Pipe Stress Analysis using CAESAR II

Presented by COADE Engineering Software

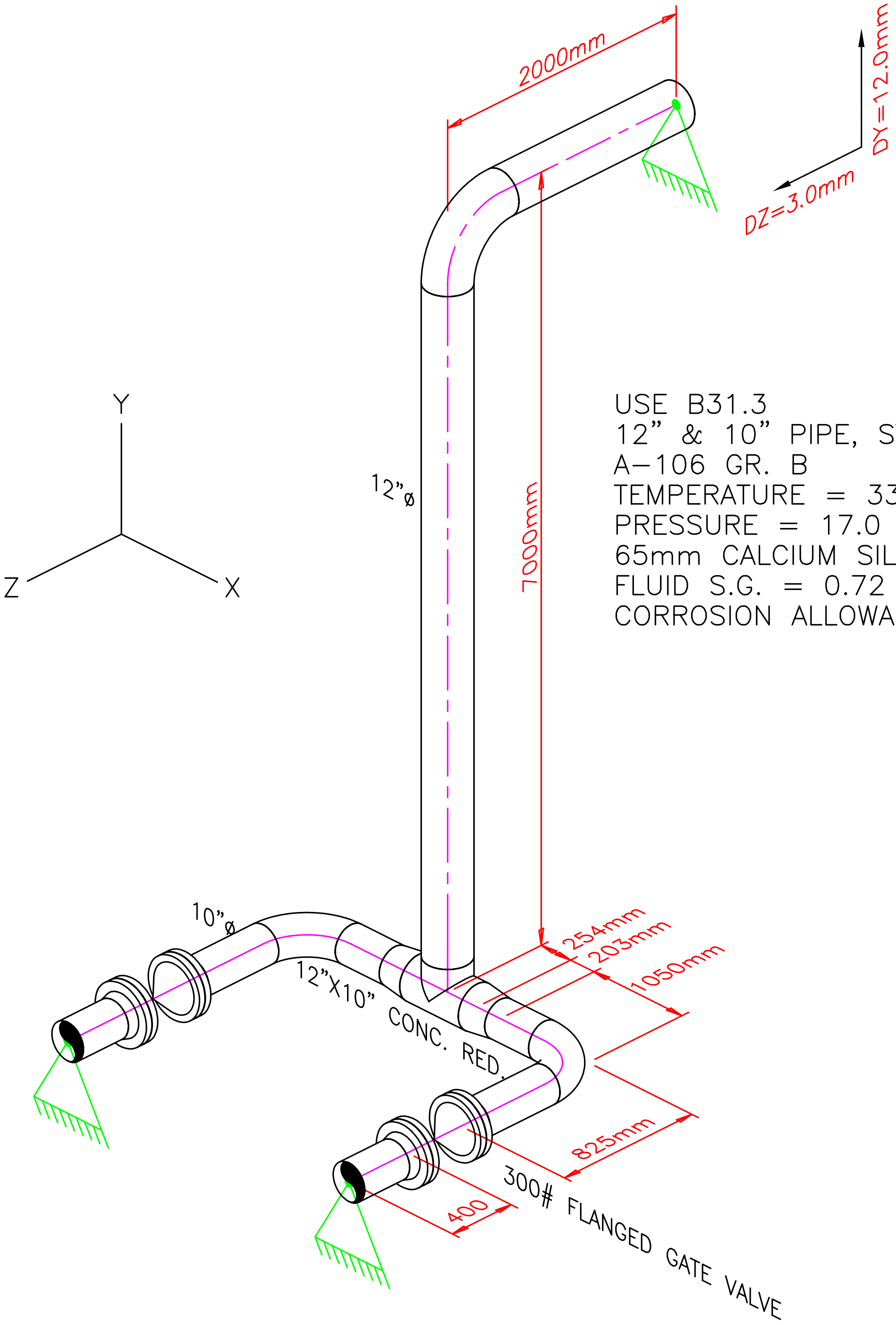
Sponsored by Fern Computer Consultancy

Derby, England

26 February – 2 March 2007

Monday AM	-	Piping Code Basics (Chapter 1)
Monday PM	-	CAESAR II Piping Input (PIPE1)
Tuesday	-	Load-based Piping Design (Chapter 2, SUPT01)
Wednesday AM	-	Assorted modeling, analysis, and compliance topics through an example (TUTOR)
Wednesday PM	-	Analysis documentation and static analysis workshop (model generation, system evaluation, system redesign)
Thursday AM	-	Continuation of TUTOR (from Wednesday morning)
Thursday PM	-	Modeling and analysis of a transmission line (buried pipe modeler, fatigue evaluation, load case manipulation) (GASTRANS)
Friday AM	-	Modeling and analysis of a jacketed riser (list/edit modeling, jacketed pipe, wind and hydrodynamic loading) (RISERJ3)
Friday PM	-	Modeling and analysis of fiberglass reinforced plastic pipe (FRP evaluation, static seismic loads) (COOLH2O)

PIPE1 - MODELING EXERCISE



USE B31.3
12" & 10" PIPE, STD. WALL
A-106 GR. B
TEMPERATURE = 330 DEG. C.
PRESSURE = 17.0 BAR
65mm CALCIUM SILICATE INS.
FLUID S.G. = 0.72
CORROSION ALLOWANCE = 3mm

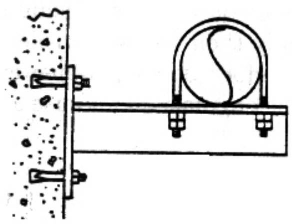
<u>Restraint Exercise</u>

Define the restraint type for each of the illustrations*. Indicate where additional definitions (stiffness, gap, etc.) are required.

The types of CAESAR II restraints are listed in the table below. The restraint type (or vector) may follow any line by defining direction cosines. They may be signed to provide restraint in only one direction. A restraint with no stiffness listed will be assumed rigid. Stiffness defined along with several other modifiers listed below. (Note that defining "Displacements" also serve as a boundary condition and mimic an anchor or rigid restraint(s) in any load case that does not include the displacement component.)

Restraint Types:

Sign	Vector	Modifiers
	ANCHOR	
(+/-)	X Y Z	+ stiff, gap, mu
(+/-)	RX RY RZ	+ stiff, gap
	GUIDE	+ stiff, gap, mu
(+/-)	LIMIT (axial)	+ stiff, gap, mu
(+/-)	XROD YROD ZROD	+ stiff, length, Fi
(+/-)	X2 Y2 Z2	+ K1, K2, Fy
(+/-)	RX2 RY2 RZ2	+ K1, K2, Fy
	XSPR YSPR ZSPR	+ stiff, "x", F
(+/-)	XSNB YSNB ZSNB	+ stiff



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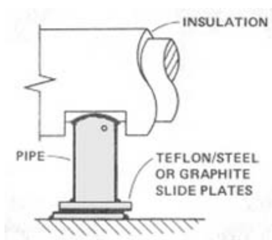

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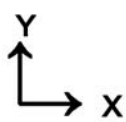

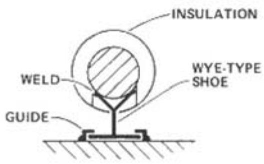
INSULATION
WELD
WYE-TYPE SHOE
GUIDE

3) ______________________________

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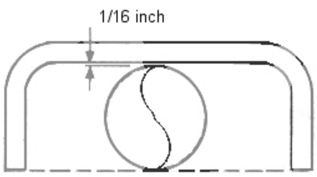
1/16 inch

4) ______________________________

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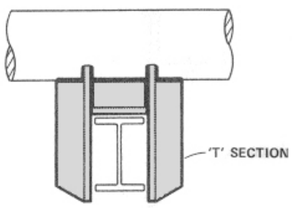
'T' SECTION

5) ______________________________

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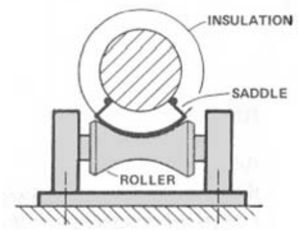
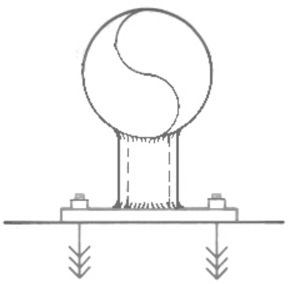

