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8.1.13 DNV Rules for Submarine Pipeline Systems, 1996 by Det norske Veritas

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8.0 Piping Code Compliance Reports

The Piping Code Compliance Reports generated by TRIFLEX® Windows were designed to provide the piping stress User with a quick and efficient means of comparing a piping system design for compliance with that allowed by a given piping code.

Compliance reports for the following piping codes are presently available:

- **B31.1** - Power Piping Code
- **B31.3** - Chemical Plant and Petroleum Refinery Piping Code
- **B31.4** - Liquid Petroleum Transportation Piping Code
- **B31.8** - DOT Guidelines for Gas Transmission and Distribution Piping System
- **NAVY** - General Specifications for Ships of the U.S. Navy, Section 505
- **CLAS2** - ASME Section III - Division 1 (Subsection NC)
- **CLAS3** - ASME Section III - Division 1 (Subsection ND)
- **SPC1** - Swedish Piping Code (Method 1 - Section 9.4)
- **SPC2** - Swedish Piping Code (Method 2 - Section 9.5)
- **TBK5-1** - Norwegian General Rules for Piping Systems (Method 1 Section 9.4)
- **TBK5-2** - Norwegian General Rules for Piping Systems (Method 2 Section 9.5)
- **DNV** - DnV Rules for Submarine Pipeline Systems, 1981 by Det norske Veritas
- **DNV** - DnV Rules for Submarine Pipeline Systems, 1996 by Det norske Veritas
- **DNV** - DnV Rules for Submarine Pipeline Systems, 2000 by Det norske Veritas
- **NPD** - Guidelines for Design, Fabrication and Installation, Submarine Pipelines and Risers, 1984 by the Norwegian Petroleum Directorate
- **STOL** - Design, Specifications Offshore Installations - F-sd-101 by Statoil
- **POL1** - Polska Norma PN-79 / M-34033 Steam and Water Piping
- **SNIP** - 2.05-06-85 - FSU Transmission Piping Code
- **BS7159** - British Standard Code for Glass Reinforced Plastic Piping Systems
- **UKOOA** - UK Offshore Operator Association
- **BS8010** - British Standard Code for Piping Systems
- **EURO** - European Standard prEN 13480-3
With a minimum amount of additional data input by the User, TRIFLEX® Windows will compute the minimum required wall thickness, the allowable pressure and the allowable stress values, and compare them with the actual calculated values found for the piping system.

The discussions that follow will familiarize the piping stress User with:

- stress requirements of the various piping codes
- input requirements for the TRIFLEX® Windows Compliance Reports
- solution techniques applied by TRIFLEX® Windows in the Compliance Reports.

The design temperature or expansion coefficient used in coding a TRIFLEX® Windows Piping Code Compliance run should reflect the total range of temperature expected during the operation of the piping system. This can be accomplished in one computer run by specifying the "Design Temperature" as the expected operating (HOT) temperature and by specifying the Base Temperature as the minimum temperature expected during the life of the system.

If a piping system operates cryogenically, then the minimum temperature expected (Design Temperature) should be specified as the operating temperature, and the maximum temperature expected should be specified as the Base Temperature.

The various piping codes are very specific in prohibiting the use of Cold Spring to reduce expansion stresses. For example, ANSI B31.3, paragraph 319.2.4 states:

"Inasmuch as the service life of a system is affected more by the range of variation than by the magnitude of stress at a given time, no credit for cold spring is permitted in stress range calculations."

See also ANSI B31.1, Para. 119.9, ANSI B31.4, Para. 419.6.4 (b) and (c), and Department of Transportation Guide for Gas Transmission and Distribution Piping Systems, Para. 832.37.

In Figure 1 Cold Spring Drawing, the calculated stress magnitude of 25000 psi represented by the solid line (no credit taken for Cold Spring) is the same as the 25000-psi stress range that will exist after several thermal cycles of the system. The operating temperature stress that will be measured after several cycles will be less than 25000 psi due to the "Self-Springing" discussed in ANSI B31.3, Para. 319.2.3; i.e., the stress that is relieved at operating temperature by "Self-Springing" shows up at ambient temperature as a stress of opposite sign.

Now, if we consider taking credit for 50% Cold Spring, we will calculate an expansion stress of 12,500 psi for the operating temperature case and a stress of 12500 psi in the opposite direction for the ambient temperature case (see the dashed line). The Expansion Stress Range is still 25000 psi, so the Cold Spring has done nothing to relieve the stress.
range between the maximum hot and maximum cold conditions. This explains why credit for Cold Spring should not be taken in Piping Code Compliance Analyses.

The piping codes are explicit in stating that the modulus of elasticity at installation temperature must be used to calculate the magnitude of the Thermal Stress Range. For example, ANSI B31.3, Para. 319.4.4 (a) states:

"Bending and torsional stresses shall be computed using the as installed modulus of elasticity $E(a)$ and then combined in accordance with Equation 17 to determine the computed displacement stress range $S_E$, which shall not exceed the allowable stress range $S_A$ in 302.3.5(d)."

See also ANSI B31.1, Para. 119.6.4 A; ANSI B31.4, Para. 419.6.2, and DOT Guide for Gas Transmission and Distribution Piping Systems, Para. 832.38.

**Note:** The Code Compliance Reports are designed to inform the User as to whether the piping system stresses calculated as per the code formulas are within the allowable stresses specified.

The User is warned that under certain conditions stresses far in excess of those printed in the Compliance Reports may be present in the piping system. Therefore, all of the analyses generated in the TRIFLEX® Windows output should be studied carefully.
Figure 1 Cold Spring Drawing
The Code Compliance Report generated by TRIFLEX®Windows organizes and compares the computed and allowable design values. Each data point with a diameter and a wall thickness will be checked for its:

- pressure-containing ability
- ability to sustain the dead weight + pressure distribution at operating conditions
- ability to conform without failure to a different shape as a result of displacement strains and thermal expansion or contraction.

TRIFLEX®Windows will compute the Longitudinal Stress due to Sustained Loads, the Longitudinal Stress due to Occasional Loads, if any, and the Displacement Stress Range (Thermal Expansion Stress). These stress values are compared with the allowable stress values computed from basic material parameters input by the User. If Occasional Loads are to be considered, TRIFLEX®Windows applies a specified portion of the normal weight force to each piping component in one, two, or all three of the Global X, Y, Z directions and then compares these computed stresses with the applicable Code allowable.

To process a Code Compliance Analysis, the User should code the piping system in the ordinary manner. No single-analysis options, multiple-analysis options, or other B31 Code Compliance options should be requested. Non-linear Restraints, Flange Loading, Spring Hanger Design, and Rotating Equipment Reports may be requested.

When considering Occasional Loads, gravity factors should be specified in the CASE DATA Screen. All of the data on all node input screens might be specified in the usual manner with one exception:

TRIFLEX®Windows allows the User to consider "Dampers" or "Snubbers" in an analysis. A "Damper" is treated as a totally flexible restraint in the Thermal Analysis and in the Weight + Pressure Analysis. When TRIFLEX®Windows processes the required Weight Factor Analyses, the restraint becomes totally rigid and restricts movement in the specified directions.

To request a Code Compliance Report, the User must:

1. Enter ✔ in the "Piping Code Report?" field on the CASE DATA Screen.

Enter the hot and cold allowable on the PIPING CODE COMPLIANCE REPORT Screen.

8.0.1 Analysis Procedure

When a request for Code Compliance has been made, TRIFLEX®Windows will process at least two analyses prior to the B31 Compliance Report, a Thermal and then a Weight + Pressure Analysis. More than one type of report can be requested. TRIFLEX®Windows will perform an operating analysis (temperature, pressure, weight) to satisfy the
requirements for other reports. These reports can include a request for an Operating Analysis, a Flange Loading Analysis, Rotating Equipment Report, a Spring Hanger Design, or the use of non-linear restraints (one-directional, limit stops).

**Note:** If any of the above requested reports are made and occasional load gravity factors are given, the operating analysis will be performed with the occasional load factors acting simultaneously with temperature, pressure, and weight.

TRIFLEX®Windows processes the above requested analyses from the input data submitted and internally structures the data to match the Code Compliance requirements.

### 8.0.1.1 Performing a Thermal Analysis

In the Thermal Analysis TRIFLEX®Windows does the following:

- Excludes the effects of weight.
- Excludes the displacement stresses due to the effects of pressure (optional, may be included on the JOB DEFAULT Screen).
- Excludes all forces and moments input by the User.
- Excludes the initial loads on all flexible restraints (spring hangers, etc.).
- Includes the initial Anchor and Restraint movements as input by the User.
- For Anchor displacements due to earthquake, this displacement must be specified by the User, and added to the thermal displacement to give a total displacement to satisfy the Code Requirements.
- Excludes dampers.

### 8.0.1.2 Performing a Weight + Pressure Analysis

In the Weight + Pressure Analysis TRIFLEX®Windows does the following:

- Excludes the effects of temperature.
- Excludes the initial Anchor and Restraint movements as input by the User.
- Includes the displacement stresses due to the effects of pressure (default, may be excluded on the JOB DEFAULT Screen).
- Includes the initial loads on all flexible restraints (spring hangers, etc.).
- Includes all forces and moments as input by the User.
- Excludes dampers.

When Occasional Loads are requested, TRIFLEX®Windows processes additional Weight Factor Analyses.
8.0.1.3 Performing a Weight Factor Analysis

In each Weight Factor Analysis TRIFLEX® Windows does the following:

- Excludes the effects of temperature, pressure and weight.
- Excludes the initial Anchor and Restraint movements due to thermal and earthquake effects as input by the User.
- Includes the effects of the piping system weight multiplied by the input Weight Factor applied along the axis specified by the User; i.e., X, Y, and Z.
- Includes the effects of damper restraints.

8.0.2 With Non-linear Restraints Discussion

When a Piping Code Compliance Analysis is processed in this manner:

- Restraints which TRIFLEX® Windows finds acting on the piping system in the Operating Case Analysis will also act on the piping system in the Thermal Analysis and in the Weight + Pressure Analysis.

- Restraints which do not exert loads on the piping system in the Operating Case Analysis will be ignored in the Thermal Analysis and in the Weight + Pressure Analysis. For this reason the Weight + Pressure Analysis may show the pipe deflecting in the negative Y direction at a support location even though a rigid support exists at that location, and the weight of the pipe is actually suspended from other supports and/or Anchors.

For the purposes of determining the longitudinal pressure and weight stresses according to the piping codes, no support should be considered at locations where the pipe has moved away from the support in the operating condition.
8.1.0 Code Compliance Reports

8.1.1 ASME ANSI B31.1 Power Piping Code Compliance

The ANSI B31.1 Compliance Report consists of three Output Reports. The first Output Report lists all of the B31.1 Code Compliance Data specified by the User. The second Output Report contains the node identification, the design wall thickness vs. the required wall thickness, sustained stresses vs. allowed and expansion stresses vs. allowed. The third Output Report is generated only if the User requested Occasional Loads Analyses. This report contains a summary of all occasional stresses about each axis requested, the sustained longitudinal stress, and the resultant occasional stress vs. its allowable.

Output units and equations shown in this section are for the English system. Output units are available for the following:

(1) English (ENG)  (3) Metric (MET)
(2) System International (SI)  (4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>ALLOWABLE HOT STRESS WITH WELD F. psi</th>
<th>ALLOWABLE COLD STRESS psi</th>
<th>ALLOWABLE HOT STRESS psi</th>
<th>STRESS RANGE REDUCTION FACTOR</th>
<th>OCCASIONAL FATIGUE FACTOR</th>
<th>Y COEFFICIENT</th>
<th>MILL TOLERANCE</th>
</tr>
</thead>
</table>

From and To Data Numbers

The range of data point numbers for which the specified properties apply.

Allowable Operating Stress (SE)

The maximum allowable stress in material due to internal pressure and joint efficiency at the design temperature, psi.

Allowed Cold Stress (SC)

The basic material allowable stress at the minimum (cold) temperature from the Allowable Stress Tables.
Allowed Hot Stress (SH)

The basic material allowable stress at the maximum (hot) temperature from the Allowable Stress Tables.

Stress Range Reduction Factor

Stress range reduction Factor for cyclic conditions for total number N of full temperature cycles over total number of years during which system is expected to be in operation, from Table 102.3.2(C).

Occasional Load Factor K

Factor specified by the User based upon the duration of the occasional loads.

Y-Coefficient

As per Table 104.1.2(A) in the ANSI/ASME B31.1 Code Book.

Mill Tolerance

Manufacturer mill tolerance in percent or inches.

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>SEC 104.1.2 WALL THICKNESS DESIGN in</th>
<th>SEC 104.1.2 WALL THICKNESS REQUIRED in</th>
<th>SEC 104.8.1(11) SUSTAINED STRESS ACTUAL psi</th>
<th>SEC 104.8.1(11) SUSTAINED STRESS ALLOWED psi</th>
<th>SEC 104.8.1(11) SUSTAINED STRESS PERCENT</th>
<th>SEC 104.8.3(13) EXPANSION STRESS ACTUAL psi</th>
<th>SEC 104.8.3(13) EXPANSION STRESS ALLOWED psi</th>
<th>SEC 104.8.3(13) EXPANSION STRESS PERCENT</th>
</tr>
</thead>
</table>

Data Point

The number assigned by the User to each significant location.

Node Location

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.
Design Wall Thickness vs. Required Thickness

The Design Wall Thickness is the value input by the User. The required Wall Thickness value is calculated by TRIFLEX® Windows using the following B31.1 Code Equations (Section 104.1.2, Equation 3) and the internal pressure supplied by the User.

\[ t_{\text{min}} = \frac{P D_o}{2 (SE + P_y)} + A \]

where:

- \( t_{\text{min}} \) = minimum pipe wall thickness, inches
- \( P \) = internal design pressure as input by the User, psig
- \( D_o \) = actual pipe outside diameter, inches
- \( SE \) = maximum allowable stress in material due to internal pressure and joint efficiency at the design temperature, psi
- \( y \) = a coefficient having the values given in the Table 104.1.2(A)
- \( A \) = corrosion and wear allowance, inches

\[ t_{\text{req}} = \frac{t_{\text{min}}}{(100.0 - MT)/100} \quad \text{or} \quad t_{\text{req}} = t_{\text{min}} + MT \]

where:

- \( t_{\text{req}} \) = required wall thickness, inches
- \( MT \) = User supplied mill tolerance, percent or inches (default is 12.5%)

Stresses Due To Sustained Loads vs. Allowed Stresses

Stresses due to Sustained loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress. They are calculated using the following B31.1 Code Equation (Section 104.8.1, Equation 11):

\[ S_L = \frac{P D_o}{4t} + 0.75y \left( \frac{M_A}{Z} \right) \leq S_h \]

where:
\[ M_A = \sqrt{M_X^2 + M_Y^2 + M_Z^2} \]

- \( P \) = pressure, psig
- \( i \) = stress intensification factor; the term \((0.75i)\) shall never be taken as less than 1.0
- \( M_X \) = moment about the X-axis, inch-pounds
- \( M_Y \) = moment about the Y-axis, inch-pounds
- \( M_Z \) = moment about the Z-axis, inch-pounds
- \( S_h \) = basic material allowable stress at maximum (hot) temperature from the Allowable Stress Tables, psi

As can be seen from the equation, the longitudinal stress due to the combined pressure and weight stresses shall be less than or equal to \( S_h \).

\[ \frac{P d^2}{(D_o^2 - d^2)} \]

The first term in ANSI/ASME B31.1, Equation 11 will be replaced by

where:

\[ d = D_o - 2t \]

when the **alternate pressure option is selected**.

For full-size outlet connections:

\[ Z = \frac{\pi}{32} \left( \frac{D_o^4 - d^4}{D_o} \right) \]

For reduced outlet branch connections:

\[ Z_e = \pi r_e^2 t_e \]

where:

\[ Z = \text{section modulus, in}^3 \]
\[ Z_e = \text{effective section modulus of reduced branch, in}^3 \]
\[ r_b \quad = \quad \text{branch mean cross-sectional radius, inches} \]
\[ t_e \quad = \quad \text{effective branch wall thickness (lesser of } t_{nh} \text{ and } i \cdot t_{nb} \text{)} \]
\[ t_{nh} \quad = \quad \text{nominal wall thickness of main pipe, inches} \]
\[ t_{nb} \quad = \quad \text{nominal wall thickness of branch, inches} \]

**Thermal Expansion Stress Range**

The extent of the Thermal Expansion Stress Range induced is computed in the Thermal Analysis processed by TRIFLEX®Windows. This stress range must satisfy the following ANSI/ASME B31.1 Code Equation (Section 104.8.3, Equation 13):

\[ S_E = \frac{i M_c}{Z} \leq S_A + f (S_{b} - S_{L}) \]

where:

\[ S_A = f (1.25 S_c + 0.25 S_H) \]

where:

\[ S_c \quad = \quad \text{basic material allowable stress at minimum (cold) temperature from the Allowable Stress Tables, psi} \]

**Note:** If Occasional Loads have been requested, a third Output Report appears.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Occasional Stresses**

Occasional Stresses for each direction requested are computed in the Weight Factor Analyses.

\[ S_O = 0.75 i \left( \frac{M_{GF(axis)}}{Z} \right) \]

The moments at each piping location from each Weight Factor Analysis are combined in the following manner:
Stresses Due To Sustained Loads

Stresses due to Sustained Loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress.

\[ S_L = \frac{PD_A}{4l_n} + 0.75i \left( \frac{M_A}{Z} \right) \]

Stresses Due to Occasional Loads vs. Allowed Stresses

Stresses due to Occasional Loads, \( S_{LO} \), are the algebraic summations of the Longitudinal Sustained Weight Stress, the Longitudinal Pressure Stress, and Occasional Stress. (ANSI/ASME B31.1, Equation 12).

\[ S_{LO} = \frac{PD_A}{4l_n} + 0.75i \left( \frac{M_A + M_B}{Z} \right) \leq k S_h \]

where:

\[ M_b = \sqrt{M_{GF(X)}^2 + M_{GF(Y)}^2 + M_{GF(Z)}^2} \]

As can be seen from the equation, the Longitudinal Stress due to Occasional Loads shall be less than or equal to \( k S_h \).

where:

\[ k = \begin{cases} 
1.15 & \text{for occasional loads acting less than 10\% of operating period (see Para. 102.2.4)} \\
1.2 & \text{for occasional loads acting less than 1\% of operating period (see Para. 102.2.4).} 
\end{cases} \]
8.1.2 ANSI/ASME B31.3 Chemical Plant and Petroleum Refinery Piping Code Compliance Report – DIN 2413 Design of Steel Pressure Pipes

The ANSI B31.3 Compliance Report consists of three Output Reports. The first Output Report lists all of the B31.3 Code Compliance Data specified by the User. The second Output Report contains the node identification, the design wall thickness vs. required wall thickness, sustained stresses vs. allowed and displacement stresses vs. allowed. The third Output Report is generated only if Occasional Loads Analyses were requested by the User. This report contains a summary of all occasional stresses about each axis requested, the sustained longitudinal stress, and the resultant occasional stress vs. its allowable.

Output units and equations shown in this section are for the English system and the System International (SI). Output units are available for the following:

(1) English (ENG)  (3) System International (SI)
(2) Metric (MET)  (4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

**The first Output Report contains the following information:**

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>ALLOWABLE HOT STRESS WITH WELD F. psi</th>
<th>ALLOWABLE COLD STRESS psi</th>
<th>ALLOWABLE HOT STRESS psi</th>
<th>STRESS RANGE REDUCTION FACTOR</th>
<th>OCCASIONAL FATIGUE FACTOR</th>
<th>Y COEFFICIENT</th>
<th>MILL TOLERANCE</th>
<th>Rated over 120 deg. C</th>
<th>Fatigue Failure</th>
<th>Constant Stress Amplitude psi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**The first DIN 2413 Output Report contains the following information:**

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>Degree of Weld Utilization (DIN 2413)</th>
<th>ALLOWABLE COLD STRESS N/mm²</th>
<th>ALLOWABLE HOT STRESS N/mm²</th>
<th>STRESS RANGE REDUCTION FACTOR</th>
<th>OCCASIONAL FATIGUE FACTOR</th>
<th>Maximum Permissible Stress N/mm²</th>
<th>MILL TOLERANCE</th>
<th>Rated over 120 deg. C</th>
<th>Fatigue Failure</th>
<th>Constant Stress Amplitude KPa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FROM and TO Data Numbers**

The range of data point numbers for which the specified properties apply.

**Allowable Operating Stress (SE)**

The maximum allowable stress in material due to internal pressure and joint efficiency at the design temperature, psi.
Allowed Cold Stress (SC)

The basic material allowable stress at the minimum metal temperature expected during the displacement cycle under analysis, psi.

Allowed Hot Stress (SH)

The basic material allowable stress at the maximum metal temperature expected during the displacement cycle under analysis, psi.

Stress Range Reduction Factor

Stress range reduction Factor for displacement cyclic conditions for total number N of cycles over the expected life (from Table 302.3.5).

Occasional Load Factor K

Factor specified by the User, based upon the duration of the occasional loads.

Y-Coefficient

As per Table 304.1.1 in the ANSI/ASME B31.3 Code Book.

Mill Tolerance

Manufacturer mill tolerance in percent or (inches or millimeters).

Degree of Weld Utilization

Degree of utilization of the design stress in the weld - $\nu_w$ - DIN 2413.

Maximum Permissible Stress

Maximum permissible stress under static loading - $\sigma_{zul}$ - DIN 2413.

Rated Over 120°C

Pipes subjected to predominantly static loading and rated for a temperature over 120°C.

Fatigue Failure

Pipes subjected to fatigue loading and rated for a temperature up to 120°C.

Constant Stress Amplitude

\[ \hat{p} - \ddot{p} = \text{pressure amplitude} \]
The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>WALL THICKNESS DESIGN in</th>
<th>WALL THICKNESS REQUIRED in</th>
<th>SUSTAINED STRESS ACTUAL psi</th>
<th>SUSTAINED STRESS ALLOWED psi</th>
<th>SUSTAINED STRESS PERCENT</th>
<th>EXPANSION STRESS ACTUAL psi</th>
<th>EXPANSION STRESS ALLOWED psi</th>
<th>EXPANSION STRESS PERCENT</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Design Wall Thickness vs. Required Thickness according B31.3**

The User inputs values for the wall thickness as per B31.3. (Section 304.1.2, Equation 3a) and the User-supplied internal pressure:

\[
t = \frac{PD_o}{2(SE + PY)}
\]

\[
t_m = t + c
\]

where:

\[t_m\] = minimum pipe wall thickness, inches
\[P\] = internal design pressure as input by the User, psig
\[D_o\] = actual pipe outside diameter, inches
\[S\] = stress value for material from Table A-1, psi
\[E\] = quality factor from Table A-1A or A-1B
\[Y\] = a coefficient having the values given in the Table 304.1.1
\[c\] = corrosion and wear allowance, inches
where:

\[ t_{req} = \frac{t_{\min}}{(100.0 - MT)/100} \quad \text{or} \quad t_{req} = t_{\min} + MT \]

- \( t_{req} \) = required wall thickness, inches
- \( MT \) = User supplied mill tolerance, percent or inches (default is 12.5%)

### Design Wall Thickness vs. Required Thickness according DIN 2413

The Design Wall Thickness is input by the User. The required Wall Thickness is calculated by TRIFLEX\textsuperscript{®} using the following DIN 2413 Code Equations (Part 1, Table 3):

\[ s = s_0 + c_1 + c_2 \]

I. Pipes subjected to predominantly static loading and rated for a temperature up to 120\(^\circ\)C:

\[ s_v = \frac{d_a p}{2\sigma_{zul} \nu_{N}} \]

II. Pipes subjected to predominantly static loading and rated for a temperature over 120\(^\circ\)C:

for: \( \frac{d_a}{d_i} \leq 1.67 \)

\[ s_v = \frac{d_a}{2\sigma_{zul} \nu_{N} + 1} \]

for: \( 1.67 < \frac{d_a}{d_i} \leq 2 \)

\[ s_v = \frac{d_a}{3\sigma_{zul} \nu_{N} - 1} \]
III. Pipes subjected to fatigue loading and rated for a temperature up to 120°C:

For fatigue failure at constant stress amplitude:

\[
s_v = \frac{d_a}{2\sigma_{zul} \sqrt{\nu_N - 1}}
\]

where:

- \( s \) = required thickness of the pipe
- \( s_v \) = design wall thickness of the pipe
- \( c_1 \) = lower limit deviation for wall thickness
- \( c_2 \) = factor to allow for corrosion or wear
- \( d_a \) = pipe outside diameter
- \( d_i \) = pipe inside diameter
- \( \sigma_{zul} \) = maximum permissible stress under static loading
- \( \nu_N \) = degree of utilization of the design stress in the weld
- \( p \) = design pressure
- \( \sigma_{zul} \) = maximum permissible stress under fatigue loading
- \( p - p \) = pressure amplitude

**Stresses Due To Sustained Loads vs. Allowed Stresses**

Stresses due to Sustained loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress. They are calculated using the following Longitudinal Stress Equation [Section 302.3.5(c)]:

\[
S_L = \frac{P d^2}{(D_o^2 - d^2)} + \frac{F_A}{\frac{\pi}{4} (D_o^2 - d^2)} \pm \frac{\sqrt{(i_o M_o)^2 + (i_o M_o)^2}}{Z} \leq S_h
\]
where:

\[ S_L = \text{the sum of longitudinal stress due to pressure, weight, and other sustained loads} \]
\[ F_A = \text{axial force, lbs} \]
\[ i_1 = \text{in-plane stress intensification factor} \]
\[ i_o = \text{out-plane stress intensification factor} \]
\[ M_I = \text{in-plane bending moment, inch-pounds} \]
\[ M_o = \text{out-plane bending, inch-pounds} \]
\[ S_h = \text{basic material allowable stress at maximum (hot) temperature from the Allowable Stress Tables, psi} \]

As can be seen from the equation, the longitudinal stress due to the combined pressure and weight stresses shall be less than or equal to \( S_h \).

The third term in the longitudinal stress equation will be replaced by:

\[
\frac{\sqrt{M_I^2 + M_o^2}}{Z}
\]

when the request for no intensification factors (SUSNSI) in the sustained load case is selected.

