0	7.0–8.0	6.0–7.0	0.50–2.0
Copper	0.4	0.50	0.8–1.5	1.0–1.4	0.5–1.5	...	0.5–1.5	0.30–1.20
Nitrogen	0.25–0.36	0.30–0.50	0.1–0.2	0.15–0.25	0.10–0.25	0.17–0.24	0.15–0.25	0.35–0.60
Iron	balance	balance	balance	balance	balance	balance	balance	balance
Aluminum	...	...	...	...	0.3	...	...	...

^A Maximum %, unless range or minimum is indicated.

3.1.2 *wire, n*—cold-finished only: round, square, octagon, hexagon, and shape wire, ½ in. (12.70 mm) and under in diameter or size. Cold-finished only: flat wire, ⅜ in. to under ⅝ in. (4.76 mm to under 9.52 mm) in width, 0.010 to under ⅜ in. (0.25 to under 4.76 mm) in thickness.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered to this specification. Examples of such requirements include, but are not limited to, the following:

- 4.1.1 Quantity (weight or number of pieces),
- 4.1.2 Alloy name or UNS number,
- 4.1.3 Form (bar or wire),
- 4.1.4 Dimensions,
- 4.1.5 Finish (Section 9),
- 4.1.6 ASTM designation and year of issue,
- 4.1.7 Exceptions to the specification or special requirements, and
- 4.1.8 Certification (Section 16).

5. Materials and Manufacture

5.1 *Heat Treatment*—With the exception of UNS N08936, the material shall be supplied in the solution-treated condition except as noted in 5.2. UNS N08936 shall be supplied in the cold drawn condition.

NOTE 1—The recommended heat treatment shall consist of heating to a temperature of 2010 to 2100 °F (1100 to 1150 °C) followed by water quenching for UNS N08925, UNS N08031, UNS N08034, 1975 to 2150 °F (1080 to 1180 °C) followed by water quenching or fast air cool for UNS N08354 and UNS N08926, 2010 to 2150 °F (1100 to 1180 °C) followed by water quenching or fast air cool for UNS R20033, or 1975 °F (1080 °C) minimum followed by water quenching or rapid cooling by other means for UNS N08935.

5.2 The heat treatment shall be waived for forging quality material.

6. Chemical Composition

6.1 The material sampled in accordance with 10.2 shall conform to the requirements as to chemical composition prescribed in Table 1.

6.2 *Product Analysis*—Product analysis may be made by the purchaser to verify the identity of the finished material repre-

senting each heat or lot. Such analysis may be made by any of the commonly accepted methods that will positively identify the material.

6.2.1 If a product analysis is made, the material shall conform to the product check analysis variation per Specification B880.

7. Mechanical and Other Requirements

7.1 *Tensile Requirements*—The material shall conform to the requirements as to the mechanical property prescribed in Table 2.

8. Dimensions, Weight, and Permissible Variations

8.1 *Bar*—The material referred to as bar shall conform to the variations in dimensions prescribed in Tables 3-11 inclusive, as applicable.

8.2 *Wire*—The material referred to as wire shall conform to the permissible variations in dimensions prescribed in Tables 12-16 inclusive, as applicable.

TABLE 2 Mechanical Property Requirements^A

Alloy	Cold Finished and Hot Finished Annealed, ^B All Sizes Except Where Noted			Forging Quality, All Sizes
	Tensile Strength, min, psi (MPa) ^C	Yield Strength min, psi (MPa) ^C	Elongation in 2 in. (50.8 mm), min, %	
UNS N08925	87 000 (600)	43 000 (300)	40	^A
UNS N08031	94 000 (650)	40 000 (270)	40	^A
UNS N08034	94 000 (650)	40 000 (280)	40	^A
UNS N08926	94 000 (650)	43 000 (295)	35	^A
UNS N08354	93 000 (640)	43 000 (295)	40	^A
UNS R20033	109 000 (750)	55 000 (380)	40	^A
UNS N08935	102 000 (700)	51 000 (350)	40	^A
UNS N08936				
Up to 0.063 in. (1.60 mm) dia., incl.	280 000 (1931)	240 000 (1655)	...	...
Over 0.063 in. (1.60 mm) dia.	250 000 (1724)	220 000 (1517)	...	...

^A No tensile properties are required on forging quality.

^B UNS N08936 shall be supplied in the cold drawn condition only.

^C For cold finished and annealed wire only, tensile strength 90 000 to 120 000 psi (620 to 830 MPa).

