

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

**SPECIFICATION FOR THE
DESIGN, FABRICATION AND ERECTION
OF STRUCTURAL STEEL FOR BUILDINGS
(RIVETED, BOLTED AND ARC-WELDED CONSTRUCTION)**

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PREFACE

A specification of this type requires for completeness certain general clauses which frequently are provided in the applicable Building Code or General Specification. When so provided, the clauses in such Code or Specification shall of course govern. In the absence of such, the following clauses shall be read into, and shall form a part of, the Specification:

SCOPE.

As used throughout this Specification, the term "structural steel" refers exclusively to those items enumerated in Section 2 of the "Code of Standard Practice for Steel Buildings and Bridges" of the American Institute of Steel Construction, and nothing herein contained shall be interpreted as a recommended practice for steel joists, members formed of flat rolled sheet or strip, light-gage steel construction, skylights, marquees (except structural frame), fire escapes, or other items not specifically enumerated in that Code.

CODE.

In the execution of contracts entered into under this Specification, the "Code of Standard Practice for Steel Buildings and Bridges" of the American Institute of Steel Construction shall apply unless otherwise specified or required.

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**SPECIFICATION FOR THE
DESIGN, FABRICATION AND ERECTION
OF STRUCTURAL STEEL FOR BUILDINGS
(RIVETED, BOLTED AND ARC-WELDED CONSTRUCTION)**

This Specification defines the practice adopted by the American Institute of Steel Construction in the design, fabrication, and erection of structural steel for Buildings.

ADMINISTRATIVE PROVISIONS

SECTION 1. TYPES OF CONSTRUCTION.

Three basic types of design and design assumption are permissible, under the respective conditions stated hereinafter, and each will govern in a specific manner the sizes of members and the types and strength of their connections.

Type 1, commonly designated as "rigid-frame" (continuous, restrained frame), assumes that the end connections of all members in the frame have sufficient rigidity to hold virtually unchanged the original angles between such members and the members to which they connect.

Type 2, commonly designated as "conventional" or "simple" framing (unrestrained, free-ended), assumes that the ends of beams and girders are connected for shear only, and are free to rotate under load.

Type 3, commonly designated as "semi-rigid framing" (partially restrained), assumes that the connections of beams and girders possess a dependable and known moment capacity intermediate in degree between the complete rigidity of Type 1 and the complete flexibility of Type 2.

All connections shall be consistent in their design with the assumptions as to type of construction, as called for on the design drawings.

Type 1 construction is unconditionally permitted under this Specification. It is a necessary condition of this type that the calculated stresses and resulting strains in all members and their connections occur within the elastic range, and that the stresses do not exceed those allowed in Section 15 of this Specification.

Type 2 construction is permitted under this Specification, subject to the stipulations of the following paragraph wherever applicable. Beam-to-column connections with seats for the reactions and with top clip angles for lateral support only, are classed under Type 2.

In tier buildings, designed in general as Type 2 construction, in that the beam-to-column connections other than wind connections are flexible, the distribution of

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the wind moments, as between the several joints of the frame, may be made by a recognized empirical method provided that either:

1. The wind connections, designed to resist the assumed wind moments, are adequate to resist the moments induced by the gravity loading and the wind loading, at the increased unit stresses permitted therefor, or,
2. The wind connections, if welded and if designed to resist the assumed wind moments, are so designed that larger moments, induced by the gravity loading under the actual condition of restraint, will be relieved by deformation of the connection material without over-stress in the welds.

Type 3 (semi-rigid) construction will be permitted only upon evidence that the connections to be used are capable of resisting definite moments without overstress of the welds.* The proportioning of main members joined by such connections shall be predicated upon no greater degree of end restraint than the minimum known to be effective by the respective connections.*

Types 2 and 3 construction may necessitate some non-elastic but self-limiting deformation of a structural steel part, but under forces which do not overstress the rivets, bolts or welds.

SECTION 2. DEFINITIONS AND NOMENCLATURE, WELDED CONSTRUCTION

All terms herein relating to welds, welding and gas cutting shall be construed in accordance with the standard "Definitions of Welding Terms and Master Chart of Welding Processes" of the American Welding Society, as amended to date.

SECTION 3. PLANS AND DRAWINGS. STRESS SHEETS.

(a) Plans.

The plans (design drawings) shall show a complete design with sizes, sections, and the relative locations of the various members. Floor levels, column centers, and offsets shall be dimensioned. Plans shall be drawn to a scale large enough to convey the information adequately.

Plans shall indicate the type or types of construction (as defined in Section 1) to be employed; and shall be supplemented by such data as to the assumed loads, and the shears, moments and axial forces to be resisted by all members and their connections, as may be required for the proper preparation of the shop drawings.

(b) Shop Drawings.

Shop drawings, giving complete information necessary for the fabrication of the component parts of the structure, including the location, type, size and extent of all welds, shall be prepared in advance of the actual fabrication. They shall clearly distinguish between shop and field rivets, bolts and welds.

Shop drawings shall be made in conformity with the best modern practice and with due regard to speed and economy in fabrication and erection.

*The American Institute of Steel Construction expects to publish designs of beam-to-column connections with a statement of the experimentally determined bending resistance thereof.

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Note shall be made on the plans and on the shop drawings of those joints or groups of joints in which it is especially important that the welding sequence and technique of welding be carefully controlled to minimize locked-up stresses and distortion.

Weld lengths called for on the plans and on the shop drawings shall be the net effective lengths.

(d) Symbols for Welding.

Welding symbols used on plans and shop drawings shall preferably be the American Welding Society symbols; other adequate welding symbols may be used, provided a complete explanation thereof is shown on the plans or drawings.

SECTION 4. LOADS AND FORCES.**(a) Dead Load.**

The dead load to be assumed in design shall consist of the weight of the steelwork and all material fastened thereto or supported thereby.

(b) Live Load.

The live load, and snow load if any, shall be that stipulated by the Code under which the structure is being designed or that required by the conditions involved. In general, the live loads should not be less than those recommended in the "American Standard Building Requirements for Minimum Design Loads in Buildings and Other Structures, A58.1", latest edition.

(c) Wind.

Proper provision shall be made for stresses caused by wind both during erection and after completion of the building. The wind pressure is dependent upon the conditions of exposure and geographical location of the structure. The allowable stresses specified in Paragraphs (d) and (e) of Section 15, are based upon the steel frame being designed to carry a wind pressure of not less than twenty (20) pounds per square foot on the vertical projection of the finished structure.

(d) Other Forces.

Structures in localities subject to earthquakes, hurricanes, and other extraordinary conditions shall be designed with due regard for such conditions.

SECTION 5. WELDING.**(a) Welding.**

Welds shall be made only by operators who have been previously qualified by tests, as prescribed in the "Standard Qualification Procedure" of the American Welding Society, to perform the type of work required, except that this provision need not apply to tack welds not later incorporated into finished welds carrying calculated stress.

(b) Rivets and Bolts in Combination with Welds.

In new work, rivets or bolts in combination with welds shall not be considered as sharing the stress, and welds shall be provided to carry the entire stress for which the connection is designed.

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In making welded alterations to structures, existing rivets may be utilized for carrying stresses resulting from existing dead loads, and the welding need be adequate only to carry all additional stress.

SECTION 6. TURNED BOLTS.

Turned bolts in close fitting holes as specified in Section 33(e), may be used in shop or field work where it is impracticable to drive satisfactory rivets. The finished shank shall be long enough to provide full bearing, and washers shall be used under the nuts to give full grip when the nuts are turned tight.

The term "turned bolts", as used in this Specification, embraces all bolts regardless of the manufacturing process, which have a tolerance on the nominal diameter of 0 over, .006" under, and which have "regular semi-finished" heads conforming to "American Standard B18.2—1941" of the American Institute of Bolt, Nut and Rivet Manufacturers.