For full-size outlet connections:

\[
Z = \frac{\pi}{32} \left( \frac{D_o^4 - d^4}{D_o} \right)
\]

For reduced outlet branch connections:

\[
Z_e = \pi r_2^3 T_S
\]

where:

\[ Z = \text{section modulus, in}^3 \]
\[ Z_e = \text{effective section modulus of reduced branch, in}^3 \]
\[ r_2 = \text{mean branch cross-sectional radius, inches} \]
\[ T_S = \text{effective branch wall thickness (lesser of } T_h \text{ and } i \cdot T_h), \text{ inches} \]
\( T_h \) = thickness of pipe matching run of tee or header exclusive of reinforcing elements, inches
\( T_b \) = thickness of pipe matching branch, inches
\( d = \) inside diameter of pipe \( D_o - 2 \cdot t \) inches

**Displacement Stress Range**

The extent of the Displacement Stress Range induced is computed in the Thermal Analysis processed by TRIFLEX®. This stress range must satisfy the following ANSI/ASME B31.3 Code (Section 319.4.4, Equation 17):

\[
S_E = \sqrt{S_b^2 + 4S_t^2} \leq S_A
\]

where:

\( S_b = \) resultant bending stress, psi
\( S_t = \) torsional stress, psi
\( M_t/2Z = \) torsional moment, psi

\[
S_A = f (1.25 S_t + 0.25 S_b)
\]

where:

\( S_c = \) basic material allowable stress at minimum (cold) temperature from the Allowable Stress Tables, psi

When the liberal method is selected \( S_A \) is replaced by the following equation when \( S_L \) is less than or equal to \( S_h \):

\[
S_A = f (1.25 S_c + 0.25 S_h) + f (S_h - S_L)
\]

\[
S_h = \frac{\sqrt{(i_c M_i)^2 + (i_c M_o)^2}}{Z}
\]

If Occasional Loads have been requested, a third Output Report will appear.
Occasional Stresses for each direction requested are computed in the Weight Factor Analyses.

\[ S_o = \frac{M_{GF\text{(axis)}}}{Z} \]

The moments at each piping location from each Weight Factor Analysis are combined in the following manner:

\[ M_{GF(X)} = \sqrt{(i_i M_i)^2 + (i_o M_o)^2} \]

\[ M_{GF(Y)} = \sqrt{(i_i M_i)^2 + (i_o M_o)^2} \]

\[ M_{GF(Z)} = \sqrt{(i_i M_i)^2 + (i_o M_o)^2} \]

Stresses Due To Sustained Loads

Stresses due to Sustained Loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress.

Stresses Due to Occasional Loads vs. Allowed Stresses

\[ S_L = \frac{P d^2}{(D_o^2 - d^2)} + \frac{F_A}{\pi} \left( \frac{d}{D_o^2 - d^2} \right) \pm \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z} \]

Stresses due to Occasional Loads, \( S_{LO} \), are the algebraic summations of the Longitudinal Sustained Weight Stress, the Longitudinal Pressure Stress, and Occasional Stresses (B31.3, Section 302.3.6).

\[ S_{LO} = \frac{P d^2}{(D_o^2 - d^2)} + \frac{F_A}{\pi} \left( \frac{d}{D_o^2 - d^2} \right) \pm \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z} + \frac{M_B}{Z} \leq kS_h \]

where:

\[ M_B = \sqrt{M_{GF(X)}^2 + M_{GF(Y)}^2 + M_{GF(Z)}^2} \]
As can be seen from the equation, the Longitudinal Stress due to Occasional Loads shall be less than or equal to $k S_h$.

where:

$$K = \text{as much as 1.33 times the basic allowable stress given in Appendix A.}$$
8.1.3 ANSI B31.4 Liquid Petroleum Transportation Piping Code

The ANSI B31.4 Compliance Report consists of three to four separate Output Reports. The first Output Report lists all of the B31.4 Code Compliance Data specified by the User. The second Output Report contains the node identification, Hoop stress compared to its allowable and the design shear stress compared to its allowable. The third Output Report contains the node identification, design wall thickness vs. required wall thickness, the sustained stresses compare to its allowable and the expansion Stress range compare to its allowable. The fourth report contains a summary of all occasional stresses about each axis requested, the sustained longitudinal stress, and the resultant occasional stress vs. its allowable.

Output units and equations shown in this section are for the English system. Output units are available for the following:

(1) English (ENG)          (3) Metric (MET)
(2) System International (SI) (4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MINIMUM YIELD STRENGTH psi</th>
<th>WELD JOINT FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and To Data Number

The range of data point numbers for which the specified properties apply.

Specified Minimum Yield Strength (SMYS), psi

From Code Tables.

Weld Joint Factor (E)

From Code Tables.
The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>HOOP STRESS psi</th>
<th>HOOP ALLOWED psi</th>
<th>SHEAR STRESS psi</th>
<th>SHEAR ALLOWED psi</th>
<th>WALL THICKNESS in</th>
<th>WALL THICKNESS REQUIRED in</th>
<th>SUSTAINED STRESS ACTUAL psi</th>
<th>SUSTAINED STRESS ALLOWED psi</th>
<th>EXPANSION STRESS ACTUAL psi</th>
<th>EXPANSION STRESS ALLOWED psi</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Hoop Stress**

The standard hoop stress equation:

\[ S_{\text{hoop}} = \frac{P \cdot D}{2(t - c)} \]

where:

\[ S_{\text{hoop}} = \text{hoop stress, psi} \]
\[ P = \text{design pressure, psig} \]
\[ D = \text{actual outside diameter, in} \]
\[ t = \text{given wall thickness, in} \]
\[ c = \text{corrosion allowance, in} \]

is compared with \((0.72)(E)(\text{SMYS})\). If the S value is greater than \((0.72)(E)(\text{SMYS})\) a *B31* flag will be printed along side of the value.

where:

\[ E = \text{weld joint factor} \]
\[ \text{SMYS} = \text{specified minimum yield strength, psi} \]
Design and Allowed Shear Stress

Shear stress is computed in the Weight + Pressure Analysis processed by TRIFLEX. No other effects such as temperature or pressure (optional) are considered.

\[
S_p = \frac{(S_L + S_H)}{2} + S_{sh}
\]

\[
S_{sh} = \sqrt{\left(\frac{(S_L - S_H)}{2}\right)^2 + \left(\frac{M_i}{2Z}\right)^2}
\]

\[
S_{shear} = \text{greater of } S_{sh} \text{ or } \frac{S_p}{2} \leq 0.45 \text{SMYS}
\]

\[
S_L = \frac{P(OD - 2t)}{A_{wall}} + \frac{F_A}{A_{wall}} + \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z}
\]

where:

- \(S_p\) = maximum principal stress, psi
- \(S_{sh}\) = secondary shear stress, psi
- \(S_L\) = sum of longitudinal stresses due to pressure and other sustained loadings
- \(i_i\) = in-plane intensification factor
- \(i_o\) = out-plane intensification factor
- \(M_i\) = in-plane bending moment, in-lbs
- \(M_o\) = out-plane bending moment, in-lbs
- \(Z\) = section modulus, in\(^3\)
- \(F_A\) = axial force, lbs
- \(A_{wall}\) = area of the pipe wall, in\(^2\)

The allowable stress value in shear is calculated in accordance with B31.4 [Section 402.3.1,e].
The third Output Report contains the following information:

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Design Wall Thickness vs. Required Thickness**

The Design Wall Thickness is input by the User. The required Wall Thickness is calculated by **TRIFLEX** using the following B31.4 Code Equations (Section 404.1.2) and the User-supplied internal pressure:

\[
t = \frac{P_i D}{2S} \\
t_n = t + A
\]

where:

- \( t \) = pressure design wall thickness as calculated in accordance with Para. 404.1.2,
- \( t_n \) = nominal wall thickness satisfying requirements for pressure and allowances, inches
- \( P_i \) = internal design pressure as input by the User, psig
- \( D \) = actual pipe outside diameter, inches
- \( S \) = applicable allowable stress value in accordance with Para. 402.3.1, psi
  - \( = 0.72\text{SMYS} \)
- \( E \) = weld joint factor (see Para. 402.4.3)

**Stresses Due to Sustained Loads vs. Allowed Stresses**

Stresses due to Sustained Loads, \( S_L \), are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Sustained Weight Stress. \( S_L \) is calculated using the following B31.4 Code Equation (Section 419.6.4(c)):
where:

\[ S_{A} = 0.72 \text{SMYS} \]

The second term in the longitudinal stress equation will be replaced by

\[ \frac{\sqrt{(i_{1} M_{1})^2 + (i_{0} M_{0})^2}}{Z} \]

when a request of no intensifications factors (SUSNSI) in the sustained load case is selected.

**Expansion Stress Range Compared to Allowed Stress**

**Unrestrained Piping**

If the "FROM" data point number specified in the B314 data set is not preceded by a minus sign, the entire range of data points covered by the B314 data set will be treated as unrestrained. For unrestrained piping, the expansion stress is computed in the Thermal Analysis processed by TRIFLEX. No other effects, such as weight and pressure (optional), are considered by TRIFLEX in the Thermal Analysis.

The expansion stress for Runs, Branches, Elbows, and Miter Bends is calculated using the following B31.4 Code Equation [Section 419.6.4(a)]:

\[ S_{E} = \sqrt{S_{b}^2 + 4 S_{t}^2} \leq S_{A} \]

where:

\[ S_{E} = \text{Computed expansion stress, psi} \]

\[ S_{b} = \frac{\sqrt{(i_{1} M_{1})^2 + (i_{0} M_{0})^2}}{Z} \]

\[ S_{b} = \text{equivalent bending stress, psi} \]

\[ S_{t} = \text{torsional stress, psi} \]

\[ = \frac{M_{t}}{2Z} \]

The allowed expansion stress range for unrestrained piping is given by the following equation:
Restrained Piping

If the "FROM" data point number specified in the B314 data set for a range of data point properties is **negative** (preceded by a minus sign), then the entire range of data points described on the B314 data set is considered to be **restrained piping**. For restrained piping, TRIFLEX computes the longitudinal expansion stress from the equation given in B31.4 Section 419.6.4(b):

\[ S_L = E \alpha (T_2 - T_1) - \nu S_h \]

where:

- \( S_L \) = Longitudinal compressive stress, psi
- \( E \) = Modulus of elasticity of steel, psi
- \( S_h \) = Hoop stress due to fluid pressure, psi
- \( T_1 \) = Temperature at time of installation, degrees F
- \( T_2 \) = Maximum or minimum operating temperature, degrees F
- \( \alpha \) = Linear coefficient of thermal expansion, inches/inches/degrees F
- \( \nu \) = Poisson's ratio = 0.3 for steel.

The term \((\alpha)(T_2 - T_1)\) is determined from information input by the User.

The net longitudinal stress becomes compressive for moderate increases of \( T_2 \) and that according to the commonly used maximum shear theory of failure, this compressive stress adds directly to the hoop stress to increase the equivalent tensile stress available to cause yielding. This equivalent tensile stress shall not be allowed to exceed 90% of the specified minimum yield strength of the pipe.

If Occasional Loads have been requested, a fourth Output Report will be generated.

**The fourth Output Report contains the following information:**

**Data Point**

The number assigned by the User to each significant location.
Node Location

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

Occasional Stresses

Occasional Stresses for each direction requested are computed in the Weight Factor Analyses.

\[ S_O = \frac{M_{GF(ass)}}{Z} \]

Moments at each piping location from each Weight Factor Analysis are combined thusly:

\[ M_{GF(X)} = \sqrt{(i_i M_i)^2 + (i_o M_o)^2} \]
\[ M_{GF(Y)} = \sqrt{(i_i M_i)^2 + (i_o M_o)^2} \]
\[ M_{GF(Z)} = \sqrt{(i_i M_i)^2 + (i_o M_o)^2} \]

Stresses Due To Sustained Loads

Stresses due to Sustained Loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress.

\[ S_L = \frac{PD}{4(t - A)} + \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z} \]

Stresses Due to Occasional Loads vs. Allowed Stresses

Stresses due to Occasional Loads, \( S_{LO} \), are the algebraic summations of the Longitudinal Sustained Weight Stress, the Longitudinal Pressure Stress, and Occasional Stresses. (B31.4, Section 402.3.3)
where:

\[ S_{LO} = \frac{P_i D}{(4(t - A))} + \frac{\sqrt{(i_i M_i)^2 + (i_o M_o)^2}}{Z} + \frac{M_B}{Z} \leq 0.80 \times \text{SMYS} \]

\[ M_B = \sqrt{M_{GF(X)}^2 + M_{GF(Y)}^2 + M_{GF(Z)}^2} \]

As can be seen from the equation, the Longitudinal Stress due to Occasional Loads shall be less than or equal to 0.80SMYS.
8.1.4 ANSI B31.8 Gas Transmission and Distribution Piping Systems

The ANSI B31.8 Code Compliance Report capability in TRIFLEX can be processed for onshore piping systems and for offshore piping systems. The equations for computing stresses in the piping components are different for the Onshore criteria and for the Offshore criteria. As a result, the section immediately following this paragraph covers the Offshore piping systems and the section covering the Onshore piping is provided immediately following the conclusion of the Offshore discussion.

OFFSHORE PIPING

The ANSI B31.8 Compliance Report for Offshore piping consists of three separate Output Reports in the pre-formatted reports and two separate Output Reports in the spreadsheet output. The third pre-formatted Output Report contains the node identification, the longitudinal stress actual vs. the longitudinal stress allowed, and the combined stress based upon either the Tresca or the Von Mises equations as specified by the User vs. the combined stress allowed. The second spreadsheet Output Report contains all of the data presented in the second and third pre-formatted Output Reports.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

1) English (ENG)  
2) System International (SI)  
3) Metric (MET)  
4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MINIMUM YIELD STRENGTH Para. 841.11(a) psi</th>
<th>DESIGN FACTOR</th>
<th>WELD JOINT FACTOR</th>
<th>TEMP DERATING FACTOR Para. 841.11(a)</th>
<th>OFFSHORE FACTOR 1 Para. A842.221</th>
<th>OFFSHORE FACTOR 2 Para. A842.222</th>
<th>OFFSHORE FACTOR 3 Para. A842.223</th>
<th>ALTER COMBINE STRESS Para. A842.223</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and To

The number assigned by the User to each significant location in the piping model.

SMYS - Spec. Min. Yield Strength
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TRIFLEX displays the value entered by the User for the Specified Minimum Yield Strength of the pipe. Refer to Section 841.11(a) of the B31.8 Piping Code for more specific information.

**Temperature Derating Factor, T**

TRIFLEX displays the value entered by the User for the temperature de-rating factor as described in DOT Section 192.115. Refer to Section 841.11(a) of the B31.8 Piping Code for more specific information.

**Design Factor for Hoop Stress, F1**

TRIFLEX displays the value entered by the User for Hoop Stress Design Factor. Refer to Section A842.221 of the B31.8 Piping Code for more specific information.

**Design Factor for Long. Stress, F2**

TRIFLEX displays the value entered by the User for Longitudinal Stress Design Factor. Refer to Section A842.222 of the B31.8 Piping Code for more specific information.

**Design Factor for Combined Stress, F3**

TRIFLEX displays the value entered by the User for Combined Stress Design Factor. Refer to Section A842.223 of the B31.8 Piping Code for more specific information.

**Combined Stress Theory**

TRIFLEX will display \( \text{Tresca} \) if the User has specified that the Tresca equation be used to calculate the combined stress value at this node location or \( \text{Von Mises} \) if the User has specified that the Von Mises equation be used to calculate the combined stress value at this node location. Refer to Section A842.223 of the B31.8 Piping Code for more specific information.

The Report of Calculated Results for the Offshore capability contains the information described below. The data listed below is provided in one report in the spreadsheet capability and in two reports in the pre-formatted reports capability.

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>DESIGN WALL THICKNESS in</th>
<th>WALL THICKNESS MINIMUM REQUIRED Para. A842.221 in</th>
<th>HOOP STRESS ACTUAL psi</th>
<th>HOOP STRESS ALLOWED Para. A842.221 psi</th>
<th>LONGITUDINAL STRESS ACTUAL psi</th>
<th>LONGITUDINAL STRESS ALLOWED Para. A842.222 psi</th>
<th>COMBINED STRESS ACTUAL psi</th>
<th>COMBINED STRESS ALLOWED Para. A842.223 psi</th>
<th>COMBINED STRESS THEORY Para. A842.223 psi</th>
<th>COMBINED STRESS ALLOWED (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Point</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Data Point**
The number assigned by the User to each significant location in the piping model.

**Node Location**

The Node Location defines the exact point on the piping component at which the values are calculated; i.e., Anchor, Run Beg, Run End, Joint, Valve, Flange, Bend Beg, Bend Mid, Bend End, Reducer Beg, Reducer End, Release Element or Expansion Joint.

**Wall Thickness - Design vs. Wall Thickness - Minimum Required**

The Design Wall Thickness is entered by the User. The Minimum Required Wall Thickness is calculated by TRIFLEX using the following B31.8 Code Equation (Section A842.221, the User-entered internal pressure and the external pressure calculated by TRIFLEX using the density of the surrounding fluid and the depth of the pipe):

where:

\[
t_n = t + c
\]

\[
t = \frac{(P_i - P_e)D}{2F_1ST}
\]

where:

- \( t_n \) = required wall thickness as calculated in accordance with Para. A842.221,
- \( t \) = required wall thickness as calculated in accordance with Para. A842.221,
- \( P_i \) = internal design pressure, psi
- \( P_e \) = external pressure, psi
- \( D \) = nominal outside diameter of pipe, inches
- \( F_1 \) = hoop stress design factor obtained from Table A842.22
- \( S \) = specified minimum yield strength (SMYS), psi
- \( T \) = temperature derating factor obtained from Table A841.116A
- \( t_n \) = minimum required wall thickness satisfying the pressure and allowances requirements, inches
- \( c \) = corrosion allowance, in

**Hoop Stresses - Actual vs. Hoop Stresses - Allowed**

For pipelines and risers, the tensile hoop stress due to the difference between internal and external pressures shall not exceed the values shown below as described in the B31.8 Code Equation (Section A842.221):

\[
S_s \leq F_1ST
\]
where:

\[ S_h = \frac{P_i - P_e}{2t} D \]

- \( S_h \) = hoop stress, psi
- \( P_i \) = internal design pressure, psi
- \( P_e \) = external pressure, psi
- \( D \) = nominal outside diameter of pipe, inches
- \( t \) = nominal wall thickness, inches
- \( F_1 \) = hoop stress design factor obtained from Table A842.22
- \( S \) = specified minimum yield strength (SMYS), psi
- \( T \) = temperature derating factor obtained from Table A841.116A

**Hoop Stress - Actual / Allowed (%)**

TRIFLEX displays the percentage of the actual calculated hoop stress for the specific node divided by the allowed hoop stress. A number greater than 100 indicates that the actual calculated stress exceeds the allowed stress.

**Longitudinal Stress - Actual vs. Longitudinal Stress - Allowed**

For pipelines and risers, the longitudinal stress shall not exceed the values shown below as described in the B31.8 Code Equation (Section A842.222):

\[ |S_L| \leq F_2 S \]

where:

- \( S_L \) = maximum longitudinal stress, psi (positive tensile or negative compressive)
- \( F_2 \) = longitudinal stress design factor obtained from Table A842.22
- \( S \) = specified minimum yield strength (SMYS), psi
**Longitudinal Stress - Actual / Allowed (%)**

In this column, TRIFLEX displays the percentage of the actual calculated longitudinal stress for the specific node divided by the allowed longitudinal stress. A number greater than 100 indicates that the actual calculated stress exceeds the allowed stress.

**Combined Stress - Actual vs. Allowed**

According to Para. A842.223 of the B31.8 Piping Code, the combined stress shall not exceed the value given by the maximum shear stress equation (Tresca combined stress):

\[
F_3 S \geq 2 \sqrt{\left( \frac{S_L}{2} - \frac{S_h}{2} \right)^2 + S_s^2}
\]

where:
- \(S_L\) = maximum longitudinal stress, psi
- \(S_h\) = hoop stress, psi
- \(F_3\) = combined stress design factor obtained from Table A842.23
- \(S\) = specified minimum yield strength (SMYS), psi
- \(S_s\) = tangential shear stress, psi

Alternatively, according to Para. A842.223 of the B31.8 Piping Code, the User can require that the combined stress be calculated using the Maximum Distortional Energy Theory (Von Mises combined stress) and that the resulting longitudinal stress values not exceed the value given by the following longitudinal stress equation (Von Mises combined stress):

\[
F_3 S \geq \sqrt{\left( S_h^2 - S_L S_h + S_L^2 + 3 S_s^2 \right)}
\]

where:
- \(S_L\) = maximum longitudinal stress, psi
- \(S_h\) = hoop stress, psi
- \(F_3\) = combined stress design factor obtained from Table A842.22
- \(S\) = specified minimum yield strength (SMYS), psi
\[ S_s = \text{tangential shear stress, psi} \]

**Combined Stress Theory**

TRIFLEX lists the theory that the User has selected by which the combined stress values are to be calculated. The stress theory that TRIFLEX defaults to is Tresca = maximum shear stress equation, however, the User may request that the stress values be calculated in accordance with Von Mises Maximum Distortional Energy equation.

**Combined Stresses - Actual / Allowed (%)**

TRIFLEX displays the percentage of the actual calculated combined stress for the specific node point divided by the allowed combined stress. A number greater than 100 indicates that the actual calculated stress exceeds the allowed stress.

**ONSHORE PIPING**

The ANSI B31.8 Compliance Report for Onshore piping consists of four separate Output Reports in the pre-formatted reports and two separate Output Reports in the spreadsheet output. The third pre-formatted Output Report contains the node identification; the longitudinal sustained plus occasional stress actual vs. its allowable and the expansion stress vs. its allowable. The fourth pre-formatted Output Report contains a summary of all occasional stresses resulting from loads applied along each axis specified by the User, the longitudinal sustained stress actual, and the longitudinal sustained and occasional stress actual. The second spreadsheet Output Report contains all of the data presented in the second, third and fourth pre-formatted Output Reports.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

1) English (ENG)  3) Metric (MET)
2) System International (SI)  4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

**The first Output Reports contains the following information:**

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MINIMUM YIELD STRENGTH Para. 841.11 (a) N/mm²</th>
<th>DESIGN FACTOR Para. 841.11 (a)</th>
<th>WELD JOINT FACTOR Para. 841.11 (a)</th>
<th>TEMPERATURE DERATING FACTOR Para. 841.11 (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From and To Data Numbers

The range of data point numbers for which the specified properties apply.

SMYS - Spec. Min. Yield Strength

TRIFLEX displays the value entered by the User for the Specified Minimum Yield Strength of the pipe. Refer to Section 841.11(a) of the B31.8 Piping Code for more specific information.

Design Factor, F

TRIFLEX displays the value entered by the User for the design factor as described in DOT Section 192.111 for steel pipe. Refer to Section 841.11(a) of the B31.8 Piping Code for more specific information.

Longitudinal Joint Factor, E

TRIFLEX displays the value entered by the User for the weld joint factor for the welding process used in the manufacture of the pipe. Refer to Section 841.11(a) of the B31.8 Piping Code for more specific information.

Temperature Derating Factor, T

TRIFLEX displays the value entered by the User for the temperature de-rating factor as described in DOT Section 192.115. Refer to Section 841.11(a) of the B31.8 Piping Code for more specific information.

The Report of Calculated Results for the Onshore capability contains the below information. The data listed below is provided in one report in the spreadsheet capability and in three reports in the pre-formatted reports capability.
The number assigned by the User to each significant location in the piping model.

**Node Location**

The “Node” description defines the piping segment types; i.e, Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The “Location” description defines the exact point on the piping segment where the calculated values apply.

**Wall Thickness - Design vs. Wall Thickness - Minimum Required**

The Design Wall Thickness is entered by the User. The Minimum Required Wall Thickness is calculated by TRIFLEX using the following B31.8 Code Equation (Section 841.11 and the User-entered internal pressure):

\[
 t_n = t + c
\]

where:

\[
t = \text{required wall thickness as calculated in accordance with Para. 841.11, inches}
\]

\[
t = \frac{(P_i - P_e)D}{2SFET}
\]

\[
P_i = \text{internal design pressure, psi (see Para. 841.111)}
\]

\[
P_e = \text{external pressure, psi}
\]

\[
D = \text{nominal outside diameter of pipe, inches}
\]

\[
S = \text{specified minimum yield strength, psi [see Para. 841.112 and 817.13(h)]}
\]

\[
F = \text{design factor obtained from Table 841.114A}
\]

\[
E = \text{longitudinal joint factor obtained from Table 841.115A [see Para. 817.13(d)]}
\]

\[
T = \text{temperature derating factor obtained from Table A841.116A}
\]

\[
t_n = \text{minimum required wall thickness satisfying the pressure and allowances requirements, inches}
\]

\[
c = \text{corrosion allowance, in}
\]

For Onshore Piping Systems where internal and external pressure exists, the User should enter the differential pressure as the internal pressure.

**Combined Stress - Actual vs. Combined Stress - Allowed**
According to paragraph 833.4 of the B31.8 Piping Code, the total of the following stresses shall not exceed the specified minimum yield strength $S$:

a) the combined stress due to expansion $S_{E}$;

b) the longitudinal pressure stress as defined in paragraph 841.11 of the piping code, SFT;

c) the longitudinal bending stress due to external loads, such as weight of pipe and contents, wind or seismic, etc.,. Wind or seismic will be treated as occasional loads.

The sum of the combined stress due to expansion, $S_{E}$, the longitudinal pressure stress and longitudinal bending stresses due to sustained and occasional loads should not exceed the Specified Minimum Yield Strength, $S$. The allowable value for the sum of these stresses calculated by TRIFLEX is given in the following equation:

$$S_{A(combined)} = S$$

**Combined Stress - Actual / Allowed (%)**

TRIFLEX displays the percentage of the actual calculated combined stress for the specific node point divided by the allowed combined stress. A number greater than 100 indicates that the actual calculated stress exceeds the allowed stress.

**Longitudinal Stress Due to Sustained & Occasional Loads - Actual vs. Longitudinal Stress Due to Sustained & Occasional Loads - Allowed**

Stresses due to Sustained Loads, $S_L$, are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Stress due to Sustained Loads (pipe weight, contents weight and insulation weight). The Longitudinal Stress due to Occasional Loads is those resulting from conditions such as wind and earthquake. $S_L$ with the Occasional Loads is calculated using the following B31.8 Code Equation [Section 833.4 (b) and (c)]:

$$S_L = \frac{P \cdot D}{4(t - c)} + \frac{i \sqrt{M_i^2 + M_e^2}}{Z} + \frac{i M_B}{Z}$$

where:

- $P$ = design pressure, psi
- $OD$ = outside diameter, in
- $t$ = nominal wall thickness, in
- $c$ = corrosion allowance, in
i = stress intensification factor

Z = section modulus of pipe, in$^3$

$M_i$ = in-plane bending moment, in-lbs

$S_A = 0.75 S$

$M_b = \sqrt{M_{GF(X)}^2 + M_{GF(Y)}^2 + M_{GF(Z)}^2}$

$M_o$ = out-of-plane bending moment, in-lbs

The sum of the longitudinal pressure and bending stresses from sustained and occasional loads should not exceed 75% of the allowable stress in the hot condition. The allowable value for the sum of the longitudinal stresses calculated by TRIFLEX is given in the following equation:

In all comparisons, when the allowed value is less than the value found for the piping system, a *B31 flag is printed to the right side of the comparison.

