

$$4.5 - 2(0.337) = 3.826 \text{ in.}$$

Since I.D. is less than 4.34 in., no calculation need be made to demonstrate compliance with the compensation requirements of PG-33.

(23) **A-69**

A vessel has a series of welded connections in a definite pattern as shown in Figure A-69. The maximum allowable stress of all nozzle and vessel material is 17,500 psi. The maximum allowable working pressure of the design is 1,500 psig. See Figure A-69 for all nozzle and vessel dimensions.

The welded attachments do not qualify for the exception provided in PG-32 and must therefore comply with PG-33 as follows:

Minimum required thickness for reinforcement consideration

$$\begin{aligned} \text{Shell } t_r &= \frac{PR_v}{S_v - (1 - y)P} \\ &= \frac{1,500 \times 30}{17,500 - (1 - 0.4) \times 1500} \\ &= 2.711 \text{ in.} \\ \text{Nozzle } t_{rn} \text{ 1 and 4} &= \frac{P(0.5 d_{l1} - t_{n1})}{S_n - (1 - y)P} \\ &= \frac{1,500(0.5 \times 4.5 - 0.875)}{17,500 - (1 - 0.4) \times 1500} \\ &= 0.124 \text{ in.} \\ \text{Nozzle } t_{rn} \text{ 2 and 3} &= \frac{P(0.5 d_{l2} - t_{n2})}{S_n - (1 - y)P} \\ &= \frac{1,500(0.5 \times 5 - 1.0)}{17,500 - (1 - 0.4) \times 1500} \\ &= 0.136 \text{ in.} \end{aligned}$$

Check for overlapping limits

The sum of the limits of reinforcement on the longitudinal axis between nozzles 1 and 2, as permitted under PG-36.2.2, is

$$\begin{aligned} &= \left(\frac{d_1}{2} + t_{n1} + t \right) + \left(\frac{d_2}{2} + t_{n2} + t \right) \\ &= \frac{2.75}{2} + 0.875 + 3.25 + \frac{3.0}{2} + 1.0 + 3.25 \\ &= 11.25 \text{ in.} > D_1 \end{aligned}$$

The sum of the limits of reinforcement on the circumferential axis between nozzles 2 and 3 is

$$\begin{aligned} &= \left(\frac{d_2}{2} + t_{n2} + t \right) + \left(\frac{d_3}{2} + t_{n3} + t \right) \\ &= \frac{3.0}{2} + 1.0 + 3.25 + \frac{3.0}{2} + 1.0 + 3.25 \\ &= 11.5 \text{ in.} > D_2 \end{aligned}$$

The sum of the limits of reinforcement on the diagonal between nozzles 3 and 4 is

$$\begin{aligned} &= \left(\frac{d_3}{2} + t_{n3} + t \right) + \left(\frac{d_4}{2} + t_{n4} + t \right) \\ &= \frac{3.0}{2} + 1.0 + 3.25 + \frac{2.75}{2} + 0.875 + 3.25 \\ &= 11.25 \text{ in.} > D_3 \end{aligned}$$

Each of the above conditions is greater than the center-to-center distance, for the condition considered, between the openings; therefore, the limits of reinforcement overlap and the rule of PG-38.1 shall apply.

Nozzles 1 and 4 — area of reinforcement required in the longitudinal plane

$$\begin{aligned} A_{l1} &= (d_1 + 2t_{n1})t_r F \\ &= (2.75 + 2 \times 0.875) \times 2.711 \times 1.0 \\ &= 12.199 \text{ in.}^2 \end{aligned}$$

Nozzles 2 and 3 — area of reinforcement required in the longitudinal plane

$$\begin{aligned} A_{l2} &= (d_2 + 2t_{n2})t_r F \\ &= (3.0 + 2 \times 1.0) \times 2.711 \times 1.0 \\ &= 13.554 \text{ in.}^2 \end{aligned}$$

Nozzles 2 and 3 — area of reinforcement required in the circumferential plane

$$\begin{aligned} A_{c2} &= (d_2 + 2t_{n2})t_r F \\ &= (3.0 + 2 \times 1.0) \times 2.711 \times 0.5 \\ &= 6.777 \text{ in.}^2 \end{aligned}$$

