PAULIN RESEARCH GROUP

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# Which WRC 107 or 297 parameters should I check? When is my geometry valid for a WRC 107 or 297 analysis of a nozzle on a pressure vessel subject to external loads?

?? $20 \le \frac{D}{T} \le 2500$ $U = \frac{C_1}{0.875\sqrt{R_M \cdot T}} \le 2.2$ ????

$\left(\frac{d}{D}\right)\sqrt{\frac{D}{T}} \le 10$ $U = \frac{r_O}{\sqrt{R_M \cdot T}} \le 2.2$ $\gamma = \frac{R_M}{T}$ $5 \le \gamma \le 300$

??? $\beta = \frac{0.875 \cdot r_O}{R_M} \le 0.50$ $\mathrm{T} = \frac{r_M}{T}$ $5 \le \mathrm{T} \le 50$ ???

? $\left(\frac{d_M}{D_M}\right)\sqrt{\frac{D_M}{T}} \le 2.0$ ?? $\rho = \frac{T}{t}$ $0.25 \le \rho \le 10$ ???

These are questions that don't have to be asked when the finite element templates used for the nozzle calculations have been used in ASME Code work and run more than 100,000 times.

FE107 also automatically compares 107 and 297 results against the finite element analyses (FEA) so that users can know when 107 or 297 calculations are accurate enough.

From the comparison of FEA with WRC 107 and WRC 297 results it's easy to know if you should feel comfortable with a design.

The table below shows an example of the output from FE107

| Source | Axial | In-Plane | Out-of-Plane | Torsion |
|---|---|---|---|---|
| FEA | 9.91 | 2.57 | 5.66 | 2.42 |
| WRC 107 | 11.69 | 3.54 | 6.90 | 6.90 |
| WRC 297 | 22.52 | 4.36 | 9.41 | 9.52 |

**Comparison of FEA, WRC107 and WRC297 Stress Intensification Factors (SIFs)**

In the example shown above, the WRC 107 and 297 results are too conservative, with the 297 results being overly conservative by about two times as is often the case.

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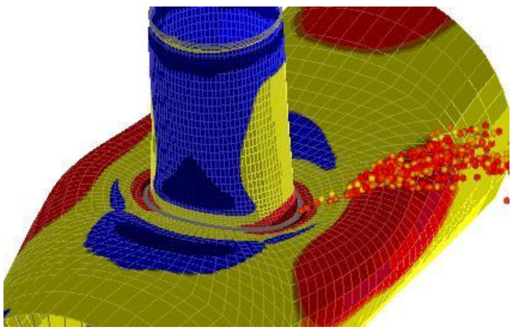
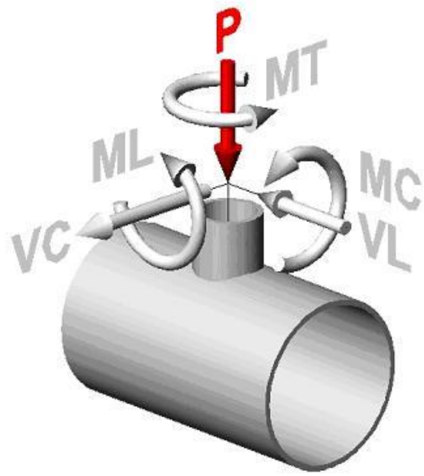
The conservatism or lack of conservatism is a function of the geometry of the problem – which is why all critical analyses should be checked.

FE107 also computes stresses AND allowable loads.



**FE107 stress plot showing high stress locations**




**Loads can be entered in local or global coordinates to avoid confusion.**

WRC 329 in Section 4.9 shows how the addition of a reinforcing pad to a nozzle would actually increase the stress because the reinforcing pad increases the stiffness, which increases the load more than the pad reduced the stress.

FE/107 solves this problem by providing correct stiffnesses, stresses and allowable loads.