SECTION 7. ERECTION.**(a) Bracing.**

The frame of steel skeleton buildings shall be carried up true and plumb, and temporary bracing shall be introduced wherever necessary to take care of all loads to which the structure may be subjected, including equipment, and the operation of same. Such bracing shall be left in place as long as may be required for safety.

(b) Adequacy of Temporary Connections.

As erection progresses, the work shall be securely bolted up, or welded, to take care of all dead load, wind and erection stresses.

(c) Erection Stresses.

Wherever piles of material, erection equipment or other loads are carried during erection, proper provision shall be made to take care of stresses resulting from the same.

(d) Alignment.

No riveting or welding shall be done until as much of the structure as will be stiffened thereby has been properly aligned.

(e) Field Connections.

All field connections may be made with unfinished bolts, except as follows:

Rivets or welds shall be used for the following connections; except that turned bolts may be used in lieu of rivets as specified in Section 6:

Column splices in all tier structures 200 feet or more in height.

Column splices in tier structures 100 to 200 feet in height, if the least horizontal dimension is less than 40 percent of the height.

Column splices in tier structures less than 100 feet in height, if the least horizontal dimension is less than 25 percent of the height.

Connections of all beams and girders to columns and of any other beams and girders on which the bracing of columns is dependent, in structures over 125 feet in height.

Roof-truss splices and connections of trusses to columns, column splices, column bracing, knee braces and crane supports, in all structures carrying cranes of over 5-ton capacity.

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Connections for supports of running machinery, or of other live loads which produce impact or reversal.

Any other connections stipulated on the design plans.

For the purpose of this Section, the height of a tier structure shall be taken as the vertical distance from the curb level to the highest point of the roof beams, in the case of flat roofs, or to the mean height of the gable, in the case of roofs having a rise of more than $2\text{-}2/3$ in 12. Where the curb level has not been established, or where the structure does not adjoin a street, the mean level of the adjoining land shall be used instead of curb level. Penthouses may be excluded in computing the height of structure.

(f) Field Riveting.

Rivets driven in the field shall be heated and driven with the same care as those driven in the shop.

(g) Field Welding.

All field assembly and welding shall be executed in accordance with the requirements for shop fabrication, excepting such as manifestly apply to shop conditions only.

Any shop paint on surfaces adjacent to joints to be field welded shall be thoroughly removed to expose clean steel for a distance of at least 2 inches on either side of the joint.

(h) Field Painting.

All field rivets, field bolts and field welds, also all serious abrasions to the shop coat, shall be spot painted with the material used for the shop coat, or an equivalent, and all mud and other firmly attached and objectionable foreign materials shall be removed, before general field painting.

Responsibility for this touch-up and cleaning, as well as for general painting, shall be allocated in accordance with accepted local practices and this allocation shall be set forth explicitly in the contract.

SECTION 8. INSPECTION.

(a) General.

Material and workmanship at all times shall be subject to the inspection of experienced engineers representing the purchaser.

(b) Cooperation.

All inspection as far as possible shall be made at the place of manufacture, and the Contractor or Manufacturer shall cooperate with the Inspector permitting access for inspection to all places where work is being done.

(c) Rejections.

Material or workmanship not conforming to the provisions of this Specification may be rejected at any time defects are found during the progress of the work.

(d) Inspection of Welding.

The inspection of welding shall be performed in accordance with the provisions of Section 5 of the "Code for Arc and Gas Welding in Building Construction" of the American Welding Society, as amended to date.

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TECHNICAL PROVISIONS

PART I. MATERIAL

SECTION 9. MATERIAL.

(a) Structural Steel.

Structural steel shall conform to the "Standard Specifications for Structural Steel for Bridges and Buildings, Serial Designation A 7" of the American Society for Testing Materials, as amended to date.

(b) Rivet Steel.

Rivet steel shall conform to the "Standard Specifications for Structural Rivet Steel, Serial Designation A141", of the American Society for Testing Materials, as amended to date.

(c) Other Metals.

Cast steel, cast iron and other metals shall conform to the applicable Specifications of the American Society for Testing Materials, as amended to date. Cast Steel for welding shall be of a grade designated as weldable in said Specifications.

(d) Stock Material.

Stock material shall be of a quality equal to that called for by Paragraph (a). Mill test reports shall constitute sufficient record as to the material taken from stock.

Unidentified stock material, if free from surface imperfections, may be used for short sections of minor importance, or for small unimportant details, where the precise physical properties of the material would not affect the strength of the structure.

(e) Filler Metal.

Arc-Welding electrodes shall conform to the requirements of the "Specifications for Iron and Steel Arc-Welding Electrodes" of the American Welding Society, latest edition. Electrodes shall be of Classification Numbers E6010, E6011, E6012, E6013, E6020 or E6030 and shall be suitable for the positions and other conditions of intended use.

With each container of electrodes the manufacturer shall furnish instructions giving recommended voltage and amperage (and polarity if direct current) for all uses and welding positions for which the electrode is suitable.

PART II. LOADS AND STRESSES

SECTION 10. LOADS AND FORCES.

(a) Steel structures shall be designed to sustain the following loads and forces:

1. Dead Load.
2. Live Load.
3. Impact.
4. Wind and other Lateral and Longitudinal Forces.
5. Erection Loads.
6. Other Forces.

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(b) Dead Load, Live Load and Other Forces.

The dead load, live load, snow load if any, wind force and any other forces due to extraordinary conditions, to be assumed in design, shall be as specified in Section 4, unless otherwise specified in the applicable Building Code or General Specification.

(c) Impact.

For structures carrying live loads which induce impact or vibration, the assumed live load shall be increased sufficiently to provide for same.

If not otherwise specified, the increase shall be:

For supports of elevators.....	100 percent
For traveling crane support girders and their connections.....	25 "
For supports of light machinery, shaft or motor driven, not less than.....	20 "
For supports of reciprocating machinery or power driven units, not less than.....	50 "
For threaded hanger rods supporting floors and balconies.....	33½ "

(d) Crane Runway Horizontal Forces.

The lateral force on crane runways to provide for the effect of moving crane trolleys shall, if not otherwise specified, be 20 percent of the sum of the weights of the lifted load and of the crane trolley (but exclusive of other parts of the crane), applied at the top of rail one-half on each side of runway; and shall be considered as acting in either direction normal to the runway rail.

The longitudinal force shall, if not otherwise specified, be taken as 10 percent of the maximum wheel loads of the crane applied at the top of rail.

SECTION 11. MEMBERS SUBJECT TO REVERSAL OF STRESS.**(a) Section of Member.**

The sectional area of the portion between connections, of members subject to reversal of stress, need not be increased by reason of the reversal, but shall be sufficient in area and disposition to provide for the maximum compression, and the maximum tension, separately.

(b) Reinforcement at Connections.

The sectional area of members subject to loads (other than wind loads) producing alternating tensile and compressive stresses shall be augmented, at the approach to a connection, by riveting or welding on additional material, so that the augmented section shall comply with the following rule:

To the net total compressive stress, and to the net total tensile stress, add arithmetically 50 percent of the smaller of these two; and proportion the connected material, and the connecting rivets, bolts, pins or welds, for each of the two increased stresses thus separately obtained at the unit stresses prescribed in Section 15 (a).

If the reversal may be expected to occur over 100,000 times in the life of the building, the unit stresses in the connected material and in the connecting rivets, bolts, pins or welds shall not exceed 75 percent of those specified in Section 15 (a). Sharp notches, copes and other sudden changes of cross section shall be particularly avoided in and adjacent to such connections.

SECTION 12. COMBINED STRESSES.**(a) Axial and Bending.**

Members subject to both axial and bending stresses shall be so proportioned that the quantity

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \text{ shall not exceed unity, in which}$$

F_a = axial unit stress that would be permitted by this Specification if axial stress only existed.

F_b = bending unit stress that would be permitted by this Specification if bending stress only existed.

f_a = axial unit stress (actual) = axial stress divided by area of member.

f_b = bending unit stress (actual) = bending moment divided by section modulus of member.

(b) Shear with Tension or Compression.

