(b) Service Limits. Level A Through D, and Test. The rules and stress limits which must be satisfied for welds for any Level A through D Service and Test Loading stated in the Design Specification are those given in NF-3256.2(a) multiplied by the appropriate base material stress limit factor given in Table NF-3251.2-1.

NF-3256.3 Effective Size. The effective sizes of welds shall be as given in NF-3324.5(d) through (f).

NF-3256.4 Consideration of Lamellar Tearing. Welded joint configurations causing significant through-thickness tensile stress [as defined in NF-1215(b)] during fabrication and/or service on rolled product forms should be avoided. However, if this type of construction is used, the designer should consider one or several of the following factors that may reduce the susceptibility of the joint to experience lamellar tearing and provide documentation, including fabrication requirements, in the Design Output Documents:
(a) Reduce volume of weld metal to the extent practical.
(b) Select materials that are resistant to lamellar tearing.
(c) Invoke any of the special fabrication requirements of NF-4441.

NF-3260 DESIGN BY ANALYSIS FOR CLASS 3
NF-3261 Stress Limits

The design of Class 3 supports shall be in accordance with the requirements of NF-3250 using one of the design procedures indicated in Table NF-3131(a)-1 for Class 3 construction.

NF-3265 Design of Bolting

The provisions of NF-3225 apply.

NF-3266 Design of Welded Joints

The types of welded joints shall be as stipulated in NF-3256 for Class 2 and MC supports, except that for groove welded T-joints, groove welded corner joints, and fillet welded T-joints, as listed in NF-3256.1(a)(2) and (a)(3), the welds may be intermittent instead of continuous. Intermittent fillet welds shall meet the requirements of NF-3324.5(d)(7). The allowable stress limits shall be as stipulated in NF-3256.2.

NF-3270 EXPERIMENTAL STRESS ANALYSIS

Supports may be designed by experimental stress analysis in accordance with Appendix II (Section III, Division I, Appendices).

NF-3280 DESIGN BY LOAD RATING
NF-3281 Procedure for Load Rating

The procedure for load rating shall consist of imposing a total load on one or more duplicate full-size samples of a support equal to or less than the load under which the support fails to perform its required function. Full-size samples composed of various parts may have each part or a number of parts load rated, provided that all parts in the load path are either load rated or otherwise qualified per NF-3200, or by experimental stress analysis. When parts are connected by bolting or welding, the connection shall be either load rated or qualified per NF-3225 or NF-3226. Should more than one part be load rated in a single load test, then the load rating equations of NF-3280 shall be evaluated for each part using the part's $S_{y(k)}$ and $S_{u(k)}$ values. The part having the lowest load rating shall establish the load rating for the combination of parts. A single test sample is permitted but, in that case, the load ratings shall be reduced by 10%. Otherwise, tests shall be run on a statistically significant number of samples. The permissible types of welded joints shall be as permitted for the specific class of construction in NF-3226.1, NF-3256.1, and NF-3266. The full-size sample shall be fabricated for testing using welds not exceeding weld sizes stipulated in the Design Drawings. Bolted joints in the test sample shall be made up using the lowest strength bolt material and minimum edge distance allowed by the specification.

NF-3282 Load Ratings in Relation to Design Service and Test Loadings

The load rating for Design Loadings shall be determined in accordance with the requirements for Service Level A limits. The load ratings for Service Loadings for which Level A, B, or C Limits have been designated shall be determined by means of the equations in the following subparagraphs. For Level D Limits, see Appendix F of Section III, Division I, Appendices. The load rating for Test Loadings shall be determined in accordance with the requirements for Service Level B limits.

NF-3282.1 Nomenclature. The symbols used in this paragraph are defined as follows:

$$K_l = \text{load rating coefficient for support in compression}$$
$$S = \text{allowable stress value at the Design Temperature (NF-3112.1) from the applicable tables of Section II, Part D, Subpart 1, ksi (MPa)}$$
$$S_u = \text{specified minimum tensile strength of the material used in the support as given in the applicable tables of Section II, Part D, Subpart 1, ksi (MPa)}$$
(2) The provisions of NF-3342.2(d)(1) need not apply in the region of the last hinge to form, in the failure mechanism assumed as the basis for proportioning a given member, nor in members oriented with their weak axis normal to the plane of bending. However, in the region of the last hinge to form and in regions not adjacent to a plastic hinge, the maximum distance between points of lateral support shall be such as to satisfy the requirements of eq. (17), (18), or (19) of NF-3322.1(d)(5), or eq. (20) or (21) of NF-3322.1(e)(1). For this case, the value of $f_a$ and $f_b$ shall be computed from the moment and axial force at factored loading, divided by the applicable load factor.