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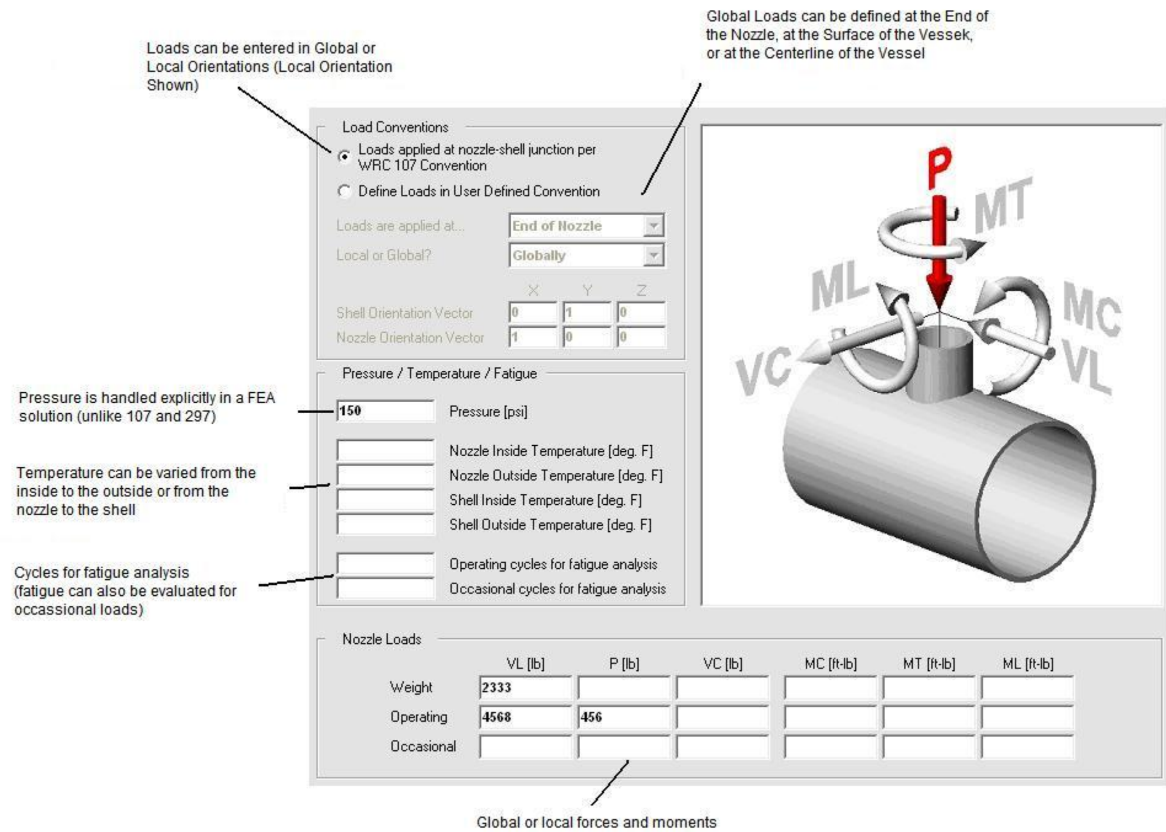
***Allowable Loads, Flexibilities, Stresses, ASME Output & "Inspector Ready" Reports***

Allowable loads and stiffnesses are calculated automatically without any loads being input. If the loads are input, FE107 will produce ASME Code output.




<u>Only four input values </u>are required to generate allowable loads, stress intensification factors and flexibilities – the diameter of the nozzle and vessel, and the thickness of the nozzle and vessel.

By Vessel Engineers – For Vessel Engineers!