Rivets, bolts and welds subject to shearing and externally applied tensile or compressive forces shall be so proportioned that the combined unit stress will not exceed the unit stress allowed for shear in Section 15 (a).

SECTION 13. COMPOSITE BEAMS.**(a) Definition.**

The term "composite beam" shall apply to any rolled or fabricated steel floor beam entirely encased in a poured concrete haunch at least four inches wider, at its narrowest point than the flange of the beam, supporting a concrete slab on each side without openings adjacent to the beam; provided that the top of the beam is at least $1\frac{1}{2}$ inches below the top of the slab and at least 2 inches above the bottom of the slab; provided that a good grade of stone or gravel concrete, with Portland cement, is used; and provided that the concrete haunch has adequate mesh, or other reinforcing steel, throughout its whole depth and across its soffit.

(b) Design Assumptions.

Composite beams may be figured on the assumption that:

1. The steel beam carries unassisted all dead loads prior to the hardening of the concrete, with due regard for any temporary support provided, and
2. The steel and concrete carry by joint action all loads, dead and live, applied after the hardening of the concrete.

(c) Unit Stresses.

The total tensile unit stress in the extreme fibre of the steel beam thus computed shall not exceed 20,000 pounds per square inch. (Section 15 (a)).

The maximum stresses in the concrete, and the ratio of Young's moduli, for steel and concrete, shall be as prescribed by the specifications governing the design of reinforced concrete for the structure.

(d) End Shear.

The web and the end connections of the steel beam shall be designed to carry the total dead and live load, except as this may be reduced by the provision of other proper support.

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SECTION 14. EFFECTIVE SPAN LENGTH.

(a) Simple Spans.

Beams, girders and trusses shall ordinarily be designed on the basis of simple spans whose effective length is equal to the distance between centers of gravity of the members to which they deliver their end reactions.

(b) End Restraint.

When designed on the assumption of end restraint full or partial, due to continuous, semi-continuous or cantilever action, the beams, girders and trusses, as well as the sections of the members to which they connect, shall be designed to carry the shears and moments so introduced, as well as all other forces, without exceeding at any point the unit stresses prescribed in Section 15 (a); except that some non-elastic but self-limiting deformation of a part of the connection may be permitted when this is essential to the avoidance of overstressing of a weld.

PART III. UNIT STRESSES

SECTION 15. ALLOWABLE UNIT STRESSES.

Except as provided in this Section under "Bending", under "Wind Only" and under "Wind and Other Forces" and as provided in Section 1, final paragraph, all parts of the structure shall be so proportioned that the unit stress in pounds per square inch shall not exceed the following values:

(a) Structural Steel, Rivets, Bolts and Weld Metal.

(1) TENSION.

Structural Steel, net section.....	20,000
Butt welds, section through throat.....	20,000
Rivets, on area based on nominal diameter.....	20,000
Bolts and other threaded parts, on nominal area at root of thread.....	20,000

(2) COMPRESSION.

Columns, gross section	
For axially loaded columns with values of l/r not greater than 120.....	$17,000 - 0.485 \frac{l^2}{r^2}$
For axially loaded columns (bracing and other secondary members) with values of l/r greater than 120.....	$\frac{18,000}{1 + \frac{l^2}{18,000 r^2}}$
(for main members, see Section 16 (b)).	

in which l is the unbraced length of the column, and r is the corresponding radius of gyration of the section, both in inches.

Plate Girder Stiffeners, gross section.....	20,000
Webs of Rolled Sections at toe of fillet (Crippling, see Section 26 (h)).....	24,000
Butt Welds—Section through throat (crushing).....	20,000

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(3) BENDING.

Tension on extreme fibers of rolled sections, plate girders, and built-up members.

(See Section 26 (a))..... 20,000

Compression on extreme fibers of rolled sections plate girders, and built-up members.

With $\frac{ld}{bt}$ not in excess of 600,..... 20,000

With $\frac{ld}{bt}$ in excess of 600, $\frac{12,000,000}{\frac{ld}{bt}}$

in which *l* is the unsupported length and *d* the depth, of the member; *b* is the width, and *t* the thickness, of its compression flange; all in inches; except that *l* shall be taken as twice the length of the compression flange of a cantilever beam not fully stayed at its outer end against translation or rotation.

Stress on extreme fibers of pins..... 30,000

Fiber stresses in butt welds, due to bending, shall not exceed the values prescribed for tension and compression, respectively.

Fully continuous beams and girders may be proportioned for negative moments which are maximum at interior points of support, at a unit bending stress 20 percent higher than above stated; provided that the section modulus used over supports shall not be less than that required for the maximum positive moments in the same beam or girder, and provided that the compression flange shall be regarded as unsupported from the support to the point of contraflexure.

For columns proportioned for combined axial and bending stresses, the maximum unit bending stress *F_b*, Sect. 12 (a) may be taken at 24,000 pounds per square inch, when this stress is induced by the gravity loading of fully or partially restrained beams framing into the columns.

(4) SHEARING.

Rivets..... 15,000

Pins, and turned bolts in reamed or drilled holes..... 15,000

Unfinished bolts..... 10,000

Webs of beams and plate girders, gross section..... 13,000

Weld Metal

on section through throat of fillet weld, or on faying surface area of plug or slot weld..... 13,600

on section through throat of butt weld..... 13,000

(Stress in a fillet weld shall be considered as shear on the throat, for any direction of applied stress. Neither plug nor slot welds shall be assigned any values in resistance to stresses other than shear.)

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(5) BEARING.	Double Shear	Single Shear
Rivets.....	40,000	32,000
Turned bolts in reamed or drilled holes.....	40,000	32,000
Unfinished bolts.....	25,000	20,000
Pins.....	32,000	
Contact Area		
Milled Stiffeners and Other Milled Surfaces....	30,000	
Fitted Stiffeners.....	27,000	
Expansion rollers and rockers (pounds per linear inch).....	600d	
in which d is diameter of roller or rocker in inches.		

(b) Cast Steel.

Compression and Bearing, same as for Structural Steel.

Other Unit Stresses, 75 percent of those for Structural Steel.

(c) Masonry Bearing.

Granite.....	800
Sandstone and Limestone.....	400
Portland Cement Concrete, unless otherwise specified	600
Hard Brick in Cement Mortar.....	250

(d) Wind Only.

Members subject only to stresses produced by wind forces may be proportioned for unit stresses 33-1/3 percent greater than those specified for dead and live load stresses. A corresponding increase may be applied to the allowable unit stresses in their connecting rivets, bolts or welds.

(e) Wind and Other Forces.

Members subject to stresses produced by a combination of wind and other loads may be proportioned for unit stresses 33-1/3 percent greater than those specified for dead and live load stresses, provided the section thus required is not less than that required for the combination of dead load, live load, and impact (if any). A corresponding increase may be applied to the allowable unit stresses in their connecting rivets, bolts or welds.

(f) Effective Areas of Weld Metal.

The effective area of butt and fillet welds shall be considered as the effective length of weld times the effective throat thickness.

The effective shearing area of plug and slot welds shall be considered as the nominal cross-sectional area of the hole or slot, in the plane of the faying surface.

The effective area of fillet welds in holes and slots shall be computed as above specified for fillet welds, using for the effective length, the length of center line of the weld through the center of the plane through the throat. However, in the case of overlapping fillets, the effective area shall not exceed the nominal cross-sectional area of the hole or slot, in the plane of the faying surface.

The effective length of a fillet weld shall be the overall length of full-size fillet, including returns.

The effective length of a butt weld shall be the width of the part joined, when ends of the weld are made as specified in Section 33 (m), final paragraph. A transverse

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skewed butt weld shall not be assumed in computations to be longer than the width of the joint or piece perpendicular to the direction of stress.

The effective throat thickness of a fillet weld shall be the shortest distance from the root to the face of the diagrammatic weld. (The effective throat thickness of an equal leg 45° fillet weld is 0.707 times the nominal size of the weld.)

