SPECIFICATIONS FOR CHINESE NATIONAL RAILWAYS

By The Ministry of Railways 25 th Year of the Chinese Republic

CONTENTS

FOREWORD

Art. 1 Scope of Specification

This specification applies to design, materials, manufacture, shipping, inspection and erection of steel bridges with fixed spans not exceeding 120 meters in length carrying a railway, but does not cover the design and construction of movable or suspension bridges nor of turntables for locomotive engines.

Art. 2 Engineer's Data

The railway engineer is expected to furnish full information with respect to the type of floor, the class of live load and other data specified in appendix. (neglected).

Art. 3 Units

The units in this specification are expressed in Chinese Government Standard system or the metric system. The British equivalents are only approximate and it is intended that the metric units shall be worked to.

PART I. DESIGN

SECTION I. GENERAL FEATURES

Art. 101 Materials

Structures shall be made wholly of structural steel except where otherwise specified. Rivet steel shall be used for rivets only. Cast steel preferably shall be used for shoes, rockers, and bearings. Cast iron may be used only where specified by the Engineer.

Art. 102 Types of Bridges

The preferred types of bridges are as follows:

Rolled beams for spans up to 10 meters.

Plate girders for spans up to 30 meters.

Riveted trusses for spans 30 meters or longer.

Pin-connected trusses for spans 100 meters or longer.

Art. 103 Dimensions for Calculation

For the calculation of stresses.

The length shall be:

For trusses and girders, the distance between centers of bearings.

For floor beams, the distance between centers of trusses or girders.

For stringers, the distance between centers of floor-beams.

For wooden sleepers, the distance between centers of stringers of deck girders.

The depth shall be:

For pin-connected trusses, the distance between centers of pins.

For riveted trusses, the distance between centers of gravity of chords.

Art. 104 Spacing of Trusses, Girders, & Stringers

The distance between centers of trusses or girders shall be sufficient to prevent overturning by the special lateral forces. In no case shall it be less than one-twentieth of the effective span for through spans nor one-fifteenth of the effective span for deck spans.

The girders of deck spans and the stringers of through spans shall be spaced not less than 2 meters between centers, except that if there are four stringers or girders under one track they shall be in pairs, one pair symmetrical about each rail.

Art. 105 Depth Ratio

The depth of trusses preferably shall be not less than one-tenth of the effective span. The depth of plate girders preferably shall be not less than one-twelfth of the effective span. The depth of rolled beams used as girders and the depth of solid floors shall be not less than one fifteenth of the effective span.

Art. 106 Clearances

For single track the clearances on straight alignement shall not be less than those specified by the C N R Standard, Drawing No. A–411–2, as shown here on **Fig. 1.**

On curved track additional clearance X shall be increased for the overhang of a car 26 m (85 ft) long 18 m (60 ft) between centers of bogie trucks to the lateral clearances (W) from the center line of track to both sides to be calculated by $X=40.5/R$ in which R is radius of curve in meters and on the inner side there shall be allowed for further additional lateral clearance of the amount M=middle ordinate of curve where chord equal to the length of the span and the amount $Y=sh/1.5$, Y being additional lateral clearnace for the super-elevation of the outer rail, s, super-elevation in meters, and h, height above base of rail in meters.

For through bridges with two or more tracks the distance between centers of the tracks shall be spaced not less than 4m, but the lateral clearance W shall be as specified above for single-track bridges.

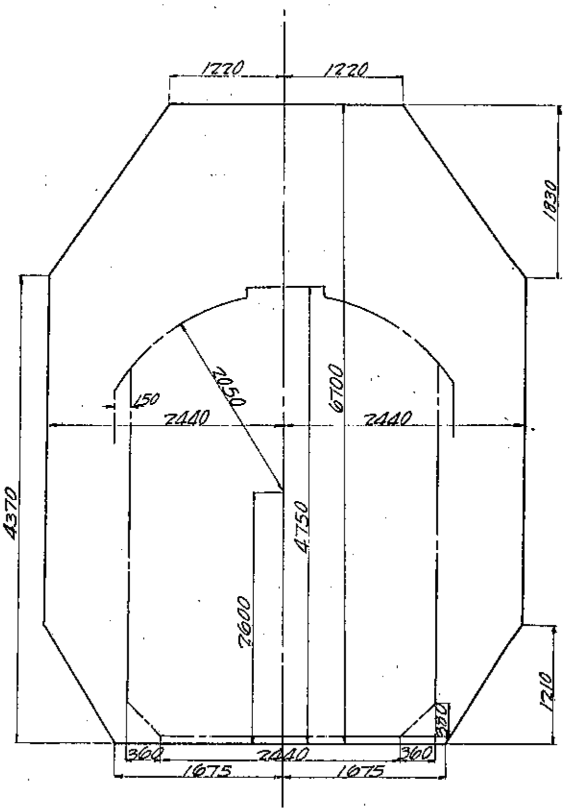
Art. 107 Super-elevation for Outer-Rail

For bridges on curves the super-elevation of outer rail shall be as specified by the engineer in conformity with the regulations and standards for the Construction of Railways (No. A-1-25).

Art. 108 End Floor Beams

Spans with floor systems shall have end floor beams unless otherwise specified. End floor beams shall be proportioned for lifting the span without exceeding the design unit stress more than 50 per cent.

Fig. 1.



MINIMUM CLEARANCE FOR BRIDGES

Art. 109 Skew Bridges

At the ends of skew bridges, the ends of the supports for each track shall be square with the line of the track.

Art. 110 Timber Floor

Wooden sleepers shall be not less than 3 meters long, and spaced not more than 150mm apart. They shall be secured against bunching.

Art. 111 Ballast Floor

Ballasted floor shall have at least 150mm of ballast under the sleepers. The floor shall be effectively water-proofed and drained.

SECTION II. LOADS & STRESSES

Art. 201 Loads & Forces

Bridges shall be proportioned for the following loads and forces:

(a) Dead load (c) Impact (e) Other lateral forces
(b) Live load (d) Centrifugal force (f) Longitudinal forces

Stresses from each of these loads and forces shall be shown separately on the stress sheet.

