FS2000

Pipeline & Pipework Design

Advanced Structural Analysis
for Windows
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Table of Contents

1.0 Introduction

FS-Pipe is an interactive program module that interfaces with FS2000 to provide pipework design checks is accordance with the following design codes.

ASME B31.1	Power Code 2010
ASME B31.3	Chemical and Petroleum Refinery Piping Code 2010
ASME B31.4	Liquid Petroleum Transportation Piping Code 2009
ASME B31.8	Gas Transmission and Distribution Piping System Code 2010
ASME B31.4	Offshore - Liquid Petroleum Transportation Piping Code 2009
ASME B31.8	Offshore - Gas Transmission and Distribution Piping System Code 2010
PD 8010	Code of Practice for Pipelines Part 3 Design,Const & Inst 2004
DNV ST-F101	Submarine Pipelines Systems 2021
DNV	Rules for Submarine Pipelines Systems 1981/1996
HISC Screening	Stress Limits for Duplex Stainless Steel exposed to CP protection (DNV-RP-112)

The standard modeling features of FS2000 allow pipe elements to be assigned pipework attributes that are used by the code checker. All pipe elements in a model are checked against the code unless the code check is restricted to a selected element group.

Section 2 describes the modeling feature available in FS2000 and the requirements necessary when creating models that are going to be code checked using FS-Pipe.

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2.0 Creating Models in FS2000

This section describes the modelling feature available in FS2000 and the few requirements necessary when creating models that are going to be code checked using FS-Pipe.

The major pipe properties used in pipework flexibility analysis and pipework design checks are:

- Material Properties - Temperature Dependent
- Geometric Properties - Corrosion allowance, mill tolerance etc.
- Flexibility Factors - Localised e.g. on bends
- Stress Intensity Factors - Localised on fitting etc.

All of these properties can be defined interactively of by command line instruction using FS2000.

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2.1 Units

FS-Pipe reads the input files and result files of models created and analysed by FS2000. To ensure units compatibility it is essential that the model be created in fundamental S.I. units.ie

Force in N (NEWTONS)

Length in M (METRES)

Stress in N/m2

or US Units

Force in Pounds (Lbs)

Length in Inches (ins)

Stress/Pressure in psi

See the FS2000 Help file for more infomation on units.

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2.2 Material Properties

The material property code attribute of an element is used to identify the appropriate material properties of an element by referencing it to an entry in the Material Property Table. Data is entered into the table using the Material Properties Input box in FS2000.

The Standard Material Property Table is a list of the following properties each with a numeric reference code.

E	Modulus of Elasticity
G	Modulus of Rigidity
Poiss	Poissons Ratio
Den	Material Density
Coef. Exp	Coefficient of Linear Expansion
Yield Stress	Yield value of Material
Ultimate Stress	Ultimate strength of Material

The Extended Material Property Table is list of properties used in pipework analysis/design which calls for thermal dependent properties. The properties available in the extended table are:

Cold Allowable Stress

Quality Factor (Pipe Weld Efficiency Factor)

Pressure Coefficient

The following are properties as a function of temperature (up to 15 points)

Temp E(T) Coef Exp(T) Allowable Stress(T)

Generally it is more convenient to retrieve properties from Material Property Libraries. Existing data in the model Material Property Table may be added to the Default Library.

The FS2000 Help topic on Material property Tables or Appendix 2 describes the input of material data for both the standard properties and the extended properties. Use the F1 button when the Material properties form is visible to show the Help topic.

Standard Structural Material Properties

Material property data can be saved and retrieved from the material property library files.

These files are text files with the file extension .PRM. These files must reside in the FS2000 directory.

See Appendix 2 for a more detailed description of Material Property Libraries.

Pipework (Temp Dep)Material Properties

These properties are retrieved from the extended material property libraries. These libraries are text files with the file extension .PRE. These files must also reside also in the FS2000 directory.

When properties are retrieved from the standard structural table they will also, if they exist, be retrieved by name association from the extended library. This means that properties in the extended library must also exist in a standard library of the same name for them to be retrieved. List order between standard and extended libraries is not important as they are linked by name association.

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2.3 Geometric Properties

The geometric property code attribute of an element is used to identify the appropriate geometric properties of an element by referencing it to an entry in the Geometric Property Table. Data is entered into the table using the Material Properties Input box in FS2000.

Pipe properties are automatically evaluated by defining the outside diameter and wall thickness of the pipe.

An additional input form is used to enter additional data relating to piping analysis/design properties. These properties are:

Corrosion Allowance

Mill Tolerance (%)

Contents Density

Insulation Thickness

Insulation Density

Lining Thickness

Lining Density

The first two are used by FS-Pipe and the latter four are used in load case self weight load evaluation.

Note that the stiffness properties of pipe elements are based the nominal wall thickness.

The FS2000 Help topic on Geometric Property Tables describes the input of geometric data . Use the F1 button when the Geometric Properties input form is visible to show the Help topic.

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2.4 Flexibility and Stress Intensification Factors

The input form in the Model Definition TASK of FS2000 can be used to define Flexibility and Stress Intensity Factors for pipe elements. The factors are evaluated in accordance with ASME B31.3 and are applicable to most national piping design codes.

The Elements menu has a sub-menu called Pipework. This menu is used to access the command associated with pipework definition and enables pipe flexibility and stress intensification factored to be included into the analysis

The following describes the menu options. This information is also included with the FS2000 Help.

This menu has the following commands.

Bends	Defines data relating to pipe bends
Tee/Connections	Defines data relating to tee and other standard connections
ListPipe	List pipework coefficients in List Box
Delete Coefficients	Removes the pipework coefficients from the element(s)

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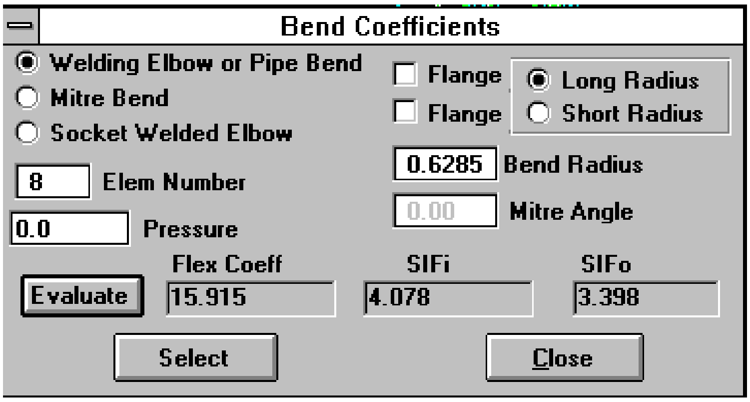
2.4.1 Pipework Bends

This form is used to define factors associated with bend elements.



The **Elem Number** is used to enter the element number of the bend element.

If the **Elem Number** box is double clicked the last element listed with the Elem Query button will be entered.

The **Evaluate** button is used to evaluate the factors based on the data and option selected on the form. These will be shown in the boxes. This button does not apply the factors to the element. It uses the element as a template for factor evaluation.

The **Pressure** box is used to include the effects of pressure stiffening. The units for this are N/m2 if SI units are being used.

The **Select** button is used to copy the factors to elements using the current SelectBY method. Active the Pipe Coefficients Display Switch to highlight elements with coefficients.

The **Long** and **Short Radius** options will automatically enter the Band Radius based on the OD of the pipe. The radius may be re-entered. For large diameter pipes (API 14" (355mm) and above) this will produce the correct radius since the nominal pipe size is the OD. For smaller API pipes and for other pipe specs ensure that the Radius is correct (API uses nominal pipe dia for small pipes)

See Pipework Orientation for the convention for in-plane and out of plane

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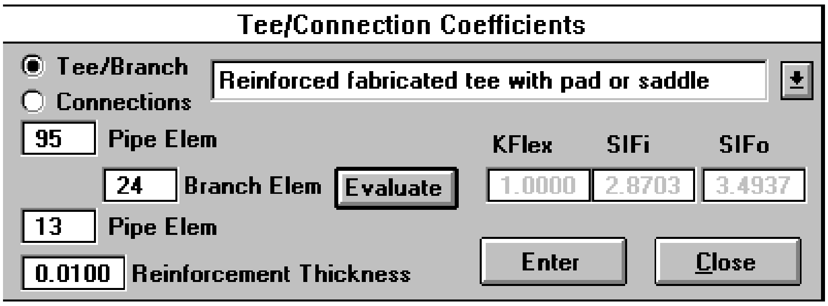
2.4.2 Pipework Tee/Connections

This form is used to define coefficients to branch connection and in-line connections.



The form above shows the form with **Tee/Branch** option active.

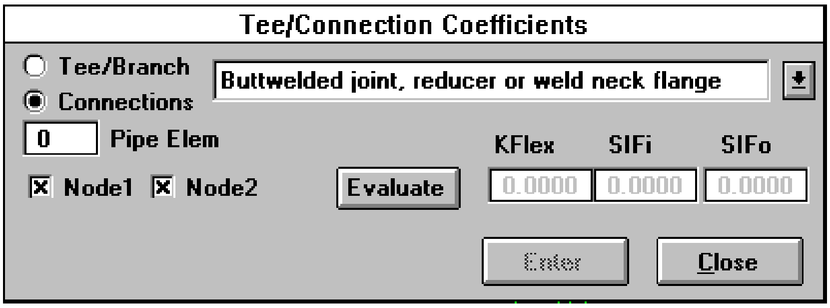
The pull down list is used to select the type of connection

The **Pipe Elem** and **Branch** boxes are use to define the elements that form the branch.

If the **Pipe Elem** and **Branch** box are double clicked the last element listed with the Elem Query button will be entered.

The **Evaluate** button is used to evaluate and display the coefficients

The **Enter** button is use to assign the coefficients to the defined elements.



The form above shows the form with **Connection** option active.

The pull down list is used to select the type of connection

The **Pipe Elem** is use to define the element with the connection.

If the **Pipe Elem** box is double clicked the last element listed with the Elem Query button will be entered. When elements are listed the Node1 of the element will be circled white.

The **Node1** and **Node2** check boxes are use to define to which node end of the element the factors are to be applied

The **Evaluate** button is used to evaluate and display the coefficients

If **User Defined** is selected from the connection list and the **Evaluate** button is pressed the user can define the coefficients displayed.

The **Enter** button is use to assign the coefficients to the defined elements.

See Pipework Orientation for the convention for in-plane and out of plane.

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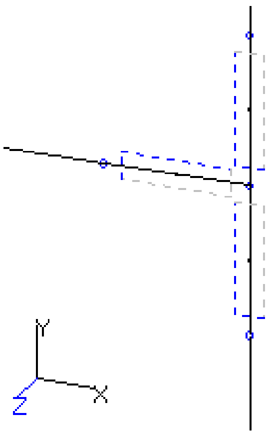
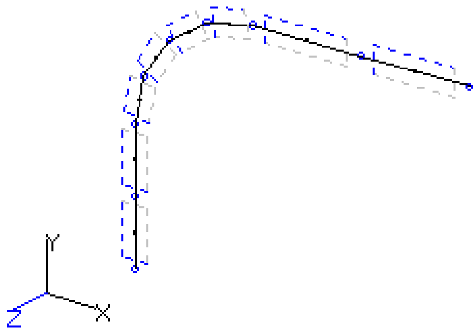
2.5 Pipework Orientation:In-plane/Out-Plane

When defining pipe stress factors it is necessary to define in-plane and out of plane directions terms of the element local orientation. The convention adopted by the program is that In-Plane is in the plane of the major axis and Out of plane is in the plane of the minor axis. This means that it will often be necessary for bends and tees elements to be rotated to ensure that this is the case.

The following examples show how elements require to be orientated for tees and bends. Note that the elements connecting to the bend or tee elements may be orientated in any direction. It is generally most convenient to orientate the elements interactively using the third node method (Local Rotation- Elements menu command).





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2.6 Thermal Dependent Properties used in the Analysis

Stiffness Analysis

The stiffness properties of elements used in the stiffness analysis are based on the cold condition i.e. the E and G values are those defined in the model Material Properties table.

Loading Analysis

The properties used to take account of the loading due to thermal expansions are dependent upon the value of the element temperature in the specific load case.

This implies that the value of the **Coefficients of Expansion** should be based on a mean effective value between ambient and the operating. The ASME pipe codes tabulate such mean properties based on an ambient temperature of 21 C (70 F). These are the values that require to be used in the model thermal properties.

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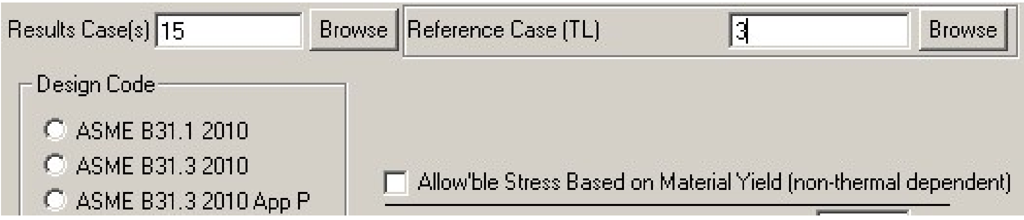
2.7 Themal Dependent Properties - Design Stresses

Load cases which define element temperatures distributions can be used to establish allowable design stresses as a function of element temperature. To activate this approach the option to use the property code yield must NOT be active.