The effective throat thickness of a complete-penetration butt weld (i. e., a butt weld conforming to the requirements of Section 33 (m), 2nd paragraph) shall be the thickness of the thinner part joined.

The effective throat thickness of an incomplete-penetration butt weld (i. e., a butt weld not conforming to the requirements of Section 33 (m), 2nd paragraph, but conforming to same Section 3rd paragraph) shall, for design purposes, be considered as 75 percent of the thickness of the thinner part joined.

PART IV. DESIGN

SECTION 16. SLENDERNESS RATIO.

(a) The ratio of unbraced length to least radius of gyration $\frac{l}{r}$ for compression members and for tension members other than rods shall not exceed:

For main compression members.....	120
For bracing and other secondary members in compression.....	200
For main tension members.....	240
For bracing and other secondary members in tension.....	300

(b) The slenderness of a main compression member may exceed 120, but not 200, provided that it is not ordinarily subject to shock or vibratory loads and provided that its unit stress under full design loading shall not exceed the following fraction of that stipulated under Section 15 (a)(2) for its actual ratio l/r :

$$1.6 - \frac{l}{200 r}$$

SECTION 17. DEPTH RATIO.

(a) Simple Spans.

The depth of beams and girders in floors shall if practicable be not less than 1/24 of the span, and where subject to shocks or vibrations not less than 1/20. If members of less depth are used, the unit stress in bending shall be decreased in the same ratio as the depth is decreased from that above recommended.

The depth of roof purlins shall if practicable be not less than 1/24 of the span, and in no case less than 1/30 of the span, except in the case of corrugated sheeting roofs, with a slope not less than $4\frac{3}{4}$ in 12.

Beams and girders supporting plastered ceilings shall if practicable be so proportioned that the maximum live load deflection will not exceed 1/360 of the span.

(b) Restrained and Continuous Spans.

Minimum depth-ratios for restrained and continuous spans shall if practicable be such that the deflections at critical points will be not greater than those of simple spans of the minimum depth-ratio recommended under Paragraph (a).

(c) Secondary Tension Members.

The horizontal projection of the length of bracing and secondary members in tension, other than rods, shall if practicable not exceed 90 times the depth.

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SECTION 18. MINIMUM THICKNESS OF MATERIAL.***(a) General.**

The minimum thicknesses required for protection against crippling, buckling, and shear are prescribed in Paragraphs (b) and (c) of this section and in Paragraph (b) of Section 26, respectively. Those stipulations assume that the material is straight and true as erected, within the limits prescribed in Section 33 (q), and is not reduced by corrosion.

No further stipulations as to minimum thickness shall apply to steelwork exposed to conditions no more seriously corroding than an indoor atmosphere controlled for human comfort, subject always to the requirements of Section 34 (a).

The following stipulations (1) and (2) as to minimum thickness shall apply to exterior steelwork enclosed in a non-impervious envelope or exposed to frequent rain or snow, and to interior steelwork subject to atmospheric exposure more corrosive than that mentioned in the preceding paragraph:

- (1) Columns, studs, lintels, girders and beams; exterior trusses, exterior bracing members; one-fourth inch minimum.
- (2) Purlins, girts, trusses and bracing members sheltered from direct exposure to rain and snow; three-sixteenths inch minimum.

The controlling thickness of rolled shapes, for the purposes of stipulations (1) and (2), shall be taken as the mean thickness of their flanges, regardless of web thickness.

Steelwork exposed to industrial fumes or vapor shall be given special protection as required in the judgment of the Engineer.

(b) Projecting Elements Under Compression.

Projecting elements of members subjected to axial compression or compression due to bending shall have ratios of width to thickness not greater than the following:

Single angle struts; 12.

Double-angle struts; angles or plates projecting from girders, columns or other compression members; compression flanges of beams; stiffeners on plate girders; flanges or stems of tees; 16.

The width of plates shall be taken from the free edge to the first row of rivets or welds; the width of legs of angles, channels and zees, and of the stems of tees, shall be taken as the full nominal dimension; the width of flanges of beams and tees shall be taken as one-half the full nominal width. The thickness of a sloping flange shall be measured halfway between a free edge and the corresponding face of the web.

When a projecting element exceeds the width-to-thickness ratio prescribed in the preceding paragraph, but would conform to same and would satisfy the stress requirements with a portion of its width considered as removed, the member will be considered acceptable without the actual removal of the excess width.

(c) Compression Members.

In compression members the unsupported width of web, cover or diaphragm plates between the nearest lines of rivets or welds, or between the roots of the flanges in case of rolled sections, shall not exceed 40 times the thickness.

When the unsupported width exceeds this limit, but a portion of its width no greater than 40 times the thickness would satisfy the stress requirements, the member will be considered acceptable.

The unsupported width of cover plates perforated with a succession of access holes, only the least net width across holes being assumed available to resist compression, may exceed 40, but shall not exceed 50, times the thickness.

*Revised June 23, 1949

SECTION 19. GROSS AND NET SECTIONS.**(a) Definitions.**

The gross section of a member at any point shall be determined by summing the products of the thickness and the gross width of each element as measured normal to the axis of the member. The net section shall be determined by substituting for the gross width the net width computed in accordance with paragraphs (c) to (g) of this Section.

(b) Application.

Unless otherwise specified, tension members shall be designed on the basis of net section. Columns shall be designed on the basis of gross section. Beams and girders shall be designed in accordance with Section 26 (a).

In determining the net section across plug or slot welds the weld metal shall not be considered as adding to the net area.

(c) Net Width.

In the case of a chain of holes extending across a part in any diagonal or zigzag line, the net width of the part shall be obtained by deducting from the gross width the sum of the diameters of all the holes in the chain, and adding, for each gage space in the chain, the quantity

$$\frac{s^2}{4g} \text{ where}$$

s = longitudinal spacing (pitch) in inches of any two successive holes.

g = transverse spacing (gage) in inches of the same two holes.

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

(d) Angles.

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

(e) Splice Members.

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

(f) Size of Holes.

In computing net area the diameter of a rivet hole shall be taken as $\frac{1}{8}$ inch greater than the nominal diameter of the rivet.

(g) Pin Holes.

In pin connected tension members, other than forged eyebars, the net section across the pin hole, transverse to the axis of the member, shall be not less than 135 percent, and the net section beyond the pin hole, parallel with the axis of the member, not less than 90 percent, of the net section of the body of the member.

In all pin-connected riveted members the net width across the pin hole, transverse to the axis of the member, shall not exceed 8 times the thickness of the member at the pin, unless lateral buckling is prevented.

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SECTION 20. EXPANSION.**(a) Transverse Expansion.**

No provision for transverse expansion in structures need be made in wall bearing spans of 50 feet and under. Wall bearing spans of over 50 feet and up to and including 100 feet shall slide on smooth surfaces at one end. Wall bearing spans of over 100 feet shall have expansion rollers or rockers at one end. Expansion ends shall be secured against lateral movement; fixed ends against movement in any direction.

(b) Longitudinal Expansion.

Provision shall be made for longitudinal expansion of the structure. All expansion provisions shall be figured for 100 degrees F. variation in temperature and for a coefficient of expansion of 0.0000065 per degree per unit of length. Expansion joints in buildings having masonry wall enclosures shall be so spaced as to inhibit visible cracking of the walls.

SECTION 21. CONNECTIONS.**(a) Minimum Connections.**

Connections carrying calculated stresses, except for lacing, sag bars, and girts, shall be designed for not less than 10,000 pounds, if welded; or if riveted or bolted, shall have no fewer than two rivets or two bolts.

(b) Eccentric Connections.

Members meeting at a point shall have their gravity axes meet at a point if practicable; if not, provision shall be made for bending stresses due to the eccentricity.

(c) Placement of Rivets and Welds.

The rivets or welds at the ends of any member transmitting stresses into that member should preferably have their centers of gravity on the gravity axis of the member; otherwise, provision shall be made for the effect of the resulting eccentricity. Pins may be so placed as to counteract the effect of bending due to dead load.