Nozzle 3 — area of reinforcement required in the diagonal plane

$$\begin{aligned} A_{d3} &= (d_3 + 2t_{n3})t_r F \\ &= (3.0 + 2 \times 1.0) \times 2.711 \times 0.88 \\ &= 11.928 \text{ in.}^2 \end{aligned}$$

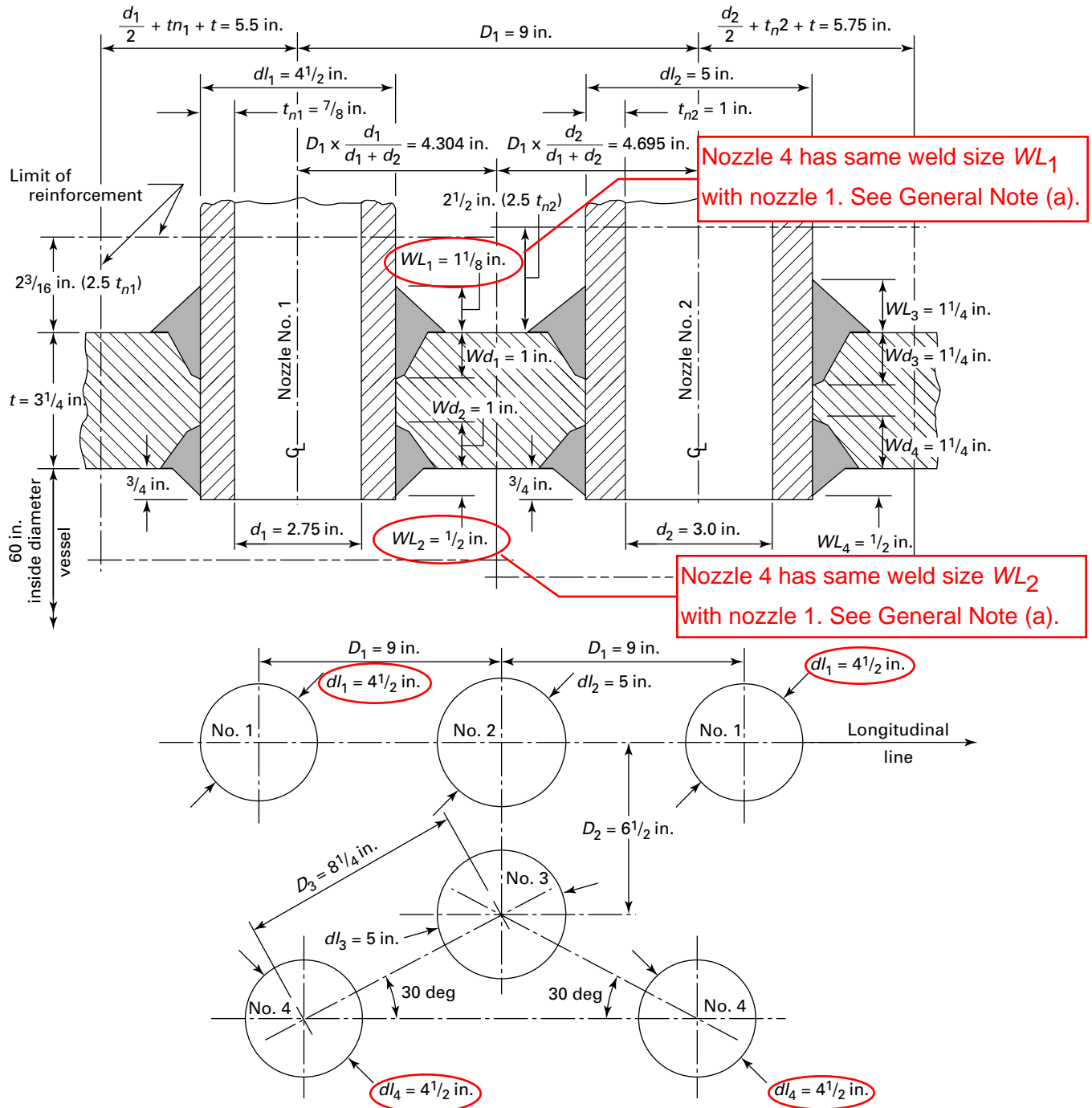
Nozzle 4 — area of reinforcement required in the diagonal plane

$$\begin{aligned} A_{d4} &= (d_4 + 2t_{n4})t_r F \\ &= (2.75 + 2 \times 0.875) \times 2.711 \times 0.88 \\ &= 10.735 \text{ in.}^2 \end{aligned}$$

