

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?

$$\begin{aligned}
 &?? \quad 20 \leq \frac{D}{T} \leq 2500 \quad U = \frac{C_1}{0.875 \sqrt{R_M \cdot T}} \leq 2.2 \quad ??? \\
 &\left(\frac{d}{D}\right) \sqrt{\frac{D}{T}} \leq 10 \quad U = \frac{r_o}{\sqrt{R_M \cdot T}} \leq 2.2 \quad \gamma = \frac{R_M}{T} \quad 5 \leq \gamma \leq 300 \\
 &?? \quad \beta = \frac{0.875 \cdot r_o}{R_M} \leq 0.50 \quad T = \frac{r_M}{T} \quad 5 \leq T \leq 50 \quad ??? \\
 &? \quad \left(\frac{d_M}{D_M}\right) \sqrt{\frac{D_M}{T}} \leq 2.0 \quad \rho = \frac{T}{t} \quad 0.25 \leq \rho \leq 10 \quad ?? \quad ???
 \end{aligned}$$

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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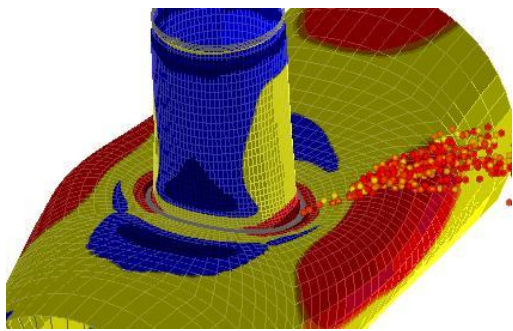
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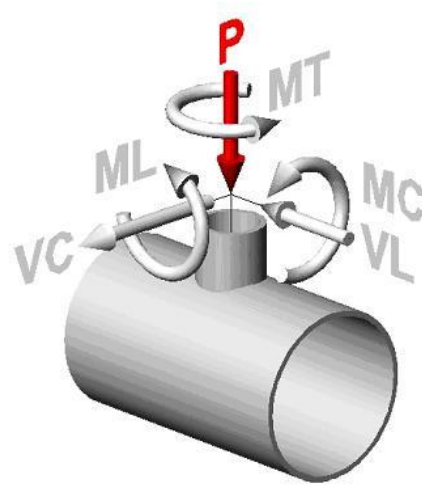
Validating the use of WRC 107/297.

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.

Loads can be entered in Global or Local Orientations (Local Orientation Shown)

Global Loads can be defined at the End of the Nozzle, at the Surface of the Vessel, or at the Centerline of the Vessel

Pressure is handled explicitly in a FEA solution (unlike 107 and 297)

Temperature can be varied from the inside to the outside or from the nozzle to the shell

Cycles for fatigue analysis (fatigue can also be evaluated for occasional loads)

Load Conventions

Loads applied at nozzle-shell junction per WRC 107 Convention

Define Loads in User Defined Convention

Loads are applied at...

Local or Global?

Shell Orientation Vector: X=0, Y=1, Z=0

Nozzle Orientation Vector: X=1, Y=0, Z=0

Pressure / Temperature / Fatigue

Pressure [psi]

Nozzle Inside Temperature [deg. F]

Nozzle Outside Temperature [deg. F]

Shell Inside Temperature [deg. F]

Shell Outside Temperature [deg. F]

Operating cycles for fatigue analysis

Occasional cycles for fatigue analysis

Nozzle Loads

	VL [lb]	P [lb]	VC [lb]	MC [ft-lb]	MT [ft-lb]	ML [ft-lb]
Weight	2333					
Operating	4568	456				
Occasional						