INSULATION
SADDLE
ROLLER

6) ______________________________



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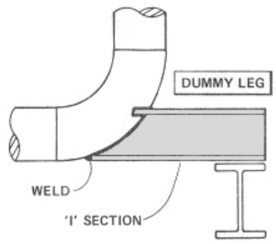
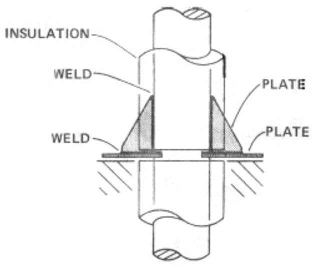
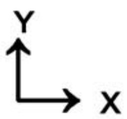
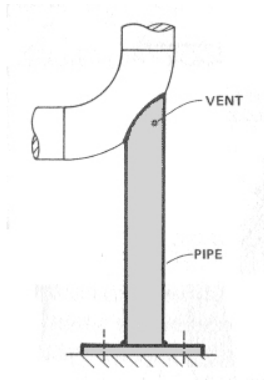

DUMMY LEG
WELD
'I' SECTION

8) ______________________________


INSULATION
WELD
PLATE
WELD
PLATE

9) ______________________________


Y
X



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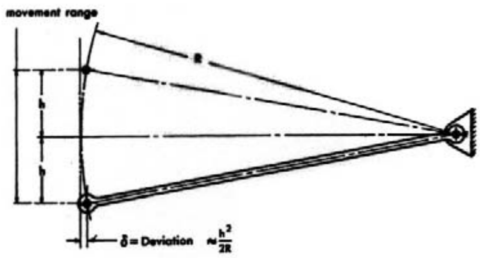

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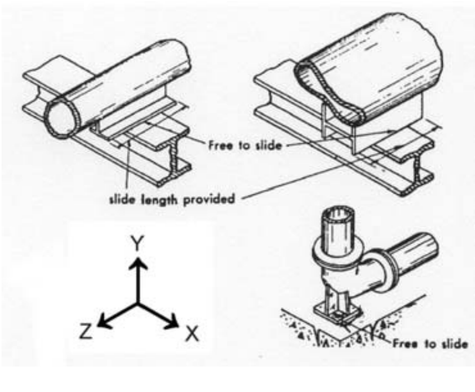

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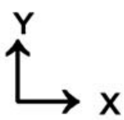

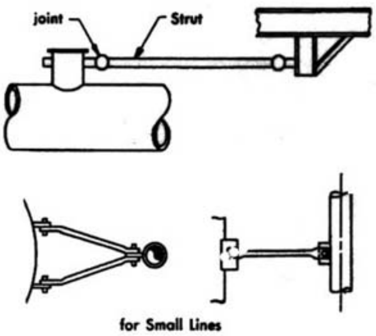

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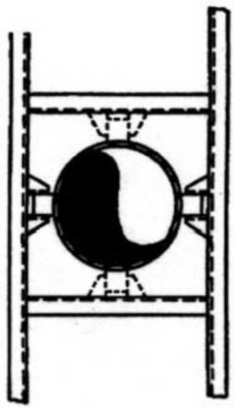

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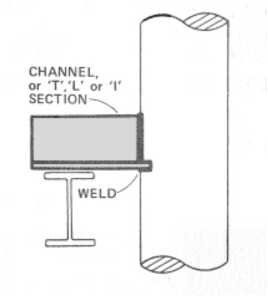

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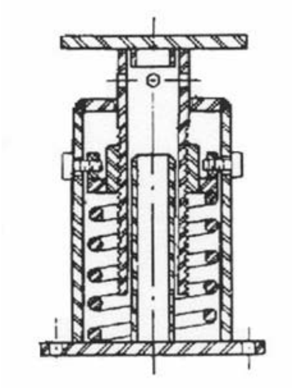

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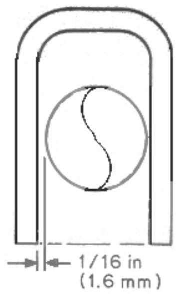

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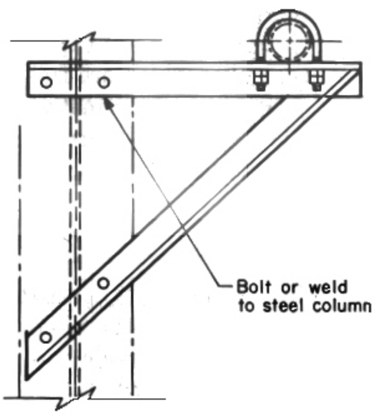

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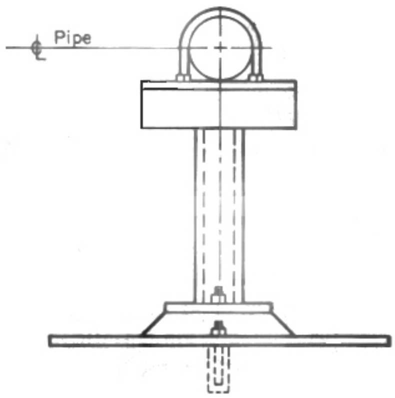

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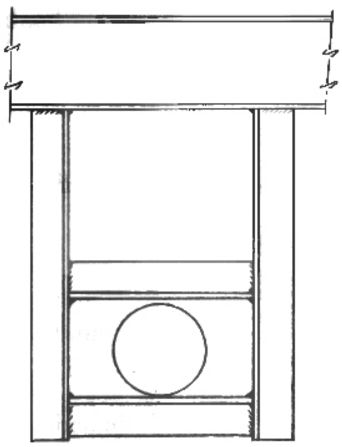

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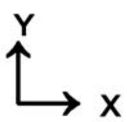

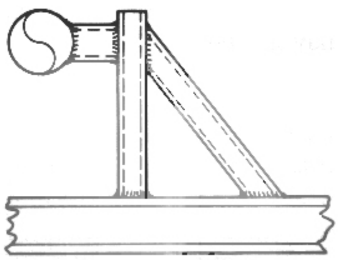

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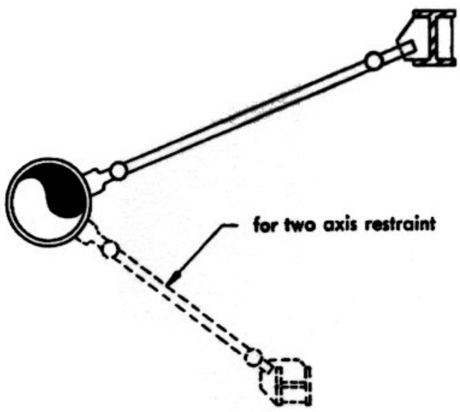

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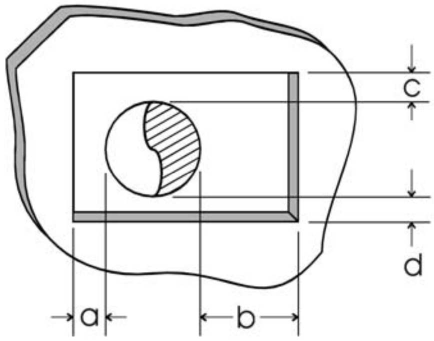