(d) Unrestrained Members.

Except as otherwise indicated by the designer, all connections of beams, girders or trusses shall be designed as flexible, and may ordinarily be proportioned for the reaction shears only. If, however, the eccentricity of the connection is excessive, provision shall be made for the resulting moment.

Flexible beam connections shall permit the ends of the beam to rotate sufficiently to accommodate its deflection by providing for a horizontal displacement of the top flange as determined as follows:

$$e = .007d \text{ if the beam is designed for full uniform load and for live load deflection not exceeding } 1/360\text{th of the span (see Section 17 (a));}$$

$$\text{or } e = \frac{f L}{3,625,000} \text{ if the beam is designed for full uniform load producing the unit stress } f \text{ at mid span;}$$

where e = the horizontal displacement between the top and bottom of the beam at its end, in inches.

f = the flexural unit stress in the beam at mid span; p.s.i.

d = the depth of the beam, in inches.

L = the span of the beam, in feet.

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(e) Restrained Members.

When beams, girders or trusses are subject both to reaction shear and end moment, due to full or partial end restraint, or to continuous or cantilever construction, their connections shall conform to the requirements of Section 12 (b).

(f) Fillers.

In riveted construction, when rivets carrying computed stress pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by enough rivets to distribute the total stress in the member uniformly over the combined sections of the member and filler.

Fillers under the stiffeners on riveted plate girders, at end bearings or at points of concentrated loads, shall be secured by sufficient rivets to prevent excessive bending and bearing stresses.

In welded construction, when a filler is used between two parts connected in shear, there shall be sufficient welding to transfer the shearing stress from one part to the filler and from the filler to the other part. Fillers of less than $\frac{1}{4}$ inch thickness shall not be used to transfer stress, but shall be trimmed flush with the welded edges of the stress-carrying element and the sizes of the welds along the edges shall be increased over the required sizes by an amount equal to the thickness of the filler.

(g) Connections of Tension and Compression Members in Trusses.

The connections at ends of tension or compression members in trusses shall either develop the full effective strength of the material, or they shall develop the strength required by the total stresses; but in no case shall such strength developed be less than 50 percent of the effective strength of the material connected.

(h) Milled Joints in Compression Members.

Where compression members are in full-milled bearing on base plates, and where full-milled tier-building columns are spliced, there shall be sufficient rivets, bolts or welds to hold all parts securely in place.

Where other compression members are spliced by full-milled bearing, the splice material and its riveting or welding shall be arranged to hold all parts in line and shall be proportioned for 50 percent of the computed stress.

All the foregoing joints shall be proportioned to resist any tension that would be developed by specified wind forces acting in conjunction with 75 percent of the calculated dead load stress and no live load, if this condition will produce more tension than with full dead load and live load applied.

(i) Combinations of Welds.

If two or more of the general types of weld (butt, fillet, plug, slot) are combined in a single joint, the effective capacity of each shall be separately computed with reference to the axis of the group, in order to determine the allowable capacity of the combination.

SECTION 22. RIVETS AND BOLTS.**(a) Diameter.**

In proportioning and spacing rivets, the nominal diameter of the undriven rivet shall be used.

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(b) Effective Bearing Area.

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

(c) Double and Single Shear Bearing.

Only that portion of a rivet or bolt shall be considered in double shear bearing, which lies between two portions which share the reaction therefrom. The remainder of the rivet or bolt shall be considered in single shear bearing.

(d) Long Grips.

Rivets which carry calculated stress, and the grip of which exceeds five diameters, shall have their number increased 1 percent for each additional $\frac{1}{16}$ inch in the rivet grip. Special care shall be used in heating and driving such rivets.

(e) Unfinished Bolts.

If unfinished bolts are provided with washers under nuts, and have unthreaded shanks extending completely through the joined parts, the shearing and bearing values elsewhere prescribed for unfinished bolts may be increased one-eighth.

SECTION 23. SPACING OF RIVETS.**(a) Minimum Pitch.**

The minimum distance between centers of rivet holes shall preferably be not less than three times the diameter of the rivet.

(b) Maximum Pitch in Compression Members.

The maximum pitch in the line of stress of compression members composed of plates and shapes shall not exceed 16 times the thickness of the thinnest outside plate or shape, nor 20 times the thickness of the thinnest enclosed plate or shape, with a maximum of 12 inches.

At right angles to the direction of stress, the distance between lines of rivets shall not exceed 32 times the thickness of the thinnest plate where there is more than one ply. For angles in built-up sections with two gage lines, with rivets staggered, the maximum pitch in the line of stress in each gage line shall not exceed 24 times the thickness of the thinnest plate with a maximum of 18 inches.

(c) End Pitch in Compression Members.

The pitch of rivets at the ends of built compression members shall not exceed four diameters of the rivets for a length equal to $1\frac{1}{2}$ times the maximum width of the member.

(d) Two-Angle Members.

In tension members composed of two angles, a pitch of 3' 6" will be allowed, and in compression members, 2' 0", but the ratio l/r for each angle between rivets shall be not more than $\frac{3}{4}$ of that for the whole member.

(e) Minimum Edge Distance.

The minimum distance from the center of any punched rivet hole to any edge shall be that given in Table I.

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TABLE I

Rivet Diameter, Inches	Minimum Edge Distance (Inches) for Punched Holes		
	In Sheared Edge	In Rolled Edge of Plates	In Rolled Edge of Structural Shapes
$\frac{1}{2}$	1	$\frac{7}{8}$	$\frac{3}{4}$ *
$\frac{5}{8}$	$1\frac{1}{8}$	1	$\frac{7}{8}$ *
$\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{8}$	1 *
$\frac{7}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{8}$ *
1	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$ *
$1\frac{1}{8}$	2	$1\frac{3}{4}$	$1\frac{1}{2}$ *
$1\frac{1}{4}$	$2\frac{1}{4}$	2	$1\frac{3}{4}$ *

*May be decreased $\frac{1}{8}$ inch when holes are near end of beam.

(f) Minimum Edge Distance in Line of Stress.

The distance from the center of any rivet under computed stress, and that end or other boundary of the connected member toward which the pressure of the rivet is directed, shall be not less than the shearing area of the rivet shank (single or double shear respectively) divided by the plate thickness.

This end distance may however be decreased in such proportion as the stress per rivet is less than that permitted under Section 15 (a); and the requirement may be disregarded in case the rivet in question is one of three or more in a line parallel to the direction of stress.

(g) Maximum Edge Distance.

The maximum distance from the center of any rivet to the near edge shall be 12 times the thickness of the plate, but shall not exceed 6 inches.

SECTION 24. WELDS.**(a) Types of Welds.**

Butt, fillet, plug or slot welds, or a combination of these types, may be used in making joints and joining component parts.

(b) Qualification of Weld Details.

The details of all joints (including for butt welds the groove form, root face, root spacing, etc. etc.) to be employed under this specification without qualification shall comply with all of the requirements for joints which are accepted without qualification test under the "Code for Arc and Gas Welding in Building Construction" of the American Welding Society. No joint form not included in the foregoing shall be employed until it shall have been qualified to the satisfaction of the Engineer in accordance with the "Standard Qualification Procedure" of the American Welding Society.

(c) Minimum Size of Fillet Welds.

The relation between weld size and the maximum thickness of material on which various sizes of fillet welds may be used shall, where practicable, conform to the following table:

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Size of Fillet Inches	Maximum Thickness of Part Inches
$\frac{3}{16}$	$\frac{1}{2}$
$\frac{1}{4}$	$\frac{3}{4}$
$\frac{5}{16}$	$1\frac{1}{4}$
$\frac{3}{8}$	2
$\frac{1}{2}$	6
$\frac{5}{8}$	Over 6

(d) Maximum Effective Size of Fillet Welds.

The maximum size of a fillet weld that may be assumed in the design of a connection shall be such that the stresses in the adjacent base material do not exceed the values allowed in Section 15 (a).

