STANDARD SPECIFICATIONS

CARNEGIE STEEL COMPANY

PITTSBURGH, PA.

SIXTH EDITION

STANDARD SPECIFICATIONS

STEEL

FOR

BRIDGES, BUILDINGS

LOCOMOTIVES, CARS, AND SHIPS

BOILERS AND RIVETS

CONCRETE REINFORCEMENT

WHEELS AND GEAR BLANKS

AXLES AND SHAFTS

CARNEGIE STEEL COMPANY

PITTSBURGH, PA.

Sixth Edition, January 1, 1917.

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THE ASSOCIATION

OF

AMERICAN STEEL MANUFACTURERS

STANDARD SPECIFICATIONS

FOR

STRUCTURAL AND BOILER STEEL

ADOPTED BY

THE ASSOCIATION OF AMERICAN STEEL MANUFACTURERS

AUGUST 9, 1895

REVISED 1896, 1902, 1903, 1912, 1914 AND

SEPTEMBER 1, 1916

MANUFACTURERS' STANDARD SPECIFICATIONS

STRUCTURAL STEEL

1. **Grades.** These specifications cover three classes of structural steel, namely:

CLASS A STEEL

To be used for railway bridges and ships.

CLASS B STEEL

To be used for buildings, highway bridges, train sheds and similar structures.

CLASS C STEEL

To be used for structural rivets.

I. MANUFACTURE

2. **Process.** Steel for classes A and C shall be made by the open-hearth process. Steel for class B may be made either by the open-hearth or by the bessemer process.

II. CHEMICAL PROPERTIES AND TESTS

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Elements Considered	Class A Steel	Class B Steel	Class C Steel
Phosphorus, maximum,			
Basic open-hearth.....per cent	0.04	0.06	0.04
Acid open-hearth.....per cent	0.06	0.08	0.04
Bessemer.....per cent	....	0.10	....
Sulphur, maximum.....per cent	0.05	....	0.045

4. **Ladle Analyses.** To determine whether the material conforms to the requirements specified in sec. 3, an analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt. A copy of this analysis shall be given to the purchaser or his representative, if requested.

5. **Check Analyses.** A check analysis of class A and class C steel may be made by the purchaser from finished material representing each melt, in which case an excess of 25 per cent above the requirements specified in sec. 3 shall be allowed.

III. PHYSICAL PROPERTIES AND TESTS

6. **Tension Tests.** The steel shall conform to the following requirements as to tensile properties:

Properties Considered	Class A Steel	Class B Steel	Class C Steel
Tensile strength...lb. per sq. inch	55,000-65,000	55,000-65,000*	46,000-56,000
Yield point, min...lb. per sq. inch	0.5 tens. str.	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min..per cent	1,400,000 † / tens. str.	1,400,000 † / tens. str.	1,400,000 / tens. str.
Elongation in 2 in., ‡ min.per cent	22	22	.....

*See sec. 8. †See sec. 9. ‡See fig. 2.

7. **Yield Point.** The yield point shall be determined by the drop of the beam of the testing machine.

8. **Modification in Tensile Strength.** Class B steel may have tensile strength up to 70,000 pounds maximum, provided the elongation is not less than the percentage required for 65,000 pounds tensile strength.

9. **Modifications in Elongation.** (*a*) For material over ¾ inch in thickness, a deduction of 1 from the percentage of elongation in 8 inches specified for classes A and B in sec. 6 shall be made for each increase of ⅛ inch in thickness above ¾ inch, to a minimum of 18 per cent.

(*b*) For material under 5/16 inch in thickness, a deduction of 2.5 from the percentage of elongation in 8 inches specified for classes A and B in sec. 6 shall be made for each decrease of 1/16 inch in thickness below 5/16 inch.

10. **Character of Fracture.** All broken tension-test specimens shall show a silky fracture.

11. **Bend Tests.** (*a*) The test specimen for plates, shapes and bars shall bend cold through 180 degrees without fracture on the outside of the bent portion, as follows: For material 3/4 inch and under in thickness, flat on itself; for material over 3/4 inch up to 1 1/4 inches in thickness, around a pin the diameter of which is equal to 1 1/2 times the thickness of the specimen; and for material over 1 1/4 inches in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for pins and rollers shall bend cold through 180 degrees around a 1-inch pin without fracture on the outside of the bent portion.

(*c*) A rivet rod shall bend cold through 180 degrees flat on itself without fracture on the outside of the bent portion.

(*d*) Bend tests may be made by pressure or by blows.

12. **Test Specimens.** (*a*) Tension-and bend-test specimens shall be taken from the finished rolled or forged product, and shall not be annealed or otherwise treated, except as specified in sec. 13.

(*b*) Tension–and bend-test specimens for plates, shapes and bars, except as specified in par. (*c*), shall be of the full thickness of material as rolled, and with both edges milled to the form and dimensions shown in fig. 1, or may have both edges parallel.

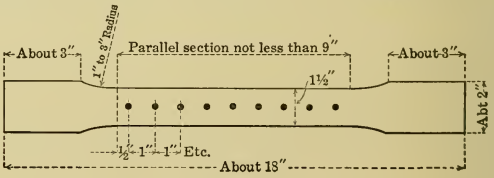


FIGURE 1.

(*c*) Tension–and bend-test specimens for plates and bars (except eye-bar flats) over 1 1/2 inches in thickness or diameter may be turned or planed to a diameter or thickness of at least 3/4 inch for a length of at least 9 inches.

(*d*) Tension-and bend-test specimens for pins and rollers shall be taken parallel to the axis, 1 inch from the surface of the bar. Tension-test specimens shall be of the form and dimensions shown in fig. 2. Bend-test specimens shall be 1 inch by ½ inch in section.

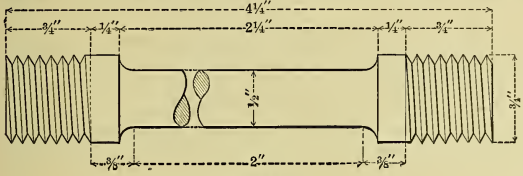


FIGURE 2.

(*e*) Rivet bars shall be tested in full-size section as rolled.

13. **Annealed Specimens.** Test specimens for material which is to be annealed or otherwise treated before use, shall be cut from properly annealed or similarly treated short lengths of the full section of the piece.

14. **Number of Tests.** (*a*) At least one tension test and one bend test shall be made from each melt. If material from one melt differs ⅜ inch or more in thickness, tests shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen develops flaws, or if an 8-inch tension-test specimen breaks outside the middle third of the gage length, or if a 2-inch tension-test specimen breaks outside the gage length, it may be discarded and another specimen substituted therefor.

(*c*) Material intended for fillers or ornamental purposes will not be subject to test.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND GAGE

15. **Permissible Variations.** (*a*) The sectional area or weight of each structural shape and of each rolled-edge plate up to and including 36 inches in width shall not vary more than 2.5 per cent from theoretical or specified amounts.

(*b*) The thickness or weight of each universal plate over 36 inches in width, and of each sheared plate shall conform to the schedules of permissible variations for sheared plates, Manufacturers' Standard Practice, appended to these specifications.

(*c*) The weights of angles, tees, zees and channels of bar sizes, and the dimensions of rounds, squares, hexagons and flats, shall conform to the Manufacturers' Standard Practice governing the allowable variations in size and weight of hot rolled bars.

V. FINISH

16. **Finish.** The finished material shall be free from injurious defects, and shall have a workmanlike finish.

VI. MARKING

17. **Marking.** The name of the manufacturer and the melt number shall be legibly marked, stamped or rolled upon all finished material, except that each pin and roller shall be stamped on the end. Rivet and lattice steel and other small pieces may be shipped in securely fastened bundles, with the above marks legibly stamped on attached metal tags. Test specimens shall have their melt numbers plainly marked or stamped.

VII. INSPECTION AND REJECTION

18. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

19. **Rejection.** Material which, subsequent to the above tests at the mills and its acceptance there, develops weak spots, brittleness, cracks or other imperfections, or is found to have injurious defects, may be rejected at the shop and shall then be replaced by the manufacturer at his own cost.

BOILER STEEL

1. **Grades.** There shall be three grades of steel for boilers, namely: flange, firebox, and boiler rivet.

I. MANUFACTURE

2. **Process.** The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Elements Considered	Flange Steel	Firebox Steel	Boiler Rivet Steel
Manganese.....per cent	0.30 to 0.60	0.30 to 0.50	0.30 to 0.50
Phosphorus, maximum,			
Basic.....per cent	0.04	0.035	0.04
Acid.....per cent	0.05	0.04	0.04
Sulphur, maximum.....per cent	0.05	0.04	0.045

4. **Ladle Analyses.** To determine whether the material conforms to the requirements specified in sec. 3, an analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt. A copy of this analysis shall be given to the purchaser or his representative.

5. **Check Analyses.** A check analysis may be made by the purchaser from a broken tension-test specimen representing each plate as rolled, and this analysis shall conform to the requirements specified in sec. 3.

III. PHYSICAL PROPERTIES AND TESTS

6. **Tension Tests.** The steel shall conform to the following requirements as to tensile properties:

Properties Considered	Flange Steel	Firebox Steel	Boiler Rivet Steel
Tensile strength...lb. per sq. inch	55,000-65,000	52,000-60,000	45,000-55,000
Yield point, min...lb. per sq. inch	0.5 tens. str.	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min...per cent	1,450,000* / tens. str.	1,450,000* / tens. str.	1,450,000 / tens. str.

*See. sec. 8.

7. **Yield Point.** The yield point shall be determined by the drop of the beam of the testing machine.

8. **Modifications in Elongation.** (*a*) For plates over ¾ inch in thickness, a deduction of 0.5 from the specified percentage of elongation will be allowed for each increase of ⅛ inch in thickness above ¾ inch, to a minimum of 20 per cent.

(*b*) For plates under 5/16 inch in thickness, a deduction of 2.5 from the percentage of elongation specified in sec. 6 shall be made for each decrease of 1/16 inch in thickness below 5/16 inch.

9. **Bend Tests.** (*a*) Cold-bend tests shall be made on the material as rolled.

(*b*) Quench-bend-test specimens, before bending, shall be heated to a light cherry red as seen in the dark (about 1200° F.) and quenched in water the temperature of which is about 80° F.

(*c*) Specimens for cold-bend and quench-bend tests of flange and firebox steel shall bend through 180 degrees without fracture on the outside of the bent portion, as follows: For material ¾ inch and under in thickness, flat on themselves; for material over ¾ inch up to 1¼ inches in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1¼ inches in thickness, around a pin the diameter of which is equal to 1½ times the thickness of the specimen.

(*d*) Specimens for cold-bend and quench-bend tests of boiler rivet steel shall bend cold through 180 degrees flat on themselves without fracture on the outside of the bent portion.

(*e*) Bend tests may be made by pressure or by blows.

10. **Test Specimens.** (*a*) Tension-and bend-test specimens for plates shall be taken from the finished product, and shall be of the full thickness of material as rolled. Tension-test specimens shall be of the form and dimensions shown in fig. 1. Bend-test specimens shall be 1½ inches to 2½ inches wide, and shall have the sheared edges milled or planed.

(*b*) The tension-and bend-test specimens for rivet bars shall be of the full-size section of material as rolled.

11. **Number of Tests.** (*a*) One tension-, one cold-bend-and one quench-bend test shall be made from each plate as rolled.

(*b*) Two tension-, two cold-bend-, and two quench-bend tests shall be made for each melt of rivet steel.

(*c*) If any test specimen develops flaws, or if a tension-test specimen breaks outside the middle third of the gage length, it may be discarded and another specimen substituted therefor.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND GAGE

12. **Permissible Variations.** (*a*) The thickness or weight of each sheared plate shall conform to the schedule of permissible variations, Manufacturers' Standard Practice, appended to these specifications.

(*b*) The dimensions of rivet bars shall conform to the Manufacturers' Standard Practice governing allowable variations in the size of hot-rolled bars.

V. FINISH

13. **Finish.** The finished material shall be free from injurious defects, and shall have a workmanlike finish.

VI. MARKING

14. **Marking.** The melt or slab number, name of the manufacturer, grade and the minimum tensile strength for its grade as specified in sec. 6 shall be legibly stamped on each plate. The melt or slab number shall be legibly stamped on each test specimen representing that melt or slab.

VII. INSPECTION AND REJECTION

15. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

16. **Rejection.** Material which, subsequent to the above tests at the mills and its acceptance there, develops weak spots, brittleness, cracks or other imperfections, or is found to have injurious defects, may be rejected at the shop, and shall then be replaced by the manufacturer at his own cost.

MANUFACTURERS' STANDARD PRACTICE
PERMISSIBLE VARIATIONS IN WEIGHT OF SHEARED PLATES WHEN ORDERED TO WEIGHT

On **Carbon Steel Plates,** when ordered to weight per square foot the weight of each lot in each shipment shall not vary from the weight ordered, more than the amount given in the following table. The weight per square foot of individual plates shall not vary from the ordered weight by more than 1½ times the amount given.

One cubic inch of rolled carbon steel is assumed to weigh 0.2833 pound.

Ordered Weight Pounds per Square Foot	Permissible Variations in Average Weight per Square Foot of Plates for Width Given, Expressed in Percentage of Ordered Weight																	
	Under 48 in.		48 in. incl. to 60 in. excl.		60 in. incl. to 72 in. excl.		72 in. incl. to 84 in. excl.		84 in. incl. to 96 in. excl.		96 in. inc. to 108 in. excl.		108 in. incl. to 120 in. excl.		120 in. incl. to 132 in. excl.		132 in. and over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...
5 incl. to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...
7.5 " " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...
10 " " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 " " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 " " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 " " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 " " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3
25 " " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 " " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3

The term "lot" applied to this table means all of the plates of each group width and group weight.

On **Nickel Steel Plates,** when ordered to weight per square foot, Carnegie Steel Company practice adds 2 per cent to the above figures for all sizes of plates ordered to a weight of 30.6 pounds per square foot or less.

MANUFACTURERS' STANDARD PRACTICE
PERMISSIBLE VARIATIONS IN GAGE OF SHEARED PLATES
WHEN ORDERED TO THICKNESS

On **Carbon Steel Plates,** when ordered to thickness, the thickness of each plate shall not vary more than 0.01 inch under that ordered. The overweight of each lot in each shipment shall not exceed the amount given in the following table.

One cubic inch of rolled carbon steel is assumed to weigh 0.2833 pound.

Ordered Gage Inch	Permissible Excess in Average Weight per Square Foot of Plates for Width Given, Expressed in Percentage of Nominal Weight								
	Under 48 in.	48 in. incl. to 60 in. excl.	60 in. incl. to 72 in. excl.	72 in. incl. to 84 in. excl.	84 in. incl. to 96 in. excl.	96 in. incl. to 108 in. excl.	108 in. incl. to 120 in. excl.	120 in. incl. to 132 in. excl.	132 in. and over
Under 1/8	9	10	12	14	..	..	..	..	..
1/8 incl. to 3/16 excl.	8	9	10	12	..	..	..	..	..
3/16 " " 1/4 "	7	8	9	10	12	..	..	..	..
1/4 " " 5/16 "	6	7	8	9	10	12	14	16	19
5/16 " " 3/8 "	5	6	7	8	9	10	12	14	17
3/8 " " 7/16 "	4.5	5	6	7	8	9	10	12	15
7/16 " " 1/2 "	4	4.5	5	6	7	8	9	10	13
1/2 " " 5/8 "	3.5	4	4.5	5	6	7	8	9	11
5/8 " " 3/4 "	3	3.5	4	4.5	5	6	7	8	9
3/4 " " 1 "	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7

The term "lot" applied to this table means all of the plates of each group width and group thickness.

On **Nickel Steel Plates,** when ordered to thickness, Carnegie Steel Company practice adds 2 per cent to the above figures for all sizes of plates to be ordered to a thickness of 5/8 inch or less.

MANUFACTURERS' STANDARD PRACTICE

ALLOWABLE VARIATIONS IN THE SIZE AND WEIGHT OF HOT-ROLLED BARS

ADOPTED 1910

I. ALLOWABLE VARIATIONS IN THE WEIGHT OF BAR SIZES OF ANGLES, TEES, ZEES AND CHANNELS

For bar sizes of angles, tees, zees and channels, the following average variations in weight will be permitted for sections of the various dimensions and thicknesses stated, namely:

Dimensions	Thickness	Variation in Weight Over and Under
Any dimension over 1½ inch	Over 3/16 inch	4 per cent
All dimensions 1½ inch and less	Over 3/16 inch	5 " "
Any dimension over 1½ inch	3/16 inch and less	6 " "
All dimensions 1½ inch and less	3/16 inch and less	7 " "

NOTE.—A channel is in "bar" size when its greatest dimension is less than 3 inches. An angle, tee or zee is in "bar" size when its greatest dimension is less than 3 inches; or when it is 3 inches or more and at the same time the thickness is less than ¼ inch.

II. ALLOWABLE VARIATIONS IN THE SIZE OF HOT-ROLLED BARS

ROUNDS, SQUARES, HEXAGONS

Size	VARIATION IN SIZE, INCHES	
	Under	Over
Up to and including ½ inch	.007	.007
Over ½ in. up to and including 1 inch	.010	.010
Over 1 in. up to and including 2 inches	1/64	1/32
Over 2 in. up to and including 3 inches	1/32	3/64
Over 3 in. up to and including 5 inches	1/32	3/32
Over 5 in. up to and including 8 inches	1/16	1/8

FLATS

Width of Flats	Variation in Width, Inches		VARIATION IN THICKNESS, INCHES UNDER AND OVER			
			Thickness of Flats			
	Under	Over	3/16 in. and under	Over 3/16 in. up to ½ in.	Over ½ in. up to 1 in	Over 1 in. up to 2 in.
Up to and including 1 in.	1/64	1/32	.006	.008	.010	....
Over 1 in. up to and including 2 in.	1/32	3/64	.008	.012	.015	1/32
Over 2 in. up to and including 4 in.	3/64	1/16	.010	.015	.020	1/32
Over 4 in. up to and including 6 in.	1/16	3/32	.010	.015	.020	1/32

MANUFACTURERS' STANDARD PRACTICE

STANDARD METHODS OF SAMPLING FOR CHECK ANALYSIS

ADOPTED 1912

INTRODUCTION

It is a recognized fact that the different parts of a piece of steel are liable to vary in composition. This variation occurs principally between the center and the outside, and to a slighter extent is dependent upon the position of the piece in the ingot, and the size of the ingot.

Where a sufficient number of check analyses have been made from drillings properly taken at different points in the heat to represent it fairly, their average has been found to compare favorably with the ladle analysis, which is the analysis of a small test ingot taken at any time during the pouring of the heat.

From this it is evident:

1. That the ladle analysis is more representative of the composition than any single analysis of the finished material.

2. That drillings for check analysis, to be fairly representative, should be taken at a point intermediate between the outside and the center of the cross section.

3. That a sufficient number of check analyses of different pieces should be made to afford a fair average to compare with the ladle analysis.

I. POINTS TO BE OBSERVED IN THE SAMPLING OF MATERIAL FOR CHECK ANALYSIS

(*a*) Each heat in a lot shall be considered separately, and pieces for sampling shall be taken to represent the heat as fairly as possible.

(*b*) Samples must be drillings or chips cut by some machine tool without the application of water, oil or other lubricant and shall be free from scale, grease, dirt or other foreign substance. If samples are taken by drilling, the size of the drill shall be not less than ½ inch nor more than ¾ inch in diameter.

(*c*) Samples must be uniformly fine and each must be carefully mixed before analysis.

(*d*) In referring samples to the manufacturer or other analysts for check analysis, a piece of the full-size section, when possible, should be submitted rather than cuttings, unless the latter are specially requested.

(*e*) Where material has been subjected to heat treatment other than annealing or simple cooling, subsequent to its manufacture, it should be annealed before sampling.

(*f*) Check analyses are not representative of the original material when its composition has been altered in any way by some operation such as casehardening, overheating, etc.

II. METHODS OF OBTAINING SAMPLES FOR CHECK ANALYSIS

Material has been divided into the following classes, depending upon the manner of sampling:

I. Material Subject to Physical Requirements:

Samples for check analysis shall be taken from a test specimen. Where it is required to make additional check analyses, samples shall be taken as indicated under II.

II. Material Not Subject to Physical Requirements:

(a) Special cast, rolled or forged, semi-finished or finished material of large size, such as Ingots, Blooms, Billets, Slabs, Rounds, Shapes, etc., subject to acceptance on check analysis.

Samples shall be taken at any point midway between the outside and the center by drilling parallel to the axis. In cases where this method is not practicable, a piece may be drilled on the side, but drillings shall not be taken until they represent the portion midway between the outside and the center. See fig. 1.

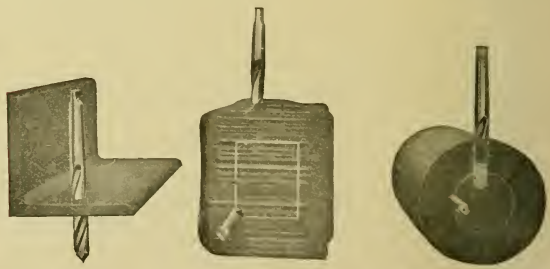


Figure 1.

(b) Small or thin material, such as Plates, Shapes, Bars, etc., subject to acceptance on check analysis.

Material for which the previous method is not applicable shall have samples for analysis taken entirely through the material at a point midway between the outside and the center, or by machining off the entire cross section.

(c) Commercial material subject to acceptance on ladle analysis.

The methods described under 11 (*a*) and (*b*) shall apply, except that samples shall be taken at any point one-third of the distance from the outside to the center.

III. METHODS OF ANALYSIS

Analyses shall be made by well-known accurate methods. Carbon shall be determined by the combustion method.

IV. REJECTION OF MATERIAL ON CHECK ANALYSIS

Any rejection of material ordered to a specific chemical range shall be based on the following:

(*a*) The minimum number of samples to be taken from a heat before rejection by the purchaser shall be as follows:

Weight in Gross Tons	Minimum Number of Samples
5 or less	3
10 or less but over 5	4
15 or less but over 10	5
over 15	6

In case the number of pieces in a heat is less than the number of samples given, one sample from each piece shall be considered sufficient.

(*b*) Separate determinations shall be made on each sample and the results averaged, unless they clearly indicate mixed grades.

AMERICAN SOCIETY

FOR

TESTING MATERIALS

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

STANDARD SPECIFICATIONS

FOR

STRUCTURAL STEEL FOR BRIDGES

SERIAL DESIGNATION: A7-16.

The specifications for this material are issued under the fixed designation A 7; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1909, 1913, 1914, 1915, 1916.

1. **Steel Castings.** The Standard Specifications for Steel Castings (Serial Designation A-27) adopted by the American Society for Testing Materials shall govern the purchase of steel castings for bridges. Unless otherwise specified, Class B castings, medium grade, shall be used.

I. MANUFACTURE

2. **Process.** The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

		Structural Steel	Rivet Steel
Phosphorus	Acid	not over 0.06 per cent	not over 0.04 per cent
	Basic	" " 0.04 " "	" " 0.04 " "
Sulphur		" " 0.05 " "	" " .045 " "

4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 3.

5. **Check Analyses.** Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulphur content thus determined shall not exceed that specified in sec. 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS

6. **Tension Tests.** (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered	Structural Steel	Rivet Steel
Tensile strength.....lb. per sq. inch	55,000–65,000*a*	46,000–56,000
Yield point, min.....lb. per sq. inch	0.5 tens. str.	0.5 tens. str.
Elongation in 8 inches, min.....per cent	$\frac{1{,}500{,}000}{\text{tens. str.}}$*b*	$\frac{1{,}500{,}000}{\text{tens. str.}}$
Elongation in 2 inches, min.....per cent	22	.....

a See par. (*b*). *b* See sec. 7.

(*b*) In order to meet the required minimum tensile strength of full-size annealed eye bars, the purchaser may determine the tensile strength to be obtained in specimen tests, the range shall not exceed 14,000 lb. per sq. inch and the maximum shall not exceed 74,000 lb. per sq. inch. The material shall conform to the requirements as to physical properties other than that of tensile strength, specified in sec. 6, 7 and 8 (*b*).

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

7. **Modifications in Elongation.** (*a*) For structural steel over $\frac{3}{4}$ inch in thickness, a deduction of 1 from the percentage of elongation in 8 inches specified in sec. 6 (*a*) shall be made for each increase of $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch to a minimum of 18 per cent.

(*b*) For structural steel under $\frac{5}{16}$ inch in thickness, a deduction of 2.5 from the percentage of elongation in 8 inches specified in sec. 6 (*a*) shall be made for each decrease of $\frac{1}{16}$ inch in thickness below $\frac{5}{16}$ inch.

8. **Bend Tests.** (*a*) The test specimen for plates, shapes and bars, except as specified in par. (*b*), (*c*) and (*d*), shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows: For material ¾ inch or under in thickness, flat on itself; for material over ¾ inch to and including 1¼ inch in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1¼ inch in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for eye-bar flats shall bend cold through 180 degrees without cracking on the outside of the bent portion as follows: For material ¾ inch or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over ¾ inch to and including 1¼ inch in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen; and for material over 1¼ inch in thickness, around a pin the diameter of which is equal to three times the thickness of the specimen.

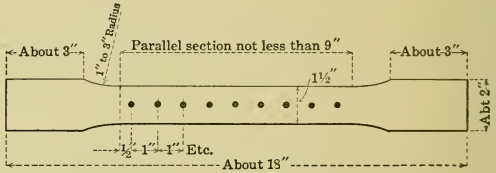


FIGURE 1.

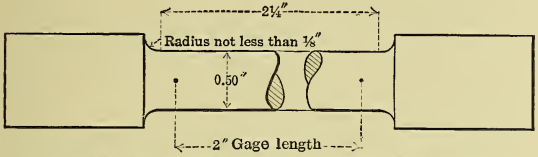
(*c*) The test specimen for pins, rollers and other bars, when prepared as specified in sec. 9 (*e*), shall bend cold through 180 degrees around a 1-inch pin without cracking on the outside of the bent portion.