TABLE 3 Permissible Variations in Size of Hot-Finished Round and Square Bars

	Permissible Variations from Specified Size, in. (mm)		Out-of-Round ^A or Out-of-Square, ^B in. (mm)
	Over	Under	
1/4 (6.35) to 5/16 (7.94), incl ^{C,D}	<i>E</i>	<i>E</i>	<i>E</i>
Over 5/16 (7.94) to 7/16 (11.11), incl ^{C,D}	0.006 (0.15)	0.006 (0.15)	0.009 (0.23)
Over 7/16 (11.11) to 5/8 (15.88), incl ^{C,D}	0.007 (0.18)	0.007 (0.18)	0.010 (0.25)
Over 5/8 (15.88) to 7/8 (22.22), incl	0.008 (0.20)	0.008 (0.20)	0.012 (0.30)
Over 7/8 (22.22) to 1 (25.40), incl	0.009 (0.23)	0.009 (0.23)	0.013 (0.33)
Over 1 (25.40) to 1 1/8 (28.58), incl.	0.010 (0.25)	0.010 (0.25)	0.015 (0.38)
Over 1 1/8 (28.58) to 1 1/4 (31.75), incl	0.011 (0.28)	0.011 (0.28)	0.016 (0.41)
Over 1 1/4 (31.75) to 1 3/8 (34.92), incl	0.012 (0.30)	0.012 (0.30)	0.018 (0.46)
Over 1 3/8 (34.92) to 1 1/2 (38.10), incl	0.014 (0.36)	0.014 (0.36)	0.021 (0.53)
Over 1 1/2 (38.10) to 2 (50.80), incl	1/64 (0.40)	1/64 (0.40)	0.023 (0.58)
Over 2 (50.80) to 2 1/2 (63.50), incl	1/32 (0.79)	0	0.023 (0.58)
Over 2 1/2 (63.50) to 3 1/2 (88.90), incl	3/64 (1.19)	0	0.035 (0.89)
Over 3 1/2 (88.90) to 4 1/2 (114.30), incl	1/16 (1.59)	0	0.046 (1.17)
Over 4 1/2 (114.30) to 5 1/2 (139.70), incl	5/64 (1.98)	0	0.058 (1.47)
Over 5 1/2 (139.70) to 6 1/2 (165.10), incl	1/8 (3.18)	0	0.070 (1.78)
Over 6 1/2 (165.10) to 8 (203.20), incl	5/32 (3.97)	0	0.085 (2.18)

^A Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross section.

^B Out-of-square section is the difference in the two dimensions at the same cross section of a square bar, each dimension being the distance between opposite faces.

^C Size tolerances have not been evolved for rounds in the size range from 1/4 to 5/8 in. (6.35 to 7.94 mm), incl. Size tolerances have not been evolved for round sections in the size range from 1/4 (6.35 mm) to approximately 5/8 in. (15.88 mm) in diameter which are produced on rod mills in coils.

^D Squares in this size are not produced as hot-rolled products.

^E Variations in size of coiled product made on rod mills are greater than size tolerances for product made on bar mills.

TABLE 4 Permissible Variations in Size of Hot-Finished Hexagonal and Octagonal Bars

Specified Sizes Measured Between Opposite Sides, in. (mm)	Permissible Variations from Specified Size, in. (mm)		Maximum Difference in 3 Measurements for Hexagons only, in. (mm)
	Over	Under	
1/4 (6.35) to 1/2 (12.70), incl	0.007 (0.18)	0.007 (0.18)	0.011 (0.28)
Over 1/2 (12.70) to 1 (25.40), incl	0.010 (0.25)	0.010 (0.25)	0.015 (0.38)
Over 1 (25.40) to 1 1/2 (38.10), incl	0.021 (0.53)	0.021 (0.53)	0.025 (0.64)
Over 1 1/2 (38.10) to 2 (50.80), incl	1/32 (0.79)	1/32 (0.79)	1/32 (0.79)
Over 2 (50.80) to 2 1/2 (63.50), incl.	3/64 (1.19)	3/64 (1.19)	3/64 (1.19)
Over 2 1/2 (63.50) to 3 1/2 (88.90), incl	1/16 (1.59)	1/16 (1.59)	1/16 (1.59)