(3) Members built into a masonry wall and having their web perpendicular to this wall can be assumed to be laterally supported with respect to their weak axis of bending.

(e) Connections

(1) General Requirements. All connections, the rigidity of which is essential to the continuity assumed as the basis for the analysis, shall be capable of resisting the moments, shears, and axial loads to which they would be subjected by the full factored loading, or any probable partial distribution thereof.

(2) Corner Connections. Corner connections (haunches) that are tapered or curved for architectural reasons shall be so proportioned that the full plastic bending strength of the section adjacent to the connection can be developed, if required.

(3) Stiffeners. Stiffeners shall be used, as required, to preserve the flange continuity of interrupted members at their junction with other members in a continuous frame. Such stiffeners shall be placed in pairs on opposite sides of the web of the member which extends continuously through the joint.

(4) Stress in Bolts and Welds. High strength bolts, SA-307 bolts, and welds shall be proportioned to resist the forces produced at factored load, using stresses equal to 1.7 times those given in NF-3324.6(a) for bolts and Table NF-3324.5(a)-1 for welds. In general, groove welds are preferable to fillet welds, but their use is not mandatory.

(5) Joints With Painted Contact Surfaces. High strength bolts may be used in joints having painted contact surfaces when these joints are of such size that the slip required to produce bearing would not interfere with the formation, at factored loading, of the plastic hinges assumed in the design.

NF-3350 DESIGN BY ANALYSIS FOR CLASS 2 AND MC

The design by analysis of Class 2 and MC supports shall be in accordance with NF-3320 and NF-3340.

NF-3360 DESIGN BY ANALYSIS FOR CLASS 3

The design by analysis of Class 3 supports shall be in accordance with NF-3320 and NF-3340.

NF-3370 EXPERIMENTAL STRESS ANALYSIS

Supports of all types may be designed by experimental stress analysis in accordance with Appendix II of Section III, Division 1, Appendices.

NF-3380 DESIGN BY LOAD RATING

NF-3381 Procedure for Load Rating

The procedure for load rating shall consist of imposing a total load on one or more duplicate full-size samples for a support equal to or less than the load under which the support fails to perform its required function. Full-size samples composed of various parts may have each part or a number of parts load rated provided that all parts in the load path are either load rated or otherwise qualified per NF-3300 or by experimental stress analysis. When parts are connected by bolting or welding, the connection shall be either load rated or qualified per NF-3225 or NF-3226. Should more than one part be load rated in a single load test, then the load rating equations of NF-3380 shall be evaluated for each part using the part's $S_{(d)}$ and $S_{(a)}$ values. The part having the lowest load rating shall establish the load rating for the combination of parts. A single test sample is permitted, but in that case, the load ratings shall be decreased by 10%. Otherwise, tests shall be run on a statistically significant number of samples. The permissible types of welded joints shall be as permitted for the specific class of construction in NF-3226.1, NF-3326.1, NF-3326.NF-3324. The requirements of NF-3324.5(b) for size of fillet and partial penetration welds do not apply, provided the full-size sample is fabricated for testing using the minimum weld stipulated in the Design Drawings. Bolted joints in the test sample shall be made up using the lowest strength bolt material and minimum edge distance allowed by the specification.

NF-3382 Load Ratings in Relation to Design Service and Test Loadings

The load rating for Design Loadings shall be determined in accordance with the requirements for Service Level A limits. The load ratings for Service Loadings for which Level A, B, or C Limits have been designated shall be determined by means of the equations in the following subparagraphs. For Level D Limits, see Appendix F of Section III, Division 1, Appendices. The load rating for Test Loadings shall be determined in accordance with the requirements for Service Level B limits.


