

OWNER

Branch Connection Reinforcement

Calculation



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1. OBJECTIVE

This calculation demonstrates that every branch connection in the station piping of the meets the reinforcement requirements of ASME B31.8 831.4, and it sets the fitting type for each branch. It also includes an informative check of the 12 in hot tap on the receiving pipeline operator's 24 in trunkline, which is the operator's design and responsibility.

2. METHODOLOGY

TORUS took the branch inventory from the piping model that produced the general arrangement and the isometrics, so every branch shown on those drawings is covered. Each branch type was then checked by the area replacement method of ASME B31.8 831.4.1. The metal removed by the opening, $d \cdot t_h$, must be replaced within the reinforcement zone by excess header wall (A_1), excess branch or fitting wall (A_2), and weld metal (A_3). The zone extends a distance d on each side of the branch centerline along the header and a height L above the header surface.

Tees were checked as if the branch were a fabricated stub-in using the pipe walls. Where that check fails, the connection shall be a wrought tee to ASME B16.9 or MSS SP-75. A wrought tee does not need an area calculation: B31.8 831.3 accepts it at the rating of the matching pipe because its crotch thickening is proved by the fitting standard's burst test. Branch outlet fittings to MSS SP-97 were checked with typical body dimensions, treating the fitting body as the branch wall. Where the fitting material is weaker than the header, its area was reduced in the ratio of the SMYS values, as 831.4.1 requires.

B31.8 Table 831.4.2-1 adds requirements by header hoop stress and diameter ratio. The station headers run at 47.1 % SMYS, below 50 %, where the stricter requirements for full-encirclement reinforcement do not apply. Every large branch in the station is a wrought tee in any case, which is the connection the code prefers. The trunk hot tap runs above 50 % SMYS with a diameter ratio over 0.5, so full-encirclement reinforcement applies there.

No reinforcing pads are used anywhere. Integral reinforcement was chosen because a pad needs a vent hole, adds a pad-to-pipe fillet weld that cannot be radiographed, and traps moisture under the pad.

3. DESIGN INPUTS

The inputs in Table 3-1 govern the calculation.

Table 3-1: Design Inputs

Input	Value	Source
Design pressure	A6 1,440 psig; A1 and D1 285 psig; S1 275 psig	MEC-CAL-001
Design factor F	0.50	GEN-DB-001
Header walls and required walls t_h	NPS 12 A6: 0.375 in STD, $t_h = 0.3531$ in	MEC-CAL-001
Hoop stress of NPS 12 A6 at MAOP	47.1 % SMYS	MEC-CAL-001
Header and pipe material	API 5L X52 PSL2 (SMYS 52,000 psi), ASTM A106 Gr B (35,000 psi), ASTM A312 TP304/304L (30,000 psi)	PIP-SPC-001
Branch outlet fitting material	ASTM A105N, SMYS 36,000 psi (A6, D1); ASTM A182 F304/304L, 30,000 psi (S1)	PIP-SPC-001
Fitting root diameter at the header	NPS 3/4: 1.69 in; 1: 2.13 in; 1-1/2: 3.00 in; 2: 3.75 in; 3: 5.50 in; 4: 6.75 in	Typical, HOLD H-15
Fitting bore	Class 6000: Sch 160 bore; Class 3000: Sch 80 bore; weldolets: branch pipe bore	MSS SP-97
Receiving pipeline operator's trunkline (informative)	NPS 24 x 0.344 in, API 5L X60, MAOP 1,200 psig	GEN-DB-001, HOLD H-04

4. ASSUMPTIONS

1. The fitting root diameters and bores are typical catalogue values. The fitting manufacturer's certified reinforcement for the specific run wall governs. *Verification required (HOLD H-15).*
2. The weld reinforcement A_3 is two fillets of leg w equal to the smaller of the header and branch walls, or 0.375 in for branch outlet fittings.
3. The trunkline data, class location and tap location are assumed. *Verification required (HOLD H-04).*
4. The split tee branch outlet is taken as 12.750 x 0.500 in X52, a typical fitting. *Verification required (HOLD H-04).*

5. REFERENCES

1. ASME B31.8-2022, Gas Transmission and Distribution Piping Systems: 831.3 fittings, 831.4.1 reinforcement of welded branch connections, Table 831.4.2-1 special requirements, Appendix F.
2. 49 CFR 192.155, Welded branch connections.