(*d*) The test specimen for rivet steel shall bend cold through 180 degrees flat on itself without cracking on the outside of the bent portion.

9. **Test Specimens.** (*a*) Tension-and bend-test specimens shall be taken from rolled steel in the condition in which it comes from the rolls, except as specified in par. (*b*).

(*b*) Tension-and bend-test specimens for pins and rollers shall be taken from the finished bars, after annealing when annealing is specified.

(*c*) Tension-and bend-test specimens for plates, shapes and bars, except as specified in par. (*d*), (*e*) and (*f*), shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in fig. 1, or with both edges parallel; except that bend-test specimens for eye-bar flats may have three rolled sides.



NOTE:—**The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the testing machine.**

FIGURE 2.

(*d*) Tension-and bend-test specimens for plates, and tension-test specimens for eye-bar flats, over 1½ inch in thickness may be machined to a thickness or diameter of at least ¾ inch for a length of at least 9 inches.

(*e*) Tension-test specimens for pins, rollers and bars (except eye-bar flats) over 1½ inch in thickness or diameter may conform to the dimensions shown in fig. 2. In this case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend-test specimens may be 1 by ½ inch in section. The axis of the specimen shall be located at any point midway between the center and surface and shall be parallel to the axis of the bar.

(*f*) Tension-and bend-test specimens for rivet steel shall be of the full-size section of bars as rolled.

10. **Number of Tests.** (*a*) One tension-and one bend test shall be made from each melt; except that if material from one melt differs ⅜ inch or more in thickness, one tension-and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 6 (*a*) and any part of the fracture

is more than ¾ inch from the center of the gage length of a 2-inch specimen or is outside the middle third of the gage length of an 8-inch specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

11. **Permissible Variations.** The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 pounds.

(*a*) **When Ordered to Weight per Square Foot:—**

The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT

Ordered Weight, Pounds per Square Foot	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights																							
	Under 48 in.		48 in. to 60 in. excl.		60 in. to 72 in. excl.		72 in. to 84 in. excl.		84 in. to 96 in. excl.		96 in. to 108 in. excl.		108 in. to 120 in. excl.		120 in. to 132 in. excl.		132 in. or over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...
7.5 to 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...
10 to 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 to 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 to 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 to 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 to 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3
25 to 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 to 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1⅛ times the amount given in this table.

(*b*) **When Ordered to Thickness:—**

The thickness of each plate shall not vary more than 0.01 inch under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

[1]The term "lot" applied to Table I means all of the plates of each group width and group weight.
[2]The term "lot" applied to Table II means all of the plates of each group width and group thickness.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS

Ordered Thickness, Inches	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights								
	Under 48 in.	48 in. to 60 in. excl.	60 in. to 72 in. excl.	72 in. to 84 in. excl.	84 in. to 96 in. excl.	96 in. to 108 in. excl.	108 in. to 120 in. excl.	120 in. to 132 in. excl.	132 in. or over
Under 1/8	9	10	12	14	....	....	....	....	....
1/8 to 8/16 excl	8	9	10	12	....	....	....	....	....
8/16 to 1/4 "	7	8	9	10	12	....	....	....	....
1/4 to 5/16 "	6	7	8	9	10	12	14	16	19
5/16 to 3/8 "	5	6	7	8	9	10	12	14	17
3/8 to 7/16 "	4.5	5	6	7	8	9	10	12	15
7/16 to 1/2 "	4	4.5	5	6	7	8	9	10	13
1/2 to 5/8 "	3.5	4	4.5	5	6	7	8	9	11
5/8 to 3/4 "	3	3.5	4	4.5	5	6	7	8	9
3/4 to 1 "	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7

V. FINISH

12. **Finish.** The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING

13. **Marking.** The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping, if practicable, on each test specimen.

VII. INSPECTION AND REJECTION

14. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check

analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

15. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

16. **Rehearing.** Samples tested in accordance with sec. 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

STANDARD SPECIFICATIONS

FOR

STRUCTURAL STEEL FOR BUILDINGS

SERIAL DESIGNATION: A9-16.

The specifications for this material are issued under the fixed designation A 9; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914, 1916.

I. MANUFACTURE

1. **Process.** (*a*) Structural steel, except as noted in par. (*b*), may be made by the bessemer-or the open-hearth process.

(*b*) Rivet steel, and steel for plates or angles over ¾ inch in thickness which are to be punched, shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

2. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

		Structural Steel	Rivet Steel
Phosphorus	Bessemer...	not over 0.10 per cent	.....
	Open-hearth	" " 0.06 " "	not over 0.06 per cent
Sulphur.....		.....	0.045 " "

3. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 2.

4. **Check Analyses.** Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulphur content thus determined shall not exceed that specified in sec. 2 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS

5. **Tension Tests.** (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered	Structural Steel	Rivet Steel
Tensile strength.....lb. per sq. inch	55,000–65,000	46,000–56,000
Yield point, min.....lb. per sq. inch	0.5 tens. str.	0.5 tens. str.
Elongation in 8 inches, min.....per cent	$\frac{1,400,000}{\text{tens. str.}}$ [a]	$\frac{1,400,000}{\text{tens. str.}}$
Elongation in 2 inches, min.....per cent	22	.....

[a] See sec. 6.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

6. **Modifications in Elongation.** (*a*) For structural steel over $\frac{3}{4}$ inch in thickness, a deduction of 1 from the percentage of elongation in 8 inches specified in sec. 5 (*a*) shall be made for each increase of $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch to a minimum of 18 per cent.

(*b*) For structural steel under $\frac{5}{16}$ inch in thickness, a deduction of 2.5 from the percentage of elongation in 8 inches specified in sec. 5 (*a*) shall be made for each decrease of $\frac{1}{16}$ inch in thickness below $\frac{5}{16}$ inch.

7. **Bend Tests.** (*a*) The test specimen for plates, shapes and bars, except as specified in par. (*b*) and (*c*), shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ inch or under in thickness, flat on itself; for material over $\frac{3}{4}$ inch to and including $1\frac{1}{4}$ inch in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ inch in thickness, around

a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for pins, rollers and other bars, when prepared as specified in sec. 8 (*e*), shall bend cold through 180 degrees around a 1-inch pin without cracking on the outside of the bent portion.

(*c*) The test specimen for rivet steel shall bend cold through 180 degrees flat on itself without cracking on the outside of the bent portion.

8. **Test Specimens.** (*a*) Tension-and bend-test specimens shall be taken from rolled steel in the condition in which it comes from the rolls, except as specified in par. (*b*).

(*b*) Tension-and bend-test specimens for pins and rollers shall be taken from the finished bars, after annealing when annealing is specified.

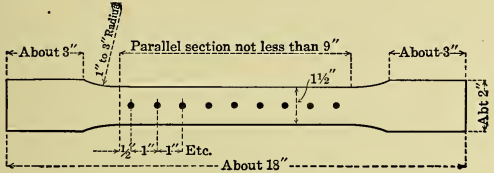


FIGURE 1.

(*c*) Tension-and bend-test specimens for plates, shapes and bars, except as specified in par. (*d*), (*e*) and (*f*), shall be of the full thickness of material as rolled; and may be machined to the form and dimensions shown in fig. 1, or with both edges parallel.

(*d*) Tension-and bend-test specimens for plates over 1½ inch in thickness may be machined to a thickness or diameter of at least ¾ inch for a length of at least 9 inches.

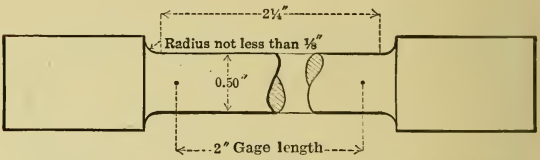
(*e*) Tension-test specimens for pins, rollers and bars over 1½ inch in thickness or diameter may conform to the dimensions shown in fig. 2. In this case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend-test specimens may be 1 by ½ inch in section. The axis of the specimens shall be located at any point midway between the center and surface and shall be parallel to the axis of the bar.

(*f*) Tension-and bend-test specimens for rivet steel shall be of the full-size section of bars as rolled.

9. **Number of Tests.** (*a*) One tension-and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ inch or more in thickness, one tension-and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 5 (*a*) and any part of the fracture is more than $\frac{3}{4}$ inch from the center of the gage length of a 2-inch specimen or is outside the middle third of the gage length of an 8-inch specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.



NOTE:—The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the testing machine.

FIGURE 2.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

10. **Permissible Variations.** The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 pound.

(*a*) **When Ordered to Weight per Square Foot:—**

The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

[1]The term "lot" applied to Table I means all of the plates of each group width and group weight.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT

Ordered Weight, Pounds per Square Foot	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights																	
	Under 48 in.		48 in. to 60 in. excl.		60 in. to 72 in. excl.		72 in. to 84 in. excl.		84 in. to 96 in. excl.		96 in. to 108 in. excl.		108 in. to 120 in. excl.		120 in. to 132 in. excl.		132 in. or over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...
7.5 to 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...
10 to 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 to 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 to 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 to 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 to 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3
25 to 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 to 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than $1\frac{1}{2}$ times the amount given in this table.

(*b*) **When Ordered to Thickness:—**

The thickness of each plate shall not vary more than 0.01 inch under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS

Ordered Thickness, Inches	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights								
	Under 48 in.	48 in. to 60 in. excl.	60 in. to 72 in. excl.	72 in. to 84 in. excl.	84 in. to 96 in. excl.	96 in. to 108 in. excl.	108 in. to 120 in. excl.	120 in. to 132 in. excl.	132 in or over
Under $\frac{1}{8}$	9	10	12	14	....	....	....	....	....
$\frac{1}{8}$ to $\frac{9}{16}$ excl	8	9	10	12	....	....	....	....	....
$\frac{9}{16}$ to $\frac{1}{4}$ "	7	8	9	10	12	....	....	....	....
$\frac{1}{4}$ to $\frac{5}{16}$ "	6	7	8	9	10	12	14	16	19
$\frac{5}{16}$ to $\frac{3}{8}$ "	5	6	7	8	9	10	12	14	17
$\frac{3}{8}$ to $\frac{7}{16}$ "	4.5	5	6	7	8	9	10	12	15
$\frac{7}{16}$ to $\frac{1}{2}$ "	4	4.5	5	6	7	8	9	10	13
$\frac{1}{2}$ to $\frac{5}{8}$ "	3.5	4	4.5	5	6	7	8	9	11
$\frac{5}{8}$ to $\frac{3}{4}$ "	3	3.5	4	4.5	5	6	7	8	9
$\frac{3}{4}$ to 1 "	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7

[2]The term "lot" applied to Table II means all of the plates of each group width and group thickness.

V. FINISH

11. **Finish.** The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING

12. **Marking.** The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping, if practicable, on each test specimen.

VII. INSPECTION AND REJECTION

13. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 4 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

15. **Rehearing.** Samples tested in accordance with sec. 4, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

STANDARD SPECIFICATIONS

FOR

STRUCTURAL NICKEL STEEL

SERIAL DESIGNATION: A8-16.

The specifications for this material are issued under the fixed designation A 8; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914 1916.

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

2. **Discard.** A sufficient discard shall be made from each ingot intended for eye bars to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

	Structural Steel	Rivet Steel
Carbon	not over 0.45 per cent	not over 0.30 per cent
Manganese	" " 0.70 " "	" " 0.60 " "
Phosphorus, Acid	" " 0.05 " "	" " 0.04 " "
Phosphorus, Basic	" " 0.04 " "	" " 0.03 " "
Sulphur	" " 0.05 " "	" " 0.45 " "
Nickel	not under 3.25 " "	not under 3.25 " "

4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 3.

5. **Check Analyses.** Analyses may be made by the purchaser from finished material representing each melt. The chemical composition thus determined shall conform to the requirements specified in sec. 3.

III. PHYSICAL PROPERTIES AND TESTS

6. **Tension Tests.** (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered	Rivet Steel	Plates, Shapes and Bars	Eye Bars and Rollers, *c* Unannealed	Eye Bars, *a* and Pins, *c* Annealed
Tensile strength, lb. per sq. inch	70,000–80,000	55,000–100,000	95,000–110,000	90,000–105,000
Yield point, min., lb. per sq. inch	45,000	50,000	55,000	52,000
Elongation in 8 inches, min., per cent	$\frac{1{,}500{,}000}{\text{tens. str.}}$	$\frac{1{,}500{,}000\,b}{\text{tens. str.}}$	$\frac{1{,}500{,}000\,b}{\text{tens. str.}}$	20
Elongation in 2 inches, min., per cent	.....	.....	16	20
Reduction of area min., per cent	40	25	25	35

a Tests of annealed specimens of eye bars shall be made for information only.
b See sec. 7.
c Elongation shall be measured in 2 inches.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

7. **Modifications in Elongations.** For plates, shapes and unannealed bars over 1 inch in thickness, a deduction of 1 from the percentage of elongation specified in sec. 6 (*a*) shall be made for each increase of $\frac{1}{8}$ inch in thickness above 1 inch, to a minimum of 14 per cent.

8. **Character of Fracture.** All broken tension-test specimens shall show either a silky or a very fine granular fracture, of uniform color, and free from coarse crystals.

9. **Bend Tests.** (*a*) The test specimen for plates, shapes and bars shall bend cold through 180 degrees without cracking on the

outside of the bent portion, as follows: For material ¾ inch or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over ¾ inch in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for pins and rollers shall bend cold through 180 degrees around a 1-inch pin without cracking on the outside of the bent portion.

(*c*) The test specimen for rivet steel shall bend cold through 180 degrees flat on itself without cracking on the outside of the bent portion.

10. **Drift Tests.** Punched rivet holes pitched two diameters from a planed edge shall stand drifting until the diameter is enlarged 50 per cent, without cracking the metal.

11. **Test Specimens.** (*a*) Tension-and bend-test specimens shall be taken from the finished material. Specimens for pins shall be taken after annealing.

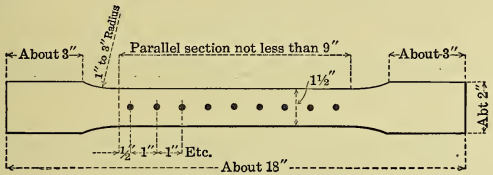


FIGURE 1.

(*b*) Tension-and bend-test specimens for plates, shapes and bars, except as specified in par. (*c*), shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in fig. 1, or with both edges parallel; except that bend-test specimens shall not be less than 2 inches in width, and that bend-test specimens for eye-bar flats may have three rolled sides.

(*c*) Tension-and bend-test specimens for plates and bars (except eye-bar flats) over 1½ inch in thickness or diameter may be machined to a thickness or diameter of at least ¾ inch for a length of at least 9 inches.

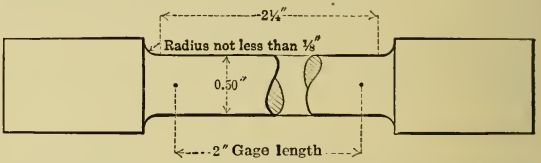
(*d*) The axis of tension-and bend-test specimens for pins and rollers shall be 1 inch from the surface and parallel to the axis of the bar. Tension-test specimens shall conform to the dimensions

shown in fig. 2. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend-test specimens shall be 1 by ½ inch in section.

(*e*) Tension-and bend-test specimens for rivet steel shall be of the full-size section of bars as rolled.

12. **Number of Tests.** (*a*) One tension-and one bend test shall be made from each melt; except that if material from one melt differs ⅜ inch or more in thickness, one tension-and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.



NOTE:—The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the testing machine.

FIGURE 2.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 6 (*a*) and any part of the fracture is more than ¾ inch from the center of the gage length of a 2-inch specimen or is outside the middle third of the gage length of an 8-inch specimen, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

13. **Permissible Variations.** The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 pound.

(*a*) **When Ordered to Weight per Square Foot:—**

The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

[1]The term "lot" applied to Table I means all of the plates of each group width and group weight.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT

Ordered Weight, Pounds per Square Foot	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights																					
	Under 48 in.		48 in. to 60 in. excl.		60 in. to 72 in. excl.		72 in. to 84 in. excl.		84 in. to 96 in. excl.		96 in. to 108 in. excl.		108 in. to 120 in. excl.		120 in. to 132 in. excl.		132 in. or over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...
7.5 to 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...
10 to 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 to 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 to 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 to 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 to 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3
25 to 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 to 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	3	2.5	3.5	3	4	3	

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1⅓ times the amount given in this table

(*b*) **When Ordered to Thickness:—**

The thickness of each plate shall not vary more than 0.01 inch under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS

Ordered Thickness, Inches	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given Expressed in Percentages of Nominal Weights								
	Under 48 in.	48 in. to 60 in. excl.	60 in. to 72 in. excl.	72 in. to 84 in. excl.	84 in. to 96 in. excl.	96 in. to 108 in. excl.	108 in. to 120 in. excl.	120 in. to 132 in. excl.	132 in. or over
Under ⅛	9	10	12	14	....	....	....	....	....
⅛ to 3/16 excl.	8	9	10	12	....	....	....	....	....
3/16 to ¼ "	7	8	9	10	12	....	....	....	....
¼ to 5/16 "	6	7	8	9	10	12	14	16	19
5/16 to ⅜ "	5	6	7	8	9	10	12	14	17
⅜ to 7/16 "	4.5	5	6	7	8	9	10	12	15
7/16 to ½ "	4	4.5	5	6	7	8	9	10	13
½ to ⅝ "	3.5	4	4.5	5	6	7	8	9	11
⅝ to ¾ "	3	3.5	4	4.5	5	6	7	8	9
¾ to 1 "	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7

[2]The term "lot "applied to Table II means all of the plates of each group width and group thickness.

V. FINISH

14. **Finish** The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING

15. **Marking.** The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that rivet and lattice bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The identification marks shall be legibly stamped on the end of each pin and roller. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

VII. INSPECTION AND REJECTION

16. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

18. **Rehearing.** Samples tested in accordance with sec. 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

VIII. FULL-SIZE TESTS

19. **Test of Eye Bars.** (*a*) Full-size tests of annealed eye bars shall conform to the following requirements as to tensile properties:

Tensile strength	lb. per sq. inch	85,000–100,000
Yield point, min	lb. per sq. inch	48,000
Elongation in 18 ft., min	per cent	10
Reduction of area, min	per cent	30

(*b*) The yield point shall be determined by the halt of the gage of the testing machine.

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PHILADELPHIA, PA., U. S. A.

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STANDARD SPECIFICATIONS

FOR

STRUCTURAL STEEL FOR SHIPS

SERIAL DESIGNATION: A12-16.

The specifications for this material are issued under the fixed designation A 12; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914, 1916.

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

2. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Acid	not over 0.06 per cent
	Basic	" " 0.04 " "
Sulphur		" " 0.05 " "

3. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 2.

4. **Check Analyses.** Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulphur content thus determined shall not exceed that specified in sec. 2. by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS

5. **Tension Tests.** (*a*) The material shall conform to the following requirements as to tensile properties:

Tensile strength	lb. per sq. inch	58,000–68,000
Yield point, min	lb. per sq. inch	0.5 tens. str.
Elongation in 8 inches, min. See sec. 6.	per cent	$\frac{1,500,000}{\text{tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

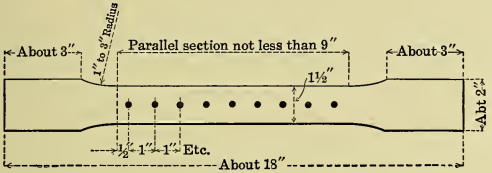

FIGURE 1.

6. **Modifications in Elongation.** (*a*) For material over ¾ inch in thickness, a deduction of 1 from the percentage of elongation specified in sec. 5 (*a*) shall be made for each increase of ⅛ inch in thickness above ¾ inch, to a minimum of 18 per cent.

(*b*) For material ¼ inch or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

7. **Bend Tests.** The test specimen shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows: For material ¾ inch or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; for material over ¾ inch to and including 1¼ inch in thickness, around a pin the diameter of which is equal to 1½ times the thickness of the specimen; and for material over 1¼ inch in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

8. **Test Specimens.** (*a*) Tension-and bend-test specimens shall be taken from the finished rolled material, and shall not be annealed or otherwise treated, except as specified in par. (*b*).

(*b*) Tension-and bend-test specimens for material which is to be annealed or otherwise treated before use, shall be cut from properly annealed or similarly treated short lengths of the full section of the piece.

(*c*) Tension-and bend-test specimens, except as specified in par. (*d*), shall be of the full thickness of material as rolled; and may be machined to the form and dimensions shown in fig. 1, or with both edges parallel.

(*d*) Tension-and bend-test specimens for plates and bars over 1½ inch in thickness or diameter may be machined to a thickness or diameter of at least ¾ inch for a length of at least 9 inches.

9. **Number of Tests.** (*a*) One tension-and one bend test shall be made from each melt; except that if material from one melt differs ⅜ inch or more in thickness, one tension-and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

10. **Permissible Variations.** The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 pound.

(*a*) **When Ordered to Weight per Square Foot:—**

The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

[1]The term "lot" applied to Table I means all of the plates of each group width and group weight.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT

Ordered Weight, Pounds per Square Foot	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights																			
	Under 48 in.		48 in. to 60 in. excl.		60 in. to 72 in. excl.		72 in. to 84 in. excl.		84 in. to 96 in. excl.		96 in. to 108 in. excl.		108 in. to 120 in. excl.		120 in. to 132 in. excl.		132 in. or over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...
7.5 to 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...
10 to 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 to 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 to 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 to 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 to 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5	3
25 to 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 to 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1⅛ times the amount given in this table.

(*b*) **When Ordered to Thickness:—**

The thickness of each plate shall not vary more than 0.01 inch under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS

Ordered Thickness, Inches	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights							
	Under 48 in.	48 in. to 60 in. excl.	60 in. to 72 in. excl.	72 in. to 84 in. excl.	84 in. to 96 in. excl.	96 in. to 108 in. excl.	108 in. to 120 in. excl.	120 in. to 132 in. excl.	132 in. or over
Under ⅛	9	10	12	14	....	....	....	....	....
⅛ to 3/16 excl	8	9	10	12	....	....	....	....	....
3/16 to ¼ "	7	8	9	10	12	....	....	....	....
¼ to 5/16 "	6	7	8	9	10	12	14	16	19
5/16 to ⅜ "	5	6	7	8	9	10	12	14	17
⅜ to 7/16 "	4.5	5	6	7	8	9	10	12	15
7/16 to ½ "	4	4.5	5	6	7	8	9	10	13
½ to 5/8 "	3.5	4	4.5	5	6	7	8	9	11
5/8 to ¾ "	3	3.5	4	4.5	5	6	7	8	9
¾ to 1 "	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4 5	5	6	7

[2]The term "lot" applied to Table II means all of the plates of each group width and group thickness.

V. FINISH

11. **Finish.** The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING

12. **Marking.** The name or brand of the manufacturer and the melt number shall be legibly rolled or stamped on all finished material. The melt number shall be legibly stamped on each test specimen.

VII. INSPECTION AND REJECTION

13. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 4 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

15. **Rehearing.** Samples tested in accordance with sec. 4, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

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STANDARD SPECIFICATIONS

FOR

RIVET STEEL FOR SHIPS

SERIAL DESIGNATION: A13-14.

The specifications for this material are issued under the fixed designation A 13; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1913, 1914.

A. Requirements for Rolled Bars.

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

2. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Acid	not over 0.06 per cent
	Basic	" " 0.04 " "
Sulphur		" " 0.045 " "

3. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical

composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 2.

4. **Check Analyses.** Analyses may be made by the purchaser from finished bars representing each melt. The phosphorus and sulphur content thus determined shall not exceed that specified in sec. 2 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS

5. **Tension Tests.** (*a*) The bars shall conform to the following requirements as to tensile properties:

Tensile strength	lb. per sq. inch	55,000–65,000
Yield point, min	lb. per sq. inch	0.5 tens. str.
Elongation in 8 inches, min (See sec. 6.)	per cent	$\frac{1,500,000}{\text{tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

6. **Modifications in Elongation.** For bars over $\frac{3}{4}$ inch in diameter, a deduction of 1 from the percentage of elongation specified in sec. 5 (*a*) shall be made for each increase of $\frac{1}{8}$ inch in diameter above $\frac{3}{4}$ inch.

7. **Bend Tests.** The test specimen shall bend cold through 180 degrees flat on itself without cracking on the outside of the bent portion.

8. **Test Specimens.** Tension-and bend-test specimens shall be of the full-size section of bars as rolled.

9. **Number of Tests.** (*a*) Two tension-and two bend tests shall be made from each melt, each of which shall conform to the requirements specified; except that if bars from one melt differ $\frac{3}{8}$ inch or more in diameter, one tension-and one bend test shall be made from both the greatest and the least diameters rolled.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN GAGE

10. **Permissible Variations.** The gage of bars 1 inch or under in diameter shall not vary more than 0.01 inch from that specified; the gage bars over 1 inch to and including 2 inches in diameter shall not vary more than $\frac{1}{64}$ inch under nor more than $\frac{1}{32}$ inch over that specified.

V. FINISH

11. **Finish.** The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING

12. **Marking.** Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

VII. INSPECTION AND REJECTION

13. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 4 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

15. **Rehearing.** Samples tested in accordance with sec. 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. Requirements for Rivets.

I. PHYSICAL PROPERTIES AND TESTS

16. **Test Certificate of Rolled Bars.** A copy of the results of tension tests of the rolled bars from which the rivets were made shall be furnished for each lot of rivets.

17. **Tension Tests.** If the test certificate required in sec. 16 cannot be furnished, the rivets shall conform to the requirements as to tensile properties specified in secs. 5 and 6, except that the elongation shall be measured on a gage length as great as the length of the rivets tested will permit.