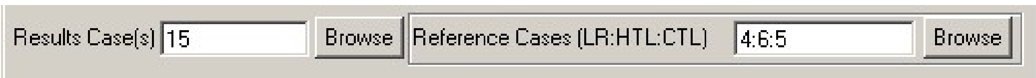
When using a reference case to establish thermal dependent allowable stresses, the reference case must be a single load case result and not a result case from a combination. The actual data used for this purpose is generated during load case pre-processing prior to analysis solution (LOADA). For this reason it is possible to:

- Reference a thermal load case providing that is included a combination that has been analysed even though there may not a specific results case for that case.
- Only pre-process the case. In Batch running LOADA 12 would generate the temperature data for load case 12 without performing the analysis solution.

Note that if using a results case based on a Pre-processed factored combination then the thermal dependent properties will based on the factored temperature of the load case defined in the load case.

In the case of B31.x expansion checks, the thermal reference case will be, by default, the subject result case. If the results case is from post combined load cases the first load case in the combination will, by default, be taken as the reference case.

Alternatively, for these codes the thermal case can be explicitly defined by appending the thermal reference case number to the sustained reference case number (separated by a colon i.e. 4:6:5 where 4 is the sustained longitudinal case, 6 is the hot thermal reference case and 5 is the cold thermal reference case).



This alternative method must be used when non-linear analysis expansion result cases are checked.

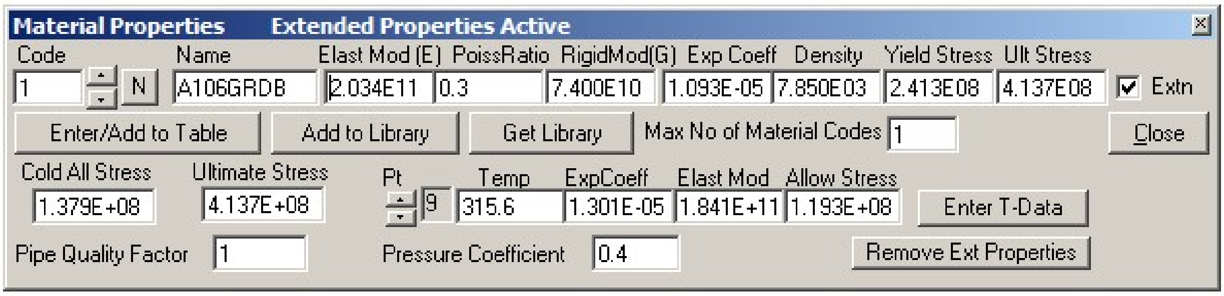
Load Factors

Load factors do not effect the thermal properties when Post-Processing load case combinations with factored combinations.

Load factors will effect the thermal properties when combinations are Pre-Processed.

Thermal Dependent Allowable Stresses

The extended material properties in FS2000 allow the specification of the basic allowable stress as used in codes like B31.3 i.e. where basic allowable stress are defined as a function of temperature in the design code.



It best practice to use extended material libraries so that thermal dependent properties can be repeatedly used on various models.

Thermal Dependent Yield Stresses

The extended material properties in FS2000 allow the specification of the yield stress as used in codes like PD8010 or DNV F101 i.e. where yield stress is defined as a function of temperature in the design code.

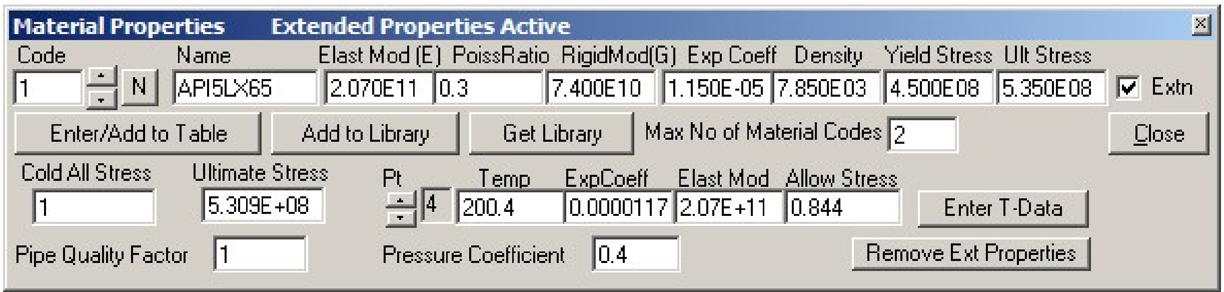
This process will be activated for the codes which use yield criteria e.g. PD8010 if the **Allowable Stress Based on Material Code Yield** option box is not active.

This done in the program by factoring the cold yield stress by the ratio of the temperature de-rated allowable stress to the cold allowable stress.

In the above example the temperature reduced yield would be **YieldStress * (AllowStress/ColdAllSress)** = 214.3*119.3/137.9 = 185.4 when used in a yeld based code.

This approach also permits the use of an allowable stress ratio to be use to define the temperature reduced yield strength providing the cold allowable stress is define as unity.

In the example below the temperature reduced yield would be evaluated as **YieldStress * (AllowStress/ColdAllSress)** i.e. Yield = 450*0.844/1 = 379.8 if the temp was 200.4



The same could be obtained in the **Cold Allowable Stress** was made equal to the **Yield Stress** and the Allow Stress was defined as the actual temperature reduced yield. If this approach was mistakenly used on a B31.3 then the allowable stress would be dangerously incorrect. Using the stress ratio would be equally invalid but the allowable stress would >> 0.

It best practice to use extended material libraries so that thermal dependent properties can be repeatedly used on various models.

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3.0 Design Codes

This section describes the various parameter that are use for each of the design codes.

The actual design code equations used by the code are presented in Appendix 1.

B31.1

B31.3

B31.4

B31.8

PD8010

DNVF101

DNV 1981/1996

HISC Screening

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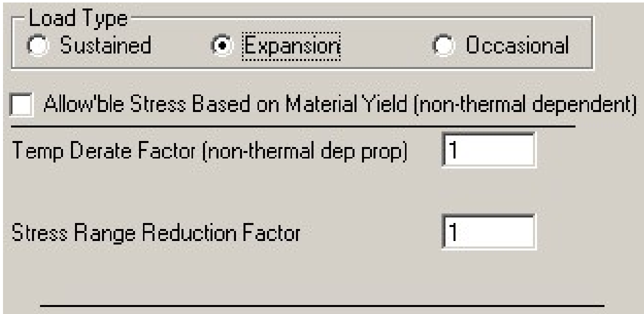
B31.1

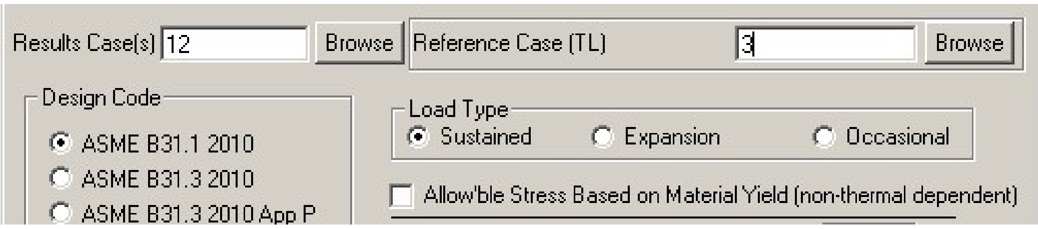
Code B31.1 Power Piping

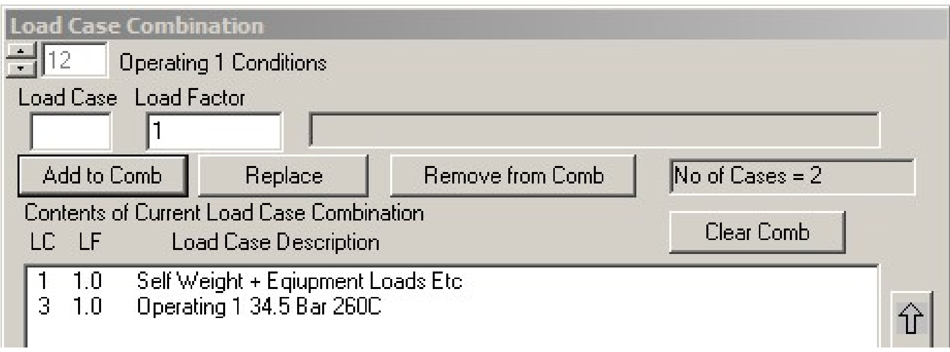


The **Stress Range Reduction Factor f** is used to evaluate the allowable thermal expansion stress. This effectively a fatigue check F is a function of number of thermal cycles

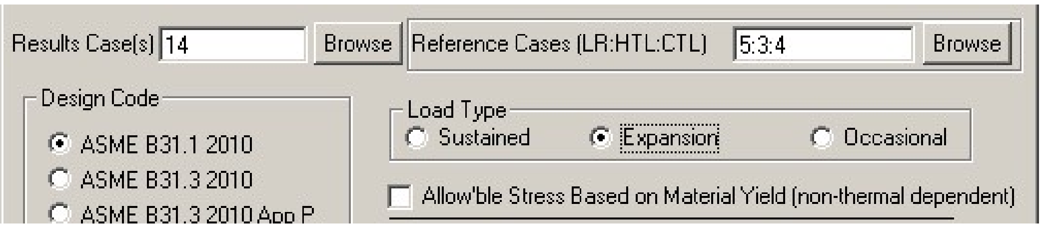
The default is to use a temperature dependent basis allowable stress (BAS) obtained from the extended material property code data. This default can be overridden if the **Allowable Stress Based on Material Code Yield** option box is checked. If this is done the BAS is based on the lower of 2/3 yield or 1/3 ultimate. The **Temp Derate Factor** can be used to define the BAS for the hot condition for a specific result case.

When undertaking a **Sustained** or **Occasional** check the basic hot allowable stress will be based on the element temperature distribution and can vary from element to element. The element temperature distribution is obtained from a **Reference Load Case** which defines the actual temperature distribution .In the example shown below the temperature Reference Case for Result Case 12 is Load Case 3.





When undertaking an **Expansion** check it necessary to define a reference longitudinal stress, a hot allowable stress and a cold allowable stress. It is best to define these explicitly.



LR is the reference longitudinal stress case

HTL is the reference case for the hot allowable stress

CTL is the reference case for the cold allowable stress

If the **CTL** case is omitted the ie LR:HTL only, then the cold allowable stress will be based on the Property Code **Cold All Stress**

If also the **HTL** is omitted i.e. LR only, then the hot allowable stress will be based on the subject Result Case if it is a single case or the first Load Case in a combination case Results Case.

Note that when undertaking nonlinear analysis the **HTL** has to be defined.

In the program the Pipe Material Quality factor (Material Code Property) is used. This equates to the Weld Joint Efficiency Factor (E) in the code.

Appendix 1 Design Code Specifications

Load Cases and Loading Categories

- Sustained

  Pressure, gravity and external sustained loads

  Reference Temp Case required for Temp dependent allowable stress evaluation **Reference Case TL**

- Expansion

  This is effectively a fatigue check between two extreme strain states and will include loads due to thermal expansion and thermal anchor or any other loads that induce a significant cyclic stress variation

  Reference Sustained Result Case required for Longitudinal Stress - **Reference Case LR**

  Temp dependent allowable stress is based on the following;

  Hot Allowable

  - Reference thermal case (necessary for non-linear analysis results) - **Reference Case HTL**, or for linear analysis
  - Subject Load Case or first Load Case in a combined Results Case ,or

  Cold Allowable

  - Explicitly defined case - **Reference Case CTL** ,or
  - Property Code **Cold All Stress**

- Occasional

  Sustained + Loading due to wind, earthquakes etc.

  Reference Temp Case Required for Temp dependent allowable stress evaluation **Reference Case TL**

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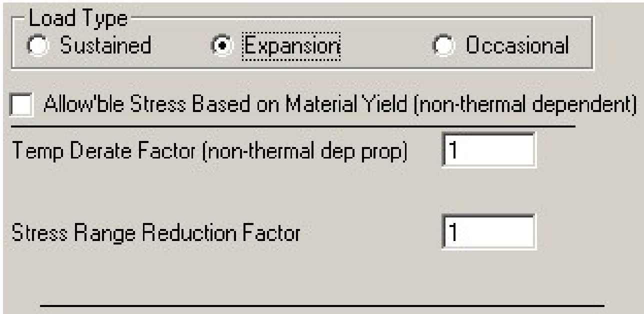
B31.3

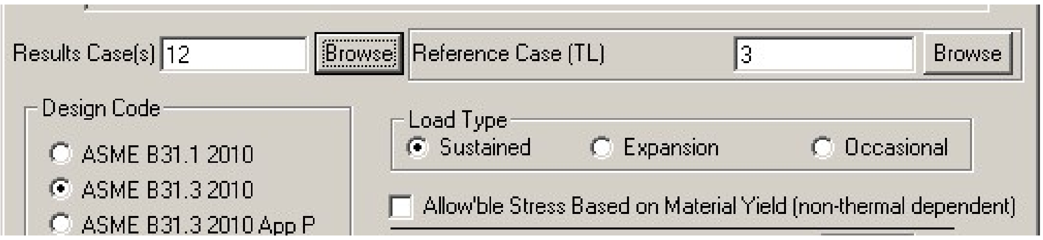
Code B31.3 Chemical & Petroleum Refinery Piping Code

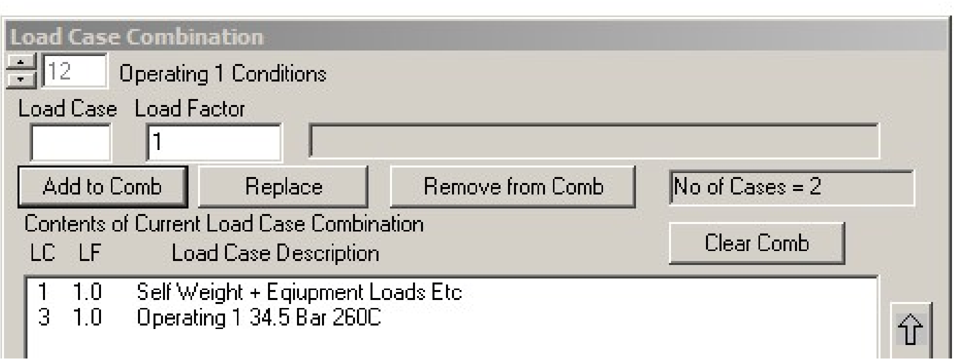


The **Stress Range Reduction Factor f** is used to evaluate the allowable thermal expansion stress. This effectively a fatigue check F is a function of number of thermal cycles

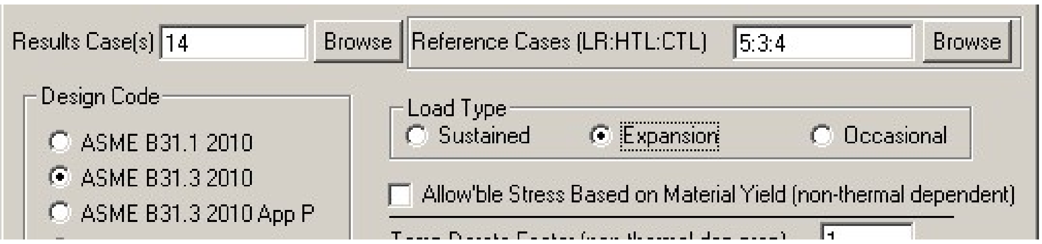
The default is to use a temperature dependent basis allowable stress (BAS) obtained from the extended material property code data. This default can be overridden if the **Allowable Stress Based on Material Code Yield** option box is checked. If this is done the BAS is based on the lower of 2/3 yield or 1/3 ultimate. The **Temp Derate Factor** can be used to define the BAS for the hot condition for a specific result case.