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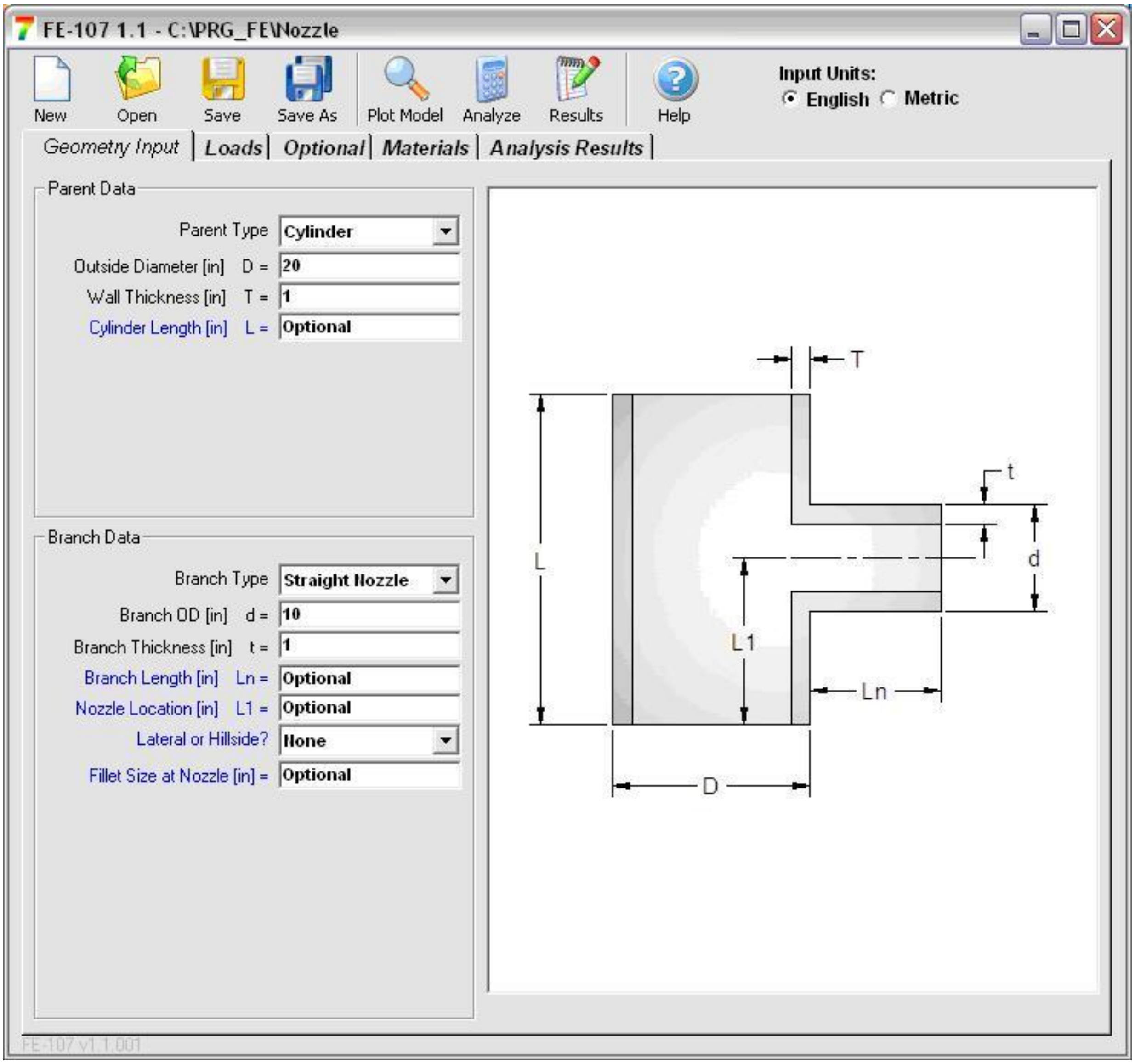
**Validating the use of WRC 107/297.**

*Simple to Understand Nozzle Input AND Output*

The input screen for FE107 is shown below:

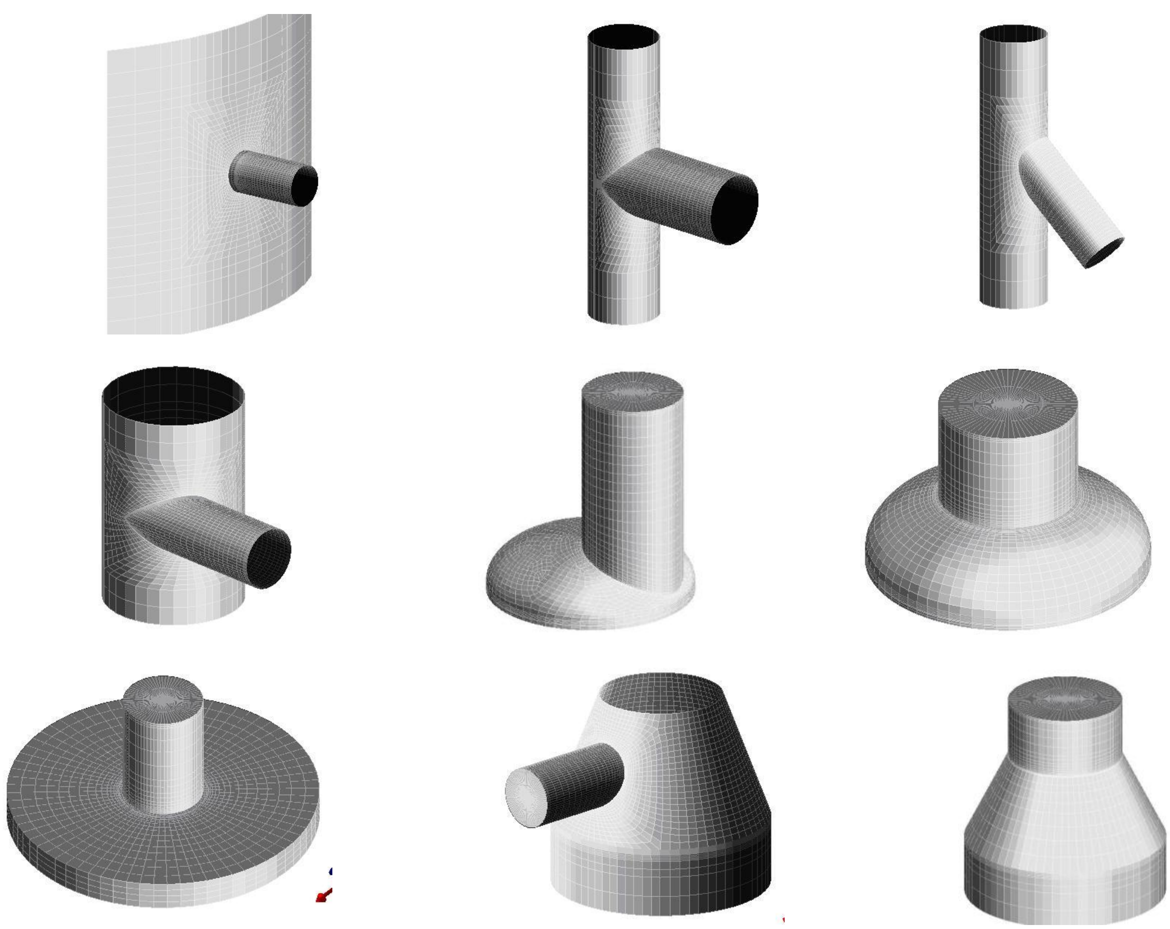



FE107 was designed by vessel engineers for vessel engineers. Anyone can put a square grid on intersection geometry these days, but understanding element types, penetration line models, boundary condition ovalization, beam load applications and Code stress calculations is an entirely different matter.

FE107 has a one minute learning curve and takes about two minutes to run.

***Various Geometries (with and without Pads)***

- Cylinder-to-cylinder intersections
- Hillside Nozzles
- Laterals
- Elliptical Heads
- Hemispherical Heads
- Dished Heads
- Conical Heads
- Flat Heads
- Pad Reinforced Nozzles
- Barrel Shaped Nozzles
- Straight Nozzles



Diameters, wall thicknesses, nozzle angles and offsets are the only inputs required to generate the above models.

Reinforcing pads and fillet weld sizes can also be entered.

*Stresses per FEA and WRC Compared*

FEA Stress | Allowables | Flexibilities | **FEA vs. WRC** | WRC 107 | WRC 297

A comparison between the maximum ASME Code stresses according to FEA, WRC-107, and WRC-297 are given in the following table. WRC-107 and WRC-297 results may be subject to error depending on the geometric parameters used in the analysis. More meaningful comparisons are made using the stress indices (see below).

| Location | Stress Category | FEA [psi] | WRC 107 [psi] | WRC 297 [psi] | Allowable [psi] |
|---|---|---|---|---|---|
| Nozzle | Max PL | 23914 | N.A. | 6246 | 30000 |
| Nozzle | Max PL+Pb+Q | 40757 | N.A. | 6246 | 60000 |
| Nozzle | Max PL+Pb+Q+F | 6952 | N.A. | 6246 | Varies |
| | | | | | |
| Shell or pad | Max PL | 23978 | 28814 | 30606 | 30000 |
| Shell or pad | Max PL+Pb+Q | 33348 | 50914 | 133176 | 60000 |
| Shell or pad | Max PL+Pb+Q+F | 38605 | 48218 | 127573 | Varies |