23) ______________________________
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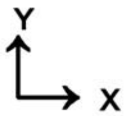
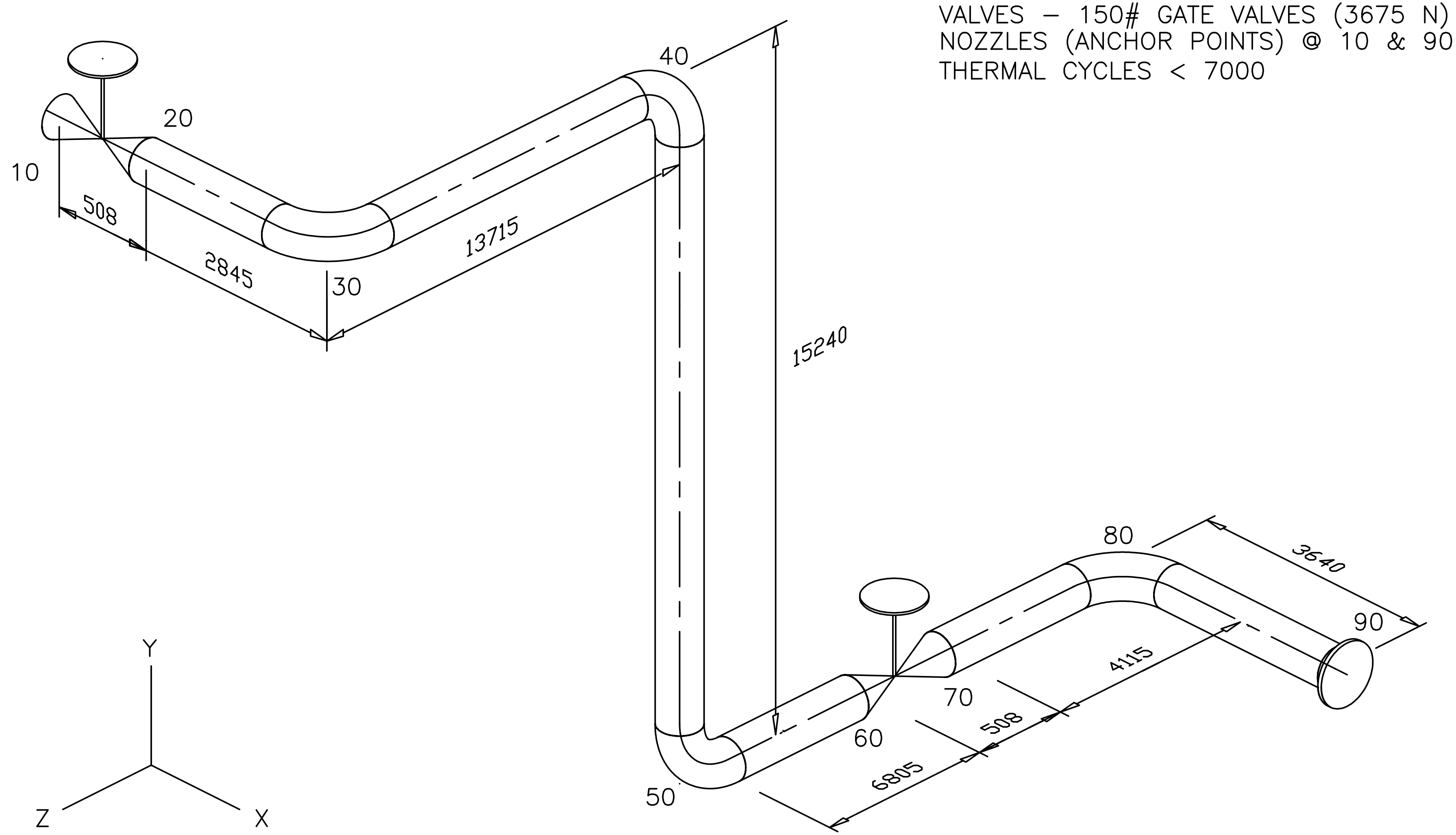


* Illustrations taken from The 'Piping Guide' for the Design and Drafting of Industrial Piping Systems by David Sherwood and Dennis Whistance published by Syentek 1991; Welding Research Council Bulletin 449—Guidelines for the Design and Installation of Pump Piping Systems by Vincent Carrucci and James Payne published by the Welding Research Council, Inc. 2000; and Piping and Pipe Support Systems by Paul Smith and Thomas Van Laan published by McGraw-Hill 1987.

SUPT01

PIPE – 12" DIA STD SCH
MAT'L – A-106 GR B
FLUID – WATER
PRESSURE – 10.5 BAR
TEMP – 175 DEGREES C
ELBOWS – LONG RADIUS
INSULATION – 50 mm CS
VALVES – 150# GATE VALVES (3675 N)
NOZZLES (ANCHOR POINTS) @ 10 & 90
THERMAL CYCLES < 7000



Supt01Metric.dwg

SUPT01

PIPE – 12" DIA STD SCH
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ELBOWS – LONG RADIUS
INSULATION – 50 mm CS
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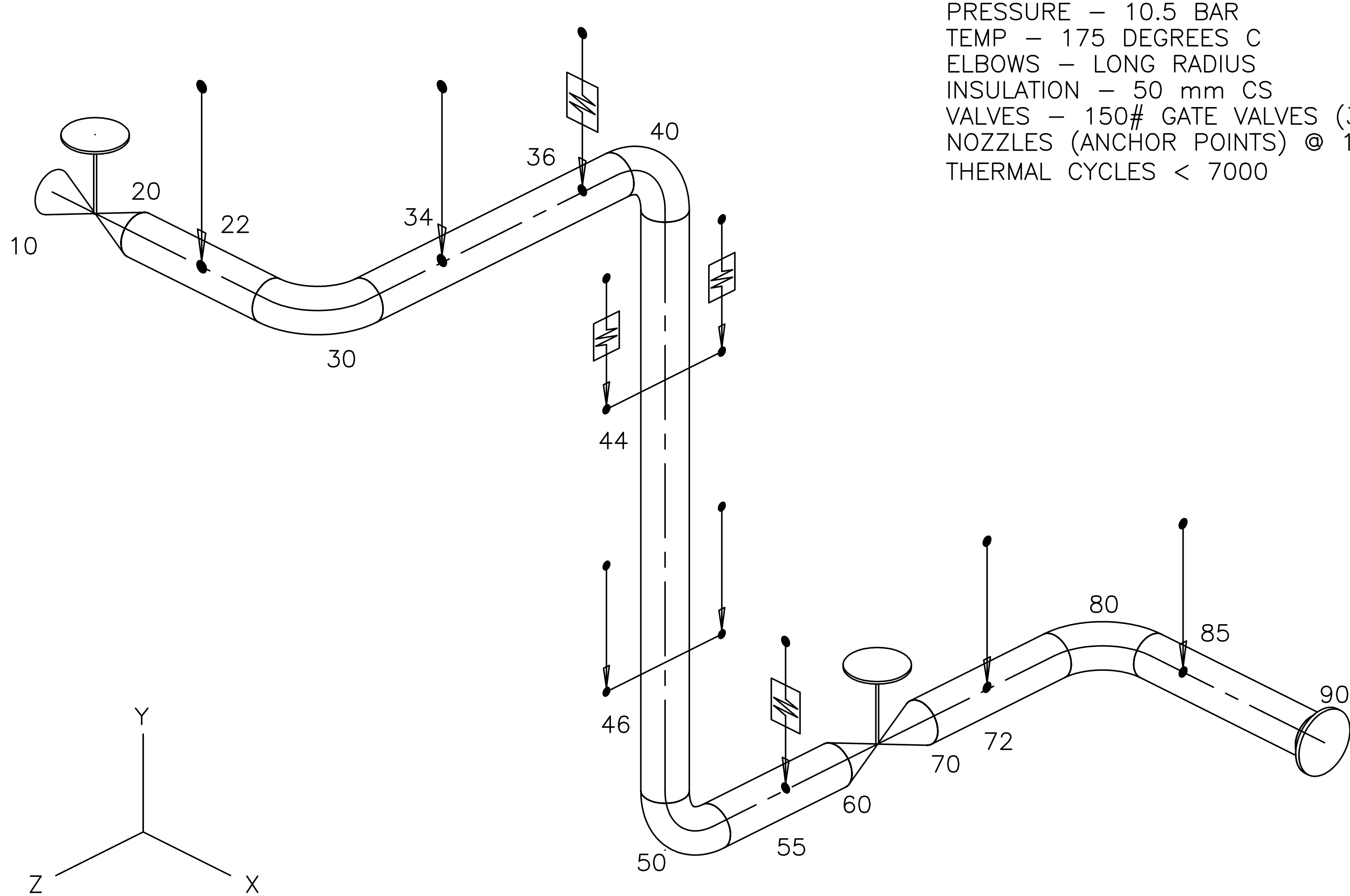


Supt01HangerMetric.dwg

Seminar Job: **TUTOR**
Static Modeling and Analysis Tutorial

Topics Addressed:

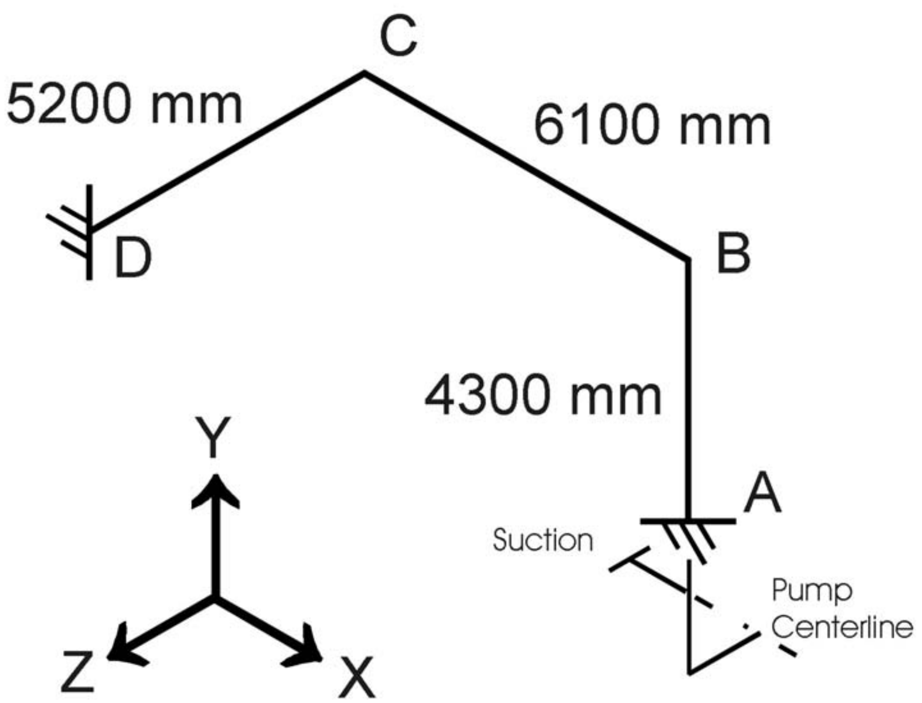
General Modeling	Stress Analysis	Pump Evaluation
Hanger Sizing	System Redesign	Structural Steel
Expansion Joints	Nozzle Flexibility	Local Stress Evaluation

Introduction:

This job reviews many of the modeling and analysis capabilities of **CAESAR II**. Starting with a quick sketch, the problem will be developed through a series of tasks, each of which will develop another aspect of the program.

Task 1: Route pipe from pump discharge (A) to fixed nozzle (D).

With A at (0,0,0), D will be at (-6100,4300,5200)
8 inch, standard wall, ASTM A-53 Gr. B pipe
Design temperature = 315C
Design pressure = 2 bar
Corrosion allowance = 0.8 mm
75 mm C.S. insulation
Content: 0.8SG (bottoms)
Pipe specification: 150 pound class components
Use B31.3



Pump Details (A):

10 inch end suction, 8 inch top discharge
suction is -380 mm in X from pump center
discharge is 500 mm above and 300 mm in Z from pump center
Piping load on suction nozzle given as: (4450,-3550,-5340) N and
(-4070,-3390,2170) N-m

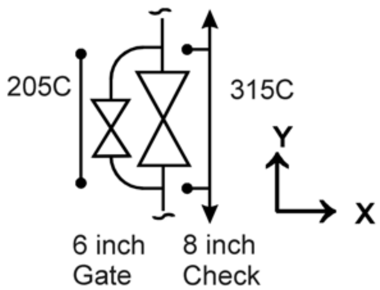
Nozzle Details (D):

Fixed end is preceded by a long weld neck flange in the -Z direction:
OD=250, wt=9.5, length=300 mm, weight=458 N
and a standard, 8 inch weld neck flange and gasket

Model:

Sketch & model the layout:

- After starting with a 8 inch 150 pound weld neck flange (in the Y direction) at the pump attachment (A), run up another 900 mm to the centerline of the 6 inch by-pass line (try a stub in connection—unreinforced fabricated tee). With the default node sequencing, the weld neck flange will be the element 10 – 20 and the short run of pipe will be 20 – 30.
- Place 8 inch flanged check valve 180 mm above the intersection
- Follow with another 180 mm to the second UFT for by-pass
- Continue up to nozzle elevation (B – node 70)
- Elbow to –X
- Run 6100 in –X
- Elbow to Z (C – node 80)
- Run about 4795 mm in Z
- Follow with a weld neck flange
- Finish with the long weld neck to (D – node 110)
- Add the 6 inch by-pass with its gate valve around the 8 inch check valve
  Run 380 mm in –X from the bottom intersection; elbow up, place the flanged gate valve on top of the elbow, set the temperature of the vertical run of 6 inch pipe to 205 C, run pipe up to the top UFT elevation and run back to the riser



Boundary conditions:

- Set thermal growth of discharge nozzle (A – node 10)
  Two approaches: 1)Calculate thermal growth of discharge nozzle from pump base point
  Alpha =.003832, therefore displ = (0,1.92,1.15,0,0,0)
  2)Add a construction element between nozzle node and pump base
  Run a rigid element from anchored base point to discharge nozzle with appropriate material and temperature – <u>use this one</u>
- Anchor long weld neck end (D – node 110)
- Support riser
  Thermal growth of riser, combined with the desire to unload discharge nozzle requires that a spring support be placed near the elbow on the horizontal run (B – node 70).

- Support horizontal run
  Suggested maximum distance between supports for 8 inch, water-filled line is 5800 mm for straight runs and 75% of that (4350 mm) for runs with horizontal bends. (See MSS SP69.) This spacing will minimize sustained stress and line deflection thus eliminating the need for a sustained stress analysis. Since we will check these stresses anyway (and since the line weight is less than water-filled,) we can exceed the suggested spacing. Place a hard Y support on the “near end” of the XZ elbow (at C – node 78).

This is job TASK1

Results:

Code Stress checks:

- Maximum sustained stress is 17 percent of the allowable on the elbow (B) above the pump
- Maximum stress to allowable ratio for the expansion case is 116 percent. This value occurs on the branch runs of the check valve by pass.

Fix:

One of the easiest fixes for an overstressed component is to replace it with a stronger component. Component strength is indicated by the stress intensification factor (SIF). Here, the stub-in branches are overstressed. Their in-plane SIF is 3.96 and their out-plane SIF is 4.95. Adding a pad to these tees will strengthen them. Check the effect of adding a pad by using the Tee SIF Scratchpad. Changing the UFT to an RFT with a pad equal to the pipe thickness will drop the SIF by almost 50%. With the stress here proportional to the SIF, the stress should be acceptable if the tees are changed. This modification will have no effect on the flexibility of the model. Run the analysis again with pads specified at these tee connections. (Note that a welding tee or some other self-reinforced attachment may be a better choice in light of the labor associated with attaching the pad.)

Results:

Code Stress checks:

- The tees still have the highest expansion stress but now they are no more than 63% of the allowable limit.
- The maximum sustained stress remains the same.

Hanger Sizing:

- A Grinnell Figure B-268 Size 12 spring is selected
  (hot load = 8755, deflection = 18, k= 79 N/mm, cold load = 10188, L.V. = 16%)

Pump load:

- Review the Restraint Summary of the operating and sustained (installed) cases. There is no indication here that the loads are excessive.
- Run API610 analysis with the pump data provided above and the discharge loads from this analysis. Use Node/Cnode Anchor model to show nozzle in the restraint report.
- Global Mx (local Mx) is just over the limit (2.10 times) and global Mz (local My) is way over the limit (9.45 times).

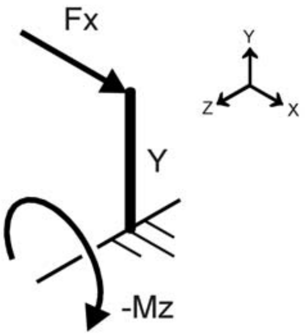
Fix:

These large pump loads exist in operation but not at “installation”. They are caused by thermal growth and without changing the positions of A & B or changing the thermal strain; the only way to reduce these loads is to add flexibility to the layout. There is no inherent flexibility that was (conveniently) excluded from the model so an expansion loop will be introduced.

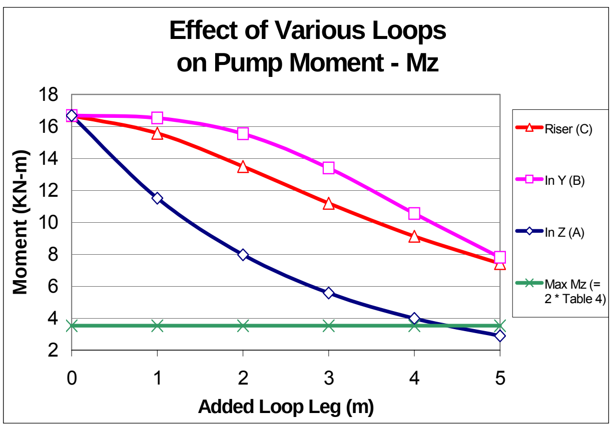
How big is big enough and where should it be placed?

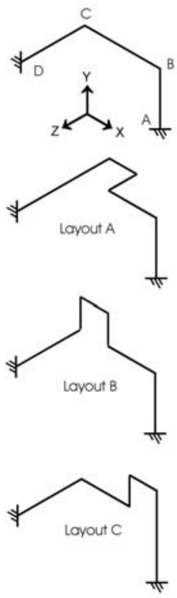
Task 2: Design an expansion loop.