18. **Bend Tests.** The rivet shank shall bend cold through 180 degrees flat on itself, as shown in fig. 1, without cracking on the outside of the bent portion.

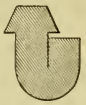

FIGURE 1.

FIGURE 2.

19. **Flattening Tests.** The rivet head shall flatten, while hot, to a diameter 2½ times the diameter of the shank, as shown in fig. 2, without cracking at the edges.

20. **Number of Tests.** (*a*) When required in accordance with sec. 17, one tension test shall be made from each size in each lot of rivets offered for inspection.

(*b*) Three bend-and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

II. WORKMANSHIP AND FINISH

21. **Workmanship.** The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

22. **Finish.** The finished rivets shall be free from injurious defects.

III. INSPECTION AND REJECTION

23. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

24. **Rejection.** Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

AMERICAN SOCIETY FOR TESTING MATERIALS

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STANDARD SPECIFICATIONS

FOR

STRUCTURAL STEEL FOR CARS

SERIAL DESIGNATION: A11-16.

The specifications for this material are issued under the fixed designation A 11; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1914; REVISED, 1916.

1. **Basis of Purchase.** These specifications apply to shapes, plates and bars over $\frac{1}{8}$ inch in thickness.

I. MANUFACTURE

2. **Process.** The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

		Structural Steel and Plates for Cold Pressing	Rivet Steel
Phosphorus	Acid	not over 0.06 per cent	not over 0.04 per cent
	Basic	" " 0.04 " "	" " 0.04 " "
Sulphur		" " 0.05 " "	" " 0.045 " "

4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 3.

5. **Check Analyses.** Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulphur content thus determined shall not exceed that specified in sec. 3 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS

6. **Tension Tests.** (*a*) The material shall conform to the following requirements as to tensile properties:

Properties Considered	Structural Steel	Rivet Steel	Plates for Cold Pressing
Tensile strength . . . lb. per sq. inch	50,000–65,000	45,000–60,000	48,000–58,000
Yield point, min . . . lb. per sq. inch	0.5 tens. str.	0.5 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent[1]	$\frac{1{,}500{,}000}{\text{tens. str.}}$	$\frac{1{,}500{,}000}{\text{tens. str.}}$	$\frac{1{,}500{,}000}{\text{tens. str.}}$

[1] See sec. 7.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

7. **Modifications in Elongation.** (*a*) For material over $\frac{3}{4}$ inch in thickness, a deduction of 1 from the percentage of elongation specified in sec. 6 (*a*) shall be made for each increase of $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch, to a minimum of 18 per cent.

(*b*) For material under $\frac{5}{16}$ inch in thickness, a deduction of 2.5 from the percentage of elongation in 8 inches specified in sec. 6 (*a*) shall be made for each decrease of $\frac{1}{16}$ inch in thickness below $\frac{5}{16}$ inch.

8. **Bend Tests.** (*a*) The test specimen for structural steel shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ inch or under in thickness, flat on itself; for material over $\frac{3}{4}$ inch to and including $1\frac{1}{4}$ inch in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ inch in thick-

ness, around a pin the diameter of which is equal to twice the thickness of the specimen.

(*b*) The test specimen for rivet steel and plates for cold pressing shall bend cold through 180 degrees flat on itself without cracking on the outside of the bent portion.

9. **Test Specimens.** (*a*) Tension-and bend-test specimens shall be taken from the finished rolled material.

(*b*) Tension-and bend-test specimens, except as specified in par. (*c*), shall be of the full thickness of material as rolled; and may be machined to the form and dimensions shown in fig. 1, or with both edges parallel.

(*c*) Tension-and bend-test specimens for plates and bars over 1½ inch in thickness or diameter may be machined to a thickness or diameter of at least ¾ inch for a length of at least 9 inches.

10. **Number of Tests.** (*a*) One tension-and one bend test shall be made from each melt; except that if material from one melt differs ⅜ inch or more in thickness, one tension-and one bend test shall be made from both the thickest and the thinnest material rolled. Shapes less than 1 sq. inch in section, and bars, except rivet rods, less than ½ sq. inch in section, need not be subjected to a tension test.

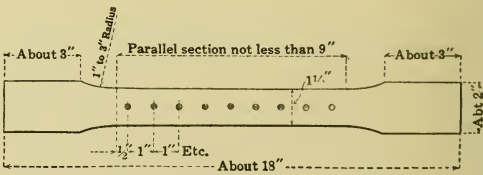

FIGURE 1.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

11. Permissible Variations. The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified; except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 pound.

(*a*) **When Ordered to Weight per Square Foot:—**

The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT

Ordered Weight, Pounds per Square Foot	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights																			
	Under 48 in.		48 in. to 60 in. excl.		60 in. to 72 in. excl.		72 in. to 84 in. excl.		84 in. to 96 in. excl.		96 in. to 108 in. excl.		108 in. to 120 in. excl.		120 in. to 132 in. excl.		132 in. or over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...
7.5 to 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...
10 to 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 to 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 to 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 to 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 to 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3
25 to 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 to 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	3	2.5	3.5	3	4	3	4

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1⅓ times the amount given in this table.

(*b*) **When Ordered to Thickness:—**

The thickness of each plate shall not vary more than 0.01 inch under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

[1]The term "lot" applied to Table I means all of the plates of each group width and group weight.
[2]The term "lot" applied to Table II means all of the plates of each group width and group thickness.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS

Ordered Thickness, Inches	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights								
	Under 48 in.	48 in. to 60 in. excl.	60 in. to 72 in. excl.	72 in. to 84 in. excl.	84 in. to 96 in. excl.	96 in. to 108 in. excl.	108 in. to 120 in. excl.	120 in. to 132 in. excl.	132 in. or over
Under 1/4	9	10	12	14	....	....	....	....	....
1/4 to 5/16 excl	8	9	10	12	....	....	....	....	....
5/16 to 1/4 "	7	8	9	10	12	....	....	....	....
1/4 to 5/16 "	6	7	8	9	10	12	14	16	19
5/16 to 3/8 "	5	6	7	8	9	10	12	14	17
3/8 to 7/16 "	4.5	5	6	7	8	9	10	12	15
7/16 to 1/2 "	4	4.5	5	6	7	8	9	10	13
1/2 to 5/8 "	3.5	4	4.5	5	6	7	8	9	11
5/8 to 3/4 "	3	3.5	4	4.5	5	6	7	8	9
3/4 to 1 "	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7

V. FINISH

12. **Finish.** The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING

13. **Marking.** The name or brand of the manufacturer and the melt number shall be legibly rolled or stamped on all finished material, except that rivet bars and other small sections shall, when loaded for shipment, be properly separated and marked for identification. The melt number shall be legibly marked, by stamping, if practicable, on each test specimen.

VII. INSPECTION AND REJECTION

14. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

15. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

16. **Rehearing.** Samples tested in accordance with sec. 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

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STANDARD SPECIFICATIONS

FOR

CARBON STEEL

CAR AND TENDER AXLES

SERIAL DESIGNATION: A21-14.

The specifications for this material are issued under the fixed designation A 21; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1913, 1914.

I. MANUFACTURE

1. Process. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

2. Chemical Composition. The steel shall conform to the following requirements as to chemical composition:

Carbon	0.35–0.55 per cent
Manganese	not over 0.70 " "
Phosphorus	" " 0.05 " "
Sulphur	" " 0.06 " "

3. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 2. This analysis shall be made from a

test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in sec. 2.

4. **Check Analyses.** An analysis may be made by the purchaser from an axle representing each melt. The chemical composition thus determined shall conform to the requirements specified in sec. 2. Drillings for analysis may be taken from the axle or from a full-size prolongation of the same, at any point midway between the center and surface.

III. PHYSICAL PROPERTIES AND TESTS

5. **Drop Tests.** (*a*) The test axle shall be so placed on supports that the tup will strike it midway between the ends. It shall be turned over after the first and third blows, and, when required, after the fifth and seventh blows. When tested in accordance with the following conditions, the axle shall stand the specified number of blows without fracture and the deflection after the first blow shall not exceed that specified:

Diameter of Axle at Center, Inches	Distance between Supports, Feet	Weight of Tup, Pounds	Height of Drop, Feet	Number of Blows	Max. Deflection after First Blow, Inches
4 1/4	3	1640	24	5	8 1/4
4 3/8	3	1640	26	5	8 1/4
4 7/16	3	1640	28 1/2	5	8 1/4
4 5/8	3	1640	31	5	8
4 3/4	3	1640	34	5	7 3/4
5 3/8	3	1640	43	5	6 1/2
5 7/8	3	1640	43	7	5
6 7/16	3	1640	43	9	3 1/2

(*b*) The deflection is the difference between the distance from a straight edge to the middle point of the axle, measured before the first blow, and the distance measured in the same manner after the blow. The straight edge shall rest only on the collars or the ends of the axle.

(*c*) The temperature of the test axle shall be between 40° and 120° F.

6. **Drop-Test Machine.** The anvil of the drop-test machine shall be supported on 12 springs, shall be free to move in a vertical direction, and shall weigh 17,500 pounds. The radii of the striking face of the tup and of the supports shall be 5 inches.

7. **Number of Tests.** One drop-test shall be made from each melt. Not less than 30 axles shall be offered from any one melt, unless otherwise agreed upon by the manufacturer and the purchaser.

IV. WORKMANSHIP AND FINISH

8. **Workmanship.** The axles shall conform to the sizes and shapes specified by the purchaser. When centered, 60-degree centers with clearance drilled for points shall be used.

9. **Finish.** The axles shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING

10. **Marking.** Identification marks shall be legibly stamped on each axle. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION

11. **Inspection.** (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the axles ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the axles are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the chemical tests to govern the acceptance or rejection of the axles in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

12. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 11 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Axles which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

13. **Rehearing.** Samples tested in accordance with sec. 11 (*b*), which represent rejected axles, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

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STANDARD SPECIFICATIONS

FOR

QUENCHED AND TEMPERED CARBON STEEL AXLES, SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS

SERIAL DESIGNATION: A19-16.

The specifications for this material are issued under the fixed designation A 19; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1912, 1914, 1916.

1. **Basis of Purchase.** When used for forgings for locomotives, these specifications cover quenched-and-tempered carbon steel driving axles, engine-and trailing-truck axles, main and side rods, straps, crank pins, and piston rods.

I. MANUFACTURE

2. **Process.** The steel may be made by the open-hearth or any other process approved by the purchaser.

3. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

4. **Prolongations for Tests.** For test purposes, a prolongation shall be left on each forging, unless otherwise specified by the purchaser.

5. **Boring.** (*a*) Unless otherwise specified by the purchaser, all forgings over 7 inches in diameter shall be bored, and all axles, shafts and similar forgings shall be rough-turned all over. The boring shall be done before quenching.

(*b*) If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

6. **Heat Treatment.** For quenching-and-tempering, the forgings shall be allowed to become cold after forging. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly.

II. CHEMICAL PROPERTIES AND TESTS

7. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Carbon	First Class by Size	0.25–0.60 per cent
	Second " " "	0.35–0.60 " "
	Third " " "	0.35–0.65 " "
	Fourth " " "	0.35–0.70 " "
Manganese		0.40–0.70 " "
Phosphorus		not over 0.05 " "
Sulphur		" " 0.05 " "

8. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 7.

9. **Check Analyses.** (*a*) An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in sec. 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

(*b*) In addition to the complete analysis specified in par. (*a*), a phosphorus determination may be made by the purchaser from each broken tension-test specimen. The phosphorus content thus determined shall conform to the requirement specified in sec. 7.

III. PHYSICAL PROPERTIES AND TESTS

10. **Tension Tests.** (*a*) The forgings shall conform to the minimum requirements as to tensile properties specified in Table I.

TABLE I.—TENSILE PROPERTIES

Size	Tensile Strength, Pounds per Sq. Inch	Elastic Limit, Pounds per Sq. Inch	Elongation in 2 Inches, Per Cent		Reduction of Area, Per Cent	
			Inverse Ratio	Not under	Inverse Ratio	Not under
FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 INCHES WHEN SOLID, AND NOT OVER 20 INCHES WHEN BORED						
Up to 4 inches outside diameter or thickness, 2-inch max. wall	90,000	55,000	$\frac{2,100,000}{\text{tens. str.}}$	20.5	$\frac{4,000,000}{\text{tens. str.}}$	39
Over 4 to 7 inches outside diameter or thickness, 3½-inch max. wall	85,000	50,000	$\frac{2,000,000}{\text{tens. str.}}$	20.5	$\frac{3,800,000}{\text{tens. str.}}$	39
Over 7 to 10 inches outside diameter or thickness, 5-inch max. wall	85,000	50,000	$\frac{1,900,000}{\text{tens. str.}}$	19.5	$\frac{3,600,000}{\text{tens. str.}}$	37
Outside diameter or thickness, not over 20 inches 5 to 8-inch wall	82,500	48,000	$\frac{1,800,000}{\text{tens. str.}}$	19	$\frac{3,400,000}{\text{tens. str.}}$	36

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 inch. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer

shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*d*) Tests of forgings shall be made only after final treatment.

11. **Bend Tests.** If specified by the purchaser, bend tests shall be made as follows:

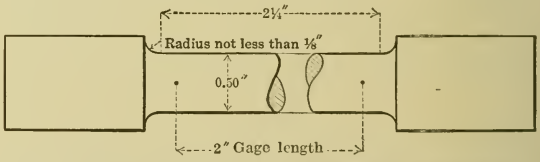
(*a*) For the first and second classes by size, the test specimen shall bend cold through 180 degrees around a 1-inch flat mandrel having a rounded edge of ½-inch radius, without cracking on the outside of the bent portion.

(*b*) For the third and fourth classes by size, the test specimen shall bend cold through 180 degrees around a 1½-inch flat mandrel having a rounded edge of ¾-inch radius, without cracking on the outside of the bent portion.

12. **Proof Tests.** Unless otherwise specified by the purchaser, all forgings shall be subjected to an impact proof test. The details of this test shall be agreed upon by the manufacturer and the purchaser.

13. **Test Specimens.** (*a*) Tension-and bend-test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars, the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.



NOTE:—The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the testing machine.

(*c*) Tension-test specimens shall be of the form and dimensions shown in fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*d*) Bend-test specimens shall be ½ inch square in section with corners rounded to a radius not over 1/16 inch, and need not exceed 6 inches in length.

14. **Number of Tests.** (*a*) One tension-and, if specified by the purchaser, one bend test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension-and, if specified, one bend test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension-and, if specified, one bend test shall be made from each melt.

(*b*) If more than one class of forgings by size is represented in any lot, one tension-and, if specified, one bend test from a forging of each class by size shall be made as specified in sec. 10, 11 and 13.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*d*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 10 (*a*) and any part of the fracture is more than ¾ inch from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

15. **Retests.** (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retemper or requench-and-temper such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in sec. 14.

(*b*) If the fracture of any tension-test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be retempered or requenched-and-tempered. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

IV. WORKMANSHIP AND FINISH

16. **Workmanship.** The forgings shall conform to the sizes and shapes specified by the purchaser. Axles, shafts, and similar forgings, unless otherwise specified, shall be rough-turned all over with an allowance of ⅛ inch on the surface for finishing. In centering, 60-degree centers with clearance drilled for points shall be used.

17. **Finish.** The forgings shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING

18. **Marking.** Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION

19. **Inspection.** (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

20. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 19 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

21. **Rehearing.** Samples tested in accordance with sec. 19 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

APPENDIX

As a guide in determining a proof test for quenched-and-tempered forgings, the following particulars regarding three methods of proof testing now being used are given.*

The Pennsylvania Railroad Company and the Standard Steel Works Company require that axles, shafts and similar forgings shall receive an impact proof test on an M. C. B. drop-test machine, with supports 3 feet apart, two blows being struck with a tup weighing 1640 or 2240 pounds. The former company requires that both blows be struck at the center of the forging, which is to be turned 90 degrees after the first blow. The other requires that the forging be supported at one end for the first blow and at the other end for the second blow; and that the forging be turned 180 degrees after the first blow. The requirements as to height of drop given in the accompanying table are derived from the following formulas: For the

1640-lb. tup: $H=0.01D^3$; 2240-lb. tup: $H=0.0073D^3$;

in which H is height of drop in feet and D is diameter of the forging at the center in inches.

The New York Central Lines and the Carnegie Steel Company require that forgings shall be submitted to an impact proof test by having them supported at the ends and being struck in the center one blow by a tup delivering the number of foot-pounds shown in the accompanying table.

PROOF TESTS FOR QUENCHED-AND-TEMPERED FORGINGS

Diameter, Inches	Pennsylvania Railroad Company, Standard Steel Works Company		New York Central Lines, Carnegie Steel Company
	Height of Drop		Energy of Blow
	1640-lb. Tup.	2240-lb. Tup.	Foot-Pounds
4½	.....	0 ft. 11 in.	700
5	.....	1 " 3 "	900
5½	1 ft. 2 in.	1 " 8 "	1200
6	1 " 7 "	2 " 2 "	1700
6½	2 " 0 "	2 " 9 "	2500
7	2 " 6 "	3 " 5 "	3500
7½	3 " 1 "	4 " 3 "	4700
8	3 " 8 "	5 " 1 "	6000
8½	4 " 6 "	6 " 2 "	7500
9	5 " 3 "	7 " 3 "	9000
9½	6 " 3 "	8 " 7 "	10000
10	7 " 4 "	10 " 0 "	11000
10½	8 " 6 "	11 " 7 "	12000
11	9 " 10 "	13 " 5 "	13000
11½	11 " 1 "	15 " 3 "	14000
12	12 " 8 "	17 " 4 "	15000

*For more detailed information concerning these methods of proof testing, see Report of Committee A-1 on Standard Specifications for Steel, Appendix IV. "Report on Proof Tests of Finished Forgings," Proceeding Am. Soc. for Test. Mats., Vol. XIV, Part II, p. 120 (1914).

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

STANDARD SPECIFICATIONS

FOR

QUENCHED-AND-TEMPERED ALLOY-STEEL AXLES, SHAFTS, AND OTHER FORGINGS, FOR LOCOMOTIVES AND CARS.

SERIAL DESIGNATED: A 63-16

The specifications for this material are issued under the fixed designation A 63; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1916

1. **Classes.** (*a*) These specifications cover the various classes of alloy-steel forgings now commonly used in locomotive and car construction.

(*b*) The purposes for which these classes are frequently used are as follows:

Class K, for forgings for main and side rods, straps, piston rods, and all other forgings which are to be machined with milling cutters or complicated forming tools;

Class L, for forgings for driving and trailing-truck axles, crank pins, and other parts not requiring the use of milling cutters or complicated forming tools.

I. MANUFACTURE

2. **Process.** The steel may be made by the open-hearth or any other process approved by the purchaser.

3. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

4. **Prolongations for Tests.** For test purposes, a prolongation shall be left on each forging, unless otherwise specified by the purchaser.

5. **Boring.** (*a*) Unless otherwise specified by the purchaser all forgings over 7 inches in diameter shall be bored, and all axles, shafts and similar forgings shall be rough-turned all over. The boring and rough-turning shall be done before quenching.

(*b*) If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

6. **Heat Treatment.** For quenching and tempering, the forgings shall be allowed to become cold after forging. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge") and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge") and allowed to cool uniformly.

II. CHEMICAL PROPERTIES AND TESTS

7. **Chemical Composition.** (*a*) The steel shall conform to the following requirements as to chemical composition:

	Acid	Basic
Phosphorus	not over 0.05 per cent	not over 0.04 per cent
Sulphur	" " 0.05 " "	" " 0.05 " "

(*b*) The composition of alloy steel, other than phosphorus and sulphur, shall be agreed upon by the manufacturer and the purchaser.*

*The question of chemical composition of the several types of alloy steels is not yet sufficiently standardized to warrant the inclusion of formal requirements covering chemical composition of such alloy steels in standard specifications.

The following compositions for Classes K and L are quoted as being as nearly typical as any now regularly manufactured:

Elements Considered	Chrome-Vanadium Steel, Per Cent	Chrome-Nickel Steel, Per Cent	Chromium Steel, Per Cent
Carbon	0.28–0.42	0.28–0.42	0.28–0.42
Manganese	0.40–0.70	0.40–0.70	0.40–0.70
Chromium	0.75–1.25	not under 0.70	0.60–0.90
Vanadium	not under 0.15	.....	.....
Nickel	.....	not under 1.25	.....

8. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese and the elements specified in sec. 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 7.

9. **Check Analyses.** (*a*) An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in sec. 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

(*b*) In addition to the complete analysis specified in par. (*a*), a phosphorus determination may be made by the purchaser from each broken tension-test specimen. The phosphorus content thus determined shall conform to the requirement specified in sec. 7.

III. PHYSICAL PROPERTIES AND TESTS

10. **Tension Tests.** (*a*) The forgings shall conform to the requirements as to tensile properties specified in Table I.

(*b*) The classification by size of the forgings shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 inch. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*d*) Tests of forgings shall be made only after final treatment.

TABLE I.—TENSILE PROPERTIES (CLASSES K AND L)

Class	Size	Tensile Strength, Pounds per Square Inch	Elastic Limit, Min. Pounds per Sq. Inch	Elongation in 2 inches, Minimum, Per Cent	Reduction of Area, Minimum, Per Cent
FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 INCHES WHEN SOLID, AND NOT OVER 20 INCHES WHEN BORED					
K ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 inches outside diameter or thickness, 1-inch max. wall	95,000–115,000	70,000	20	50
	Over 2 to 4 inches outside diameter or thickness, 2-inch max. wall	90,000–110,000	65,000	20	50
	Over 4 to 7 inches outside diameter or thickness, 3½-inch max. wall	90,000–110,000	65,000	20	50
	Over 7 to 10 inches outside diameter or thickness, 5-inch max. wall	90,000–110,000	65,000	20	50
	Outside diameter or thickness not over 20 inches, 5 to 8-inch wall	85,000–105,000	60,000	20	50
L ALLOY STEEL, QUENCHED AND TEMPERED.	Up to 2 inches outside diameter or thickness, 1-inch max. wall	105,000–125,000	80,000	20	50
	Over 2 to 4 inches outside diameter or thickness, 2-inch max. wall	100,000–120,000	75,000	20	50
	Over 4 to 7 inches outside diameter or thickness, 3½-inch max. wall	100,000–120,000	75,000	20	50
	Over 7 to 10 inches outside diameter or thickness, 5-inch max. wall	100,000–120,000	75,000	18	45
	Outside diameter or thickness not over 20 inches, 5 to 8-inch wall	95,000–115,000	70,000	18	45

11. **Bend Tests.** If specified by the purchaser, bend tests shall be made as follows:

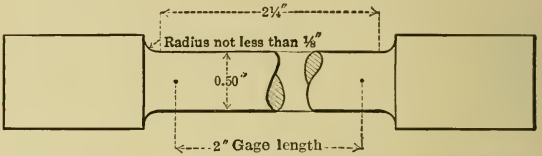
(*a*) For the first and second classes by size, the test specimen shall bend cold through 180 degrees around a 1 inch flat mandrel having a rounded edge of ½ inch radius, without cracking on the outside of the bent portion.

(*b*) For the third and fourth classes by size, the test specimen shall bend cold through 180 degrees around a 1½ inch flat mandrel having a rounded edge of ¾ inch radius, without cracking on the outside of the bent portion.

12. **Proof Tests.** Unless otherwise specified by the purchaser, all forgings shall be subjected to an impact proof test. The details of this test shall be agreed upon by the manufacturer and the purchaser.*

*For information relative to proof tests of finished forgings, see Appendix.

13. **Test Specimens.** (*a*) Tension-and bend-test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars, the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.



NOTE:—The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the testing machine.

FIGURE 1.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) Tension-test specimens shall conform to the dimensions shown in fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

(*d*) Bend-test specimens shall be ½ inch square in section with corners rounded to a radius not over 1/16 inch, and need not exceed 6 inches in length.

14. **Number of Tests.** (*a*) One tension-and, if specified by the purchaser, one bend test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension-and, if specified, one bend test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension-and, if specified, one bend test shall be made from each melt.

(*b*) If more than one class of forgings by size is represented in any lot, one tension-and, if specified, one bend test from a forging of each class by size shall be made as specified in sec. 10, 11 and 13.

(*c*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*d*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 10 (*a*) and any part of the fracture is more than ¾ inch from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

15. **Retests.** (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retemper or requench-and-temper such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in sec. 14.

(*b*) If the fracture of any tension-test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be retempered or requenched-and-tempered. The fracture shall be considered crystallin if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

IV. WORKMANSHIP AND FINISH

16. **Workmanship.** The forgings shall conform to the sizes and shapes specified by the purchaser. Axles, shafts and similar forgings, unless otherwise specified, shall be rough-turned all over with an allowance of ⅛ inch on the surface for finishing. In centering, 60 degree centers with clearance drilled for points shall be used.

17. **Finish.** The forgings shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING

18. **Marking.** Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION

19. **Inspection.** (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the

purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

20. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 19 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

21. **Rehearing.** Samples tested in accordance with sec. 19 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

APPENDIX

As a guide in determining a proof test for quenched-and-tempered forgings, the following particulars regarding three methods of proof testing now being used are given.*

The Pennsylvania Railroad Company and the Standard Steel Works Company require that axles, shafts and similar forgings shall receive an impact proof test on an M. C. B. drop-test machine, with supports 3 feet apart, two blows being struck with a tup weighing 1640 or 2240 pounds. The former company requires that both blows be struck at the center of the forging, which is to be turned 90 degrees after the first blow. The other requires that the forging be supported at one end for the first blow and at the other end for the second blow; and that the forging be turned 180 degrees after the first blow. The requirements as to height of drop given in the accompanying table are derived from the following formulas for the

1640-lb. tup: $H=0.01D^3$; 2240-lb. tup: $H=0.0073D^3$;

in which H is height of drop in feet and D is diameter of the forging at the center in inches.