TABLE 5 Permissible Variations in Thickness and Width for Hot-Finished Flat Bars

Specified Width, in. (mm)	Permissible Variations in Thickness for Thicknesses Given, in. (mm)					
	1/8 (3.18) to 1/2 (12.70), incl		Over 1/2 (12.70) to 1 (25.40), incl		Over 1 (25.40) to 2 (50.80), incl	
	Over	Under	Over	Under	Over	Under
To 1 (25.40), incl	0.008 (0.20)	0.008 (0.20)	0.010 (0.25)	0.010 (0.25)	...	...
Over 1 (25.40) to 2 (50.80), incl	0.012 (0.30)	0.012 (0.30)	0.015 (0.38)	0.015 (0.38)	0.031 (0.79)	0.031 (0.79)
Over 2 (50.80) to 4 (101.60), incl	0.015 (0.38)	0.015 (0.38)	0.020 (0.51)	0.020 (0.51)	0.031 (0.79)	0.031 (0.79)
Over 4 (101.60) to 6 (152.40), incl	0.015 (0.38)	0.015 (0.38)	0.020 (0.51)	0.020 (0.51)	0.031 (0.79)	0.031 (0.79)
Over 6 (152.40) to 8 (203.20), incl	0.016 (0.41)	0.016 (0.41)	0.025 (0.64)	0.025 (0.64)	0.031 (0.79)	0.031 (0.79)
Over 8 (203.20) to 10 (254.00), incl	0.021 (0.53)	0.021 (0.53)	0.031 (0.79)	0.031 (0.79)	0.031 (0.79)	0.031 (0.79)
	Over 2 (50.80) to 4 (101.60), incl		Over 4 (101.60) to 6 (152.40), incl		Over 6 (152.40) to 8 (203.20), incl	
	Over	Under	Over	Under	Over	Under
To 1 (25.40), incl	...	...	...	...	...	...
Over 1 (25.40) to 2 (50.80), incl	...	...	...	...	...	...
Over 2 (50.80) to 4 (101.60), incl	0.062 (1.57)	0.031 (0.79)	...	...	...	...
Over 4 (101.60) to 6 (152.40), incl	0.062 (1.57)	0.031 (0.79)	0.093 (2.36)	0.062 (1.57)	...	...
Over 6 (152.40) to 8 (203.20), incl	0.062 (1.57)	0.031 (0.79)	0.093 (2.36)	0.062 (1.57)	0.125 (3.18)	0.156 (3.96)
Over 8 (203.20) to 10 (254.00), incl	0.062 (1.57)	0.031 (0.79)	0.093 (2.36)	0.062 (1.57)	0.125 (3.18)	0.156 (3.96)
	Permissible Variations in Width, in. (mm)					
	Over		Under			
To 1 (25.40), incl	0.015 (0.38)		0.015 (0.38)			
Over 1 (25.40) to 2 (50.80), incl	0.031 (0.79)		0.031 (0.79)			
Over 2 (50.80) to 4 (101.60), incl	0.062 (1.57)		0.031 (0.79)			
Over 4 (101.60) to 6 (152.40), incl	0.093 (2.36)		0.062 (1.57)			
Over 6 (152.40) to 8 (203.20), incl	0.125 (3.18)		0.156 (3.96)			
Over 8 (203.20) to 10 (254.00), incl	0.156 (3.96)		0.187 (4.75)			

9. Workmanship, Finish, and Appearance

9.1 The material shall be uniform in quality and condition, smooth, commercially straight or flat, and free of injurious defects.

9.2 Bars in the hot-finished condition may be furnished with one of the following finishes:

9.2.1 Scale not removed,

9.2.2 Pickled or descaled, or

TABLE 6 Permissible Variations in Size of Cold-Finished Round Bars

Specified Size, in. (mm)	Permissible Variations from Specified Size, in. (mm) ^{A,B}	
	Over	Under
Over ½ (12.70) to 1 (25.40), excl	0.002 (0.05)	0.002 (0.05)
1 (25.40) to 1½ (38.10), excl	0.0025 (0.06)	0.0025 (0.06)
1½ (38.10) to 4 (101.60), incl ^C	0.003 (0.08)	0.003 (0.08)

^A Unless otherwise specified, size tolerances are over and under as shown in the above table. When required, however, they may be specified all over and nothing under, or all under and nothing over, or any combination of over and under, if the total spread in size tolerance for a specified size is not less than the total spread shown in the table.

^B When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

^C Cold-finished bars over 4 in. (101.60 mm) in diameter are produced; size tolerances for such bars have not been evolved.

TABLE 7 Permissible Variations in Size of Cold-Finished Hexagonal, Octagonal, and Square Bars

Specified Size, in. (mm)	Permissible Variations from Specified Size, in. (mm) ^A	
	Over	Under
Over ½ (12.70) to 1 (25.40), incl	0	0.004 (0.10)
Over 1 (25.40) to 2 (50.80), incl	0	0.006 (0.15)
Over 2 (50.80) to 3 (76.20), incl	0	0.008 (0.20)
Over 3 (76.20)	0	0.010 (0.25)

^A When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

TABLE 8 Permissible Variations in Width and Thickness of Cold-Finished Flat Bars

Width, in. (mm)	Permissible Variations in Width, over and under, in. (mm) ^A	
	For Thicknesses ¼ (6.35) and Under	For Thicknesses Over ¼ (6.35)
	Over	Under
⅜ (9.52) to 1 (25.40), incl	0.004 (0.10)	0.002 (0.05)
Over 1 (25.40) to 2 (50.80), incl	0.006 (0.15)	0.003 (0.08)
Over 2 (50.80) to 3 (76.20), incl	0.008 (0.20)	0.004 (0.10)
Over 3 (76.20) to 4½ (114.30), incl	0.010 (0.25)	0.005 (0.13)
Thickness, in. (mm)	Permissible Variations in Thickness, over and under, in. (mm) ^A	
⅛ (3.18) to 1 (25.40), incl	0.002 (0.05)	
Over 1 (25.40) to 2 (50.80), incl	0.003 (0.08)	
Over 2 (50.80) to 3 (76.20), incl	0.004 (0.10)	
Over 3 (76.20) to 4½ (114.30), incl ^B	0.005 (0.13)	

^A When it is necessary to heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

^B Cold-finished flat bars over 4½ in. (114.30 mm) wide or thick are produced; width and thickness tolerances for such bars have not been evolved.