Area of reinforcement provided in nozzle 1 in the longitudinal plane

Since $w_d = 0$ and due to the overlapping limits of reinforcement, the equation for A_1 (given in Figure PG-33.1) will require modification. To prevent any reinforcement available between the nozzles from being counted more than once, the reinforcement limit is reduced such that the available reinforcement in the shell is divided and attributed to either nozzle's compensation in proportion to its relative size. For nozzle 1, this limit is $D_1 [d_1 / (d_1 + d_2)]$. The limit on the other side remains unchanged as $d_1/2 + t_{n1} + t$.

Figure A-69
Example for Typical Nozzle Computations



GENERAL NOTES:

- Nozzles 1 and 4 are identical dimensionally and nozzles 2 and 3 are identical dimensionally.
- This example was performed using computer software. The example was generated by performing the entire calculation without rounding off during each step. Accuracy of the final results beyond three significant figures is not intended or required.

$$\begin{aligned}
 A_1 &= \left\{ t + D_1 [d_1 / (d_1 + d_2)] - \frac{d_1}{2} \right\} \\
 &\quad (t - Ft_r) \\
 &= \{ 3.25 + 9 [2.75 / (2.75 + 3.0)] \\
 &\quad - 4.5/2 \} \times (3.25 - 1.0 \times 2.711) \\
 &= 2.860 \text{ in.}^2 \\
 A_2 &= 2(t_{n1} - t_{rn1}) 2.5 t_{n1} \\
 &= 2(0.875 - 0.12424) \times 2.5 \times 0.875 \\
 &= 3.285 \text{ in.}^2 \\
 A_3 &= 2 t_{n1} h \\
 &= 2 \times 0.875 \times 4.0 \\
 &= 7.0 \text{ in.}^2 \\
 A_{41} + A_{43} &= WL_1^2 + WL_2^2 \\
 &= 1.125^2 + 0.5^2 \\
 &= 1.516 \text{ in.}^2
 \end{aligned}$$

Total area of available reinforcement provided by nozzle 1 in the longitudinal plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 14.660 \text{ in.}^2 \geq A_{I1}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided in nozzle 2 in the longitudinal plane

Since nozzle 2 has its limits of reinforcement restricted on both sides by nozzle 1, the reduced limit of $D_1 [d_2 / (d_1 + d_2)]$ is applicable to both sides.

$$\begin{aligned}
 A_1 &= \{ 2 \times D_1 [d_2 / (d_1 + d_2)] - d_2 \} \\
 &\quad (t - Ft_r) \\
 &= \{ 2 \times 9 [3.0 / (2.75 + 3.0)] - 5.0 \} \\
 &\quad \times (3.25 - 1.0 \times 2.711) \\
 &= 2.368 \text{ in.}^2 \\
 A_2 &= 2(t_{n2} - t_{rn2}) 2.5 t_{n2} \\
 &= 2(1.0 - 0.136) \times 2.5 \times 1.0 \\
 &= 4.322 \text{ in.}^2 \\
 A_3 &= 2 t_{n2} h \\
 &= 2 \times 1.0 \times 4.0 \\
 &= 8.0 \text{ in.}^2 \\
 A_{41} + A_{43} &= WL_3^2 + WL_4^2 \\
 &= 1.25^2 + 0.5^2 \\
 &= 1.812 \text{ in.}^2
 \end{aligned}$$