The New York Central Lines and the Carnegie Steel Company require that forgings shall be submitted to an impact proof test by having them supported at the ends and being struck in the center one blow by a tup delivering the number of foot-pounds shown in the accompanying table.

PROOF TESTS FOR QUENCHED-AND-TEMPERED FORGINGS

Diameter, Inches	Pennsylvania Railroad Company, Standard Steel Works Company		New York Central Lines, Carnegie Steel Company
	Height of Drop		Energy of Blow
	1640-lb. Tup.	2240-lb. Tup.	Foot-Pounds
4½	0 ft. 11 in.	.....	700
5	1 " 3 "	.....	900
5½	1 " 8 "	1 ft. 2 in.	1200
6	2 " 2 "	1 " 7 "	1700
6½	2 " 9 "	2 " 0 "	2500
7	3 " 5 "	2 " 6 "	3500
7½	4 " 3 "	3 " 1 "	4700
8	5 " 1 "	3 " 8 "	6000
8½	6 " 2 "	4 " 6 "	7500
9	7 " 3 "	5 " 3 "	9000
9½	8 " 7 "	6 " 3 "	10000
10	10 " 0 "	7 " 4 "	11000
10½	11 " 7 "	8 " 6 "	12000
11	13 " 5 "	9 " 10 "	13000
11½	15 " 3 "	11 " 1 "	14000
12	17 " 4 "	12 " 8 "	15000

*For more detailed information concerning these methods of proof testing, see Report of Committee A-1 on Standard Specifications for Steel, Appendix IV, "Report on Proof Tests of Finished Forgings," Proceedings Am. Soc. Test. Mats., Vol. XIV, Part II, p. 120 (1914).

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

STANDARD SPECIFICATIONS

FOR

STRUCTURAL STEEL FOR LOCOMOTIVES

SERIAL DESIGNATION: A10-16.

The specifications for this material are issued under the fixed designation A 10; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1916.

1. **Basis of Purchase.** These specifications apply to shapes, plates (except boiler and firebox plates) and bars over ½ inch in thickness.

I. MANUFACTURE

2. **Process.** The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Phosphorus	not over 0.05 per cent
Sulphur	" " 0.05 " "

4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical

composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 3.

5. **Check Analyses.** Analyses may be made by the purchaser from finished material representing each melt. The phosphorus and sulphur content thus determined shall conform to the requirements specified in sec. 3.

III. PHYSICAL PROPERTIES AND TESTS

6. **Tension Tests.** (*a*) The material shall conform to the following requirements as to tensile properties:

Tensile strength	lb. per sq. inch	55,000–65,000
Yield point, min	lb. per sq. inch	0.5 tens. str.
Elongation in 8 inches, min (See sec. 7.)	per cent	$\frac{1,500,000}{\text{tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

7. **Modifications in Elongation.** (*a*) For material over $\frac{3}{4}$ inch in thickness, a deduction of 1 from the percentage of elongation specified in sec. 6 (*a*) shall be made for each increase of $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch, to a minimum of 18 per cent.

(*b*) For material under $\frac{5}{16}$ inch in thickness, a deduction of 2.5 from the percentage of elongation in 8 inches specified in sec. 6 (*a*) shall be made for each decrease of $\frac{1}{16}$ inch in thickness below $\frac{5}{16}$ inch.

8. **Bend Tests.** The test specimen shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows: For material $\frac{3}{4}$ inch or under in thickness, flat on itself; for material over $\frac{3}{4}$ inch to and including $1\frac{1}{4}$ inch in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over $1\frac{1}{4}$ inch in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

9. **Test Specimens.** (*a*) Tension-and bend-test specimens shall be taken from the finished rolled material.

(*b*) Tension-and bend-test specimens, except as specified in par. (*c*), shall be of the full thickness of material as rolled; and may be machined to the form and dimensions shown in fig. 1, or with both edges parallel.

(*c*) Tension-and bend-test specimens for plates and bars over 1½ inch in thickness or diameter may be machined to a thickness or diameter of at least ¾ inch for a length of at least 9 inches.

10. **Number of Tests.** (*a*) One tension-and one bend test shall be made from each melt; except that if material from one melt differs ⅜ inch or over in thickness, one tension-and one bend test shall be made from both the thickest and the thinnest material rolled. Shapes less than 1 sq. inch in section, and bars less than ½ sq. inch in section, need not be subjected to a tension test.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

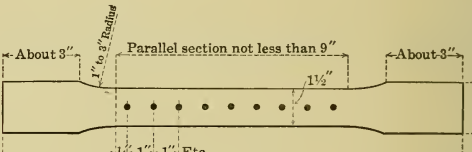


FIGURE 1

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

11. **Permissible Variations.** The cross-section or weight of each piece of steel shall not vary more than 2.5 per cent from that specified, except in the case of sheared plates, which shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 pound.

(*a*) **When Ordered to Weight per Square Foot:—**

The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

[1]The term "lot" applied to Table I means all of the plates of each group width and group weight.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT

Ordered Weight, Pounds per Square Foot	Permissible Variations in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Ordered Weights																					
	Under 48 in.		48 in. to 60 in. excl.		60 in. to 72 in. excl.		72 in. to 84 in. excl.		84 in. to 96 in. excl.		96 in. to 108 in. excl.		108 in. to 120 in. excl.		120 in. to 132 in. excl.		132 in. or over	
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...
5 to 7.5 excl.	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...
7.5 to 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...
10 to 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3
12.5 to 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3
15 to 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3
17.5 to 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3
20 to 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3
25 to 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3
30 to 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1⅓ times the amount given in this table.

(*b*) **When Ordered to Thickness:—**

The thickness of each plate shall not vary more than 0.01 inch under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS

Ordered Thickness, Inches	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights								
	Under 48 in.	48 in. to 60 in. excl.	60 in. to 72 in. excl.	72 in. to 84 in. excl.	84 in. to 96 in. excl.	96 in. to 108 in. excl.	108 in. to 120 in. excl.	120 in. to 132 in. excl.	132 in. or over
Under ⅛	9	10	12	14	....	....	....	....	....
⅛ to 5/16 excl.	8	9	10	12	....	....	....	....	....
5/16 to ¼ "	7	8	9	10	12	....	....	....	....
¼ to 5/16 "	6	7	8	9	10	12	14	16	19
5/16 to ⅜ "	5	6	7	8	9	10	12	14	17
⅜ to 7/16 "	4.5	5	6	7	8	9	10	12	15
7/16 to ½ "	4	4.5	5	6	7	8	9	10	13
½ to ⅝ "	3.5	4	4.5	5	6	7	8	9	11
⅝ to ¾ "	3	3.5	4	4.5	5	6	7	8	9
¾ to 1 "	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7

[2]The term "lot" applied to Table II means all of the plates of each group width and group thickness.

V. FINISH

12. **Finish.** The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING

13. **Marking.** The name or brand of the manufacturer and the melt number shall be legibly stamped or rolled on all finished material, except that small sections shall, when loaded for shipment, be properly separated and marked for identification. The melt number shall be legibly marked, by stamping, if practicable, on each test specimen.

VII. INSPECTION AND REJECTION

14. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

15. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

16. **Rehearing.** Samples tested in accordance with sec. 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

STANDARD SPECIFICATIONS

FOR

BOILER AND FIREBOX STEEL FOR LOCOMOTIVES

SERIAL DESIGNATION: A30-16.

The specifications for this material are issued under the fixed designation A 30; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914, 1916.

1. **Grades.** These specifications cover two grades of steel for boilers for locomotives, namely:

FLANGE

AND

FIREBOX

I. MANUFACTURE

2. **Process.** The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

	Flange	Firebox
Carbon	..... per cent	0.12–0.25 per cent
Manganese	0.30–0.60 " "	0.30–0.50 " "
Phosphorus, Acid	not over 0.05 " "	not over 0.04 " "
Phosphorus, Basic	" " 0.04 " "	" " 0.035 " "
Sulphur	" " 0.05 " "	" " 0.04 " "
Copper	..... " "	" " 0.05 " "

4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 3.

5. **Check Analyses.** An analysis may be made by the purchaser from a broken tension-test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in sec. 3.

III. PHYSICAL PROPERTIES AND TESTS

6. **Tension Tests.** (*a*) The material shall conform to the ollowing requirements as to tensile properties:

	Flange	Firebox
Tensile strength.....lb. per sq. inch	55,000–65,000	52,000–62,000
Yield point, min.....lb. per sq. inch	0.5 tens. str.	0.5 tens. str.
Elongation in 8 inches, min...per cent (See sec. 7.)	$\frac{1,500,000}{\text{tens. str.}}$	$\frac{1,500,000}{\text{tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

7. **Modifications in Elongation.** (*a*) For material over $\frac{3}{4}$ inch in thickness, a deduction of 0.5 from the percentages of elongation specified in sec. 6 (*a*) shall be made for each increase of $\frac{1}{8}$ inch in thickness above $\frac{3}{4}$ inch.

(*b*) For material $\frac{1}{4}$ inch or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

8. **Bend Tests.** (*a*) *Cold-bend Tests.*—The test specimen shall bend cold through 180 degrees without cracking on the outside of the bent portion, as follows: For material 1 inch or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 inch in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

9. **Homogeneity Tests.** For firebox steel, a sample taken from a broken tension-test specimen shall not show any single seam or cavity more than ¼ inch long, in either of the three fractures obtained in the test for homogeneity, which shall be made as follows: The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about 1/16 inch deep, in three places about 2 inches apart. The first groove shall be made 2 inches from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about ¼ inch above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two grooves in the same manner. The object of this test is to open and render visible to the eye any seams due to failure to weld up or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the lengths of the seams and cavities determined, a pocket lens being used if necessary.

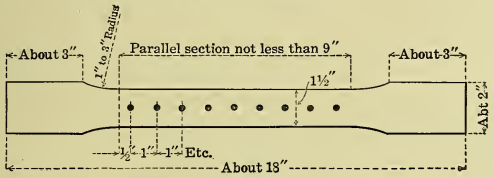


FIGURE 1.

10. **Test Specimens.** Tension-test specimens shall be taken longitudinally from the bottom of the finished rolled material, and bend-test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimens shall be taken in the direction of the longitudinal axis of the ingot, and the transverse test specimens at right angles to that axis. They shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in fig. 1; except that bend-test specimens may be machined with both edges parallel.

11. **Number of Tests.** (*a*) One tension-, and one bend test shall be made from each plate as rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen

is less than that specified in sec. 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

12. **Permissible Variations.** *When Ordered to Thickness:—*

The thickness of each plate shall not vary more than 0.01 inch under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table I. One cubic inch of rolled steel is assumed to weigh 0.2833 pound.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS

Ordered Thickness, Inches	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights								
	Under 48 in.	48 in. to 60 in. excl.	60 in. to 72 in. excl.	72 in. to 84 in. excl.	84 in. to 96 in. excl.	96 in. to 108 in. excl.	108 in. to 120 in. excl.	120 in. to 132 in. excl.	132 in. or over
Under 1/8	9	10	12	14	....	....	....	....	....
1/8 to 3/16 excl	8	9	10	12	....	....	....	....	....
3/16 to 1/4 "	7	8	9	10	12	....	....	....	....
1/4 to 5/16 "	6	7	8	9	10	12	14	16	19
5/16 to 3/8 "	5	6	7	8	9	10	12	14	17
3/8 to 7/16 "	4.5	5	6	7	8	9	10	12	15
7/16 to 1/2 "	4	4.5	5	6	7	8	9	10	13
1/2 to 5/8 "	3.5	4	4.5	5	6	7	8	9	11
5/8 to 3/4 "	3	3.5	4	4.5	5	6	7	8	9
3/4 to 1 "	2.5	3	3.5	4	4.5	5	6	7	8
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7

V. FINISH

13. **Finish.** The finished material shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING

14. **Marking.** (*a*) The name or brand of the manufacturer, melt or slab number, grade, and lowest tensile strength for its grade specified in sec. 6 (*a*), shall be legibly stamped on each plate.

[1]The term "lot" applied to Table I means all of the plates of each group width and group thickness.

The melt or slab number shall be legibly stamped on each test specimen.

(*b*) When specified on the order, plates shall be match-marked as defined in paragraph (*c*) so that the test specimens representing them may be identified. When more than one plate is sheared from a single slab or ingot, each shall be match-marked so that they may all be identified with the test specimens representing them.

(*c*) Each match mark shall consist of two over-lapping circles each not less than 1½ inches in diameter, placed upon the shear lines, and made by separate impressions of a single-circle steel die.

(*d*) Match-marked coupons shall match with the sheets represented and only those which match properly shall be accepted.

VII. INSPECTION AND REJECTION

15. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

16. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

17. **Rehearing.** Samples tested in accordance with sec. 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

STANDARD SPECIFICATIONS

FOR

CARBON STEEL FORGINGS FOR LOCOMOTIVES

SERIAL DESIGNATION: A20-16.

The specifications for this material are issued under the fixed designation A 20; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1913, 1914, 1916.

1. **Basis of Purchase.** (*a*) These specifications cover untreated and annealed carbon-steel driving axles, engine-and trailing-truck axles, main and side rods, straps, crank pins, and piston rods.

(*b*) The manufacturer may, at his option, furnish annealed forgings when untreated forgings are specified by the purchaser, provided they conform to the requirements specified for untreated forgings.

I. MANUFACTURE

2. **Process.** The steel may be made by the open-hearth or any other process approved by the purchaser.

3. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

4. **Prolongations for Tests.** The manufacturer and the purchaser shall agree upon forgings on which a prolongation for test purposes shall be provided.

5. **Heat Treatment.** For annealing, the forgings shall be allowed to become cold after forging. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge" and allowed to cool uniformly.

II. CHEMICAL PROPERTIES AND TESTS

6. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Manganese	0.40–0.70 per cent
Phosphorus	not over 0.05 " "
Sulphur	" " 0.05 " "

7. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon and the elements specified in sec. 6. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 6.

8. **Check Analyses.** An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in sec. 6. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface; or turnings may be taken from a test specimen.

III. PHYSICAL PROPERTIES AND TESTS

9. **Tension Tests.** (*a*) The forgings shall conform to the following minimum requirements as to tensile properties:

Tensile Properties

For Forgings Whose Maximum Outside Diameter or Over-all Thickness is not over 12 Inches when Untreated and not over 20 Inches when Annealed

Size Outside Diameter or Over-all Thickness	Tensile Strength, lb. per sq. inch	Yield Point, lb. per sq. inch	Elongation in 2 inches, per cent		Reduction of Area, per cent	
			Inverse Ratio	Not under	Inverse Ratio	Not under
Untreated						
Not over 8 inches....	75,000	0.5 tens. str.	1,600,000 / tens. str.	18	2,200,000 / tens. str.	24
Over 8 to 12 inches, incl.....	75,000	0.5 tens. str.	1,500,000 / tens. str.	17	2,000,000 / tens. str.	22
Annealed						
Not over 8 inches....	80,000	0.5 tens. str.	1,800,000 / tens. str.	20	2,800,000 / tens. str.	32
Over 8 to 12 inches, incl.....	80,000	0.5 tens. str.	1,725,000 / tens. str.	19	2,640,000 / tens. str.	30
Over 12 to 20 inches, incl.....	80,000	0.5 tens. str.	1,650,000 / tens. str.	18	2,400,000 / tens. str.	28

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

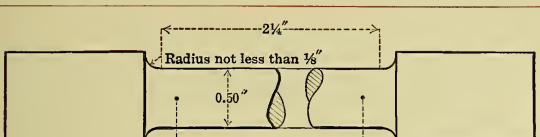
(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

(*d*) Tests of forgings shall be made only after final treatment.

10. **Tension-Test Specimens.** (*a*) Tension-test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars, the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of the forging, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) Test specimens shall be of the form and dimensions shown in fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.



NOTE:—The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the testing machine.

11. **Number of Tests.** Unless otherwise specified by the purchaser, tests shall be made as follows:

(*a*) For untreated forgings, one tension test shall be made from each melt.

(*b*) For annealed forgings, one tension test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension test shall be made from each melt.

(*c*) If more than one class of forgings by size is represented in any lot, one tension test from a forging of each class by size shall be made as specified in sec. 9 and 10.

(*d*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*e*) If the percentage of elongation of any test specimen is less than that specified in sec. 9 (*a*) and any part of the fracture is more than ¾ inch from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

12. **Retests.** (*a*) If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may reanneal such lot, but not more than three additional times unless authorized by the purchaser, and retests shall be made as specified in sec. 11.

(*b*) When annealed forgings are specified, if the fracture of any test specimen shows over 15 per cent crystallin, a second test shall be made. If the fracture of the second specimen shows over 15 per cent crystallin, the forgings represented by such specimen shall be reannealed. The fracture shall be considered crystallin, if the crystals which it contains are so large that the cleavage planes or sides of these crystals are easily visible to the eye.

IV. WORKMANSHIP AND FINISH

13. **Workmanship.** The forgings shall conform to the sizes and shapes specified by the purchaser. When centered, 60-degree centers with clearance drilled for points shall be used.

14. **Finish.** The forgings shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING

15. **Marking.** Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION

16. **Inspection.** (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

17. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 16 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

18. **Rehearing.** Samples tested in accordance with sec. 16 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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STANDARD SPECIFICATIONS

FOR

SOLID WROUGHT CARBON-STEEL WHEELS FOR STEAM RAILWAY SERVICE

SERIAL DESIGNATION : A 57-16

The specifications for this material are issued under the fixed designation A 57; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1912; REVISED, 1916

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

2. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS.

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

	ACID	BASIC
Carbon	0.60–0.80 per cent	0.65–0.85 per cent
Manganese	0.55–0.80 " "	0.55–0.80 " "
Phosphorus	not over 0.05 " "	not over 0.05 " "
Sulphur	" " 0.05 " "	" " 0.05 " "
Silicon	0.15–0.35 " "	0.10–0.30 " "

4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 3.

5. **Check Analyses.** An analysis may be made by the purchaser from a wheel representing each melt. The chemical composition thus determined shall conform to the requirements specified in sec. 3. A sample may be taken from any one point in the plate; or two samples may be taken, in which case they shall be on radii at right angles to each other. Samples shall not be taken in such a way as to impair the usefulness of the wheel. Drillings for analysis shall be taken by boring entirely through the sample parallel to the axis of the wheel; they shall be clean and free from scale, oil and other foreign substances. All drillings from any one wheel shall be thoroughly mixed together.

III. MATING

6. **Mating.** The wheels shall be mated as to tape sizes and shipped in pairs.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS*

7. **Permissible Variations.** The wheels shall conform to the dimensions specified within the following permissible variations:

Flange

(*a*) *Height of Flange.*—The height of flange shall not be less but may be $\frac{1}{8}$ inch more than that specified.

(*b*) *Thickness of Flange.*—The thickness of flange shall not vary more than $\frac{1}{16}$ inch from that specified.

(*c*) *Radius of Throat.*—The radius of throat shall not vary more than $\frac{1}{16}$ inch from that specified.

*To facilitate the use of the specifications, the various dimensions are illustrated in fig. 1, and the permissible variations in those dimensions are also given in tabular form in Table I.

Rim

(*d*) *Thickness of Rim.*—The rim may vary in thickness, but the variation less than that specified shall not exceed 3/16 inch. The thickness of rim shall be measured from the inner edge of the rim to a base line drawn from the intersection of the throat radius and the tread, parallel to the axis of the wheel.

(*e*) *Width of Rim.*—The width of rim shall not vary more than 1/8 inch from that specified.

(*f*) *Plane.*—The wheels shall be gaged with a ring gage placed concentric with and perpendicular to the axis of the wheel. For all points on the back face of the rim equidistant from the center, the variation from the plane of the gage when so placed shall not exceed 1/16 inch.

(*g*) *Rotundity.*—The tread shall be gaged with a ring gage, and the opening between the tread and this gage at any point shall not exceed 1/16 inch.

(*h*) *Block Marks on Tread.*—Block marks shall not exceed 1/64 inch in height.

(*i*) *Tape Sizes.*—The wheels shall not vary more than 9 tapes over nor more than 5 tapes under the size specified.

(*j*) *Limit-of-Wear Groove.*—When a limit-of-wear groove is specified, its location shall not vary more than 1/8 inch from that specified, and its distance from the inner edge of the rim shall not at any point be less than 3/4 inch.

Plate

(*k*) *Thickness of Plate.*—The plate may vary in thickness, but the variation less than that specified shall not exceed 1/32 inch for each 1/8 inch in the thickness of the plate.

Hub

(*l*) *Diameter of Hub.*—The diameter of hub may vary, but the thickness of wall of the finished bored hub shall not be less than 1 1/8 inch at any point for bores 7 inches or under in diameter, nor less than 1 3/8 inch for bores over 7 inches in diameter, unless otherwise specified. The thickness of wall of the hub shall not vary more than 3/8 inch at any two points on the same wheel.

(*m*) *Length of Hub.*—The length of hub shall not vary more than 1 1/8 inch from that specified.

(*n*) *Depression of Hub.*—For car and tender wheels and wheels of similar design, the depression of the hub below the front face of the rim shall not be less, but may be $\frac{1}{8}$ inch more, than that specified.

(*o*) *Projection of Hub.*—For locomotive-truck wheels and wheels of similar design, the projection of the hub beyond the back face of the rim shall not be less, but may be $\frac{1}{8}$ inch more, than that specified.

Bore

(*p*) *Diameter of Rough Bore.*—The diameter of rough bore shall not vary more than $\frac{1}{16}$ inch over nor more than $\frac{1}{8}$ inch under that specified. When finished-bore diameter only is specified, the rough-bore diameter shall be made $\frac{1}{4}$ inch less with the permissible variations specified above.

(*q*) *Black Spots in Bore.*—Black spots in rough bore within 2 inches of either face of the hub shall not exceed $\frac{1}{16}$ inch in depth.

(*r*) *Eccentricity of Bore.*—The eccentricity between the tread at its center line and the rough bore shall not exceed $\frac{3}{64}$ inch.

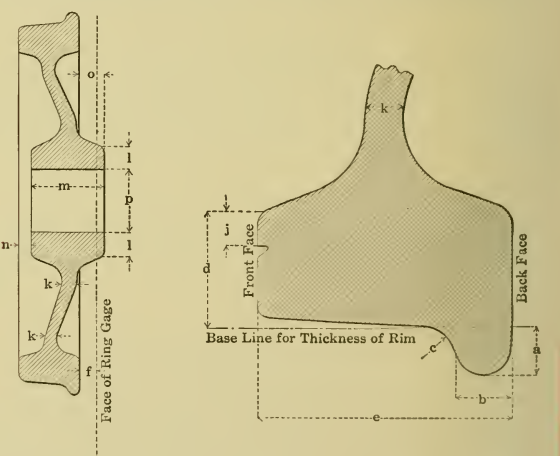

FIGURE 1.—Diagram showing Points at which the Dimensions Covered by the Specifications Are Measured. For the Permissible Variations in these Dimensions, see Table I or sec. 7.

V. FINISH

8. **Finish.** (*a*) The wheels shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Wheels shall not be offered for inspection if covered with paint, rust, or any other substance to such an extent as to hide defects.

VI. MARKING

9. **Marking.** (*a*) The name or brand of the manufacturer, date, and serial number shall be legibly stamped on each wheel in such a way that the wheel may be readily identified.

(*b*) The tape size shall be legibly marked on each wheel.

VII. INSPECTION AND REJECTION

10. **Inspection.** (*a*) The gages and tapes used shall be based on Master Car Builders' standards.

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of wheels in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*d*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

11. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 10 (*c*) shall be reported within five working days from the receipt of samples.

(*b*) Wheels which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

12. **Rehearing.** Samples tested in accordance with sec. 10 (*c*), which represent rejected wheels, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TABLE I.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF WROUGHT-STEEL WHEELS FOR STEAM RAILWAY SERVICE.

	Dimensions	Permissible Variations in Dimensions	
		Over	Under
	FLANGE		
(a)	Height	1/8"	0
(b)	Thickness	1/16"	1/16"
(c)	Radius of Throat	1/16"	1/16"
	RIM		
(d)	Thickness, from Inner Edge to Intersection of Throat and Tread	.....	3/16"
(e)	Width	1/8"	1/8"
(f)	Maximum Departure of any Circle on Back Face from Plane	1/16"	
(g)	Maximum Departure of Tread from Rotundity	1/16"	
(h)	Maximum Height of Block Marks on Tread	1/64"	
(i)	Tape Sizes	9	5
(j)	Limit-of-Wear Groove:		
	1. Maximum Departure from Specified Position	1/8"	
	2. Minimum Distance from Inner Edge of Rim	3/4"	
	PLATE		
(k)	Thickness, Variation for each 1/8 inch of thickness	.....	1/32"
	HUB		
(l)	1. Diameter	.....	Limited by wall thickness
	2. Minimum Thickness of Wall, for Bore 7 inches or under	1 1/8"	
	3. Minimum Thickness of Wall, for Bore over 7 inches	1 3/8"	
	4. Maximum Variation in Thickness of Wall in any One Wheel	3/8"	
(m)	Length	1/8"	1/8"
(n)	Depression below Front Face of Rim	1/4"	0
(o)	Projection beyond Back Face of Rim	1/8"	0
	BORE		
	(If not specified, Rough Bore shall be 1/4 inch less than Finished Bore.)		
(p)	Diameter of Rough Bore	1/16"	1/8"
(q)	Maximum Depth of Black Spots in Rough Bore within 2 inches of End of Bore	1/16"	
(r)	Maximum Eccentricity of Rough Bore in Relation to Tread	3/64"	

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

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STANDARD SPECIFICATIONS

FOR

SOLID WROUGHT CARBON STEEL WHEELS FOR ELECTRIC RAILWAY SERVICE

SERIAL DESIGNATION: A 25-16

The specifications for this material are issued under the fixed designation A 25; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ADOPTED, 1913; REVISED, 1916

1. **Classes.** These specifications cover two classes of wheels, as follows:

CLASS A

Wheels furnished rough-bored with hub faced on both sides and other surfaces as rolled or forged.