When the User places a check in the box in the option on the Code Data dialog for no intensifications factors to be included in the longitudinal bending stresses, TRIFLEX will replace the second term in the longitudinal stress equation with the following:

$\sqrt{M_i^2 + M_o^2}$

$Z$

**Longitudinal Stress Due to Sustained & Occasional Loads - Actual/Allowed (%)**

In this column, TRIFLEX displays the percentage of the actual calculated longitudinal sustained & occasional stress for the specific node point divided by the allowed longitudinal sustained & occasional stress. A number greater than 100 indicates that the actual calculated stress exceeds the allowed stress.

**Combined Stress due to Expansion, $S_E$ - Actual vs. Combined Stress due to Expansion, $S_E$ - Allowed**

The expansion stress is computed in the Thermal Analysis processed by TRIFLEX. No other effects such as weight and/or pressure are considered in this Thermal Analysis. The expansion stress is calculated using the following B31.8 Code Equation [Section 833.2]:

where:

$S_E = \text{combined expansion stress, psi}$

$S_E = \sqrt{S_b^2 + 4 S_i^2}$
S_b = resultant bending stress, psi
   = i M_b/z

S_t = torsional stress, psi
   = M_t/2z

M_b = resultant bending moment in-lb

i = stress intensification factor

The allowed expansion stress range is calculated by TRIFLEX using the following equation [Section 833.3]:

**Combined Stress due to Expansion, S_E - Actual / Allowed (%)**

In this column, TRIFLEX displays the percentage of the actual calculated expansion stress for the specific node point divided by the allowed expansion stress. A number greater than 100 indicates that the actual calculated stress exceeds the allowed stress.

If Occasional Loads have been requested, the data listed below will be generated. In the spreadsheet capability, the data will be listed to the right of the data listed above. In the pre-formatted reports capability, the data will be listed in a fourth report.

**Longitudinal Bending Stresses due to Occasional Loads by Axis**

Occasional Stresses resulting from occasional loads applied in each direction specified by the User are computed in the Weight Factor Analyses and displayed in the columns entitled X Occasional Stress, Y Occasional Stress and Z Occasional Stress. The Occasional Stress is calculated using the following equation:

\[ S_o = \frac{M_{GF(axis)}}{Z} \]

\[ M_{GF(X)} = \sqrt{M_i^2 + M_o^2} \]

\[ M_{GF(Y)} = \sqrt{M_i^2 + M_o^2} \]

\[ M_{GF(Z)} = \sqrt{M_i^2 + M_o^2} \]

The moments at each piping location from each Weight Factor Analysis are combined in the following manner:

The stresses resulting from the X Weight Factor Analysis are listed in the first stress column. The stresses resulting from the Y Weight Factor Analysis are listed in the second stress column. The stresses resulting from the Z Weight Factor Analysis are listed in the third stress column.
Longitudinal Bending Stress due to Resultant Occasional Loads

The Resultant Occasional Stresses are calculated using the following equation:

\[ S_{LO} = \frac{i M_B}{Z} \]

where:

- \( S_{LO} \) = resultant longitudinal occasional stress, psi
- \( i \) = stress intensification factor
- \( Z \) = section modulus of pipe, \( \text{in}^3 \)

\[
M_B = \sqrt{M_{GF(X)}^2 + M_{GF(Y)}^2 + M_{GF(Z)}^2}
\]

where:

\[
M_{GF(X)} = \sqrt{(M_X^2 + M_Y^2 + M_Z^2)}
\]

\[
M_{GF(Y)} = \sqrt{(M_X^2 + M_Y^2 + M_Z^2)}
\]

\[
M_{GF(Z)} = \sqrt{(M_X^2 + M_Y^2 + M_Z^2)}
\]
8.1.5 NAVY S505 Piping Code Compliance

The NAVY Piping Code Compliance Report consists of two to three Output Reports. The first Output Report lists all of the NAVY S505 Piping Code Compliance Data specified by the User. The second Output Report contains the node identification, sustained stresses vs. allowed stresses, and displacement stresses vs. allowed stresses. The third Output Report is generated only if Occasional (temporary) Loads Analyses were requested by the User. This report contains a summary of all occasional stresses about each axis requested, the sustained stress, and the resultant occasional stress vs. its allowable stress.

Output units and equations shown in this section are for the English system. Output units are available for the following:

1. English (ENG)
2. System International (SI)
3. Metric (MET)
4. International Units 1 (IU1)

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>OPERATING HOT STRESS WITH WELD F. psi</th>
<th>ALLOWABLE COLD STRESS psi</th>
<th>ALLOWABLE HOT STRESS psi</th>
<th>STRESS RANGE REDUCTION FACTOR</th>
<th>OCCASIONAL FATIGUE FACTOR</th>
<th>Y COEFFICIENT</th>
<th>MILL TOLERANCE</th>
</tr>
</thead>
</table>

From and to Data Numbers

The range of data point numbers for which the specified properties apply.

Allowable Operating Stress (SE)

The maximum allowable stress in material due to internal pressure and joint efficiency at the design temperature, psi.

Allowed Cold Stress (SC)

The basic material allowable stress at the minimum (cold) temperature from the Allowable Stress Tables, psi.
Allowed Hot Stress (SH)

The basic material allowable stress at the maximum (hot) temperature from the Allowable Stress Tables, psi.

**Stress Range Reduction Factor**

Factor specified by User to reduce stress allowable because of cyclic conditions.

**Occasional Load Factor K**

Factor specified by the User, based upon the duration of the occasional loads.

**Y-Coefficient**

Per the NAVY Code Book (Table VII).

**Mill Tolerance**

Manufacturer mill tolerance in percent or (inches or millimeters).

The **second Output Report contains the following information:**

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>WALL THICKNESS DESIGN in</th>
<th>WALL THICKNESS REQUIRED in</th>
<th>SUSTAINED STRESS ACTUAL psi</th>
<th>SUSTAINED STRESS ALLOWED psi</th>
<th>SUSTAINED STRESS PERCENT</th>
<th>EXPANSION STRESS ACTUAL psi</th>
<th>EXPANSION STRESS ALLOWED psi</th>
<th>EXPANSION STRESS PERCENT</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Design Wall Thickness vs. Required Thickness**

The Design Wall Thickness is input by the User. The required Wall Thickness is calculated by TRIFLEX using the following equation and the User-supplied internal pressure:
where:

\[ t_{\text{min}} = \frac{P \cdot D_o}{2(SE + P_y)} + A \]

\[ t_{\text{req}} = \frac{t_{\text{min}}}{(100.0 - MT)/100} \]

Stresses Due To Sustained Loads vs. Allowed Loads

Stresses due to Sustained loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress. They are calculated using the following equation:

\[ S_L = \frac{P \cdot OD}{4t} + \frac{i \cdot M_A}{Z} \leq S_h \]

where:

- \( S_L \) = the sum of longitudinal stress due to pressure, weight, and other sustained loads
- \( P \) = pressure, psig
- \( OD \) = Outside diameter, inches

\[ M_A = \sqrt{M_i^2 + M_o^2} \]
\( M_i \) = in-plane bending moment, inch-pounds
\( M_o \) = out-plane bending, inch-pounds
\( i \) = stress intensification factor

As can be seen from the equation, the longitudinal stress due to the combined pressure and weight stresses shall be less than or equal to the \( S_h \).

For full-size outlet connections:

\[
Z = \frac{\pi}{32} \left( \frac{OD^4 - ID^4}{OD} \right)
\]

For reduced outlet branch connections:

\[
Z_e = \pi r_m^2 t_s
\]

where:

\( Z \) = section modulus, \( \text{in}^3 \)
\( Z_e \) = effective section modulus of reduced branch, \( \text{in}^3 \)
\( r_m \) = the mean radius of the branch, inches
\( t_s \) = effective wall thickness of branch (the smaller of \( t_h \) and \( i@ \)), inches
\( t_h \) = nominal wall thickness of main pipe, inches
\( t_b \) = nominal wall thickness of branch, inches
\( OD \) = the nominal outside diameter of the pipe, inches
\( ID \) = inside diameter of pipe \( OD - 2@ \) inches

**Expansion Stress Range**

The extent of the expansion stress range induced is computed in the Thermal Analysis processed by TRIFLEX. This stress range must satisfy the condition:

\[
S_e = \frac{i \sqrt{M_i^2 + M_o^2 + i^2}}{Z} \leq S_A
\]
\[ S_A = f(1.25S_c + 0.25S_h) \]

- \( S_c \) = basic material allowable stress at minimum (cold) temperature from the Allowable Stress Tables, psi
- \( S_h \) = basic material allowable stress at maximum (hot) temperature from the Allowable Stress Tables, psi

An alternative formula is:

\[ S_E = \frac{i}{Z} \left( \frac{M_i^2 + M_o^2}{Z} \right) \leq S_A + f(S_h - S_L) \]

where:
- \( M_i \) = in-plane bending moment, inch-pounds
- \( M_o \) = out-plane bending, inch-pounds
- \( M_t \) = torsional moment, inch-pounds

which will be used when the liberal method is requested. If Occasional Loads have been requested, a third Output Report will be generated.

**The third Output Report contains the following information:**

**Occasional Stresses**

Occasional Stresses for each direction requested are computed in the Weight Factor Analyses.

\[ S_O = 0.75i \left( \frac{M_b}{Z} \right) \]

where:

\[ M_b = \sqrt{M_{GF(X)}^2 + M_{GF(Y)}^2 + M_{GF(Z)}^2} \]

The moments at each piping location from each Weight Factor Analysis are combined in the following manner:

\[ M_{GF(X)} = \sqrt{(M_i^2 + M_o^2 + M_t^2)} \]

\[ M_{GF(Y)} = \sqrt{(M_i^2 + M_o^2 + M_t^2)} \]
\[ M_{GF/Z} = \sqrt{(M_i^2 + M_o^2 + M_{\text{od}}^2)} \]

**Stresses Due To Sustained Loads**

Stresses due to Sustained Loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress.

\[ S_L = \frac{P \cdot OD}{4t} + i\frac{\sqrt{M_i^2 + M_o^2}}{Z} \]

**Stress Due to Occasional Loads vs. Allowed Stresses**

Stresses due to Occasional Loads, \( S_{LO} \), are the algebraic summations of the Longitudinal Sustained Weight Stress, the Longitudinal Pressure Stress, and Occasional Stress.

\[ S_{LO} = \frac{P \cdot OD}{4t_n} + \frac{iM_A}{Z} + \frac{0.75iM_{\text{od}}}{Z} \leq kS_h \]

As can be seen from the equation, the Longitudinal Stress due to Occasional Load shall be less than or equal to \( kS_h \).
8.1.6  ASME Class 2 Components - Section III Subsection NC

The ASME Class 2 Compliance Report consists of three Output Reports. The first Output Report lists all of the Class 2 Code Compliance Data specified by the User. The second Output Report contains the node identification, the design wall thickness vs. the required wall thickness, sustained stresses vs. allowed and expansion stresses vs. allowed. The third Output Report is generated only if Occasional Loads Analyses were requested by the User. This report contains a summary of all occasional stresses about each axis requested, the sustained longitudinal stress, and the resultant occasional stress vs. its allowable.

Output units and equations shown in this section are for the English system. Output units are available for the following:

1. English (ENG)
2. System International (SI)
3. Metric (MET)
4. International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MATERIAL YIELD STRENGTH psi</th>
<th>ALLOWABLE COLD STRESS psi</th>
<th>ALLOWABLE HOT STRESS psi</th>
<th>STRESS RANGE REDUCTION FACTOR</th>
<th>EXPANSION STRESS RATIO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and To Data Point Numbers

The range of data point numbers for which the specified properties apply.

Specific Minimum Yield (SY)

Material yield strength at temperature consistent with the loading under consideration.

Minimum Stress (SC)

The basic material allowable stress value at room temperature from Tables I-7.0, psi.

Maximum Stress (SH)

The material allowable stress at temperature consistent with the loading under consideration.
Stress Range Reduction Factor

The stress range reduction factor for cyclic conditions for total number $N$ of full temperature cycles over total number of years during which system is expected to be in service from Table NC-3611.2 (e)-1.

Ratio of Installed to Operating Modulus

When using Para. NB-3672.5, which allows the use of the hot (operating) modulus to be used in determining moments and forces and hence the expansion stresses, this multiplier will be used to increase the stresses by the ratio of the installed to operating modulus of elasticity, psi. If the installed modulus was used in the analysis a ratio of 1.0 should be used. The second Output Report contains the following information:

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>SUSTAINED STRESS ACTUAL psi</th>
<th>SUSTAINED STRESS ALLOWED psi</th>
<th>EXPANSION STRESS ACTUAL psi</th>
<th>EXPANSION STRESS ALLOWED psi</th>
<th>TOTAL STRESS ACTUAL psi</th>
<th>TOTAL STRESS ALLOWED psi</th>
</tr>
</thead>
</table>

Data Point

The number assigned by the User to each significant location.

Node Location

The "Node" description defines the piping segment types; i.e., Anchor, Run, and Bend. The "Location" description defines the exact point on the piping segment where the calculated values apply.

Stresses Due to Sustained Loads Vs. Allowed Stresses

Stresses due to Sustained Loads, $S_{SL}$, are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight stress. $S_{SL}$ is calculated using the following ASME Class 2 Code Equation (NC-3652, Equation 8):
\[ S_{SL} = B_1 \frac{P D_o}{2 t_n} + B_2 \frac{M_A}{Z} \leq 1.5 S_h \]

\[ M_A = \sqrt{M_X^2 + M_Y^2 + M_Z^2} \]

where:

- \( Z \) = Section modulus, \( \text{in}^3 \)
- \( t_n \) = Nominal thickness, \( \text{inches} \)
- \( D_o \) = Outside diameter, \( \text{inches} \)
- \( P \) = Internal design pressure, \( \text{psi} \)
- \( M_A \) = Resultant moment loading on cross section due to weight and other sustained loads, \( \text{in-lbs} \)
- \( B_1, B_2 \) = primary stress indices for the specific product under investigation (NB-3680) see the table at the end of this section
- \( S_h \) = Material allowable stress at temperature consistent with the loading under consideration, \( \text{psi} \)

For full-size outlet connections:

\[ Z = \frac{\pi}{32} \left( \frac{D_o^4 - d^4}{D_o} \right) \]

For reduced outlet branch connections:

\[ Z_e = \pi r_b^2 t_e \]

where:

- \( Z_e \) = effective section modulus of reduced branch, \( \text{in}^3 \)
- \( r_b \) = branch mean cross-sectional radius, \( \text{inches} \)
- \( t_e \) = effective branch wall thickness (lesser of \( t_{nh} \) and \( i@b \))
\[ t_{\text{nh}} = \text{nominal wall thickness of main pipe, inches} \]
\[ t_{\text{nb}} = \text{nominal wall thickness of branch, inches} \]
\[ d = \text{inside diameter of pipe } D_0 - 2\text{ inches} \]

**Thermal Expansion Stress vs. Allowed Stresses**

For Service Loading for which Level A and B Service Limits are designated, the requirements of either equation (10) or equation (11) must be met. (NC-3653.2)

a) The calculated thermal expansion stresses must be in compliance with Eq. (10):

\[ S_E = \frac{i M_c}{Z} \leq S_A \]

where:

\[ S_A = f \left( 1.25 S_c + 0.25 S_{bh} \right) \]

\[ M_c = \text{range of resultant moments due to thermal expansion, in-lbs; also include moment effects of anchor displacements due to earthquake.} \]

\[ f = \text{Stress range reduction factor} \]

\[ S_c = \text{Basic material allowable stress value at room temperature from Tables I-7.0, psi} \]

b) The stress values resulting from any single non-repeated anchor movements must be in compliance with equation (10a):

\[ S_E = \frac{i M_D}{Z} \leq 3 S_c \]

where:

\[ M_D = \text{resultant moment due to any single non-repeated anchor movement (e.g. predicted building settlement), in-lbs} \]

\[ S_c = \text{Basic material allowable stress value at room temperature from Tables I-7.0, psi} \]
c) The stress values resulting from effects of pressure, weight, other sustained loads and thermal expansion must be in compliance with equation (11) (Total Stress):

\[
S_{TE} = \frac{P D_0}{4 t_n} + 0.75 i \left( \frac{M_A}{Z} \right) + i \left( \frac{M_C}{Z} \right) \leq (S_h + S_A)
\]

If Occasional Loads have been requested, a third Output Report will be generated and contains the following information:

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Occasional Stresses**

Occasional Stresses for each direction requested are computed in the Weight Factor Analyses. The moments at each piping location from each Weight Factor analysis are combined in the following manner:

\[
S_O = 0.75 i \left( \frac{M_{GF(axial)}}{Z} \right)
\]

where:

\[
M_{GF(X)} = \sqrt{(M^2_X + M^2_Y + M^2_Z)}
\]

\[
M_{GF(Y)} = \sqrt{(M^2_X + M^2_Y + M^2_Z)}
\]

\[
M_{GF(Z)} = \sqrt{(M^2_X + M^2_Y + M^2_Z)}
\]
Stresses Due To Sustained Loads

Stresses due to Sustained Loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress

\[ S_{SL} = B_1 \frac{P D_o}{2 t_n} + B_2 \frac{M_A}{Z} \leq 1.5 S_h \]

Stresses Due to Occasional Loads vs. Allowed Stresses

Stresses due to Occasional Loads, \( S_{OL} \), are the algebraic summations of the Longitudinal Sustained Weight Stress, the Longitudinal Pressure Stress, and Occasional Stress. \( S_{OL} \) for Levels A or B is calculated using the following ASME Class 2 Code, Equation (NC-3653.1, Eq. 9):

\[ S_{OL} = B_1 \frac{P_{max} D_o}{2 t_n} + B_2 \left( \frac{M_A + M_B}{Z} \right) \leq 1.8 S_h \]

But not greater than \( 1.5 S_y \).

\[ M_B = \sqrt{M_{GF(X)}^2 + M_{GF(Y)}^2 + M_{GF(Z)}^2} \]

where:

\( M_B \) = Resultant moment loading on cross section due to occasional loads, in-lbs.

The allowable stress to be used for a Level C Service (NC-3654) is \( 2.25 S_h \), but not greater than \( 1.8 S_y \).

The allowable stress to be used for a Level D Service (NC-3655) is \( 3.0 S_h \), but not greater than \( 2 S_y \).
<table>
<thead>
<tr>
<th>Reference Table NB-3681(a)-1 Fig NC-3673.2(b)-1</th>
<th>Code</th>
<th>Internal Pressure (B1)</th>
<th>Moment Loading (B2)</th>
<th>Stress Intensification Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight pipe, remote from welds or other discontinuities</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Longitudinal butt welds in straight pipe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) flush</td>
<td>LBWF</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>(b) as-welded t &gt; 3/16 in</td>
<td>LBWAW</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>(c) as-welded t #3/16 in</td>
<td>LBWAW</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Girth butt welds between nominally identical wall thickness items</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) flush</td>
<td>GBWF</td>
<td>0.5</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>(b) as-welded</td>
<td>GBWAW</td>
<td>0.5</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Girth fillet weld to socket weld, fittings, socket weld valves, slip-on or socket welding flanges</td>
<td>GFW</td>
<td>0.75</td>
<td>1.5</td>
<td>2.1</td>
</tr>
<tr>
<td>NB-4250 Transitions</td>
<td>TAPTR</td>
<td>0.5</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Transitions within a 1:3 slope envelope</td>
<td>TAPTR</td>
<td>0.5</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Butt welding reducers per ANSI B16.9 or MSS SP-87</td>
<td>RED</td>
<td>0.5</td>
<td>1.0</td>
<td>NC-3673.2(b)-1</td>
</tr>
<tr>
<td>Curved pipe or butt welding elbows</td>
<td></td>
<td></td>
<td></td>
<td>NC-3673.2(b)-1</td>
</tr>
<tr>
<td>Branch connections NC-3643</td>
<td>0.5</td>
<td>1.0</td>
<td></td>
<td>NC-3673.2(b)-1</td>
</tr>
<tr>
<td>Butt welding tees</td>
<td></td>
<td></td>
<td></td>
<td>NC-3673.2(b)-1</td>
</tr>
<tr>
<td>Circumferential fillet welds</td>
<td>CFW</td>
<td>0.5</td>
<td>1.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Socket welded joints</td>
<td>SWJ</td>
<td>0.5</td>
<td>1.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Threaded pipe joint or threaded flange</td>
<td>THPF</td>
<td>0.5</td>
<td>1.0</td>
<td>NC-3673.2(b)-1</td>
</tr>
<tr>
<td>Brazed joint</td>
<td>BJ</td>
<td>0.5</td>
<td>1.0</td>
<td>2.1</td>
</tr>
</tbody>
</table>
For a curved pipe or butt welding elbow (NB-3683.7)

\[ B_1 = -0.1 + 0.4 \ h \text{ but not } < 0.0 \text{ nor } > 0.5 \]

\[ B_2 = \frac{1.3}{h^{2/3}} \text{ but not } < 1.0 \]

For a tee:

\[ B_1 = 0.5 \]

\[ B_2 = \frac{0.9}{h^{2/3}} \text{ but not } < 1.0 \]
8.1.7 ASME Class 3 Components - Section III Subsection ND

The ASME Class 3 Compliance Report consists of three Output Reports. The first Output Report lists all of the Class 3 Code Compliance Data specified by the User. The second Output Report contains the node identification, the design wall thickness vs. the required wall thickness, sustained stresses vs. allowed and expansion stresses vs. allowed. The third Output Report is generated only if Occasional Loads Analyses were requested by the User. This report contains a summary of all occasional stresses about each axis requested, the sustained longitudinal stress, and the resultant occasional stress vs. its allowable.

Output units and equations shown in this section are for the English system. Output units are available for the following:

(1) English (ENG)      (3) Metric (MET)
(2) System International (SI)  (4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM TO</th>
<th>MATERIAL YIELD STRENGTH psi</th>
<th>ALLOWABLE COLD STRESS psi</th>
<th>ALLOWABLE HOT STRESS psi</th>
<th>STRESS RANGE REDUCTION FACTOR</th>
<th>EXPANSION STRESS RATIO</th>
</tr>
</thead>
</table>

From and To Data Point Numbers

The range of data point numbers for which the specified properties apply.

Specific Minimum Yield (SY)

Material yield strength at temperature consistent with the loading under consideration.

Minimum Stress (SC)

The basic material allowable stress value at room temperature from Tables I-7.0, psi.

Maximum Stress (SH)

The material allowable stress at temperature consistent with the loading under consideration.
Stress Range Reduction Factor

The stress range reduction factor for cyclic conditions for total number $N$ of full temperature cycles over total number of years during which system is expected to be in service from Table ND-3611.2(e)-1.

Ratio of Installed to Operating Modulus

When using Para. NB-3672.5, which allows the use of the hot (operating) modulus to be used in determining moments and forces and hence the expansion stresses, this multiplier will be used to increase the stresses by the ratio of the installed to operating modulus of elasticity, psi. If the installed modulus was used in the analysis, a ratio of 1.0 should be used.

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>SUSTAINED STRESS ACTUAL psi</th>
<th>SUSTAINED STRESS ALLOWED psi</th>
<th>EXPANSION STRESS ACTUAL psi</th>
<th>EXPANSION STRESS ALLOWED psi</th>
<th>TOTAL STRESS ACTUAL psi</th>
<th>TOTAL STRESS ALLOWED psi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Point

The number assigned by the User to each significant location.

Node Location

The "Node" description defines the piping segment types; i.e., Anchor, Run, and Bend. The "Location" description defines the exact point on the piping segment where the calculated values apply.

Stresses Due to Sustained Loads Vs. Allowed Stresses

Stresses due to Sustained Loads, $S_{sl}$, are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight stress. $S_{sl}$ is calculated using the following ASME Class 3 Code (ND-3652, Equation 8):

$$ S_{sl} = B_1 \frac{P D_b}{2 t_a} + B_2 \frac{M_\Delta}{Z} \leq 1.5 S_h $$

where:
\[ M_A = \sqrt{M_X^2 + M_Y^2 + M_Z^2} \]

- **Z** = Section modulus, in³
- **t_n** = Nominal thickness, inches
- **D_o** = Outside diameter, inches
- **P** = Internal design pressure, psi
- **M_A** = Resultant moment loading on cross section due to weight and other sustained loads, in-lbs
- **B_1, B_2** = primary stress indices for the specific product under investigation (NB-3680) see the table at the end of this section
- **S_h** = Material allowable stress at temperature consistent with the loading under consideration, psi

For full-size outlet connections:

\[ Z = \frac{\pi}{32} \left( \frac{D_o^4 - d^4}{D_o} \right) \]

For reduced outlet branch connections:

\[ Z_e = \pi r_b^2 t_e \]

where:

- **Z_e** = effective section modulus of reduced branch, in³
- **r_b** = branch mean cross-sectional radius, inches
- **t_e** = effective branch wall thickness (lesser of **t_nh** and **t_nb**)
- **t_nh** = nominal wall thickness of main pipe, inches
- **t_nb** = nominal wall thickness of branch, inches
- **d** = inside diameter of pipe **D_o** - 2 inches
Thermal Expansion Stress vs. Allowed Stresses

For Service Loading for which Level A and B Service Limits are designated, the requirements of either equation (10) or equation (11) must be met. (ND-3653.2)

a) The calculated thermal expansion stresses must be in compliance with equation (10):

\[ S_E = \frac{i M_C}{Z} \leq S_A \]

where:

\[ S_A = f \left( 1.25 S_c + 0.25 S_h \right) \]

- \( M_C \) = range of resultant moments due to thermal expansion, in-lbs; also include moment effects of anchor displacements due to earthquake.
- \( f \) = Stress range reduction factor
- \( S_c \) = Basic material allowable stress value at room temperature from Tables I-7.0, psi

b) The stress values resulting from any single non-repeated anchor movements must be in compliance with Equation (10a):

\[ S_E = \frac{i M_D}{Z} \leq 3 S_C \]

where:

- \( M_D \) = resultant moment due to any single non-repeated anchor movement (e.g. predicted building settlement), in-lbs
- \( S_c \) = Basic material allowable stress value at room temperature from Tables I-7.0, psi

c) The stress values resulting from effects of pressure, weight, other sustained loads and thermal expansion must be in compliance with Equation (11) (Total Stress):

\[ S_{TE} = \frac{P D_o}{4 t_n} + 0.75 i \left( \frac{M_A}{Z} \right) + i \left( \frac{M_C}{Z} \right) \leq ( S_h + S_A ) \]
If Occasional Loads have been requested, a third Output Report will be generated and contains the following information.