Total area of available reinforcement provided by nozzle 2 in the longitudinal plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 16.502 \text{ in.}^2 \geq A_{I2}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided in nozzle 2 or 3 in the circumferential plane

$$\begin{aligned}
 A_1 &= \left\{ t + D_2 [d_2 / (d_2 + d_3)] - \frac{d_2}{2} \right\} \\
 &\quad (t - Ft_r) \\
 &= \left\{ 3.25 + 6.5 [3.0 / (3.0 + 3.0)] - \frac{5.0}{2} \right\} \\
 &\quad \times (3.25 - 0.5 \times 2.711) \\
 &= 7.578 \text{ in.}^2 \\
 A_2 &= 2(t_{n2} - t_{rn2}) 2.5 t_{n2} \\
 &= 2(1.0 - 0.13554) \times 2.5 \times 1.0 \\
 &= 4.3223 \text{ in.}^2 \\
 A_3 &= 2 t_{n2} h \\
 &= 2 \times 1.0 \times 4.0 \\
 &= 8.0 \text{ in.}^2 \\
 A_{41} + A_{43} &= WL_3^2 + WL_4^2 \\
 &= 1.25^2 + 0.5^2 \\
 &= 1.8125 \text{ in.}^2
 \end{aligned}$$

Total area of available reinforcement provided by nozzle 2 or 3 in the circumferential plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 21.713 \text{ in.}^2 \geq A_{c2}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided by nozzle 3 in the diagonal plane

Although nozzle 1 does not lie exactly in the same plane as nozzles 3 and 4 and is slightly farther away, for simplicity the limit on both sides of nozzle 3 are restricted to the reduced limit between nozzles 3 and 4.

$$\begin{aligned}
 A_1 &= \{ 2 \times D_3 [d_3 / (d_3 + d_4)] - d_3 \} \\
 &\quad (t - Ft_r) \\
 &= \{ 2 \times 8.25 \times [3.0 / (3.0 + 2.75)] - 5.0 \} \\
 &\quad \times (3.25 - 0.88 \times 2.711) \\
 &= 3.120 \text{ in.}^2 \\
 A_2 &= 2(t_{n3} - t_{rn3}) 2.5 t_{n3} \\
 &= 2(1.0 - 0.136) \times 2.5 \times 1.0 \\
 &= 4.322 \text{ in.}^2 \\
 A_3 &= 2 t_{n3} h \\
 &= 2 \times 1.0 \times 4.0 \\
 &= 8.0 \text{ in.}^2 \\
 A_{41} + A_{43} &= WL_3^2 + WL_4^2 \\
 &= 1.25^2 + 0.5^2 \\
 &= 1.812 \text{ in.}^2
 \end{aligned}$$

Total area of available reinforcement provided by nozzle 3 in the diagonal plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 17.254 \text{ in.}^2 \geq A_{d3}$$

as required for demonstration of compliance with PG-33.

Area of reinforcement provided in nozzle 4 in the diagonal plane

$$\begin{aligned}
 A_1 &= \left\{ t + D_3 \times [d_4 / (d_4 + d_3)] - \frac{dl_4}{2} \right\} \\
 &\quad (t - Ft_r) \\
 &= \{ 3.25 + 8.25 \times [2.75 / (2.75 + 3.0)] \\
 &\quad - \frac{4.5}{2} \} \times (3.25 - 0.88 \times 2.711) \\
 &= 4.275 \text{ in.}^2 \\
 A_2 &= 2(t_{n4} - t_{m4}) 2.5t_{n4} \\
 &= 2(0.875 - 0.124) \times 2.5 \times 0.875 \\
 &= 3.285 \text{ in.}^2 \\
 A_3 &= 2t_{n4}h \\
 &= 2 \times 0.875 \times 4.0 \\
 &= 7.0 \text{ in.}^2 \\
 A_{41} + A_{43} &= \boxed{WL_3^2 + WL_2^2} \\
 &= \boxed{1.25^2 + 0.5^2} \\
 &= 1.516 \text{ in.}^2
 \end{aligned}$$

$WL_1^2 + WL_2^2$

1.125^2

Total area of available reinforcement provided by nozzle 4 in the diagonal plane

$$A_1 + A_2 + A_3 + A_{41} + A_{43} = 16.076 \text{ in.}^2 \geq A_{d4}$$

as required for demonstration of compliance with PG-33.