3. ASME B16.9-2018, Factory-Made Wrought Buttwelding Fittings; MSS SP-75-2019, High-Strength, Wrought, Butt-Welding Fittings.
4. MSS SP-97-2019, Integrally Reinforced Forged Branch Outlet Fittings.
5. API Standard 1104, 22nd Edition (2021), Welding of Pipelines and Related Facilities, Annex B, In-service Welding; API RP 2201, Safe Hot Tapping Practices, edition per the receiving pipeline operator.
6. GEN-DB-001, Basis of Design; GEN-RPT-002, Design Decisions Register.
7. MEC-CAL-001, Pipe Wall Thickness, Hoop Stress and Buried Lateral External Loads; MEC-CAL-007, Pig Receiver PR-101 Sizing and Closure Safety.
8. PIP-SPC-001, Piping Material Specification; PIP-DWG-001, Piping General Arrangement Plan; PIP-DWG-004, Tie-in and Outlet Lateral 1042 Plan and Profile.

6. CALCULATION

6.1. BRANCH INVENTORY

Table 6-1 lists the 108 branch connections in the station piping by class, size and type. The larger branches are these:

- The control valve branches 1031 and 1032 are NPS 12. They take off the 1022 inlet header and join the 1033 outlet header through 12 x 12 tees, with 12 x 8 reducers at the FCV flanges. NPS 12 was chosen over NPS 8 so that the pipe downstream of each low-noise valve carries lower velocity and noise.
- The only 12 x 8 reducing tee is the PR-101 kicker tee on line 1001. The barrel-side 16 x 8 kicker tee with guide bars is part of PR-101 (MEC-CAL-007).
- The 12 x 10 tees are on the meter skid SK-110 headers. The skid fabricator shall use this calculation.
- The seven NPS 12 x 1 sockolets are the two ends of each NPS 1 equalizing bypass around SDV-101, SDV-102 and SDV-103 (lines 1103, 1162 and 1171), and the HV-133D vent on line 1033.
- The S1 vent header 1070 carries two 8 x 4 weldolets for lines 1072 and 1073.
- The D1 4 x 2 tees are on line 1060 downstream of RO-104 and on the T-101 inlet manifold 1190. The A6 2 x 2 tees are the ends of the LCV-104 bypass, and the S1 2 x 2 tee joins line 1170 to line 1074.

Table 6-1: Branch Connections by Type

Class	Header NPS	Branch NPS	Connection	Quantity
A6	12	12	Barred tee	1
A6	12	12	Tee	9
A6	12	10	Tee	4

Class	Header NPS	Branch NPS	Connection	Quantity
A6	12	8	Tee	1
A6	12	2	Weldolet	7
A6	12	2	Weldolet, SP-141 probe	1
A6	12	1-1/2	Weldolet, thermowell	4
A6	12	1	Sockolet, Class 6000	7
A6	12	3/4	Nipolet, Class 6000	10
A6	12	3/4	Sockolet, Class 6000	31
A6	10	10	Tee	2
A6	10	1-1/2	Weldolet, thermowell	4
A6	10	3/4	Sockolet, Class 6000	6
A6	8	3/4	Sockolet, Class 6000	1
A6	2	2	Tee	2
D1	3	2	Tee	2
D1	3	3/4	Sockolet, Class 6000	3
S1	8	8	Tee	1
S1	8	4	Weldolet	2
S1	8	3	Weldolet	1
S1	8	2	Weldolet	4
S1	8	1	Sockolet, Class 3000	1
S1	8	3/4	Sockolet, Class 6000	1
S1	2	2	Tee	1
S1	2	1	Sockolet, Class 3000	1
S1	2	3/4	Sockolet, Class 3000	1
Total				108

Note 1: Quantities are the connections in the piping model. Vendor skid internals and equipment nozzles are excluded.