Global or local forces and moments

Only four input values 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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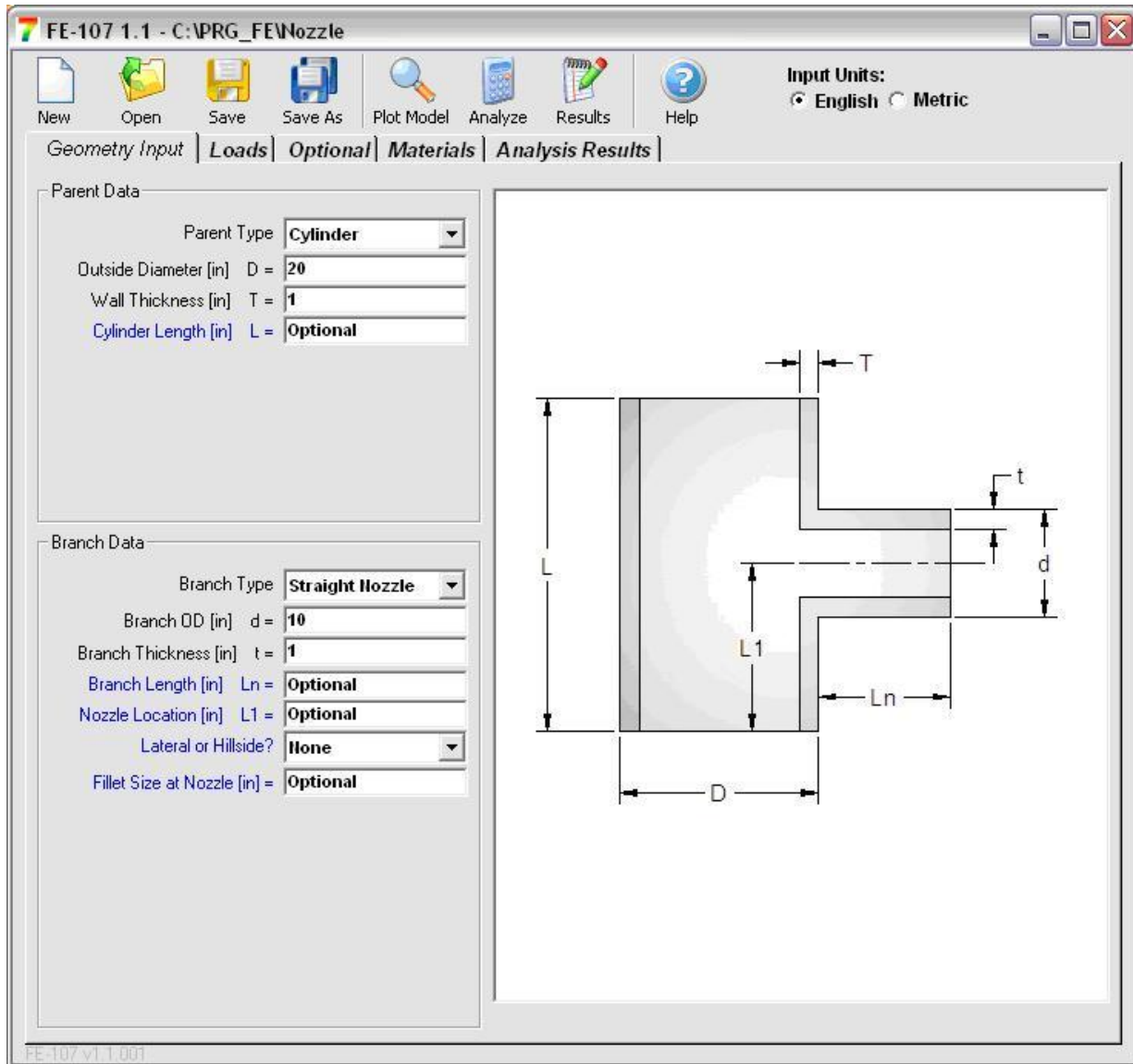
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Simple to Understand Nozzle Input AND Output

The input screen for FE107 is shown below:

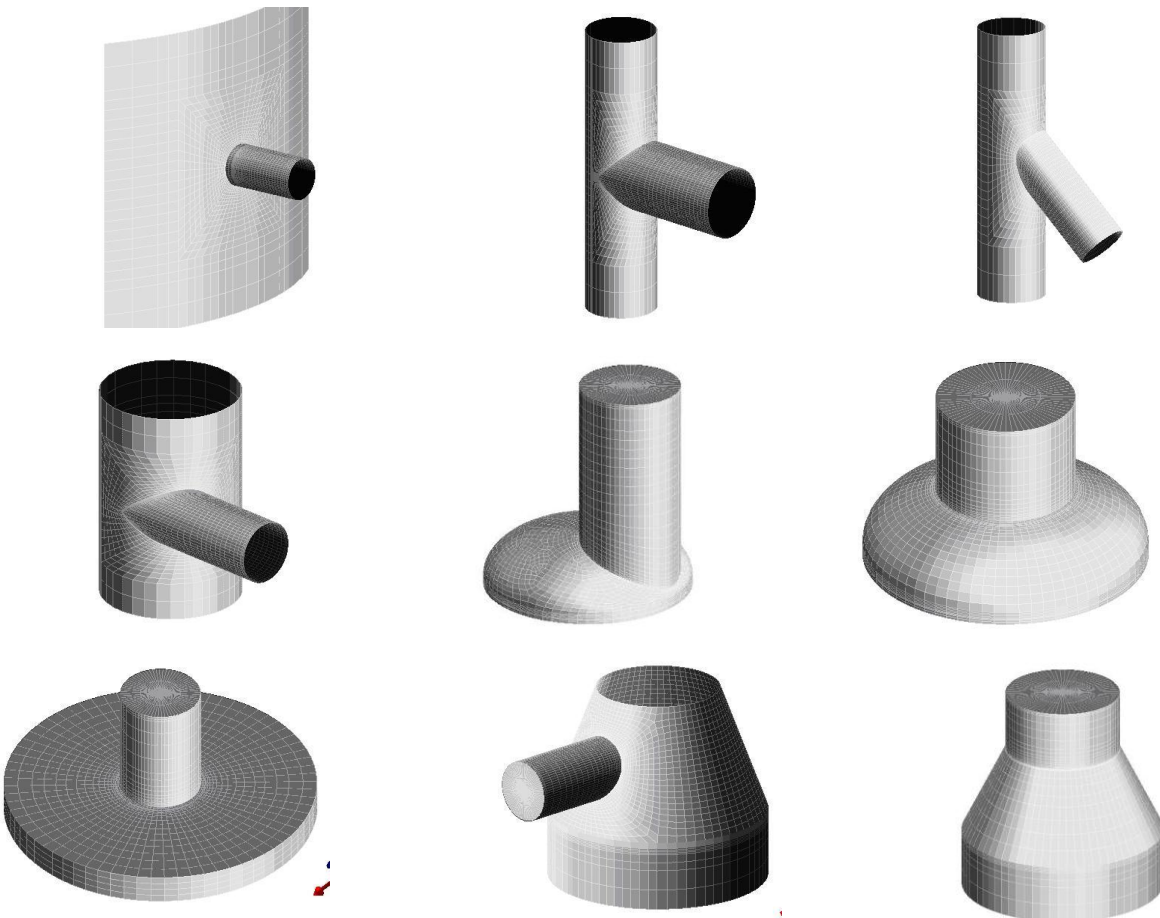


FE107 was designed by vessel engineers for vessel engineers. Anyone can put a square grid on intersection geometry these days, but understanding element types, penetration line models, boundary condition ovalization, beam load applications and Code stress calculations is an entirely different matter.

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.

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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.

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Load Definition is **one of the biggest mistakes in nozzle analysis!**

Don't get the load directions wrong!

FE107 load input is clear and uncomplicated.

Loads can be entered in Global or Local Orientations (Local Orientation Shown)

Global Loads can be defined at the End of the Nozzle, at the Surface of the Vessel, or at the Centerline of the Vessel

Pressure is handled explicitly in a FEA solution (unlike 107 and 297)

Temperature can be varied from the inside to the outside or from the nozzle to the shell

Cycles for fatigue analysis (fatigue can also be evaluated for occasional loads)

Global or local forces and moments

Load Conventions

Loads applied at nozzle-shell junction per WRC 107 Convention

Define Loads in User Defined Convention

Loads are applied at...

Local or Global?

Shell Orientation Vector

X	Y	Z
0	1	0

Nozzle Orientation Vector

X	Y	Z
1	0	0

Pressure / Temperature / Fatigue

Pressure [psi]

Nozzle Inside Temperature [deg. F]

Nozzle Outside Temperature [deg. F]

Shell Inside Temperature [deg. F]

Shell Outside Temperature [deg. F]

Operating cycles for fatigue analysis

Occasional cycles for fatigue analysis

Nozzle Loads

	VL [lb]	P [lb]	VC [lb]	MC [ft-lb]	MT [ft-lb]	ML [ft-lb]
Weight	2333					
Operating	4568	456				
Occasional						

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](#).

The screenshot displays the MatPRO software interface with the following sections:

- Fatigue Options:** Two radio buttons are present. The first, "Stress is known, get # of cycles", is selected. The second, "# Cycles is known, get allowable stress", is unselected.
- Fatigue Data:** A dropdown menu shows "A-106, Gr. B, Smls. pipe, Carbon steel". To its right is a button with a double arrow and the text "...pick material". Below this are several input fields:
 - PL - psi: 0.00 (with a globe icon and "...for WRC 474 Method")
 - PL+Pb+Q - psi: 23000 (with a globe icon and "...for API, BS, EN, WRC")
 - PL+Pb+Q+F - psi: 15525 (with a globe icon and "...for ASME and MarkI")
 - Min/Max Temp - °F: 100 and 100 (with "...range of temp for cycle")
 - API Fatigue Curve: 63 (Nozzle V) (with a dropdown arrow)
 - BS 5500 Curve: Use API Curve (with a dropdown arrow)
 - EN-13445 Curve: Use API Curve (with a dropdown arrow)
 - Material Thickness - in.: 1.0 (with "...for API, BS, EN, WRC")
 - Creep Life (hrs): 0
- Report Options:** A grid of checkboxes:
 - Include MarkI Results: checked
 - Include API Results: checked
 - Include WRC-474: checked
 - Include BS-5500: checked
 - Include EN-13445: checked
 - No thickness correction < 1.0": unchecked