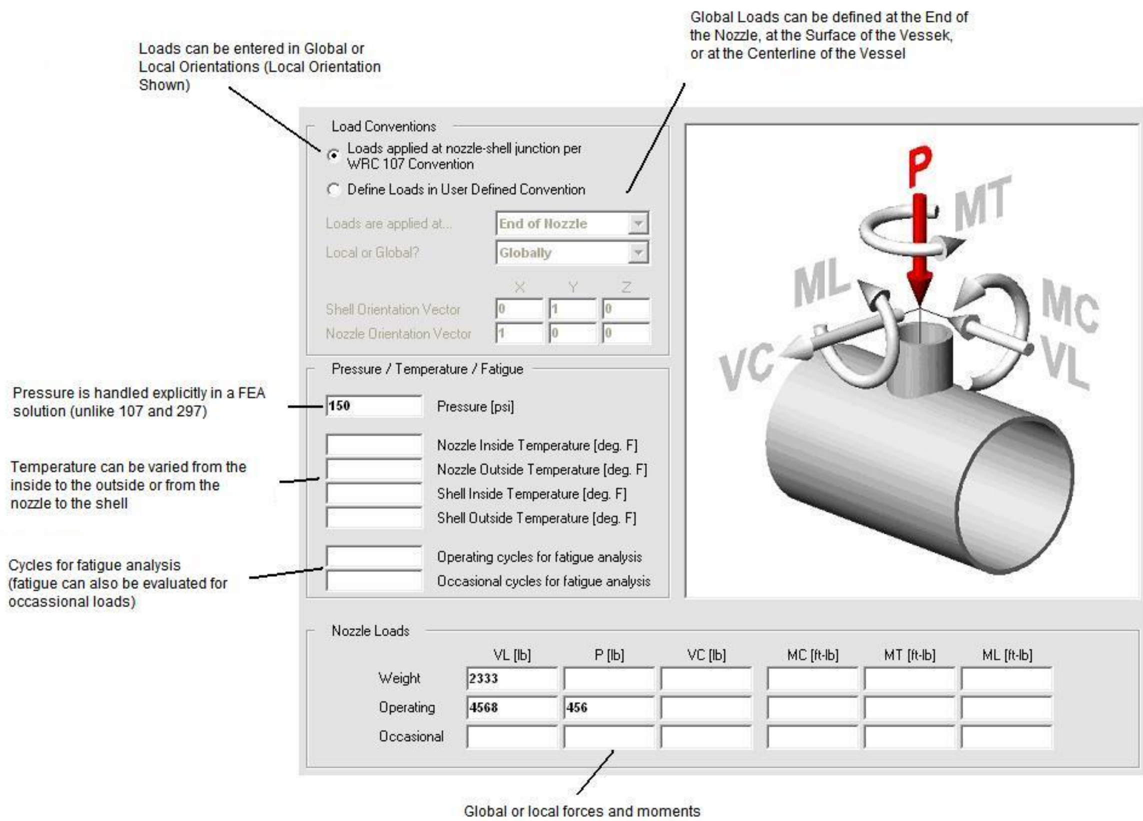
If the stress is 10% of the allowable, then you can be off by 10 times and still not have a problem. If the stress is 100% of the allowable, then you cannot be off at all!

**FE107 helps the user evaluate the criticality of a vessel nozzle geometry and the load.**

Load Definition is **<u>one of the biggest mistakes in nozzle analysis!</u>**

**Don't get the load directions wrong!**

FE107 load input is clear and uncomplicated.




**Local and global definitions of loads are available, along with pressure and varying temperature analyses.**

Material properties come into FE107 automatically from MatPRO.

