COADE's Application of Welding Research Council Bulletins 107, 297 and 368.

- WRC-107, entitled "Local Stresses in Spherical and Cylindrical Shells due to External Loadings", was released in 1965 and updated in 1979. WRC-297 was released in 1984 and goes under the title of "Local Stresses in Cylindrical Shells due to External Loadings – Supplement to WRC Bulletin No. 107"

- Both deal with "local" stress states in the vicinity of an attachment to a vessel or pipe. As indicated by their titles, WRC-107 can be used for attachments to both spherical and cylindrical shells while WRC-297 only addresses cylinder to cylinder connections. While both bulletins are used for nozzle connection. WRC-107 is based on un-penetrated shell, while WRC-297 assumes a circular opening in vessel. Both bulletins assume that the nozzle (or attachment) axis is normal to the vessel. Furthermore, WRC-107 defines values for solid and hollow attachments of either round and rectangular shape for spherical shells but drops the solid/hollow distinction for attachments to cylindrical shells. WRC-297, on the other hand, is intended only for cylindrical nozzles attached to cylindrical shells.

- The cook-book approach found in WRC-107 resulted from the analytical work of Prof. P. P. Bijlaard and assume a shallow shell theory for spherical shells and flexible loading surfaces for cylindrical vessels. Therefore, WRC-107 requires that the D_m/T ratio be greater than 50 and limits the d/D ratio to below 0.3.

- WRC-297 can be applied to a larger d/D ratio (up to 0.5) since the analysis is based on a different, thin shell theory (derived and developed by Prof. C. R. Steele).

- WRC-107 only computes the stress states of the vessel/header shell while WRC-297 also provides stress states for the nozzle/branch connection. WRC-297 also provides calculations for nozzle/branch flexibilities.

- Neither bulletin considers shell reinforcement nor do they address stress due to pressure.

- There are several limitations to the proper application of these bulletins. These limits are listed below. CAESAR II and PVElite & CodeCalc will not extrapolate data from the charts when they are exceeded. Extrapolated data may not be appropriate.

WRC-107:

Spherical Shells

- $d_i/D_i \leq 1/3$ but less if D_m/T between 20-55
- $U \leq 2.2$ ($U = ro / ((R_m T)^{0.5}$, for nozzle and $= C_1/ (0.875(R_m T)^{0.5})$ for square attachment)
- $0.25 \leq t/T \leq 10$
- $5 \leq r_m/t \leq 50$

Cylindrical Shells:

- $d/D \leq ¼$ for cylinders or < 0.6 with significant warnings
- $D/T \leq 600$
- $L/D \geq 1.5$
- $¼ \leq C_1/C_2 \leq 4$

WRC-297:

- $20 \leq d/t \leq 100$ unless nozzle is "rigid" (having a large t), then any d/t is valid
- $20 \leq D/T \leq 2500$
- $d/T \geq 5$
- $d/D \leq 0.5$ (but also dependent on D/T), however, subsequent evaluation show d/D should be ≤ 0.33
- Nozzle must be isolated (it may not be close to a discontinuity) – not within $2\sqrt{DT}$ on vessel and not within $2\sqrt{dt}$ on nozzle
- Nozzle axis is normal to the vessel.
- Not applicable for the nozzles that protrude inside the vessel.
- It is advisable to check vessel stresses when the pipe stress on the attached nozzle exceeds 2/3's of the allowable limit.
- WRC 107 & WRC 297 can give different results in some situations.
- Typically, WRC-107 is used for local stress calculations and WRC-297 is used for flexibility calculations.

WRC Bulletin 368

WRC-368, entitled "Stresses in Intersecting Cylinders Subjected to Pressure" was released in 1991. It is based on the finite element analyses performed by Prof. C.R. Steele, using the same program that was used in the development of WRC-297.

- WRC-368 addresses *internal pressure* loads for *nozzle-cylinder* junctions
- It reports the *maximum* Membrane (Pm+Pl) and the *maximum* Membrane+Bending (Pm+Pl+Q) stress intensities (due to internal pressure) in both shell and nozzle.
- It does not explicitly address reinforcing pads, though it gives a rule of thumb on when to include their effects—include the pad if the pad width is greater than both $1.65 * \sqrt{RT}$ and $d / 2$.
- It has geometric limitations similar to those in WRC Bulletins 107 and 297.
    - $10 < D/T < 1000$
    - $4 < d/t < 1000$
    - $0.1 < t/T < 3$
    - $0.3 < Dt/dT < 6$
    - $0.3 < d / \sqrt{Dt} < 6.5$
    - Nozzle must be isolated (it may not be close to a discontinuity) – not within $2.5\sqrt{RT}$ on vessel and not within $2.5\sqrt{rt}$ on nozzle
    - Results are based on nozzles extending normal to the vessel, on the outside only.
- WRC-368 uses the full load due to pressure thrust ($P * A_{in}$), even though the attached piping may reduce or even eliminate this structural load.
- The maximum stress intensities (due to internal pressure) for Pm+Pl and Pm+Pl+Q from WRC-368 may be combined with other stress intensity components (Pl and Q) obtained using WRC-107 (or WRC-297) caused by sustained and expansion loads. But, WRC-368 does not provide the location of maximum stress intensity. Moreover, the location of maximum internal pressure stress may different from the point where stress from external loads is highest. So, it can be very conservative to combine the results from WRC-368 to that from WRC-107/297.

  Note that when evaluating Pm stress intensity alone, this Pm should be based on Code-provided equations.
- For cases **without a pad,** the stress intensities from WRC 368 were relatively close to the FEA results (within +/- 20%).
- This bulletin is implemented in PVElite and CodeCalc.