When undertaking a **Sustained** or **Occasional** check the basic hot allowable stress will be based on the element temperature distribution and can vary from element to element. The element temperature distribution is obtained from a **Reference Load Case** which defines the actual temperature distribution .In the example shown below the temperature Reference Case for Result Case 12 is Load Case 3.





When undertaking an **Expansion** check it necessary to define a reference longitudinal stress, a hot allowable stress and a cold allowable stress. It is best to define these explicitly.



LR is the reference longitudinal stress case

HTL is the reference case for the hot allowable stress

CTL is the reference case for the cold allowable stress

If the **CTL** case is omitted the ie LR:HTL only, then the cold allowable stress will be based on the Property Code **Cold All Stress**

If the **HTL** case is also omitted i.e. LR only, then the hot allowable stress will be based on the subject Result Case if it is a single case or the first Load Case in a combination case Results Case.

Note that when undertaking nonlinear analysis the **HTL** has to be defined.

In the program the Pipe Material Quality factor (Material Code Property) is used. This equates to the Weld Joint Efficiency Factor (E) in the code.

Appendix 1 Design Code Specifications

Load Cases and Loading Categories

- Sustained

  Pressure, gravity and external sustained loads

  Reference Temp Case required for Temp dependent allowable stress evaluation **Reference Case TL**

- Expansion

  This is effectively a fatigue check between two extreme strain states and will include loads due to thermal expansion and thermal anchor or any other loads that induce a significant cyclic strain variation.

  Reference Sustained Result Case required for Longitudinal Stress - **Reference Case LR**

  Temp dependent allowable stress is based on the following;

  Hot Allowable

  - Reference thermal case (necessary for non-linear analysis results) - **Reference Case HTL**, or for linear analysis
  - Subject Load Case or first Load Case in a combined Results Case ,or

  Cold Allowable

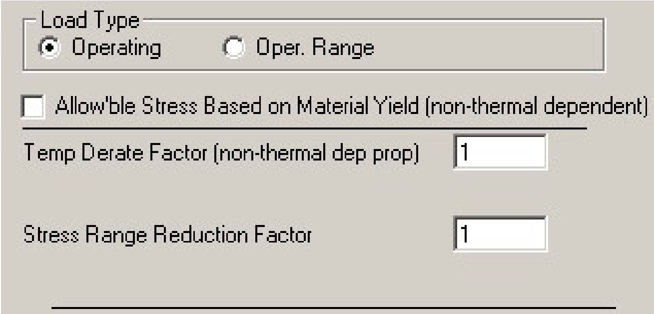
  - Explicitly defined case - **Reference Case CTL** ,or
  - Property Code **Cold All Stress**

- Occasional

  Sustained + Loading due to wind, earthquakes etc.

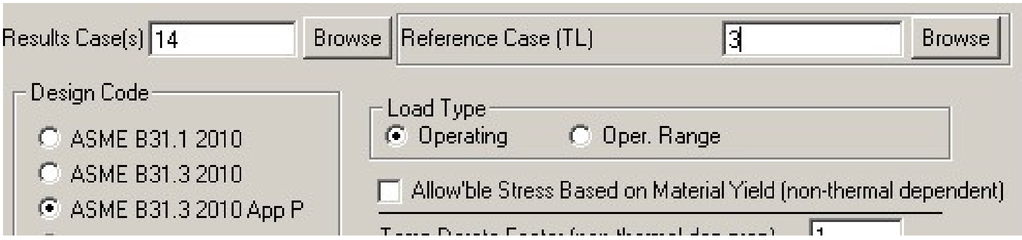
  Reference Temp Case Required for Temp dependent allowable stress evaluation **Reference Case TL**

B31.3 Appendix P



- Operating

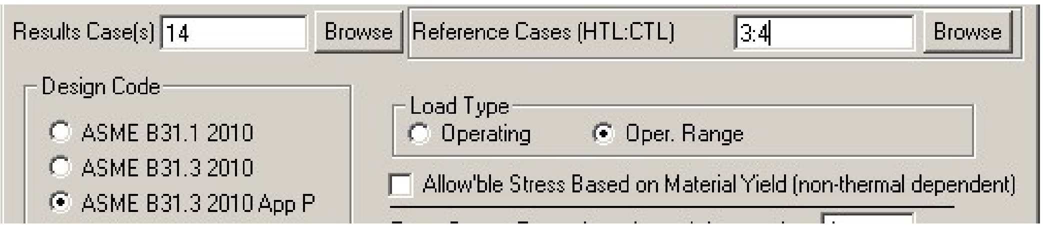
All concurrent loading is combined and checked using the combined stress criteria and the code defined Design factors.



Reference Temp Case required for Temp dependent allowable stress evaluation **Reference Case TL**

- Operating Range

This is effectively a fatigue check. All concurrent loading is combined to obtain the difference between operating states and checked using the combined stress criteria and the code defined Design factors,



Reference Temp Case required for Temp dependent hot allowable stress evaluation **Reference Case HTL.**

Reference Temp Case required for Temp dependent cold allowable stress evaluation **Reference Case CTL.**

If the **CTL** case is omitted the ie HTL only, then the cold allowable stress will be based on the Property Code **Cold All Stress.**

If the **HTL** case is also omitted i.e. LR only, then the hot allowable stress will be based on the subject Result Case if it is a single case or the first Load Case in a combination case Results Case.

Note that when undertaking nonlinear analysis the **HTL** has to be defined.

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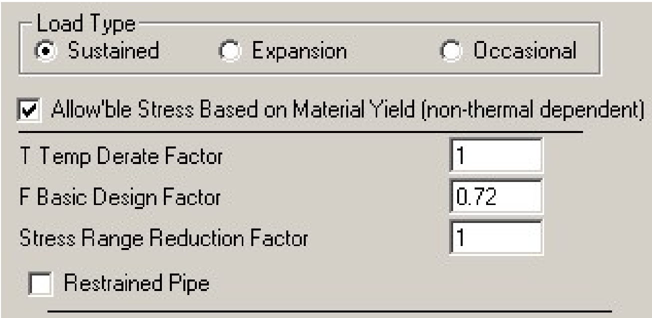
B31.4

Code B31.4 Liquid Petroleum Transport Piping Code



The **Temperature De-rating Factor** (T) are used in accordance with the code.

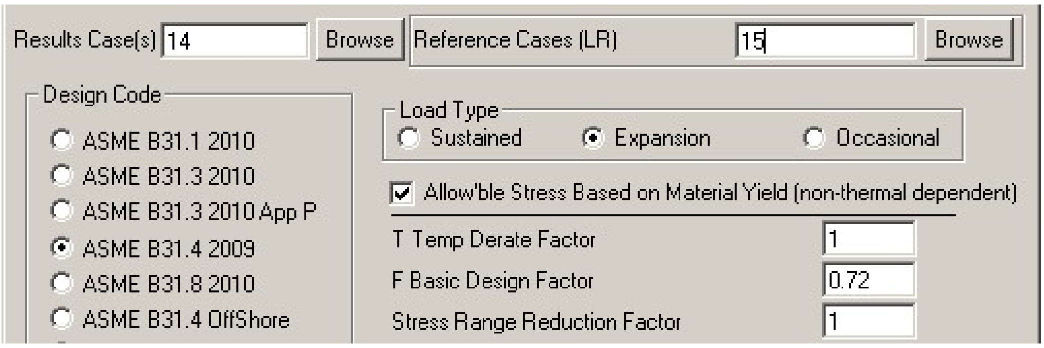
The **F Basic Design Factor** (not greater than 0.72).

The **Stress Range Reduction Factor f** is used to evaluate the allowable cyclic stress used in the Expansion check.

The default is to use the **Allowable Stress Based on Material Code Yield i.e. the** option box is checked. The **Temp Derate Factor** can be used to derate the material yield strength.

This default can be overridden if the **Allowable Stress Based on Material Code Yield** option box is unchecked. If this is done the yield will be based on a temperature dependent basis obtained from the extended material property code data. See Sect 7 for more information on material library requirements for temperature dependent yield.

When undertaking an **Expansion** check it necessary to define a reference longitudinal stress.



In the program the Pipe Material Quality factor (Material Code Property) is used. This equates to the Longitudinal Joint Factor (E) in the code.

Appendix 1 Design Code Specifications

Load Cases and Loading Categories

- Longitudinal

  Pressure, gravity and external sustained loads

  Allowable Based on Material Property Code Yield (+temp derating factor) or optionally on a Reference Temp Case for the Temp dependent allowable stress evaluation **Reference Case TL**

- Expansion (and periodic 403.3.2)

  This is effectively a fatigue check between two extreme strain states and will include loads due to thermal expansion and thermal anchor or any other loads that induce a significant cyclic strain variation.

  Note that the check can be set for a 'unrestrained' or 'restrained' case.

  Reference Sustained Result Case required for Longitudinal Stress (unrestrained case) - **Reference Case LR**

  Temp dependent allowable stress is based on the following;

  Hot Allowable

  - Derated Property Code Yield (default - **Allowable Stress Based on Material Code Yield** option box is unchecked)
  - Reference thermal case (necessary for non-linear analysis results) - **Reference Case HTL**, or for linear analysis
  - Subject Load Case or first Load Case in a combined Results Case ,or

  Cold Allowable

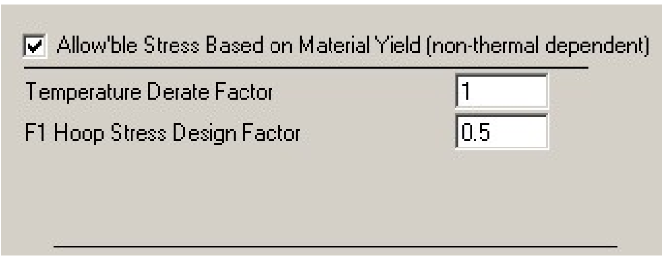
  - Property Code Yield (default - **Allowable Stress Based on Material Code Yield** option box is unchecked)
  - Explicitly defined case - **Reference Case CTL** ,or
  - Property Code **Cold All Stress**

- Occasional

  Sustained + Loading due to wind, earthquakes etc.

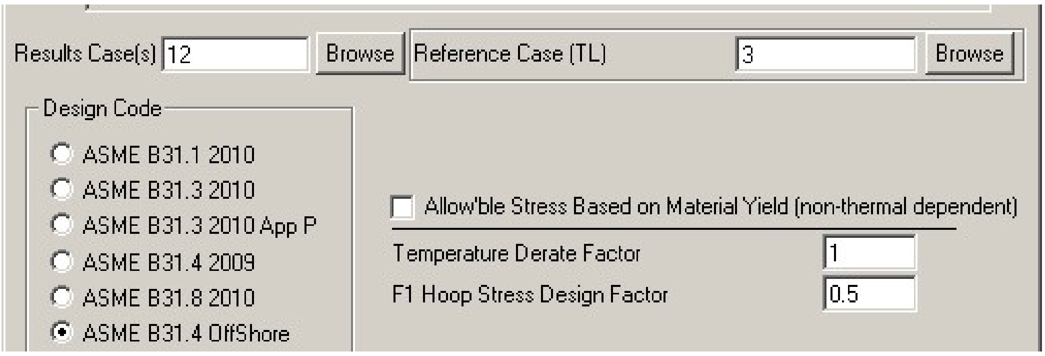
  Reference Temp Case Required for Temp dependent allowable stress evaluation **Reference Case TL**

Code B31.4 Offshore   Liquid Petroleum Transport Piping Code



The model property code yield stress value is used to evaluate the allowable stresses.

This default can be overridden if the **Allowable Stress Based on Material Code Yield** option box is unchecked. If this is done the yield will be based on a temperature dependent basis obtained from the extended material property code data using a reference load case. See Sect 7 for more information on material library requirements for temperature dependent yield.