**Occasional Stresses**

Occasional Stresses for each direction requested are computed in the Weight Factor Analyses. The moments at each piping location from each Weight Factor Analysis are combined in the following manner:

\[
S_O = 0.75i \left( \frac{M_{GF(\text{axis})}}{Z} \right)
\]

**Stresses Due To Sustained Loads**

\[
M_{GF(X)} = \sqrt{M_X^2 + M_Y^2 + M_Z^2}
\]

\[
M_{GF(Y)} = \sqrt{M_X^2 + M_Y^2 + M_Z^2}
\]

\[
M_{GF(Z)} = \sqrt{M_X^2 + M_Y^2 + M_Z^2}
\]

Stresses due to Sustained Loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress.

**Stresses Due to Occasional Loads vs. Allowed Stresses**

\[
S_{OL} = B_1 \frac{P_D}{2 t_n} + B_2 \frac{M_A}{Z} \leq 1.5 S_h
\]

Stresses due to Occasional Loads, \(S_{OL}\), are the algebraic summations of the Longitudinal Sustained Weight Stress, the Longitudinal Pressure Stress, and Occasional Stress.

\(S_{OL}\) for Levels A or B is calculated using the following ASME Class 3 Code (ND-3653.1, Equation 9):

\[
S_{OL} = B_1 \frac{P_{\text{max}}}{2 t_n} + B_2 \left( \frac{M_A + M_B}{Z} \right) \leq 1.8 S_h
\]
But not greater than \(1.5\sigma_y\).

\[
M_B = \sqrt{M_{GF(X)}^2 + M_{GF(Y)}^2 + M_{GF(Z)}^2}
\]

where:

\[M_B\] = Resultant moment loading on cross section due to occasional loads, in-lbs

The allowable stress to be used for a Level C Service (ND-3654) is 2.25 \(\sigma_h\), but not greater than 1.8 \(\sigma_y\).

The allowable stress to be used for a Level D Service (ND-3655) is 3.0 \(\sigma_h\) but not greater than 2.\(\sigma_y\).
## Reference Table NB-3681(a)-1

<table>
<thead>
<tr>
<th>Description</th>
<th>Code</th>
<th>Internal Pressure (B1)</th>
<th>Moment Loading (B2)</th>
<th>Stress Intensification Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight pipe, remote from welds or other discontinuities</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Longitudinal butt welds in straight pipe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) flush</td>
<td>LBWF</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>(b) as-welded t &gt; 3/16 in</td>
<td>LBWAW</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>(c) as-welded t 3/16 in</td>
<td>LBWAW</td>
<td>0.5</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Girth butt welds between nominally identical wall thickness items</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) flush</td>
<td>GBWF</td>
<td>0.5</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>(b) as-welded</td>
<td>GBWAW</td>
<td>0.5</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Girth fillet weld to socket weld, fittings, socket weld valves, slip-on or</td>
<td>GFW</td>
<td>0.75</td>
<td>1.5</td>
<td>2.1</td>
</tr>
<tr>
<td>socket welding flanges</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NB-4250 Transitions</td>
<td>TAPTR</td>
<td>0.5</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Transitions within a 1:3 slope envelope</td>
<td>TAPTR</td>
<td>0.5</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Butt welding reducers per ANSI B16.9 or MSS SP-87</td>
<td>RED</td>
<td>0.5</td>
<td>1.0</td>
<td>ND-3673.2(b)-1</td>
</tr>
<tr>
<td>Curved pipe or butt welding elbows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Branch connections ND-3643</td>
<td>0.5</td>
<td>1.0</td>
<td>ND-3673.2(b)-1</td>
<td></td>
</tr>
<tr>
<td>Butt welding tees</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Circumferential fillet welds</td>
<td>CFW</td>
<td>0.5</td>
<td>1.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Socket welded joints</td>
<td>SWJ</td>
<td>0.5</td>
<td>1.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Threaded pipe joint or threaded flange</td>
<td>THPF</td>
<td>0.5</td>
<td>1.0</td>
<td>ND-3673.2(b)-1</td>
</tr>
<tr>
<td>Brazed joint</td>
<td>BJ</td>
<td>0.5</td>
<td>1.0</td>
<td>2.1</td>
</tr>
</tbody>
</table>
(a) For a curved pipe or butt-welding elbow (NB-3683.7)

\[ B_1 = -0.1 + 0.4 \text{ h but not } < 0.0 \text{ nor } > 0.5 \]

\[ B_2 = \frac{1.3}{h^{2/3}} \text{ but not } < 1.0 \]

(b) For a tee:

\[ B_1 = 0.5 \]

\[ B_2 = \frac{0.9}{h^{2/3}} \text{ but not } < 1.0 \]
8.1.8 Swedish Piping Code Compliance (Section 9.4 - Method 1) SPC1

The Swedish Piping Code Compliance Report for Method 1 consists of two Output Reports. The first report lists all of the Swedish Piping Code Compliance Data specified by the User. The second report contains the node identification, wall thickness vs. required wall thickness and Comparative stresses vs. the allowed stress.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

(1) English (ENG)  (3) System International (SI)
(2) Metric (MET)   (4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first report contains the following information:

<table>
<thead>
<tr>
<th>FROM TO</th>
<th>PERMISSIBLE STRESS psi</th>
<th>CIRCUMFERENTIAL FACTOR</th>
<th>LONGITUDINAL FACTOR</th>
<th>MILL TOLERANCE</th>
</tr>
</thead>
</table>

From and To Data Numbers

The range of data point numbers for which the specified properties apply.

Circumferential Weld Strength Factor

The strength factor of circumferential welds specified by the User per Section 5.5.2.

Longitudinal Weld Strength Factor

The strength factor of longitudinal or spiral welds specified by the User per Section 5.5.1.

Allowable Value of the Effective Stress at the Design Temperature

The allowable stress specified by the User at the design metal temperature.
Mill Tolerance

Manufacturer mill tolerance in percent or millimeters.

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>WALL THICKNESS DESIGN in</th>
<th>WALL THICKNESS REQUIRED in</th>
<th>INSIDE PIPE RJ' psi</th>
<th>INSIDE PIPE RJ'' psi</th>
<th>OUTSIDE PIPE RJ' psi</th>
<th>OUTSIDE PIPE RJ'' psi</th>
<th>COMPARATIVE STRESS ALLOWED psi</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Design Wall Thickness and Required Wall Thickness**

The Design Wall Thickness is input by the User. The required Wall Thickness is calculated by TRIFLEX® Windows using the following equation and the User-supplied internal pressure (Section 6.1.3):

\[
S_{\text{min}} = \frac{D_s p m}{20 \sigma_m z_i + p}
\]

\[
S_{\text{nom min}} = (S_{\text{min}} + c) \psi
\]

where:

\(S_{\text{min}}\)  =  minimum pipe wall thickness, mm

\(S_{\text{nom min}}\)  =  minimum nominal pipe wall thickness including allowances for corrosion, wear and minus tolerance, mm

\(S_{\text{nom}}\)  =  nominal pipe wall thickness, mm
$S_{\text{eff}} = \text{usable thickness, mm}$

$m = 1$

$p = \text{Pressure as input by the User, bar (gauge)}$

$D_y = \text{Actual pipe outside diameter, mm}$

$\sigma_{\text{tn}} = \text{allowable stress at a given design temperature, N/mm}^2$

$z(z_l) = \text{joint efficiency of longitudinal (spiral) weld according to Sec. 5.5.}$

$c = \text{corrosion and wear allowance, mm}$

$\psi = \text{coefficient allowing wall thickness minus tolerance; see Sec. 5.6}$

\[
\psi = \frac{1}{1 - \frac{\text{MT}}{100}}
\]

$\text{MT} = \text{Manufacturer mill tolerance in percent (default of 12.5%)}$

\[
S_{\text{eff}} = \frac{S_{\text{nom}}}{\psi} - c
\]

**Effective Stresses**

In Method 1 "no distinction is made between stresses caused by loads related to forces or stresses caused by loads related to displacement". The simultaneous action of axial, tangential, radial stresses and shear stress due to torque is referred to as the effective stress. This stress is based on the deformation hypothesis (Von Mises theorem) and is expressed in the equation shown below.

\[
\sigma_j = \sqrt{\frac{1}{2} \left[ \left( \sigma_t - \sigma_{a1} \right)^2 + \left( \sigma_r - \sigma_r \right)^2 + \left( \sigma_{a1} - \sigma_r \right)^2 \right] + 3 \cdot \tau_v^2}
\]

where all stresses are expressed in N/mm$^2$

- $\sigma_j = \text{Effective stress}$
- $\sigma_t = \text{Tangential stress due to internal pressure}$
- $\sigma_{a1} = \text{Resultant axial stress}$
- $\sigma_r = \text{combination of axial stresses due to pressure and loads}$
- $\tau_v = \text{radial stress due to internal pressure}$
- $\tau_v = \text{shear stress due to Torque}$. 
The additional subscript u in a stress symbol means the outside of the pipe, and an i means inside.

**Stresses Due to Internal Pressure**

Symbols:

- $D_i$ = inside diameter of pipe, $(D_i = D_y - 2 \Theta_{eff})$, mm
- $D_y$ = nominal outside diameter of pipe mm
- $p$ = internal pressure in bar
- $S_{eff}$ = usable wall thickness of pipe mm
- $\sigma_{ap}$ = axial stress N/mm$^2$
- $\sigma_i$ = tangential stress N/mm$^2$

**Axial Stress**

$$\sigma_{ap} = \frac{p}{10 \left[ \frac{D_y^2}{D_i^2} \right]} = \frac{\sigma_{tu}}{2}$$

For thin-walled pipes ($S_{eff} \# 0.05 D_i$), the axial stress is approximately

$$\sigma_{ap} = \frac{p D_i}{40 S_{eff}}$$

**Tangential Stress**

inside of pipe:

$$\sigma_{ti} = \sigma_{t_{max}} = \frac{p (D_y^2 + D_i^2)}{10 (D_y^2 - D_i^2)}$$

outside of pipe:

$$\sigma_{tu} = \sigma_{t_{min}} = \frac{2 p D_i^2}{10 (D_y^2 - D_i^2)}$$

The relationship between $\sigma_{ti}$ and $\sigma_{tu}$ is
For thin-walled pipes ($S_{\text{eff}} \# 0.05 D_i$) the tangential stress is approximately

$$\sigma_{rt} = \sigma_{ri} - \frac{P}{10}$$

Radial Stress

inside of pipe:

$$\sigma_{ri} = -\frac{P}{10}$$

outside of pipe:

$$\sigma_{ru} = 0$$

For thin-walled pipes, it can be assumed that $\sigma_r (\sigma_{ri}) = 0$.

Stresses Due to Force and Displacement Controlled loads

$$A = \frac{\pi}{4} (D_y^2 - D_i^2)$$

- $D_i$ = inside diameter of pipe in mm = $D_y - 2S_{\text{nom}}$
- $D_y$ = nominal outside diameter of pipe in mm
- $S_{\text{nom}}$ = nominal pipe wall thickness mm
- $M_b$ = resultant bending moment in N-mm
- $M_v$ = resultant torque in N-mm
- $N$ = resultant force (tensile or compressive) along pipe in N
\[ W_i = \frac{\pi}{32} \left( \frac{D_i^4 - D_i^3}{D_i} \right) \]

\[ W_y = \frac{\pi}{32} \left( \frac{D_y^4 - D_y^3}{D_y} \right) \]

\[ \sigma_a = \text{axial stress in N/mm}^2 \]

\[ \tau_v = \text{shear stress in N/mm}^2 \]

\[ k_1 = \text{stress intensifier} \]

inside of pipe:

\[ \sigma_a = \frac{N}{A} \pm \frac{M}{W_i} k_1 \]

\[ \tau_v = \frac{M_v}{2 W_i} \]

outside of pipe:

\[ \sigma_a = \frac{N}{A} \pm \frac{M}{W_y} k_1 \]

\[ \tau_v = \frac{M_v}{2 W_y} \]

**Resultant Axial Stress**

Stresses due to internal pressure combined with stresses due to loads related to forces and loads related to displacement.

inside of pipe:

\[ \sigma_{ai} = \sigma_{ap} + \sigma_{ai} \]

outside of pipe:

\[ \sigma_{alo} = \sigma_{ap} + \sigma_{ao} \]
Allowable Value of Effective Stress $\sigma_j$

$$\frac{\sigma_{a2}^2}{z} + (\sigma_j - \sigma_{a2}) \leq 1.35 \sigma_{tn}$$

where:

$\sigma_{a2}$ = Total axial stress $\sigma_{al}$, less bending stress in the axial direction.

$z$ = Strength factors of circumferential welds.

---

Note 1: In the case of non-prestressing (no cold spring) the factor $1.35 \sigma_{tn}$ may be set equal to $1.5 \sigma_{tn}$.

Note 2: When $\sigma_{a2} < 0$ formula 9.8 becomes $\sigma_j \# 1.35 \sigma_{tn}$
8.1.9 Swedish Piping Code Compliance (Section 9.5 - Method 2)

The Swedish Piping Code Compliance Report for Method 2 consists of three Output Reports. The first Output Report lists all of the Swedish Piping Code Compliance Data specified by the User. The second Output Report contains the node identification, forced controlled load stresses vs. allowed stresses, and displacement controlled load stresses vs. allowed stresses. The third Output Report is generated only if Occasional (temporary) Loads Analyses were requested by the User. This report contains a summary of all occasional stresses about each axis requested, the forced controlled load stress, and the resultant occasional stress vs. its allowable stress.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

(1) English (ENG)   (3) Metric (MET)
(2) System International (SI)  (4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>ULTIMATE TENSILE STRENGTH psi</th>
<th>ALLOWABLE COLD STRESS psi</th>
<th>ALLOWABLE HOT STRESS psi</th>
<th>STRESS RANGE REDUCTION FACTOR</th>
<th>OCCASIONAL FATIGUE FACTOR</th>
<th>CIRCUMFERENCIAL FACTOR</th>
<th>LONGITUDINAL FACTOR</th>
<th>MILL TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and to Data Numbers

The range of data point numbers for which the specified properties apply.

**Ultimate Tensile Strength (RM), N/mm²**

The Ultimate Tensile Strength of the material at room temperature.

**Allowed Cold Stress (F1), N/mm²**

The basic material allowable stress at the "shut-down" metal temperature specified by the User.

**Allowed Hot Stress (F2), N/mm²**

The basic material allowable stress at the design metal temperature specified by the User.

**Stress Range Reduction Factor (FR)**
Factor specified by User to reduce stress allowable because of cyclic conditions.

**Occasional Load Factor K**

Factor specified by the User, based upon the duration of the occasional loads.

**ZL**

Strength factor for longitudinal and spiral welds, (5.5.1).

**ZC**

Strength factor for circumferential welds, (5.5.2).

**Mill Tolerance**

Manufacturer mill tolerance in percent or millimeters.

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>WALL THICKNESS DESIGN #</th>
<th>WALL THICKNESS REQUIRED #</th>
<th>SUSTAINED STRESS ACTUAL psi</th>
<th>SUSTAINED STRESS ALLOWED psi</th>
<th>SUSTAINED STRESS PERCENT</th>
<th>EXPANSION STRESS ACTUAL psi</th>
<th>EXPANSION STRESS ALLOWED psi</th>
<th>EXPANSION STRESS PERCENT</th>
<th>OCCASIONAL WIND psi</th>
<th>OCCASIONAL STRESS psi</th>
<th>OCCASIONAL STRESS ALLOWED psi</th>
<th>OCCASIONAL STRESS PERCENT</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Design Wall Thickness vs. Required Thickness**

The Design Wall Thickness is input by the User. The required Wall Thickness is calculated by TRIFLEX using the following equation and the User-supplied internal pressure (Section 6.1.3):

\[ S_{\text{min}} = \frac{D_y \cdot p \cdot m}{20 \cdot \sigma_m \cdot z_l + p} \]

\[ S_{\text{nom, min}} = (S_{\text{min}} + c)\psi \]
where:

\[ S_{\text{min}} = \text{minimum pipe wall thickness, mm} \]

\[ S_{\text{nom min}} = \text{minimum nominal pipe wall thickness including allowances for corrosion, wear and minus tolerance, mm} \]

\[ S_{\text{nom}} = \text{nominal pipe wall thickness, mm} \]

\[ S_{\text{eff}} = \text{usable thickness, mm} \]

\[ m = 1 \]

\[ p = \text{Pressure as input by the User, bar (gauge)} \]

\[ D_y = \text{Actual pipe outside diameter, mm} \]

\[ \sigma_m = \text{allowable stress at a given design temperature, N/mm}^2 \]

\[ z(z_l) = \text{joint efficiency of longitudinal (spiral) weld according to Section 5.5.} \]

\[ c = \text{corrosion and wear allowance, mm} \]

\[
\psi = \frac{1}{1 - \frac{MT}{100}}
\]

\[ \varphi = \text{coefficient allowing for wall thickness minus tolerance; see Section 5.6} \]

\[ \text{MT} = \text{Manufacturer mill tolerance in percent (default of 12.5%)} \]

\[ S_{\text{eff}} = \frac{S_{\text{nom}}}{\psi} \cdot c \]

\[ \text{Stresses Due To Forced Controlled Loads (9.5.3.2)} \]

Stresses due to Forced controlled loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress. They are calculated using the following equation (Section 9.5.3.2, Equation 9:37):
\[
\frac{p D_t}{4 S_{eff} z} + 0.75 k_1 \left( \frac{M_A}{W_y} \right) \leq \sigma_{m2}
\]

where:

\( z \) = joint efficiency for a circumferential weld according to Section 5.5.2

\( \sigma_{tn\,1} \) = allowable stress at room temperature N/mm²

\( \sigma_{tn\,2} \) = allowable stress at design temperature N/mm²

\( k_1 \) = stress intensifier

\[
M_A = \sqrt{M_z^2 + M_y^2 + M_z^2}
\]

The factor 0.75 \( k_1 \) in the above formulas shall not be less than 1.0.

As can be seen from the equation, the longitudinal stress due to the combined pressure and weight stresses shall be less than or equal to the \( \sigma_{tn\,2} \).

For full-size outlet connections:

\[
W_y = \frac{\pi}{32} \left( \frac{D_t^2 - D_y^2}{D_y} \right)
\]

For reduced outlet branch connections:

\[
W_a = \pi r_a^2 S'
\]

where:

\( r_a \) = the mean radius of the branch, mm

\( SN \) = effective wall thickness of branch (the smaller of \( S_h \) and \( k_1 S_a \)), mm

\( S_h \) = nominal wall thickness of main pipe, mm

\( S_a \) = nominal wall thickness of branch, mm
\[ D_y = \text{the nominal outside diameter of the pipe, mm} \]
\[ D_i = \text{inside diameter of pipe } D_y - 2\delta_{\text{nom}}, \text{ mm} \]
\[ W_y = \text{bending resistance of pipe with respect to the inside outside diameter, mm}^3 \]
\[ W_a = \text{effective bending resistance of reduced branch, mm}^3 \]

**Displacement Controlled Loads**

The extent of the stress range induced by displacement-controlled loads is computed in the Thermal Analysis processed by TRIFLEX. This stress range must satisfy the condition (Section 9.5.3.2, Eq. 9:39):

\[
\frac{k_i M_c}{W_y} \leq S_r
\]

When the liberal method is requested, an alternative formula will be used:

\[
\frac{p D_y}{4 S_{\text{off}} I_z} + 0.75 k_i \left( \frac{M_A}{W_y} \right) + k_i \left( \frac{M_c}{W_y} \right) \leq \sigma_{\text{m2}} + S_r
\]

The moments for each piping location found by the Thermal Analysis of the piping system are combined in the following manner:

\[
M_c = \sqrt{M_x^2 + M_y^2 + M_z^2}
\]

where:

\[
S_r = f (1.17 \sigma_1 + 0.17 \sigma_2)
\]

\( \sigma_1 \) = smaller of 0.267 \( \sigma_m \) or \( \sigma_{m1} \)
$\sigma_2 = \text{smaller of } 0,367 \sigma_{Rm} \text{ or } \sigma_{m2}$

When requested as an option, the allowable of $S_r$ is selected as follows for certain conditions of material and temperatures. The limits 0,267 $\sigma_{Rm}$ and 0,367 $\sigma_{Rm}$ is disregarded if $S_r$ is selected equal to the smaller of $S_rN$ and $S_rQ$

where:

$$S_r' = 1,17 \sigma_{m1} + 0,20 \sigma_{m2}$$

and:

$$S_r'' = f(290 \text{ N/mm}^2 - \sigma_{m2})$$

**Occasional Stresses, N/mm²**

Occasional Stresses for each direction requested are computed in the Weight Factor Analyses.

$$S_o = 0,75 k_j \left( \frac{M_{g(faxial)}}{W_y} \right)$$

The moments at each piping location from each Weight Factor Analysis are combined in the following manner:

where:

$$M_{g(fX)} = \sqrt{M_x^2 + M_y^2 + M_z^2}$$

$$M_{g(fY)} = \sqrt{M_x^2 + M_y^2 + M_z^2}$$

$$M_{g(fZ)} = \sqrt{M_x^2 + M_y^2 + M_z^2}$$
Stresses Due To Forced Controlled loads (9.5.3.2)

Stresses due to Forced controlled loads are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress. They are calculated using the following equation (Section 9.5.3.2, Equation 9:37):

\[
\frac{P}{4 S_{\text{eff}}} \frac{D_y}{z} + 0.75 k_1 \left( \frac{M_A}{W_y} \right)
\]

where:

\[
M_A = \sqrt{M_x^2 + M_y^2 + M_z^2}
\]

Stresses Due to Occasional Loads vs. Allowed Stresses

Stresses due to Occasional Loads, \( S_{LO} \), are the algebraic summations of the Longitudinal Sustained Weight Stress, the Longitudinal Pressure Stress, and Occasional Stress.

For normal and temporary force controlled loads:

\[
\frac{P}{4 T_{\text{eff}}} \frac{D_y}{z} + 0.75 k_1 \left( \frac{M_A + M_B}{W_y} \right) \leq 1.2 \sigma_{m2}
\]

Where \( M_B \) is the square root of the sum of the squares of the resultant moments from the weight factor analysis. They are combined as follows:

\[
M_B = \sqrt{M_{B/X}^2 + M_{B/Y}^2 + M_{B/Z}^2}
\]

As can be seen from the equation, the Longitudinal Stress due to Occasional Load shall be less than or equal to 1.2 \( \sigma_{m2} \).
8.1.10 Norwegian Piping Code Compliance (Section Annex D-Alternative Method)

The Norwegian Piping Code Compliance Report for the alternative method consists of two Output Reports. The first report lists all of the Norwegian Piping Code Compliance Data specified by the User. The second report contains the node identification, wall thickness vs. required wall thickness and Comparative stresses vs. the allowed stress.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

1. English (ENG)  
2. System International (SI)  
3. Metric (MET)  
4. International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>PERMISSIBLE STRESS psi</th>
<th>CIRCUMFERENTIAL FACTOR</th>
<th>LONGITUDINAL FACTOR</th>
<th>MILL TOLERANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and To Data Numbers

The range of data point numbers for which the specified properties apply.

Circumferential Weld Strength Factor

The strength factor of circumferential welds specified by the User per Clause 14.6.3.

Longitudinal Weld Strength Factor

The strength factor of longitudinal or spiral welds specified by the User per Clause 14.6.3.

Permissible Stress at the Design Temperature, N/mm²

The allowable stress specified by the User at the design metal temperature.

Mill Tolerance

Manufacture mill tolerance in percent or millimeters.
The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>WALL THICKNESS DESIGN in</th>
<th>WALL THICKNESS REQUIRED in</th>
<th>INSIDE PIPE RJ psi</th>
<th>INSIDE PIPE RJ'' psi</th>
<th>OUTSIDE PIPE RJ psi</th>
<th>OUTSIDE PIPE RJ'' psi</th>
<th>COMPARATIVE STRESS ALLOWED psi</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Design Wall Thickness and Required Wall Thickness, mm**

\[
T_{\text{min}+} = (T_{\text{min}} + c) p_s
\]

\[
T_{\text{min}} = \frac{D p m}{2 f z + p}
\]

The Design Wall Thickness is input by the User. The required wall thickness is calculated by **TRIFLEX** using the following equation and the User-supplied internal pressure (Section 7.1.2, Equation 7.1, 7.2):

where:

\[
T_{\text{min}} = \text{minimum pipe wall thickness, mm}
\]

\[
T_{\text{min}+} = \text{minimum nominal pipe wall thickness in mm including allowances for corrosion, wear and minus tolerance}
\]

\[
T = \text{wall thickness of pipe, mm}
\]

\[
T_{\text{eff}} = \text{usable wall thickness, mm}
\]
m = 1

p = Pressure as input by the User, N/mm$^2$

D = Actual pipe outside diameter, mm

f = permissible stress at design temperature, N/mm$^2$

$z(z_l)$ = strength factor of longitudinal (spiral) weld, Clause 14.6.3

c = corrosion and wear allowance, mm

$p_s$ = coefficient allowing for minus tolerance of wall thickness; Clause 6.7.

$$p_s = \frac{1}{1 - \frac{MT}{100}}$$

$MT$ = Manufacturer mill tolerance in percent (default of 12.5%)

**Comparative Stresses**

$$T_{eff} = \frac{T}{p_s} \cdot c$$

In the alternative method, "no distinction is made between stresses caused by loads related to forces or stresses caused by loads related to displacement". The simultaneous action of axial, tangential, radial stresses and shear stress due to torque is referred to as the comparative stress. This stress is based on the deformation hypothesis (Von Mises theorem) and is expressed in the equation shown below.

$$R_j = \sqrt{\frac{1}{2} \left[ (R_t - R_{al})^2 + (R_t - R_a)^2 + (R_{al} - R_a)^2 \right] + 3\tau_{av}^2}$$

where all stresses are expressed in N/mm$^2$

$R_j$ = Comparative stress

$R_t$ = Tangential stress due to internal pressure

$R_{al}$ = Resultant axial stress
\[ \sigma = \text{combination of axial stresses due to pressure and loads} \]

\[ R_r = \text{Radial stress due to internal pressure} \]

\[ \sigma_{av} = \text{shear stress due to torque} \]

The additional subscript \( u \) in a stress symbol means the outside of the pipe, \( i \) means inside.