TABLE NF-3251.2-1
ELASTIC ANALYSIS STRESS CATEGORIES AND STRESS LIMIT FACTORS FOR CLASS 2, 3, AND MC PLATE- AND SHELL-TYPE SUPPORTS DESIGNED BY ANALYSIS

<table>
<thead>
<tr>
<th>Stress Category</th>
<th>Design</th>
<th>Service Level A [Note (2)]</th>
<th>Service Level B [Note (3)]</th>
<th>Service Level C [Note (4)]</th>
<th>Service Level D [Note (5)]</th>
<th>Test Loadings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary stresses</td>
<td>$K_m = 1.0$</td>
<td>$K_m = 1.0$</td>
<td>$K_m = 1.33$</td>
<td>$K_m = 1.5$</td>
<td>$\ldots$</td>
<td>$K_m = 1.33$</td>
</tr>
<tr>
<td>[Notes (4), (5)]</td>
<td>$K_p = 1.0$</td>
<td>$K_p = 1.0$</td>
<td>$K_p = 1.33$</td>
<td>$K_p = 1.5$</td>
<td>$\ldots$</td>
<td>$K_p = 1.33$</td>
</tr>
<tr>
<td>$K_{ok} = 1.0$</td>
<td>$K_{ok} = 1.0$</td>
<td>$K_{ok} = 1.33$</td>
<td>$K_{ok} = 1.5$</td>
<td>$\ldots$</td>
<td>$K_{ok} = 1.33$</td>
<td></td>
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<tr>
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<td>but stress $\leq \frac{1}{2}$</td>
<td>but stress $\leq \frac{1}{2}$</td>
<td>but stress $\leq \frac{1}{2}$</td>
<td>$\ldots$</td>
<td>but stress $\leq \frac{1}{2}$</td>
<td></td>
</tr>
<tr>
<td>$K_{sk}$</td>
<td>$K_{sk}$</td>
<td>$K_{sk}$</td>
<td>$K_{sk}$</td>
<td>$\ldots$</td>
<td>$K_{sk}$</td>
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<td>of critical</td>
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<td>of critical</td>
<td>of critical</td>
<td>$\ldots$</td>
<td>of critical</td>
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<tr>
<td>buckling stress</td>
<td>buckling stress</td>
<td>buckling stress</td>
<td>buckling stress</td>
<td>$\ldots$</td>
<td>buckling stress</td>
<td></td>
</tr>
</tbody>
</table>

**GENERAL NOTE:**

$K_m = $ stress limit factor applicable to the Design allowable membrane stress or membrane plus bending stress (compression only)

$K_p = $ stress limit factor applicable to the Design allowable membrane stress or membrane plus bending stress (see NF-3251.1 and NF-3261)

$K_{ok} = $ stress limit factor applicable to the Design allowable shear stress (see NF-3252.2 and NF-3261)

**NOTES:**

(1) Control of deformation is not assured by these stress limit factors. When required by Design Specification, deformation control must be considered separately.

(2) $K_m$ and $K_{sk}$ = 1.0 for design of snubbers and dampers.

(3) Stress shall not exceed 0.7$S_p$.

(4) For Service Levels A, B, C, and D, stresses induced on the supports by restraint of free-end displacement and anchor motions of piping shall be considered as primary stresses.

(5) Thermal stresses within the support as defined by NF-3121.11 need not be evaluated.

(6) Shear stress shall not exceed 0.42$S_p$.

(b) Corner Joints. Corner joints shall be one of the following:

(1) full penetration, as shown in Fig. NF-3256.1-1, sketch (c)

(2) partial penetration with a fillet weld as shown in Fig. NF-3256.1-1, sketches (d) and (e)

(c) Tee Joints. Tee joints shall be one of the following:

(1) full penetration, single or double welded, Fig. NF-3256.1-1, sketches (f-1), (f-2), and (h)

(2) partial penetration, with or without additional fillet welds, Fig. NF-3256.1-1, sketch (g)

(3) partial penetration, single welded between a plate and the end surface of a closed tubular section or a closed formed section, Fig. NF-3256.1-1, sketch (j)

(4) fillet, double welded, Fig. NF-3256.1-1, sketch (k-1); single welded when double members are used, Fig. NF-3256.1-1, sketch (k-2)

(5) fillet, single welded between a flat surface and the end surface of a closed tubular section or a closed formed section, Fig. NF-3256.1-1, sketch (l)

(d) Lap Joints. Lap joints shall be fillet, double welded, Fig. NF-3256.1-1, sketch (m).

(e) The applicable welds for the joints permitted in NF-3256.1(a) through (d) are

(1) square groove, bevel groove, J groove, flare bevel groove, U groove and V groove

(2) plug and slot welds are permitted in NF-3256.1(c) and (d) only

(3) fillet welds are permitted in NF-3256.1(c)(4), (c)(5), and (d) only

**NF-3256.2 Allowable Stress Limits**

(a) Design Limits. The allowable stress limits which must be satisfied for the Design Loadings stated in the Design Specification shall be the following:

(1) Full Penetration Groove Welds. The allowable stress limits for full penetration groove welds shall not exceed the applicable allowable stress value for the base metal being jointed, as specified in NF-3251.1 and Table NF-3324.5(a)-1.