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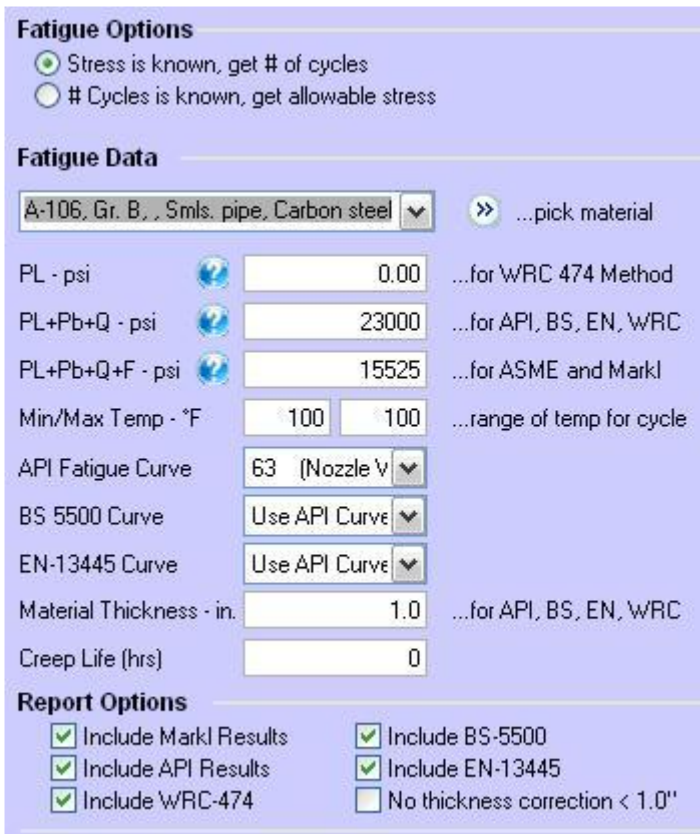
*MatPRO – Materials for FE107 and much more!*

FE107 links to the powerful and economically priced material database and "condition calculator" MatPRO.

- How close a stress is to cyclic failure
- If creep-fatigue interaction is a concern
- Whether a crack, corroded, or eroded area satisfies API 579 Fitness for Service Rules

MatPRO features are listed on the MatPRO product page.




MatPRO lets you enter stresses from CAESAR, ANSYS, or any other program! Read more about using MatPRO.

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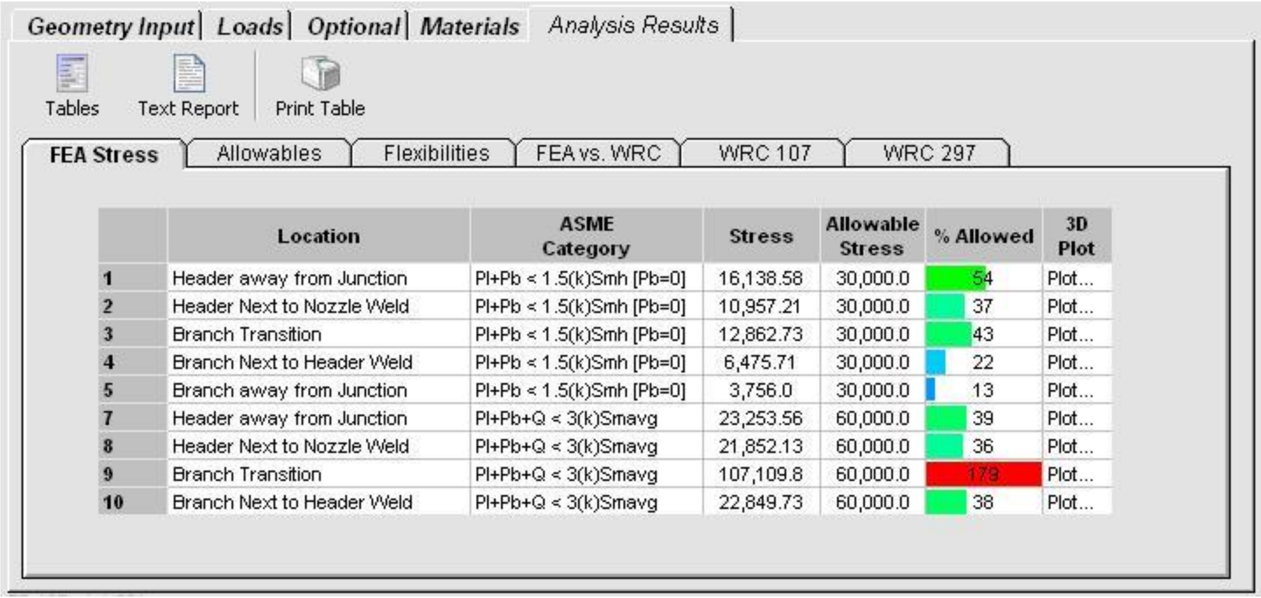
*FE107 results are easy to understand and use.*