9.2.3 Turned (rounds only).

9.3 Bars in the cold-finished condition may be furnished with one of the following finishes:

- 9.3.1 Cold-drawn,
- 9.3.2 Centerless ground (rounds only), or
- 9.3.3 Polished (rounds only).

9.4 Wire in the cold-finished condition may be furnished with one of the following finishes:

- 9.4.1 Cold-drawn,
- 9.4.2 Centerless ground (rounds only),
- 9.4.3 Polished (rounds only), or

TABLE 9 Permissible Variations in Length of Hot-Finished or Cold-Finished Bars

NOTE 1—The order should specify random lengths or specific lengths. When random lengths are ordered, the length tolerance is not less than 24 in. (609.60 mm). When specific lengths are ordered, Table 9 or Table 10 shall apply.

Specified Size of Rounds, Squares, Hexagons, and Octagons, and Widths of Flats, ^A in. (mm)	Permissible Variations in Length, in. (mm)			
	For Lengths Up to 12 ft (3658 mm), incl		For Lengths Over 12 ft (3658 mm) to 25 ft (7620 mm), incl	
	Over	Under	Over	Under
To 2 (50.80), incl	½ (12.70)	0	¾ (19.05)	0
Over 2 (50.80) to 4 (101.60), incl	¾ (19.05)	0	1 (25.40)	0
Over 4 (101.60) to 6 (152.40), incl	1 (25.40)	0	1¼ (31.75)	0
Over 6 (152.40) to 9 (228.60), incl	1¼ (31.75)	0	1½ (38.10)	0
Over 9 (228.60) to 12 (304.80), incl	1½ (38.10)	0	2 (50.80)	0

^A The maximum width of bar flats is 10 in. (254.00 mm).

TABLE 10 Permissible Variations in Length of Hot-Finished or Cold-Finished Bars Machine Cut After Machine Straightening

NOTE 1—The order should specify random lengths or specific lengths. When random lengths are ordered, the length tolerance is not less than 24 in. (609.60 mm). When specific lengths are ordered, Table 9 or Table 10 shall apply.

Specified Size of Rounds, Squares, Hexagons, and Octagons, and Widths of Flats, ^A in. (mm)	Permissible Variations in Length, in. (mm)			
	For Lengths Up to 12 ft (3658 mm), incl		For Lengths Over 12 ft (3658 mm) to 25 ft (7620 mm), incl	
	Over	Under	Over	Under
To 3 (76.20), incl	⅙ (3.18)	0	⅓ (4.76)	0
Over 3 (76.20) to 6 (152.40), incl	⅓ (4.76)	0	¼ (6.35)	0
Over 6 (152.40) to 9 (228.60), incl	¼ (6.35)	0	⅓ (7.94)	0
Over 9 (228.60) to 12 (304.80), incl	½ (12.70)	0	½ (12.70)	0

^A The maximum width of bar flats is 10 in. (254.00 mm).

TABLE 11 Permissible Variations in Straightness of Machine Straightened Hot-Finished or Cold-Finished Bars

Measurement is taken on the concave side of the bar with a straightedge. Unless otherwise specified, hot-finished or cold-finished bars for machining purposes are furnished machine straightened to the following tolerances:

Hot finished:
 ⅛ in. (3.18 mm) in any 5 ft (1524 mm), but may not exceed ⅛ in. (3.18 mm) × (length in feet (mm))/(5 ft (1524 mm))

Cold finished:
 ⅛ in. (1.59 mm) in any 5 ft (1524 mm), but may not exceed ⅛ in. (1.59 mm) × (length in feet (mm))/(5 ft (1524 mm))

9.4.4 Pickled.

10. Sampling

10.1 Lots for Chemical Analysis and Mechanical Testing:

- 10.1.1 A lot for chemical analysis shall consist of one heat.
- 10.1.2 A lot for testing and inspection purposes shall consist of material from one heat of the same condition (temper), finish, and cross section, and in no case more than 30 000 lb (13 600 kg) in mass.

NOTE 2—Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (227 kg) of material in the same thickness and condition, except that for pieces weighing over 500 lb, only one specimen shall be taken.