**Stresses Due to Internal Pressure**

Symbols:

\[ D_i = \text{inside diameter of pipe, } (D_i = D - 2 \, \Theta_{eff}), \text{mm} \]

\[ D = \text{outside diameter of pipe, mm} \]

\[ p = \text{internal pressure, N/mm}^2 \]

\[ T_{eff} = \text{usable wall thickness of pipe, mm} \]

\[ R_{ap} = \text{axial stress, N/mm}^2 \]

\[ R_r = \text{radial stress, N/mm}^2 \]

\[ R_t = \text{tangential stress, N/mm}^2 \]

(a) **Axial Stress**

\[ R_{ap} = \frac{p \, D_i^2}{(D^2 - D_i^2)} = \frac{p}{(D/D_i)^2 - 1} = \frac{R_{in}}{2} \eqno{55} \]

For pipes with thin walls \( (T_{eff} \geq 0.05 \, D_i) \), the formula (9.10) may be written as:

\[ R_{ap} = \frac{p \, D_i}{4 \, T_{eff}} \eqno{56} \]

where \( R_{ap} \) indicates an approximate stress.

(b) **Tangential stress**

- inside of pipe:
Outside of pipe:

\[ R_{tu} = R_{min} = \frac{2p D_i^2}{(D^2 - D_i^2)} \]

The relationship between \( R_{ri} \) and \( R_{tu} \) is

\[ R_{tu} = R_{ri} - p \]

For pipe with thin wall \( t_{eff} \# 0.05 \ D_i \), it can be assumed that

\( R_{e}(R_{ri}) = 0 \)

\[ R_{ri} = \frac{p D_i}{2 \ tau_{eff}} \]

Radial Stress

\[ R_{ri} = - p \]

\[ R_{ru} = 0 \]

Stresses due to loads related to force and loads related to displacement (except stresses caused by internal pressure).

Symbols

\[ A = \frac{\pi}{4} (D^2 - D_i^2) \]

\( D_i \) = inside diameter of pipe, mm \( (D - 2 \ icrof) \)

\( D \) = outside diameter of pipe in mm
T = wall thickness of pipe, mm

\( M_b \) = resultant bending moment in N-mm

\( M_v \) = resultant torque in N-mm

\( N \) = resultant force (tensile or compressive) along pipe in N

\( k_1 \) = stress intensifier

\[
W_i = \frac{\pi}{32} \left( \frac{D_i^4 - D_i^4}{D_i} \right)
\]

\[
W_i = \frac{\pi}{32} \left( \frac{D_i^4 - D_i^4}{D_v} \right)
\]

\( R_a \) = axial stress, N/mm²

\( \sigma_v \) = shear stress, N/mm²

- On the inside of the pipe:

\[
R_a = \frac{N}{A} \pm \frac{M_b}{W_i} k_1
\]

\[
\tau_v = \frac{M_v}{2 W_i}
\]

- On the outside of the pipe:

\[
R_a = \frac{N}{A} \pm \frac{M_b}{W_y} k_1
\]

\[
\tau_v = \frac{M_v}{2 W_y}
\]

Resultant Axial Stress
- stresses due to internal pressure combined with stresses due to loads related to forces and loads related to displacement.

- On the inside of the Pipe:

\[ R_{ali} = R_{ap} + R_{ai} \]

- On the outside of the Pipe:

\[ R_{alo} = R_{ap} + R_{ao} \]

**Allowable Value of Effective Stress** \( R_j \)

\[
\frac{R_{a2}^2}{z} + (R_j - R_{a2}) \leq 1.35 f
\]

where:

- \( R_{a2} \) = the resulting axial stress \( R_{ai} \), less bending stress in the axial direction.
- \( z \) = Strength factors of circumferential welds.

**Note 1:** In the case of non-prestressing (no cold spring), the factor 1.35- \( f \) may be set equal to 1.5 @.

**Note 2:** When \( R_{a2} < 0 \) formula 9.8 becomes \( R_j \# 1.35 @ \)
8.1.11 TBK 5-6 Norwegian Piping Code Compliance (Section 10.5)

The TBK 5-6 Compliance Report consists of three Output Reports. The first Output Report lists all of the TBK 5-6 Code Compliance Data specified by the User. The second Output Report contains the node identification, stresses caused by loads related to forces vs. allowed stresses, and stresses caused by loads related to displacement vs. allowed stresses. The third Output Report is generated only if Occasional (temporary) Loads Analyses were requested by the User. This report contains a summary of all occasional stresses about each axis requested, the stresses caused by loads related to forces, and the resultant occasional stress vs. its allowable stress.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

(1) English (ENG)                      (3) Metric (MET)

(2) System International (SI)          (4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM TO</th>
<th>ULTIMATE TENSILE STRENGTH psi</th>
<th>ALLOWABLE COLD STRESS psi</th>
<th>ALLOWABLE HOT STRESS psi</th>
<th>STRESS RANGE REDUCTION FACTOR</th>
<th>OCCASIONAL FATIGUE FACTOR</th>
<th>CIRCUMFERENCIAL FACTOR</th>
<th>LONGITUDINAL FACTOR</th>
<th>MILL TOLERANCE</th>
</tr>
</thead>
</table>

From and to Data Numbers

The range of data point numbers for which the specified properties apply.

Ultimate Tensile Strength (RM), N/mm²

The Ultimate Tensile Strength of the material at room temperature.

Allowed Cold Stress (F1), N/mm²

The basic material allowable stress at the "shut-down" metal temperature specified by the User.

Allowed Hot Stress (F2), N/mm²
The basic material allowable stress at the design metal temperature specified by the User.

**Stress Range Reduction Factor (FR)**

Factor specified by User to reduce stress allowable because of cyclic conditions.

**Occasional Load Factor K**

Factor specified by the User, based upon the duration of the occasional loads.

**ZL**

Strength factor for longitudinal and spiral welds according to clause 14.6.3

**ZC**

Strength factor for circumferential welds according to clause 14.6.3

**Mill Tolerance**

Manufacturer mill tolerance in percent or millimeters.

**The second Output Report contains the following information:**

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>WALL THICKNESS DESIGN in</th>
<th>WALL THICKNESS REQUIRED in</th>
<th>SUSTAINED STRESS ACTUAL psi</th>
<th>SUSTAINED STRESS ALLOWED psi</th>
<th>EXPANSION STRESS ACTUAL psi</th>
<th>EXPANSION STRESS ALLOWED psi</th>
<th>EXPANSION STRESS PERCENT</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Design Wall Thickness vs. Required Thickness, mm**

The Design Wall Thickness is input by the User. The required wall thickness is calculated by TRIFLEX using the following equation and the User-supplied internal pressure (Section 7.1.2, Equation 7.1, 7.2):
\[ T_{\text{min}} = \frac{D \cdot p \cdot m}{2 \cdot f \cdot z + p} \]

where:

\[ T_{\text{min}+} = (T_{\text{min}} + c) \cdot P_s \]

- \( T_{\text{min}} \) = minimum pipe wall thickness, mm
- \( T_{\text{min}+} \) = minimum nominal pipe wall thickness in mm including allowances for corrosion, wear and minus tolerance
- \( T \) = wall thickness of pipe, mm
- \( T_{\text{eff}} \) = usable wall thickness, mm
- \( m = 1 \)
- \( p \) = Pressure as input by the User, N/mm²
- \( D \) = Actual pipe outside diameter, mm
- \( f \) = permissible stress at design temperature, N/mm²
- \( z(\eta) \) = strength factor of longitudinal (spiral) weld according to clause 14.6.3
- \( c \) = corrosion and wear allowance, mm
- \( P_s \) = coefficient allowing for minus tolerance of wall thickness; see clause 6.7

\[ P_s = \frac{1}{1 - \frac{MT}{100}} \]

- \( MT \) = Manufacturer mill tolerance in percent (default of 12.5%)

\[ T_{\text{eff}} = \frac{T}{P_s} - c \]

**Stresses Due To Loads related to Forces (10.5.3.2)**

Stresses due to Loads related to Forces are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress. They are calculated using the following equation (Section 10.5.3.2, Equation 10.72):
\[
\frac{p D}{4 T_{\text{eff}} z} + \frac{0.75 k_1 M_A}{W} \leq f_2
\]

where:

- \( z \) = strength factor for circumferential welds, see clause 14.6.3
- \( f_1 \) = permissible stress in cold condition N/mm\(^2\)
- \( f_2 \) = permissible stress in hot condition N/mm\(^2\)
- \( k_1 \) = stress intensifier

\[
M_A = \sqrt{M_z^2 + M_y^2 + M_x^2}
\]

The factor 0.75 \( k_1 \) in the above formulas shall not be less than 1.0.

As can be seen from the equation, the longitudinal stress due to the combined pressure and weight stresses shall be less than or equal to the \( f_2 \).

For full-size outlet connections:

\[
W = \frac{\pi (D^4 - D_i^4)}{32 \cdot D}
\]

For reduced outlet branch connections:

\[
W_g = \pi r_g^2 T'
\]

where:

- \( D_i \) = \( D - 2t \), mm
- \( r_g \) = the mean radius of the branch, mm
- \( TN \) = effective wall thickness of branch (the smaller of \( T_h \) and \( k_1 T_g \)), mm
- \( T_h \) = nominal wall thickness of main pipe, mm \( T_g \) = nominal wall thickness of branch, mm
- \( D \) = outside diameter of the pipe, mm
- \( D_i \) = inside diameter of pipe (\( = D - 2t_{\text{min}} \)), mm
\[ W = \text{section modulus of bending mm}^3 \]

\[ W_g = \text{effective section modulus of bending for a reduced branch mm}^3 \]

**Loads Related to Displacement**

The extent of the stress range induced by loads related to displacement is computed in the Thermal Analysis processed by **TRIFLEX**. This stress range must satisfy the condition (Section 10.5.3.2, Equation 10.19):

\[ \frac{k_1 M_x}{W} \leq S_r \]

An alternative formula is:

\[ \frac{p D}{4 T_{eff} z} + \frac{0.75 k_1 M_{Ay}}{W} + \frac{k_1 M_e}{W} \leq f_r + S_r \]

which will be used when the liberal method is requested.

The moments for each piping location found by the Thermal Analysis of the piping system are combined in the following manner:

\[ M_c = \sqrt{M_x^2 + M_y^2 + M_z^2} \]

where:

\[ S_r = f_r (1.25 R_1 + 0.25 R_2) \]

where:

\[ R_1 = \text{smaller of 0.250 } R_m \text{ or } f_1 \]

\[ R_2 = \text{smaller of 0.250 } R_m \text{ or } f_2 \]

\[ f_r = \text{stress range reduction factor based on load cycles} \]

\[ R_m = \text{ultimate tensile strength at room temperature} \]

Note: When requested as an option by using the Alternate Material field, the allowable of \( S_r \) is selected as follows:
\[ S_r' = 1.25 f_1 + 0.25 f_2 \]

\[ S_r'' = f_1 R_s - f_2 \]

where:

\( R_s \) is the permissible extent of stress for 7000 load cycles (See Table 10.2.)

\( S_r \) is set equal to the smaller of \( S_r' \) and \( S_r'' \).

If \( S_r \) is negative, formula (10.10) shall be used.

<table>
<thead>
<tr>
<th>Material</th>
<th>( R_s ) N/mm(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon and low alloy steel</td>
<td>290</td>
</tr>
<tr>
<td>Austenitic Stainless steel</td>
<td>400</td>
</tr>
<tr>
<td>Copper alloys, annealed</td>
<td>150</td>
</tr>
<tr>
<td>Copper alloys, cold worked</td>
<td>100</td>
</tr>
<tr>
<td>Aluminum</td>
<td>130</td>
</tr>
<tr>
<td>Titanium</td>
<td>200</td>
</tr>
</tbody>
</table>

**Occasional Stresses**, N/mm\(^2\)

Occasional Stresses for each direction requested are computed in the Weight Factor Analyses.

\[ S_O = \frac{0.75 k_1 M_{g(asi)}}{W} \]

The moments at each piping location from each Weight Factor Analysis are combined in the following manner:
Stresses Due To Loads related to Forces (10.5.3.2), N/mm²

Stresses due to loads related to forces are the algebraic summations of the Longitudinal Pressure Stress and Longitudinal Weight Stress. They are calculated using the following equation (Section 10.5.3.2, Equation 10.7):

\[
\frac{p D}{4 T_{eff}} \frac{0.75 k_1 M_A}{W} + (M_{GF(X)} + M_{GF(Y)} + M_{GF(Z)}) \leq 1.2 f_2
\]

Stress Due to Occasional Loads Vs. Allowed Stresses, N/mm²

Stresses due to Occasional Loads are the algebraic summations of the Longitudinal Sustained Weight Stress, the Longitudinal Pressure Stress, and Occasional Stress.

For normal and temporary force controlled loads:

\[
\frac{p D}{4 T_{eff}} \frac{0.75 k_1 (M_A + M_B)}{W} \leq 1.2 f_2
\]

Where \( M_B \) is the square root of the sum of the squares of the resultant moments from the weight factor analysis. They are combined as follows:

\[
M_B = \sqrt{(M_{GF(X)}^2 + M_{GF(Y)}^2 + M_{GF(Z)}^2)}
\]

As can be seen from equation 10.8, the Longitudinal Stress due to Occasional Load shall be less than or equal to 1.2 \( f_2 \).
8.1.12  DNV Rules for Submarine Pipeline Systems, 1981 by Det norske Veritas

The DnV Compliance Report consists of two Output Reports. The first Output Report lists all of the DnV Code Compliance Data specified by the User. The second Output Report contains the node identification, hoop stresses vs. allowed stresses, and equivalent stresses vs. allowed stresses.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

(1) English (ENG)         (3) System International (SI)
(2) Metric (MET)          (4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MATERIAL YIELD STRENGTH psi</th>
<th>WELD JOINT FACTOR</th>
<th>TEMP. REDUCTION FACTOR</th>
<th>HOOP STRESS DESIGN FACTOR</th>
<th>EQUIVALENT STRESS DESIGN FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and to Data Numbers

The range of data point numbers for which the specified properties apply.

Specified Minimum Yield Strength (F1)

Specified minimum yield strength.

Weld Factor (KW)

Strength factor for weld joints.

Temperature Reduction Factor (K1)

Temperature reduction factor.

Hoop Stress Design Factor (NH)
Hoop stress design factor.

**Design Factor, Equivalent Stress ($\eta_{EP}$)**

Equivalent stress design factor

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>DATA POINT</th>
<th>NODE LOCATION</th>
<th>HOOP STRESS psi</th>
<th>HOOP ALLOWED psi</th>
<th>EQUIVALENT STRESS psi</th>
<th>EQUIVALENT ALLOWED psi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The *node* description defines the piping segment types; i.e., anchor, run, joint, valve, flange, bend, or expansion joint. The *location* description defines the exact point on the piping segment where the calculated values apply.

**Hoop Stress Actual vs. Permissible**

Hoop stress are based on the following equation:

$$\sigma_y = (P_i - P_e) \frac{D}{2t}$$

where:

- $\sigma_y$ = Hoop Stress, N/mm$^2$
- $P_i$ = Internal Pressure, N/mm$^2$
- $P_e$ = External Pressure (considered 0)
- $D$ = Nominal Outside Diameter of Pipe, mm
- $t$ = $t_n - t_c$
- $t_n$ = Nominal wall thickness, mm
- $t_c$ = Any erosion or corrosion allowance to be subtracted from the nominal wall thickness, mm
and is not to exceed the permissible value $\sigma_{yp}$:

$$\sigma_{yp} = \eta_h \sigma_p k_i$$

where:

- $\sigma_{yp}$ = permissible hoop stress, N/mm$^2$
- $\eta_h$ = design factor, hoop stress
- $\sigma_p$ = specified minimum yield strength, N/mm$^2$

**Equivalent Stress vs. Permissible (4.2.2.8)**

Equivalent stress is defined as

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3 \tau_{xy}^2}$$

where:

- $\sigma_e$ = Equivalent Stress, N/mm$^2$
- $\sigma_x$ = total longitudinal stress, N/mm$^2$
- $\sigma_y$ = total hoop stress, N/mm$^2$
- $\tau_{xy}$ = total tangential shear stress, N/mm$^2$

and is not to exceed $\sigma_{yp}$ as shown below:

$$\sigma_{yp} = \eta_{ep} \sigma_p k_i$$

where:

- $\sigma_{yp}$ = permissible value, N/mm$^2$
- $\eta_{ep}$ = usage factor
- $k_i$ = temperature derating factor
8.1.13 DNV Rules for Submarine Pipeline Systems, 1996 by Det norske Veritas

The DnV Compliance Report consists of two Output Reports. The first Output Report lists all of the DnV Code Compliance Data specified by the User. The second Output Report contains the node identification, hoop stresses vs. allowed stresses, longitudinal stresses vs. allowed stresses and equivalent stresses vs. allowed stresses.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

1. English (ENG)
2. Metric (MET)
3. System International (SI)
4. International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MATERIAL YIELD STRENGTH psi</th>
<th>WELD JOINT FACTOR</th>
<th>TEMP. REDUCTION FACTOR</th>
<th>HOOP STRESS DESIGN FACTOR</th>
<th>EQUIVALENT STRESS DESIGN FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and to Data Numbers

The range of data point numbers for which the specified properties apply.

Specified Minimum Yield Strength (F1)

Specified minimum yield strength.

Weld Factor (KW)

Strength factor for weld joints.

Temperature Reduction Factor (K1)

Temperature reduction factor

Hoop Stress Design Factor (NH)
Hoop stress design factor.

**Design Factor, Equivalent Stress ($\eta_{EP}$)**

Equivalent stress design factor

---

**The second Output Report contains the following information:**

<table>
<thead>
<tr>
<th>DATA POINT</th>
<th>NODE LOCATION</th>
<th>HOOP STRESS PSI</th>
<th>HOOP ALLOWED PSI</th>
<th>EQUIVALENT STRESS PSI</th>
<th>EQUIVALENT ALLOWED PSI</th>
<th>LONGITUDINAL STRESS PSI</th>
<th>LONGITUDINAL ALLOWED PSI</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The node description defines the piping segment types; i.e., anchor, run, joint, valve, flange, bend, or expansion joint. The location description defines the exact point on the piping segment where the calculated values apply.

**Hoop Stress Actual vs. Permissible**

Hoop stress are based on the following equation:

$$\sigma_y = (P_i - P_e) \frac{D}{2t}$$

where:

- $\sigma_y$ = Hoop Stress, N/mm$^2$
- $P_i$ = Internal Pressure, N/mm$^2$
- $P_e$ = External Pressure (considered 0)
- $D$ = Nominal Outside Diameter of Pipe, mm
- $t$ = $t_n - t_e$
- $t_n$ = Nominal wall thickness, mm
\[ t_c = \text{Any erosion or corrosion allowance to be subtracted from the nominal wall thickness, mm} \]

and is not to exceed the permissible value \( \sigma_{yp} \):

\[ \sigma_{yp} = \eta_h \sigma_p k_i \]

where:

- \( \sigma_{yp} \) = permissible hoop stress, N/mm\(^2\)
- \( \eta_h \) = design factor, hoop stress
- \( \sigma_p \) = specified minimum yield strength, N/mm\(^2\)

### Equivalent Stress vs. Permissible (4.2.2.8)

Equivalent stress is defined as:

\[ \sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3 \tau_{xy}^2} \]

where:

- \( \sigma_e \) = Equivalent Stress, N/mm\(^2\)
- \( \sigma_x \) = total longitudinal stress, N/mm\(^2\)
- \( \sigma_y \) = total hoop stress, N/mm\(^2\)
- \( \tau_{xy} \) = total tangential shear stress, N/mm\(^2\)

The following stress conditions are to be satisfied:

\[ \sigma_{yp} \leq \eta_{ep} \sigma_p k_i \]

\[ \sigma_x \leq \eta_{ep} \sigma_p k_i \]

where:

- \( \sigma_{yp} \) = permissible value, N/mm\(^2\)
- \( \eta_{ep} \) = usage factor
- \( k_1 \) = temperature derating factor
8.1.14 DNV Rules for Submarine Pipeline Systems, 2000 by Det norske Veritas

The DnV Compliance Report consists of two Output Reports. The first Output Report lists all of the DnV Code Compliance Data specified by the User. The second Output Report contains the node identification, hoop stresses vs. allowed stresses, longitudinal stresses vs. allowed stresses and equivalent stresses vs. allowed stresses.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

1. English (ENG)
2. Metric (MET)
3. System International (SI)
4. International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MATERIAL YIELD STRENGTH psi</th>
<th>WELD JOINT FACTOR</th>
<th>TEMP. REDUCTION FACTOR</th>
<th>HOOP STRESS DESIGN FACTOR</th>
<th>EQUIVALENT STRESS DESIGN FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and to Data Numbers

The range of data point numbers for which the specified properties apply.

Specified Minimum Yield Strength (F1)

Specified minimum yield strength.

Weld Factor (KW)

Strength factor for weld joints.

Temperature Reduction Factor (K1)

Temperature reduction factor.

Hoop Stress Design Factor (NH)

Hoop stress design factor.
Design Factor, Equivalent Stress ($\eta_{EP}$)

Equivalent stress design factor.

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>Hoop Stress</th>
<th>Hoop Allowed</th>
<th>Equivalent Stress</th>
<th>Equivalent Allowed</th>
<th>Longitudinal Stress</th>
<th>Longitudinal Allowed</th>
</tr>
</thead>
</table>

Data Point

The number assigned by the User to each significant location.

Node Location

The node description defines the piping segment types; i.e., anchor, run, joint, valve, flange, bend, or expansion joint. The location description defines the exact point on the piping segment where the calculated values apply.

Hoop Stress Actual vs. Permissible

Hoop stress are based on the following equation:

$$
\sigma_y = \left( P_i - P_e \right) \frac{D}{2t}
$$

where:

- $\sigma_y$ = Hoop Stress, N/mm²
- $P_i$ = Internal Pressure, N/mm²
- $P_e$ = External Pressure (considered 0)
- $D$ = Nominal Outside Diameter of Pipe, mm
- $t$ = $t_n - t_c$
- $t_n$ = Nominal wall thickness, mm
- $t_c$ = Any erosion or corrosion allowance to be subtracted from the nominal wall thickness, mm
and is not to exceed the permissible value $\sigma_{yp}$:

$$\sigma_{yp} = \eta_h \sigma_p k_l$$

where:

$\sigma_{yp}$ = permissible hoop stress, N/mm$^2$

$\eta_h$ = design factor, hoop stress

$\sigma_p$ = specified minimum yield strength, N/mm$^2$

**Equivalent Stress vs. Permissible**

Equivalent stress is defined as

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 2 \tau_{xy}^2}$$

where:

$\sigma_e$ = Equivalent Stress, N/mm$^2$

$\sigma_x$ = total longitudinal stress, N/mm$^2$

$\sigma_y$ = total hoop stress, N/mm$^2$

$\tau_{xy}$ = total tangential shear stress, N/mm$^2$

The following stress conditions are to be satisfied

$$\sigma_{yp} \leq \eta_p \sigma_p k_l$$

$$\sigma_x \leq \eta_p \sigma_p k_l$$

where:

$\sigma_{yp}$ = permissible value, N/mm$^2$

$\eta_p$ = usage factor

$k_l$ = temperature derating factor
8.1.15 "Guidelines for Design, Fabrication, Submarine Pipelines and Risers", 1984 by the Norwegian Petroleum Directorate

The NPD Compliance Report consists of two Output Reports. The first Output Report lists all of the NPD Code Compliance Data specified by the User. The second Output Report contains the node identification, hoop stresses vs. allowed stresses, and equivalent stresses vs. allowed stresses.

Output units and equations shown in this section are for the System International (SI) system and International Units 1 (IU1). Output units are available for the following:

1. English (ENG)  
2. System International (SI)  
3. Metric (MET)  
4. International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MATERIAL YIELD STRENGTH psi</th>
<th>WELD JOINT FACTOR</th>
<th>TEMP. REDUCTION FACTOR</th>
<th>HOOP STRESS DESIGN FACTOR</th>
<th>EQUIVALENT STRESS DESIGN FACTOR</th>
</tr>
</thead>
</table>

From and to Data Numbers

The range of data point numbers for which the specified properties apply.

Specified Minimum Yield Strength (F1)

Material Yield Strength.

Weld Factor (KW)

Strength factor for weld joint factor.

Temperature Reduction Factor (KT)

Temperature reduction factor.

Hoop Stress Design Factor (NH)
Hoop Stress design factor.

**Design Factor, Equivalent Stress (NEP)**

Equivalent stress design factor.

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>DATA POINT</th>
<th>NODE LOCATION</th>
<th>HOOP STRESS psi</th>
<th>HOOP ALLOWED psi</th>
<th>EQUIVALENT STRESS psi</th>
<th>EQUIVALENT ALLOWED psi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Hoop Stress Actual vs. Permissible**

Hoop stress is based on the following equation from section 5.4.2.2:

\[
\sigma_y = (P_i - P_e) \frac{D_{\text{max}} - 2t_{\text{min}}}{2t_{\text{min}}}
\]

where:

\[\sigma_y = \text{Hoop Stress, N/mm}^2\]
\[P_i = \text{Internal Pressure, N/mm}^2\]
\[P_e = \text{External Pressure (considered 0), N/mm}^2\]
\[D_{\text{max}} = \text{Outside Diameter of Pipe mm}\]
\[t_{\text{min}} = t_n - t_t - t_c, \text{ mm}\]
\[t_n = \text{Nominal wall thickness of pipe, mm}\]
Fabrication tolerance, percent or mm

erosion or corrosion allowance to be subtracted, mm

and is not to exceed the permissible value $\sigma_{yp}$ of Section 5.4.2.1:

$$\sigma_{yp} = \eta_h \sigma_f k_w k_t$$

where:

$\sigma_{yp}$ = permissible hoop stress, N/mm$^2$

$\eta_h$ = design factor, hoop stress, N/mm$^2$

$\sigma_F$ = specified minimum yield strength, N/mm$^2$

$k_w$ = weld joint factor

$k_t$ = temperature factor

**Equivalent Stress vs. Permissible (5.4.2.3)**

Equivalent stress is defined as:

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3 \tau_{xy}^2}$$

where:

$\sigma_e$ = Equivalent Stress, N/mm$^2$

$\sigma_x$ = total longitudinal stress, N/mm$^2$

$\sigma_y$ = total hoop stress, N/mm$^2$

$\tau_{xy}$ = total tangential shear stress, N/mm$^2$

$N$ = axial force, N

$$\sigma_x = \sigma_x^p + \sigma_x^N \pm \sigma_x^M$$

$$\sigma_x = P_i \frac{\pi (D - 2t_{min})}{4 A_w} + \frac{N}{A_w} + \frac{\sqrt{M_i^2 + M_o^2}}{W} \cdot 10^3$$
\[ A_w = \frac{\pi}{4} (D^2 - (D - 2t_{\text{min}})^2) \text{, mm}^2 \]

\[ W = \frac{\pi}{32} \frac{D^4 - (D - 2t_{\text{min}})^4}{D} \text{, mm}^4 \]

\[ M_i = \text{in-plane bending moment, N-m} \]

\[ M_o = \text{out-of-plane bending moment, N-m} \]

and is not to exceed \( \sigma_{ep} \) as shown below:

\[ \sigma_{ep} = \eta_{ep} \sigma_F k_w k_t \]

where:

\[ \sigma_{ep} = \text{permissible value, N/mm}^2 \]

\[ \eta_{ep} = \text{design factor, equivalent stress} \]

\[ \sigma_F = \text{specified minimum yield strength, N/mm}^2 \]

The Statoil Compliance Report consists of two Output Reports. The first Output Report lists all of the Statoil Code Compliance Data specified by the User. The second Output Report contains the node identification, hoop stresses vs. allowed stresses, and equivalent stresses vs. allowed stresses.