- Added legs of loop should be laid perpendicular to the thermal growth causing the load (See page 2-28 of the course notes.)
- Determine which element causes the high moment (-16,647 Nm) about the Z axis
  - o What force acting on the Y cantilever leg causes a negative Z moment in the nozzle?
  - o +FX cross Y gives a negative Z moment at 10
  - o The thermal growth of the X run causes the negative Z moment



- The added loop legs can go in the Y or Z direction
- What is the most effective orientation and location?
  - o A Z loop on the “C end” of the X run (Layout A)
  - o A Y loop on the “C end” of the X run (Layout B)
  - o A Y loop on the “B end ” of the X run (Layout C)
  - o A Z loop on the “B end” of the X run and a Y loop on either end of the Z run is the same as Layout B
- Run through bending moment equation (LOOP LEG.XLS)
  - o Page 2-28 of course notes shows the bending stress at the nozzle is estimated as $SE=6ER\Delta L_j/\Sigma(L_i^3)$
  - o Use this to evaluate the change in moment by changing the flexible legs
  - o SE=M/Z=MR/I
  - o $M=6EI\Delta L_j/\ \Sigma(L_i^3)$; $6EI\Delta$ is constant; let $6EI\Delta=K$
  - o Solve for K using current M and Current L’s
  - o Now calculate M as L changes for each design





- Sketch A is most effective indicating about a 4000 mm run in Z

Why? It makes the long leg longer and this value is cubed in the denominator.

- While the advantage of the loop in Sketch A is clear, the estimated effect is quite conservative as the simple equation does not consider the rigid elements or elbows.
- Try a 2400 mm leg in Z 1200 mm before “C” and add 2400 mm to the existing Z run

Model:

Add loop:

- This is TASK2 (Open TASK1 and immediately ‘Save As’ TASK2, this will keep TASK1 as the original for other modifications.)
- Check the position of the far terminal (long weld neck). Use this location to check layout after modification.
- Break the X run adding new node (170), 1200 mm from end; add a bend at the new node
- Insert new element after the 4900 mm leg (From 170 To 180), -2400 mm in Z, with a bend at the end
- Re-connect the remaining pipe by changing the following pipe (170 – 80) by replacing the From Node of 170 with 180
- Add another 2400 mm to the long Z run
- Check the distance from A to D: (-6100,4300,5200)

Reconsider the supports:

- Recall that suggested spacing between supports on straight horizontal runs is about 5800 mm (to minimize stress and limit sag) and about 4350 mm on horizontal runs with bends
- Remove the existing support from the “near end” of the bend at C
- Add a new Y support at the middle of the new Z offset and match it with a second Y support directly across the loop (1200 mm in Z from C)

Save the job (now TASK2) and run

Results:

Code Stress checks pass:

- Maximum sustained stress is 13 percent of the allowable near the long weld neck flange
- Maximum stress to allowable ratio for the expansion case is 57 percent on the lower tee

A Grinnell Figure B-268 Size 10 spring is selected (hot load = 4751, deflection = 17.2, k= 46 N/mm, cold load = 5533)

The Y support on the new Z leg has an installation load of –4783 N. but this load drops to only –454 N when the system heats up. What if this load turned positive?

- Can the support assembly be designed to hold the pipe down, or, should the pipe be allowed to lift off the support (+Y)?
- What are the sustained stresses in the line if the pipe lifts off the support?
- How does this support affect the pump loads? Would a spring support be necessary?

Pump load looks much better

- Rerun API610 check with new data to confirm
- (Global) Mz of –2648 Nm is 1.5 times the allowable. Perhaps a smaller loop would pass.
- Other Appendix F checks (validating the 2 timed Table 4 approach) also pass.

Conclusion:

- The Z moment is 75 percent of its allowable limit (1.5/2.0). How much confidence do we have in this calculation?
- What is an easy way to reduce the Y load on the discharge nozzle? Will doing so improve the overall loads? How does this affect the confidence in the pump loads?

	FX	FY	FZ	MX	MY	MZ
Std. design	1908	-5848	-642	-1968	-3248	-2648
Rel. anchor	1908	-1541	-642	-1968	-3248	-2648

- Should the loop be extended?

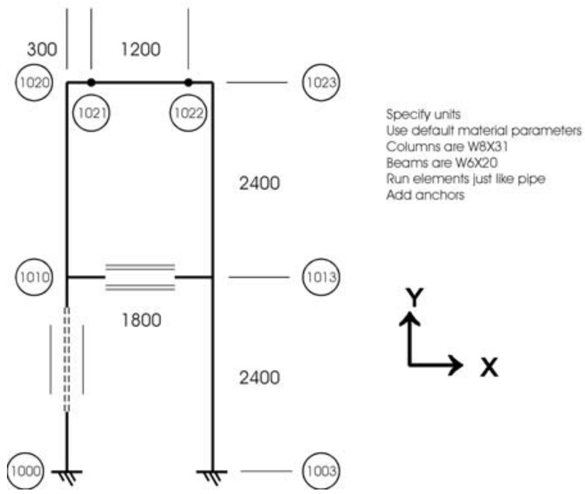
Task 2a: Support the expansion loop on structural steel.

- Build a model of the steel and include it in the analysis.

Model:

Build the steel

FRAME



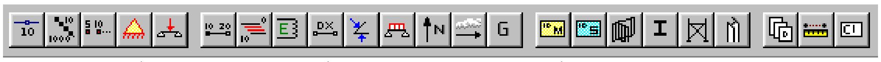
Incorporate the structural steel in the piping model

- Specify the appropriate connecting nodes (CNODE) for the two loop supports.
- Plot the model.

CAESAR II Structural Steel Input Strategy

1) Overview

   - Click on the toolbar to display the input form

   Restraints Elements Materials / Sections

   - Click + to add the completed form to the input file

   Add at end / Insert Before- / Replace- / Erase-Highlighted Line

   - Click “Disk” to save and error check the data

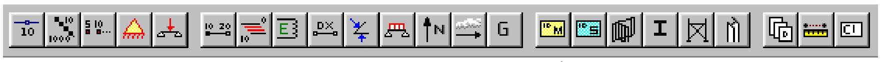
   

   New- / Open Existing- / Save & Error Check-File

2) Confirm Units

   - The first line of data will list the units file for this session. If the listing is incorrect, click on that line and then choose your units from the list shown on the form. Click the Replace button to update the data.

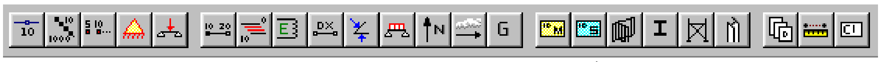
3) Define Material(s)



☝ Materials

- If necessary, click on the Materials button. Specify Material # 1 but do not add data. Click the Add button to include this data. Default material values will be used (Young's Mod. = 206,842 MPa, Poisson's Ratio = 0.3, Shear Mod. = 75842 MPa, Density = 0.00783 kg/cu.cm).

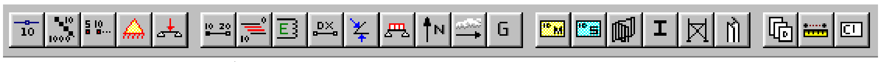
4) Select Section(s)



☝ Sections

- Define Section #1 as AISC W8X31 from the section database
- Define Section #2 as AISC W6X20

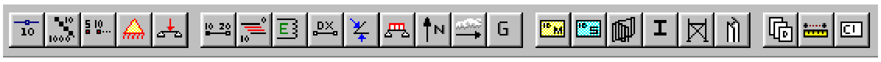
5) Lay out Elements



☝ Elements

- Use the EDIM (Element Dimension) button to display a format similar to piping input. Enter the From Node, To Node, DX/DY/DZ, Material ID & Section ID.

6) Add Restraints



☝ Restraints

- Anchors are "Fixity" in all 6 degrees of freedom.

7) Plot

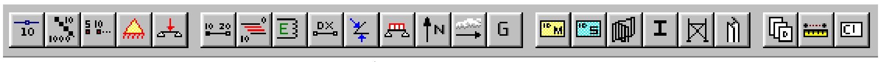
☝ Plot

- Show the volume plot to check the different sections and their orientation.

8) Edit if necessary

- Fix the Section orientation.

  Click on the first element you wish to rotate.