CLASS B

Wheels furnished rough-bored with hubs faced on both sides, and front face of rim, tread, flange, and back face of rim machined.

2. **Basis of Purchase.** The class of wheel to be furnished shall be agreed upon by the manufacturer and the purchaser. Wheels ordered to Class A may be machined if necessary, but the permissible variations from the dimensions specified shall remain those given in sec. 9 for Class A.

I. MANUFACTURE

3. **Process.** The steel shall be made by the open-hearth process.

4. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS

5. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

	Acid	Basic
Carbon	0.60–0.80 per cent	0.65–0.85 per cent
Manganese	0.55–0.80 " "	0.55–0.80 " "
Phosphorus	not over 0.05 " "	not over 0.05 " "
Sulphur	" " 0.05 " "	" " 0.05 " "
Silicon	0.15–0.35 " "	0.10–0.30 " "

6. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 5. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 5.

7. **Check Analyses.** An analysis may be made by the purchaser from a wheel representing each melt. The chemical composition thus determined shall conform to the requirements specified in sec. 5. A sample may be taken from any one point in the plate; or two samples may be taken, in which case they shall be on radii at right angles to each other. Samples shall not be taken in such a way as to impair the usefulness of the wheel. Drillings for analysis shall be taken by boring entirely through the sample parallel to the axis of the wheel; they shall be clean and free from scale, oil and other foreign substances. All drillings from any one wheel shall be thoroughly mixed together.

III. MATING

8. **Mating.** The wheels shall be mated as to tape sizes and shipped in pairs.

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS*

9. **Permissible Variations.** The wheels shall conform to the

*To facilitate the use of the specifications, the various dimensions are illustrated in fig. 1, and the permissible variations in those dimensions are also given in tabular form in Table I.

dimensions specified within the following permissible variations:

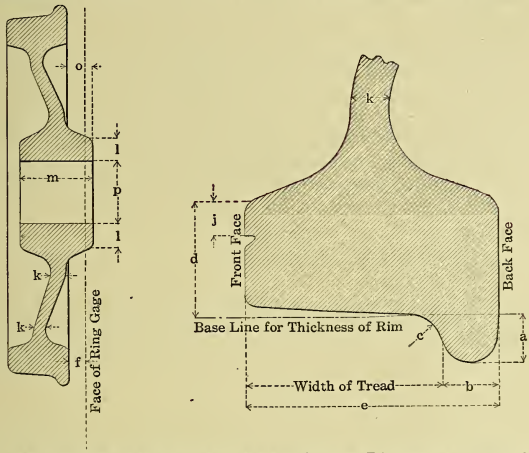

FIGURE 1.—Diagram showing Points at which the Dimensions Covered by the Specifications are Measured. For the Permissible Variations in these dimensions, see Table I or sec. 9.

FLANGE

(*a*) *Height of Flange.*—The height of flange shall not vary from that specified more than 1/16 inch for Class A or 1/32 inch for Class B wheels.

(*b*) *Thickness of Flange.*—The thickness of flange shall not vary from that specified more than 1/16 inch for Class A or 1/32 inch for Class B wheels.

(*c*) *Radius of Throat.*—The radius of throat shall not vary from that specified more than 1/16 inch for Class A or 1/32 inch for Class B wheels.

RIM

(*d*) *Thickness of Rim.*—The thickness of rim shall not vary more than 1/4 inch over nor more than 1/8 inch under that specified. The thickness of rim shall be measured from the inner edge of the rim to a base line drawn from the intersection of the throat radius and the tread, parallel to the axis of the wheel.

(*e*) *Width of Rim.*—The width of rim shall not vary from that specified more than $\frac{1}{8}$ inch for Class A or $\frac{1}{16}$ inch for Class B wheels.

(*f*) *Plane.*—The wheels shall be gaged with a ring gage placed concentric with and perpendicular to the axis of the wheel. For all points on the back of the rim equidistant from the center, the variation from the plane of the gage when so placed shall not exceed $\frac{1}{16}$ inch for Class A or $\frac{1}{32}$ inch for Class B wheels.

(*g*) *Rotundity.*—The tread shall be gaged with a ring gage, and the opening between the tread and this gage at any point shall not exceed $\frac{1}{16}$ inch for Class A wheels or $\frac{1}{64}$ inch for Class B wheels.

(*h*) *Block Marks on Tread.*—Block marks shall not exceed $\frac{1}{64}$ inch in height.

(*i*) *Tape Sizes.*—Wheels with treads under 3 inches in width shall not vary more than 6 tapes over nor more than 4 tapes under the size specified. Wheels with treads 3 inches or over in width shall not vary more than 9 tapes over nor more than 5 tapes under the size specified.

(*j*) *Limit-of-Wear Groove.*—When a limit-of-wear groove is specified, its location shall not vary more than $\frac{1}{16}$ inch from that specified.

Plate

(*k*) *Thickness of Plate.*—The plate may vary in thickness, but the variation less than that specified shall not exceed $\frac{1}{32}$ inch for each $\frac{1}{8}$ inch in the thickness of the plate.

Hub

(*l*) *Diameter of Hub.*—The diameter of hub shall not be less but may be $\frac{3}{4}$ inch more than that specified. The thickness of wall of the finished bored hub shall not be less than 1 inch at any point for bores 6 inches or under in diameter, nor less than $1\frac{1}{4}$ inches for bores over 6 inches in diameter, unless otherwise specified. The thickness of wall of the hub shall not vary more than $\frac{3}{8}$ inch at any two points on the same wheel.

(*m*) *Length of Hub.*—The length of hub shall not vary more than $\frac{1}{8}$ inch from that specified.

(*o*) *Projection of Hub.*—The projection of the hub beyond the back face of the rim shall not vary more than $\frac{1}{16}$ inch from that specified.

BORE

(*p*) *Diameter of Rough Bore.*—The diameter of rough bore shall not vary more than 1/16 inch over nor more than 1/8 inch under that specified. When finished-bore diameter only is specified, the rough-bore diameter shall be made 1/4 inch less with the permissible variations specified above.

(*q*) *Black Spots in Bore.*—Black spots in rough bore within 2 inches of either face of the hub shall not exceed 1/16 inch in depth.

(*r*) *Eccentricity of Bore.*—The eccentricity between the tread at its center line and the rough bore shall not exceed 3/64 inch.

V. FINISH

10. **Finish.** (*a*) The wheels shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Wheels shall not be offered for inspection if covered with paint, rust or any other substance to such an extent as to hide defects.

VI. MARKING

11. **Marking.** (*a*) The name or brand of the manufacturer, date, and serial number, shall be legibly stamped on each wheel in such a way that the wheel may be readily identified.

(*b*) The tape size shall be legibly marked on each wheel.

VII. INSPECTION AND REJECTION

12. **Inspection.** (*a*) The manufacturer shall provide suitable gages and tapes, which shall conform to the contour and dimensions specified.

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of wheels in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*d*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

13. **Rejection.** (*a*) Unless otherwise specified any rejection based on tests made in accordance with sec. 12 (*c*) shall be reported within ten working days from receipt of samples.

(*b*) Wheels which show injurious defects while being finished by purchaser will be rejected, and the manufacturer shall be notified.

14. **Rehearing.** Samples tested in accordance with sec. 12 (*c*), which represent rejected wheels, shall be preserved for one month from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TABLE I.—PERMISSIBLE VARIATIONS IN DIMENSIONS OF WROUGHT STEEL WHEELS FOR ELECTRIC RAILWAY SERVICE

	Dimensions	Permissible Variations in Dimensions			
		Class A		Class B	
		Over	Under	Over	Under
	FLANGE				
(a)	Height	1/16″	1/16″	1/32″	1/32″
(b)	Thickness	1/16″	1/16″	1/32″	1/32″
(c)	Radius of Throat	1/16″	1/16″	1/32″	1/32″
	RIM				
(d)	Thickness, from Inner Edge to Intersection of Throat and Tread	1/4″	1/8″	1/4″	1/8″
(e)	Width	1/8″	1/8″	1/16″	1/16″
(f)	Maximum Departure of any Circle on Back Face from Plane	1/16″		1/32″	
(g)	Maximum Departure of Tread from Rotundity	1/16″		1/64″	
(h)	Maximum Height of Block Marks on Tread	1/64″		1/64″	
(i)	Tape Sizes:				
	1. For Treads under 3 inches in Width	6	4	6	4
	2. For Treads 3 inches or over in Width	9	5	9	5
(j)	Limit-of-Wear Groove: Maximum Departure from Specified Position	1/16″		1/16″	
	PLATE				
(k)	Thickness, Variation for each 1/8 inch of Thickness	...	1/32″	....	1/32″
	HUB				
(l)	1. Diameter	3/4″	0	3/4″	0
	2. Minimum Thickness of Wall, for Bore 6 inches or under	1″		1″	
	3. Minimum Thickness of Wall, for Bore over 6 inches	1 1/4″		1 1/4″	
	4. Maximum Variation in Thickness of Wall in any One Wheel	3/8″		3/8″	
(m)	Length	1/8″	1/8″	1/8″	1/8″
(o)	Projection beyond Back Face of Rim	1/16″	1/16″	1/16″	1/16″
	BORE				
	(If not specified, Rough Bore shall be 1/4 inch less than Finished Bore.)				
(p)	Diameter of Rough Bore	1/16″	1/8″	1/16″	1/8″
(q)	Maximum Depth of Black Spots in Rough Bore within 2 inches of End of Bore	1/16″		1/16″	
(r)	Maximum Eccentricity of Rough Bore in Relation to Tread	8/64″		8/64″	

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

STANDARD SPECIFICATIONS

FOR

BOILER RIVET STEEL

SERIAL DESIGNATION: A 31-14.

The specifications for this material are issued under the fixed designation A 31; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1909, 1912, 1913, 1914.

A. Requirements for Rolled Bars.

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

2. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Manganese	0.30–0.50 per cent
Phosphorus	not over 0.04 " "
Sulphur	" " 0.045 " "

3. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical

composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 2.

4. **Check Analyses.** Analyses may be made by the purchaser from finished bars representing each melt. The chemical composition thus determined shall conform to the requirements specified in sec. 2.

III. PHYSICAL PROPERTIES AND TESTS

5. **Tension Tests.** (*a*) The bars shall conform to the following requirements as to tensile properties:

Tensile strength.....lb. per sq. inch	45,000–55,000
Yield point, min.....lb. per sq. inch	0.5 tens. str.
Elongation in 8 inches, min.....per cent	$\frac{1{,}500{,}000}{\text{tens. str.}}$
but need not exceed 30 per cent.	

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

6. **Bend Tests.** (*a*) *Cold-bend Tests.*—The test specimen shall bend cold through 180 degrees flat on itself without cracking on the outside of the bent portion.

(*b*) *Quench-bend Tests.*—The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200° F.) and quenched at once in water the temperature of which is between 80° and 90° F., shall bend through 180 degrees flat on itself without cracking on the outside of the bent portion.

7. **Test Specimens.** Tension-and bend-test specimens shall be of the full-size section of bars as rolled.

8. **Number of Tests.** (*a*) Two tension-, two cold-bend-, and two quench-bend tests shall be made from each melt, each of which shall conform to the requirements specified.

(*b*) If any test specimen develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN GAGE

9. **Permissible Variations.** The gage of each bar shall not vary more than 0.01 inch from that specified.

V. WORKMANSHIP AND FINISH

10. **Workmanship.** The finished bars shall be circular within 0.01 inch.

11. **Finish.** The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI. MARKING

12. **Marking.** Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

VII. INSPECTION AND REJECTION

13. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 4 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

15. **Rehearing.** Samples tested in accordance with sec. 4, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

B. Requirements for Rivets.

I. PHYSICAL PROPERTIES AND TESTS

16. **Tension Tests.** The rivets, when tested, shall conform to the requirements as to tensile properties specified in sec. 5, except

that the elongation shall be measured on a gage length not less than four times the diameter of the rivet.

17. **Bend Tests.** The rivet shank shall bend cold through 180 degrees flat on itself, as shown in fig. 1, without cracking on the outside of the bent portion.

18. **Flattening Tests.** The rivet head shall flatten, while hot, to a diameter 2½ times the diameter of the shank, as shown in fig. 2, without cracking at the edges.

FIGURE 1.

FIGURE 2.

19. **Number of Tests.** (*a*) When specified, one tension test shall be made from each size in each lot of rivets offered for inspection.

(*b*) Three bend-and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

II. WORKMANSHIP AND FINISH

20. **Workmanship.** The rivets shall be true to form, concentric, and shall be made in a workmanlike manner.

21. **Finish.** The finished rivets shall be free from injurious defects.

III. INSPECTION AND REJECTION

22. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the rivets ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the rivets are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

23. **Rejection.** Rivets which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

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STANDARD SPECIFICATIONS

FOR

CARBON STEEL AND ALLOY STEEL FORGINGS

SERIAL DESIGNATION: A18-16.

The specifications for this material are issued under the fixed designation A 18; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1901; REVISED, 1905, 1914, 1916.

1. **Classes.** (*a*) These specifications cover the various classes of carbon-steel and alloy-steel forgings now commonly used and not covered by other existing specifications of the American Society for Testing Materials.

(*b*) The purposes for which these classes are frequently used are as follows:

Class A, for forgings which may be welded or case-hardened;

Class B, for mild-steel forgings for structural purposes, for minor ship fittings, etc.;

Class C, for mild-steel forgings for structural purposes, for ships, etc.;

Classes D, E, F, G, H and I, for various machinery forgings, choice depending upon design and upon the stresses and services to be imposed.

Classes K, L and M for various machinery forgings, choice depending upon design and upon the stresses and services to be imposed, and upon the character of machining operations to be done.

I. MANUFACTURE

2. **Process.** The steel may be made by the open-hearth or any other process approved by the purchaser.

3. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

4. **Prolongations for Tests.** The manufacturer and the purchaser shall agree upon forgings on which a prolongation for test purposes shall be provided.

5. **Boring.** If boring is specified, the diameter of the hole shall be at least 20 per cent of the maximum outside diameter or thickness of the forging, exclusive of collars and flanges.

6. **Heat Treatment.** Heat treatment, if required, shall consist of either annealing or quenching-and-tempering, as specified.

(*a*) For annealing, the forgings shall be allowed to become cold after forging. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformly.

(*b*) For quenching-and-tempering, the forgings shall be allowed to become cold after forging. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly.

II. CHEMICAL PROPERTIES AND TESTS

7. **Chemical Composition.** (*a*) The steel shall conform to the following requirements as to chemical composition:

Elements Considered	Class A, Per Cent	Classes B,C,D,E,F,G, Per Cent	Classes H, I, Per Cent	Classes K, L, Per Cent	Class M, Per Cent
Manganese	0.30–0.55	0.40–0.80	0.40–0.80	.....	.....
Phosphorus:					
Acid	Not over 0.05	Not over 0.05	Not over 0.04	Not over 0.05	Not over 0.04
Basic	" " 0.05	" " 0.05	" " 0.04	" " 0.04	" " 0.04
Sulphur	" " 0.05	" " 0.05	" " 0.05	" " 0.05	" " 0.05
Nickel	.....	.....	Not under 3.00	.....	.....

(*b*) The composition of alloy steel, other than phosphorus and sulphur, to be used in forgings of classes K, L and M, shall be agreed upon by the manufacturer and purchaser.*

8. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese and the elements specified in sec. 7. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in sec. 7.

9. **Check Analyses.** An analysis may be made by the purchaser from a forging representing each melt. The chemical composition thus determined shall conform to the requirements specified in sec. 7. Drillings for analysis may be taken from the forging or from a full-size prolongation of the same, at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings; or turnings may be taken from a test specimen.

III. PHYSICAL PROPERTIES AND TESTS

10. **Tension Tests.** (*a*) The forgings shall conform to the requirements as to tensile properties specified in Tables I, II and III.

(*b*) The classification by size of the forging shall be determined by the specified diameter or thickness which governs the size of the prolongation from which the test specimen is taken.

(*c*) The yield point shall be determined by the drop of the beam of the testing machine.

*The question of chemical composition of the several types of alloy steels is not yet sufficiently standardized to warrant the inclusion of formal requirements covering chemical composition of such alloy steels in standard specifications.

The following compositions are quoted as being as nearly typical as any now regularly manufactured:

Elements Considered	Chrome-Vanadium Steel		Chrome-Nickel Steel		Chromium Steel
	Classes K, L, Per Cent	Class M, Per Cent	Classes K, L, Per Cent	Class M, Per Cent	Classes K, L, Per Cent
Carbon	0.28–0.42	0.35–0.50	0.28–0.42	0.35–0.50	0.28–0.42
Manganese	0.40–0.70	0.50–0.90	0.40–0.70	0.50–0.90	0.40–0.70
Chromium	0.75–1.25	0.75–1.25	Not under 0.70	Not under 0.70	0.60–0.90
Vanadium	Not under 0.15	Not under 0.15			
Nickel			Not under 1.25	Not under 2.75	

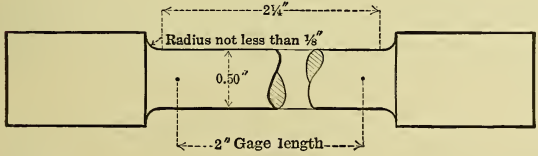
(*d*) The elastic limit called for by these specifications shall be determined by an extensometer reading to 0.0002 inch. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer shall then be removed from the specimen, and the test continued to determine the tensile strength.

(*e*) Tests of forgings shall be made only after final treatment.

11. **Tension-Test Specimens.** (*a*) Tension-test specimens shall be taken from a full-size prolongation of any forging. For forgings with large ends or collars, the prolongation may be of the same cross-section as that of the forging back of the large end or collar. Specimens may be taken from the forging itself with a hollow drill, if approved by the purchaser.

(*b*) The axis of the specimen shall be located at any point midway between the center and surface of solid forgings, and at any point midway between the inner and outer surfaces of the wall of bored forgings, and shall be parallel to the axis of the forging in the direction in which the metal is most drawn out.

(*c*) Test specimens shall conform to dimensions shown in fig. 1. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.



NOTE:—The gage length, parallel portions and fillets shall be as shown, but the ends may be of any form which will fit the holders of the testing machine.

FIGURE 1.

12. **Number of Tests.** Unless otherwise specified by the purchaser, tests shall be made as follows:

(*a*) For untreated forgings, one tension test shall be made from each melt.

(*b*) For annealed forgings, one tension test shall be made from each annealing charge. If more than one melt is represented in an annealing charge, one tension test shall be made from each melt.

(*c*) For quenched-and-tempered forgings, one tension test shall be made from each tempering charge. If more than one quenching charge is represented in a tempering charge, one tension test shall be made from each quenching charge. If more than one melt is represented in a quenching charge, one tension test shall be made from each melt.

(*d*) If more than one class of forgings by size is represented in any lot, one tension test from a forging of each class by size shall be made as specified in sec. 10 and 11.

(*e*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*f*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 10 (*a*) and any part of the fracture is more than ¾ inch from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

13. **Retests.** (*a*) If the results of the physical tests of any test lot of forgings in Classes A to I, inclusive, do not conform to the requirements specified, the manufacturer may re-treat such lot, one or more times, and retests shall be made as specified in sec. 12.

(*b*) If the results of the physical tests of any test lot of forgings in Classes K, L or M do not conform to the requirements specified, the manufacturer may retemper or requench and temper such lot, but no more than three additional times unless authorized by the purchaser, and retests shall be made as specified in sec. 12.

IV. WORKMANSHIP AND FINISH

14. **Workmanship.** The forgings shall conform to the sizes and shapes specified by the purchaser. When centered, 60-degree centers with clearance drilled for points shall be used.

15. **Finish.** The forgings shall be free from injurious defects and shall have a workmanlike finish.

V. MARKING

16. **Marking.** Identification marks shall be legibly stamped on each forging and on each test specimen. The purchaser shall indicate the location of such identification marks.

VI. INSPECTION AND REJECTION

17. **Inspection.** (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the forgings ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the forgings are being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of the forgings in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

18. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 17 (*b*) shall be reported within five working days from the receipt of samples.

(*b*) Forgings which show injurious defects while being finished by the purchaser will be rejected, and the manufacturer shall be notified.

19. **Rehearing.** Samples tested in accordance with sec. 17 (*b*), which represent rejected forgings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TABLE I.—TENSILE PROPERTIES (CLASSES A TO F, INCLUSIVE)

CLASS	SIZE Outside Diameter or Over-all Thickness	Tensile Strength, min. (except Class A), Pounds per Sq. Inch	Yield Point, min., Pounds per Sq. Inch	Elongation in 2 Inches, min., Per Cent		Reduction of Area, min., Per Cent	
				Inverse Ratio	Not under	Inverse Ratio	Not under
FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 20 INCHES							
A UNTREATED	All sizes.....	47,000 to 60,000	0.5 tens. str.	1,500,000 tens. str.	..	2,500,000 tens. str.	..
B UNTREATED	Not over 12 inches	60,000	0.5 tens. str.	1,550,000 tens. str.	22	2,400,000 tens. str.	35
	Over 12 to 20 inches, inclusive	60,000	0.5 tens. str.	1,480,000 tens. str.	21	2,220,000 tens. str.	32
C ANNEALED	Not over 12 inches	60,000	0.5 tens. str.	1,700,000 tens. str.	25	2,700,000 tens. str.	38
	Over 12 to 20 inches, inclusive	60,000	0.5 tens. str.	1,600,000 tens. str.	24	2,520,000 tens. str.	36
D UNTREATED	Not over 8 inches	75,000	0.5 tens. str.	1,600,000 tens. str.	18	2,200,000 tens. str.	24
	Over 8 to 12 inches, inclusive	75,000	0.5 tens. str.	1,500,000 tens. str.	17	2,000,000 tens. str.	22
	Over 12 to 20 inches,	75,000	0.5 tens. str.	1,400,000 tens. str.	16	1,800,000 tens. str.	20
E ANNEALED	Not over 8 inches	75,000	0.5 tens. str.	1,800,000 tens. str.	20	2,800,000 tens. str.	33
	Over 8 to 12 inches, inclusive	75,000	0.5 tens. str.	1,725,000 tens. str.	19	2,640,000 tens. str.	31
	Over 12 to 20 inches, inclusive	75,000	0.5 tens. str.	1,650,000 tens. str.	18	2,460,000 tens. str.	29
F ANNEALED	Not over 8 inches	80,000	0.5 tens. str.	1,800,000 tens. str.	20	2,800,000 tens. str.	32
	Over 8 to 12 inches, inclusive	80,000	0.5 tens. str.	1,725,000 tens. str.	19	2,640,000 tens. str.	30
	Over 12 to 20 inches, inclusive	80,000	0.5 tens. str.	1,650,000 tens. str.	18	2,400,000 tens. str.	28

TABLE II.—TENSILE PROPERTIES (CLASSES G, H AND I)

CLASS	SIZE	Tensile Strength, Min., Pounds per Sq. Inch	Elastic Limit Min., Pounds per Sq. Inch	Elongation in 2 Inches, Min. Per Cent		Reduction of Area, Min., Per Cent	
				Inverse Ratio	Not under	Inverse Ratio	Not under
FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 INCHES WHEN SOLID, AND NOT OVER 20 INCHES WHEN BORED							
G QUENCHED AND TEMPERED	Up to 4 inches outside diameter or thickness, 2-inch max. wall	90,000	55,000	2,100,000 / tens. str.	20.5	4,000,000 / tens. str.	39
	Over 4 to 7 inches outside diameter or thickness, 3½-inch max. wall	85,000	50,000	2,000,000 / tens. str.	20.5	3,800,000 / tens. str.	39
	Over 7 to 10 inches outside diameter or thickness, 5-inch max. wall	85,000	50,000	1,900,000 / tens. str.	19.5	3,600,000 / tens. str.	37
	Outside diameter or thickness not over 20 ins., 5 to 8-inch wall	82,500	48,000	1,800,000 / tens. str.	19	3,400,000 / tens. str.	36
FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 20 INCHES							
H NICKEL STEEL, ANNEALED	Outside diameter or over-all thickness not over 12 inches	80,000	50,000	2,000,000 / tens. str.	22	3,600,000 / tens. str.	40
	Outside diameter or over-all thickness over 12 to 20 inches, inclusive.	80,000	50,000	1,900,000 / tens. str.	21	3,400,000 / tens. str.	38
FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 INCHES WHEN SOLID, AND NOT OVER 20 INCHES WHEN BORED							
I NICKEL STEEL, QUENCHED AND TEMPERED	Up to 4 inches outside diameter or thickness, 2-inch max. wall.	100,000	70,000	2,200,000 / tens. str.	20	4,500,000 / tens. str.	41
	Over 4 to 7 inches outside diameter or thickness, 3½-inch max. wall	100,000	65,000	2,100,000 / tens. str.	20	4,300,000 / tens. str.	41
	Over 7 to 10 inches outside diameter or thickness 5-inch max. wall	90,000	60,000	2,000,000 / tens. str.	20	4,100,000 / tens. str.	41
	Outside diameter or thickness not over 20 ins., 5 to 8-inch wall	85,000	55,000	1,900,000 / tens. str.	20	3,900,000 / tens. str.	41

TABLE III.—TENSILE PROPERTIES (CLASSES K, L AND M)

Class	Size	Tensile Strength, Pounds per Sq. Inch	Elastic Limit, Minimum, Pounds per Sq. Inch	Elongation in 2 inches, Minimum, Per Cent	Reduction of Area, Minimum, Per Cent
FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR THICKNESS IS NOT OVER 10 INCHES WHEN SOLID, AND NOT OVER 20 INCHES WHEN BORED					
K ALLOY STEEL, QUENCHED AND TEMPERED	Up to 2 inches outside diameter or thickness, 1-inch max. wall	95,000–115 000	70,000	20	50
	Over 2 to 4 inches outside diameter or thickness, 2-inch max. wall	90,000–110,000	65,000	20	50
	Over 4 to 7 inches outside diameter or thickness, 3½-inch max. wall	90,000–110,000	65,000	20	50
	Over 7 to 10 inches outside diameter or thickness, 5-inch max. wall	90,000–110,000	65,000	20	50
	Outside diameter or thickness not over 20 inches, 5 to 8-inch wall	85,000–105,000	60,000	20	50
L ALLOY STEEL, QUENCHED AND TEMPERED	Up to 2 inches outside diameter or thickness, 1-inch max. wall	105,000–125,000	80,000	20	50
	Over 2 to 4 inches outside diameter or thickness, 2-inch max. wall	100,000–120,000	75,000	20	50
	Over 4 to 7 inches outside diameter or thickness, 3½-inch max. wall	100,000–120,000	75,000	20	50
	Over 7 to 10 inches outside diameter or thickness, 5-inch max. wall	100,000–120,000	75,000	18	45
	Outside diameter or thickness not over 20 inches, 5 to 8-inch wall	95,000–115,000	70,000	18	45
M ALLOY STEEL, QUENCHED AND TEMPERED	Up to 2 inches outside diameter or thickness, 1-inch max. wall	125,000	105,000	16	50
	Over 2 to 4 inches outside diameter or thickness, 2-inch max. wall	115,000	95,000	16	45
	Over 4 to 7 inches outside diameter or thickness, 3½-inch max. wall	110,000	85,000	16	45
	Over 7 to 10 inches outside diameter or thickness, 5-inch max. wall	100,000	75,000	18	45
	Outside diameter or thickness not over 20 inches, 5 to 8-inch wall	100,000	70,000	18	45

AMERICAN SOCIETY FOR TESTING MATERIALS

PHILADELPHIA, PA., U. S. A.