| | Location | ASME Category | Stress | Allowable Stress | % Allowed | 3D Plot |
|---|---|---|---|---|---|---|
| 1 | Header away from Junction | Pl+Pb < 1.5(k)Smh [Pb=0] | 16,138.58 | 30,000.0 | 54 | Plot... |
| 2 | Header Next to Nozzle Weld | Pl+Pb < 1.5(k)Smh [Pb=0] | 10,957.21 | 30,000.0 | 37 | Plot... |
| 3 | Branch Transition | Pl+Pb < 1.5(k)Smh [Pb=0] | 12,862.73 | 30,000.0 | 43 | Plot... |
| 4 | Branch Next to Header Weld | Pl+Pb < 1.5(k)Smh [Pb=0] | 6,475.71 | 30,000.0 | 22 | Plot... |
| 5 | Branch away from Junction | Pl+Pb < 1.5(k)Smh [Pb=0] | 3,756.0 | 30,000.0 | 13 | Plot... |
| 7 | Header away from Junction | Pl+Pb+Q < 3(k)Smavg | 23,253.56 | 60,000.0 | 39 | Plot... |
| 8 | Header Next to Nozzle Weld | Pl+Pb+Q < 3(k)Smavg | 21,852.13 | 60,000.0 | 36 | Plot... |
| 9 | Branch Transition | Pl+Pb+Q < 3(k)Smavg | 107,109.8 | 60,000.0 | 179 | Plot... |
| 10 | Branch Next to Header Weld | Pl+Pb+Q < 3(k)Smavg | 22,849.73 | 60,000.0 | 38 | Plot... |

Stresses are classified by location in the model. ASME Allowable values are color coded for easy identification. 3D plots animated results for each ASME Code stress category are available with the click of a button.