Output units and equations shown in this section are for the English system and the System International (SI). Output units are available for the following:

1. English (ENG)
2. System International (SI)
3. Metric (MET)
4. International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MATERIAL YIELD STRENGTH ( \text{psi} )</th>
<th>WELD JOINT FACTOR</th>
<th>TEMP. REDUCTION FACTOR</th>
<th>HOOP STRESS DESIGN FACTOR</th>
<th>EQUIVALENT STRESS DESIGN FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and to Data Numbers

The range of data point numbers for which the specified properties apply.

Specified Minimum Yield Strength (F1), \( \text{N/mm}^2 \)

Material Yield Strength.

Weld Factor (KW)

Strength factor for weld joint factor.

Temperature Reduction Factor (KT)

Temperature reduction factor.
Hoop Stress Design Factor (NH)

Hoop Stress design factor.

Design Factor, Equivalent Stress (NEP)

Equivalent stress design factor.

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>DATA POINT</th>
<th>NODE LOCATION</th>
<th>HOOP STRESS psi</th>
<th>HOOP ALLOWED psi</th>
<th>EQUIVALENT STRESS psi</th>
<th>EQUIVALENT ALLOWED psi</th>
</tr>
</thead>
</table>

Data Point

The number assigned by the User to each significant location.

Node Location

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply.

Hoop Stress Actual vs. Permissible

Hoop stress is based on the following equation from Section 5.4.2.2:

$$\sigma_y = (P_i - P_e) \cdot \frac{D_{max} - 2 \cdot t_{min}}{2 \cdot t_{min}}$$

where:

- $\sigma_y$ = Hoop Stress N/mm²
- $P_i$ = Internal Pressure N/mm²
- $P_e$ = External Pressure (consider 0)
- $D_{max}$ = Outside Diameter of Pipe mm
- $t_{min}$ = Minimum wall thickness mm
  = (nominal wall thickness - allowable tolerances for fabrication)
and is not to exceed the permissible value $\sigma_{yp}$ of Section 5.4.2.1:

$$\sigma_{yp} = \eta_h \cdot \sigma_F \cdot k_w \cdot k_i$$

where:

- $\sigma_{yp}$ = permissible hoop stress, N/mm$^2$
- $\eta_h$ = design factor, hoop stress, N/mm$^2$
- $\sigma_F$ = specified minimum yield strength, N/mm$^2$
- $k_w$ = weld joint factor
- $k_t$ = temperature factor

**Equivalent Stress vs. Permissible (5.4.2.3)**

Equivalent stress is defined as

$$\sigma_e = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_x \sigma_y + 3 \cdot \tau_{xy}^2}$$

where:

- $\sigma_e$ = Equivalent Stress N/mm$^2$
- $\sigma_x$ = total longitudinal stress N/mm$^2$
- $\sigma_y$ = total hoop stress N/mm$^2$
- $\sigma_{xy}$ = total tangential shear stress N/mm$^2$

and is not to exceed $\sigma_{ep}$ as shown below:

$$\sigma_{ep} = \eta_{ep} \cdot \sigma_F \cdot k_w \cdot k_i$$

where:

- $\sigma_{ep}$ = permissible value N/mm$^2$
- $\eta_{ep}$ = design factor, equivalent stress
- $\sigma_F$ = specified minimum yield strength N/mm$^2$
8.1.17 Polska Norma PN-79 / M-34033

The PN-79 / M-34033 Compliance Report consists of two Output Reports. The first report lists the PN-79 / M-34033 data specified by the User. The second report contains the node identification, the design wall thickness vs. required wall thickness, sustained stresses vs. allowed, and displacement stresses vs. allowed.

Output units and equations shown in this section are for the English system and the System International (SI). Output units are available for the following:

1. English (ENG)
2. Metric (MET)
3. System International (SI)
4. International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

It is not our intent to duplicate the Polska Norma PN-79 / M-34033 Codebook, but only to highlight the areas dealing with the calculation of stresses in the pipe. This report is in fact the input echo data for Code Compliance.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM TO</th>
<th>RM, Rz(2e5)n0, Rz(1e5)n0, R1(1e5)n0, N/mm²</th>
<th>DESC.</th>
<th>DELTA N</th>
<th>RETO, Rz(2e5)n0, R1(1e5)n0, Rz(1e5)n0+Δt, N/mm²</th>
<th>DESC.</th>
<th>Z</th>
<th>MILL TOLERANCE PERCENTAGE FOR C1</th>
<th>WORK HOURS 100000-200000</th>
<th>TEMP LEVEL</th>
<th>PRESSURE LEVEL</th>
<th>EQUATION NO.</th>
</tr>
</thead>
</table>

From and To Data Numbers
The range of data point numbers for which these specified properties apply.

Allowable Stress

Depending upon the conditions to be evaluated, one or two allowable stress values are furnished by the User for TRIFLEX to calculate the permissible stress for the piping system. These allowables are provided in the following manner:

(a.) When the design temperature is not higher than the limit temperature, the following two stresses are supplied by the User:

\[ R_m \quad - \quad \text{Specified Minimum Tensile Strength at room temperature (psi, N/mm}^2\) \]

\[ R_{yt,d} \quad - \quad \text{Specified Yield Point (minimal value) at design temperature (psi, N/mm}^2\) \]

(b.) When the design temperature is higher than the limit temperature, the following two conditions may exist:
1.) The User will furnish:

$$R_{z(2\times10^5)t_o}$$ Temporary Creep Strength (average value) at $2\times10^5$ hours at the design temperature $t_o$ (psi, N/mm$^2$)

and

$$\Delta$$ Maximal negative deviation of temporary creep strength at $10^5$ hours and at the design temperature $t_o$. (percent)

2.) Or, the User will furnish:

$$R_{z(10^5)t_o}$$ Temporary Creep Strength (average value) at $10^5$ hours at the design temperature $t_o$. (psi, N/mm$^2$)

and

$$R_{r(10^4)t_o}$$ Creep Strength Limit (average value) with 1% permanent elongation, at $10^4$ hours and at the design temperature $t_o$. (psi, N/mm$^2$)

$$R_{z(10^5)t_o+t}$$ Temporary Creep Strength (average value) at $10^5$ hours at the temperature $t_o + t$. (psi, N/mm$^2$)

Two of these values are presented in the columns:

In the column named DESC are described which value are presented in the previous column.

**DELTA %** Maximal negative deviation of temporary creep strength at $10^5$ hours and at the design temperature $t_o$. (percent)

**Z:** Strength factor of weld connection

- 1.0 - for seamless pipe
- 0.9 - for pipes with longitudinal double-sided wall
- 0.8 - for pipes with longitudinal one side weld as well as for pressure welded pipes.
Mill Tolerance

Manufacturer mill tolerance. (percent) or (inches or millimeters))

Work Hours 100000-200000

Specify if working time is above 100000 and up to 200000 hours

Temp Level

The L-tag says that the design temperature is not higher than the limit temperature for this material, while the H-tag says that the design temperature is higher than the limit temperature for this material.

Pressure Level (for reference, see Table 2) shall be specified as:

0 - pipes destined for pipelines where internal pressure and additional external loads occur.

1 - pipes destined for pipelines where only internal pressure occurs

Equation No.

The number of equation used to calculate the permissible stress.

The second report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>Allowable Stress k n/mm²</th>
<th>Wall Thickness Design mm.</th>
<th>Wall Thickness Require mm.</th>
<th>Comparative Stress n/mm²</th>
<th>Cross Sec Point</th>
<th>Permissible Stress n/mm²</th>
<th>Comparative Stress Percentage</th>
<th>Creep Permissible Stress n/mm²²</th>
<th>Comparative Stress vs Creep Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Point

The number assigned by the User to each significant location.

Node Location

Node Location is comprised of two columns. The node defines the piping segment types; i.e., anchor, run, joint, valve, flange, bend, or expansion joint. The location defines the exact point on the piping segment (beg, mid, end) where the calculated values apply.
Allowable Stress $k$

Permissible stress for wall thickness calculations. (psi, N/mm$^2$)

Wall Thickness Required

The required wall thickness is calculated by TRIFLEX using PN-79/M-34033 code requirements. (in, mm)

Wall Thickness Design

The design wall thickness is input by the User. (in, mm)

Comparative Stress

A sum of stresses in pipeline’s elements – caused by internal pressure and external forces action accordingly to formula (16). (psi, N/mm$^2$)

Cross Sec Point

Location where the comparative stress occurs. (Table I-2.)

Permissible Stress

Allowable stress level for permissible stress. (psi, N/mm$^2$)

Comparative Stress Percentage

Percentage of comparative stress vs. permissible stress.

Rules Concerned with Tubes Wall Thickness Calculations

Polska Norma PN-79 / M-34033 should be used for systems in the range of temperatures as for steel tubes, but not higher than 560° C (833 K) - for which the proportion of external diameter $D_z$ to internal diameter $D_w$ equals:

$$D_z / D_w \leq 1.7$$

Polska Norma PN-79 / M-34033 is not concerned with:

- tubes that are produced out of austenitic steel grades
- tubes and elements made of tubes that are subjected to different Codes.

Wall Thickness Calculations

The design wall thickness is input by the User. The required wall thickness is calculated by TRIFLEX using the following PN-79/M-34033 Section 2 code equations:
\[ g_o = \frac{D_w \cdot P_o}{2.3 \cdot k \cdot z - P_o} \quad \text{or} \quad \frac{D_z \cdot P_o}{2.3 \cdot k \cdot z + P_o} \quad (1) \]

where:
- \( g_o \) = Calculated wall thickness, (inches, mm)
- \( P_o \) = Internal design pressure as input by the User, psig
- \( D_z \) = Actual pipe outside diameter, inches, mm
- \( D_w \) = Actual pipe inside diameter, inches, mm
- \( k \) = Permissible stress
- \( a \) = Coefficient depending on quotient \( D_z \) by \( D_w \)
- \( z \) = Strength factor of weld connection

Nominal wall thickness of a straight segment of pipeline - to be calculated according to the following formula:

\[ g \geq g_o + C_1 + C_2 \quad (2) \]

As for bends, the bigger of the following (calculated according to formulas) values should be used:

1) for inside generating line of bend - \( (R - \frac{D_z}{2}) \)

\[ g \geq A_1 \cdot g_o + C_1 + C_2 \quad (3) \]

2) for outside generating line of bend - \( (R + \frac{D_z}{2}) \)

\[ g \geq A_2 \cdot g_o + C_1 + C_2 + C_3 \quad (4) \]

Values to be Used for Calculations:

**Tube’s Diameter:** The tube’s diameter should be as indicated in appropriate subject Standards.

**Calculations:** The calculations shall be performed as based at \( D_z \) (when production of tubes is based at constant external diameter), or as based at \( D_w \) (where technology of tube’s production is based at constant internal diameter).
Material’s Strength Properties

The values of $R_{m0}$ and $R_{z0}$ that are to be used for calculations should correspond to those indicated in appropriate Polish Standards or smallest values according to different Standards; for $R_{z(1e5)0}$; $R_{z(2e5)0}$; $R_{z(3e5)0}$; (as based at PN-H-84024, or mean values based at different Standards).

The values of $R_{e0}$ in the temperatures range between $20^\circ C$ up to limit temperature can be linearly interpolated out of the lowest values of $R_{e11}$ and $R_{e12}$, in the ranges closest to temperatures $t_1$ and $t_2$, (as given values in appropriate Standards).

In cases where the period for pipeline’s work is restricted, the User is allowed to use values as interpolated linearly in double logarithmic co-ordinate system out of mean values of $R_{z(2e5)0}$ or $R_{z(ee5)0}$ and $R_{z(1e5)0}$ or $R_{z(ee5)0}$ and $R_{z(3e5)0}$.

Values of Allowable Stresses for Steel Tubes:

1.) The Design temperature does not exceed limit temperature.

For given steel grade, the lower out of values shall be used as calculated below:

$$k' = \frac{R_{m0}}{x_1}$$  \hspace{1cm} (5)

or

$$k'' = \frac{R_{e0}}{x_2}$$  \hspace{1cm} (6)

where:

$x_1$ and $x_2$ are coefficients (see Table 2), depending on material grade (quality) and working conditions.
Table 2

<table>
<thead>
<tr>
<th>Tube’s kind</th>
<th>Coefficient</th>
<th>A&lt;sup&gt;1) &lt;/sup&gt;</th>
<th>B&lt;sup&gt;2) &lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel boiler tubes</td>
<td>X₁</td>
<td>2.68</td>
<td>2.60</td>
</tr>
<tr>
<td></td>
<td>X₂</td>
<td>1.73</td>
<td>1.65</td>
</tr>
<tr>
<td>Quality tubes of carbon steel with impact properties acc. to relevant Standard</td>
<td>X₁</td>
<td>2.75</td>
<td>2.60</td>
</tr>
<tr>
<td></td>
<td>X₂</td>
<td>1.80</td>
<td>1.65</td>
</tr>
<tr>
<td>Tubes of other carbon steels</td>
<td>X₁</td>
<td>2.90</td>
<td>2.75</td>
</tr>
<tr>
<td></td>
<td>X₂</td>
<td>2.00</td>
<td>1.80</td>
</tr>
</tbody>
</table>

<sup>1) </sup> Tubes destined for pipelines, where there are internal pressure and external forces acting.

<sup>2) </sup> Tubes destined for pipelines, where there is internal pressure only.

**Design Temperature is Higher than Limit Temperature**

For given steel grade, the lower out of values shall be used as calculated here:

a) working time is above 100000 and up to 200000 hours, uses the following formula:

\[ k^{'''} = \frac{R_{x(\text{min})(2*10^5)t_o}}{1.15} \]  \( (7) \)

where:

\[ R_{x(\text{min})(2*10^5)t_o} = \frac{100 - \Delta}{100} \cdot R_{x(2*10^5)t_o} \]  \( (8) \)

or when there is no \( R_{x(2*10^5)t_o} \) value for given material, the lowest value as calculated by the following formulas are to be used:

\[ k^{'''} = \frac{R_{x(10^5)t_o}}{X_4} \]  \( (9) \)
(10) \[ k^V = R_{i(10^5)_{t_e}} \]

\[ k^{VI} = \frac{R_{z(10^5)_{t_w}} + P_1}{1.15} \quad (11) \]

where: \( x_4 \) = according to Table 3.

Table 3

<table>
<thead>
<tr>
<th>Tube’s kind</th>
<th>Coefficient</th>
<th>( A^{1)} )</th>
<th>( B^{1)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler and alloy steels</td>
<td>( X_4 )</td>
<td>1.73</td>
<td>1.65</td>
</tr>
</tbody>
</table>

\( ^1) \) \( A \) \& \( B \) as in Table 2.

b) working time is less than or equal to 100,000 hours, use the lowest of the values calculated according to formulas (9); (10); (11), with \( X_4 \) value set to 1.65.

Coefficient \( \alpha \) - according to Table 4.

Table 4

<table>
<thead>
<tr>
<th>( D_z / D_w )</th>
<th>1.4</th>
<th>1.5</th>
<th>1.6</th>
<th>1.7</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a )</td>
<td>1.000</td>
<td>1.025</td>
<td>1.050</td>
<td>1.075</td>
</tr>
</tbody>
</table>

Coefficient \( z \) – for tubes bearing Steel Mill Certificates should be as follows:

<table>
<thead>
<tr>
<th>( z ) - Coefficient</th>
<th>1.0</th>
<th>For seamless tubes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.9</td>
<td>for welded tubes (longitudinal double side weld)</td>
</tr>
<tr>
<td></td>
<td>0.8</td>
<td>for welded tubes (longitudinal one side weld) and resistant welded tubes</td>
</tr>
</tbody>
</table>

Bigger coefficient values can be used, when Producer will guarantee to keep such a value, and nondestructive testing will be done for the whole weld.

\( C_1 \) Coefficient – For as drawn and as-rolled tubes (without welding seams), and for tubes with welding seams (drawn afterwards), the Coefficient to be used depends upon on allowed minus tolerance for wall thickness, and as it is stated in appropriate Standards and of \( C_2 \) Coefficient shown below and calculated according to Table 5.
Table 5

<table>
<thead>
<tr>
<th>a&lt;sub&gt;g&lt;/sub&gt; %</th>
<th>10</th>
<th>12.5</th>
<th>15.0</th>
<th>17.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&lt;sub&gt;1&lt;/sub&gt;</td>
<td>mm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.11(g&lt;sub&gt;o&lt;/sub&gt; + C&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>0.14(g&lt;sub&gt;o&lt;/sub&gt; + C&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>0.18(g&lt;sub&gt;o&lt;/sub&gt; + C&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>0.21(g&lt;sub&gt;o&lt;/sub&gt; + C&lt;sub&gt;2&lt;/sub&gt;)</td>
<td></td>
</tr>
</tbody>
</table>

1) For different a<sub>g</sub> - C<sub>1</sub> = a<sub>g</sub> (g<sub>o</sub> + C<sub>2</sub>) / (100 - a<sub>g</sub>)

For tubes with welding seams (not drawn afterwards) or resistant welded, the C<sub>1</sub> Coefficient should be equal to sum of maximum biggest lower wall thickness tolerance for wall thickness and a value of biggest possible wall thickness thinning, when performing further shaping operations.

C<sub>2</sub> Coefficient - For non-aggressive water and steam (with no solid particles, which can cause wall thickness abrasion) C<sub>2</sub> value = (0.3 up to 1.0 mm). [Designer’s decision.]

C<sub>3</sub> Coefficient - Which takes into account the wall thickness thinning at external generatrix during bending process, or otherwise shaped by different plastic deformation:

a) For bends with R ≥ 3D<sub>z</sub> made of tubes with D<sub>z</sub> ≤ 406.4 mm according to formulas

\[
C_3 = \frac{D_z}{2R} g_\sigma \quad \text{for mechanical bending} \quad (12)
\]

\[
C_3 = \frac{D_z}{2.5R + D_z} g_\sigma \quad \text{for electric induction bending} \quad (12a)
\]

b) For bends produced using different technological methods (as compared with “a” above) and where R < 3D<sub>z</sub>, as well as for tubes with D<sub>z</sub> > 406.4 mm, the Producer’s given values should be used instead.

Corrective Coefficients A<sub>1</sub> and A<sub>2</sub>. (Coefficients are concerned with as-bend only)

The required reinforcing of wall thickness at internal bend’s generatrix should be calculated accordingly to formula (13) or Table 6, depending on quotient g / D<sub>z</sub>.

a) For bends made of thin wall tubes, where quotient g / D<sub>z</sub> ≤ 0.04 as per the formula:

\[
A_1 = \frac{2R - \frac{1}{2} D_m}{2R - D_m} \quad (13)
\]

b) For bends made of tubes, where \( \frac{g}{D_z} > 0.04 \) according to Table 6.
Table 6

<table>
<thead>
<tr>
<th>R/Dz</th>
<th>g / Dz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A₁</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

The allowed weakening of wall thickness at external bend’s generatrix should be calculated according to the formula below:

\[
A₂ = \frac{2R + \frac{1}{2}D_m}{2R + D_m} \tag{14}
\]

where:

\[
D_m = D_z - g_o \tag{15}
\]

**Pipeline’s Material Stresses**

The comparative stresses in pipelines \(\sigma_{xz}\) should be calculated as a sum of stresses in pipeline’s elements caused by internal pressure and the external forces action by the below formula:

\[
\sigma_{xz} = \sqrt{\sigma_i^2 + \sigma^2 + \sigma_{a}^2 - \sigma_{y} \sigma_{a} - \sigma_{u} \sigma_{a} - \sigma_{y} \sigma_{y} + 3\tau^2} \tag{16}
\]
The highest $\sigma_{zr}$. Stress value as calculated for subsequent points of tubes and bents should be used for such calculations.

**Permissible stresses - Safety Factors**

1) For pipelines, where the basis for elements wall thickness calculations – values of $R_m$ or $R_{eto}$ (taking into account the short lived pressure or temperature increases), the following should be fulfilled:

$$R_{eto} / \sigma_{zr} \geq 1.25 \quad (\sigma_{zr} \leq R_{eto} / 1.25) \quad (17)$$

2) For pipelines, where the basis for wall thickness calculations was $R_z(2ee5)_{to}$, the following should be completed:

$$R_{eto} / \sigma_{zr} \geq 1.25 \quad (\sigma_{zr} \leq R_{eto} / 1.25) \quad (18)$$

Where the minimum $R_{e_{min.(2ee5)}}$ value should be as calculated using appropriate formula (8).

3) For pipelines, where the basis for wall thickness calculations was $R_z(2ee5)$ to or $R_1(2ee5)$ to, the following should be completed:

$$R_1(2ee5)_{to} / (\sigma_{zr}) \geq 1.1 \quad (\sigma_{zr} \leq R_1(2ee5)_{to} / 1.1) \quad (19)$$

4) For pipeline’s particular nodal points, where creep strength periodic control is taking place, the following shall be completed:

$$R_{z(10ee5)to} / \sigma_{zr} \geq 1.25 \quad (\sigma_{zr} \leq R_{z(10ee5)to} / 1.25) \quad (20)$$

5) Where maximal short-lived pressure or temperature increase occurs, the following condition should be fulfilled:

$$R_{z(10ee5)to + t} / \sigma_{zr} \geq 1.1 \quad (\sigma_{zr} \leq R_{z(10ee5)to + t} / 1.1) \quad (21)$$

6) In case of requirement for hydrostatic test, the following formula should be satisfied:

$$R_{eto} / \sigma_{zr} \geq 1.1 \quad (\sigma_{zr} \leq R_{eto} / 1.1) \quad (22)$$

Formulas developed for partial stresses calculations for straight pieces due to internal pressure $p_o$, bending $M_g$ and torsion $M_s$ actions are according to Drawing I-1 and Table I-1.
Table I-1

<table>
<thead>
<tr>
<th>Type of Stress</th>
<th>Caused by</th>
<th>For point of cross section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoop Stress $\sigma_t$</td>
<td>internal pressure action</td>
<td>$I: \frac{2p_o}{u^2-1}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$II: \frac{u^2+1}{u^2-1}$</td>
</tr>
<tr>
<td>Axial Stress $\sigma_a = \Sigma$</td>
<td>internal pressure action</td>
<td>$I: \frac{1}{u^2-1}$</td>
</tr>
<tr>
<td></td>
<td>resultant bending moment action</td>
<td>$II: \frac{M_g D_z}{2I}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\frac{M_s D_w}{2I}$</td>
</tr>
<tr>
<td>Radial Stress $\sigma_r$</td>
<td>internal pressure action</td>
<td>$I: 0$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$II: -p_o$</td>
</tr>
<tr>
<td>Shear Stress $\tau$</td>
<td>torsional moment action</td>
<td>$I: \frac{M_s D_z}{4I}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$II: \frac{M_s D_w}{4I}$</td>
</tr>
</tbody>
</table>

$I$ – in cm$^4$; $D_z$ and $D_w$ - in cm; $M_g$ and $M_s$ - in daN * cm ( kG * cm). Coefficient $u$ – according to point 8.