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	PI+Pb < 1.5(k)Smh [Pb=0]	16,138.58	30,000.0	54	Plot...
2	Header Next to Nozzle Weld	PI+Pb < 1.5(k)Smh [Pb=0]	10,957.21	30,000.0	37	Plot...
3	Branch Transition	PI+Pb < 1.5(k)Smh [Pb=0]	12,862.73	30,000.0	43	Plot...
4	Branch Next to Header Weld	PI+Pb < 1.5(k)Smh [Pb=0]	6,475.71	30,000.0	22	Plot...
5	Branch away from Junction	PI+Pb < 1.5(k)Smh [Pb=0]	3,756.0	30,000.0	13	Plot...
7	Header away from Junction	PI+Pb+Q < 3(k)Smavg	23,253.56	60,000.0	39	Plot...
8	Header Next to Nozzle Weld	PI+Pb+Q < 3(k)Smavg	21,852.13	60,000.0	36	Plot...
9	Branch Transition	PI+Pb+Q < 3(k)Smavg	107,109.8	60,000.0	179	Plot...
10	Branch Next to Header Weld	PI+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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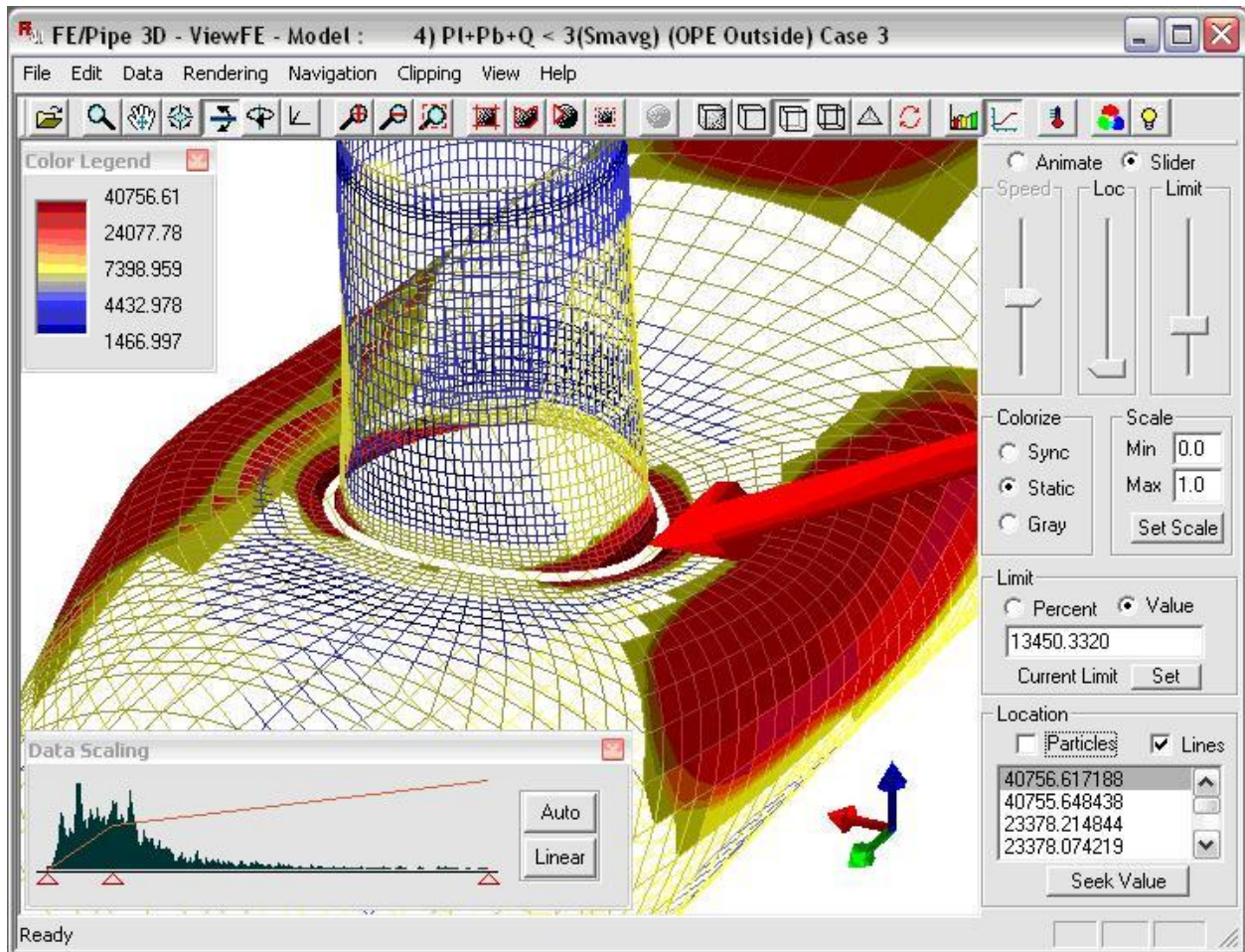
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Graphics You Can Use!

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 zoom 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.