The maximum size fillet weld applied to a nominally square edge of plate or shape shall be $\frac{1}{8}$ inch less than the nominal thickness of the edge, and the size of fillet weld used along the toe of an angle or the rounded edge of a flange shall not exceed three-fourths the nominal thickness of the angle leg or three-fourths the nominal edge thickness of the flange; except that when required by the design conditions and specially designated on the drawings, fillet welds equal in size to the edge of a plate or rolled section may be used, provided that the weld is built out in such a manner as to insure full throat thickness, full fusion area, and no injury to the base metal that will reduce its thickness adjacent to the weld.

(e) Length of Fillet Welds.

The minimum effective length of a strength fillet weld shall be not less than four times the nominal size, or else the size of the weld shall be considered not to exceed one-fourth of its effective length.

The effective length of any segment of intermittent fillet welding shall be not less than four times the weld size with a minimum of $1\frac{1}{2}$ inches.

If longitudinal fillet welds are used alone in end connections, the length of each fillet weld shall be not less than the perpendicular distance between them.

(f) End Returns of Fillet Welds.

Side or end fillet welds terminating at ends or sides, respectively, of parts or members shall, wherever practicable, be returned continuously around the corners for a distance not less than twice the nominal size of the weld. This provision shall apply to side and top fillet welds connecting brackets beam seats and similar connections, at the tension side of such connections, on the plane about which bending moments are computed. End returns shall be indicated on the design and detail drawings.

(g) Plug and Slot Welds.

Plug or slot welds, or fillet welds in holes or slots, may be used in plates not more than one inch thick, where subjected principally to shearing stresses or where needed to prevent buckling of lapped parts.

The diameter of the holes for plug welds and the width of slot welds shall be not less than the thickness of the part containing the hole or slot, plus $\frac{5}{16}$ inch rounded to the next greater odd sixteenth. The diameter of plug welds and the width of slot welds shall not be greater than 3 times the thickness of the weld metal.

The maximum length of slot welds shall not exceed 10 times the thickness of the part containing the slot.

SECTION 25. SPACING OF WELDS.**(a) Longitudinal Fillet Welds.**

The transverse spacing of longitudinal fillet welds used in end connections shall not exceed 8 inches, unless the design otherwise prevents excessive transverse bending in the connection.

(b) Intermittent Fillet Welds.

Intermittent fillet welds may be used to transfer calculated stress across a joint or faying surfaces when the strength required is less than that developed by a continuous fillet weld of the smallest practical size. The clear spacing in the direction of stress, between the effective lengths of such segments at the edges of plates and at the unsupported edges of rolled shapes carrying calculated stress, shall not exceed the following number times the thickness of the thinner part joined: for compression, 16; for tension, 24; and shall in no case be more than 12 inches. The effective length of longitudinal fillet welds at the ends of built-up members shall be not less than the width of the component part joined.

(c) Lap Joints.

The minimum width of laps, on lap joints, shall be five times the thickness of the thinner part joined and not less than 1 inch. Lap joints joining plates or bars subjected to axial stress shall be fillet welded along the edge of both lapped parts except where deflection of the lapped parts is sufficiently restrained to prevent opening of the joint under maximum loading.

(d) Slot Welds.

The clear distance from the edge of a slot to the adjacent edge of the slotted part, and the clear distance between adjacent slots, measured in a direction perpendicular to that of the main stress, shall be not less than five times the thickness of the slotted part nor less than twice the width of the slot.

(e) Stitch Welds.

If two or more plates or rolled shapes are used to build up a member, sufficient stitch welding (of the fillet, plug or slot type) to make the parts act in unison shall be provided as follows, except where transfer of calculated stress between the parts joined requires closer spacing.

1. For plates, the longitudinal clear spacing between stitch welds shall not exceed the provisions of paragraph (b) of this section and the transverse spacing shall not exceed 32 times the thickness of the thinner plate joined.
2. For members composed of two or more rolled shapes, in contact one with another, the longitudinal spacing of stitch welds shall not exceed 24 inches or the limits prescribed in (3).
3. For members composed of rolled shapes, separated one from the other by a gusset plate, the component parts shall be stitched together at intervals such that the critical ratio l/r , for each component, between stitching, shall not exceed three-fourths the critical ratio for the whole member.

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SECTION 26. PLATE GIRDERS AND ROLLED BEAMS.**(a) Proportioning.**

Riveted and welded plate girders, cover-plated beams, and rolled beams shall in general be proportioned by the moment of inertia of the gross section. No deduction shall be made for standard shop or field rivet holes in either flange; except that in special cases where the reduction of the area of either flange by such rivet holes, calculated in accordance with the provisions of Section 19, exceeds 15 percent of the gross flange area, the excess shall be deducted. If such members contain other holes, as for bolts, pins, countersunk rivets, or plug or slot welds, the full deduction for such holes shall be made. The deductions thus applicable to either flange shall be made also for the opposite flange if the corresponding holes are there present.

(b) Web.

Plate girder webs shall have a thickness of not less than $1/170$ of the unsupported distance between flanges.

(c) Flanges.

The thickness of outstanding parts of flanges shall conform to the requirements of Section 18 (b).

Each flange of welded plate girders should in general consist of a single plate rather than two or more plates superimposed. The single plate may comprise a series of shorter plates, laid end to end and butt welded at their junctions.

Unstiffened cover plates on riveted girders shall not extend more than 16 times the thickness of the thinnest outside plate beyond the outer row of rivets connecting them to the angles. The total cross-sectional area of cover plates of riveted girders shall not exceed 70 percent of the total flange area.

If the girder is subjected to substantial fluctuations in loading, stiffeners, lateral plates or other appurtenant material shall not be welded to the tension flange, except at points where the maximum flange stress is less than half the allowable.

(d) Flange Development.

Rivets and welds connecting flange to web, or cover plates to flange, shall be proportioned to resist the maximum horizontal shear at the plane in question, resulting from the bending forces on the girder. Additionally, rivets and welds connecting flange to web shall be proportioned to transmit any loads applied directly to the flange.

(e) Stiffeners.

Bearing stiffeners shall be placed in pairs on the webs of plate girders at unframed ends and at points of concentrated loads. Such stiffeners shall have a close bearing against the loaded flanges, and shall extend as closely as possible to the edge of the flange plates or flange angles. They shall be designed as columns subject to the provisions of Section 15 (a); assuming the column section to comprise the pair of stiffeners and a centrally located strip of the web equal to not more than 25 times its thickness at interior stiffeners or a strip equal to not more than 12 times its thickness when the stiffeners are located at the end of the web. The column length shall be taken as not less than $\frac{3}{4}$ of the length of the stiffeners in computing the ratio l/r . Only that portion of the stiffener outside of the angle fillet or the flange-to-web welds shall be considered effective in bearing. Angle bearing stiffeners shall not be crimped.

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If $\frac{h}{t}$ is equal to or greater than 70, intermediate stiffeners shall be required at all points where v exceeds $\frac{64,000,000}{(h/t)^2}$, in which

h = the clear depth between flanges, in inches.

t = the thickness of the web, in inches.

v = the greatest unit shear in the panel, in pounds per square inch, under any condition of complete or partial loading.

The clear distance between intermediate stiffeners, when stiffeners are required by the foregoing, shall not exceed 84 inches or that given by the formula

$$d = \frac{11,000 t}{\sqrt{v}} \quad \text{where}$$

d = the clear distance between stiffeners, in inches.

Intermediate stiffeners may be applied in pairs, one on each side of the web, or if preferred may alternate on opposite side of the web.

Intermediate angle stiffeners may be crimped over the flange angles. Intermediate stiffeners employed to stay the web plate against buckling, and not for the transfer of concentrated loads from flange to web, shall be of a section not less than that required by the formula

$$I_s = 0.00000016 H^4, \text{ in which}$$

H = total depth of web.