Art. 202 Dead Load

In estimating the weight for the purpose of computing dead load stresses, the following unit weights shall be used:

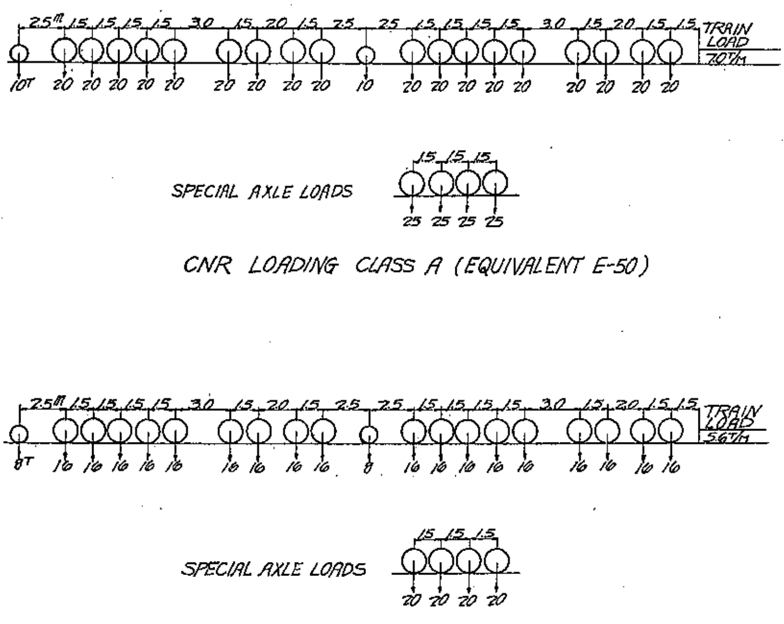
Steel	7 850 kg/m³
Concrete	2 400 „
Sand, gravel and ballast	1 920 „
Asphalt-mastic	2 400 „
Bituminous Macadam	2 100 „
Granite blocks	2 720 „
Paving bricks	2 400 „
Timber	960 „

The track rails, inside guard rails, and fastenings shall be assumed to weigh 225kg per linear meter for each track.

Art. 203 Live Load

The live load for each track shall consist of two typical engines followed by a uniform train load or a system of wheels to be known as CNR loading class "A" or class "B" as shown in Fig. 2.

Fig. 2.



CNR LOADING CLASS A (EQUIVALENT E-50)

CNR LOADING CLASS B (EQUIVALENT E-40)

The engineer shall specify the class of live load to be used.

For bridges on curves, provisions shall be made for increased proportions carried by any truss, girders, or stringers due to the eccentricity of the load.

For members receiving load from more than one track, the proportions of full live load on the tracks shall be as follows:

For two tracks full live load.
For three tracks full live load on two tracks and one-half on other track.
For four tracks, full live load on two tracks, one-half on one track, and one-fourth on the remaining one.

The selection of the tracks for these proportions shall be such as will give the greatest live load stress.

Art. 204 Distribution of Live Load

Wooden sleepers shall be designed for the maximum wheel load specified distributed over three ties and without impact.

Floors consisting of longitudinal beams or stringers shall be designed for the wheel loads specified.

Floors consisting of transverse beams or floor beams that are spaced close enough to carry the track loads without stringers shall be designed for a proportion of the max. axle load equal to the ratio of the floor beam spacing to the axle spacing. These floor beams shall be connected by solid-web diaphragms at intervals not exceeding 12 times the flange width, with at least one diaphragm for each track.

For ballasted floor bridges, the lateral distribution of the live load on each track shall be taken as uniform over a width of 3.0 m.

Art. 205 Impact

To the maximum computed static live load stresses, there shall be added the impact, consisting of:

(a) The lurching effect:

A percentage of the static live load stress equal to.......... $30^{\#}/S$

S=spacing, in meters, between centers of longitudinal girders, stringers, or trusses; or length, in meters, of floor beams or transverse girders.

(b) The direct vertical effect:

For steam locomotives due to hammer blow, track irregularities, and car impact, a percentage of the static live load stress equal to:

For L less than 30.5 m.. $(100-2L)^{\#}$
For L 30.5 m or more .... $\left(540/_{L-12}+10\right)^{\#}$
L=length, in meters, center to center of bearings, for longitudinal stringers, girders, or trusses.
L=length of floor beams or transverse girders, in meters, for floor beams, floor beam hangers and transverse girders.
\# The impact shall not exceed 100 % of the static live load.

Art. 206 Centrifugal Force

On curves the centrifugal force (assumed to act 1.8 meters above the raill) shall be taken equal to a persentage of the live load, including impact, according to the following table:

D	0°-30′	1°-0′	1°-30′	2°-0′	2°-30′	3°-0′	3°-30′	4°-0′	4°30′	5°-0′	6°-0′	7°-0′	8°-0′
V	120	120	98	85	76	69	64	60	57	54	49	45	43
%	5	10	10	10	10	10	10	10	10	10	10	10	10

D=Degree of curve with 20 m chord
V=Speed in kilometers per hour

%=per cent of centrifugal force to live load of $V^2/127R$

Art. 207 Wind on Loaded Bridge

The wind force shall be considered as a moving load acting in any horizontal direction. The wind force on the bridge shall be taken at 150 kilograms a square meter of

(a) one and one-half times the vertical projection of the floor system and girders,

(b) the vertical projection of all trusses,

but not less than 300 kg a linear meter of the loaded chord or flange and 225 kg a linear meter of the unloaded chord or flange.

(c) the vertical projection of the columns and tower bracings.

The wind force on the train shall be taken as 450 kg a linear meter on one track applied 2.4 meters above the top of the rail.

Art. 208 Wind on Unloaded Bridge

If a wind force of 250 kg a square meter of surface as defined above on the unloaded bridge would produce greater stress than the wind forces specified on loaded bridge combined with live load, the members where such greater stresses occur shall be designed therefor.

Art. 209 Sway of Locomotives

The lateral force to provide for the effect of the sway ofl ocomotives (in addition to the other lateral forces specified) shall be a moving concentrated load of 7 000 kg or 5 600 kg according to the class of live load and applied to the top of the rail, in either horizontal direction or at any point of the span.

Art. 210 Stability of Spans and Towers

In calculation the stability of spans and towers, the live load on one track shall be 1800 kg per linear meter taken without impact. On multiple track bridges this live load shall be on the leeward track. The lateral force shall be those in Arts. 206, 207 and 208.

Art. 211 Bracing between Compression Members

The lateral bracing of the compression chords or flanges of trusses and deck girders and between posts of viaduct towers shall be proportioned for a transverse shear in any panel equal to $2\,_{1/2}$ per cent of the total axial stress in both members in that panel, in addition to the shear from the specified lateral forces.

Art. 212 Longitudinal Forces

The longitudinal force resulting from the starting and stopping of trains shall be the larger of

(a) Force due to braking

Fifteen per cent of the live load reaction on the tower, without impact, but not less than 520 kg per meter of track.