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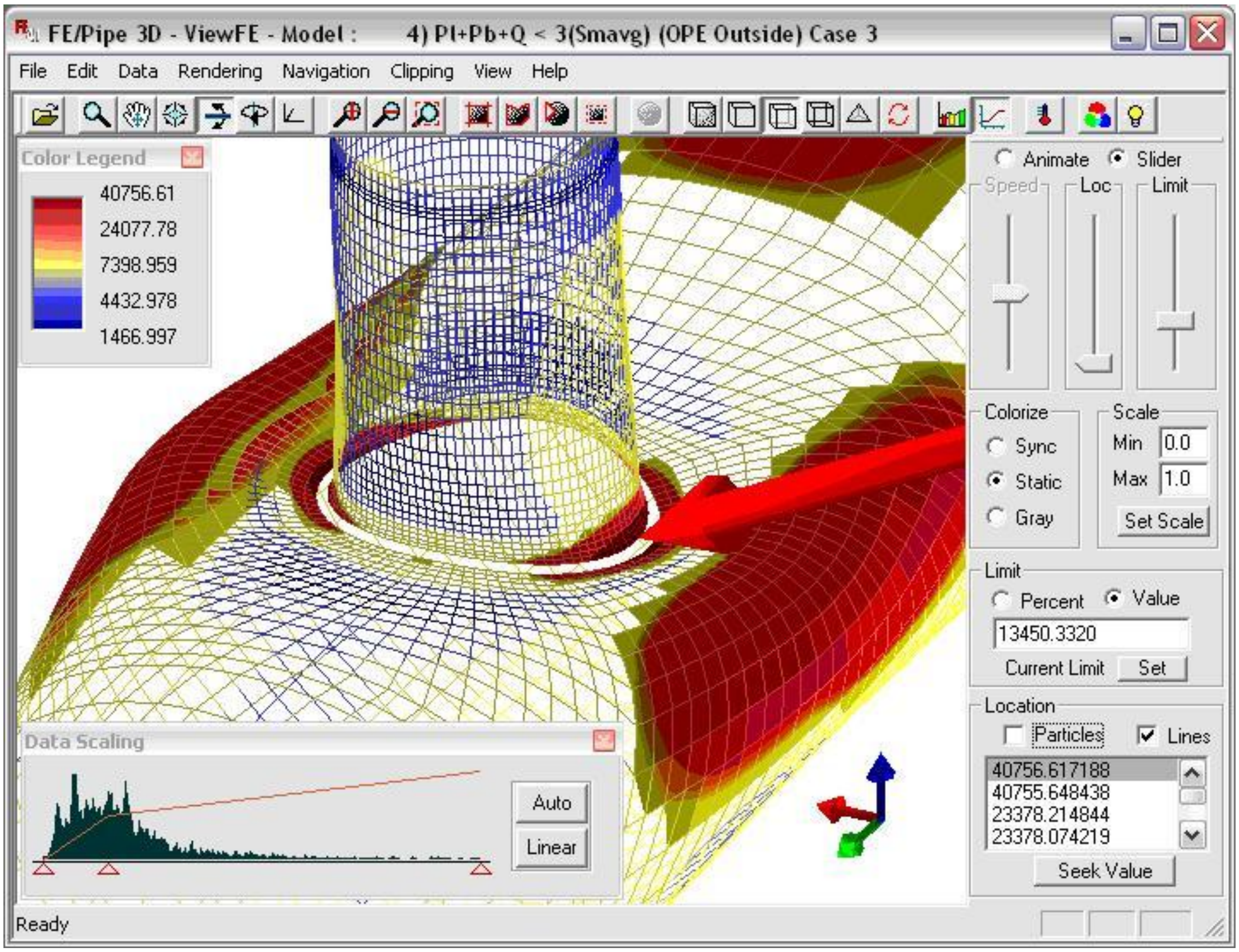
*Graphics You Can Use!*

FE107 graphic engine was designed by the first Microsoft® VIP for DirectX® and Tony Paulin, and was designed for pressure vessel and piping geometries.




Rotate, pan and zoon animated displaced shape models while viewing static or dynamic stress states. Stresses beyond certain limits may be shown, arrows and sprites can be used to show the highest stress state and a variety of other interrogation tools are available.

The FE107 animated graphics is the fastest way possible to review and validate finite element output results.

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**Validating the use of WRC 107/297.**

*Inspector Ready Reports*

The key to any analysis is communicating the results to others.

It's not just good enough to "know" the system is OK, a concise, easy to understand report must make that clear to the inspector and the owner. FE107 generates automatic reports *with figures and graphics* showing input values, FEA plots and colorized stress tables.

```
                        GEOMETRY INPUT
=======================================================
Dimensions for Cylindrical Shell
Outside Diameter                  D =         33 [in.]
Wall Thickness                    T =          1 [in.]

Dimensions for Unreinforced Branch
Branch Diameter                   d =         12 [in.]
Branch Wall Thickness             t =          1 [in.]
```

Geometry Input | Loads | Optional | Materials | Analysis Results

Tables   Text Report   Print Table

FEA Stress | Allowables | Flexibilities | FEA vs. WRC | WRC 107 | WRC 297

| | Location | ASME Category | Stress | Allowable Stress | % Allowed | 3D Plot |
|---|---|---|---|---|---|---|
| 1 | Header away from Junction | Pl+Pb < 1.5(k)Smh [Pb=0] | 16,138.58 | 30,000.0 | 54 | Plot... |
| 2 | Header Next to Nozzle Weld | Pl+Pb < 1.5(k)Smh [Pb=0] | 10,957.21 | 30,000.0 | 37 | Plot... |
| 3 | Branch Transition | Pl+Pb < 1.5(k)Smh [Pb=0] | 12,862.73 | 30,000.0 | 43 | Plot... |
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*Start with No Obligation!*

A SHAREWARE version of FE107 is available on the PRG website that includes WRC 107 and WRC 297 capability without the FEA.

The SHAREWARE download is smaller than 5Mb and can be emailed anywhere.

For more information, please contact us at Sales@paulin.com