6.2. TEES

The required header wall for NPS 12 A6 is:

ASME B31.8 841.1.1

$$t_h = \frac{PD}{2SF} = \frac{1440 \times 12.750}{2 \times 52,000 \times 0.50} = 0.3531 \text{ in}$$

For a full-size 12 x 12 branch with the same 0.375 in wall, the opening is $d = 12.750 - 2(0.375) = 12.000$ in, and the required area is:

$$A_R = d t_h = 12.000 \times 0.3531 = 4.237 \text{ in}^2$$

The zone height is $L = \min(2.5 H, 2.5 B) = 0.938 \text{ in}$, with $H = B = 0.375 \text{ in}$ and no pad. The areas available are:

ASME B31.8 831.4.1

$$A_1 = (H - t_h) d = (0.375 - 0.3531)(12.000) = 0.263 \text{ in}^2$$

$$A_2 = 2 (B - t_b) L = 2 (0.375 - 0.3531)(0.938) = 0.041 \text{ in}^2, \quad A_3 = w^2 = 0.375^2 = 0.141 \text{ in}^2$$

The 0.445 in² available is about one tenth of the 4.237 in² required. The NPS 12 STD header has only 0.022 in of wall above its requirement, so it cannot reinforce any large opening. Table 6-2 shows the same result for the 12 x 10 and 12 x 8 branches, and that the smaller tees would pass even as fabricated branches.

Table 6-2: Tees Checked as Fabricated Branch Connections

Class	Size, NPS	Opening d , in	A_R , in ²	A_1 , in ²	A_2 , in ²	A_3 , in ²	Result as fabricated
A6	12 x 12	12.000	4.237	0.263	0.041	0.141	Not adequate, wrought tee required
A6	12 x 10	9.562	3.376	0.210	0.556	0.141	Not adequate, wrought tee required
A6	12 x 8	7.625	2.692	0.167	0.490	0.141	Not adequate, wrought tee required
A6	10 x 10	9.562	2.847	2.833	0.880	0.353	Adequate
A6	2 x 2	1.939	0.189	0.233	0.131	0.048	Adequate
D1	4 x 2	1.939	0.071	0.582	0.217	0.048	Adequate
S1	8 x 8	7.981	0.631	1.939	0.391	0.104	Adequate
S1	2 x 2	2.067	0.045	0.273	0.102	0.024	Adequate

Note 1: A_3 for the 10 x 10 tee uses the 0.594 in Sch 80 wall as the fillet leg; without it the tee still passes.

All NPS 12 x 12, 12 x 10 and 12 x 8 branches, including the barred tee, shall be MSS SP-75 WPHY-52 wrought tees matched to the 0.375 in run wall. Fabricated stub-ins are not permitted in class A6 at NPS 8 and larger. The 10 x 10 crossover tees are also wrought tees, though they would pass as fabricated, because the meter tubes need a smooth bore.

6.3. BRANCH OUTLET FITTINGS

The governing fitting is the 12 x 2 weldolet on the 0.375 in header, used for the fuel take-off, the blowdown and relief connections, the SP-141 sample probe and the PR-101 equalizing line. The bore is that of NPS 2 Sch 80, $d = 1.939$ in, and the fitting body is $B = (3.75 - 1.939)/2 = 0.905$ in thick at the root:

ASME B31.8 831.4.1

$$A_R = d t_h = 1.939 \times 0.3531 = 0.685 \text{ in}^2, \quad A_1 = (0.375 - 0.3531)(1.939) = 0.043 \text{ in}^2$$

The body required wall uses the A105N yield strength, $t_b = 1,440(2.375)/(2 \times 36,000 \times 0.50) = 0.095$ in, and $L = \min(2.5 \times 0.375, 2.5 \times 0.905) = 0.938$ in. Because A105N (36,000 psi) is weaker than X52 (52,000 psi), the body area is reduced in the ratio of the two:

ASME B31.8 831.4.1, material of lower strength

$$A_2 = 2(B - t_b)L \frac{S_{fitting}}{S_{header}} = 2(0.905 - 0.095)(0.938) \frac{36,000}{52,000} = 1.052 \text{ in}^2$$

With $A_3 = 0.141 \text{ in}^2$, the available area is 1.235 in^2 , 1.8 times the requirement. Table 6-3 gives the result for every fitting size and header. The lowest ratio is the 12 x 2 weldolet; every other fitting has at least twice the area required.