(b) Force due to traction

Twenty-five per cent of the weight on the driving wheels, without impact. The longitudinal force shall be taken on one track only and shall be assumed to act 1.8 m above the top of the rail.

For bridges where, by reason of continuity of members or frictional resistance, much of the longitudinal force will be carried directly to the abutments (such as ballasted deck bridges of only three or four spans) only one-half of the longitudinal force shall be considered effective.

Art. 213 Reversal of Stress

Members subject to reversal of stress under the passage of the live load shall be proportioned as follows:

Determine the resultant tensile stress and the resultant compressive stress and increase each by 50 % of the smaller; then proportion the member so that it will be capable of resisting either increased resultant stress. The connections shall be proportioned for the sum of the resultant stresses.

Art. 214 Combined Stress

Members subject to both axial and bending stresses shall be so proportioned that the combined fiber stress will not exceed the allowed axial stress. In members continuous over panel points, only three-fourth of the bending stress computed as for simple beams shall be added to the axial stress.

Members subject to stresses produced by a combination of dead load, live load, impact, and centrifugal force with other lateral forces and with longitudinal force or with bending due to such forces, may be proportioned for unit stress 25 % greater than those specified in Art. 301; but the section of the member shall not be less than that required for the combination of dead load, live load, impact and centrifugal force.

Art. 215 Secondary Stresses

The design and details shall be such that secondary stresses will be as small as practicable. Secondary stresses due to truss distortion or floor beam deflection usually need not be considered in any member whose width, measured parallel to the plane of distortion is less than 1/10 of its length. If the secondary stress exceeds 3.00 kg per sq. mm for the tension members and 2.00 kg per sq. mm for compression members the excess shall be treated as a primary stress.

SECTION III. UNIT STRESSES

Art. 301 Unit Stresses

The allowable unit stresses to be used in proportioning the parts of a bridge shall be as follows:

(a) Structural & Rivet Steel

For Parts in tension — kg/mm^2

Axial tension, structural steel, net section ········ 12.5

Tension in extreme fibers of rolled shapes, girders and built up sections subject to bending ········ 12.5

For Parts in compression

Axial compression, gross section:

For stiffeners of plate girders ········ 12.5

For columns centrally loaded and with values of l/r not greater than 120

Riveted ends $f=10.5-l/4\,800 \cdot l^2/r^2$

Pin ends $f=10.5-l/3\,600 \cdot l^2/r^2$

l = length of member in mm

r = radius of gyration of member in mm.

For columns with values of l/r greater than 120

Riveted ends $f=13.5-1/20 \cdot l/r$

Pins $f=12.5-1/20 \cdot l/r$

Compression in extreme fiber of rolled shapes, girders and built up section subject to bending (value for l/b not to exceed 40) ········

$12.5-1/300 \cdot l^2/b^2$

l = length, in mm, of unsupported flange between lateral connections or knee braces

b = flange width in mm

For parts in shear — kg/mm^2

Shear in plate girder webs, gross section ········ 7.5

Shear in power driven shop rivets and pins ········ 9.0

Shear in power-driven field rivets ········ 8.0

Shear in hand-driven rivets and turned bolts ········ 7.0

For parts on bearing

Bearing on pins ········ 16.0

Bearing on power-driven shop rivets, milled stiffeners and other steel parts in contact ········ 18.0

Bearing on power-driven field rivets ········ 16.0

Bearing on hand-driven rivets and turned bolts ········ 14.0

Bearing on rocker pins ········ 8.0

Bearing on expansion rollers and rockers, kilograms per linear millimeter

For diameters up to 600 mm ········ $40d$

For diameters from 600 mm up ········ $10\sqrt{d}$

d = diameter of roller or rocker in mm

For Pins subject to bending

Stress in extreme fiber of pins ········ 18.0

(b) Cast steel

For cast steel shoes and pedestals, the allowable unit stresses in compression and in bearing shall be the same as those for structural steel. Other allowable unit stresses shall be three-fourth of those for structural steel.

(c) Masonry

Bearing pressure — kg/mm^2

Granite ········ 0.56

Concrete ········ 0.42

Sandstone & Limestone ········ 0.28

(d) Timber for wooden sleepers

Extreme fiber stress in bending

Douglas fir, structural grade ········ 1.0

White oak ········ 0.8

Chinese pine or cypress ········ 0.7

Art. 302 Effective Diameter of Rivets

The nominal diameter of rivets shall be considered the effective diameter.

Art. 303 Effective Bearing Area

The effective bearing area of pins, bolts, and rivets shall be the diameter multiplied by the length in bearing, except for countersunk rivets, half the depth of the countersink shall be deducted.

Art. 304 Slenderness Ratio

The slenderness ratio, being the ratio of unsupported length to least radius of gyration shall not exceed:

100 for main compression members

120 for wind and sway bracings in compression

140 for single lacing

200 for double lacing

200 for tension members other than eye bars.

Art. 305 Proportioning Web Members

Web members shall be so proportioned that a live load will increase the total unit stresses in the chords one-third will produce unit stresses in the web members not more than one-third greater than the designing stresses.

SECTION IV. DETAILS OF DESIGN

(a) Proportioning of Parts

Art. 401 Accessibility

Details shall be such that all parts will be accessible for inspection, clearing and painting. Closed sections shall be avoided wherever possible.

Art. 402 Drainage of Pockets

Pockets or depressions that would hold water shall have effective drain holes or else be filled with concrete or other suitable material.

Art. 403 Thickness of Materials

Materials, except for fillers, shall be not less than 10 mm thick. Parts subject to marked corrosive influence shall be of greater thickness than otherwise required or else protected against such influences.

The thickness of gusset plates connecting the chords and web members of a truss shall be proportionate to the stress to be transferred but not less than 13 mm.

Art. 404 Eccentric Connecions

Eccentric connections shall be avoided if practicable, but if they are unavoidable the members shall be so proportioned that the combined stresses will not exceed the allowable axial stress. Members shall be so arranged that their gravity axes will intersect in a point.

Art. 405 Strength of Connections

Connections shall have a strength not less than that of the member connected, based on the allowable unit stress in the member. Connections shall be made as nearly symmetrical as practicable about the axes of the members.

Art. 406 Compression Members

Compression members shall be so designed that the main elements of the section will be connected direct to the gusset plates, pins or other members.

The center of gravity of a built-up section shall coincide as nearly as practicable with the center line of the section. Preferably the segments shall be connected by solid webs.