AFFILIATED WITH THE

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS

STANDARD SPECIFICATIONS

FOR

BILLET STEEL CONCRETE REINFORCEMENT BARS

SERIAL DESIGNATION: A15-14.

The specifications for this material are issued under the fixed designation A 15; the final number indicates the year of original issue or, in the case of revision, the year of last revision.

ADOPTED, 1911; REVISED, 1912, 1913, 1914.

1. **Classes.** (*a*) These specifications cover three classes of billet steel concrete reinforcement bars, namely: plain, deformed and cold-twisted.

(*b*) Plain and deformed bars are of three grades, namely: structural steel, intermediate and hard.

2. **Basis of Purchase.** (*a*) The structural steel grade shall be used unless otherwise specified.

(*b*) If desired, cold-twisted bars may be purchased on the basis of tests of the hot-rolled bars before twisting, in which case such tests shall govern and shall conform to the requirements specified for plain bars of structural steel grade.

I. MANUFACTURE

3. **Process.** (*a*) The steel may be made by the bessemer-or the open-hearth process..

(*b*) The bars shall be rolled from new billets. No rerolled material will be accepted.

4. **Cold-twisted Bars.** Cold-twisted bars shall be twisted cold with one complete twist in a length not over 12 times the thickness of the bar.

II. CHEMICAL PROPERTIES AND TESTS

5. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Phosphorus { Bessemer..... not over 0.10 per cent
Open-hearth..... " " 0.05 " "

6. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulphur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in sec. 5.

7. **Check Analyses.** Analyses may be made by the purchaser from finished bars representing each melt of open-hearth steel, and each melt, or lot of ten tons, of bessemer steel. The phosphorus content thus determined shall not exceed that specified in sec. 5 by more than 25 per cent.

III. PHYSICAL PROPERTIES AND TESTS

8. **Tension Tests.** (*a*) The bars shall conform to the following requirements as to tensile properties:

TENSILE PROPERTIES

Properties Considered	Plain Bars			Deformed Bars			Cold-twisted Bars
	Structural-Steel Grade	Intermediate Grade	Hard Grade	Structural-Steel Grade	Intermediate Grade	Hard Grade	
Tensile strength, lb. per sq. inch	55,000 to 70,000	70,000 to 85,000	80,000 min.	55,000 to 70,000	70,000 to 85,000	80,000 min.	Recorded only
Yield point, min., lb. per sq. inch	33,000	40,000	50,000	33,000	40,000	50,000	55,000
Elongation in 8 inches, min., per cent	1,400,000*a* tens. str.	1,300,000*a* tens. str.	1,200,000*a* tens. str.	1,250,000*a* tens. str.	1,125,000*a* tens. str.	1,000,000*a* tens. str.	5

a See sec. 9.

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

9. **Modifications in Elongation.** (*a*) For plain and deformed bars over ¾ inch in thickness or diameter, a deduction of 1 from the percentages of elongation specified in sec. 8 (*a*) shall be made for each increase of ⅛ inch in thickness or diameter above ¾ inch.

(*b*) For plain and deformed bars under 7/16 inch in thickness or diameter, a deduction of 1 from the percentages of elongation specified in sec. 8 (*a*) shall be made for each decrease of 1/16 inch in thickness or diameter below 7/16 inch.

10. **Bend Tests.** The test specimen shall bend cold around a pin without cracking on the outside of the bent portion, as follows:

BEND TEST REQUIREMENTS

Thickness or Diameter of Bar	Plain Bars			Deformed Bars			Cold-twisted Bars
	Structural-Steel Grade	Intermediate Grade	Hard Grade	Structural-Steel Grade	Intermediate Grade	Hard Grade	
Under ¾ inch	180 deg. d=t	180 deg. d=2t	180 deg. d=3t	180 deg. d=t	180 deg. d=3t	180 deg. d=4t	180 deg. d=2t.
¾ inch or over....	180 deg. d=t	90 deg. d=2t	90 deg. d=3t	180 deg. d=2t	90 deg. d=3t	90 deg. d=4t	180 deg. d=3t

EXPLANATORY NOTE: d = the diameter of pin about which the specimen is bent; t = the thickness or diameter of the specimen.

11. **Test Specimens.** (*a*) Tension-and bend-test specimens for plain and deformed bars shall be taken from the finished bars, and shall be of the full thickness or diameter of bars as rolled; except that the specimens for deformed bars may be machined for a length of at least 9 inches, if deemed necessary by the manufacturer to obtain uniform cross-section.

(*b*) Tension-and bend-test specimens for cold-twisted bars shall be taken from the finished bars, without further treatment; except as specified in sec. 2 (*b*).

12. **Number of Tests.** (*a*) One tension-and one bend test shall be made from each melt of open-hearth steel, and from each melt, or lot of ten tons, of bessemer steel; except that if material from one melt differs ⅜ inch or more in thickness or diameter, one tension-and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension-test specimen is less than that specified in sec. 8 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT

13. **Permissible Variations.** The weight of any lot of bars shall not vary more than 5 per cent from the theoretical weight of that lot.

V. FINISH

14. **Finish.** The finished bars shall be free from injurious defects and shall have a workmanlike finish.

VI. INSPECTION AND REJECTION

15. **Inspection.** The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the bars ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the bars are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

16. **Rejection.** (*a*) Unless otherwise specified, any rejection based on tests made in accordance with sec. 7 shall be reported within five working days from the receipt of samples.

(*b*) Bars which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

17. **Rehearing.** Samples tested in accordance with sec. 7, which represent rejected bars, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

CARNEGIE STEEL COMPANY

CARNEGIE STEEL COMPANY

STANDARD SPECIFICATIONS

FORGED AND ROLLED CARBON STEEL WHEELS

FOR

MINE AND INDUSTRIAL LOCOMOTIVES

JANUARY 1, 1917

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

2. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Carbon	0.65 to 0.85 per cent
Manganese	0.55 to 0.80 " "
Phosphorus	not to exceed 0.05 " "
Sulphur	not to exceed 0.05 " "
Silicon	0.10 to 0.30 " "

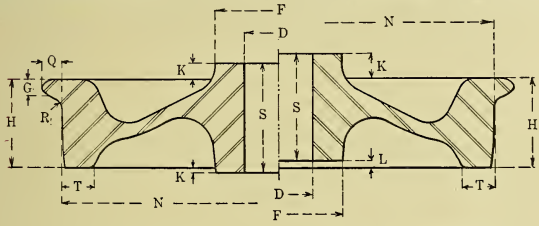
4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 3. This analysis shall be made from a test ingot taken during the pouring of each melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements in sec. 3.

III. MATING

5. **Mating.** The wheels shall be mated as to tape sizes and shipped in pairs.

IV. WORKMANSHIP AND PERMISSIBLE VARIATIONS IN DIMENSIONS

6. **Workmanship and Permissible Variations.** Wheels shall be furnished with contour of tread and flange machined and shall conform to the dimensions specified within the following permissible variations:



	Maximum	Minimum
Q—Height of Flange	Q + 1/32″	Q—1/32″
G—Width of Flange	G + 1/16″	G—1/16″
R—Throat Radius	R + 1/16″	R—1/16″
H—Width of Rim	.....	H—1/8″
T—Thickness of Rim	.....	T—3/16″
D—Diameter of Rough Bore*	D + 1/16″	D—1/8″
E—Eccentricity of Bore to Tread	E=3/64″	
F—Hub Diameter—The diameter of hub may vary, but the thickness of wall of the finished bored hub shall not be less than 1 inch at any point for bores up to 6 inches, inclusive, 1 1/4 inches for bores over 6 inches to 7 inches, inclusive, and 1 3/8 inches for bores over 7 inches.		
S—Hub Length	S + 1/8″	S—1/8″
L—Depression of Hub†	L + 1/8″	L—1/8″
K—Projection of Hub†	K + 1/8″	K—1/8″
C—Circumference of Wheels	C + 5 tapes	C—5 tapes

Measured by Carnegie Steel Company's Standard Tape.

*Unless otherwise specified, the diameter of rough bore shall be 1/4 inch less than that of the finished bore within these tolerances.

†Where either face of hub is to be used for bearing purposes, dimensions K or L will be furnished + 1/4 inch maximum or — 0 minimum.

7. **Black Spots in Hub.** Black spots in rough bore within 2 inches of either face of the hub shall not exceed 1/16 inch in depth.

8. **Tape.** All wheels shall be measured with the Carnegie Steel Company's tape, based on an M. C. B. tape, graduated in eighths of an inch with zero at seven feet.

V. FINISH

9. **Finish.** (*a*) The wheels shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Wheels shall not be offered for inspection if covered with paint, rust or any other substance to such an extent as to hide defects.

VI. MARKING

10. **Marking.** (*a*) The name or brand of the manufacturer and serial number shall be legibly stamped on each wheel in such a way that the wheel may be readily identified.

(*b*) The tape size shall be legibly marked on each wheel.

VII. INSPECTION

11. **Inspection.** The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. Tests and inspection shall be made at the place of manufacture prior to shipment.

12. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

CARNEGIE STEEL COMPANY

STANDARD SPECIFICATIONS

FORGED AND ROLLED CARBON STEEL WHEELS

FOR

INDUSTRIAL PURPOSES

JANUARY 1, 1917

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

2. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS

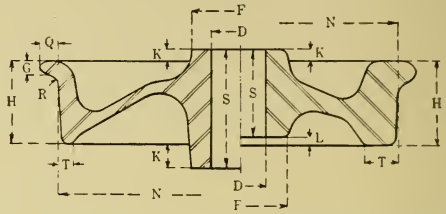
3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Carbon	0.65 to 0.85 per cent
Manganese	0.55 to 0.80 " "
Phosphorus	not to exceed 0.05 " "
Sulphur	not to exceed 0.05 " "
Silicon	0.10 to 0.30 " "

4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 3. This analysis shall be made from a test ingot taken during the pouring of each melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements in sec. 3.

III. WORKMANSHIP AND PERMISSIBLE VARIATIONS IN DIMENSIONS

5. **Workmanship and Permissible Variations.** The wheels may be furnished with contours as rolled, and shall conform to the dimensions specified within the following tolerances:



	Maximum	Minimum
Q—Height of Flange	Q+3/32″	Q—3/32″
G—Width of Flange	G+3/32″	G—3/32″
H—Width of Rim	.....	H—3/16″
T—Thickness of Rim	.....	T—3/16″
D—Diameter of Rough Bore*	D+1/16″	D—1/8″
E—Eccentricity of Bore to Tread	E=3/64″	
F—Hub Diameter—The diameter of hub may vary, but the thickness of wall of the finished bored hub shall not be less than 1 inch at any point for bores up to 6 inches, inclusive, 1 1/4 inches for bores over 6 inches to 7 inches, inclusive, and 1 3/4 inches for bores over 7 inches.		
S—Hub Length	S +3/16″	S —3/16″
L—Depression of Hub	L+3/16″	L—3/16″
K—Projection of Hub	K+3/16″	K—3/16″
C—Circumference of Wheels	C+9 tapes	C—6 tapes

Measured by Carnegie Steel Company's Standard Tape.

*Unless otherwise specified, the diameter of rough bore shall be 1/4 inch less than that of the finished bore within these tolerances.

IV. FINISH

6. **Finish.** (*a*) The wheels shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Wheels shall not be offered for inspection if covered with paint, rust or any other substance, to such an extent as to hide defects.

V. MARKING

7. **Marking.** The name and brand of the manufacturer and

serial number shall be legibly stamped on each wheel in such a way that the wheel may be readily identified.

VI. INSPECTION

8. **Inspection.** The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. Tests and inspection shall be made at the place of manufacture prior to shipment.

9. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works

CARNEGIE STEEL COMPANY

STANDARD SPECIFICATIONS

FORGED AND ROLLED CARBON STEEL BLANKS

FOR

CRANE TRACK WHEELS

JANUARY 1, 1917

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

2. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS

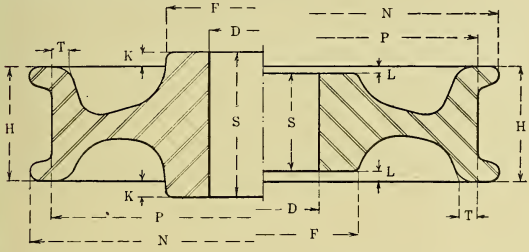
3. **Chemical Composition.** The steel shall conform to the following limits in chemical composition:

Carbon	0.65 to 0.85 per cent
Manganese	0.55 to 0.80 " "
Phosphorus	not to exceed 0.05 " "
Sulphur	" " " 0.05 " "
Silicon	0.10 to 0.30 " "

4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 3. This analysis shall be made from a test ingot taken during the pouring of each melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements in sec. 3.

III. WORKMANSHIP AND PERMISSIBLE VARIATIONS IN DIMENSIONS

5. **Workmanhip and Permissible Variations.** Double flange crane track wheel blanks shall be ordered either to drawing showing complete finished dimensions, including contour of tread and flanges, or to drawing showing finished dimensions, except for contour of tread and flanges, and shall be furnished rough-turned to finished rim and hub dimensions shown on drawing within the following tolerances:



	Maximum	Minimum
H—Width of Rim	H+¼″	H— 0′
T—Thickness of Rim	.....	T—⅛″
D—Diameter of Rough Bore*	D+1/16″	D—⅛″
E—Eccentricity of Bore to Tread	E=3/64″	
F—Diameter of Hub—The diameter of hub may vary, but the thickness of wall of the finished bored hub shall not be less than 1 inch at any point for bores up to 6 inches, inclusive, 1⅛ inches for bores over 6 inches to 7 inches, inclusive, and 1⅜ inches for bores over 7 inches.		
S—Hub Length	S+¼″	S— 0″
K—Projection of Hub	K+⅛″	K— 0″
L—Depression of Hub	L+⅛″	L— 0″
P—Diameter of Tread	P+⅜″	P+⅛″
N—Outside Diameter	N+⅜″	N+⅛″

*Unless otherwise specified, the diameter of rough bore shall be ¼ inch less than that of the finished bore within these tolerances.

IV. FINISH

6. **Finish.** (*a*) The wheel blanks shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Wheel blanks shall not be offered for inspection if covered with paint, rust or any other substance to such an extent as to hide defects.

V. MARKING

7. **Marking.** Where practicable, the name or brand of the manufacturer and serial number shall be legibly stamped on each wheel blank in such a way that the wheel blank may be readily identified.

VI. INSPECTION

8. **Inspection.** The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheel blanks ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the crane track wheel blanks are being furnished in accordance with these specifications. Tests and inspection shall be made at the place of manufacture prior to shipment.

9. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

CARNEGIE STEEL COMPANY

STANDARD SPECIFICATIONS

FORGED AND ROLLED CARBON STEEL BLANKS

FOR

SPUR GEARS

JANUARY 1, 1917

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

2. **Discard.** A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

II. CHEMICAL PROPERTIES AND TESTS

3. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

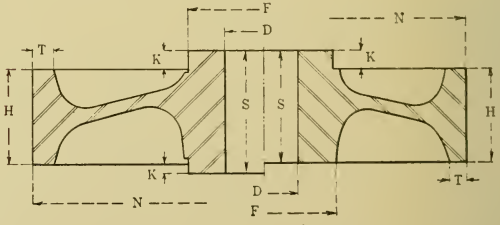
Elements	Soft Grade for Case Hardened Gears	Medium Grade for Untreated Gears When Ease of Machining is Desired	Hard Grade for Untreated or Quench-Hardened Gears
	Per Cent	Per Cent	Per Cent
Carbon	0.10 to 0.25	0.35 to 0.50	0.55 to 0.65
Manganese	0.40 to 0.60	0.40 to 0.60	0.60 to 0.90
Phosphorus.....not to exceed	0.05	0.05	0.05
Sulphur.....not to exceed	0.05	0.05	0.05

4. **Ladle Analyses.** An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in sec. 3. This analysis shall be made from a test ingot taken during the pouring of each melt. The chemical composition thus determined, together with such identifying records as may be desired, shall be reported to the purchaser or his representative, and shall conform to the requirements in sec. 3.

A check analysis may be made by the purchaser from one gear blank representing each melt, and this analysis shall conform to the requirements specified in sec. 3, with the exception that the carbon must not be more than 0.02 per cent below nor more than 0.03 per cent above the requirements shown in sec. 3. A sample may be taken from any one point in the plate; or two samples may be taken, in which case they shall be on radii at right angles to each other. Samples shall not be taken in such a way as to impair the usefulness of the gear blank. Drillings for analysis shall be taken by boring entirely through the sample parallel to the axis of the gear blank; they shall be clean and free from scale, oil and other foreign substances. All drillings from any one gear blank shall be thoroughly mixed together.

III. WORKMANSHIP AND PERMISSIBLE VARIATIONS IN DIMENSIONS

5. **Workmanship and Permissible Variations.** Gear blanks shall be ordered to drawing showing the finished dimensions, and shall be furnished rough-turned to finished rim and hub dimensions shown on drawing within the following tolerances:



	Maximum	Minimum
H—Width of Face	H + 1/4″	H + 1/8″
T—Thickness of Rim	T + 3/16″	T + 1/16″
D—Diameter of Rough Bore*	D + 1/16″	D — 1/8″
E—Eccentricity of Bore to Tread	E = 3/64″	
F—Diameter of Hub	F + 1/4″	F + 1/8″
S—Length of Hub	S + 3/8″	S + 1/8″
K—Projection of Hub	K + 3/16″	K + 1/16″
N—Outside Diameter	N + 1/4″	N + 1/8″

*Unless otherwise specified, the diameter of rough bore shall be 1/4 inch less than that of the finished bore within these tolerances.

IV. FINISH

6. **Finish.** (*a*) The gear blanks shall be free from injurious defects and shall have a workmanlike finish.

(*b*) Gear blanks shall not be offered for inspection if covered with paint, rust, or any other substance to such an extent as to hide defects.

V. MARKING

7. **Marking.** The name or brand of the manufacturer and serial number shall be legibly stamped on each gear blank in such a way that the blank may be readily identified; all marks shall be placed on the web.

VI. INSPECTION

8. **Inspection.** The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the gear blanks ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the gear blanks are being furnished in accordance with these specifications. Tests and inspection shall be made at the place of manufacture prior to shipment.

9. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

MASTER CAR BUILDERS' ASSOCIATION

MASTER CAR BUILDERS' ASSOCIATION

STANDARD SPECIFICATIONS

FOR

STEEL AXLES

1916

I. MANUFACTURE

1. **Process.** The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS

2. **Chemical Composition.** The steel shall conform to the following requirements as to chemical composition:

Carbon	0.38–0.52 per cent
Manganese	0.40–0.60 " "
Phosphorus	not over 0.05 " "
Sulphur	" " 0.05 " "

3. **Ladle Analyses.** An analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt, to determine the percentage of carbon, manganese, phosphorus, sulphur, and silicon. Drillings for analysis shall be taken not less than ¼ inch beneath the surface of the test ingot. A copy of this analysis shall be given the purchaser or his representative. This analysis shall conform to the requirements specified in sec. 2.

4. **Check Analyses.** A check analysis shall be made from the finished material representing each melt, by the purchaser or his representative, and shall meet the requirements specified in sec. 2.

III. PHYSICAL PROPERTIES AND TESTS

5. **Drop Tests.** The axles shall conform to the following drop-test requirements:

(*a*) The test axle shall be so placed on the supports, three feet apart, that the tup will strike it midway between the ends. It shall be turned over after the first and third blows. When tested in accordance with the following conditions, the axle shall stand the specified number of blows without fracture, and the deflection after the first blow shall not exceed that specified in the following table:

Size of Axle, Inches		Weight of Tup, 2240 Pounds Supports 3 Feet Apart		
Journal	Diameter at Center	Height of Drop	Number of Blows	Maximum Permanent Set After First Blow
4¼ x 8	4 3/4	22½ Feet	5	7½ Inches
5 x 9	5 3/8	29 "	5	6½ "
5½ x 10	5 7/8	34½ "	5	5½ "
6 x 11	6 7/16	41½ "	5	*4½ "

(*b*) Formulas: (1) The above heights of drop were derived from the following formula:

$H = d^2$, where

H=height of drop, in feet

d=diameter of axle in center, in inches

(2) The above values for maximum permanent set after first blow were derived from the following formula:

Maximum permanent set in inches $= \left(\frac{L}{1.9d} - \frac{d}{2}\right) + \frac{3}{4}$, where

L=length of axle in inches

(*c*) The deflection is the difference between the distance from a straight edge to the middle point of the axle, measured before the first blow, and the distance measured in the same manner after the blow. The straight-edge shall rest only on the collars or the ends of the axle.

*The value derived from the above formula for permanent set was 5 inches for the 6 x 11 axle, but the allowable permanent set was dropped to 4½ inches, as more nearly representing what would be obtained in practice.

6. **Drop-Test Machine.** The anvil of the drop-test machine shall be supported on 12 springs, as shown on the M. C. B. drawings, and shall be free to move in a vertical direction, and shall weigh 17,500 pounds. The radii of the striking face of the tup and of the supports shall be 5 inches.

7. **Number of Tests.** (*a*) One drop-test shall be made from each melt. Unless otherwise specified, not less than 30 axles shall be offered from any one melt.

(*b*) If the test axle passes the physical tests, the inspector shall draw a straight line 10 inches long, parallel with the axis of the axle, and starting with one end of it he shall prick-punch this line at several points. A piece, 6 inches long, shall be cut off from this same axle so as to leave some prick-punch marks on each piece of axle. Drillings for chemical analysis shall be taken by using a $\frac{5}{8}$-inch drill and drilling in the cut-off end 50 per cent of the distance from the center to the circumference and parallel with the axis of the axle.

IV. WORKMANSHIP AND FINISH

8. **Workmanship.** All axles shall be made and finished in a workmanlike manner and all journals and wheel seats shall be rough-turned. In centering, unless otherwise specified, 60-degree centers shall be used with large diameter of countersink not less than $\frac{7}{8}$ inch and with clearance drilled $\frac{1}{2}$ inch deep.

9. **Finish.** The axles shall be free from injurious defects and shall have a workmanlike finish.

V. PERMISSIBLE VARIATIONS AND WEIGHTS

10. **Permissible Variations.** The axle shall conform in size and shape to the standard M. C. B. drawings. Length shall not be less than shown and not more than $\frac{3}{32}$ inch over.

VI. MARKING AND STORING

11. **Marking.** The manufacturer's name or brand, melt number and month and year when made shall be legibly stamped on each axle on the unfinished portion, unless otherwise specified.

12. **Storing.** If, as a result of the inspection and tests, more axles are accepted than the order calls for, such accepted axles in

excess shall be stamped by the inspector with his own name, and will then be piled and allowed to remain in stock at the works, subject to further orders from the purchasing agent. On receipt of further orders, axles once accepted will not be subject to further test. In all cases the inspector will keep an accurate record of the melt numbers and the number of axles in each melt which are stored and will transmit this information with each report.

VII. INSPECTION AND REJECTION

13. **Inspection.** (*a*) The inspector shall examine each axle in each melt for workmanship, defects, and to see whether the axles conform to the dimensions given on the order or tracing, or whether they conform to the specifications. All axles not satisfactory in these respects shall not be considered further. If in this inspection defects are found which the manufacturer can remedy while the inspector is at the works, he may be allowed to correct such defects.

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*d*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

14. **Rejection.** Material which, subsequently to above tests at the mills or elsewhere, and its acceptance develops any imperfections, shall be rejected and shall be replaced by the manufacturer at his own expense.

15. **Rehearing.** Samples tested in accordance with this specification, which represent rejected material, shall be preserved for 14 days from date of test report. In case of dissatisfaction with results of the tests, the manufacturer may make claim for a rehearing within that time.