Formulas developed for partial stresses calculations for bend’s walls due to internal pressure $p_o$, bending $M_g$ and torsion $M_s$ actions are according to Drawing I-2 and Table I-2.
Table I-2

<table>
<thead>
<tr>
<th>Type of Stress</th>
<th>Hoop Stress $\sigma_t$</th>
<th>Axial Stress $\sigma_a$</th>
<th>Radial Stress $\sigma_r$</th>
<th>Shear Stress $\tau$</th>
</tr>
</thead>
<tbody>
<tr>
<td>For point of cross section</td>
<td>Caused by internal pressure action and bending moment in arc plane ($M'_g$)</td>
<td>Caused by internal pressure, bending moment in arc plane ($M'_g$) and bending moment in plane perpendicular to arc plane ($M''_g$)</td>
<td>Caused by internal pressure action</td>
<td>Caused by torsional moment action</td>
</tr>
<tr>
<td>I</td>
<td>$p_o \left( \frac{2}{u^2 - 1} + \left( - \frac{M'_g D_z}{2l} \right) n_1 \right)$</td>
<td>$p_o \left( \frac{1}{u^2 - 1} + \frac{M'_g D_z}{2l} m \right)$</td>
<td>0.0</td>
<td>$\frac{M'_s D_m}{4l}$</td>
</tr>
<tr>
<td>II</td>
<td>$p_o \left( \frac{u^2 + 1}{u^2 - 1} + \frac{M'_w D_w}{2l} n_1 \right)$</td>
<td>$p_o \left( \frac{1}{u^2 - 1} + \frac{M'_w D_w}{2l} m \right)$</td>
<td>$-p_o$</td>
<td>$\frac{M'_s D_m}{4l}$</td>
</tr>
<tr>
<td>III</td>
<td>$p_o \left( \frac{u^2 + 1}{u^2 - 1} + \frac{M'_s D_w}{2l} n_1 \right)$</td>
<td>$p_o \left( \frac{1}{u^2 - 1} + \left( - \frac{M'_s D_w}{2l} \right) m \right)$</td>
<td>$-p_o$</td>
<td>$\frac{M'_s D_m}{4l}$</td>
</tr>
<tr>
<td>IV</td>
<td>$p_o \left( \frac{2}{u^2 - 1} + \left( - \frac{M'_g D_z}{2l} \right) n_1 \right)$</td>
<td>$p_o \left( \frac{1}{u^2 - 1} + \left( - \frac{M'_g D_z}{2l} \right) m \right)$</td>
<td>0.0</td>
<td>$\frac{M'_s D_m}{4l}$</td>
</tr>
<tr>
<td>V</td>
<td>$p_o \left( \frac{2}{u^2 - 1} + \frac{M'_g D_z}{2l} (n_1 - n_2) \right)$</td>
<td>$p_o \left( \frac{1}{u^2 - 1} + \frac{M'_g D_z}{2l} \right)$</td>
<td>0.0</td>
<td>$\frac{M'_s D_m}{4l}$</td>
</tr>
<tr>
<td>VI</td>
<td>$p_o \left( \frac{u^2 + 1}{u^2 - 1} + \left( - \frac{M'_g D_w}{2l} \right) (n_1 + n_2) \right)$</td>
<td>$p_o \left( \frac{1}{u^2 - 1} + \frac{M'_g D_w}{2l} \right)$</td>
<td>$-p_o$</td>
<td>$\frac{M'_s D_m}{4l}$</td>
</tr>
<tr>
<td>VII</td>
<td>$p_o \left( \frac{u^2 + 1}{u^2 - 1} + \left( - \frac{M'_w D_w}{2l} \right) (n_1 + n_2) \right)$</td>
<td>$p_o \left( \frac{1}{u^2 - 1} + \left( - \frac{M'_w D_w}{2l} \right) \right)$</td>
<td>$-p_o$</td>
<td>$\frac{M'_s D_m}{4l}$</td>
</tr>
<tr>
<td>VIII</td>
<td>$p_o \left( \frac{2}{u^2 - 1} + \frac{M'_s D_z}{2l} (n_1 - n_2) \right)$</td>
<td>$p_o \left( \frac{1}{u^2 - 1} + \left( - \frac{M'_s D_z}{2l} \right) \right)$</td>
<td>0.0</td>
<td>$\frac{M'_s D_m}{4l}$</td>
</tr>
</tbody>
</table>
I - in cm$^4$; Dz and Dw - in cm; Mg' and Mg'' as well as Ms - in daN * cm (kG * cm)

The User is allowed to calculate the comparative stresses ($\sigma_{xz}$) occurring in bent tubes under the assumption that extreme values of axial and hoop stresses are existing in the same points of cross section of bend. When using this simplification for $\lambda < 1.472$, the real comparative stress shall not be bigger than calculated stresses.

where:

**Axial moment of inertia for perpendicular cross section of tube**

$$I = \frac{\pi}{64} (Dz^4 - Dw^4)$$  \hspace{1cm} \text{Dz and Dw (in cm)} \hspace{1cm} (I-2)

where:

$$D_w + D_z - g_1;$$  \hspace{1cm} (I-3)

$$g_1 = g - (C_1 + C_2)$$  \hspace{1cm} (I-4)

$C_1$ Coefficient – according to Table 5 taken as for „g”

$u$ - Coefficient

$$u = \frac{D_z}{D_w}$$  \hspace{1cm} (I-5)

where: $D_w$ – according to formulas I-3 & I-4.

$n_1$ and $n_2$ Coefficients

$$n_1 = \frac{18\lambda}{1 + 12\lambda^2}$$  \hspace{1cm} (I-6)

$$n_2 = \frac{r_m}{R} \cdot \frac{2 + 12\lambda^2}{1 + 12\lambda^2}$$  \hspace{1cm} (I-7)
where:

\[ \lambda = \frac{g_1 R}{r_m^2} \]  
\[ (I-8) \]

\[ r_m = \frac{D_m}{2} = \frac{D_z + D_w}{4} \]  
\[ (I-9) \]

\[ g_1 \text{-according to Formula (I-4)} \]

\[ m \text{- Coefficient} \]

\[ m = \frac{12\lambda^2 - 2}{12\lambda^2 + 1} \quad \text{For } \lambda \geq 1.472 \]  
\[ (I-10) \]

\[ m = \frac{2}{3\lambda} \sqrt{\frac{5 + 6\lambda^2}{12}} \quad \text{For } \lambda < 1.472 \]  
\[ (I-11) \]

where:

\[ K = \frac{12\lambda^2 + 1 - j}{12\lambda^2 + 10 - j} \]  
\[ (I-12) \]

\[ j \text{- value depending at } \lambda \text{ according to Table I-3 below:} \]

<table>
<thead>
<tr>
<th>( \lambda )</th>
<th>0.00</th>
<th>0.05</th>
<th>0.10</th>
<th>0.20</th>
<th>0.30</th>
<th>0.50</th>
<th>0.75</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1764</td>
<td>1.00</td>
<td>0.7625</td>
<td>0.5684</td>
<td>0.3074</td>
<td>0.07488</td>
<td>0.03526</td>
<td>0.02026</td>
<td></td>
</tr>
</tbody>
</table>

Intermediate \( \lambda \) values can be obtained using linear interpolation.

\( S_1 \) and \( S_2 \) Coefficients

\[ S_1 = \frac{1}{1 + \frac{r_m}{R}} \]  
\[ (I-13) \]

\[ S_2 = \frac{1}{1 - \frac{r_m}{R}} \]  
\[ (I-14) \]
8.1.18 SNIP 2.05-06-85 - FSU Transmission Piping Code

The SNIP 2.05-06-85 Compliance Report consists of three Output Reports. The first Output Report lists the entire SNIP 2.05-06-85 Code Compliance Data specified by the User. The second Output Report contains the node identification, the hoop stress vs. the hoop stress allowable and the longitudinal axial stress vs. the allowed longitudinal axial stress, the longitudinal stress and allowables for both the tensile fiber and compressive fiber, and the stress intensity (combined stress) actual vs. the allowable.

Output units and equations shown in this section are for the English system. Output units are available for the following:

1. English (ENG)  
2. Metric (MET)  
3. System International (SI)  
4. International Units 1 (IU1)

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>LOAD FACTOR LF</th>
<th>LOADING CONDITION LC</th>
<th>PIPELINE CATEGORY COEFF M</th>
<th>MATERIAL DEPENDENT RELIABILITY COEFF K1</th>
<th>MATERIAL DEPENDENT RELIABILITY COEFF K2</th>
<th>LINE RELIABILITY COEFF KN</th>
<th>ULTIMATE TENSILE YIELD STRENGTH R1</th>
<th>ULTIMATE TENSILE YIELD STRENGTH R2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and to Data Numbers

The range of data point numbers for which the specified properties apply.

Load Factor

The load factor states whether the loads are factored (YES) are nominal (NO).

Loading Condition

The loading condition states whether the pipe is above or below ground (YES) (NO).

M

The coefficient for pipeline category from Section 2.3, Table 1.

K1

Material dependent reliability coefficient k₁ from Section 8.3, Table 9.
K2

Material dependent reliability coefficient $k_2$ from Section 8.3, Table 10.

KN

Reliability coefficient $k_n$ for pipeline characteristic Section 8.3, Table 11.

R1N

Ultimate tensile strength ($R_{(1,n)}$).

R2N

Yield strength ($R_{(2,n)}$).

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>DATA POINT</th>
<th>NODE LOCATION</th>
<th>HOOP STRESS ACTUAL psi</th>
<th>HOOP STRESS ALLOWED psi</th>
<th>HOOP STRESS PERCENTAGE</th>
<th>LONGITUDINAL STRESS AXIAL ACTUAL psi</th>
<th>LONGITUDINAL STRESS AXIAL ALLOWED psi</th>
<th>LONGITUDINAL STRESS AXIAL PERCENTAGE</th>
<th>LONGITUDINAL STRESS TENSILE FIBER ACTUAL psi</th>
<th>LONGITUDINAL STRESS TENSILE FIBER ALLOWED psi</th>
<th>LONGITUDINAL STRESS TENSILE FIBER PERCENTAGE</th>
<th>LONGITUDINAL STRESS COMPRESSION FIBER ACTUAL psi</th>
<th>LONGITUDINAL STRESS COMPRESSION FIBER ALLOWED psi</th>
<th>LONGITUDINAL STRESS COMPRESSION FIBER PERCENTAGE</th>
<th>STRESS INTENSITY COMBINED ACTUAL psi</th>
<th>STRESS INTENSITY COMBINED ALLOWED psi</th>
<th>STRESS INTENSITY COMBINED PERCENTAGE</th>
</tr>
</thead>
</table>

Data Point

The number assigned by the User to each significant location.

Node Location
The “node” description defines the piping segment types; i.e., anchor, run, joint, valve, flange, bend, or expansion joint. The “location” description defines the exact point on the piping segment where the calculated values apply.

\[ S_{\text{hoop}} = \frac{P(OD - 2t)}{2t} \]  

(Equation 1)

**Hoop Stress**

where:

- \( S_{\text{hoop}} \) = hoop stress (psi, N/mm², kg/cm², N/mm²)
- \( P \) = design pressure (gauge), (psi, k-N/m², kg/cm², bars)
- \( t \) = nominal wall thickness, (in, mm, cm, mm)

If a corrosion allowance and/or a mill tolerance are provided, they will be removed from the nominal wall thickness prior to calculations. Both corrosion allowance and mill tolerance for the SNIP 2.05-06-85 default to 0.0.

**Hoop Stress Allowable**

Hoop stress is compared to:

If the loads are factored:

\[ S_{\text{hoop,allow}} = R_1 \]  

(Equation 2)

If the loads are nominal:

\[ S_{\text{hoop,allow}} = R_3 \]  

(Equation 2)

where:

\[ R_1 = \frac{m \cdot R_{(1n)}}{k_i \cdot k_n} \]

\[ R_3 = \frac{m \cdot R_{(2n)}}{0.9 \cdot k_n} \]

\( m \) = Coefficient for pipeline category from Section 2.3, Table 1.
k1 = Material dependent reliability coefficient k1 from Section 8.3, Table 9.

Kn = Reliability coefficient kn for pipeline characteristic Section 8.3, Table 11.

R(1,n) = Ultimate Tensile Strength (psi, N/mm2, kg/cm2, N/mm2)

R(2,n) = Yield Strength (psi, N/mm2, kg/cm2, N/mm2)

**Longitudinal Axial Stress**

\[
S_{L,\text{axial}} = \frac{F_a + \frac{\pi}{4} P(OD - 2t)^2}{A_{\text{wall}}} \quad \text{(Equation 3)}
\]

The longitudinal axial stress is determined using the following equation:

where:

\[ F_a \] = axial force, (lbs, N, kg, N)

\[ A_{\text{wall}} \] = Area of the wall of the pipe (in\(^2\), mm\(^2\), cm\(^2\), mm\(^2\))

**Longitudinal Axial Stress Allowable**

Longitudinal axial stress is compare to the following allowable:

Longitudinal axial stress is checked only when loads are factored.

**Loads are factored**

If the pipe is above ground:

\[
S_{L,\text{axial}} = \psi \cdot R \quad \text{(Equation 4)}
\]

where:

\[ R_2 = \frac{m \cdot R_{(2,n)}}{k_2 \cdot k_n} \]

If \( S_{L,\text{axial}} \geq 0.0 \) then \( \psi_d = 1.0 \)

If \( S_{L,\text{axial}} < 0.0 \) and \( \frac{S_{\text{hoop}}}{R_2} \leq 1.0 \)

\[
\psi_d = \sqrt{1 - 0.75 \left( \frac{S_{\text{hoop}}}{R_2} \right)^2} - 0.5 \frac{S_{\text{hoop}}}{R_2}
\]
If \( S_{L,\text{axial}} < 0.0 \) and \( \frac{S_{\text{hoop}}}{R_i} > 1.0 \) \( \psi_2 = 0.0 \)

\[ k_2 = \text{Material dependent reliability coefficient } k_2 \text{ from Section 8.3, Table 10.} \]

If the pipe is below ground:

\[ S_{L,\text{axial,allow}} = \psi_2 \cdot R_1 \quad \text{(Equation 4)} \]

where:

If \( S_{L,\text{axial}} \geq 0.0 \) then \( \psi_2 = 1.0 \)

If \( S_{L,\text{axial}} < 0.0 \) and \( \frac{S_{\text{hoop}}}{R_i} > 1.0 \) then \( \psi_2 = 0.0 \)

\[ \psi_2 = \sqrt{1 - 0.75 \left( \frac{S_{\text{hoop}}}{R_i} \right)^2 - 0.5 \frac{S_{\text{hoop}}}{R_i}} \]

If \( S_{L,\text{axial}} < 0.0 \) and \( \frac{S_{\text{hoop}}}{R_i} \leq 1.0 \)

**Longitudinal Stress in Tensile Fiber**

\[ S_{L,t} = \frac{\sqrt{\left( i_{x,M} \right)^2 + \left( i_{y,M} \right)^2}}{Z} + \frac{F_a + \frac{\pi}{4} P(OD - 2t)}{A_{\text{wall}}} \quad \text{(Equation 5)} \]

**Factored Loads**

If pipe is above ground:

\[ S_{L,t,\text{allow}} = \psi_4 \cdot R_2 \quad \text{(Equation 7a)} \]

where:

\[ R_2 = \frac{m \cdot R_{(2,\text{v})}}{k_2 \cdot k_n} \]

If \( S_{L,t} \geq 0.0 \) then \( \psi_4 = 1.0 \)
If \( S_{lt} < 0.0 \) and \( \frac{S_{hoop}}{R_2} > 1.0 \), \( \psi_4 = 0.0 \)

\[
\psi_4 = \sqrt{1 - 0.75 \left( \frac{S_{hoop}}{R_2} \right)^2} - 0.5 \frac{S_{hoop}}{R_2}
\]

If \( S_{lt} < 0.0 \) and \( \frac{S_{hoop}}{R_2} > 1.0 \), \( \psi_4 = 0.0 \)

If pipe is below ground, then longitudinal stress is not checked.

**Loads are nominal**

If pipe is above ground, then longitudinal stress is not checked.

If pipe is below ground:

\( S_{lt,allow} = \psi_3 \cdot R_3 \)

where:

If \( S_{lt} \geq 0.0 \) then \( \psi_3 = 1.0 \)

If \( S_{lt} < 0.0 \) and \( \frac{S_{hoop}}{R_3} \leq 1.0 \)

\[
\psi_3 = \sqrt{1 - 0.75 \left( \frac{S_{hoop}}{R_3} \right)^2} - 0.5 \frac{S_{hoop}}{R_3}
\]

If \( S_{lt} < 0.0 \) and \( \frac{S_{hoop}}{R_3} > 1.0 \), \( \psi_3 = 0.0 \)

**Longitudinal Stress in Compressive Fiber**

\[
S_{lc} = -\frac{\sqrt{(i_i \ M_i)^2 + (i_o \ M_o)^2}}{Z} + \frac{F_a + \frac{\pi}{4} P(OD - 2t)^2}{A_{wall}} \quad \text{(Eq. 6)}
\]

**Longitudinal Compressive Stress Allowable**

**Factored Loads**
If pipe is above ground:

\[ S_{L,c,allow} = \psi_4 \cdot R_2 \]  

(Equation 7b)

where:

\[ R_2 = \frac{m \cdot R_{(2,n)}}{k_2 \cdot k_n} \]

If \( S_{L,c} \geq 0.0 \) then \( \psi_4 = 1.0 \)

If \( S_{L,c} < 0.0 \) and \( \frac{S_{hoop}}{R_2} \leq 1.0 \)

\[ \psi_4 = \sqrt{1 - 0.75 \left( \frac{S_{hoop}}{R_2} \right)^2} - 0.5 \frac{S_{hoop}}{R_2} \]

If \( S_{L,c} < 0.0 \) and \( \frac{S_{hoop}}{R_2} > 1.0 \) \( \psi_4 = 0.0 \)

If pipe is below ground, then longitudinal stress is not checked.

**Loads are nominal**

If pipe is above ground, then longitudinal stress is not checked.

If pipe is below ground:

\[ S_{L,c,allow} = \psi_3 \cdot R_3 \]

where:

If \( S_{L,c} \geq 0.0 \) then \( \psi_3 = 1.0 \)

If \( S_{L,c} < 0.0 \) and \( \frac{S_{hoop}}{R_3} \leq 1.0 \)

\[ \psi_3 = \sqrt{1 - 0.75 \left( \frac{S_{hoop}}{R_3} \right)^2} - 0.5 \frac{S_{hoop}}{R_3} \]

If \( S_{L,c} < 0.0 \) and \( \frac{S_{hoop}}{R_3} > 1.0 \) \( \psi_3 = 0.0 \)
Stress Intensity

\[ S_{i,act} = \sqrt{S_{\text{hoop}}^2 - S_{\text{hoop}} S_L + S_L^2} + 3 S_i^2 \]  
(Equation 8)

\[ S_L = \pm \sqrt{\left( i_i M_i \right)^2 + \left( i_o M_o \right)^2} \frac{Z}{Z} + \frac{F_a + \frac{\pi}{4} P(OD - 2t)^2}{A_{\text{wall}}} \]

\[ S_i = \frac{M_\Delta}{2 Z} \]

Stress Intensity Allowable

If pipe is above ground:

\[ S_{i,allow} = R_2 \]

If pipe is below ground, then stress intensity is not checked.

Loads are Nominal

If pipe is above ground, then stress intensity is not checked.

If pipe is below ground

\[ S_{i,allow} = R_3 \]

The BS 7159 Compliance Report consists of two Output Reports. The first Output Report lists all of the required design data that has been specified by the User. The second Output Report contains the following information for each point in the piping system where deflections, rotations, forces, moments and stresses are calculated: the Data Point Number, the Node Location, the Circumferential Stress, the Longitudinal Stress, the Torsional Stress and the Combined Stress vs. the Allowed Combined Stress.

Output units and equations shown in this section are for the System International (SI) units system. Output units are available for the following:

(1) English (ENG)  
(2) System International (SI)  
(3) Metric (MET)  
(4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>DESIGN STRESS</th>
<th>DESIGN STRAIN</th>
<th>LAMINATE TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>psi</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and To Data Point Numbers

The range of data point numbers for which the specified properties apply.

Design Stress (psi, k-N/m², kg/cm², N/mm²)

The design stress to be entered by the User is the numeric value of the Maximum Combined Stress as obtained from the FRP/GRP pipe manufacturer.

Design Strain (Unit-less)

The design strain (εN) to be entered by the User is the numeric value of the maximum allowed strain as obtained from the FRP/GRP pipe manufacturer. The sum of the circumferential strain induced by pressure and the circumferential tensile strain resulting from the longitudinal compressive stress induced by temperature change shall not exceed the design strain.
Laminate Type (1, 2 or 3)

For specific details concerning the laminate types, please consult the BS 7159 Code for the Design and Construction of Glass Reinforced Plastics Piping Systems for Individual Plants or Sites. Section 4 of BS 7159 describes the three types of laminates and Section 7 of BS 7159 describes the flexibility factors and stress intensification factors for bends and branch connections for each laminate type.

**Type 1** - All chopped strand mat (CSM) construction with an internal and an external surface tissue reinforced layer.

**Type 2** - Chopped strand mat (CSM) and woven roving (WR) construction with an internal and an external surface tissue reinforced layer.

**Type 3** - Chopped strand mat (CSM) and multi-filament roving construction with an internal and an external surface tissue reinforced layer.

---

**Note 1:** When a User specifies “FR” in a piping model, only the stiffness method should be specified to obtain a solution.

**Note 2:** When performing a BS 7159 code compliance analysis, the User should only specify a static analysis in the Case Data.

**Note 3:** In reviewing the output results of an analysis of a fiberglass-reinforced plastic piping system, valid stress results are given on the code compliance report. Any stresses calculated and displayed on the System Stresses Report are to be disregarded or ignored. The flexibility factors and stress intensification factors used by TRIFLEX are not shown on any report. They are computed in accordance with the BS 7159 Code and used in the computation of the stresses in the BS 7159 Code Compliance Report.

---

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>CIRCUMFERENTIAL STRESS (psi)</th>
<th>LONGITUDINAL STRESS (psi)</th>
<th>TORSIONAL STRESS (psi)</th>
<th>COMBINED STRESS (psi)</th>
<th>ALLOWED STRESS (psi)</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply; i.e., Begin (Beg), Mid Point (Mid) or End (End).
Circumferential Stress

The total Circumferential Stress $F_N$ is the sum of the Circumferential Pressure Stress $F_{NP}$ and the Circumferential Bending Stress $F_{NB}$, i.e.,

$$F_N = F_{NP} + F_{NB} \quad (7.20)$$

where values for these circumferential stresses may be obtained as follows:

(a) Circumferential Pressure Stress

$$F_{NP} = mp(D_i + t_d) / 20t_d \quad (7.21)$$

where:

- $m$ is the pressure stress multiplier for a straight pipe (=1) or a bend as applicable.
- $p$ is the internal pressure (gauge) (bar)
- $D_i$ is the internal diameter (mm)
- $t_d$ is the design thickness of the reference laminate (mm)

See Section 7.3.1.7 and Figure 7.1 in the BS 7159 Code for the pressure stress multiplier for a bend. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information.

(b) Circumferential Bending Stress

For straight pipes, $F_{NB}$ should be taken as zero.

For bends:

$$F_{NB} = \{(D_i + 2t_d) / 2l\} \{(M_i SIF_{Ni})^2 + (M_o SIF_{No})^2\}^{0.5} \quad (7.22)$$

where:

- $M_i$ is the maximum in-plane bending moment (N-mm)
- $M_o$ is the maximum out-of-plane bending moment (N-mm)
- $SIF_{Ni}$ is the circumferential stress intensification factor, in-plane
- $SIF_{No}$ is the circumferential stress intensification factor, out-of-plane.

See Section 7.3.1.4 and Figure 7.1 in the BS 7159 Code for the circumferential stress intensification of a bend. Also see Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information;
See Section 7.3.1.4 and Figure 7.1 in the BS 7159 Code for the circumferential stress intensification for a bend. Also see Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information;

\[ I \quad \text{is the second moment of area about an axis through the centroid normal to the axis of the pipe (mm}^4)\]

\[ D_i \quad \text{is the internal diameter of the fitting (mm)}\]

\[ t_d \quad \text{is the design thickness of the reference laminate (mm)}\]

**Longitudinal Stress**

The total Longitudinal Stress \( F_x \) is the sum of the Longitudinal Pressure Stress \( F_{xp} \) and the Longitudinal Bending Stress \( F_{xb} \), i.e.,

\[ F_x = F_{xp} + F_{xb} \quad (7.23) \]

where values for these circumferential stresses may be obtained as follows:

a) **Longitudinal Pressure Stress**

This stress may be calculated for both straight pipe and bends from the following equation:

\[ F_{xp} = \frac{p(D_i + t_d)}{40t_d} \quad (7.24) \]

where:

\[ p \quad \text{is the internal pressure (gauge) (bar)}\]

\[ D_i \quad \text{is the internal diameter (mm)}\]

\[ t_d \quad \text{is the design thickness of the reference laminate (mm)}\]

b) **Longitudinal Bending Stress**

For straight pipe:

\[ F_{xb} = \left\{ \frac{(D_i + 2t_d)}{2I} \right\} \left( M_r^2 + M_o^2 \right)^{0.5} \quad (7.25) \]

For bends:

\[ F_{xb} = \left\{ \frac{(D_i + 2t_d)}{2I} \right\} \left\{ (M_iSIF_{xi})^2 + (M_oSIF_{xo})^2 \right\}^{0.5} \quad (7.26) \]

where for equations (7.24), (7.25) and (7.26):
\( p \) is the internal pressure (gauge) (bar)

\( D_i \) is the internal diameter (mm)

\( t_d \) is the design thickness of the reference laminate (mm)

\( l \) is the second moment of area about an axis through the centroid normal to the axis of the pipe (mm\(^4\))

\( M_i \) is the maximum in-plane bending moment (N-mm)

\( M_o \) is the maximum out-of-plane bending moment (N-mm)

\( SIF_{xi} \) is the longitudinal stress intensification factor, in-plane bending.

See Section 7.3.1.4 and Figure 7.1 in the BS 7159 Code for the longitudinal stress intensification for a bend for in-plane bending. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information;

\( SIF_{xo} \) is the longitudinal stress intensification factor out-of-plane bending.

See Section 7.3.1.4 and Figure 7.1 in the BS 7159 Code for the longitudinal stress intensification for a bend for out-of-plane bending. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information.

**Torsional Stress**

For both straight pipes and bends, the Torsional Stress \( F_s \) is given by:

\[
F_s = \frac{M(D_i + 2t_d)}{4I}
\]

(7.27)

where:

\( M_s \) is the maximum torsional moment (N-mm)

\( D_i \) is the internal diameter (mm)

\( t_d \) is the design thickness of the reference laminate (mm)

\( l \) is the second moment of area about an axis through the centroid normal to the axis of the pipe (mm\(^4\))

**Combined Stress - (branch connections)**

The combined stress at a branch junction should be determined from the following equation:
\[ F_{cB} = \left( (F_{NP} + F_{bB})^2 + 4F_{SB}^2 \right)^{0.5} \]  

(7.28)

where:

- \( F_{cB} \) is the branch-combined stress (MPa)
- \( F_{NP} \) is the branch-circumferential pressure stress (MPa)
- \( F_{bB} \) is the non-directional bending stress (MPa)
- \( F_{SB} \) is the branch-torsional stress (MPa)

**Stress functions - (branch connections)**

**Circumferential Pressure Stress**

The Circumferential Pressure Stress \( F_{NP} \) should be determined from the following equation:

\[ F_{NP} = mp(D_i + t_M) / 20t_M \]  

(7.29)

where:

- \( m \) is the pressure stress multiplier.

See Equation 7.15 and Figures 7.12 and 7.16 in the BS 7159 Code for data on the pressure stress multiplier. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information;

- \( p \) is the internal pressure (gauge) (bar)
- \( D_i \) is the internal diameter of the main header section of the tee at the junction of the branch (mm)
- \( t_M \) is the minimum thickness of the reference laminate(s) of the tee main header section of at the branch junction (mm)

**Non-directional Bending Stress.**

The Non-directional Bending Stress at branch junctions should be the greatest value applicable to each of the three connections determined as follows:

a) The bending stress in the branch as it comes out of the main header section of the tee, \( F_{bB} \), as given by the equation:

\[ F_{bB} = \left( (D_i + 2t_d) / 2I \right) \left\{ (M_iSIF_B)^2 + (M_oSIF_{B0})^2 \right\}^{0.5} \]  

(7.30)
where:

\[ D_i \] is the internal diameter of the main header section of the tee at the junction of the branch (mm)

\[ t_d \] is the design thickness of the reference laminate (mm)

\[ I \] is the second moment of area about an axis through the centroid normal to the axis of the main header section of the tee (mm^4)

\[ M_i \] is the in-plane bending moment in either end of the main header section of the tee at the junction of the branch; (N-mm)

\[ M_o \] is the out-of-plane bending moment in either end of the main header section of the tee at the junction of the branch; (N-mm)

\[ SIF_{Bl} \] is the in-plane stress intensification factor, bending.

\[ SIF_{xo} \] is the out-of-plane stress intensification factor, bending.

b) **The bending stress** at the branch junction as it comes out of the main header section of the tee should be determined as for the main header section of the tee, but with the in- and out-of-plane moments being those applicable to the branch connection. The radius should be that of the branch. The moment of inertia should be that calculated using the branch radius and the lesser of the main thickness or branch thickness multiplied by the out-of-plane stress intensification factor of the branch.

c) **The torsional stress** at the branch junction as it comes out of the main header section of the tee should be the value applicable at any connection and where the torsional stress is as defined for straight pipe sections and bends in Section 7.3.4.3 of the BS 7159 Code.
8.1.20 UKOOA – SPECIFICATION & RECOMMENDED PRACTICE FOR THE USE OF GRP PIPING OFFSHORE

The UKOOA Compliance Report consists of two Output Reports. The first Output Report lists all of the required design data that has been specified by the User. The second Output Report contains the following information for each point in the piping system where deflections, rotations, forces, moments and stresses are calculated: the Data Point Number, the Node Location, the Circumferential Stress, the Longitudinal Stress, the Torsional Stress and the Combined Stress vs. the Allowed Combined Stress.