In the program the Pipe Material Quality factor (Material Code Property) is used. This equates to the Longitudinal Joint Factor in the code.

Definition of the Hoop Stress Design Factor defines the Longitudinal and the Combined Stress Factors.

Location	Hoop	Longitudinal	Combined
Pipeline	0.72	0.8	0.9
Risers	0.6	0.8	0.9

Appendix 1 Design Code Specifications

Load Cases and Loading Categories

For offshore pipelines B31.4 does not distinguish between load categories i.e. sustained, expansion etc. as ASME B31.4 onshore does. All concurrent loading is combined and checked using the longitudinal and combined stress criteria and the code defined Design factors.

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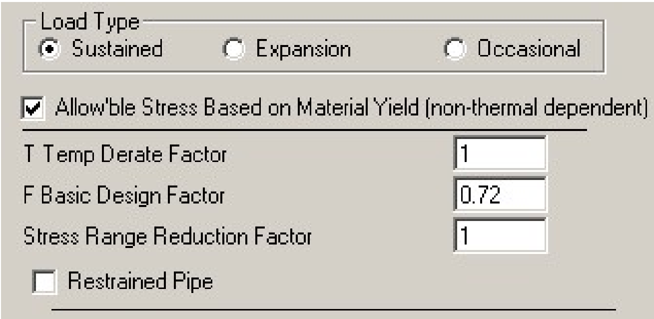
B31.8

Code B31.8 Gas Transmission and Distribution Piping Systems Code



The **Temperature De-rating Factor** (T) are used in accordance with the code.

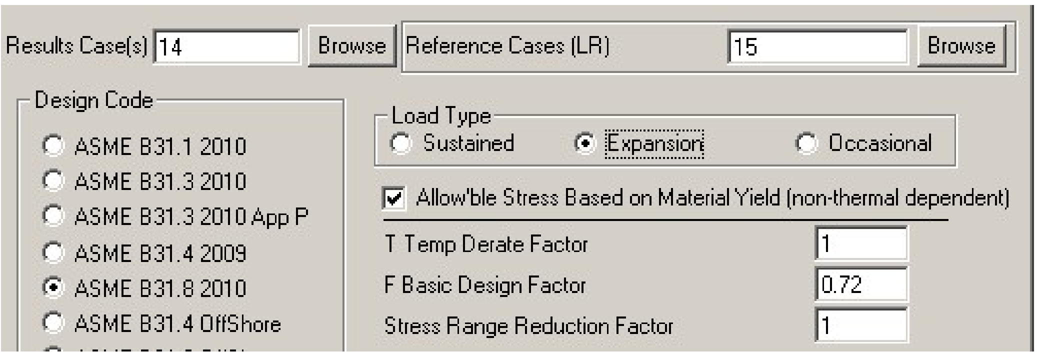
The **F Basic Design Factor** should be to Table 8.4.1.1-1 on the code

The **Stress Range Reduction Factor f** is used to evaluate the allowable cyclic stress used in the Expansion check.

The default is to use the **Allowable Stress Based on Material Code Yield i.e. the** option box is checked. The **Temp Derate Factor** can be used to derate the material yield strength.

This default can be overridden if the **Allowable Stress Based on Material Code Yield** option box is unchecked. If this is done the yield will be based on a temperature dependent basis obtained from the extended material property code data. See Sect 7 for more information on material library requirements for temperature dependent yield.

When undertaking an **Expansion** check it necessary to define a reference longitudinal stress.



In the program the Pipe Material Quality factor (Material Code Property) is used. This equates to the Longitudinal Joint Factor (E) in the code.

Appendix 1 Design Code Specifications

Load Cases and Loading Categories

- Longitudinal

  Pressure, gravity and external sustained loads

  Allowable Based on Material Property Code Yield (+temp derating factor) or optionally on a Reference Temp Case for the Temp dependent allowable stress evaluation **Reference Case TL**

- Expansion (and periodic 833.8)

  This is effectively a fatigue check between two extreme strain states and will include loads due to thermal expansion and thermal anchor or any other loads that induce a significant cyclic strain variation.

  Note that the check can be set for a 'unrestrained' or 'restrained' case.

  Reference Sustained Result Case required for Longitudinal Stress (unrestrained case) - **Reference Case LR**

  Temp dependent allowable stress is based on the following;

  Hot Allowable

  - Derated Property Code Yield (default - **Allowable Stress Based on Material Code Yield** option box is unchecked)
  - Reference thermal case (necessary for non-linear analysis results) - **Reference Case HTL**, or for linear analysis
  - Subject Load Case or first Load Case in a combined Results Case ,or

  Cold Allowable

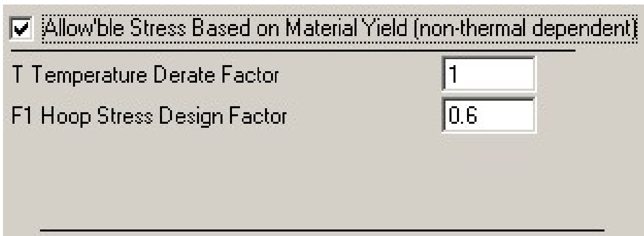
  - Property Code Yield (default - **Allowable Stress Based on Material Code Yield** option box is unchecked)
  - Explicitly defined case - **Reference Case CTL** ,or
  - Property Code **Cold All Stress**

- Occasional

  Sustained + Loading due to wind, earthquakes etc.

  Reference Temp Case Required for Temp dependent allowable stress evaluation **Reference Case TL**

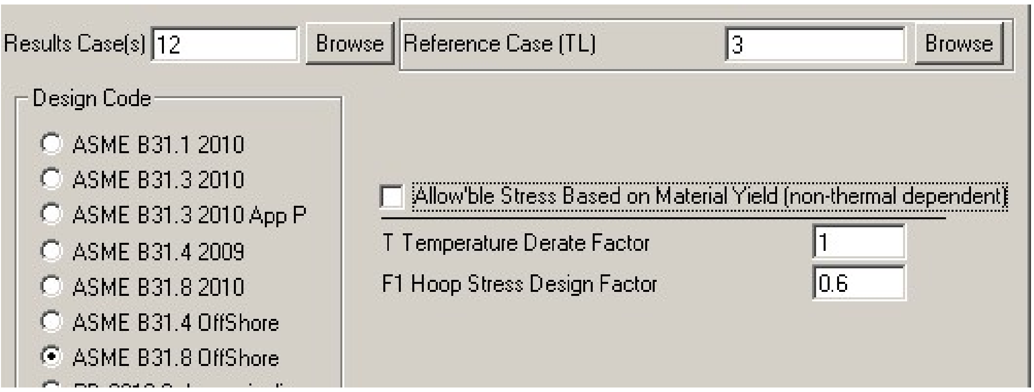
Code B31.8 Offshore Gas Transmission and Distribution Piping Systems Code



The **Temperature De-rating Factor** (T) are used in accordance with the code.

The model property code yield stress value is used to evaluate the allowable stresses.

This default can be overridden if the **Allowable Stress Based on Material Code Yield** option box is unchecked. If this is done the yield will be based on a temperature dependent basis obtained from the extended material property code data using a reference load case. See Sect 7 for more information on material library requirements for temperature dependent yield.



In the program the Pipe Material Quality factor (Material Code Property) is used. This equates to the Longitudinal Joint Factor in the code.

Definition of the Hoop Stress Design Factor F1 defines the Longitudinal and the Combined Stress Factors.

Location	Hoop (F1)	Longitudinal (F2)	Combined (F3)
Pipeline	0.72	0.8	0.9
Risers	0.6	0.8	0.9

Appendix 1 Design Code Specifications

Load Cases and Loading Categories

For offshore pipelines B31.8 does not distinguish between load categories i.e. sustained, expansion etc. as B31.8 onshore does. All concurrent loading is combined and checked using the longitudinal and combined stress criteria using code defined Design factors.

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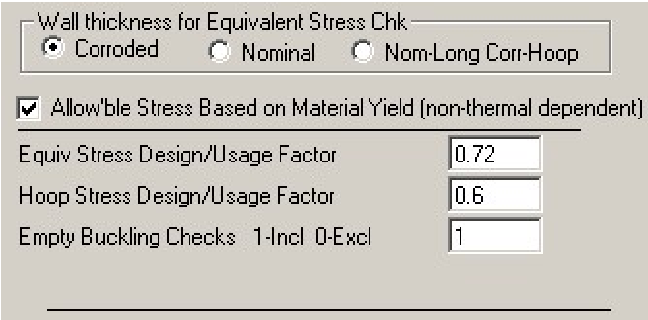
PD8010

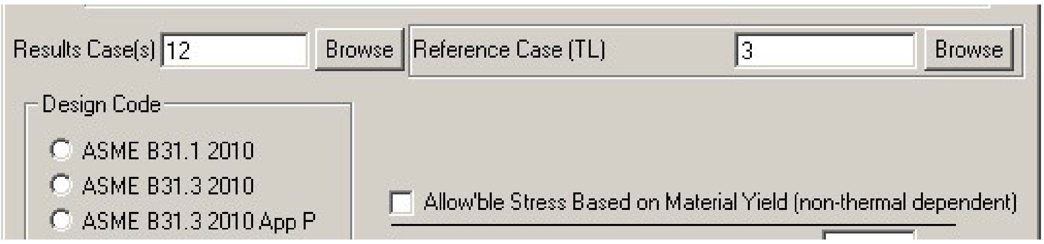
PD 8010 Part 2 Subsea Pipelines



The **Hoop Stress Design Factor** and the **Equivalent Stress Design Factor** can be defined.

The model property code yield stress value is used to evaluate the allowable stresses.

This default can be overridden if the **Allowable Stress Based on Material Code Yield** option box is unchecked. If this is done the yield will be based on a temperature dependent basis obtained from the extended material property code data using a reference load case. See Sect 7 for more information on material library requirements for temperature dependent yield.



Location	Hoop	Equivalent	Const'n/Hydro Equivalent
Pipeline	0.72	0.96	1.0
Risers	0.6	0.72	1.0

Load Cases and Loading Categories

All concurrent loading is combined and checked using the Von-Mises stress criteria using code defined Design factors.

Appendix 1 Design Code Specifications

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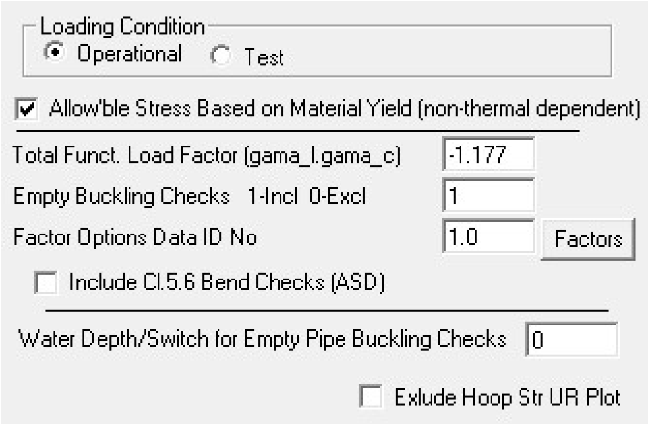
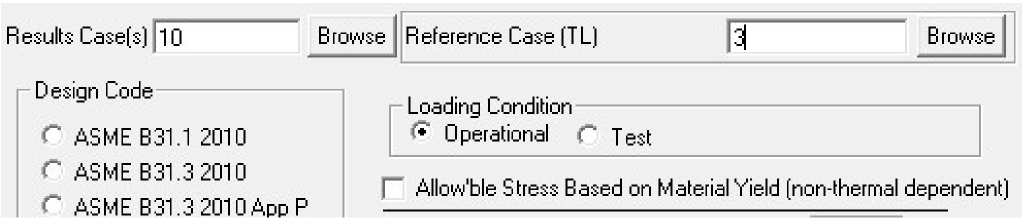
DNV F101

DNV ST-F101 Submarine Pipelines

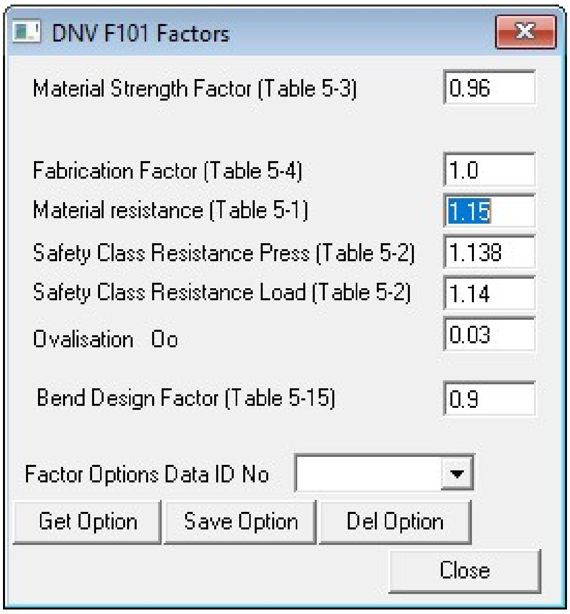


The model property code yield stress value is used to evaluate the allowable stresses.

This default can be overridden if the **Allowable Stress Based on Material Code Yield** option box is unchecked. If this is done the yield will be based on a temperature dependent basis obtained from the extended material property code data using a reference load case. See Appendix 2 for more information on material library requirements for temperature dependent yield.



This code has a large number of load and resistance factors. Most of these factors are save under a Factor Options Data set. These data sets are identified by an ID number so that they may be varied between different result cases.



DNV OS-F101

This code is LRFD code where design load effects must not exceed the design resistance. The design loads are obtained from factored load combinations which are categorised and factored in accordance with D204 and DNV Table 5-6 & Table 5-7.