(2) Partial Penetration Groove Welds

(a) Compression Normal to Effective Throat or Shear on Effective Throat. The allowable stress limits shall be as specified in Table NF-3324.5(a)-1.

(b) Tension Normal to the Axis on the Effective Throat. The stress limits shall be as specified in Table NF-3324.5(a)-1.

(3) Fillet Welds. The allowable stress limit for fillet welds shall be as specified in Table NF-3324.5 (a)-1.
NF-3121.2 Primary Stress. Primary stress is any normal stress or shear stress developed by an imposed loading that is necessary to satisfy the laws of equilibrium of external and internal forces and moments. The basic characteristic of a primary stress is that it is not self-limiting. Primary stresses that considerably exceed the yield strength will result in failure or, at least, in gross distortion. Primary membrane stress is divided into general and local categories. A general primary membrane stress is one that is so distributed in the support that no redistribution of load occurs in the support as a result of yielding. Examples of primary stress are

(a) general membrane stress in a circular cylindrical shell or a spherical shell due to internal pressure or to distributed loads
(b) bending stress in a cantilever beam due to a normal end load

For evaluation purposes, stresses induced in the support by restraint of free end displacement [NF-3111(e)] and anchor motion [NF-3111(f)] of piping are considered primary stresses.

NF-3121.3 Secondary Stress. Secondary stress is a stress or a shear stress developed by the constraint of adjacent material or by self-constraint of the structure. The basic characteristic of a secondary stress is that it is self-limiting. Local yielding and minor distortions can satisfy the conditions that cause the stress to occur, and failure from one application of the stress is not to be expected.

Examples of secondary stress are

(a) general thermal stress [NF-3213.11(a)]
(b) bending stress at a gross structural discontinuity

NF-3121.4 Peak Stress. Peak stress is the increment of stress that is additive to the primary plus secondary stresses by reason of local discontinuities or local thermal stress (NF-3121.11), including the effects, if any, of stress concentrations. The basic characteristic of a peak stress is that it does not cause any noticeable distortion and is objectionable only as a possible source of a fatigue crack or a brittle fracture. A stress that is not highly localized falls into this category if it is of a type that cannot cause noticeable distortion. Evaluation of peak stresses in the support is not required by this Subsection.

NF-3121.5 Normal Stress. Normal stress is the component of stress normal to the plane of reference. This is also referred to as direct stress. Usually the distribution of normal stress is not uniform through the thickness of a part, so this stress is considered to have two components, one uniformly distributed and equal to the average stress across the thickness under consideration, and the other varying from this average value across the thickness.

NF-3121.6 Shear Stress. Shear stress is the component of stress tangent to the plane of reference.

NF-3121.7 Membrane Stress. Membrane stress is the component of normal stress that is uniformly distributed and equal to the average stress across the thickness of the section under consideration.

NF-3121.8 Bending Stress. Bending stress is the component of normal stress that varies across the thickness. The variation may or may not be linear.

NF-3121.9 Total Stress. Total stress is the sum of the primary and secondary stress contributions. Recognition of each of the individual contributions is essential to establishment of appropriate stress limitations.

NF-3121.10 Critical Buckling. Critical buckling occurs when a support is loaded to a state at which an infinitesimal additional load or disturbance causes the support to change from an equilibrium condition to one of instability.

NF-3121.11 Thermal Stress. Thermal stress is a self-balancing stress produced by a nonuniform distribution of temperature or by differing thermal coefficients of expansion. Thermal stress is developed in a solid body whenever a volume of material is prevented from assuming the size and shape that it normally would under a change in temperature. Evaluation of thermal stresses in the support is not required by this Subsection.

NF-3121.12 Free End Displacement. Free end displacement consists of the relative motions that would occur between an attachment and connected structure or equipment if the two members were separated and permitted to move.

NF-3121.13 Anchor Point Motion Stress. Anchor point motion stresses are those stresses resulting from the differential motion of support points. An example is differential building settlement.

NF-3121.14 Gross Structural Discontinuity. Gross structural discontinuity is a geometric or material discontinuity that affects the stress or strain distribution through the entire thickness of the member. Gross discontinuity-type stresses are those portions of the actual stress distributions that produce net bending and membrane force results when integrated through the thickness. Examples of a gross structural discontinuity are head-to-shell junctions, flange-to-shell junctions, nozzles, and junctions between parts of different diameters or thicknesses.