I_s = moment of inertia of the stiffeners or stiffener (figured with a common axis at the centerline of web for stiffeners in pairs and with the axis at the interface between stiffener and web for single stiffeners).

Rivets connecting stiffeners to the girder web shall be spaced not over 8 times their diameter, or more closely if so required in order to transmit the stress due to concentrated loads. If intermittent fillet welds are used, their spacing shall conform to the provisions of Section 25 (b).

(f) Splices.

Web splices in plate girders and in beams shall be proportioned to transmit the full shearing and bending stresses in the web at the point of splice. Web splices in welded girders shall preferably be complete penetration butt welds.

If the flanges are spliced, the splices shall either develop the full effective strength of the material or they shall develop the strength required by the total stresses, but in no case shall the strength developed be less than 50 percent of the effective strength of the material spliced, nor shall butt-welded joints be only partially welded.

(g) Horizontal Forces.

The flanges of plate girders supporting cranes or other moving loads shall be proportioned to resist the horizontal forces produced by such loads. (See Section 10 (d)).

(h) Web Crippling of Beams.

Rolled beams shall be so proportioned that the compressive stress at the web toe of the fillets, resulting from concentrated loads not supported by bearing stiffeners,

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shall not exceed the value of 24,000 pounds per square inch allowed in Section 15 (a).

The governing formulas shall be

$$\text{For interior loads } \frac{R}{t(N + 2k)} = \text{not over 24,000}$$

$$\text{For end-reactions } \frac{R}{t(N + k)} = \text{not over 24,000}$$

where

R = concentrated interior load or end reaction, in pounds.

t = thickness of web, in inches.

N = length of bearing, in inches.

k = distance from outer face of flange to web toe of fillet, in inches.

SECTION 27. SEPARATORS.

(a) Separators.

Where two or more rolled beams or channels are used to form a girder, they shall be connected together at intervals of not more than 5 feet. Through-bolts and separators may be used provided that in beams having a depth of 12 inches or more, no fewer than 2 bolts shall be used with each separator. When concentrated loads are carried from one beam to the other, or distributed between the beams, diaphragms shall be used, designed with sufficient stiffness to distribute the load. Where beams are exposed, they shall be sealed against corrosion of interior surfaces, or spaced sufficiently far apart to permit cleaning and painting.

SECTION 28. TIE PLATES.

(a) Compression Members.

The open sides of compression members built up from plates or shapes shall be provided with lacing having tie plates at each end, and at intermediate points if the lacing is interrupted. Tie plates shall be as near the ends as practicable. In main members carrying calculated stress the end tie plates shall have a length of not less than the distance between the lines of rivets or welds connecting them to the segments of the member, and intermediate ones of not less than one-half of this distance. The thickness of tie plates shall be not less than one-fiftieth of the distance between the lines of rivets or welds connecting them to the segments of the members. In riveted construction, the rivet pitch in tie plates shall be not more than six diameters and the tie plates shall be connected to each segment by at least three rivets. In welded construction, the welding on each line connecting a tie plate shall aggregate not less than one-third the length of the plate.

(b) Tension Members.

Tie plates shall be used to secure the parts of tension members built up from plates or shapes. They shall have a length not less than two-thirds of the length specified for tie plates in compression members. Otherwise they shall conform to the requirements of Section 28 (a).

SECTION 29. LACING.**(a) Spacing.**

Lacing bars (which term comprehends for the purposes of this Section flat bars, angles, channels or other shapes employed as lacing) of compression members shall be so spaced that the ratio l/r of the flange included between their connections shall be not over $\frac{3}{4}$ of the critical ratio for the member as a whole.

(b) Proportioning.

Lacing bars shall be proportioned to resist a shearing stress normal to the axis of the member equal to two percent of the total compressive stress in the member.

Lacing bars shall preferably be arranged in single system, for which the ratio l/r shall not exceed 140. For double lacing this ratio shall not exceed 200. Double lacing bars shall be joined at their intersections.

In determining the section required for lacing bars, the compression formula shall be used, l being taken as the unsupported length of the lacing bar between rivets or welds connecting it to the segments, for single lacing, and 70 percent of that distance for double lacing.

(c) Inclination.

The inclination of lacing bars to the axis of the member shall preferably be not less than 60 degrees for single lacing and 45 degrees for double lacing. When the distance between the lines of rivets or welds in the flanges is more than 15 inches, the lacing shall preferably be double or be made of angles.

(d) Perforated Cover Plates.

The function of tie plates and lacing may be assumed to be performed by the material in continuous cover plates perforated with a succession of access holes, the net width of which plates across holes is assumed available to resist axial stress, provided that: the ratio of length (in direction of stress) to width of hole shall not exceed 2; the clear distance between holes in the direction of stress shall be not less than the transverse distance between nearest lines of connecting rivets or welds; and the periphery of the holes at all points shall have a minimum radius of $1\frac{1}{2}$ inches.

SECTION 30. CAMBER.**(a) Shown on Plans.**

Cambering, if any, of trusses, beams or girders shall be called for on the design plans.

(b) Trusses and Girders.

Trusses of 80 feet or greater span should generally be cambered for approximately the dead load deflection. Crane girders of 75 feet or greater span should generally be cambered for approximately the dead and half live load deflection.

(c) Beams.

Specified camber for rolled beams over 15 inches in depth, shall be only that offered as cold cambering at the mill.

(d) Camber for Other Trades.

If camber is required in order to bring a loaded member into proper relation with the work of other trades, as for the attachment of runs of sash, the requirements shall be set forth on the plans and on the detail drawings.

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(e) Erection.

Required camber of trusses shall be shown on the erection diagram. If camber involves the erection of any member under a straining force, this shall be noted on the erection diagram.

SECTION 31. COLUMN BASES.**(a) Loads.**

Proper provision shall be made to transfer the column loads, and moments if any, to the footings and foundations.

(b) Alignment.

Column bases shall be set level and to correct elevation with full bearing on the masonry.

(c) Finishing.

Column bases shall be finished to accord with the following requirements:

1. Rolled steel bearing plates, 2 inches or less in thickness, may be used without planing, provided a satisfactory contact bearing is obtained; rolled steel bearing plates, over 2 inches but not over 4 inches in thickness, may be straightened by pressing; or, if presses are not available, by planing on all bearing surfaces, to obtain a satisfactory contact bearing; rolled steel bearing plates, over 4 inches in thickness, shall be planed on all bearing surfaces (except as noted under 3).
2. Column bases other than rolled steel bearing plates shall be planed on all bearing surfaces (except as noted under 3).
3. The bottom surfaces of bearing plates and column bases which rest on masonry foundations and are grouted to insure full bearing contact need not be planed.

SECTION 32. ANCHOR BOLTS.**Anchor Bolts.**

Anchor bolts shall be designed to provide resistance to all conditions of tension and shear at the bases of columns, including the net tensile components of any bending moments which may result from fixation or partial fixation of columns.

PART V. FABRICATION**SECTION 33. WORKMANSHIP.****(a) General.**

All workmanship shall be equal to the best practice in modern structural shops.

(b) Straightening.

All material shall be clean and straight. If straightening or flattening is necessary, it shall be done by a process and in a manner that will not injure the material. Sharp kinks or bends shall be cause for rejection.

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(c) Gas Cutting.

The use of a cutting torch is permissible if the metal being cut is not carrying substantial stress during the operation. Gas-cut edges which will be subjected to substantial tensile stress shall be cut by a mechanically-guided torch, or if hand cut shall be carefully examined and any nicks removed. The radii of re-entrant gas-cut fillets shall be as large as practicable, but never less than 1 inch. Edges and grooves may be prepared for welding by gas cutting, as defined in Section 33 (h).

(d) Planing of Edges.

Planing or finishing of sheared edges of plates or shapes, or of edges gas-cut with a mechanically guided torch, will not be required unless specifically called for on the drawings, or included in a stipulated edge preparation for welding.

(e) Riveted Construction—Holes.