☝ Rotate strong axis

Use the Angle command to enter the angle of orientation (=90).

☝ Insert Before the Highlighted Line

Click on the next element which does not have this new orientation and repeat the process to reset the orientation (=0).

- Click on any line of input to display its input form. Edit the form and use the Replace button to update the input file.

☝ Replace the Highlighted Line

9) End the session

☝ Save

Clicking on Save will save the data, check it for errors, and build the “scratch files” needed for the (piping) analysis.

Results:

Compare the pump operating loads with and without the structure.

- The structure plays no role in the pump loads.

	FX	FY	FZ	MX	MY	MZ
TASK1	5569	-2604	-2034	-7405	-3460	-16647
Rel. anchor	1908	-1541	-642	-1968	-3248	-2648
TASK2a	1908	-1534	-642	-1974	-3246	-2647

Conclusion:

The steel looks good but it doesn’t change much. Would friction increase the significance of the structure? Why?

Task 3: No room for a loop; install an expansion joint instead.

- Select an 3.5 kg/cm^2 class, 8 inch expansion joint out of the Senior Flexonics / Pathway catalog.
- What sort of joint is needed here? Review the types of joint assemblies.
- A tied expansion joint on the riser and below the valve will be best suited to absorb the horizontal pipe growth over the pump. The vertical loads associated with thermal expansion can be adjusted by the spring at Node 70.
- Have CAESAR II calculate the free horizontal growth of the joint by breaking the system above the pump. Use this value to select the number of convolutions. Then install the expansion joint and analyze its suitability.

Model:

Open TASK1 and immediately Save As TASK3

Break the run above the pump:

- Change the From Node of the element 20 – 30 to 21. The relative horizontal displacements of nodes 20 & 21 (between elements 10 – 20 and 21 – 30) will be close to the required deflection of the expansion joint.
- (The plot will have the two sub-systems sharing the same origin.)

Reconnect 20 and 21 in the appropriate directions:

- Add a restraint in the Y direction at 20 with 21 as its connecting node
- Add the three rotational restraints between 20 and 21
- (Leave the transverse directions , X & Z, free)
- (The plot once again is fine.)

Results:

Using the <u>expansion</u> case displacements, calculate the change in position between Node 20 and Node 21.

- Nodes 20 & 21 move together in Y, RX, RY, & RZ because of the NODE/CNODE restraint definitions
- Delta X is 28 mm and delta Z is 21 mm resulting in a relative horizontal displacement of 35 mm

Check the pump operating loads.

- The Z moment on the pump is –2167 N.
- This is a very high load for a “zero stiffness” expansion joint. Why is it so high?

The catalog shows a 20 convolution joint provides 38.8 mm of lateral deflection

- But it also adds a lateral stiffness of 6 kg/mm or 58.7 N/mm.
- This stiffness, if modeled, would reduce the deflection.
- Reduced deflection drops the required number of convolutions and, in turn, increases the stiffness between 20 & 21
- Model the stiffness, check the deflection, select the joint, and model the stiffness until the deflection test fails or the pump load components become too high.

Conclusion:

Iterate to find the required number of convolutions

- Add those final two restraints, in X and Z, between 20 & 21 with a stiffness set to 58.8 N/mm
- Relative lateral displacement = 25.2 mm, Mz = -2351 N

- 16 convolutions allow 24.8 mm lateral deflection; K = 118 N/mm
- Set restraints to 118
- Relative lateral displacement = 20.0 mm but the pump load (Mz) is too big at-5200
- 20 convolutions are required (consult manufacturer for other options)

Model the 20 convolution expansion joint:

- The flanged expansion joint would be located between the discharge nozzle and the existing weld neck flange. To save time in this examination, the expansion joint will be placed between the flange and pipe rather than between the nozzle and flange. The error introduced will be small.
- Once again open TASK1 and immediately 'Save As' TASK3
- Move to the pipe element 20 – 30
- Enter Expansion Joint Modeler
- Select a 50 pound class, tied, 20 convolution tied expansion joint with slip on ends
- Place the joint at the From end (20)
- Adjust stiffness to pipe temperature
- Note details:

Non-concurrent Movement				Spring Rate				Length		
axial	lateral	angular	torsion	axial	lateral	angular	torsion	bellows	overall	weight
87.9	38.9	9	0.212	69	59	9	7102	317.5	406.4	412.8
				73	62	9	7504	:adjusted to 315 C		

Results:

Using the expansion case displacements, calculate the lateral deflection between Nodes 21 and 22, which bound the expansion joint.

- Delta X is 22.5 mm and delta Z is 9.4 mm resulting in a lateral displacement of 24.4 mm. A quick check of the catalog shows that this works for a 20 convolution joint
- There is minimal axial deflection and angular rotation. Torsional rotation (Ry) is 0.099 deg.

Check the pump loads

- Operating loads Mx & Mz at node 10 look large—Mx = -2080 Nm and Mz = --2671 Nm. Sustained (installed) loads are small indicating that these large loads are due to thermal growth.
- Running the API 610 report shows that this layout is acceptable with the largest load component being the global Mz at 1.52 times Table 4.

Evaluate the expansion joint:

- Estimate the number of expansion cycles for the life of this joint at 2000.
- Run through the linear interaction formula for a quick check

	Actual	Allowed	Ratio
Axial	0.34	87.9	0.004
Lateral	24.5	38.9	0.630
Bending	0.0005	9	0.000
		Sum of ratios:	0.634

- Confirm the twist is within its limit: actual = 0.0872 deg. & allowed = 0.212 deg.

- Run through the EJMA check

	Actual
Axial	0.0137 = X
Lateral	24.5 = Y
Bending	0.0005 = Theta
Eff. Dia.	239.6 = D
Flex. Length	317.5 = L

X+0.00872665*D*Theta+3*D*Y/L = 55.48

- These checks are also available in CAESAR II

Conclusion:

A 20 convolution expansion joint will safely provide the added flexibility required for proper pump operation.

Complete the Expansion Joint Specification Sheet (Appx. A of the Standards of EJMA)

Other convolution counts are available; watch out for fatigue (rating of 2000 cycles); consult the manufacturer.

Task 4: What if the long weld neck flange is connected to a vessel?

- There may be sufficient flexibility in the vessel wall to satisfy the pump requirements.
- The thermal growth of the vessel may reduce or increase the pump loads.
- The vessel connection may require examination
- Assume: vertical vessel
  OD = 1500 mm
  wall = 4.75 mm
  nozzle pad is 4.75 mm. thick and 100 mm. wide
  nozzle is 2200 mm above skirt
  skirt is 3000 mm above foundation
  a tray is within 600 mm of the nozzle and a stiffener ring is 1000 mm on the other side
- Incorporate the new boundary conditions

Model:

Replace the fixed termination of the long weld neck (at D) with a vessel model. (Note that the imposed displacements could be defined without modeling the vessel.)

- Starting again with TASK1, open TASK1 and immediately 'Save As' TASK4
- Press Ctrl+End to jump to the end of the input
- Continue the vessel model by starting with 110 (D) to 6010 as a rigid construction element to the vessel centerline and follow with elements down through the vessel and skirt
- Anchor the bottom of the skirt (6030).
- Remove the anchor at 110

Results:

Compare the pump operating loads in TASK4 with TASK1.

- The moment about Z is just as bad as before.
- Other loads are similar

	FX	FY	FZ	MX	MY	MZ
TASK1	5569	-2604	-2034	-7405	-3460	-16647
TASK4	5452	-2645	-2062	-8560	-3534	-16189

Model:

Add the Welding Research Council Bulletin 297 nozzle flexibility:

- Evaluate the vessel/nozzle parameters to confirm that the WRC 297 approach is valid. Here, T will be the vessel thickness plus the pad thickness.
  $d/t \geq 20$: here $d/t = 26$
  $20 \leq D/T \leq 2500$; here $D/T = 158$
  $5 \leq d/T \leq 100$; here $d/T = 26$
- Break the system at the nozzle junction by changing the From Node of 110 – 6010 to 6000. (The element sequence is now 100-110, 6000-6010 and the system is disconnected. It will be re-connected by the nozzle specification next.)
- On 100 – 110 insert the WRC297 nozzle to connect 110 to 6000 using the data above
- Review the nozzle flexibilities listed in the error review. The nozzle provides no axial flexibility but the longitudinal and circumferential bending flexibilities appear significant.

Results:

Compare the updated pump loads.