In members consisting of segments connected by cover plates or lacing, or segments connected by webs, the thickness of the webs of the segments shall be not less than 1/30 of the unsupported distance between the nearest rivet lines or the roots of the flanges of rolled segments. The thickness of the cover plates or webs connecting the segments shall be not less than 1/40 of the unsupported distance between the nearest lines of their connecting rivets or the roots of their rolled flanges.

Art. 407 Outstanding Legs of Angles

The width of the outstanding legs of angles in compression, except those reinforced plates, shall not exceed the following:

(a) For stringers and girders where the ties rest on the flange, ten times the thickness.
(b) For main members carrying axial stress, and for stringers and girders not included in (a), twelve times the thickness.
(c) For bracing and other secondary members, fourteen times the thickness.

Art. 408 Net Section

The net section of a riveted tension member is the sum of the net sections of the component parts of the member. The net section of a part is the product of the thickness of the prat multiplied by its least net width.

The net width for any chain of holes extending progressively across the part of the member shall be obtained by (1) deduction from the gross width the sum of the diameters (h) of all the holes in the chain and (2) adding, for each gage space in the chain, the quantity

$$S^2/4g$$

in which S=pitch of any two successive holes in the chain, in mm.
g=gage of the same holes in mm.

The net section of the part is obtained from that chain which gives the least net width.

For angles the gross width shall be the sum of the widths of the legs less the thickness of the angles. The gage for holes in opposite legs shall be the sum of the gages from back of angle less the thickness.

For splice members the thickness shall be only that part of the thickness of the members which has been developed by rivets beyond the section considered.

The diameter of the hole shall be taken as 3 mm greater than the nominal diameter of the rivet.

Art. 409 Effective Sections of Angles

If angles in tension are so connected that bending cannot occur in any direction, the effective section shall be the net section of the angle. If connected on one side of a gusset plate, the effective section shall be the net section of the connected leg plus one-half the section of the unconnected leg.

Art. 410 Section at Pin Holes

In pin-connected riveted tension members the net section beyond the pin hole, parallel with the axis of the member, shall be not less than the net section of the member. The net section through the pin hole, transverse to the axis of the member, shall be at least 40% greater than the net section of the member. The ratio of the net width, through the pin hole transverse to the axis of the member, to the thickness of the segment preferably shall not be more than 12.

Art. 411 Rigid Member

The bottom chord sections in the first and second panels at each end of single track pin-connected truss spans, and the hip verticals and members with similar functions in all spans, shall be rigid.

Art. 412 Counters

If web members are subject to reversal of stress, their end connections preferably shall be riveted. Adjustable counters shall have open turnbuckles.

Art. 413 Proportioning Section of Plate Girders

Plate girders and other members subject to bending that produces net tension of one face shall be proportioned by the moment-of-inertia method, using the net section of the compression side as well as of the tension side.

Art. 414 Flange Section

The gross section of a plate girder or a rolled beam shall not be less than the gross section of the tension flange.

Flanges of plate girders preferably shall be made without cover plates or side plates unless angles of greater section than 150 mm by 150 mm by 22 mm would otherwise be required.

Cover plates shall be equal in thickness or shall diminish in thickness from the flange angles outward. No plate shall be thicker than the flange angles. When cover plates are used, at least one plate on each flange shall extend the full length of the girder. Other flange plates shall extend at least 300 mm beyond the theoretical end and there shall be enough rivets to develop the plate between its end and the theoretical end of the next plate outside. In through bridges, there shall be end and corner cover plates.

Art. 415 Flange Rivets

The flanges of plate girders shall be connected to the web with enough rivets to transmit to the flange section the horizontal shear at any point together with any load that is applied directly on the flange. Where the ties rest on the flange, one wheel load shall be assumed to be distributed over three ties.

Art. 416 Flange Splices

Flange members that are spliced shall be covered by extra material equal in section to the member spliced. There shall be enough rivets on each side of the splice to transmit to the splice material the stress value of the part cut.

Flange angles shall be spliced with angles. No two members shall be spliced at the same cross-section.

Art. 417 Web Splices

Splices in the webs of plate girders shall be designed for the full strength of the web in both shear and bending.

Art. 418 Thickness of Web Plate

The thickness of web plates shall be not less than 1/170 of the clear distance betwee the flanges.

Art. 419 Stiffeners at Points of Bearing

Stiffeners shall be placed at end bearings of plate girders and at points of bearing of concentrated loads. They shall extend as nearly as practicable to the edges of the flange angles and shall be connected to the web by enough rivets to transmit the stress. Such stiffeners shall not be crimped. Only that part of the stiffener cross-section which lies without fillet of the flange shall be considered effective in bearing.

Art. 420 Intermediate Stiffeners

If the depth of the web between the flanges or side plates of a plate girder exceeds 60 times its thicknesss, it shall be stiffened by pairs of angles riveted to the web. The clear distance between stiffeners shall not exceed 1800 mm nor that given by the formula:

$$d=\frac{2\,000t}{S}\sqrt[3]{\frac{St}{a}}$$

d=the clear distance between stiffeners in mm.

t=thickness of web in mm.

a=the clear depth of the web between flanges or side plates in mm.

S=the unit shearing stress on gross section in the web at the point considered in kg per square mm.

The width of the outstanding leg of each angle shall be not more than 16 times its thickness and not less than 50 mm plus 1/30 of the depth of the girders.

Art. 421 Bracing of Top Flanges of Through Girders

The top flange of through plate girders shall be braced at panel points by brackets with web plates. The brackets shall extend to the top flange of the main girder and be as wide as the clearance will allow. They shall be attached securely to a stiffener angle on the girder and to the top flange of the floor beam. On solid floor bridges the brackets shall be not more than 4 m apart.

Art. 422 Floor Beams

Floor beams preferably shall be square to the girders or truss.

Art. 423 End Connection Angles

The connection angles for stringers, floor beams, and beams in solid floor section shall be not less than 100 mm in width and 12 mm in finished thickness.

Art. 424 Lateral Bracing

There shall be bottom lateral bracing in all spans except deck spans less than 15 m long.

There shall be top lateral bracing in deck spans and in through spans that have enough head room.

Art. 425 Portal and Sway Bracing

In through truss spans there shall be portal bracing, with knee braces, as deep as the clearance will allow. There shall be sway bracing at the intermediate panel points if the trusses are high enough to allow a depth of 2 meters or more for such bracing. If they are not high enough to allow that depth, the top lateral struts shall be of the same depth as the chord, and there shall be knee braces as deep as the clearnace will allow.

In deck truss spans there shall be sway bracing at the panel points. The top lateral forces shall be carried to the supports by means of a complete system of bracing in the planes of the top chords and the main end posts.