METHOD 1 - Non-Factored Loading

Results Factored by a Single Load Factor by the Code Checker

If the **Total Functional Load Factor (gamma_l.gamm_c)** is defined as a negative value the code checker will factor the result case by this value (absolute). The would be used in cases where the result case is based on non-factored loading.

The default **Total Functional Load Factor (gamma_l.gamm_c)** is -1.177. Note that this method can only be applied for cases where the partial load factors are the same.

METHOD 2 - *Factored Loading*

No Factors applied by code checker

Applying partial load factors can be very easily done in FS2000 by simply creating an appropriately factored load case combination and using the post-processed results as input to the code checker. This can be done for both linear and non-linear analysis. A typical combination is shown below. Note that a Load Effect Factor (Table 4-5) of 1.07 has been included in the Table below.

Load case	Load Factor (gamma_l.gamm_c)
Dead-weight loads	1.177
Pressure & Temperature loads	1.177
Environmental loads	1.391

Note: The Total Functional Load Factor (gamma_l.gamm_c) used for the pressure loading component must be defined as code check parameter. This is because the factor is used by the FS-Pipe to evaluate the non-factored internal pressure from the factored result case. A value of 1.177 for **gamma_l.gamm_c** would be used if the load factors above were being applied.

METHOD 3 - *Non Factored Loading*

Results Factored by Partial Factors in Code Checker

In some cases involving partial load factors it is more convenient to factor the loading results in the code checker using a load case combination. This approach avoids the difficulty of associating load factors with resistances, which are a function of loading i.e. frictional resistance in non-linear analysis.

When using this method any **Total Functional Load Factor (gamma_l.gamm_c**) defined is ignored since a special load case combination is used t define the partial factors.

For loading conditions where environmental loads are considered and partial load factors are applicable, the following approach can be adopted:

1. A functional condition is analysed (no load factors to be applied);
2. A functional + environmental condition is analysed (no load factors to be applied);
3. The differences from the results of 1) and 2) gives the magnitude of the environmental loading.

4. The functional load case is factored (1.177) and combined with the factored(1.391) environmental loading.

The F101 design checker uses Special Load Case Combinations to undertake this additional post-processing. In such combinations the combined cases are result cases rather than load cases. Only two cases can be contained in the combination. The first case is the functional load case and the second the functional + environmental. The load factor corresponding to the first case is the total functional load case factor (e.g. 1.1 * 1.07) and the second factor is the total environmental load factor (e.g. 1.3 * 1.07).

Entering C200 or C200-235 for a range in the Result Case box will initiate the special processing described above. The results from the code check will be identified by the result case number of the second case in the combination i.e. the functional + environmental result case. An example of the use of a Special Load Case Combinations:

C200 Desc: Functional & Environmental F101 Design Check

Load Case	Description	Factor
20	Functional Loads	1.177
21	Functional + Environmental	1.391

The Resulting Case from the Code check would be Case 21 using the description for case 21.

Cl 5.4.6 Combined Loading Criteria

If the limiting conditions of

D/t2 <= 45

is not complied with a warning will be give at the bottom of the stress listing

If the limiting conditions of

Ssd / Sp < 0.4

is not complied with, a value of 10 will added to the UR at the fore node of those elements.

Optional Cl 5.6 - Bend Checks

If the **Include Cl 5.6 Bend Check** is activated the equivalent stress check and the collapse check (if being undertaken) will be taken in accordance with clause Cl 5.6.2. Note that this is an ASD check. The non-factored loads will evaluated by the code checker from the factored loads.

If the bend check is active the equivalent stress utilisation (UR) will only be indicated in the full output for each bend element or the individual element check.

If governing, the bend UR will be shown in all output.

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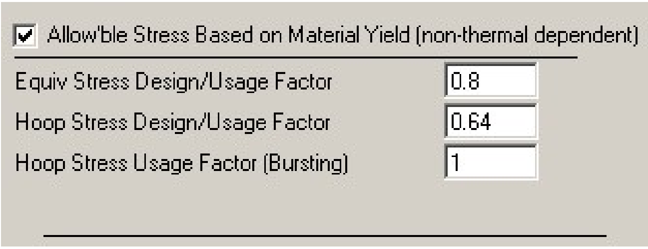
DNV 1981/1996

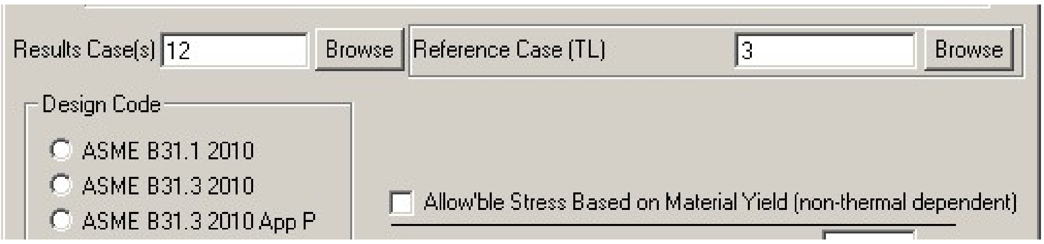
DNV 1981/1996



The **Hoop Stress Usage Factor (Yield)**, **Hoop Stress Usage Factor (Bursting)**, and the **Equivalent Stress Usage Factor** can be defined.

The model property code yield stress value and the ultimate stress value is used to evaluate the allowable stresses.

This default can be overridden if the **Allowable Stress Based on Material Code Yield** option box is unchecked. If this is done the yield and UTS will be based on a temperature dependent basis obtained from the extended material property code data using a reference load case. See Sect 7 for more information on material library requirements for temperature dependent yield.



Load Cases and Loading Categories

All concurrent loading is combined and checked using the longitudinal and the Von-Mises stress criteria using code defined Usage factors.

Appendix 1 Design Code Specifications

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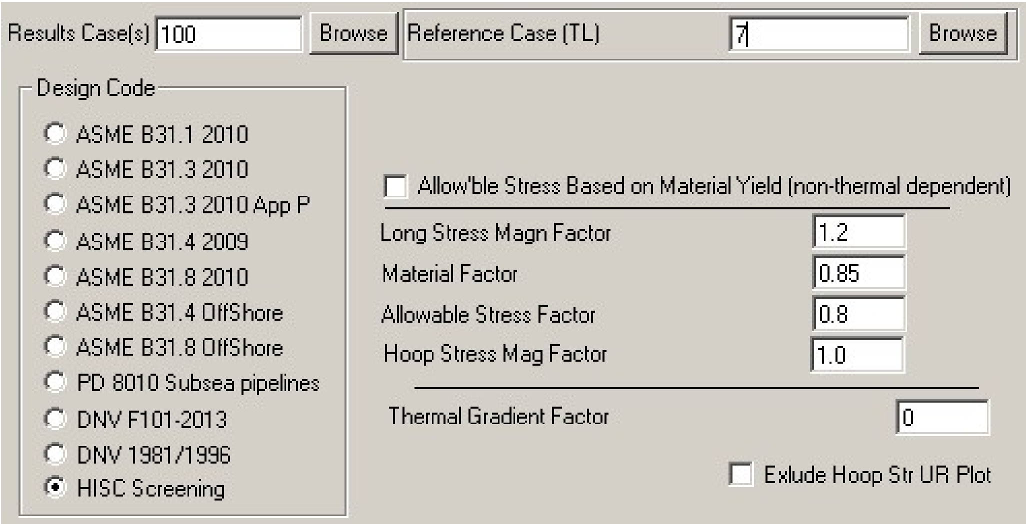
HISC Screening

The stresses evaluated in this check correspond to those defined in DNV F112 Category 1 Assessment.



The **Reference Case** is the thermal load case that defines the element temperature difference distribution (Δt_e) used the the thermal expansion solution.

The **Thermal Gradient Factor** is used to to obtain the thermal gradient stress (Clause 5.3.3 - 5.5). ΔT = Gradient Factor.Δt_e

The **Allowable Stress Factor** = $\alpha.\beta.\gamma.(1.1-.07*LSPF)$ (Clause 5.5.1)

The **Material Factor** = γ (Clause 5.2)

The **Long Stress Mag Factor** = S_{mag} = Stress Magnification Factor in the longitudonal direction (Clause 5.3.4)

The **Hoop Stress Mag Factor** = S_{mag} = Stress Magnification Factor in the hoop direction(Clause 5.3.4)

The equations used to evaluate the stresses are given in Appendix 1 Design Code Specifications

The above factors are global factor but can be applied to specific elements using groups identification for selection and linked sub-case for output.

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4.0 Operation of the CodeChecker

FS-Pipe can be be run in Interactively Mode or in Batch Mode.

Interactive Mode is started by either selecting the Pipework command in the Design menu. (Results Output TASK) or double clicking the FS-Pipe icon in the FS2000 program group.

When the program is loaded in interactive mode the FS-Pipe Window will be visible. The FS-Pipe module runs as a separate windows application to FS2000 and there is no further interaction with FS2000.

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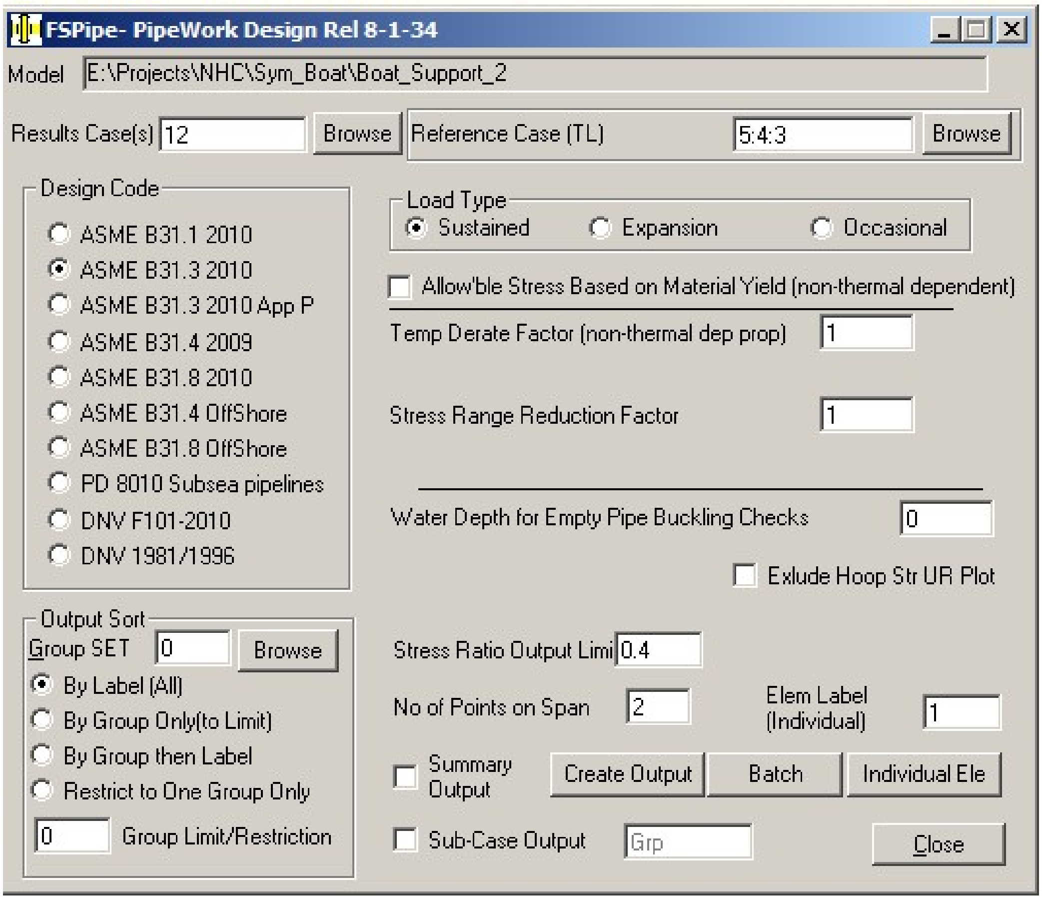
4.1 Interactive Operation

The following windows becomes visible when FS-Pipe is started in interactive mode.



Results Case is used to define the Processed Results Case to be code checked. The **Browse** button is used to select from a list.

The **Design Code** box is used to select the pipework design code. When a code is selected different option become available. These options are described in the Design Codes section.

The **Reference Case** (when used with ASME B31.x codes). This is used when checking Expansion cases which require a longitudinal stress and a thermal stresses for evaluation of the allowable expansion stress . It is also used when checking Sustained and Occasional Loading which require a thermal case to define the hot allowable stress when it is different to the subject case. Up to three reference cases may be defined, one for sustained, one for hot thermal and one for cold thermal, this is done by specifying the case numbers and separating them with a colon LR:HTL:CTL e.g. 4:6:5.

The caption prompts in the reference case inputs for expansion checks are:

LR Longitudinal Result Case

HTL Hot Temperature Load Case

CTL Cold Temperature Load Case

The caption prompts in the reference case inputs for sustained checks are:

TL Temperature Load Case

Note that the Browse button will only show load cases. Result cases can be entered but not selected.

The **Reference Case** (use with Yield Design codes eg BS8010). This can be used to establish the yield strength as a function of temperature. This is achieved by factoring the material properties yield by the ratio of the temperature de-rated allowable stress to the cold allowable stress in the extended material properties. The **Allow Stress Based on Material Yield** must be de-activated for this to be used.

The caption prompt in the reference case inputs is:

TL Temperature Load Case

If the **Allow Stress Based on Material Yield** is active than the allowable stresses will be based on the standard material properties, no extended properties and no thermal reference case is required to be defined. See Design Code Options

Water Depth for Empty Pipe Buckling Checks is used to define the depth of water of the the combined hydrostatic loading checks. This check is effectively an installation case check and assumes zero internal pressure. This has two modes of operation depending whether the external pressure is define explicitly in a load case or is not.