The rule of PG-38.4 for the minimum required net cross-sectional area between any two finished openings shall apply as follows:

Net area required in longitudinal plane between nozzles 1 and 2

$$\begin{aligned}
 nar &= 0.7Ft_rD_1 \\
 &= 0.7 \times 1.0 \times 2.711 \times 9 \\
 &= 17.078 \text{ in.}^2
 \end{aligned}$$

Net area provided in vessel wall

$$\begin{aligned}
 nav &= [D_1 - 0.5(dl_1 + dl_2)]t \\
 &= [9 - 0.5 \times (4.5 + 5)] \times 3.25 \\
 &= 13.812 \text{ in.}^2
 \end{aligned}$$

Net area provided in nozzle wall fused to vessel wall

$$\begin{aligned}
 nan &= t_{n1}Wd_1 + t_{n1}Wd_2 + t_{n2}Wd_3 + t_{n2}Wd_4 \\
 &= 0.875 \times 1.0 + 0.875 \times 1.0 + 1.0 \times 1.25 \\
 &\quad + 1.0 \times 1.25 \\
 &= 4.25 \text{ in.}^2
 \end{aligned}$$

Total net area provided in the longitudinal plane between nozzles 1 and 2

$$nav + nan = 18.0625 \text{ in.}^2 \geq nar$$

as required for demonstration of compliance with PG-38.4.

Net area required in the circumferential plane between nozzles 2 and 3

$$\begin{aligned}
 nar &= 0.7Ft_rD_2 \\
 &= 0.7 \times 0.5 \times 2.711 \times 6.5 \\
 &= 6.167 \text{ in.}^2
 \end{aligned}$$

Net area provided in vessel wall

$$\begin{aligned}
 nav &= [D_2 - 0.5(dl_2 + dl_3)]t \\
 &= [6.5 - 0.5 \times (5 + 5)] \times 3.25 \\
 &= 4.875 \text{ in.}^2
 \end{aligned}$$

Net area provided in the nozzle wall fused to the vessel wall

$$\begin{aligned}
 nan &= t_{n2}Wd_3 + t_{n2}Wd_4 + t_{n3}Wd_3 + t_{n3}Wd_4 \\
 &= 1.0 \times 1.25 + 1.0 \times 1.25 + 1.0 \times 1.25 \\
 &\quad + 1.0 \times 1.25 \\
 &= 5 \text{ in.}^2
 \end{aligned}$$

Total net area provided in the circumferential plane between nozzles 2 and 3

$$nav + nan = 9.875 \text{ in.}^2 \geq nar$$

as required for demonstration of compliance with PG-38.4.

Net area required in the diagonal plane between nozzles 3 and 4

$$\begin{aligned}
 nar &= 0.7Ft_rD_3 \\
 &= 0.7 \times 0.88 \times 2.711 \times 8.25 \\
 &= 13.776 \text{ in.}^2
 \end{aligned}$$

Net area provided in vessel wall

$$\begin{aligned}
 nav &= [D_3 - 0.5(dl_3 + dl_4)]t \\
 &= [8.25 - 0.5 \times (5 + 4.5)] \times 3.25 \\
 &= 11.375 \text{ in.}^2
 \end{aligned}$$

Net area provided in the nozzle wall fused to the vessel wall

$$\begin{aligned}
 nan &= t_{n3}Wd_3 + t_{n3}Wd_4 + t_{n4}Wd_1 + t_{n4}Wd_2 \\
 &= 1.0 \times 1.25 + 1.0 \times 1.25 + 0.875 \times 1.0 \\
 &\quad + 0.875 \times 1.0 \\
 &= 4.25 \text{ in.}^2
 \end{aligned}$$

Total net area provided in the diagonal plane between nozzles 3 and 4

$$nav + nan = 15.625 \text{ in.}^2 \geq nar$$

as required for demonstration of compliance with PG-38.4.

Nozzles 1 and 4 — The required minimum strength to be provided by the combined load-carrying elements through each load-carrying path (see PG-37 and PW-15)