Art. 426 Rigid Bracing

Lateral bracing shall be rigid and there shall be not less than three rivets in each end connection.

If the bracing is a double system and the members meet the requirements for both tension and compression members, both systems may be considered effective simultaneously.

Art. 427 Cross Frames

In deck plate girder spans there shall be cross frames at the ends and at intervals not exceeding 5 m. The end frames shall be proportioned for the centrifugal and lateral forces.

If there are two lines of stringers under each track in panels more than 6 meters in length, they shall be connected by cross frames.

Art. 428 Viaducts

Viaducts shall consist of spans supported on bents. The bents preferably shall be composed of not more than two columns braced together. They shall be united in pairs by bracing to form towers except where single bents are necessary.

The columns preferably shall be made with a transverse batter of one horizontal to six vertical for single track viaducts, and one horizontal to eight vertical for double track viaducts.

The bracing of bents and towers shall consist of double systems of rigid diagonals with struts at caps and bases and at intermediate panel points. In double track towers there shall be bracing to transmit the longitudinal force to both sides.

The bottom struts shall be proportioned for either the calculated stresses or a stress in tension or compression equal to one-fourth of the dead load reaction on one pedestal, whichever is greater. The column bearings shall be so designed to allow for the expansion and contraction of the tower bracing.

Where long spans are supported on short single bents the bents shall be made with hinged ends or else the columns and anchorage shall be proportioned for the bending stresses produced by temperature changes and the elastic deformation of the span.

(b) Detailing

Art. 429 Eye-Bars

The thickness of eye-bars shall be not less than 25 mm not more than 50 mm. The section of the head through the center of the pin-hole shall exceed that of the body of the bar at least 35 %. The form of the head shall be submitted to the engineer for approval before the bars are made. The diameter of the pins shall be not less than 8/10 of the width of the widest bars attached.

Art. 430 Eye-Bar Packing

The eye-bars of a set shall be symmetrical about the central plane of the truss and as nearly parallel as practicable. The inclination of any bar to the plane of the truss shall not exceed 1 in 200. The bars shall be packed close, held against lateral movement, and so arranged that those in the same panel will not be in contact.

Art. 431 Minimum Spacing of Rivets

The distance between centers of rivets shall be not less than three times the diameter of the rivets.

Art. 432 Edge Distance of Rivets

The distance from the center of a rivet to a sheared edge shall not be less than one and three-fourth times the diameter, nor to a rolled or planed edge less than one and one-half times the diameter except in flanges of beams and channels, where the minimum distance may be one and one-fourth times the diameter.

The distance from the center of a rivet to the edge of a plate shall not exceed eight times the thickness of the plate.

Art. 433 Sizes of Rivets in Angles

The diameter of the rivets in angles 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, 25 mm rivets may be used in 90 mm legs, 22 mm rivets in 75 mm legs, and 19 mm rivets in 65 mm legs.

Art. 434 Pitch of Rivets

The pitch in the direction of stress for members composed of plates and shapes shall not exceed seven times the diameter of the rivets except for web stitch rivets.

At the ends of built compression members, the pitch in the direction of stress shall not exceed four times the diameter of the rivets for a distance one and one-half times the width of the member.

Art. 435 Grip of Rivets

If the grip of rivets carrying calculated stress exceeds four and one-half times the diameter, the number of rivets shall be increased at least one per cent for each additional 2 mm of grip. If the grip exceeds six times the diameters, the shanks shall be specially designed to fill the holes completely when driven.

Art. 436 Stitch Rivets

Where two or more web plates are in contact, there shall be stitch rivets to make them act in unison. In compression members, the pitch of such rivets in the direction of stress shall not exceed 12 times the thickness of the thinnest outside plate connected, and the gage 24 times that thickness. In tension members, the maximum pitch or gage of such rivets shall be 24 times that thickness. In tension members composed of two angles in contact, the pitch of the stitch rivets shall not exceed 300 mm.

Art. 437 Extra Rivets

If splice plates are not in direct contact with the parts which they connect, there shall be rivets on each side of the joint in excess of the number required in the case of direct contact, to the extent of two extra lines for each intervening plate.

If rivets carrying stress pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by enough additional rivets to develop the value of the filler.

Art. 428 Compression Splices

Members subject to compression only, if faced for bearing, shall be spliced on four sides sufficiently to hold the abutting parts true to place. The splice shall be as near a panel point as practicable and shall be designed to transmit at least one-half of the stress through the splice material. Members not faced for bearing shall be fully spliced.

Art. 439 Stay Plates

On the open sides of compression member, the segments shall be connected by lacing bars and there shall be stay plates as near each end as practicable. There shall be stay plates at intermediate points where the lacing is interrupted. In main members the length of the end stay plates shall be not less than one and one-fourth times the distance between the lines of rivets connecting them to the outer flanges. The length of intermediate stay plates shall be not less than three-fourths of that distance.

The segments of tension members composed of shapes shall be stayed together. The length of the stay plates shall be not less than two-thirds of the lengths specified for stay plates on compression members. They shall be connected to each segment by at least three rivets.

The thickness of stay plates shall be not less than one-fiftieth of the distance between the lines of rivets connecting them to the outer flanges for main members, or one-sixtieth of that distance for bracing members.

Art. 440 Lacing

Lacing bars of compression members shall be so spaced that the slenderness ratio of the portion of the flange included between the lacing bar connections will be not more than 40 nor more than two-thirds of the slenderness ratio of the member.

In compression members, the shearing stress normal to the member in the plane of the lacing shall be that obtained by the following formula,

$$V=\frac{P}{100}\left(\frac{100}{l/r+10}+\frac{l/r}{100}\right)$$

V = normal shearing stress,
P = allowable compressive axial load on member,
l = length of member, in mm.
r = radius of gyration of section about the axis perpendicular to plane of lacing, in mm.

To the shear so determined shall be added any shear due to the weight of the member or to other forces, and the lacing proportioned for the combined shear.

The shear shall be considered as divided equally among all parallel plates in which there are shear resisting elements, whether continuous plates or lacing. The section of the lacing bars shall be determined by the formula for axial compression in which l is taken as the distance along the bar between its connections to the main segments for single lacing, and as 70 per cent of that distance for double lacing.

If the distance across the the member between rivet lines in the flanges is more than 380 mm and a bar with a single rivet in the connection is used, the lacing shall be double and riveted at the intersections.

The angle between the lacing bars and the axis of the member shall be approximately 45 degrees for double lacing and 60 degrees for single lacing.