- Explicit External Pressure Definition

  If the external pressure is defined explicitly in a load case or in a load case generated from FS-Wave the the **Water Depth** parameter is interpreted only as a switch. Any non-zero value will active the collapse check based on the result case external pressure. Note that this is an empty pipe check an assumes Pi is zero.

- Non-Explicit External Pressure Definition

  The **Water Depth** is used to define the depth of water of the combined hydrostatic loading checks. It a non zero value is entered and Po is zero this value will be interpreted as depth of water relative to the model Y origin. The local external pressure is evaluated based on a water density of 1025 kg/m3. Note that this water column pressure is only used for the an empty pipe check i.e. Pi =0.

Summary Output option selects the summary mode which shows only unity ratio output. A results file will be created and may be viewed

Full Check option produces the stress mode which produces output the shows the actual and allowable loading A results file will be created and may be viewed

Individual Check option will show the full stress results for a single defined element.

Number of Locations on Span defines the number of points along an element at which the code checks are to be carried out. Up to 20 points along the length of the element may be specified. Generally 2 or 3 are sufficient but this is dependent on the loading on the element. Specifying a high number will increase the output and computational time.

Stress Ratio Limit is used to restrict the output to the elements whose maximum unity ratios are greater than that specified. The default value is zero. This facility is extremely useful since it reduces the output from the program and identifies critical elements more quickly.

The **Exclude Hoop Str UR Plot** option is used to remove the direct pressure related (hoop, hoop buckling etc) unity ratios from the UR plots. This option is useful when expansion/restraint effects are of major significance . The Hoop stress ratios are always included in stress and stress summary text output.

The **Batch** button converts the set options to command line switches for batch operation and appends the FSPIPE command line to the .BRM batch run file.

Groups

The **Group SET** box is used to define the group SET to be loaded. Basic element labels will be used for reference in the lists.

The **Restrict to One Group** option is used to restrict elements to only those elements with the same group number as defined by the Group Limit/Restriction box (a zero value indicates that all data will be shown). This option is useful when model contains structural pipe elements which are not required to be included in the output.

Important Note The unity stress data which is plotted using the plot facility of FS2000 will only show results relating the elements processed.

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5.0 Output Results

The output results data from FS-Pipe use the same naming convention for the output files as the member design code checkers. To view the results of pipework from FS2000 the result files are selected using the Member menu command option. If a model is used to check both structural and pipework design duplicate load cases may be required or the use of Sub-cases.

Plotting Design Results

Unity ratio data can be plotted using the Plot UR(Unity Ration) command in the Plot menu of the Resulsts TASK.

Sorting Results Cases

The Unity Ratio sort may be used to sort single and multiple results cases

FS-Pipe produces the following text output.

Full Output

In this mode of output all stress data relating to the pipe element will be shown. The output is divided into two sections. The first section gives the actual stresses and shows the parameters used to evalaute the stress eg stress intensification factors. The second sections gives the actual and allowable stresses. The component Unity Ratios (Actual/Allowable) are also given.

If a UR unity ratio exceeds 1 the element will be marked accordingly.

If the hoop stress UR (unity ratio) exceed 1 the minimum wall thickness to achieve unity will be shown

Summary Output

In this mode of output the output is restricted to one line of data per element only the maximum Unity Ratios for each element are given.

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APPENDIX 1 Design Code Specifications

Code Specifications

This appendix presents the design criteria used by the program for each of the design codes. These codes are:

ASME B31.1	Power Code 2010
ASME B31.3	Chemical and Petroleum Refinery Piping Code 2010
ASME B31.3 Appendix P	Chemical and Petroleum Refinery Piping Code 2010
ASME B31.4	Liquid Petroleum Transportation Piping Code 2009
ASME B31.3	Gas Transmission and Distribution Piping System Code 2010
BS 8010	Code of Practice for Pipelines Part 3 Design,Const & Installation 2004
DNV-F101	Rules for Submarine Pipelines Systems 2010
DNV	Rules for Submarine Pipelines Systems 1981/96

Common Definitions

Do	Outside diameter	
tnom	Nominal wall thickness	
dnom	Pipe inside diameter based on tnom	
c	Corrosion allowance	
tcor	Corroded wall thickness	= tnom - c
dcor	Pipe inside diameter based on tcor	
m	Mill (Manufacturing) tolerence %	
tred	Reduced wall thickness	= tnom x (1 - m/100) - c
Znom	Pipe section modulus based on tnom	
Zcor	Pipe section modulus base on tcor	

ASME B31.1 Power Code

Hoop Stress

Actual Hoop Stress = p.Do / 2tred - pY

Allowable Hoop Stress = SAH = E.BAS

where E = Weld Efficiency factor

BAS = Hot allowable stress

Longitudinal Stress (Sustained)

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = 0.75i.M/Zcor

where F = axial force in the pipe

i = the stress intensification factor

M = Resultant moment on the pipe

Allowable Longitudonal Stress = SAL

SAL = E.BAS (same as Allowable Hoop Stress)

Longitudonal Stress - Occasional

SLO = Same as Sustained Longitudonal Stress

Allowable Longitudonal Stress = SALO

SALO = k.BAS

Where k = 1.15 if acting < 10% of time

k = 1.20 if acting < 1% of time

In the program k = 1.15

Thermal Expansion Stress

SE = i.M/Zcor

Allowable Expansion Stress = SAE

SAE = f.(1.25CAS + 0.25BAS)

If SAE > SE and SL < BAS the allowable stress is evaluated from

SAE = SAE + f.(BAS - SL) = f.(1.25(CAS + BAS) - SL)

where f = stress range reduction factor for cyclic conditions

CAS = Cold allowable stress

ASME B31.3 Chemical and Petroleum Refinery Piping Code

Hoop Stress

Actual Hoop Stress = p.Do / 2tred - pY

Allowable Hoop Stress = SAH = E.BAS

where E = Weld Efficiency factor

BAS = Hot allowable stress

Longitudinal Stress (Sustained)

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

where F = axial force in the pipe

io = the stress intensification factor

ii = the stress intensification factor

Mo = Resultant moment on the pipe

Mi = Resultant moment on the pipe

Allowable Longitudonal Stress = SAL

SAL = E.BAS (same as Allowable Hoop Stress)

Longitudonal Stress - Occasional

SLO = Same as Sustained Longitudonal Stress

Allowable Longitudonal Stress = SALO

SALO = 1.33.BAS

Thermal Expansion Stress

SE = (Sb**2 + 4St**2)**0.5

Sb = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Znom

St = Mtt / 2Znom

where io = the stress intensification factor

ii = the stress intensification factor

Mo = Resultant moment on the pipe

Mi = Resultant moment on the pipe

Mtt = Torsional moment

Allowable Expansion Stress = SAE

SAE = f.(1.25CAS + 0.25BAS)

If SAE > SE and SL < BAS the allowable stress is evaluated from

SAE = SAE + f.(BAS - SL) = f.(1.25(CAS + BAS) - SL)

where f = stress range reduction factor for cyclic conditions

CAS = Cold allowable stress

ASME B31.3 Appendix P Chemical and Petroleum Refinery Piping Code

Hoop Stress

Actual Hoop Stress = p.Do / 2tred - pY

Allowable Hoop Stress = SAH = E.BAS

where E = Weld Efficiency factor

BAS = Hot allowable stress

Operating Stress (Sustained)

SO = ((Abs(Sa) + Sb)**2 + 4St**2)**0.5

Sa = ia.(p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2))

Sb = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

where F = axial force in the pipe

ia = the axial stress intensification factor

io = the stress intensification factor

ii = the stress intensification factor

Mo = Resultant moment on the pipe

Mi = Resultant moment on the pipe

Allowable Operating Stress = SOA

SOA = 1.5(CAS + BAS)

where CAS = Cold allowable stress

BAS = Hot allowable stress

If Sy/Sult > 0.8 SOA = 0.85SOA

Operating Range Stress (Expansion)

SE = ((Abs(Sa) + Sb)**2 + 4St**2)**0.5

Sb = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Znom

St = Mtt / 2Znom

where io = the stress intensification factor

ii = the stress intensification factor

Mo = Resultant moment on the pipe

Mi = Resultant moment on the pipe

Mtt = Torsional moment

Allowable Operating Range Stress = SEA

SEA = 1.25f(CAS + BAS)

where f = stress range reduction factor for cyclic conditions

CAS = Cold allowable stress

BAS = Hot allowable stress

ASME B31.4 Liquid Petroleum Transportation Piping Code

Hoop Stress

Actual Hoop Stress = SH = p.Do / 2tcor

Allowable Hoop Stress = SAH = 0.72E.SMYS (Table 403.3.1-1)

where E = Weld Efficiency factor

SMYS = Yield Stress at pipe temperature - Pipe Material Code

Longitudinal Stress (Sustained)

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

where F = axial force in the pipe

io = the stress intensification factor

ii = the stress intensification factor

Mo = Resultant moment on the pipe

Mi = Resultant moment on the pipe

Allowable Longitudonal Stress = SAL

SAL = 0.54SMYS (Table 403.3.1-1)

Longitudonal Stress - Occasional

SLO = Same as Sustained Longitudinal Stress

Allowable Longitudinal Stress = SALO

SALO = 0.8SMYS (Table 403.3.1-1)

Thermal Expansion Stress

a) Unrestrained Case

SE = (Sb**2 + 4St**2)**0.5

Sb = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

St = Mtt / 2Zcor

where io = the stress intensification factor

ii = the stress intensification factor

Mo = Resultant moment on the pipe

Mi = Resultant moment on the pipe

Mtt = Torsional moment

Allowable Expansion Stress = SAE

SAE = f.(1.25(Sc + Sh) - SL)

where f = stress range reduction factor for cyclic conditions

Sc = 2/3SMYS at minimum temperature

Sh = 2/3SMYS at maximum temperature

SL = Longitudonal stress

b) Restrained Case

SE = SEQ (see **Combined Stresses** below)

SAE = 0.9SMYS (Table 403.3.1-1)

Combined Stresses - Restained Case (Sustained or Occasional) (402.7)

SEQ = ((SH**2 + SL**2 - SH.SL+ 3St**2)**0.5

where

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

SH = p.Do / 2tcor

St = Mtt / 2Zcor

Allowable Expansion Stress = SAEQ

SAEQ = 0.8SMYS

Note that SEQ is only shown in individual element output but is included in all UR checks

ASME B31.4 Liquid Petroleum Transportation Piping Code -Offshore Pipelines

The design requirements for B31.4 for offshore pipelines are similar to those for B31.8 _Offshore given in a following section. The differences in B31.4 compared with B31.8 are:

- The Hoop stress design factor is 0.6 for risers
- Thick wall hoop stress is not applied
- Lonitudonal & Combined Stress are always based on the corroded thickness

ASME B31.8 Gas Transmission and Distribution Piping System Code

Hoop Stress

Actual Hoop Stress = p.Do / 2tcor

If D/tcor < 30 Actual Hoop Stress = p.(Do-tcor) / 2tcor

Allowable Hoop Stress = SAH = F.E.T.SMYS

where E = Weld Efficiency factor

F = Contruction Type Factor

T = Temperature Derating Factor

In the program F & T are combined into a single factor

SMYS = Yield Stress at pipe temperature - Pipe Material Code

Longitudinal Stress

a) Unrestrained Case

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

where F = axial force in the pipe
io = the stress intensification factor
ii = the stress intensification factor
Mo = Resultant moment on the pipe
Mi = Resultant moment on the pipe

Allowable Longitudonal Stress = SAL

SAL = 0.75T.SMYS

b) Restrained Case

Longitudonal Stress - Occasional (Total)

Allowable Longitudonal Stress = SALO

SALO = 0.75T.SMYS

Thermal Expansion (Cyclic) Stress - Unrestrained

SE = (Sb**2 + 4St**2)**0.5

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

St = Mtt / 2Zcor

where io = the stress intensification factor
ii = the stress intensification factor
Mo = Resultant moment on the pipe
Mi = Resultant moment on the pipe
Mtt = Torsional moment

Allowable Expansion Stress = SAE

SAE = f.(1.25(Sc + Sh) - SL)

where f = stress range reduction factor for cyclic conditions
Sc = 0.33UTS.T at minimum temperature
Sh = 0.33UTS.T at maximum temperature
SL = Longitudonal stress

Thermal Expansion (Cyclic) Stress - Restrained Case

SE = SEQ (see **Combined Stresses** below)

SAE = 0.9SMYS (Table 403.3.1-1)

Combined Stresses - Restained Case (Sustained or Occasional) (833.4)

SEQ = ((SH**2 + SL**2 - SH.SL+ 3St**2)**0.5

where

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

SH = p.Do / 2tcor

St = Mtt / 2Zcor

Allowable Expansion Stress = SAEQ

SAEQ =0.9T.SMYS Sustained

SAEQ =T.SMYS Occasional

Note SEQ is only shown in individual element output but is included in all UR checks

ASME B31.8 Gas Transmission and Distribution Piping System Code

Offshore Pipelines

Hoop Stress

Actual Hoop Stress = p.Do / 2tcor

For Do / t < 30 Actual Hoop Stress = p.(Do-tcor) / 2tcor

Allowable Hoop Stress = SAH = F1.SMYS.T

where F1 = Hoop Stress Design Factor (0.72 for pipelines : 0.5 for risers)

T = Temperature Derating Factor

In the program F & T are combined into a single factor

SMYS = Yield Stress - Pipe Material Code

Longitudinal Stress

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

where F = axial force in the pipe

io = the stress intensification factor

ii = the stress intensification factor

Mo = Resultant moment on the pipe

Mi = Resultant moment on the pipe

Allowable Longitudinal Stress = SAL

SAL = F2.SMYS

where F2 = Longitudinal Stress Design Factor = 0.8

Combined Stress

The combined stress will evaluated as the lowest of the Tresca combined stress and the Von-Mises combined stress.