Output units and equations shown in this section are for the System International (SI) units system. Output units are available for the following:

1) English (ENG)   3) Metric (MET)
2) System International (SI) 4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>DESIGN STRESS psi</th>
<th>DESIGN STRAIN</th>
<th>LAMINATE TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and To Data Point Numbers

The range of numbers for which the specified properties are to be applied.

Design Stress (psi, k-N/m², kg/cm², N/mm²)

The design stress to be entered by the User is the numeric value of the Maximum Combined Stress as obtained from the FRP/GRP pipe manufacturer.

Design Strain (Unit-less)

The design strain ($\varepsilon_N$) to be entered by the User is the numeric value of the maximum allowed strain as obtained from the FRP/GRP pipe manufacturer. The sum of the circumferential strain induced by pressure and the circumferential tensile strain resulting from the longitudinal compressive stress induced by temperature change shall not exceed the design strain.
**Laminate Type (1, 2 or 3)**

For specific details concerning the laminate types, please consult the BS 7159 Code for the Design and Construction of Glass Reinforced Plastics Piping Systems for Individual Plants or Sites. Section 4 of BS 7159 describes the three types of laminates and Section 7 of BS 7159 describes the flexibility factors and stress intensification factors for bends and branch connections for each laminate type.

**Type 1** - All chopped strand mat (CSM) construction with an internal and an external surface tissue reinforced layer.

**Type 2** - Chopped strand mat (CSM) and woven roving (WR) construction with an internal and an external surface tissue reinforced layer.

**Type 3** - Chopped strand mat (CSM) and multi-filament roving construction with an internal and an external surface tissue reinforced layer.

**NOTE 1:** When a User specifies “FR” in a piping model, only the stiffness method should be specified to obtain a solution.

**NOTE 2:** When performing a UKOOA code compliance analysis, the User should only specify a static analysis in the Case Data.

**NOTE 3:** In reviewing the output results of an analysis of a fiberglass-reinforced plastic piping system, valid stress results are given on the code compliance report. Any stresses calculated and displayed on the System Stresses Report are to be disregarded or ignored. The flexibility factors and stress intensification factors used by TRIFLEX are not shown on any report. They are computed in accordance with the BS 7159 Code and used in the computation of the stresses in the BS 7159 Code Compliance Report.

### The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>Circumferential Stress psi</th>
<th>Longitudinal Stress psi</th>
<th>Torsional Stress psi</th>
<th>Combined Stress psi</th>
<th>Allowed Stress psi</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location in the piping system.

**Node Location**

The "Node" description defines the piping segment types; i.e., Anchor, Run, Joint, Valve, Flange, Bend, or Expansion Joint. The "Location" description defines the exact point on the piping segment where the calculated values apply; i.e., Begin (Beg), Mid Point (Mid) or End (End).
Circumferential Stress

The total Circumferential Stress $F_N$ is the sum of the Circumferential Pressure Stress $F_{Np}$ and the Circumferential Bending Stress $F_{Nb}$, i.e.

$$F_N = F_{Np} + F_{Nb} \quad (7.20)$$

where values for these circumferential stresses may be obtained as follows:

a) **Circumferential Pressure Stress**

$$F_{Np} = mp(D_i + t_d) / 20t_d \quad (7.21)$$

where:

- $m$ is the pressure stress multiplier for a straight pipe (=1) or a bend as applicable. See Section 7.3.1.7 and Figure 7.1 in the BS 7159 Code for the pressure stress multiplier for a bend. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information;
- $p$ is the internal pressure (gauge) (bar)
- $D_i$ is the internal diameter (mm)
- $t_d$ is the design thickness of the reference laminate (mm)

b) **Circumferential Bending Stress**

For straight pipes, $F_{Nb}$ should be taken as zero.

For bends:

$$F_{Nb} = \{ (D_i + 2t_d) / 2l \} \{ (M_i SIF_{Ni})^2 + (M_o SIF_{No})^2 \}^{0.5} \quad (7.22)$$

where:

- $M_i$ is the maximum in-plane bending moment (N-mm)
- $M_o$ is the maximum out-of-plane bending moment (N-mm)
- $SIF_{Ni}$ is the circumferential stress intensification factor, in-plane.

See Section 7.3.1.4 and Figure 7.1 in the BS 7159 Code for the circumferential stress intensification for a bend. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information;

$SIF_{No}$ is the circumferential stress intensification factor, out-of-plane.
See Section 7.3.1.4 and Figure 7.1 in the BS 7159 Code for the circumferential stress intensification for a bend. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information;

\[ l \] is the second moment of area about an axis through the centroid normal to the axis of the pipe (mm\(^4\))

\[ D_i \] is the internal diameter of the fitting (mm)

\[ t_d \] is the design thickness of the reference laminate (mm)

**Longitudinal Stress**

The total Longitudinal Stress \( F_x \) is the sum of the Longitudinal Pressure Stress \( F_{xp} \) and the Longitudinal Bending Stress \( F_{xb} \), i.e.,

\[ F_x = F_{xp} + F_{xb} \] (7.23)

where values for these circumferential stresses may be obtained as follows:

a) **Longitudinal Pressure Stress**

This stress may be calculated for both straight pipe and bends from the following equation:

\[ F_{xp} = \frac{\rho (D_i + t_d)}{40t_d} \] (7.24)

where:

\[ \rho \] is the internal pressure (gauge) (bar)

\[ D_i \] is the internal diameter (mm)

\[ t_d \] is the design thickness of the reference laminate (mm)

b) **Longitudinal Bending Stress**

For straight pipe:

\[ F_{xb} = \left\{ \frac{(D_i + 2t_d)}{2l} \right\} \left( M_i^2 + M_o^2 \right)^{0.5} \] (7.25)

For bends:

\[ F_{xb} = \left\{ \frac{(D_i + 2t_d)}{2l} \right\} \left\{ (M_iSIF_{xi})^2 + (M_oSIF_{xo})^2 \right\}^{0.5} \] (7.26)

where for equations (7.24), (7.25) and (7.26):

\[ \rho \] is the internal pressure (gauge) (bar)
\[ D_i \] is the internal diameter (mm)

\[ t_d \] is the design thickness of the reference laminate (mm)

\[ I \] is the second moment of area about an axis through the centroid normal to the axis of the pipe (mm\(^4\))

\[ M_i \] is the maximum in-plane bending moment (N-mm)

\[ M_o \] is the maximum out-of-plane bending moment (N-mm)

\[ SIF_{xi} \] is the longitudinal stress intensification factor, in-plane bending.

See Section 7.3.1.4 and Figure 7.1 in the BS 7159 Code for the longitudinal stress intensification for a bend for in-plane bending. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information;

\[ SIF_{xo} \] is the longitudinal stress intensification factor, out-of-plane bending.

See Section 7.3.1.4 and Figure 7.1 in the BS 7159 Code for the longitudinal stress intensification for a bend for out-of-plane bending. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information;

**Torsional Stress**

For both straight pipes and bends, the Torsional Stress \( F_s \) is given by:

\[
F_s = \frac{M(D_i + 2t_d)}{4I}
\]

(7.27)

where:

\[ M_s \] is the maximum torsional moment (N-mm)

\[ D_i \] is the internal diameter (mm)

\[ t_d \] is the design thickness of the reference laminate (mm)

\[ I \] is the second moment of area about an axis through the centroid normal to the axis of the pipe (mm\(^4\))

**Combined Stress - (branch connections)**

The combined stress at a branch junction should be determined from the following equation:

\[
F_{cB} = \left( (F_{Nb} + F_{BB})^2 + 4F_{sB}^2 \right)^{0.5}
\]

(7.28)

where:
\( F_{cB} \) is the branch combined stress (MPa)

\( F_{Np} \) is the branch circumferential pressure stress (MPa)

\( F_{bB} \) is the non-directional bending stress (MPa)

\( F_{SB} \) is the branch torsional stress (MPa)

**Stress functions - (branch connections)**

**Circumferential Pressure Stress.**

The Circumferential Pressure Stress \( F_{Np} \) should be determined from the following equation:

\[
F_{Np} = mp(D_i + t_M) / 20t_M
\]

(7.29)

where:

\( m \) is the pressure stress multiplier.

See Equation 7.15 and Figures 7.12 and 7.16 in the BS 7159 Code for data on the pressure stress multiplier. See also Section 3.2.6.18 in the TRIFLEX User’s Manual for this same information.

\( p \) is the internal pressure (gauge) (bar)

\( D_i \) is the internal diameter of the main header section of the tee at the junction of the branch (mm)

\( t_M \) is the minimum thickness of the reference laminate(s) of the main header section of the tee at the junction of the branch (mm)

**Non-directional Bending Stress**

The Non-directional Bending Stress at branch junctions should be the greatest value applicable to each of the three connections determined as follows:

a) The bending stress in the branch as it comes out of the main header section of the tee, \( F_{bB} \), as given by the equation:

\[
F_{bB} = \left\{ \left( D_i + 2t_d \right) / 2I \right\} \left\{ (M_i SIF_B)^2 + (M_0 SIF_{B0})^2 \right\}^{0.5}
\]

(7.30)

where:

\( D_i \) is the internal diameter of the main header section of the tee at the junction of the branch (mm)

\( t_d \) is the design thickness of the reference laminate (mm)
$I$ is the second moment of area about an axis through the centroid normal to the axis of the main header section of the tee (mm$^4$)

$M_i$ is the in-plane bending moment in either end of the main header section of the tee at the junction of the branch; (N-mm)

$M_o$ is the out-of-plane bending moment in either end of the main header section of the tee at the junction of the branch; (N-mm)

$SIF_{Bi}$ is the in-plane stress intensification factor, bending.

$SIF_{xo}$ is the out-of-plane stress intensification factor, bending.

b) The bending stress at the branch junction as it comes out of the main header section of the tee should be determined as for the main header section of the tee but with the in- and out-of-plane moments being those applicable to the branch connection. The radius should be that of the branch. The moment of inertia should be that calculated using the branch radius and the lesser of the main thickness or branch thickness multiplied by the out-of-plane stress intensification factor of the branch.

c) The torsional stress at the branch junction as it comes out of the main header section of the tee should be the value applicable at any connection, where the torsional stress is as defined for straight pipe sections and bends in Section 7.3.4.3 of the BS 7159 Code.
8.1.21 BS 8010 Pipelines Subsea Piping Code Compliance Report

The BS 8010 Compliance Report consists of two Output Reports. The first Output Report lists all of the BS 8010 Code Compliance Data specified by the User. The second Output Report contains the node identification, hoop stresses vs. allowed and equivalent stresses vs. allowed.

Output units and equations shown in this section are for the English system and the System International (SI). Output units are available for the following:

1) English (ENG) 
2) Metric (MET) 
3) System International (SI) 
4) International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>MATERIAL YIELD STRENGTH psi</th>
<th>HOOP STRESS DESIGN FACTOR</th>
<th>EQUIVALENT STRESS DESIGN FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and To Data Numbers

The range of data point numbers for which the specified properties apply.

Material Yield Strength SMYS

Specified Minimum Yield Strength of the pipe to be covered by the Code Compliance.

Hoop Stress Design Factor, FDH

The Hoop Stress Design Factor (FDH) as described in the BS8010 Code for Pipelines.

Equivalent Stress Design Factor, FD

Equivalent Stress Design Factor (FD) as described in the BS8010 Code for Pipelines.

The second Output Report contains the following information:

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>HOOP STRESS psi</th>
<th>HOOP ALLOWED psi</th>
<th>EQUIVALENT STRESS psi</th>
<th>EQUIVALENT ALLOWED psi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Point

The number assigned by the User to each significant location.
Node Location

The node description defines the piping segment types; i.e., anchor, run, joint, valve, flange, bend, or expansion joint. The location description defines the exact point on the piping segment where the calculated values apply.

Hoop Stress Actual vs. Permissible

Hoop stress are based on the following equation:

\[ \sigma_h = (P_i - P_e) \frac{D}{2t} \]

where:
- \(\sigma_h\) = Hoop Stress, N/mm²
- \(P_i\) = Internal Pressure, N/mm²
- \(P_e\) = External Pressure (considered 0)
- \(D\) = Nominal Outside Diameter of Pipe, mm
- \(t\) = \(t_n - t_c\)
- \(t_n\) = Nominal wall thickness, mm
- \(t_c\) = Any erosion or corrosion allowance to be subtracted from the nominal wall thickness, mm

\[ \sigma_A = f_d \sigma_y \]

and is not to exceed the permissible value \(\sigma_A\):

where:
- \(\sigma_A\) = the allowable stress, N/mm²
- \(f_d\) = design factor, hoop stress
- \(\sigma_y\) = specified minimum yield stress, N/mm²

Equivalent Stress vs. Permissible (4.2.5.4)

Equivalent stress is defined as shown in the following equation:

\[ \sigma_e = \sqrt{\sigma_h^2 + \sigma_L^2 - \sigma_A \sigma_L + 3 \tau^2} \]
where:

\[ \sigma_e = \text{Equivalent Stress, N/mm}^2 \]
\[ \sigma_L = \text{total longitudinal stress, N/mm}^2 \]
\[ \sigma_h = \text{total hoop stress, N/mm}^2 \]
\[ \tau = \text{the shear stress, N/mm}^2 \]

and is not to exceed the permissible value \( \sigma_A \):

\[ \sigma_A = f_d \sigma_y \]
\[ \sigma_e \leq \eta \sigma_p k_i \]

where:

\[ \sigma_A = \text{the allowable stress, N/mm}^2 \]
\[ f_d = \text{design factor, hoop stress} \]
\[ \sigma_y = \text{specified minimum yield stress, N/mm}^2 \]
8.1.22 EURO CODE –European Standard prEN 13480-3

The European Standard prEN 13480-3 Compliance Report consists of three Output Reports. The first Output Report lists all of the European Standard prEN 13480-3 Code Compliance Data specified by the User. The second Output Report contains the node identification, the design wall thickness vs. the required wall thickness, sustained stresses vs. allowed and expansion stresses vs. allowed. The third Output Report is generated only if Occasional Loads Analyses are requested by the User. This report contains a summary of all occasional stresses about each axis requested, the sustained longitudinal stress, and the resultant occasional stress vs. its allowable.

Output units and equations shown in this section are for the English system. Output units are available for the following systems:

1. English (ENG)  
2. System International (SI)  
3. Metric (MET)  
4. International Units 1 (IU1)

Constants in equations are modified for each different system of units where necessary.

The first Output Report contains the following information:

<table>
<thead>
<tr>
<th>FROM</th>
<th>TO</th>
<th>ALLOWABLE COLD STRESS N/mm²</th>
<th>ALLOWABLE HOT STRESS N/mm²</th>
<th>STRESS RANGE REDUCTION FACTOR U</th>
<th>OCCASIONAL LOAD FACTOR</th>
<th>JOINT COEFFICIENT Z</th>
<th>MILL TOLERANCE</th>
<th>TEMP OVER 120°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From and To Data Point Numbers

The range of data point numbers for which the specified properties apply.

Minimum Cold Stress ($f_c$)

The basic material allowable stress value at room temperature.

Maximum Hot Stress ($f_h$)

The material allowable stress at temperature consistent with the loading under consideration.

Stress Range Reduction Factor U

The stress range reduction factor for cyclic conditions for total number $N$ of full temperature cycles over total number of years during which system is expected to be in service from Table 12.1.3-1.

Occasional Load Factor $k$
Factor specified by the User, based upon the duration of the occasional loads (12.3-3)

**Joint Coefficient Z**

The joint coefficient z shall be used in the calculation for the thickness of components including one of several butt welds, other than circumferential (4.5).

**Mill Tolerance**

Manufacturer mill tolerance in percent or millimeters.

**Temp Over 120° C**

If the design temperature is above 120° C, the word “YES” appears in the field.

**The second Output Report contains the following information:**

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Node Location</th>
<th>WALL THICKNESS DESIGN mm.</th>
<th>WALL THICKNESS REQUIRED mm.</th>
<th>SUSTAINED STRESS ACTUAL 12.3.2-1 N/mm²</th>
<th>SUSTAINED STRESS ALLOWED 12.3.2-1 N/mm²</th>
<th>SUSTAINED STRESS PERCENT</th>
<th>EXPANSION STRESS ACTUAL 12.3.4-1 N/mm²</th>
<th>EXPANSION STRESS ALLOWED 12.3.4-1 N/mm²</th>
<th>EXPANSION STRESS PERCENT</th>
<th>CREEP RANGE STRESS ACTUAL 12.3.5-1 N/mm²</th>
<th>CREEP RANGE STRESS ALLOWED 12.3.5-1 N/mm²</th>
<th>CREEP RANGE STRESS PERCENT</th>
<th>OCCASIONAL STRESS ACTUAL X-AXIS N/mm²</th>
<th>OCCASIONAL STRESS ALLOWED X-AXIS N/mm²</th>
<th>OCCASIONAL PERCENT</th>
</tr>
</thead>
</table>

**Data Point**

The number assigned by the User to each significant location.

**Node Location**
The "Node" description defines the piping segment types; i.e., Anchor, Run, and Bend. The "Location" description defines the exact point on the piping segment where the calculated values apply.

**Wall Thickness Design vs. Required Thickness**

The Design Wall Thickness is the value input by the User. The required Wall Thickness value is calculated by TRIFLEX®Windows using the following PrEN 13480-3 Code Equations (Section 6.1) and the internal pressure supplied by the User.

a) at a temperature up to and including 120° C

or

b) at a temperature above 120° C, and where \( D_0/D_i \leq 1.7 \)

or

c) at a temperature above 120° C, and where \( D_0/D_i > 1.7 \)

\[
e = \frac{p_c \cdot D_o}{2 \cdot f \cdot z}
\]

\[
e = \frac{p_c \cdot D_i}{2 \cdot f \cdot z + 2 \cdot p_c}
\]

where:

\[
e = \frac{p_c \cdot D_o}{(2f - p_c)z + 2p_c}
\]

\( e \) = minimum pipe wall thickness, mm

\[
e = \frac{p_c \cdot D_i}{(2 \cdot f - 2 \cdot p_c)z}
\]

\( p_c \) = internal design pressure as input by the User N/mm²

\( D_o \) = actual pipe outside diameter, mm

\[
e = \frac{D_o}{2} \left( 1 - \frac{fz - p_c}{fz + p_c} \right)
\]

\( D_i \) = actual pipe outside diameter, mm
\[ f = \text{maximum allowable stress in material due to internal pressure} \]
\[ N/mm^2 \]
\[ z = \text{the joint coefficient} \]

The ordered (minimum) thickness required is:

\[ Z = \frac{\pi}{32} \left( \frac{d_o^4 - d_i^4}{d_o} \right) \]

\[ e_{ord} = (e + c_0 + c_2) \frac{100}{(100-x)} \]

where:

\( c_0 = \text{the corrosion or erosion tolerances} \)
\( c_2 = \text{the thinning allowance for possible thinning} \)
\( x = \text{manufacturer mill tolerance in percent (\%)} \)

**Stresses Due to Sustained Loads vs. Allowed Stresses**

The sum of primary stresses \( \sigma_1 \) due to the calculation pressure, \( p_c \) and the resultant moment \( M_A \) from weight and other sustained mechanical loads shall satisfy the following equation:

\[ \sigma_1 = \frac{p_c \cdot d_o}{4 \cdot e_n} + \frac{0.75 \cdot i \cdot M_A}{Z} \leq f \]  \hspace{1cm} (12.3.2.1)

where:

\[ M_A = \sqrt{M_X^2 + M_Y^2 + M_Z^2} \]

\[ Z = \text{Section modulus, in}^3 \]
\[ e_n = \text{Nominal thickness, inches} \]
\[ d_o = \text{Outside diameter, mm} \]
\[ p_c = \text{Internal design pressure, N/mm}^2 \]
\[ M_A = \text{Resultant moment loading on cross section due to weight and other sustained loads, N-mm} \]
\[ i = \text{stress intensification factor} \]
\[ f = \text{Material allowable stress at temperature consistent with the loading under consideration, psi} \]
For full-size outlet connections:

For reduced outlet branch connections (Table F1):

where:

\[ Z_e = \text{effective section modulus of reduced branch, mm}^3 \]
\[ r_b = \text{branch mean cross-sectional radius, inches} \]
\[ e_x = \text{effective branch wall thickness (lesser of } e_n \text{ and } e_{nb}) \]

\[ Z_e = \pi r_b^2 e_x \]

\[ e_n = \text{nominal wall thickness of main pipe, mm} \]
\[ e_{nb} = \text{nominal wall thickness of branch, mm} \]
\[ d_i = \text{inside diameter of pipe, mm} \]

**Stresses Due to Occasional or Exceptional Loads**

The sum of primary stresses, \( \sigma_2 \), due to internal pressure, \( p_c \), resultant moment \( M_A \) from weight and other sustained mechanical loads and resultant moment, \( M_B \), from occasional or exceptional loads shall satisfy the following equation:

\[
\sigma_2 = \frac{p_c d_o}{4 e_n} + 0.75 i \left( \frac{M_A}{Z} \right) + 0.75 i \left( \frac{M_B}{Z} \right) \leq kf
\]  

(12.3.3-1)

where:

\( M_B = \text{the resultant moment from the occasional or exceptional loads which shall be determined by using the most unfavorable combination of the following loads:} \)

Wind loads (\( T_B \leq T_B/10 \))

Snow loads

Dynamic loads from switching operations (\( T_B \leq T_B/100 \))

Seismic loads (\( T_B \leq T_B/10 \))

Effects of the anchor displacements due to earthquake may be excluded if they are included in the equation (12.3.4-1).
Unless specified otherwise, the following agreement applies:

a) the action time $T$ corresponds to the bracketed values referring to the operating time $T_B$

b) snow and wind are not applied simultaneously

c) loading with $T_B \leq T_B/100$ are not applied simultaneously

$k = 1$ if the occasional load is acting for more than 10% in any 24-hour operating period, e.g. normal snow, normal wind

$k = 1.15$ if the occasional load is acting for less than 10% in any 24-hour operating period

$k = 1.2$ if the occasional load is acting less than 1% in any 24-hour operating period; e.g., dynamic loading due to valve closing/opening, design basis earthquake

$k = 1.3$ for exceptional loads with very low probability e.g. very heavy snow/wind (1.75 x normal)

$k = 1.8$ for safe shutdown earthquake

$p_c = \text{is the maximum calculation pressure occurring at the considered loading condition, the calculation pressure shall be taken as a minimum}$

“$f$” shall be determined for the calculation temperature

**Stress Range Due to Thermal Expansion and Alternating Loads**

The stress range, $\sigma_3$, due to resultant moment, $M_c$, from thermal expansion and alternating loads, e.g. seismic loads, shall satisfy the following equation:

$$\sigma_3 = \frac{i M_c}{Z} \leq f_a$$  \hspace{1cm} (12.3.4-1)

where:

$$f_a = U \left( 1.25 f_c + 0.25 f_h \right) \frac{E_h}{E_c}$$  \hspace{1cm} (12.1.3-1)

$U = \text{stress range reduction factor (Table 12.1.3-1)}$

$E_c = \text{the value of the modulus of elasticity at the minimum metal temperature consistent with the loading under consideration}$
\( E_n \) = the value of the modulus of elasticity at the maximum metal temperature consistent with the loading under consideration

\( f_c \) = the basic allowable stress at the minimum metal temperature consistent with the loading under consideration

\( f_h \) = the allowable stress at the maximum metal temperature consistent with the loading under consideration

Where the conditions of equation (12.3.4-1) are not met, the sum of stresses \( \sigma_4 \) due to calculation pressure \( p_c \), resultant moment \( M_A \), from sustained mechanical loads and the resultant moment, \( M_C \), from thermal expansion and alternating loads shall satisfy the following equation:

\[
\sigma_4 = \frac{p_c}{4e_n} + 0.75i\left(\frac{M_A}{Z}\right) + i\left(\frac{M_C}{Z}\right) \leq (f + f_a)
\]  (12.3.4-2)

where:

\( M_C = \) range of resultant moments due to thermal expansion and alternating loads which shall be determined from the greatest difference between moments using the modulus of elasticity at the relevant temperatures.

Particular attention shall be given to:

- longitudinal expansion, including terminal point movements, due to thermal expansion and internal pressure
- terminal point movements due to earthquake if anchor displacement effect were omitted from equation (12.3.3-1)
- terminal point movements due to wind
- frictional forces
- the condition of the piping during shutdown shall be considered
- cold spring, if any, applied during installation shall not be taken in account. The operating case pertinent to \( M_C \) shall be designed as if not cold spring was applied.

**Additional Conditions for the Creep Range**

For piping operating within the creep range, stresses \( \sigma_5 \) due to calculation pressure \( p_c \), resultant moment \( M_A \), from weight and other sustained mechanical loadings, and the resultant moment, \( M_C \), for thermal expansion and alternating loadings, shall satisfy the following equation:
\[
\sigma_6 = \frac{p_d d_o}{4 e_n} + 0.75 i \left( \frac{M_A}{Z} \right) + i \left( \frac{M_c}{3Z} \right) \leq f \quad (12.3.5-1)
\]

**Stress Due to a Single Non-repeated Anchor Movement**

\(\sigma_6 = \) the resultant moment \(M_D\) due from a single non-repeated anchor/restraint movement shall satisfy the following equation:

\[
\sigma_6 = \frac{i M_D}{Z} \leq \min(3f; 2R_{p0.2}) \quad (12.3.6-1)
\]

where:

\(M_D = \) the resultant moment due to any single non-repeated anchor movement (e.g., predicted building settlement), in-N