	FX	FY	FZ	MX	MY	MZ
w/o 297 flex	5452	-2645	-2062	-8560	-3534	-16189
with 297 flex	1788	-2000	-1910	-7538	-3553	-3717

- Mx to Table 4 ratio is 2.14 and (global) Mz to Table 4 ratio is 2.11. These loads are greatly improved but still exceed the limit of 2.00. Including this flexibility in the loop and expansion joint models will be left to the student.

Check other structural results and pipe stresses.
- A Size 12 Grinnell spring supports the riser.
- The Y support at 78 carries load in the installed and operating positions
- Pipe stress is not a problem.

Conclusion:

The drop in load is significant but additional flexibility (either the loop or expansion joint) is required to satisfy the pump limitations.
Assuming that added flexibility for the pump will drop the vessel loads, evaluate the current vessel loads.

Model:

Enter the nozzle/vessel data in the Welding Research Council Bulletin 107
- Evaluate the vessel/nozzle parameters to confirm that the WRC 107 approach is valid
  $d/D \leq 0.3$; here $d/D = 0.1667$
  $Dm/T \geq 50$; here $Dm/T = 157$
- The nozzle vector must point to the center of the vessel for proper load conversion
- The (ASME Section VIII Division 2) design stress intensities for SA-516 Gr. 70 is 160.647 MPa cold and 128.932 MPa hot
- The (ASME Section VIII Division 1) maximum allowable stress values for SA-516 Gr. 70 is 137.895 MPa cold and 133.758 MPa hot
- Pull the sustained and expansion loads from TASK4

A mixed approach is offered here to examine the local stresses in the vessel wall around the nozzle connection. Stresses are calculated using a Division 1 – Design by Rule – approach while they are evaluated using the Division 2 – Design by Analysis – approach. Since not all of the Division 2 criteria will be examined here, the Division 1 maximum allowable stress limits (defined above) will be used rather than the Division 2 design stress intensities. Calculate local stresses using WRC 107 but use the stress summations from ASME BPVC Section VIII Div. 2 Appendix 4 – Design Based on Stress Analysis. See also WRC Bulletin 429 – 3D Stress Criteria Guidelines for Application.
- Push the button
- Pm (general, primary membrane) stress has yield strength as its limit thus ensuring no failure by gross distortion. This is away from the junction discontinuity and is simply calculated using pressure stress equations. $Pm < Smh$
- Pm+PL (primary membrane) stress is an indicator of excessive plastic deformation. This stress combines the local membrane stress (stress that is constant across the cross section) due to sustained loads (from WRC 107) with the pressure term in Pm. $Pm+PL<1.5Smh$
- Pm+PL+Q (primary plus secondary) stress monitors shakedown. These primary plus secondary stresses are used to monitor fatigue. Q is calculated using the WRC 107

results—bending stress from sustained loads and membrane and bending stress from expansion loads. Pm+PL+Q<1.5(Smc+Smh)

- There is no Pb stress in this evaluation. Pb is bending due to pressure. This is monitored just as Pm but the limit is 1.5Smh to account for the shape factor.
- Additional checks would be required if fatigue failure is anticipated; in which case the peak stresses need be calculated and comparisons be made to the endurance limit.

Results:

Vessel shell is thick enough to carry the pipe's operating loads even if the entire pressure thrust load is carried by the nozzle. (Test this by running the analysis with and without pressure thrust.)

Task 5: What effect does friction have on the pump loads?

- Friction on those Y supports will change the pump loads.
- Use the loop model to examine the effects of friction
- *Friction should not be used as a method to reduce pump loads*.

Model:

What are typical values for the coefficient of friction?

- Steel-on-steel centers around 0.3
- Steel-on-Teflon® centers on 0.15

Starting with TASK2, open TASK2 and immediately 'Save As' TASK5

- Locate the two Y supports and specify a coefficient of friction of 0.3 on each

Results:

Compare the pump operating loads in TASK5 with TASK2 (the second TASK2, with anchor released to size the hanger).

- The moment about Z is much larger.
- Other loads are similar

	FX	FY	FZ	MX	MY	MZ
TASK2	1908	-1541	-642	-1968	-3248	-2648
TASK5 (0.3)	2419	-1650	-444	-1229	-3116	-4373

- Fz and Mx are lower but Fx and Mz are greater. Mz to Table 4 ratio is 2.48. The limit is 2.00.

Model:

Try 0.15 for the coefficient of friction

Results:

The loads are still too high

	FX	FY	FZ	MX	MY	MZ
TASK2	1908	-1541	-642	-1968	-3248	-2648
TASK5 (0.15)	2187	-1601	-534	-1565	-3175	-3591

- Mz to Table 4 ratio drops to 2.04.

Conclusion:

Pump loads are very sensitive to system supports and their friction.

Task 6: Document the analysis.

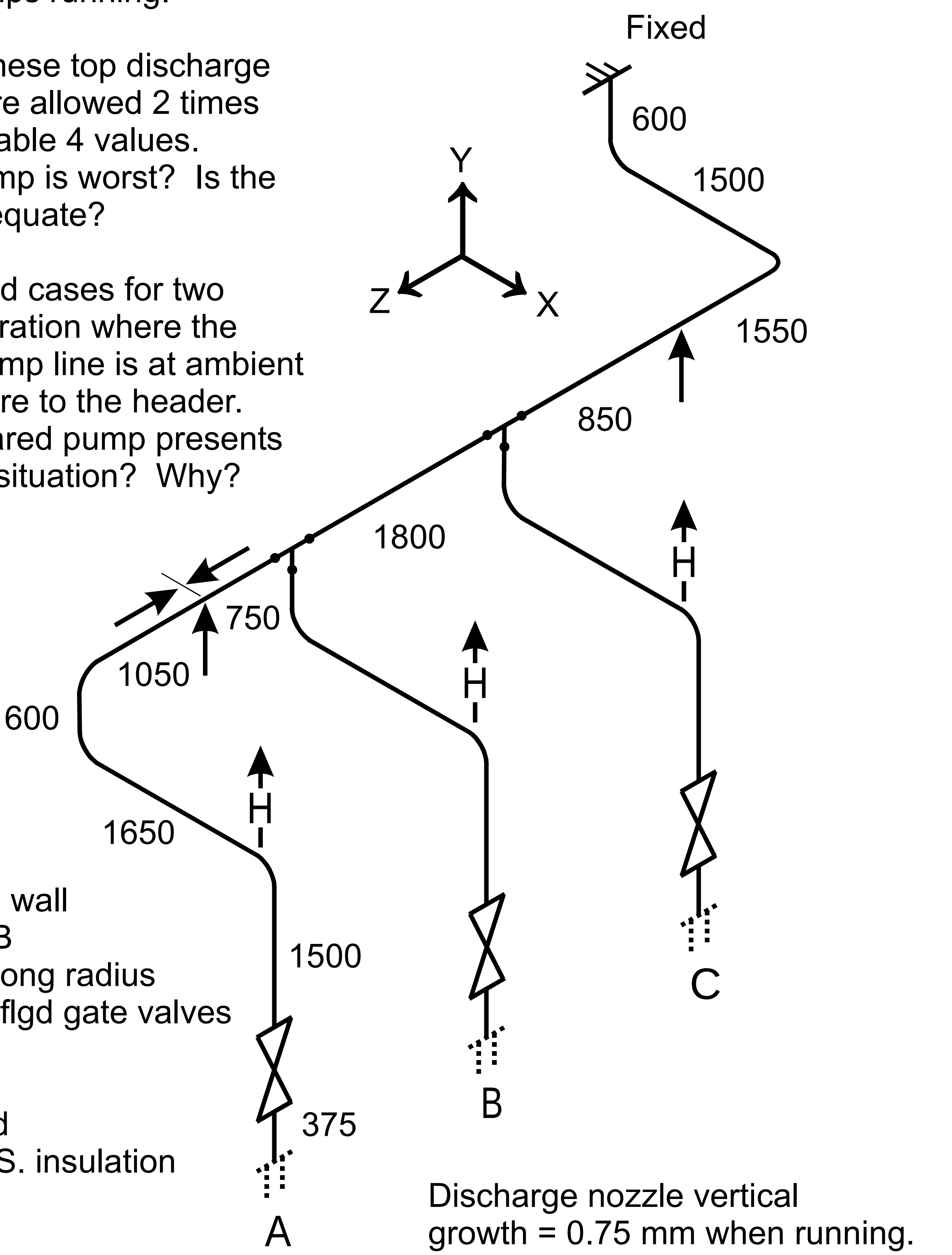
Input echo
Plot
Output report
Annotated stress isometric
File backup

Pump Manifold

Model system and size springs for all pumps running.