Holes for rivets or unfinished bolts shall be $\frac{1}{16}$ inch larger than the nominal diameter of the rivet or bolt. If the thickness of the material is not greater than the nominal diameter of the rivet or bolt plus $\frac{1}{8}$ inch, the holes may be punched. If the thickness of the material is greater than the nominal diameter of the rivet or bolt plus $\frac{1}{8}$ inch, the holes shall be either drilled from the solid, or sub-punched and reamed. The die for all sub-punched holes, and the drill for all sub-drilled holes, shall be at least $\frac{1}{16}$ inch smaller than the nominal diameter of the rivet or bolt.

Drifting to enlarge unfair holes shall not be permitted. Holes that must be enlarged to admit the rivets shall be reamed. Poor matching of holes shall be cause for rejection.

Holes for turned bolts shall be drilled or reamed truly cylindrical and not more than $\frac{1}{50}$ inch larger than the external diameter of the bolt. Drilling or reaming for turned bolts shall be done after the parts to be connected are assembled; except that if such drilling or reaming after assembly is impracticable, it may be done through steel templets with hardened bushings.

(f) Riveted Construction—Assembling.

All parts of riveted members shall be well pinned or bolted and rigidly held together while riveting. Drifting done during assembling shall not distort the metal or enlarge the holes.

(g) Riveting.

Rivets shall be driven by power riveters, of either compression or manually-operated type, employing pneumatic, hydraulic or electric power. After driving they shall be tight and their heads shall be in full contact with the surface.

Rivets shall ordinarily be hot-driven, in which case their finished heads shall be of approximately hemispherical shape and shall be of uniform size throughout the work for the same size rivet, full, neatly finished and concentric with the holes. Hot-driven rivets shall be heated uniformly to a temperature not exceeding 1950° F; they shall not be driven after their temperature has fallen below 1000° F.

Rivets may be driven cold if approved measures are taken to prevent distortion of the riveted material. The requirements for hot-driven rivets shall apply except as modified in the "Tentative Specifications for Cold-Driven Rivets" of the American Institute of Bolt, Nut and Rivet Manufacturers.

(h) Welded Construction—Preparation of Material.

Surfaces to be welded shall be free from loose scale, slag, rust, grease, paint and any other foreign material, except that mill scale which withstands vigorous wire

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brushing, may remain. A light film of linseed oil may be disregarded. Joint surfaces shall be free from fins and tears. Preparation of edges by gas cutting shall, wherever practicable, be done with a mechanically guided torch.

(k) Welded Construction—Assembling.

Parts to be fillet welded shall be brought in as close contact as practicable and in no event shall be separated more than $\frac{3}{16}$ inch. If the separation is $\frac{1}{16}$ inch or greater, the size of the fillet welds shall be increased by the amount of the separation. The separation between faying surfaces of lap joints shall not exceed $\frac{1}{16}$ inch. The fit of joints at contact surfaces which are not completely sealed by welds, shall be close enough to exclude water after painting.

Abutting parts to be butt welded shall be carefully aligned. Misalignments greater than $\frac{1}{8}$ inch shall be corrected and, in making the correction, the parts shall not be drawn into a sharper slope than two degrees ($\frac{1}{16}$ inch in 12 inches).

The work shall be positioned for flat welding whenever practicable.

In assembling and joining parts of a structure or of built-up members, the procedure and sequence of welding shall be such as will avoid needless distortion and minimize shrinkage stresses. Where it is impossible to avoid high residual stresses in the closing welds of a rigid assembly, such closing welds shall be made in compression elements.

In the fabrication of cover-plated beams and built-up members, all shop splices in each component part shall be made before such component part is welded to other parts of the member.

(l) Welded Construction—Temperatures.

No welding shall be done when the temperature of the base metal is lower than 0° F. At temperatures between 32° F. and 0° F., the surface of all areas within three inches of the point where a weld is to be started, shall be heated to a temperature at least warm to the hand before welding is started.

When welds are being made in parts thicker than $1\frac{1}{2}$ inches, the temperature of the base material adjacent to the welding shall be at least 70° F.

(m) Welding.

The technique of welding employed, the appearance and quality of welds made, and the methods used in correcting defective work shall conform to the "Code for Arc and Gas Welding in Building Construction" of the American Welding Society, Section 4—Workmanship.

All complete-penetration butt welds, except when produced with the aid of backing material or welded in the flat position from both sides in square-edge material not more than $\frac{5}{16}$ inch thick with root opening not less than one-half the thickness of the thinner part joined, shall have the root of the initial layer gouged or chipped out on the back side before welding is started from that side, and shall be so welded as to secure sound metal and complete fusion throughout the entire intended cross section. Butt welds made with the use of a backing of the same material as the base metal shall have the weld metal thoroughly fused with the backing material. Backing strips may be removed by means of gas cutting, after welding is completed, provided no injury is done to the base and weld metal and the weld surface is left flush or slightly convex, with full throat thickness.

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Incomplete-penetration butt welds shall be made with as nearly complete penetration and internal soundness as the formation of the joint and the method of welding will permit. (See Section 15 (f), final paragraph).

To insure soundness, the ends of butt welds that carry stresses approaching the maximum allowable working stress shall be extended past the edges of the parts joined, by means of short extension bars providing a similar joint preparation and having a width not less than the thickness of the thicker part joined. Where the metal is not more than $\frac{3}{4}$ inch in thickness, the extension bars may be omitted if the ends of the butt weld are chipped or cut down to solid metal and side welds are applied to fill out the ends to the same reinforcement as the faces of the weld. If extension bars are removed upon completion of the weld, the ends of the weld shall be left smooth and flush with the edges of the abutting parts.

(n) Welded Construction—Peening.

Where required, multiple-layer welds may be peened with light blows from a power hammer, using an elongated round-nose tool. Peening shall be done after the weld has cooled to a temperature warm to the hand. Care shall be exercised to prevent scaling, flaking or cold working of weld and base metal from over-peening.

(o) Finishing.

Compression joints depending upon contact bearing shall have the bearing surfaces machined to a common plane after the members are completed.

(p) Lacing Bars.

The ends of lacing bars shall be neat and free from burrs.

(q) Tolerances.

Finished members shall be true to line and free from twists, bends and open joints.

Compression members may have a lateral variation not greater than $1/1000$ of the axial length between points which are to be laterally supported.

A variation of $\frac{1}{32}$ inch is permissible in the overall length of members with both ends milled.

Members without milled ends which are to be framed to other steel parts of the structure may have a variation from the detailed length not greater than $\frac{1}{16}$ inch for members 30 feet or less in length, and not greater than $\frac{1}{8}$ inch for members over 30 feet in length.

(r) Castings.

Steel castings shall be annealed.

SECTION 34. SHOP PAINTING.

(a) Shop Coat.

After inspection and approval and before leaving the shop, all steel work shall be thoroughly cleaned, by effective means, of all loose mill scale, rust, spatter, slag or flux deposit, oil, dirt and other foreign matter. Except where encased in concrete,

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and excepting edges and surface areas adjacent to edges, to be field welded, all steel work shall be given one coat of approved metal protection, applied thoroughly and evenly and well worked into the joints and other open spaces. All paint shall be applied to dry surfaces.

(b) Inaccessible Parts.

Parts inaccessible after assembly shall be given two coats of shop paint, preferably of different colors.

(c) Contact Surfaces.

Contact surfaces shall be cleaned, by effective means, before assembly, but not painted.

(d) Finished Surfaces.

Machine-finished surfaces shall be protected against corrosion by a suitable coating.

(e) Surfaces to be Field Welded.

Surfaces which are to be welded after erection shall where practicable not receive a shop coat of paint. If painted, such paint shall be removed before field welding, for a distance of at least 2 inches on either side of the joint.

SECTION 35. ADMINISTRATIVE PROVISIONS.

All of the Administrative Provisions contained in this Specification, preceding the Technical Provisions, are to be complied with under any contract invoking the Technical Provisions, unless and except as otherwise provided in the applicable Building Code or General Specifications.