When the Hoop Stress Design Factor F1 is set to 0.5 the properties used for combined stress evaluation will be based on the **Reduced** wall thickness otherwise on the **Corroded** properties as shown below.

Tresca

SCOMB = 2*((SL - SH)**2 + St**2)**0.5

Von-Mises

SCOMB = ((SH**2 + SL**2 - SH.SL+ 3St**2)**0.5

where

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

SH = p.Do / 2tcor

St = Mtt / 2Zcor + 2Fs/ Acor

Allowable Longitudinal Stress = SAL

SAL = F3.SMYS

where F3 = Combined Stress Design Factor = 0.9

PD 8010 Code of Practice for Pipelines Part 3 Design,Const & Installation

Clauses 4.2.4 and 4.2.5

Hoop Stress

For D/t > 20

Actual Hoop Stress = SH = p.Do / 2tred

For D/t <= 20

Actual Hoop Stress = SH = p.(Do **2 + d**2) / (Do **2 - d**2)

Allowable Hoop Stress = SAH = fd.SMYS

where fd = Hoop Stress Design factor

SMYS = Yield Stress at pipe temperature - Pipe Material Code

Equivalent Stress

The equivalent stress may be evaluated on all (corroded), all (nominal) or (nominal longitudonal and hoop corroded) wall thickness (user option). The formula shown below are for the corroded condition.

SEQ = ((SH**2 + SL**2 - SH.SL+ 3St**2)**0.5

where

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

SH = p.Do / 2tcor

St = Mtt / 2Zcor + 2Fs/ Acor

Allowable Equivalent Stress = SAEQ = fd.SMYS

where fd = Equivalent Stress Design Factor

SMYS = Yield Stress at pipe temperature - Pipe Material Code

DNV Rules for Submarine Pipelines Systems 1981/1996

The following stress acceptance criteria is similar in both the 1981 rules and the 1996 rules. The differences are in the usage factors used and the omission of a longitudinal stress criteria in the 1981 rules.

Hoop Stress

Actual Hoop Stress = SH = p.(Do -tred) / 2tred

Allowable Hoop Stress = SAH = lower of Us.SMYS or Uu.SMTS

where Us = Pressure Usage factor (Yield)

UU = Pressure Usage factor (Bursting))

SMYS = Yield Stress at pipe temperature - Pipe Material Code

SMTS = Tensile Stress at pipe temperature - Pipe Material Code

Longitudinal Stress

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

Equivalent Stress

SEQ = ((SH**2 + SL**2 - SH.SL+ 3St**2)**0.5

where

SL = SLP + SLB

SLP = p.Do/4tcor + 4F/Pi.(Do**2 - dcor**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zcor

SH = p.Do / 2tcor

St = Mtt / 2Zcor + 2Fs/ Acor

Allowable Longitudinal and Equivalent Stress = SA = Uf.SMYS

where Uf = Equivalent Stress Usage factor

SMYS = Yield Stress at pipe temperature - Pipe Material Code

DNV ST-F101 Submarine Pipelines Systems

The following design acceptance criteria are checked by the program

Clause	Description
5.4.2	Pressure Containment - Only the first terms in 5.6 and 5.7
5.4.4	External Pressure Collapse
5.4.5	Propagation Buckling - Not included as a critical utilisation but reported
5.4.6.5	Combined loading Criteria - Internal overpressure
5.4.6.9	Combined loading Criteria - External overpressure
5.6.2.2	Bend Checks - Optional ASD check

Load Factors and Resistance Factors

Load Factors

The pipeline design loads can be obtained by using factored load case combinations. Using this approach the summation of the various load effects can be correctly summed to produce a single results case for both linear and non-linear analysis.

Resistance Factors

The following default factors are used in FS-Pipe. These can be modified but required to be saved as Factor Options Data .

Material Strength Factor (Table 5-3)	0.96
Fabrication Factor (Table 5-4)	1
Material resistance (Table 5-1)	1.15
Safety Class Resistance Press (Table 5-2)	1.138
Safety Class Resistance Load (Table 5-2)	1.14
Ovalisation Oo	0.03
Bend Design Factor (Table 5-15)	0.9

Note that the total functional load factor ($\gamma l.\gamma c$) used in the load combination to generate the results case must also be defined as a code check parameter.

HISC Screening - DNV F112 Category 1 Assessment

The following equations are used to evaluate the stresses at the mid wall and outside diameter of a pipe subjected to internal pressure and external loading. The hoop and bending stresses shown on the output correspond to the outer wall location.

Membrane Hoop Stress

Inner Hoop Stress = SHi = p.(ro**2 + ri**2) / (ro**2 - ri**2) - Lame's Equation

Outer Hoop Stress = SHo = p.ri**2 / (ro**2 - ri**2) - Lame's Equation

Where ri are based on the minimum thickness tred

SH = (SHi + SHo) / 2

Membrane Longitudinal Stress

SL = SLP + SLB

SLP = p.dcor**2 / (Do**2 - dred**2) + 4F/Pi.(Do**2 - dred**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zred-rm

Thermal Gradient Stress

SG = α.E.ΔT/2/(1-μ).TGF

ΔT = Temperature Difference from the Thermal Reference Case

TGF - Thermal Gradient Factor

Outer Hoop Stress

Outer Hoop Stress = SHo = 2.p.ri**2 / (ro**2 - ri**2) - Lame's Equation

Where ri are based on the minimum thickness tred

SHO = (Outer Hoop Stress.SCFH + SG)

SCFH = Hoop SCF (Stress magnification factor)

Outer Longitudinal Stress

SL = SLP + SLB

SLP = p.dcor**2 / (Do**2 - dred**2) + 4F/Pi.(Do**2 - dred**2)

SLB = ((io.Mo)**2 + (ii.Mi)**2)**.5 / Zred-ro

SLO =(SL.SCFL + SG)

SCFL = Longitudonal SCF (Stress magnification factor)

Allowable Stress Limits

Allowable Membrane Stress = $0.8.\gamma$.SMYS

where γ = Material Factor

SMYS = Yield Stress at pipe temperature or Pipe Material Code

Allowable Outer Stress = U.SMYS

where U= Allowable Stress Factor = $\alpha.\beta.\gamma.(1.1 - 0.007*LSPF)$

SMYS = Yield Stress at pipe temperature or Pipe Material Code

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APPENDIX 2 Pipework Material Property Libraries

Pipework Material Property Libraries

Material properties library files may be created by the user to enable frequently used properties to be entered by simple list selection. The libraries are ASCII text files and providing the file formats are followed may be created by the user using any type of text editor. Inspection of an existing file will clearly show the format structure used. Note that all data has to be present.

A Material Library Utility program is provided that allows the used to create libraries without the need to use a text editor and worry about file formats. This described in the latter part of this appendix. The Material input form of FS2000 also allows data from models to be added to existing libraries.

Two type of library files are used by FS2000/FS-Pipe. These files must reside in the FS2000 directory.

Standard Structural Material Properties

These files are text files with the file extension **<name>.PRM**

Pipework (Temp Dep)Material Properties (Extended Material Properties)

These libraries are text files with the file extension **<name>.PRE**

The Extended material properties are :

Ultimate Strength	N/m2	ksi
Cold Allowable Strength	N/m2	ksi
Modulus of Elasticity (E)	N/m2	ksi

The following are defined as a function of temperature

Coefficient of Thermal Expansion (ALPHA)	m/m/C	ins/ins/F
Allowable Stress	N/m2	ksi

The units used must be the same as those used by the model i.e S.I. Units or USA Units.

The following illustrates the format for **PRE** files:

```
MATNAM,A53-GrdA
Spare Data Field , 0
Ultimate Tensile Strength ,3.309E08
Cold Allowable Stress ,1.103E08
Number of Temperature Definition Pts , 14
 Temp        Coeff of Exp   Mod of Elast    Allow Stress
-198.3        9.000E-06      2.165E11       1.103E08
-101.1        9.900E-06      2.124E11       1.103E08
-45.6         1.044E-05      2.082E11       1.103E08
21.1          1.093E-05      2.034E11       1.103E08
93.3          1.148E-05      1.986E11       1.103E08
148.9         1.188E-05      1.951E11       1.103E08
204.4         1.228E-05      1.910E11       1.103E08
260           1.264E-05      1.882E11       1.103E08
315.6         1.301E-05      1.841E11       1.020E08
371.1         1.339E-05      1.758E11       9.928E07
426.7         1.377E-05      1.669E11       6.412E07
482.2         1.411E-05      1.544E11       4.482E07
537.8         1.435E-05      1.407E11       1.724E07
593.3         1.462E-05      1.241E11       6.895E06
```

The above is typical of properties explicitly defined in B31.3.

For design codes which use only the yield strength e.g. DNV and wish to employ thermal de-rating from a library i.e. the **Allo'bl Stress Based on Material Yield** option is not active, the material yield stress is de-rated by using **YieldStress *AllowStress / ColdAllStress.** Using using specific stress values as in the above enables the yield to be reduced in line with the specified allowable stress.

An alternative for yield only codes is to use a unity ratio approach as shown below. This format uses a unit value for the cold allowable stress and uses a unity ratio based yield reduction factor for the **Allow Stress** which is visibly more apparent.

```
MATNAM,STEEL
Spare Data Field , 0
Ultimate Tensile Strength ,4.550E8
Cold Allowable Stress ,1
Number of Temperature Definition Pts , 7
 Temp        Coeff of Exp   Mod of Elast    Allow Stress
-198.3        9.000E-06      2.165E11       1.0
-101.1        9.900E-06      2.124E11       1.0
-45.6         1.044E-05      2.082E11       1.0
21.1          1.093E-05      2.034E11       1.0
93.3          1.148E-05      1.986E11       0.9
148.9         1.188E-05      1.951E11       0.8
204.4         1.228E-05      1.910E11       0.7
```

When properties are retrieved from the standard structural table they will also, if they exist, be retrieved by name association from the extended library. This means that properties in the extended library must also exist in a standard library of the same name for them to be retrieved. List order between standard and extended libraries is not important as they are linked by name association.

Property Data Provided with FS-Pipe

The ASME codes categorises the temperature dependent properties E and ALPHA into generic material types. The most commonly used of these have been included into a material library called ASME (both standard and extended). In this library all data relating to strength is entered as zero.

This library can be used as a template to create specific material libraries by entering the strength data, renaming the material entry and saving the library under a different name. This process is most conveniently done using the Material Property Utility as this utility can be used to copy entries between libraries. It also converts from data Imperial units to S.I. units. A procedure to do this is described below in the Material Property Utility description.

The temperure points used to define the property curves use the F scales used in the ASME codes. In the ASME.PRE library this data is presented in C. The following table equates the two.

F	C
-325	-198.3
-150	-101.1
-50	-45.6
70	21.1
200	93.3
300	148.9
400	204.4
500	260
600	315.6
700	371.1
800	426.7
900	482.2
1000	537.8
1100	593.3
1200	648.9

ASME Generic Material Type The ASME library contains the following material type

Library Name	Description	
LowCarb	Low Carbon Steel	C <= 0.3%
HighCarb	High Carbon Steel	C > 0.3%
CarbMoly	Carbon Moly Steels	
LowChr	Low Chrome Steels	Through 3Cr
IntChr	Intermediate Crome Steels	5Cr-Mo to 9Cr-Mo
ChrStl	Chrome Steels	12Cr, 17Cr, 27Cr
AustStSt	Austenitic Steels	Type 304, 309, 310, 316, 321, 347
Monel	Monel	67Ni-30Cu
CuNi	Copper Nickle	70Cu-30Ni

Material Property Utility

A Material Property Utility which is used to add and convert data to Material Property Libraries is described in Appendix 4.

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APPENDIX 3 Batch (Command Line) Operation

Batch (Command Line) Operation

This appendix defines the command line options for the codechecker. For further details of command line operation refer to FS2000 Help.

FSPIPE C1/C2/C3/C4/C5/C6/C7/C8/C9/C10/C11/C12/ C13/

C1 is the results file ie 0 to N

Ranges may be processed e.g. 1-10 would process Results Cases 1 to 10 . If cases do not exist when processing ranges a warning will be given and the process will continue to the next case.

C2 Reference Case

For B31.1 & B31.3 Expansion checks the reference case can be used to specify both sustained and thermal reference case (necessary for non-linear analysis). The case numbers are separated by a colon i.e 4:6

C3 Text file output format 1- Full Report 2-Summary Report

C4 Design Code

1 - B31.1, 2 - B31.3, 3 - B31.4, 4 - B31.8,

5 - BS 8010, 6 - DNV:F101, 7 - B31.4 Offshore, 8 - DNV ASD, 9 - B31.8 Offshore

10 - B31.3 App P, 11 - HISC

C5 Code dependent

C6 Code dependent

C7 Code dependent

C8 Code dependent

C9 Use Std Property Code Yield Stress 0 - No 1 - Yes

C10 Stress Unity Ratio Output Limit

C11 No of points on Pipe span for stress check

C12 Group Set

C13 Restrict output to element Group attribute defined by C12, 0 for all elements

C14 Subcase name

C15 Group Only Switch

C16 Exclude Hoop stress UR from UR Plots 0 - Include 1 - Exclude

C17 Depth of water above model y co-ordinate origin(Non-Explicit Po Definition) / Switch for Buckling Check(Explicit Po Definition)

Code dependent command line options

B31.1

C5 Load Type S - Sustained, E - Expansion, O - Occasional

C6 Yield De-rating Factor

C7 Not used

C8 Stress Range Reduction Factor

B31.3

C5 Load Type S - Sustained, E - Expansion, O - Occasional

C6 Yield De-rating Factor

C7 Not used

C8 Stress Range Reduction Factor

B31.4

C4 If C4 is set to -3 then expansion cases will be taken to be restrained cases.