Table 6-3: Integrally Reinforced Branch Outlet Fittings

Class	Size, NPS	Fitting	Bore d , in	Body B , in	A_R , in ²	$A_1 + A_2 + A_3$, in ²	Available / required
A6	12 x 2	Weldolet	1.939	0.905	0.685	1.235	1.8
A6	12 x 1-1/2	Weldolet, thermowell	1.500	0.750	0.530	1.048	2.0
A6	12 x 1	Sockolet, Class 6000	0.815	0.657	0.288	0.944	3.3
A6	12 x 3/4	Nipolet, Class 6000	0.612	0.539	0.216	0.799	3.7
A6	12 x 3/4	Sockolet, Class 6000	0.612	0.539	0.216	0.799	3.7
A6	10 x 1-1/2	Weldolet, thermowell	1.500	0.750	0.447	1.971	4.4
A6	10 x 3/4	Sockolet, Class 6000	0.612	0.539	0.182	1.249	6.9
A6	8 x 3/4	Sockolet, Class 6000	0.612	0.539	0.146	1.161	7.9
D1	3 x 3/4	Sockolet, Class 6000	0.612	0.539	0.017	1.052	60.3
S1	8 x 4	Weldolet	4.026	1.362	0.318	3.208	10.1

Class	Size, NPS	Fitting	Bore d , in	Body B , in	A_R , in ²	$A_1 + A_2 + A_3$, in ²	Available / required
S1	8 x 3	Weldolet	3.068	1.216	0.243	2.755	11.4
S1	8 x 2	Weldolet	2.067	0.841	0.163	1.926	11.8
S1	8 x 1	Sockolet, Class 3000	0.957	0.587	0.076	1.261	16.7
S1	8 x 3/4	Sockolet, Class 6000	0.612	0.539	0.048	1.105	22.8
S1	2 x 1	Sockolet, Class 3000	0.957	0.587	0.021	0.593	28.4
S1	2 x 3/4	Sockolet, Class 3000	0.742	0.474	0.016	0.479	29.7

Note 1: The SP-141 probe weldolet is the same 12 x 2 fitting and is covered by the first row. Its bore of 1.939 in admits the retractable probe.

All MSS SP-97 fittings, NPS 3/4 to 4 on NPS 2 to 12 headers, meet the area requirement with typical body dimensions. The fitting manufacturer shall certify the reinforcement for the specific run wall (0.375, 0.594, 0.500, 0.300 and 0.322 in) and design pressure. S1 fittings are ASTM A182 F304/304L.

6.4. FITTING DETAILS

The connection types are built as follows:

- Wrought tees: MSS SP-75 WPHY-52 butt-weld tees, bevels matched to the 0.375 in run wall and to the branch wall per ASME B16.25. The 10 in Sch 80 and 8 in XS branches need the fitting branch end supplied in the heavier wall, or a 1:3 taper per ASME B31.8 Appendix I. Girth welds are 100 % radiographed or tested by automated ultrasonic testing.
- Barred tee on line 1001: an SP-75 WPHY-52 12 x 12 tee with guide bars inside the branch outlet, parallel to the run, spaced not more than 0.25 D, welded to the branch bore only and ground flush with the run bore so pigs pass. The bars are welded by the fitting manufacturer before heat treatment.
- Weldolets: contoured to the 12.750 in run, full-penetration groove weld with cover fillet, 100 % magnetic particle examination of the attachment weld. The 1-1/2 in thermowell weldolets carry a Class 600 weld neck flange for a flanged thermowell.
- Sockolets and nipolets: Class 6000 in A6 and D1, Class 3000 or 6000 in S1, full-penetration attachment weld with cover fillet, socket welds with a 1/16 in expansion gap, 100 % magnetic particle or liquid penetrant examination.

6.5. INFORMATIVE: 12 IN HOT TAP ON THE 24 IN TRUNKLINE

The hot tap fitting, tap valve and in-service welding are the receiving pipeline operator's scope; this package connects the outlet lateral 1042 to the outboard flange of the tap valve only. TORUS checked the tap on the assumed trunk data (HOLD H-04) to confirm the interface is feasible and to flag conditions the operator should review.