Lacing bars may be shapes or flat bars. For main members the minimum thickness of flat bars shall be one-fortieth of the distance along the bar between its connections for single lacing, and one-sixtieth for double lacing. For bracing members, the limits shall be one-fiftieth for single lacing and one-seventy-fifth for double lacing.

The diameter of the rivets in lacing bars shall not exceed one-third of the width of the bar. There shall be at least two rivets in each end of lacing bars riveted to flanges more than 130 mm in width.

Art. 441 Reinforcing Plates in Pin Holes

Where necessary for the required section or bearing area, the section at pin holes shall be increased on each segment by plates so arranged as to reduce the eccentricity of the segment to a minimum. One plate on each side shall be as wide as the outstanding flanges will allow. At least one full width plate on each segment shall extend to the far edge of the stay plate and the others not less than 150 mm beyond the near edge. These plates shall be connected by enough rivets to transmit the bearing pressure and so arranged to distribute it uniformly over the full section.

Art. 442 Forked Ends

Forked ends will be permitted only when unavoidable. There shall be enough pin plates on forked ends to make the section of each jaw equal to that of the member. The pin plates shall be long enough to develop the pin plates beyond the near edge of the stay plate, but not less than the length required by Art. 441.

Art. 443 Pins

In pins more than 200 mm in diameter there shall be a hole not less than 50 mm in diameter bored longitudinally on the center line.

The turned bodies of pins shall be long enough to extend at the ends 6 mm beyond the outside faces of the parts connected. The pins shall be secured by chambered nuts or by solid nuts end washers. If the pins are bored, through rods with cap washers may be used. The screw ends shall be long enough to allow burring the threads.

Pin connected members shall be secured in such a way as to limit lateral movement on the pin. Filler rings shall be made of metal not less than 13 mm thick.

Art. 444 Expansion

The design shall be such as to allow for the changes in length of the span, resulting from changes in temperature, at the rate of ten mm in twelve meters. Provision shall be made for changes in length of the span resulting from live load stresses. In spans more than 90 m long, allowance shall be made for the expension in the floor.

Art. 445 End Bearings

In spans more than 20 m long, there shall be rollers or rockers at one end. Shorter spans shall be designed to slide on bearings with smooth surface.

Bearings and ends of spans shall be secured against lateral movement.

End bearings on masonry preferably shall be raised above the bridge seat by metal pedestal or bolsters.

Art. 446 Rollers

Expension rollers may be either cylindrical or segmental end shall be not less than 150 mm in diameter. They shall be coupled together with substantial side bars end geared to the upper and lower plates. The roller nest shall be so designed that the parts may be cleaned readily.

Art. 447 Pedestals and Shoes

Pedestals and shoes preferably shall be made of cast steel. Base plates may be rolled slabs. The difference in width between the top and the bottom bearing surfaces shall not exceed twice the vertical distance between them. For hinged bearings, this distance shall be measured from the center of the pin. In built pedestals and shoes, the web plates and the angles connecting them to the base plate shall be not less than 19 mm thick. If the size of the pedestal permits, the webs shall be rigidly connected by diaphragms. The minimum thickness of the metal in cast steel pedestals shall be 25 mm. Pedestals and shoes shall be so designed that the load will be distributed uniformly over the entire bearing surface.

In spans more than 20 meters long there shall be hinged bearings at both ends.

Art. 448 Inclined Bearings

For spans on an inclined grade and without hinged bearings, the sole plates shall be beveled so that the masonry surfaces may be made level.

Art. 449 Anchor Bolts

Anchor bolts shall be not less than 32 mm in diameter. There shall be washers under the nuts. Anchor bolt holes in pedestals and sole plates shall be 10 mm larger in diamter than the bolts and at expansion points the holes in the sole plate shall be slotted.

Anchor bolts that do not take uplift shall be long enough to extend 300 mm into the masonry. Those that do take uplift shall be designed to engage a mass of masonry the weight of which is one and one-half times the uplift.

Art. 450 Camber

The camber of trusses shall be equal to the deflection produced by the dead load plus a load of 3 200 kg per meter of track. The camber of plate girders more than 27 meters in length shall be equal to the deflection produced by the dead load only. Plate girders 27 meters or less in length and rolled beams need not be cambered.

Art. 451 Name Plates

There shall be a name plate, showing in raised letters and figures the name of the manufacturer and the year of construction, bolted to the bridge near each end at a point convenient for inspection.

PART II. MATERIALS

SECTION V. STRUCTURAL & RIVET STEEL

Art. 501 Process

Structural and rivet steel shall be made by the open-hearth process.

Art. 502 Chemical Composition

The steel shall conform to the following requirements as to chemical composition.

	Structural steel	Rivet steel
Phosphorus, per cent		
Acid	not over 0.06	not over 0.06
Basic	„ „ 0.05	„ „ 0.05
Sulphur	„ „ 0.05	„ „ 0.05

Art. 503 Ladle Analysis

An analysis of each melt of steel be made by the manufacturer to determine the percentage 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 engineer or his inspector, and if it does not conform to the requirements of Art. 502 the melt shall be rejected.

Ar. 504 Check Analysis

Analysis may be made by the engineer from fininshed material representing each melt. If the phosphorus and sulphur content thus determined exceeds that specified in Art. 502 by more than 25 per cent, the melt shall be rejected.

Art. 505 Rolled Base Plates

Rolled base plates over 50 mm in thickness, for bearing purposes, shall be of steel containing 0.20 to 0.35 per cent carbon. The chemical composition shall conform to the requirements of Art. 502. A discard shall be made from each ingot sufficient to secure sound plates. Physical tests will not be required.

Art. 506 Physical Properties

The steel shall conform to the following requirements as to physical properties, excepted as otherwise modified.

Properties considered	Structural Steel	Rivet Steel
Tensile strength, kgs/mm^2	42.00 to 50.00	36.00 to 44.00
Yield point, minimum kgs/mm^2	0.5 tens. str.	0.5 tens. str.
but in no case less than	23.00	20.00
Elongation in 200 mm, minimum per cent	$\frac{1054}{\text{Tens. str.}}$	$\frac{1054}{\text{Tens. str.}}$
Elongation in 50 mm, minimum per cent	22	....

Tension tests will not be required for flat rolled steel 5 mm and under in thickness, shapes less than 650 sq mm in section, and bars, other than flats, less than 13 mm in thickness or diameter.

Art. 507 Full Size Annealed Eye-Bars

In order to meet the requirements of Art. 804 for the physical properties of full-sized annealed eye-bars, the manufacturer of the eye-bars shall determine the physical properties required for the specimen tests. The steel shall conform to the requirements of Art. 506, 508 and 511 as to physical properties other than tensile strength.