NF-3121.15 Limit Analysis — Collapse Load. The methods of limit analysis are used to compute the maximum load or combination of loads a structure made of ideally plastic (nonstrain-hardening) material can carry. The deformations of an ideally plastic structure increase without bound at this load, which is termed the collapse load.
NF-3140 GENERAL DESIGN PROCEDURES

NF-3141 Types of Procedures

(a) The design procedure which may be used is dependent on the type of support being designed and the Class of construction involved. Three design procedures are recognized, namely

(1) design by analysis
   (a) maximum shear stress theory
   (b) maximum stress theory
(2) experimental stress analysis (Section III, Division 1, Appendices, Appendix II)
(3) load rating
   (b) Unless either the experimental stress analysis procedure or the load rating procedure is used, the requirements of the following paragraphs apply.

NF-3142 Plate- and Shell-Type Supports — Analysis Procedure

(a) Elastic analysis based on maximum shear stress theory in accordance with the rules of NF-3200 shall be used in the design of Plate- and Shell-Type Supports of Class 1 construction.

(b) Elastic analysis based on maximum stress theory shall be used in the design of Plate- and Shell-Type Supports of Class 2, 3, and MC construction. Supports for Class 2 vessels designed to NC-3200 shall be designed in accordance with Class 1 requirements.

NF-3143 Linear-Type Supports — Analysis Procedure

(a) The analysis procedure shall comply with NF-3143(a)(1) or (a)(2).

(1) Elastic analysis based on maximum stress theory in accordance with the rules of NF-3300 shall be used for the design of Linear-Type Supports for Class 1, 2, and 3 and MC construction.

(2) Limit analysis in accordance with the procedures of NF-3340 shall be used in the design of Linear-Type Supports for Class 1, 2, and 3 and MC construction when members and their connections are subject to high cycle fatigue as defined in NF-3331.

(b) High cycle fatigue analysis in accordance with procedures of NF-3330 shall be used in the design of Linear-Type Supports for Class 1 construction.

NF-3144 Standard Supports — Analysis Procedure

Standard Supports designed by analysis shall be designed to either the requirements of NF-3142 or NF-3143, according to whether they are Plate- and Shell-Type or Linear-Type Standard Supports.

NF-3200 DESIGN RULES FOR PLATE- AND SHELL-TYPE SUPPORTS

NF-3210 GENERAL REQUIREMENTS

NF-3211 Basis for Determining Stresses in Design by Analysis

The theory of failure used in the rules of this Subsection for combining stresses for the design of Class 1 Plate- and Shell-Type Supports is the maximum shear stress theory; for Class 2, 3, and MC Plate- and Shell-Type Supports, it is the maximum stress theory.

NF-3212 Definitions

Terms used in the design of Plate- and Shell-Type Supports by stress analysis are defined in NF-3211 and in NF-3212.1 below.

NF-3212.1 Stress Intensity. Stress intensity is defined as twice the maximum shear stress which is the difference between the algebraically largest principal stress and the algebraically smallest principal stress at a given point. Tensile stresses are considered positive and compressive stresses are considered negative.

NF-3220 DESIGN BY ANALYSIS FOR CLASS 1

NF-3221 Stress Limits

Stress limits for elements of Class 1 supports are given in this paragraph. Stress limits for bolts and welds are given in NF-3225 and NF-3226. General requirements concerning stress determinations, definitions, derivations of stress intensities, and classification of stresses are given in NF-3210.

Plate- and Shell-Type Supports may be designed by either elastic or limit analysis, stress intensity limits for which are given in NF-3221.1 through NF-3221.4.

NF-3221.1 Design Limits. The stress intensity limits which must be satisfied for the Design Loadings stated in the Design Specification are the two limits of this paragraph and the Special Stress Limits of NF-3223. The design stress intensity values \( S_m \) are given in NF-3224.

(a) General primary membrane stress intensity \( P_m \) is derived from the average value across the thickness of a section of the general primary stresses produced by specified Design Mechanical Loads, but excluding all secondary stresses. Averaging is to be applied to the stress components prior to determination of the stress intensity values. The allowable value of this stress intensity is \( S_m \) at the Design Temperature.

\[ S_m \]

1 This definition of stress intensity is not related to the definition of stress intensity applied in the field of fracture mechanics.