The trunk hoop stress at MAOP is:

ASME B31.8 841.1.1

$$S_H = \frac{PD}{2t} = \frac{1200 \times 24.000}{2 \times 0.344} = 41,860 \text{ psi} = 69.8 \% \text{ SMYS}$$

This is acceptable only in a Class 1 location, where $F = 0.72$ and the required wall is 0.333 in. In a Class 2 location ($F = 0.60$) the required wall would be 0.400 in, more than the assumed 0.344 in. With the finished opening $d = 11.750$ in, the excess trunk wall and the split tee branch outlet provide $A_1 = 0.125$ in² and $A_2 = 0.509$ in² of the 3.917 in² required. The sleeve must provide the rest:

ASME B31.8 831.4.1, full-encirclement reinforcement

$$T_s = \frac{A_R - A_1 - A_2}{d} = \frac{3.917 - 0.125 - 0.509}{11.750} = 0.279 \text{ in}$$

Table 6-4 summarizes the check and Table 6-5 gives three standard sleeve thicknesses.

Table 6-4: Informative Check of the 12 in Hot Tap on the 24 in Trunkline

Item	Symbol	Value	Unit
Required trunk wall, Class 1 location, $F = 0.72$	t_h	0.333	in
Required trunk wall, Class 2 location, $F = 0.60$	t_h	0.400	in
Trunk hoop stress at MAOP	S_H	41,860 (69.8 % SMYS)	psi
Branch to header diameter ratio	d/D	0.53	
Opening, cutter not larger than the branch bore	d	11.750	in
Required area	A_R	3.917	in ²
Excess trunk wall	A_1	0.125	in ²
Split-tee branch outlet, 12.750 x 0.500 in X52	A_2	0.509	in ²
Sleeve thickness required within the zone	T_s	0.279	in
Sleeve end fillet, maximum 1.4 x trunk wall		0.482	in

Table 6-5: Full-Encirclement Split Tee Sleeve Options, X60

Sleeve thickness T_s , in	A_3 , in ²	$A_1 + A_2 + A_3$, in ²	A_R , in ²	Result
0.375	4.406	5.040	3.917	Adequate
0.500	5.875	6.509	3.917	Adequate

Sleeve thickness T_s , in	A_3 , in ²	$A_1 + A_2 + A_3$, in ²	A_R , in ²	Result
0.625	7.344	7.978	3.917	Adequate

A full-encirclement split tee is required, because the trunk runs above 50 % SMYS and the diameter ratio exceeds 0.5. A 0.375 in or thicker X60 sleeve is adequate by area. The fitting manufacturer's rating and the operator's standards govern.

7. RESULTS AND CONCLUSIONS

Table 7-1 gives the connection type for each branch group.

Table 7-1: Branch Connection Selection

Branch group	Connection	Governing result
A6 NPS 12 x 12, 12 x 10, 12 x 8, barred tee	MSS SP-75 WPHY-52 wrought tee	Fabricated branch has 0.445 in ² of 4.237 in ² required
A6 NPS 10 x 10 crossovers	MSS SP-75 WPHY-52 wrought tee	Smooth meter-tube bore
A6, D1 and S1 NPS 2 x 2 and 4 x 2	ASME B16.9 wrought tee	Adequate even as fabricated
NPS 3/4 to 4 branches on NPS 2 to 12 headers	MSS SP-97 weldolet, sockolet or nipolet	Lowest ratio 1.8, 12 x 2 weldolet
12 in hot tap on 24 in trunk (operator scope)	Full-encirclement split tee	Sleeve of 0.279 in minimum; 0.375 in X60 adequate

TORUS draws the following conclusions:

1. Every branch connection in the station meets ASME B31.8 831.4 and 49 CFR 192.155 with the connection types in Table 7-1. No reinforcing pads are used.
2. Fabricated stub-in branches are not permitted in the NPS 12 class A6 headers, because the STD wall has only 0.022 in of excess thickness. This shall be stated in the piping material specification and on the fabrication drawings.
3. The fitting manufacturer shall certify the reinforcement of each MSS SP-97 fitting for its run wall and design pressure (HOLD H-15).
4. For the receiving pipeline operator's review: the assumed 0.344 in trunk wall is adequate only in a Class 1 location, and the 12 in hot tap needs a full-encirclement split tee with in-service welding to API 1104 Annex B. The sleeve end fillets should not exceed 1.4 times the trunk wall, 0.482 in. The trunk data, class location and tap location remain HOLD H-04.