C5 Load Type S - Sustained, E - Expansion, O - Occasional

C6 Not used

C7 Not used

C8 Not used

B31.4 Offshore

C5 Not used

C6 Yield De-rating Factor

C7 Hoop Stress Design Factor

C8 Not used

B31.8

C4 If C4 is set to -4 then expansion cases will be taken to be restrained cases.

C5 Load Type S - Sustained, E - Expansion, O - Occasional

C6 Temperature/Construction De-rating factor

C7 Not used

C8 Not used

B31.8 Offshore

C5 Not used

C6 Yield De-rating Factor

C7 Hoop Stress Design Factor

C8 Not used

PD8010

C5 Wall for equivalent stress check C- Corroded N - Nominal NC - Nominal Longitudinal and Corroded Hoop otherwise corroded

C6 Equiv Stress Design Factor

C7 Hoop Stress Design Factor

C8 Empty Buckling Checks 0 - Exclude 1- Include

DNV OS-F1010

C5 OP - Operational, TE - Testing (OPB - Operational TEB - Testing each with F200 Bend Checks)

C6 Functional Load Factor

C7 Empty Buckling Checks 0 - Exclude 1- Include

C8 Resistance Factor Options Data ID

DNV 1981/1996

C5 Not used

C6 Equiv Stress Usage Factor

C7 Hoop Stress Usage Factor (Yield)

C8 Hoop Stress Usage factor (Bursting)

HISC

C5 Not used

C6 Local SCF

C7 Membrane Stress Usage Factor (Yield)

C8 Membrane+Bending Stress Usage Factor (Yield)

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APPENDIX 4 Material Library Utility

Material Property Utility

This describes the main operating features of the Material Property Utility.

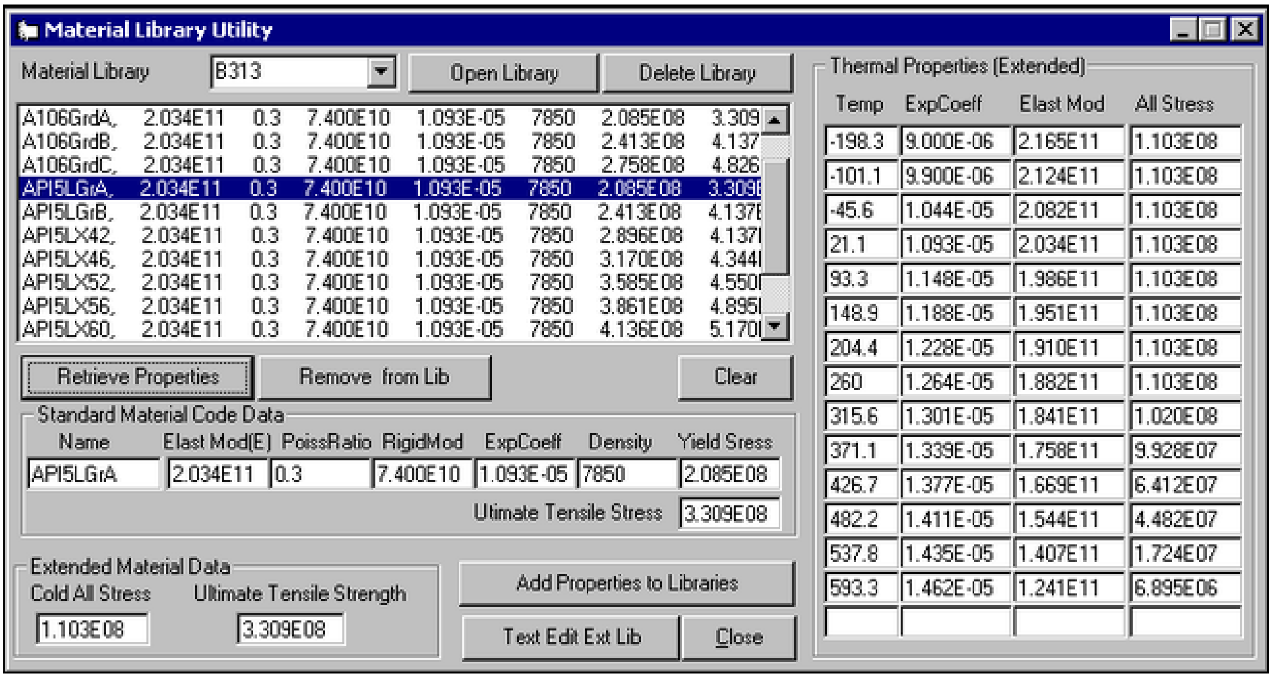
The program name is **MLIBUTIL.EXE** and it is located in the FS2000\system directory.   The program may be started from the Icon in the FS2000 program group or from the Material Properties input form in FS2000's GUI.

This utility can be used to create or modify (simultaneously):

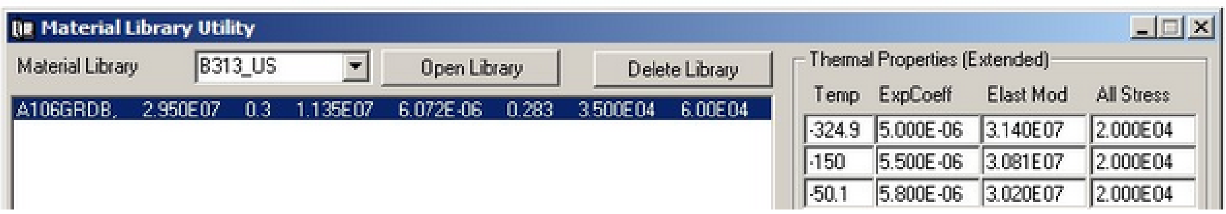
- Standard Material Libraries <name>.PRM, and
- Extended Material Libraries <name.PRE

These libraries are located in the FS2000 user folder. These are text files and can copied or can be edited by any suitable text editor.

SI Units



US Units



Opening a Library

The pull down list may be used to select from existing libraries. The library will be automatically loaded.

If a library name in entered, this **Open** button cab be used to open that existing library.

When a library is opened the entries in the standard library (.PRM) are shown in the library list box. Note that the external properties will not change and still be those previously entered.

Creating a New Library

To create a new library simple enter the name of the new library. When the **Add Properties to Library** button is pressed the new library will be created. This new library will only have one entry and the properties will be those currently displayed.

To copy an existing Library simply copy both the <name>.PRM and <name>.PRE files that are located in the FS20000 user folder

Delete Library

This button is used to delete an existing library.

Retrieve Properties

This button will load the properties of the selected library entry into the property boxes. To select an entry use the mouse to highlight an entry in the library list box.

The library list box shows the entries in the standard material library. If an extended library exists and contains entries for that material the extended properties will be retrieved. If not the extended property boxes will be blank.

Remove Properties

This button will remove the properties of the selected library entry from the standard library. It will not remove properties from the extended library so it is important to check that duplicate entries do not exist.

This must be done using a text editor - Use **Edit Ext Lib** button to do this,

It will not remove the entries in the property boxes

Clear

The Clear button will remove all entries from the property input boxes

Add Properties to Library

This button will add the current property entries to the current library. If the entry name is not changed it will be duplicated. If no extended properties are entered no entry will be added to the extended library. If the **Material Library** Name is changed a new library containing one entry will be created.

Data - Units Conversion

The temperature and thermally dependent properties may be converted using a user defined conversion factor by double clicking any of the temperature dependent input boxes. The whole column will be converted. The default conversions factors are those used to convert ASME properties from the American unit to S.I. units.

Adding New Library Entries

The following procedure should be used create a new library using an existing one as a template.

Open the existing Library library

Select the material category e.g. API5LX42

Press the **Retrieve Properties** button

Edit the material properties - both standard and thermal properties

Change the material entry name e.g. API5LX42 to API5LX60

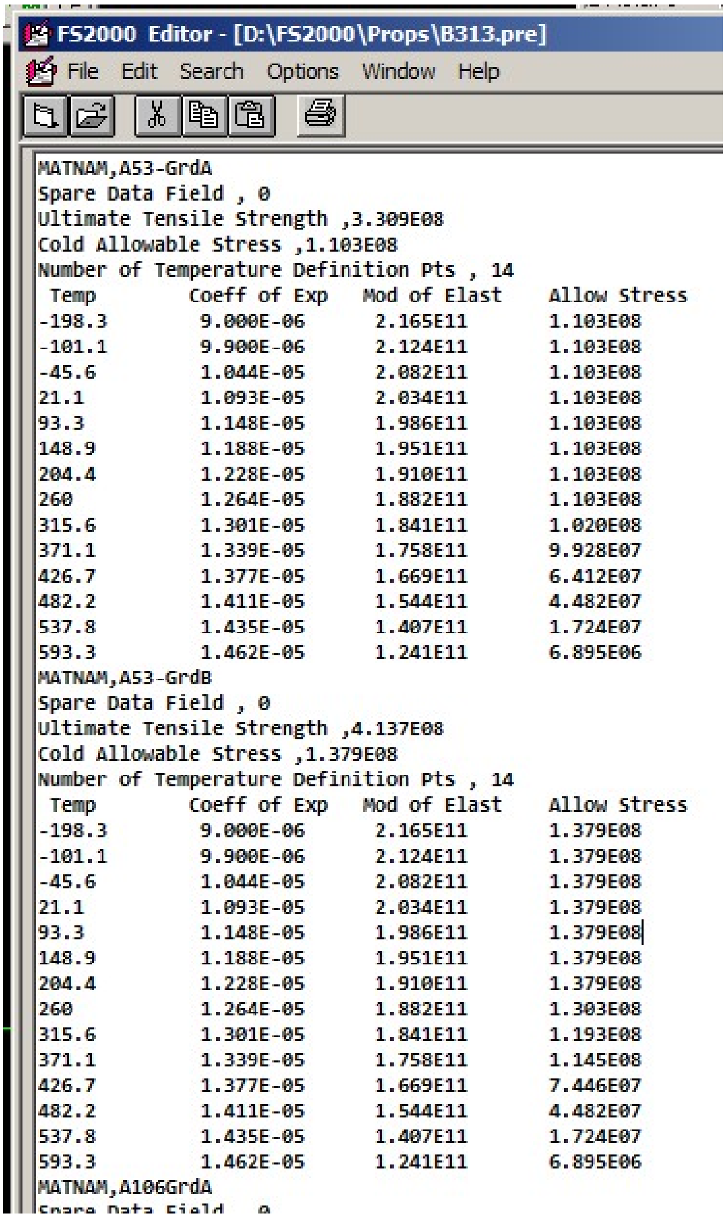
Press the **Add Properties** to Library button - If the Material Library nam is changed a new library containing one entry will be created.

The **Text Edit Ext Lib** button will start the user preferred FS2000 text editor (See FS2000 Help topic Run Editor command Menu:File) and load the extended library.

Use this to delete or modify entries in the extended library.

The following show the data format of the extended property library.

Note that only spaces or , should be used to delimit data, not Tabs.




```
MATNAM,A53-GrdA
Spare Data Field , 0
Ultimate Tensile Strength ,3.309E08
Cold Allowable Stress ,1.103E08
Number of Temperature Definition Pts , 14
 Temp         Coeff of Exp   Mod of Elast    Allow Stress
-198.3         9.000E-06      2.165E11       1.103E08
-101.1         9.900E-06      2.124E11       1.103E08
-45.6          1.044E-05      2.082E11       1.103E08
21.1           1.093E-05      2.034E11       1.103E08
93.3           1.148E-05      1.986E11       1.103E08
148.9          1.188E-05      1.951E11       1.103E08
204.4          1.228E-05      1.910E11       1.103E08
260            1.264E-05      1.882E11       1.103E08
315.6          1.301E-05      1.841E11       1.020E08
371.1          1.339E-05      1.758E11       9.928E07
426.7          1.377E-05      1.669E11       6.412E07
482.2          1.411E-05      1.544E11       4.482E07
537.8          1.435E-05      1.407E11       1.724E07
593.3          1.462E-05      1.241E11       6.895E06
MATNAM,A53-GrdB
Spare Data Field , 0
Ultimate Tensile Strength ,4.137E08
Cold Allowable Stress ,1.379E08
Number of Temperature Definition Pts , 14
 Temp         Coeff of Exp   Mod of Elast    Allow Stress
-198.3         9.000E-06      2.165E11       1.379E08
-101.1         9.900E-06      2.124E11       1.379E08
-45.6          1.044E-05      2.082E11       1.379E08
21.1           1.093E-05      2.034E11       1.379E08
93.3           1.148E-05      1.986E11       1.379E08
148.9          1.188E-05      1.951E11       1.379E08
204.4          1.228E-05      1.910E11       1.379E08
260            1.264E-05      1.882E11       1.303E08
315.6          1.301E-05      1.841E11       1.193E08
371.1          1.339E-05      1.758E11       1.145E08
426.7          1.377E-05      1.669E11       7.446E07
482.2          1.411E-05      1.544E11       4.482E07
537.8          1.435E-05      1.407E11       1.724E07
593.3          1.462E-05      1.241E11       6.895E06
MATNAM,A106GrdA
Spare Data Field , 0
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