Art. 508 Modification in Elongation

For structural steel over 19 mm in thickness or diameter, or under 8 mm in thickness deductions from the percentage of elongation in 200 mm specified in Art. 306 shall be made as follows:

over 19 mm, deduct 0.3 per cent for each 1 mm.
over 19 mm, to a minimum elongation of 18 per cent;
under 8 mm, deduct 1.6 per cent for each 1 mm under 8 mm.

Art. 509 Yield Point

The yield point shall be determined by the drop of the beam or the halt in the gage of the testing machine.

Art. 510 Speed of Testing Machine

The cross head speed of the test machine shall be such that the beam can be kept balanced, but in no case shall the values given in the following table be exceeded:

Gage length of Specimen	Maximum cross head speed in mm per minute in determining. Yield Point	Tensile Strength
50 mm	10	50
200 mm	50	150

Art. 511 Bend Tests

The test specimens for structural steel shall be bent cold through 180 degrees around a pin the diameter of which is in the following ratio to the thickness of the specimen.

Thickness of material	Ratio	Thickness of material	Ratio
up to 19 mm incl.	1/2	39 to 50 mm incl.	2-1/2
20 to 25 mm incl.	1	over 50 mm incl.	3
26 to 38 mm incl.	1-1/2		

If there is any cracking on the outside of the bent portion, the melt shall be rejected.

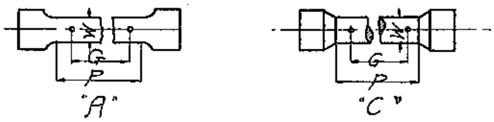
Art. 512 Test Specimen

Test specimen shall be prepared from the material in its rolled or forged condition excepting:

Test specimen for annealed material, except eye-bars shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

Tension and bend test specimen for rivet bars that have been cold drawn shall be normalized before testing.

Test specimen shall be taken that the axis coincide with the direction of rolling, and except as hereafter specified, shall be of the full thickness or diameter of the material as rolled.



TEST PIECES	THICKNESS OR DIA	MAX WIDTH	G	P	REMARKS
A	<9mm	60mm	200mm	225mm	For steel plates flats & sections
	9-23mm incl	50mm	"	"	"
	>23mm	40mm	"	"	"
C	14mm		50mm	60mm	For round test pieces only taken from forgings, axles, tyres, rails, and fostenings ets

Fig. 3. Standard Forms of Tensile Test Pieces

Test specimen for pates, shapes, and flats may be machined to the form and dimensions as shown in Standard Form of Tensile Test pieces CNRS–No. 2–25 Test Pieces "A".

Tension test specimen for materials over 33 mm in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of not less than 19 mm for a length of not less than 230 mm or they may conform to the dimensions for CNRS–No. 2–25 Test Pieces "C". Bend test specimen for materials over 38 mm in thickness or diameter, except pins and rollers, may be machined to a thickness or diameter of not less than 19 mm or to a section 26×13 mm.

Tension test specimen for pins and rollers shall conform to the dimension for CNRS–No. 2–25 Test Pieces "C" and bend test specimen shall be 25×13 mm in section. Such specimens shall be so taken that the axis is 26 mm from the surface.

The machined edges of rectangular bend test specimens may have the corners rounded to a radius of not over 1.5 mm.

Art. 513 Number of Test

Two tension and two bend tests shall be made from each melt, unless the finished material from the melt is less than 30 tons, when one tension and one bend test will be sufficient. If the material rolled from one melt varies 9 mm or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest materials regardless of the weights represented.

If the test specimen shows defective machining or invelops flaws, it may be discarded and another specimen substituted.

Art. 514 Retests

A retest shall be allowed if the percentage of elongation of any specimen is less than that specified in Art. 506 and if, in addition, any part of the fracture of a 50 mm specimen is more than 19 mm from the center of the gage length or of a 200 mm specimen is outside the middle third of the gage length as indicated by scribe marks made on the specimen before testing.

Art. 515 Finish

The finished material shall be free from injurious defects. The finish shall be workmanlike.

Art. 516 Permissible Variation in Weight & Thickness

The steel is assumed to weigh 7 850 kg per cu. meter.

The section or weight of any structural size shapes or of any universal mill plate up to and including 900 mm in width shall not differ more than 2.5 per cent from that specified. The thickness and weight of rectangular sheared plates and of rectangular universal mill plates over 900 mm in width shall not vary more than 0.2 mm in thickness under that ordered.

Art. 517 Permissible Variation in Diameter

The diameter of rivet bars shall not differ from the size ordered more than the amount given in the following table:

Diameter	Difference in mm Over	Under
Up to and including 13 mm	0.2 mm	0.2 mm
Over 13 mm and including 25 mm	0.3 mm	0.3 mm
Over 25 mm and including 50 mm	0.8 mm	0.4 mm

Art. 518 Identification Marks

The name or brand of the manufacturer and the melt number shall be stamped or rolled legibly on the finished material, except the rivet bars, lacing bars, and other small sections shall be made into bundles and the bundles marked for identification. The identification marks shall be stamped legibly on one end of each pin and roller. The melt number shall be marked legibly, by stamping if practicable, on each test specimen.

SECTION VI. CAST STEEL

Art. 601 Process

Cast steel shall be made by one or more of the following processes: open-hearth, electric furnace, converter, or crucible.

Art. 602 Annealing

Castings shall be thoroughly annealed by heating uniformly to the proper temperature to refine the grain and allowing to cool slowly and uniformly in the furnace.

Art. 603 Chemical & Physical Properties

Test specimens of cast steel shall conform to the following requirements as to chemical and physical properties:

Chemical Properties:	
Phosphorus, maximum per cent	0.06
Manganese, per cent	0.50 to 1.00
Silicon, per cent	0.20 to 0.75
Sulphur, maximum per cent	0.06
Physical Properties:	
Tensile strength minimum kg/mm^2	49.0
Yield point minimum in kg/mm^2	23.0
Elongation in 50 mm, minimum per cent	24
Reduction of Area, minimum per cent	36

Art. 604 Ladle Analysis

An analysis of each melt of steel shall be made by the manufacturer to determine the percentage of carbon, manganese, silicon, phosphorus, and sulphur. This analysis shall be made from drillings taken at least 6 mm beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the engineer and if it does not conform to the requirements of Art. 603, the melt shall be rejected.