AMERICAN RAILWAY ENGINEERING ASSOCIATION

AMERICAN RAILWAY ENGINEERING ASSOCIATION

GENERAL SPECIFICATIONS

FOR

STEEL RAILWAY BRIDGES

1910

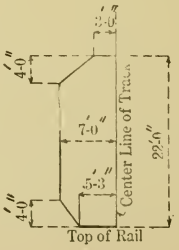
Reprinted from Seventh Edition

PART FIRST—DESIGN

I. GENERAL

1. **Materials.** The material in the superstructure shall be structural steel, except as otherwise specified.

2. **Clearances.** If the alignment is straight, clearances shall be not less than shown on the diagram. If the alignment is curved, the width of the diagram shall be increased so as to provide the same minimum clearances for a car 80 feet long, 14 feet high and 60 feet center to center of trucks, allowance being made for curvature and superelevation of rails. The height of rail shall be assumed as 6 inches.



3. **Spacing Trusses.** The width center to center of girders and trusses shall not be less than 1/20 of the effective span, and not less than is necessary to prevent overturning under the assumed lateral loading.

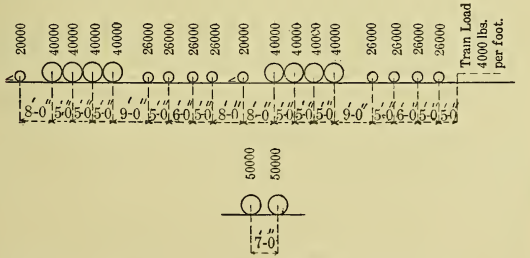
4. **Skew Bridges.** In skew bridges without ballasted floors, the ends of girders and beams supporting the track shall be square with the track at the abutments.

5. **Floors.** Wooden tie floors shall be secured to the stringers and shall be proportioned to carry the maximum wheel load, with 100 per cent impact, distributed over three ties, with fiber stress not to exceed 2000 pounds per square inch. Ties shall be not less than 10 feet in length. They shall be spaced with not more than 6-inch openings; and shall be secured against bunching.

II. LOADS

6. **Dead Load.** The dead load shall consist of the estimated weight of the entire suspended structure. Timber shall be assumed to weigh 4½ pounds per foot, b. m.; ballast, 100 pounds per cubic foot, reinforced concrete, 150 pounds per cubic foot, and rails and fastenings, 150 pounds per linear foot of track.

7. **Live Load.** The live load, for each track, shall consist of two typical engines followed by a uniform load, according to Cooper's series, or a system of loading giving practically equivalent stresses. The minimum loading shall be Cooper's E-40, as shown in the following diagrams:



the diagram that gives the larger stresses shall be used.

8. **Heavier Loading.** Heavier loadings shall be proportional to the above loadings with the same wheel spacing.

9. **Impact.** The dynamic increment of the live load shall be added to the maximum computed live load stresses and shall be determined by the formula $I = S\frac{300}{L+300}$, where

I=impact or dynamic increment to be added to live-load stresses.
S=computed maximum live-load stress.
L=loaded length of track in feet loaded to produce the maximum stress in the member. For bridges carrying more than one track, the aggregate length of all tracks loaded to produce the stress shall be used.

Impact shall not be added to stresses produced by longitudinal, centrifugal and lateral or wind forces.

10. **Lateral Forces.** All spans shall be designed for a lateral force on the loaded chord of 200 pounds per linear foot plus 10 per cent of the specified train load on one track, and 200 pounds per linear foot on the unloaded chord; these forces being considered as moving.

11. **Wind Force.** Viaduct towers shall be designed for that one of the following loads, considered as moving, which gives the greater stress:

(*a*) A force of 50 pounds per square foot applied on one and one-half times the vertical projection of the tower and the portion of the structure which it supports.

(*b*) A force of 30 pounds per square foot, applied on the same surface, plus 400 pounds per linear foot of structure applied 7 feet above the top of the rail, for assumed wind force on train, when the structure is loaded, on either one or both tracks, with empty cars weighing 1200 pounds per linear foot.

12. **Longitudinal Force.** Viaduct towers and similar structures shall be designed for a longitudinal force of 20 per cent of the live load applied at the top of the rail.

13. Structures on curves shall be designed for the centrifugal force of the live load applied at the top of the high rail. The centrifugal force shall be considered as live load and shall be derived from the speed in miles per hour given by the expression $60-2\frac{1}{2}D$, in which D=degree of curve.

III. UNIT STRESSES AND PROPORTION OF PARTS

14. **Unit Stresses.** Structures shall be so proportioned that the sum of the maximum stresses produced by the foregoing loads will not exceed the following amounts in pounds per square inch, except as modified in par. 22 to 25.

15. **Tension.** Axial tension on net section..... 16000

16. **Compression.** Axial compression on gross section of columns 16000—70 l/r with a maximum of..... 14000
where l is the length of the member in inches and
r is the least radius of gyration in inches.
Direct compression on steel castings..... 16000

17. **Bending.** Bending on extreme fibers of rolled shapes, built sections, girders and steel castings; net section..... 16000
Bending on extreme fibers of pins..... 24000

18. **Shearing.** Shearing: Shop driven rivets and pins..... 12000
Field driven rivets and turned bolts..... 10000
Plate girder webs; gross section..... 10000

19. **Bearing.** Bearing: Shop driven rivets and pins..... 24000
Field driven rivets and turned bolts..... 20000
Expansion rollers; per linear inch..... 600 d
where d is the diameter of the roller in inches.
Bearing on masonry..... 600

20. **Limiting Length of Members.** The ratio of length to least radius of gyration shall not exceed 100 for main compression members nor 120 for wind and sway bracing.

21. The lengths of riveted tension members in horizontal or inclined positions shall not exceed 200 times their radius of gyration about the horizontal axis. The horizontal projection of the unsupported portion of the member shall be considered as the effective length.

22. **Alternate Stresses.** Members subject to alternate stresses of tension and compression shall be proportioned for the kind of stress requiring the larger section. If the alternate stresses occur in succession during the passage of one train, as in stiff counters, each stress shall be increased by 50 per cent of the smaller. The connections of such members shall in all cases be proportioned for the sum of the stresses so increased.

23. If the live load and dead load stresses are opposite in character, only two-thirds of the dead load stress shall be considered as effective in counteracting the live load stress. This reduction of dead load shall not be made in proportioning members subject to alternate stresses.

24. **Combined Stresses.** Members subject to both axial and bending stresses shall be proportioned so that the combined fiber stresses will not exceed the allowed axial stress.

25. Members subject to stresses produced by combinations of lateral, longitudinal, and wind forces with dead load, live load, impact, and centrifugal force, may be proportioned for unit stresses 25 per cent greater than those specified in par. 15 to 19, inclusive; but the section shall be not less than that required for dead load, live load, impact, and centrifugal force.

26. **Net Section at Rivets.** In proportioning tension members, the diameter of the rivet holes shall be taken $\frac{1}{8}$ inch larger than the nominal diameter of the rivet.

27. **Rivets.** In proportioning rivets, the nominal diameter of the rivet shall be used.

28. **Net Section at Pins.** The minimum net section through the pin hole of pin-connected riveted tension members shall be at least 25 per cent in excess of the net section of the body of the member. The minimum net section back of the pin hole, parallel with the axis of the member, shall be not less than the net section of the body of the member.

29. **Plate Girders.** Plate girders shall be proportioned either by the moment of inertia of their net section; or by assuming that the flanges are concentrated at their centers of gravity; in the latter case $\frac{1}{8}$ of the gross section of the web, if properly spliced, may be used as flange section. The thickness of web plates shall be not less than $\frac{1}{160}$ of the unsupported distance between flange angles (see par. 38).

30. **Compression Flange.** The gross section of the compression flanges of plate girders shall be not less than the gross section of the tension flanges. If the compression flange of any beam or girder consists of angles only or if the cover consists of flat plates, the stress per square inch shall not exceed 16,000—200 l/b. If the cover consists of a channel section, the stress per square inch shall not exceed 16,000—150 l/b. l represents the length of unsupported flange, and b is the flange width.

31. **Flange Rivets.** The flanges of plate girders shall be connected to the web with a sufficient number of rivets to transfer in a distance equal to the effective depth of the girder at any given point the total shear at that point combined with any load that is applied directly on the flange. If the ties rest on the flanges, each wheel load shall be assumed to be distributed over three ties.

32. **Depth Ratios.** The depth of trusses shall preferably be not less than $\frac{1}{10}$ of the span. The depth of plate girders and rolled beams, used as girders, shall preferably be not less than $\frac{1}{12}$ of the

span. If shallower trusses, girders or beams are used, the section shall be increased so that the maximum deflection will not be greater than if the above limiting ratios had not been exceeded.

IV. DETAILS OF DESIGN

General Requirements

33. **Open Sections.** Structures shall be so designed that all parts will be accessible for inspection, cleaning and painting.

34. **Pockets.** Pockets or depressions which would hold water shall be provided with drain holes, or be filled with waterproof material.

35. **Symmetrical Sections.** Main members shall be so designed that the neutral axis will be as nearly as practicable in the center of section, and the neutral axes of intersecting main members of trusses shall meet at a common point.

36. **Counters.** Rigid counters are preferred. If subject to reversal of stress, the chord connections shall preferably be riveted. Adjustable counters shall have open turnbuckles.

37. **Strength of Connections.** The strength of connections shall be sufficient to develop the full capacity of the member for the kind of stress it is to carry even though the computed stress is less than such capacity.

38. **Minimum Thickness.** The minimum thickness of metal shall be $\frac{3}{8}$ inch, except for fillers.

39. **Pitch of Rivets.** The minimum distance between centers of rivet holes shall be three diameter of the rivet; but the distance shall preferably be not less than 3 inches for $\frac{7}{8}$-inch rivets and $2\frac{1}{2}$ inches for $\frac{3}{4}$-inch rivets. The maximum pitch in the line of stress for members composed of plates and shapes shall be 6 inches for $\frac{7}{8}$-inch rivets and 5 inches for $\frac{3}{4}$-inch rivets. For angles with two gage lines and rivets staggered, the maximum pitch in each line shall be twice the above. Where two or more plates are used in contact, rivets not more than 12 inches apart in either direction shall be used to hold the plates together. In tension members, composed of two angles in contact, a pitch of 12 inches may be used for riveting these angles together.

40. **Edge Distance.** The minimum distance from the center of any rivet hole to a sheared edge shall be $1\frac{1}{2}$ inches for $\frac{7}{8}$-inch

rivets and 1¼ inches for ¾-inch rivets, and to a rolled edge 1¼ inches and 1⅛ inches, respectively. The maximum distance from any edge shall be 8 times the thickness of the plate, but shall not exceed 6 inches.

41. **Maximum Diameter.** The diameter of the rivets in any angle whose size is determined by calculated stress shall not exceed one-fourth of the width of the leg in which they are driven; in angles whose size is not so determined ⅞-inch rivets may be used in 3-inch legs, and ¾-inch rivets in 2½-inch legs.

42. **Long Rivets.** Rivets carrying calculated stress and whose grip exceeds four diameters shall be increased in number at least one per cent for each additional 1/16 inch of grip.

43. **Pitch at Ends.** The pitch of rivets at the ends of built compression members shall not exceed four diameters of the rivets, for a distance equal to one and one-half times the maximum width of member.

44. **Compression Members.** In built compression members the metal shall be concentrated in the webs and flanges. The thickness of each web shall be not less than 1/30 of the distance between the lines of rivets, connecting it to the flanges. The thickness of cover plates shall be not less than 1/40 of the distance between the nearest rivet lines.

45. **Minimum Angles.** The minimum thickness of flange angles of girders and built members without cover plates shall be 1/12 of the width of the outstanding leg.

46. **Tie-Plates.** The open sides of compression members shall be provided with lacing bars and shall have tie-plates as near each end as practicable. Tie-plates shall be provided at intermediate points where the lacing is interrupted. In main members the length of end tie-plates shall be not less than the distance between the nearest lines of rivets connecting them to the flanges and the length of intermediate tie-plates not less than one-half that distance. Their thickness shall be not less than 1/50 of the same distance.

47. **Lacing.** The lacing of compression members shall be proportioned to resist the shearing stresses corresponding to the allowance for flexure for uniform load provided in the column formula in par. 16 by the term $70\,l/r$. The minimum width of lacing bars shall be 2½ inches for ⅞-inch rivets, 2¼ inches for ¾-inch rivets, and 2 inches for ⅝-inch rivets, if used. The thickness shall be not less than 1/40 of the distance between end rivets

for single lacing, and 1/60 for double lacing. Shapes of equivalent strength may be used instead of bars.

48. 5/8-inch rivets shall be used for lacing flanges less than 2 1/2 inches wide, 3/4-inch rivets for flanges from 2 1/2 to 3 1/2 inches wide; 7/8-inch rivets for flanges 3 1/2 inches and over, in width, lacing bars with at least two rivets in each end shall be used for flanges over 5 inches wide.

49. The inclination of lacing bars with the axis of the member shall be not less than 45 degrees. If the distance between rivet lines in the flanges is more than 15 inches and a single rivet bar is used, the lacing shall be double and riveted at the intersections.

50. Lacing bars shall be so spaced that the portion of the flange included between their connections will be as strong as the member as a whole.

51. **Faced Joints.** Abutting joints in compression members faced for bearing shall be sufficiently spliced on four sides to hold the connecting members accurately in place. Other joints in riveted work, whether in tension or compression, shall be fully spliced.

52. **Pin Plates.** Pin-holes shall be reinforced by plates if necessary, and at least one plate shall be as wide as the flanges will allow and be on the same side as the angles. Pin plates shall contain sufficient rivets to distribute their portion of the pin pressure to the full cross-section of the member.

53. **Forked Ends.** The ends of compression members shall not be forked unless unavoidable; with forked ends, a sufficient number of pin-plates shall be provided to give the jaws twice the sectional area of the member. At least one of these plates shall extend to the far edge of the farthest tie-plate, and the others to the far edge of the nearest tie-plate, but not less than 6 inches beyond the near edge of the farthest tie-plate.

54. **Pins.** Pins shall be long enough to insure a full bearing of all the parts connected upon the turned body of the pin. They shall be secured by chambered nuts or be provided with washers if solid nuts are used. The screw ends shall be long enough to admit of burring the threads.

55. Pin-connected members shall be held against lateral movement on the pins.

56. **Bolts.** Where members are connected by bolts, the turned bodies of the bolts shall be long enough to extend through the metal.

A washer at least ¼ inch thick shall be used under the nut. Bolts shall not be used in place of rivets except by special permission. Heads and nuts shall be hexagonal.

57. **Indirect Splices.** If splice plates are not in direct contact with the parts which they connect, rivets shall be used on each side of the joint in excess of the number required in the case of direct contact to the extent of one-third of that number for each intervening plate.

58. **Fillers.** Where rivets carrying stress pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by additional rivets equal in number to 50 per cent of those required to carry the stress.

59. **Expansion.** Provision shall be made for expansion and contraction in all bridge structures to the extent of ⅛ inch for each 10 feet of length. Means shall be provided to prevent excessive motion at any point.

60. **Expansion Bearings.** Spans of 80 feet and over resting on masonry shall have turned rollers or rockers at one end. Spans of less length shall be arranged to slide on smooth surfaces. These expansion bearings shall be designed to permit motion in one direction only.

61. **Fixed Bearings.** Fixed bearings shall be firmly anchored to the supports.

62. **Rollers.** Expansion rollers shall be not less than 6 inches in diameter. They shall be coupled together with substantial side bars, which shall be so arranged that the rollers can be readily cleaned. Segmental rollers shall be geared to the upper and lower plates.

63. **Bolsters.** Bolsters or shoes shall be so constructed that the load will be distributed uniformly over the entire bearing. Spans of 80 feet and over shall have hinged bolsters at each end.

64. **Wall Plates.** Wall plates may be cast or built-up; and shall be so designed as to distribute the load uniformly over the entire bearing. They shall be secured against displacement.

65. **Anchorage.** Anchor bolts for viaduct towers and similar structures shall be designed to engage a mass of masonry the weight of which is at least one and one-half times the uplift.

66. **Inclined Bearings.** The sole plates of bridges on an inclined grade without pin shoes shall be beveled so that the masonry and expansion surfaces will be level.

Floor Systems

67. **Floor Beams.** Floor beams shall preferably be square to the girders or trusses. They shall be riveted directly to the girders or trusses or may be placed on top of deck bridges.

68. **Stringers.** Stringers shall preferably be riveted to the webs of intermediate floor beams by means of connection angles not less than ½ inch thick. Shelf angles or other supports provided to support the stringer during erection shall not be considered as carrying any of the reaction.

69. **Stringer Frames.** End floor beams shall be used if possible. Stringers resting on masonry shall be connected at their ends by cross frames. The frames shall be riveted to girders or truss shoes where practicable.

Bracing

70. **Rigid Bracing.** Lateral, longitudinal and transverse bracing shall be composed of rigid members.

71. **Portals.** The end posts and top chords of the through-truss spans shall be rigidly connected by riveted portal braces. The braces shall be as deep as the clearance will allow.

72. **Transverse Bracing.** An intermediate transverse frame shall be used at each panel of through spans having vertical truss members where the clearance will permit.

73. **End Bracing.** Deck spans shall have transverse bracing at each end proportioned to carry the lateral load to the support.

74. **Laterals.** The minimum-sized angle to be used in lateral bracing shall be 3½ by 3 by ⅜ inches. There shall be not less than three rivets at each end connection of the angles.

75. Lateral bracing beneath the track shall be low enough to clear the ties.

76. **Tower Struts.** The struts at the base of viaduct towers shall be strong enough to slide the movable shoes when the track is unloaded.

Plate Girders

77. **Camber.** If camber is desired, it shall be provided in plate

girder spans over 50 feet in length at the rate of $\frac{1}{16}$ inch per 10 feet of length.

78. **Top Flange Cover.** Where flange cover plates are used, one cover plate of the top flange shall extend the whole length of the girder.

79. **Web Stiffeners.** There shall be web stiffeners, generally in pairs, over bearings, and at points of concentrated loading. Other web stiffeners shall be used if the width of the unsupported web between flange angles is greater than 60 times its thickness. The distance between stiffeners shall not exceed:

(*a*) 6 feet,

(*b*) the width of the unsupported web,

(*c*) the value of d in the following formula:

$$d=(12000-s)\ t/40,$$

Where d=clear distance between stiffeners of flange angles.

t=thickness of web.

s=shear per square inch.

The stiffeners at the end and at points of concentrated loading shall be proportioned by the formula of par. 16, by assuming the effective length of column equal to one-half the depth of the girder. End stiffeners and those under concentrated loading shall be on fillers. Their outstanding legs shall be as wide as the flange angles will allow and shall fit tightly against them. Intermediate stiffeners may be crimped or on fillers and their outstanding legs shall be not less than 2 inches plus $\frac{1}{30}$ of the depth of the girder.

80. **Stays for Top Flanges.** Top flanges of through plate girders shall be stayed by knee braces or gusset plates at every floor beam, or in solid floor bridges at distances not exceeding 12 feet.

Trusses

81. **Camber.** Truss spans shall be given a camber by so proportioning the length of the members that the tops of the stringers will be in a straight line when the bridge is fully loaded.

82. **Rigid Members.** Hip verticals and members performing similar functions, and the two end panels of the bottom chords of single track pin-connected trusses shall be rigid.

83. **Eye Bars.** The eye bars composing a member shall be so arranged that adjacent bars will not be in contact. The bars shall be as nearly parallel to the axis of the truss as possible, the maximum inclination of any bar being one inch in 16 feet.

84. **Pony Trusses.** Pony trusses shall be riveted structures, with double-webbed chords. The web members shall be laced or otherwise effectively stiffened.

PART SECOND—MATERIALS AND WORKMANSHIP

V. MATERIAL

85. **Steel.** Steel shall be made by the open-hearth process.

86. **Properties.** The chemical and physical properties shall conform to the following limits:

Elements Considered	Structural Steel	Rivet Steel	Steel Castings
Phosphorus, max. { Basic	0.04 per cent	0.04 per cent	0.05 per cent
{ Acid	0.06 " "	0.04 " "	0.08 " "
Sulphur, maximum	0.05 " "	0.04 " "	0.05 " "
Yield point, minimum, lb. per sq. in.	30,000	25,000	33,000
Ultimate tensile strength, lb. per sq. in.	desired: 60,000	desired: 50,000	not less than: 65,000
Elong., min., per cent in 8″ fig. 1	1,500,000* ult. tens. str.	1,500,000 ult. tens. str.	15 per cent
Elong., min., per cent in 2″, fig. 2	22		
Character of fracture	silky	silky	silky or fine granular
Cold bends without fracture	180° flat†	180° flat‡	90°; d=3t

*See par. 96. †See par. 97, 98 and 99. ‡See par. 100.

87. In order that the ultimate strength of full-sized annealed eye bars may meet the requirements of par. 163, the ultimate strength in test specimens may be determined by the manufacturers. The tests other than those for ultimate strength shall conform to the above requirements.

88. **Allowable Variations.** If the ultimate strength varies more than 4,000 pounds from that desired, a retest shall be made on the same gage, which, to be acceptable, shall be within 5,000 pounds of the desired ultimate.

89. **Chemical Analyses.** Chemical determinations of the percentages of carbon, phosphorus, sulphur, and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel. A copy of each analysis shall be furnished to the engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent above the limits specified will be permitted.

90. **Specimens.** Plate-shape-and bar specimens for tensile-and

bending tests shall be made by cutting coupons from the finished product. The test specimens shall have both faces rolled and both edges milled either parallel or to the form shown by fig. 1; or the specimens may be turned to a diameter of ¾ inch for a length of at least 9 inches, with enlarged ends.

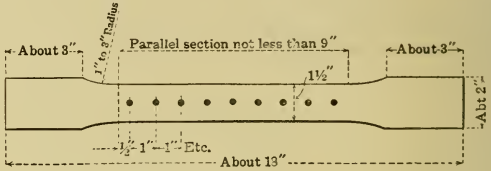


FIGURE 1.

91. Test specimens of rivet steel shall be cut full size from the rods as rolled.

92. Pin-and roller specimens shall be cut from the finished rolled or forged bar, in such manner that the center of the specimen will be one inch from the surface of the bar. The specimen for tensile test shall be turned to the form shown by fig. 2. The specimen for bending test shall be one inch by ½ inch in section.

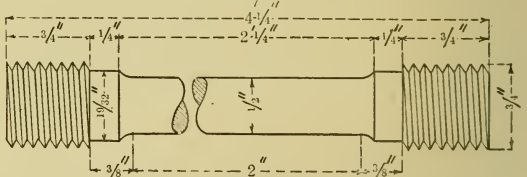


FIGURE 2.

93. The number of tests for steel castings shall depend on the character and importance of the castings. Specimens shall be cut cold from coupons molded and cast on some portion of one or more castings from each melt or from the sink heads, if the heads are of sufficient size. The coupon or sink head, so used, shall be annealed with the casting before it is cut off. Test specimens shall be of the form prescribed for pins and rollers.

93a. The yield points shall be determined by the drop of beam of the testing machine. The beam shall be kept balancing between the upper and lower cross pieces for some time preceding the drop. The speed of the machine shall be such that the beam may be

kept balanced and, except for the initial tightening of the specimen in the grips, shall not exceed ½ inch per minute for the standard form of specimen for plates, bars and shapes, and shall not exceed ⅛ inch per minute for the standard form of specimen for pins, rollers, and steel castings. The speed after the yield point shall not exceed 6 inches per minute, and the beam shall be kept at balance when the ultimate strength is attained.

94. **Specimens of Rolled Steel.** Rolled steel shall be tested in the condition in which it comes from the rolls.

95. **Number of Tests.** At least one tensile-and one bending test shall be made from each melt of steel as rolled. In case steel differing ⅜ inch or more in thickness is rolled from one melt, a test shall be made from the thickest and thinnest material rolled.

96. **Modification in Elongation.** A deduction of 1 per cent will be allowed from the specified percentage for elongation, for each ⅛ inch in thickness above ¾ inch.

97. **Bending Tests.** Bending tests may be made by pressure or by blows. Plates, shapes and bars less than one inch thick shall bend as called for in par. 86.

98. **Thick Material.** Full-sized material for eye bars and other steel one inch thick and over, tested in the same condition as when rolled, shall bend cold 180 degrees around a pin, the diameter of which is equal to twice the thickness of the bar, without fracture on the outside of the bend.

99. **Bending Angles.** Angles ¾ inch and less in thickness shall open flat, and angles ½ inch and less in thickness shall bend shut, cold, under blows of a hammer, without sign of fracture. This test shall be made only when required by the inspector.

100. **Nicked Bends.** Rivet steel, when nicked and bent around a bar of the same diameter as the rivet rod, shall give a gradual break and a fine silky uniform fracture.

101. **Finish.** Finished material shall be free from injurious seams, flaws, cracks, defective edges and other defects, and have a smooth, uniform and workmanlike finish. Plates 36 inches in width and under shall have rolled edges.

102. **Melt Numbers.** Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it. Steel for pins and rollers shall be stamped on the end. Rivet and lacing steel and other small parts may be bundled with the above marks on an attached metal tag.

103. **Defective Material.** Material which develops weak spots brittleness, cracks or other imperfections, or is found to have injurious defects, may be rejected at the shop and shall be replaced by the manufacturer at his own cost.

104. **Variation in Weight.** A variation in cross-section or weight of any piece of steel of more than 2½ per cent from that specified will be sufficient cause for rejection, except that sheared plates shall be subject to the following permissible variations, which shall apply to single plates, when ordered to weight:

105. Plates weighing 12½ pounds or more per square foot.

(*a*) Up to 100 inches wide, 2½ per cent more or less than the nominal weight.

(*b*) 100 inches wide and over, 5 per cent more or less than the nominal weight.

106. Plates weighing less than 12½ pounds per square foot.

(*a*) Up to 75 inches wide, 2½ per cent more or less than the nominal weight.