Art. 605 Check Analysis

Check analysis may be made by the engineer from a broken tension test specimen or from a casting representing each melt. The chemical composition thus determined shall conform to the requirements of Article 603. Drillings for analysis shall be taken not less than 6 mm beneath the surface.

Art. 606 Yield Point

The yield point shall be determined by the drop of the beam or the halt in the gage of the testing machine at a cross head speed not exceeding 3 mm per minute. The tensile strength shall be determined at a cross head speed not exceeding 38 mm per minute.

Art. 607 Test Specimens

Tension test specimens shall be taken from test bar cast attached to the castings where practicable. If, in the judgement of the manufacturer, the design of the casting is such that test bars attached directly to the castings might affect the castings or the test specimens injuriously. The test bars shall be cast attached to special blocks. Test bars from which tension test specimens are to be taken shall remain sttached to the castings or blocks, through annealing and until presented for inspection. Test bars shall be provided in sufficient numbers to furnish the tests required.

Test specimens shall conform to the dimensions for CNRS–No. 2–25 Test Piece "C".

Art. 608 Number of Test

One tension test shall be made from each melt in each annealing charge and when specified, from each casting weighing 250 kgs or more. If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen from the same lot substituted.

Art. 609 Retest

A retest shall be allowed if the percentage of elongation of any specimen is lees than that specified in Art. 603 and if, in addition, any part of the fracture is more than 19 mm from the center of the gauge length as indicated by scribe mark made on the specimen before testing.

If the results of the physical tests of any lot do not conform to the requirements, the manufacturer may re-anneal such lot not more than twice and retest shall be made as specified.

Art. 610 Workmanship & Finish at Foundry

The castings shall conform substantially to the drawings and shall be made in a workmanlike manner. The castings shall be free from injurious defects.

Art. 611 Identification Marks

The name or brand of the manufacturer and the melt number shall be stamped legibly on the finished castings. The melt number shall be marked legibly, by stamping, if practicable, on each test specimen.

SECTION VII. CAST IRON

Art. 701 Process

Cast iron shall be gray iron made by the cupola process.

Art. 702 Finish

Castings shall be true to pattern and free from excessive shrinkage. They shall be free from cracks, cold shorts, blow holes, and other flaws.

Art. 703 Chemical Composition

The sulphur content of cast iron shall not exceed

For light castings	0.10 per cent
For medium castings	0.10 per cent
For heavy castings	0.12 per cent

Drillings taken from the fractured ends of the transverse test bars shall be used for the sulphur determinations. One determination shall be made from each of the two sets of test bars representing a melt.

Art. 704 Classification

Castings shall be classified as light, medium, and heavy.

a) Light castings are those with any section less than 12 mm thick.

b) Heavy castings are those with no section less than 50 mm thick.

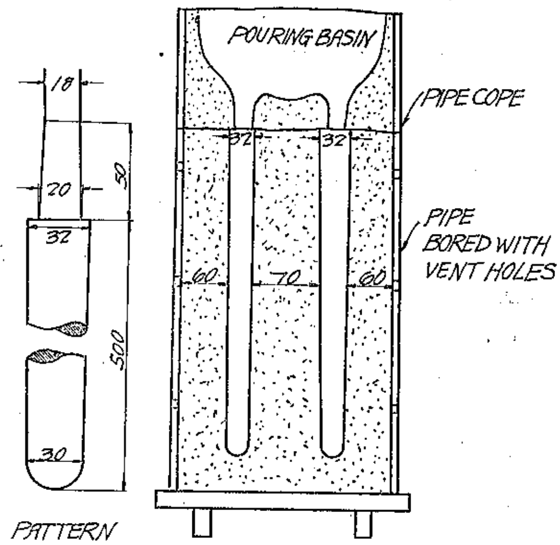
c) Medium castings are those not included in either of the above classes.

Art. 705 Test Bars

Transverse tests shall be made on the "Transverse Test Bar" (see CNRS–B–9–25)

Two sets of two bars each shall be made from each melt, one set from the first iron poured and the other set from the last iron poured. If the melt exceeds 20 tons, an additional set of two bars shall be cast from each additonal 20 tons or fraction thereof. Each set of two bars shall be cast in a single mold.

Fig. 4. Mold for Transverse Test Bar



Art. 706 Transverse Tests

A transverse test of each bar shall be made. The bar shall be placed on supports 450 mm apart and a load applied at the center.

The application of the load shall be at a rate that will produce a central deflection of 2.5 mm from 20 to 40 seconds.

One bar of each set shall conform to the following minimum requirements, otherwise the melt shall be rejected:

	Class of casting		
	Light	Medium	Heavy
Load at center, kgs	700	800	900
Deflection at center, mm	6	6	6

Art. 707 Identification Marks

There shall be marks cast on each casting in raised letters.

SECTION VIII. FULL-SIZE TESTS OF EYE-BARS

Art. 801 Eye-Bars

The acceptance of eye-bars shall depend on the results of full-size tests. The Contractor shall furnish, without charge, the testing machines, tools, and labor necessary to make the tests.

Art. 802 Number of Full-size Tests

The number and size of the bars to be tested shall be stipulated by the engineer before the mill order is placed. The number shall not exceed 5 per cent of the whole number of bars ordered, with a minimum of two bars.

Art. 803 Selection of Test Bars

Test bars shall be of the same section and with pin holes of the same size as the bars ordered and of the same length if within the capacity of the testing machine. They shall be selected by the inspector from the forged and annealed bars, except that those from bars too long for the testing machine shall be selected from the full-length bars after the heads on one end have been formed. They then shall be cut and the second head formed to make a bar of the greatest length that can be tested.

Art. 804 Physical Properties

The minimum requirements for full-size eye-bar tests shall be as follows:

Yield point, kgs/mm²	2 300
Ultimate strength, kgs/mm²	4 200
Elongation in 11 m	12 per cent

The measurement of the elongation shall be made in the part of the bar that includes the fracture.

The fracture shall be in the body of the bar. The appearance of the surface at the fracture shall be silky throughout, indicating a finely granular structure.

Art. 805 Retests

If a bar fails to meet the requirements of Art. 804, two additional bars of the same size from the same mill heat shall be tested. The bars represented by the test may be reannealed before the additional bars are tested. If two of the three bars tested fail, the bars of that size and mill heat shall be rejected.

Art. 806 Payment for Test Bars

Bars tested full-size shall be paid for by the purchaser at the same rate as the bars accepted if they meet the requirements of the specification. Bars that fail to meet the requirements and those rejected as a result of tests, shall not be paid for by the purchaser. The scrap from bars tested shall be the property of the contractor.