(*b*) 75 inches and up to 100 inches wide, 5 per cent more or 3 per cent less than the nominal weight.

(*c*) 100 inches wide and over, 10 per cent more or 3 per cent less than the nominal weight.

107. Plates when ordered to gage will be accepted if they measure not more than 0.01 inch less than the ordered thickness.

108. An excess over the nominal weight, corresponding to the dimensions on the order, will be allowed for each plate, if not more than that shown in the following table, one cubic inch of rolled steel being assumed to weigh 0.2833 pound:

Thickness Ordered, Inches	Nominal Weights, Pounds per Square Foot	Allowable Excess Expressed as Percentage of Nominal Weights For Width of Plate as follows:			
		Up to 75 in.	75 in. and up to 100 in.	100 in. and up to 115 in.	Over 115 in.
1/4	10.20	10	14	18	.....
5/16	12.75	8	12	16	.....
3/8	15.30	7	10	13	17
7/16	17.85	6	8	10	13
1/2	20.40	5	7	9	12
9/16	22.95	4½	6½	8½	11
5/8	25.50	4	6	8	10
Over 5/8	.....	3½	5	6½	9

109. **Cast Iron.** Castings shall be made of tough gray iron, with sulphur not over 0.10 per cent, except where chilled iron is specified. They shall be true to pattern, out of wind and free from flaws and excessive shrinkage. If tests are required, they shall be made on the "arbitration bar" of the American Society for Testing Materials, which is a round bar 1¼ inches in diameter and 15 inches long. The transverse test shall be made on a clear span of 12 inches with the load at the middle. The minimum breaking load so applied shall be 2,900 pounds, with a deflection of at least ⅒ inch before rupture.

110. **Wrought Iron.** Wrought iron shall be double-rolled, tough, fibrous and uniform in character. It shall be thoroughly welded in rolling and free from surface defects. When tested in specimens of the form of fig. 1, or in full-sized pieces of the same length, it shall show an ultimate strength of at least 50,000 pounds per square inch, an elongation of at least 18 per cent in 8 inches, with fracture wholly fibrous. Specimens shall bend cold, with the fiber, through 135 degrees, without sign of fracture, around a pin the diameter of which is twice the thickness of the piece tested. When nicked and bent, the fracture shall show at least 90 per cent fibrous.

VI. INSPECTION AND TESTING AT THE MILLS

111. **Mill Orders.** The purchaser shall be furnished complete copies of mill orders, and no material shall be rolled nor work done before the purchaser has been notified where the orders have been placed, so that he may arrange for the inspection.

112. **Facilities for Inspection.** The manufacturer shall furnish all facilities for inspecting and testing the weight and quality of all material at the mill where it is manufactured. He shall furnish a suitable testing machine for testing the specimens, as well as prepare the pieces for the machine, free of cost to the purchaser.

113. **Access to Mills.** The inspector representing the purchaser at the mills, shall have access, at all times, to all parts of mills where material to be inspected by him is being manufactured.

VII. WORKMANSHIP

114. **General.** All parts forming a structure shall be built in accordance with approved drawings. The workmanship and finish shall be equal to the best practice in modern bridge works.

Material at the shops shall be kept clear and protected from the weather.

115. **Straightening.** Material shall be thoroughly straightened in the shop, by methods that will not injure it, before being laid off or worked in any way.

116. **Finish.** Shearing and chipping shall be neatly and accurately done and all portions of the work exposed to view neatly finished.

117. **Size of Rivets.** The size of rivets, called for on the plans, shall be the actual size of the rivet before heating.

118. **Rivet Holes.** If general reaming is not required, the diameter of the punch shall not be more than $\frac{1}{16}$ inch greater than the diameter of the rivet; nor the diameter of the die more than $\frac{1}{8}$ inch greater than the diameter of the punch. Material more than $\frac{3}{4}$ inch thick shall be subpunched and reamed or drilled from the solid.

119. **Punching.** Punching shall be accurately done. There shall be no drifting to enlarge unmatched holes. If the holes must be enlarged to admit the rivet, they shall be reamed. Poor matching of holes will be cause for rejection.

120. **Reaming.** Where subpunching and reaming are required, the diameter of the punch used shall be not less than $\frac{3}{16}$ inch smaller than the nominal diameter of the rivet. The holes shall then be reamed to a diameter not more than $\frac{1}{16}$ inch greater than the nominal diameter of the rivet. (See par. 135.)

121. **Reaming after Assembling.** If general reaming is required it shall be done after the pieces forming one built member are assembled and so firmly bolted together that the surfaces are in close contact. If it be necessary to take the pieces apart for shipping and handling, the respective pieces reamed together shall be so marked that they may be reassembled in the same position in the final setting up. No interchange of reamed parts will be permitted.

122. Reaming shall be done with twist drills without lubricant.

123. The outside burrs on reamed holes shall be removed to the extent of making a $\frac{1}{16}$-inch fillet.

124. **Assembling.** The parts of riveted members shall be well pinned and firmly drawn together with bolts, before riveting is commenced. Contact surfaces shall be painted. (See par. 152.)

125. **Lacing Bars.** The ends of lacing bars shall be neatly rounded, unless otherwise called for.

126. **Web Stiffeners.** Stiffeners shall fit neatly between the flanges of girders. Where tight fits are called for, the ends of the stiffeners shall be faced and shall be brought to a true contact bearing with the flange angles.

127. **Splice Plates and Fillers.** Web splice plates and fillers under stiffeners shall be cut to fit within $\frac{1}{8}$ inch of the flange angles.

128. **Web Plates.** Web plates of girders, which have no cover plates, shall be flush with the backs of the flange angles or project above them not more than $\frac{1}{8}$ inch, unless otherwise called for. When web plates are spliced, not more than $\frac{1}{4}$ inch clearance between ends of plates will be allowed.

129. **Floor Beams and Stringers.** The main sections of floor beams and stringers shall be milled to exact length after riveting and the connection angles accurately set flush and true to the milled ends. (If required by the purchaser the milling shall be done after the connection angles are riveted in place, the milling to extend over the entire face of the member.) The removal of more than $\frac{3}{32}$ inch from the thickness of the connecting angles will be cause for rejection.

130. **Riveting.** Rivets shall be uniformly heated to a light cherry red heat in a gas-or oil furnace so constructed that it can be adjusted to the proper temperature. They shall be driven by pressure tools wherever possible. Pneumatic hammers shall be used in preference to hand driving.

131. Rivet heads shall be of approved shape, uniform in size and of neat and finished appearance. They shall be central on the shank and shall grip the assembled pieces firmly. Recupping and calking will not be allowed. Loose, burned or otherwise defective rivets shall be cut out and replaced. In cutting out rivets, care shall be taken not to injure the adjacent metal. If necessary, they shall be drilled out.

132. **Turned Bolts.** Wherever bolts are used in place of rivets which transmit shear, the holes shall be reamed parallel and the bolts shall make a driving fit, with the threads entirely outside of the holes. A washer not less than $\frac{1}{4}$ inch thick shall be used under nut.

133. **Members to be Straight.** The several pieces forming one built member shall be straight and fit closely together. Finished members shall be free from twists, bends and open joints.

134. **Finish of Joints.** Abutting joints shall be cut or dressed true and straight and fitted close together, especially where open to view. In compression joints, depending on contact bearing, the surfaces shall be truly faced, so as to provide even bearings after they have been perfectly aligned and riveted complete.

135. **Field Connections.** Holes for floor beam and stringer connections shall be subpunched and reamed to a steel templet not less than one inch thick. (If required, all other field connections, except those for laterals and sway bracing, shall be assembled in the shop and the unmatched holes reamed; and when so reamed the pieces shall be match-marked before being taken apart.)

136. **Eye Bars.** Eye bars shall be straight and true to size, and free from twists, folds in the neck or head, and other defect. The heads shall be made by upsetting, rolling or forging. Welding will not be allowed. The form of the heads will be determined by the dies in use at the works where the eye bars are made, if satisfactory to the engineer, but the manufacturer shall guarantee the bars to break in the body when tested to rupture. The thickness of the head and neck shall not vary more than $\frac{1}{16}$ inch from that specified. (See par. 163.)

137. **Boring Eye Bars.** Before boring, each eye bar shall be properly annealed and carefully straightened. Pin holes shall be in the center line of the bar and in the center of the heads. Bars of the same length shall be bored so accurately that, when placed together, pins $\frac{1}{32}$ inch smaller in diameter than the pin holes can be passed through the holes at both ends of the bars at the same time without forcing.

138. **Pin Holes.** Pin holes shall be bored true to gages, smooth straight, at right angles to the axis of the member and parallel to each other, unless otherwise called for. The boring shall be done after the member is riveted.

139. The distance center to center of pin holes shall be correct within $\frac{1}{32}$ inch, and the diameter of the holes not more than $\frac{1}{30}$ inch larger than that of the pin, for pins up to 5 inches diameter, and $\frac{1}{32}$ inch for larger pins.

140. **Pins and Rollers.** Pins and rollers shall be accurately turned to gages and shall be straight, smooth and free from flaws.

141. **Screw Threads.** Screw threads shall make tight fits in the nuts and shall be U. S. standard, except above the diameter of $1\frac{3}{8}$ inches, when they shall be made with six threads per inch.

142. **Annealing.** Steel which has been partially heated, shall be properly annealed, except where used in minor details.

143. **Steel Castings.** Steel castings shall be annealed and free from large or injurious blowholes.

144. **Welds.** Welds in steel will not be allowed.

145. **Bed Plates.** Expansion bed plates shall be planed true and smooth. Cast wall plates shall be planed top and bottom. The finishing cut of the planing tool shall be fine and parallel with the direction of expansion.

146. **Pilot Nuts.** Pilot-and driving nuts shall be furnished for each size of pin, in such numbers as may be ordered.

147. **Field Rivets.** Field rivets shall be furnished to the amount of 15 per cent plus ten rivets in excess of the nominal number required for each size.

148. **Shipping Details.** Pins, nuts, bolts, rivets and other small parts shall be boxed or crated.

149. **Weight.** The scale weight of every piece and box shall be marked on it in plain figures.

150. **Finished Weight.** Payment for pound price contracts shall be by scale weight. Not over 2 per cent of the total weight of the structure as computed from the plans will be allowed for excess weight.

VIII. SHOP PAINTING

151. **Cleaning.** Steel work, before leaving the shop, shall be thoroughly cleaned and given one good coating of pure linseed oil, or such paint as may be called for, well worked into all joints and open spaces.

152. **Contact Surfaces.** In riveted work, the surfaces coming in contact shall each be painted before being riveted together.

153. **Inaccessible Surfaces.** Pieces and parts which will not be accessible for painting after erection, including tops of stringers, eye bar heads, ends of posts and chords, etc., shall have an additional coat of paint before leaving the shop.

154. **Condition of Surfaces.** Painting shall be done only when the surface of the metal is perfectly dry. It shall not be done in wet or freezing weather, unless protected under cover.

155. **Machine-Finished Surfaces.** Machine-finished surfaces shall be coated with white lead and tallow before shipment or before being put out into the open air.

IX. INSPECTION AND TESTING AT THE SHOPS

156. **Facilities for Inspection.** The manufacturer shall furnish all facilities for inspecting and testing the weight of material and quality of workmanship at the shop where material is manufactured. He shall furnish a suitable testing machine for testing full-sized members, if required.

157. **Starting Work.** The purchaser shall be notified well in advance of the start of the work in the shop, in order that he may have a representative on hand to inspect material and workmanship.

158. **Access to Shop.** The inspector shall have access, at all times, to all parts of the shop where material to be inspected by him is being manufactured.

159. **Accepting Material.** The inspector shall stamp each piece accepted with a private mark. Any piece not so marked may be rejected at any time and at any stage of the work. If the inspector, through an oversight or otherwise, has accepted material or work which is defective or contrary to the specifications, this material, no matter in what stage of completion, may be rejected by the purchaser.

160. **Shop Plans.** The purchaser shall be furnished complete shop plans.

161. **Shipping Invoices.** Complete copies of all shipping invoices shall be furnished to the purchaser with each shipment. Shipping invoices shall show the scale weights of individual pieces.

X. FULL-SIZED TESTS

162. **Eye Bar Tests.** Full-sized tests of eye bars and similar members, to prove the workmanship, shall be made at the manufacturer's expense, and the members so tested shall be paid for by the purchaser at contract price, if the tests are satisfactory. If the tests are not satisfactory, the members represented by them will be rejected.

163. In eye bar tests, the minimum ultimate strength shall be 55,000 pounds per square inch. The elongation in 10 feet, including the fracture, shall be not less than 15 per cent. Bars shall generally break in the body and the fracture shall be silky or fine granular. The elastic limit as indicated by the drop of the mercury shall be recorded. Should a bar break in the head and develop the specified elongation, ultimate strength and character of fracture, it shall not be cause for rejection, provided not more than one-third of the total number of bars tested break in the head. (See par. 136.)

AMERICAN BRIDGE COMPANY

AMERICAN BRIDGE COMPANY

SPECIFICATIONS

FOR

STEEL STRUCTURES

DESIGN, DETAILS OF CONSTRUCTION AND WORKMANSHIP

ADOPTED 1912

DESIGN

1. **Loads.** The steel frame of all structures shall be designed so as to safely support the dead and live loads. The dead load shall consist of the weight of all permanent construction and fixtures, such as walls, floors, roofs, interior partitions, and fixed or permanent appliances. The live load shall consist of movable loads on floors, loads due to machinery or other appliances, and the exterior loads due to snow on the roof and to wind.

2. For structures carrying traveling machinery, such as cranes, conveyors, etc., 25 per cent shall be added to the stresses resulting from such live load, to provide for the effect of impact and vibrations.

3. The wind pressure shall be assumed acting horizontally in any direction as follows:—

First: For finished structures—A pressure of 20 pounds per square foot on the sides and ends of buildings and on the vertical projection of roof surfaces, or

Second: In process of construction—A pressure of 30 pounds per square foot on vertical surfaces and the vertical projection of inclined surfaces of all exposed metal or other frame work.

4. **Unit Stresses.** All parts of structures shall be proportioned so that the sum of the dead and live loads, together with the impact, if any, shall not cause the stresses to exceed the following amounts in pounds per square inch:

Tension, net section, rolled steel.....16000

Direct compression, rolled steel and steel castings.....16000

Bending, on extreme fibers of rolled shapes, built sections, girders, and steel castings.....16000

Bending on extreme fibers of pins.....24000

Shear on shop rivets and pins.....12000

Shear on bolts and field rivets.....10000

Shear—average—on webs of plate girders and rolled beams, gross section.....10000

Bearing pressure on shop rivets and pins.....24000

Bearing on bolts and field rivets.....20000

Pressure per linear inch on expansion rollers shall not exceed 600 times the diameter of rollers in inches.

Axial compression of gross sections of columns, for ratio of l/r up to 120.....$19000-100\,l/r$
with a maximum of.....13000

where l=effective length of member in inches,
r=corresponding radius of gyration of section in inches.

For ratios of l/r up to 120, and for greater ratios up to 200, use the amounts given in the following table. For intermediate ratios, use proportional amounts.

Ratio	Amount	Ratio	Amount
60	13000	130	6500
70	12000	140	6000
80	11000	150	5500
90	10000	160	5000
100	9000	170	4500
110	8000	180	4000
120	7000	190	3500

5. For bracing and combined stresses due to wind and other loading, the permissible working stresses may be increased 25 per cent—provided the section thus found is not less than that required by the dead and live loads alone.

6. **General.** The effective or unsupported length of main compression members shall not exceed 120 times, and for secondary members 200 times, the least radius of gyration.

7. In proportioning columns, provision must be made for eccentric loading.

8. In proportioning tension members, net section must be used. Rivet holes deducted must be taken $\frac{1}{8}$ inch larger than the nominal size of rivets.

9. Members subject to the action of both axial and bending stresses shall be proportioned so that the greatest fiber stress will not exceed the allowed limits in that member.

10. Members subject to alternate stresses of tension and compression shall be proportioned for the stress giving the largest section, but their connections shall be proportioned for the sum of the stresses.

11. **Girders.** Rolled beams and channels, and built-up members used as beams and girders shall be proportioned by the moment of inertia of their gross sections.

12. Plate girder webs shall have a thickness not less than $\frac{1}{160}$ of the unsupported distance between flange angles. The webs shall have stiffeners, generally in pairs, over bearings, at points of concentrated loading, and at other points where the thickness of the web is less than $\frac{1}{60}$ of the unsupported distance between flange angles, generally not farther apart than the depth of the web plate, with a maximum limit of 6 feet.

13. The lateral unsupported length of beams and girders shall not exceed 40 times the width of the compression flange. When the unsupported length (l) exceeds 10 times the width (b) of the compression flange, the stress per square inch in the compression flange shall not exceed $19000—300\,l/b$.

DETAILS OF STEEL CONSTRUCTION

14. **General.** Adjustable members in any part of structures shall preferably be avoided.

15. Sections shall preferably be made symmetrical.

16. No connection, except lattice bars, shall have less than two rivets.

17. Trusses shall preferably be riveted structures. Heavy trusses of long span, where the riveted field connections would become unwieldy, or for other good reasons, may be designed as pin-connected structures.

18. Abutting joint in compression members faced for bearing shall be spliced sufficiently to hold the connecting members accurately in place. All other joints in riveted work, whether in tension or compression, shall be fully spliced.

19. Lateral, longitudinal and transverse bracing in all structures shall preferably be composed of rigid members, and shall be designed to be sufficient to withstand wind and other lateral forces when building is in process of erection as well as after completion.

20. **Girders.** When two or more rolled beams are used to form a girder, they shall be connected by bolts and separators at intervals of not more than 5 feet. All beams having a depth of 12 inches and more shall have at least two bolts to each separator.

21. The flange plates of all girders shall be limited in width, so as not to extend more than 6 inches beyond the outer line of rivets connecting them to the angles, or 8 times the thickness of the thinnest plate.

22. Web stiffeners shall be in pairs, and shall have a close bearing against the flange angles. Those over the end bearing or forming the connection between girder and column shall be on fillers. Intermediate stiffeners may be on fillers or crimped over the flange angles.

23. Web plates of girders must be spliced at all points by a plate on each side of the web, capable of transmitting the full stress through splice rivets.

24. **Riveting.** The minimum distance between centers of rivet holes shall be three diameters of the rivet; but the distance shall preferably be not less than 3 inches for $\frac{7}{8}$-inch rivets, $2\frac{1}{2}$ inches for $\frac{3}{4}$-inch rivets, 2 inches for $\frac{5}{8}$-inch rivets, and $1\frac{3}{4}$ inches for $\frac{1}{2}$-inch rivets. The maximum pitch in the line of the stress for members composed of plates and shapes will be 6 inches for $\frac{7}{8}$-inch rivets, 6 inches for $\frac{3}{4}$-inch rivets, $4\frac{1}{2}$ inches for $\frac{5}{8}$-inch rivets and 4 inches for $\frac{1}{2}$-inch rivets.

25. For angles in built sections with two gage lines, with rivets staggered, the maximum pitch in each line shall be twice as great as given above. Where two or more plates are in contact, rivets not more than 12 inches apart in either direction shall be used to hold the plates together.

26. The minimum distance from the center of any rivet hole to a sheared edge shall be 1½ inches for ⅞-inch rivets, 1¼ inches for ¾-inch rivets, 1⅛ inches for ⅝-inch rivets, and 1 inch for ½-inch rivets; and to a rolled edge, 1¼, 1⅛, 1, and ⅞ inches, respectively.

27. The maximum distance from any edge shall be eight times the thickness of the plate.

28. The pitch of rivets at the ends of built compression members shall not exceed four diameters of the rivets for a length equal to one and one-half times the maximum width of the member.

29. **Latticing.** The open sides of compression members shall be provided with lattice bars, having tie plates at each end and at intermediate points where the lattice is interrupted. The tie plates shall be as near the ends as practicable. In main members carrying calculated stresses, the end tie plates shall have a length not less than the distance between the lines of rivets connecting them to the flanges, and intermediate ones not less than half this distance. Their thickness shall not be less than 1/50 of the same distance.

30. The latticing of compression members shall be proportioned to resist a shearing stress equal to 2 per cent of the direct stress. The minimum thickness of lattice bars shall be for single lattice, 1/40, and for double lattice, 1/60 of the distance between the end rivets. Their minimum width shall be as follows:

For 15-inch channels, or
built sections with 3½ and 4-inch angles, 2½ inches (⅞-inch rivets).
For 12-10-and 9-inch channels, or
built sections with 3-inch angles . . . . . 2¼ inches (¾-inch rivets).
For 8-and 7-inch channels, or
built sections with 2½-inch angles . . . . . 2 inches (⅝-inch rivets).
For 6-and 5-inch channels, or
built sections with 2-inch angles . . . . . 1¾ inches (½-inch rivets).

31. The inclination of lattice bars with the axis of the member shall generally be not less than 45 degrees. When the distance between the rivet lines in the flanges is more than 15 inches, if a single rivet bar is used, the lattice shall be double.

32. The pitch of lattice connections, along the flange, divided by the least radius of gyration of the member between connections, shall be less than the corresponding ratio of the member as a whole.

33. **Pins.** Pin holes shall be reinforced by plates where necessary. At least one plate shall be as wide as the projecting flanges will allow; where angles are used, this plate shall be on the same side as the angles. The plates shall contain sufficient rivets to distribute their portion of the pin pressure to the full cross section of the member.

34. Pins shall be long enough to insure a full bearing of all parts connected upon the turned-down body of the pin. Members packed on pins shall be held against lateral movement.

WORKMANSHIP

35. **General.** The workmanship shall be equal to the best practice in modern structural works. Shearing shall be done accurately, and all portions of the work exposed to view shall be neatly finished.

36. **Punching.** The diameter of the punch shall not be more than $\frac{1}{16}$ inch, nor that of the die more than $\frac{1}{8}$ inch, larger than the diameter of the rivet. Punching shall be done accurately, but an occasional slight inaccuracy in the matching of holes may be corrected with reamer. Drifting to enlarge unfair holes will not be allowed.

37. **Riveting.** The size of rivets shall be as called for on the plans. Rivets shall be driven by pressure tools wherever possible. Pneumatic hammers shall be used in preference to hand driving. Rivets shall look neat and finished, with heads of approved shape, full and of equal size. They shall be centered on the shank and shall grip the assembled pieces firmly.

38. **Assembling.** Riveted members shall have all parts well pinned up and firmly drawn together with bolts before riveting is commenced. Contact surfaces shall be painted. Abutting joints shall be cut or dressed true and straight and fitted closely together. In compression joints depending on contact bearing, the surfaces shall be truly faced, so as to have even bearing after they are riveted up complete and when perfectly aligned. The several pieces forming one built member shall be straight and shall fit closely together, and finished members shall be free from twists, bends or open joints.

39. **Eye Bars.** Eye bars shall be straight and true to size, and shall be free from twists, folds in the neck or head, or any other defect. Heads shall be made by upsetting, rolling or forging. Welding will not be allowed. Before boring, each eye bar shall be perfectly annealed and carefully straightened. Pin holes shall be in the center line of bars and in the center of heads. Bars of the same length shall be bored so accurately that, when placed together, pins $\frac{1}{32}$ inch smaller in diameter than the pin holes can be passed through the holes at both ends of the bars at the same time.

40. **Pins.** Pins and rollers shall be turned accurately to gages, and shall be straight, smooth and entirely free from flaws. Pin holes shall be bored true to gages, smooth and straight, at right angles to the axis of the member and parallel to each other, unless otherwise called for. Wherever possible, the boring shall be done after the member is riveted up. The distance from center to center of pin holes shall be correct within $\frac{1}{32}$ inch, and the diameter of the hole not more than $\frac{1}{50}$ inch larger than that of the pin for pins up to 5 inches diameter, and $\frac{1}{32}$ inch for larger pins.

41. **Bed Plates.** Expansion bed plates shall be planed true and smooth. The cut of the planing tool shall correspond with the direction of expansion.

42. **Annealing.** Steel, except in minor details, which has been partially heated, shall be properly annealed. Welds in steel will not be allowed. All steel castings shall be annealed.

43. **Painting.** Steel work, before leaving the shop, shall be thoroughly cleaned and given one good coating of such paint as may be called for, well worked into all joints and open spaces.

44. In riveted work, the surfaces coming in contact shall be painted before being riveted together.

45. Machine-finished bearing surfaces coming in contact with similar surfaces should be coated with white lead and tallow before shipment.

46. **Inspection.** The manufacturer shall furnish all facilities for inspecting and testing the weight, quality of material and workmanship. He shall furnish a suitable testing machine for testing the specimens, as well as prepare the pieces for the machine free of charge.

47. He shall give the inspector for the purchaser free access to all parts of the works where the material under inspection is manufactured.

CARNEGIE STEEL COMPANY

GENERAL OFFICES:

Pittsburgh, Carnegie Building.

DISTRICT OFFICES:

Birmingham, Brown-Marx Building,
Boston, 120 Franklin Street,
Buffalo, Marine National Bank Building,
Chicago, 208 South La Salle Street,
Cincinnati, Union Trust Building,
Cleveland, Rockefeller Building,
Denver, First National Bank Building,
Detroit, Ford Building,
New Orleans, Maison Blanche,
New York, Hudson Terminal, 30 Church Street,
Philadelphia, Widener Building,
Pittsburgh, Carnegie Building,
St. Louis, Third National Bank Building,
St. Paul, Pioneer Building.

EXPORT REPRESENTATIVES:

UNITED STATES STEEL PRODUCTS CO.,
New York, Hudson Terminal, 30 Church Street.

PACIFIC COAST REPRESENTATIVES:

UNITED STATES STEEL PRODUCTS CO., PACIFIC COAST DEPT.
Los Angeles, Jackson Street and Central Avenue,
Portland, Selling Building,
San Francisco, Rialto Building,
Seattle, 4th Avenue South and Connecticut Avenue.