Assume these top discharge nozzles are allowed 2 times API 610 Table 4 values. Which pump is worst? Is the layout adequate?

Set up load cases for two pump operation where the spared pump line is at ambient temperature to the header. Which spared pump presents the worst situation? Why?

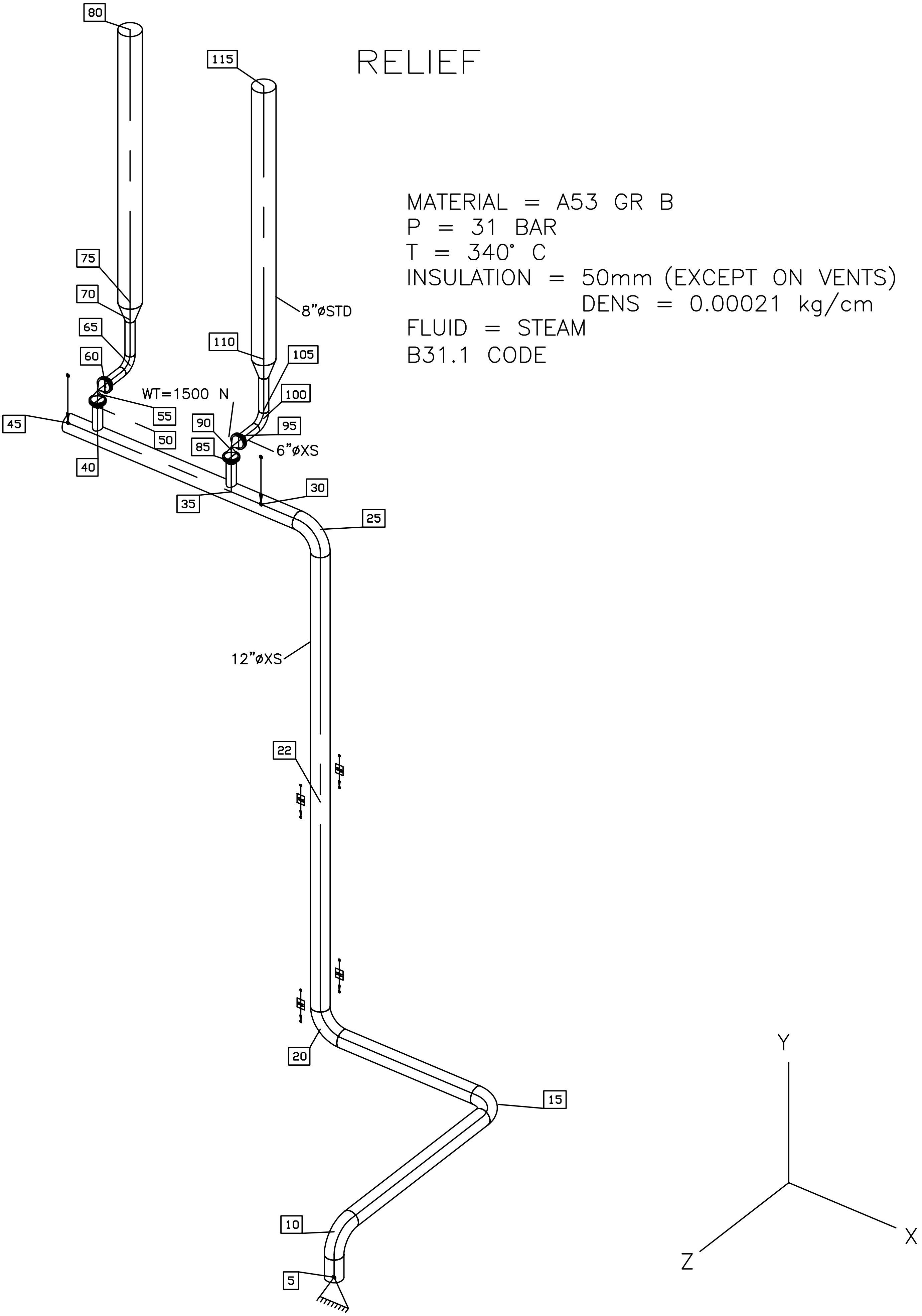


4 inch std. wall
A106 Gr. B
all bends long radius
class 300 flgd gate valves
T=120 C
P=20 bar
water filled
50 mm C.S. insulation

Discharge nozzle vertical growth = 0.75 mm when running. Pump centerline is in X.

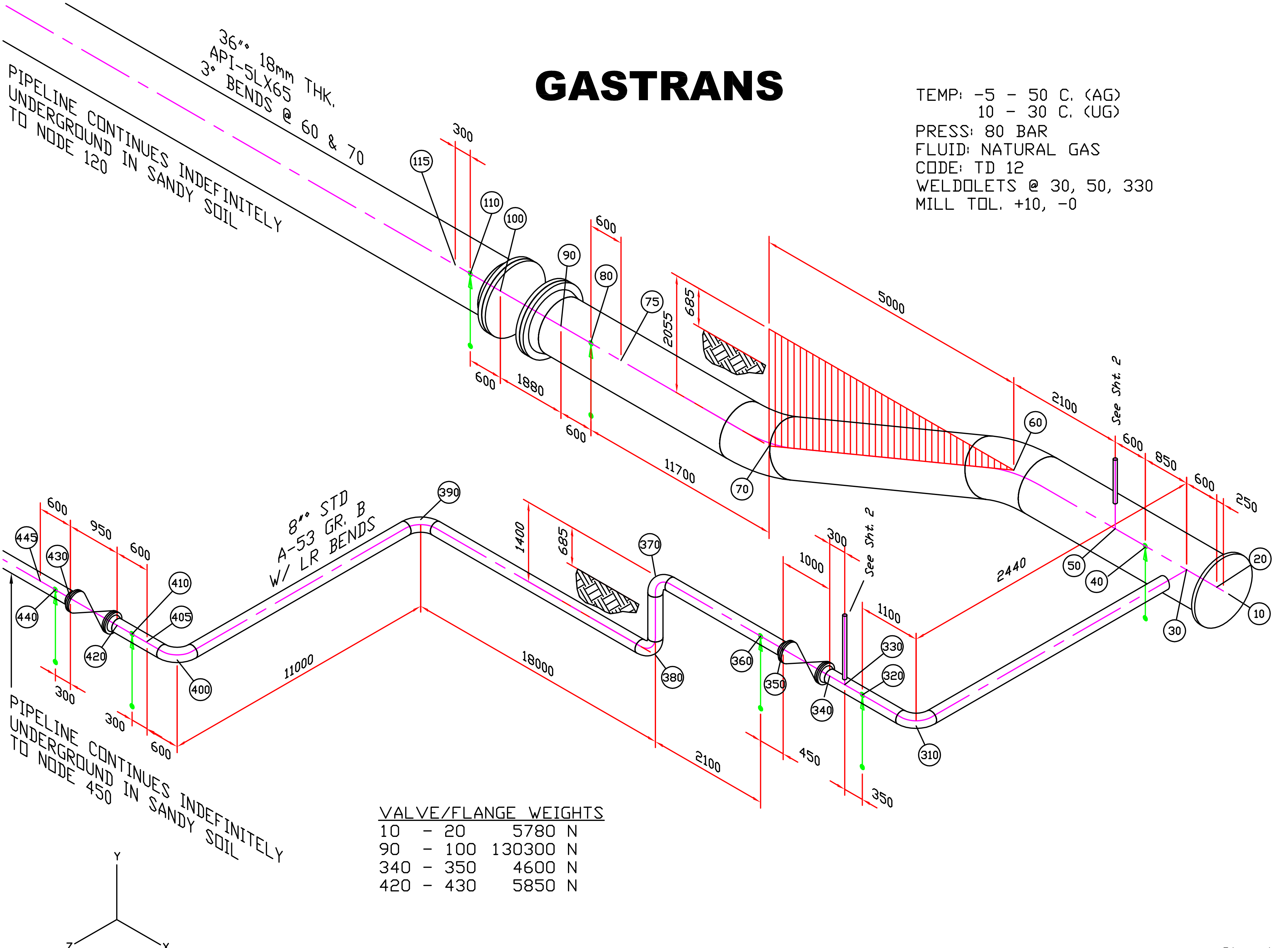
RELIEF

MATERIAL = A53 GR B
P = 31 BAR
T = 340° C
INSULATION = 50mm (EXCEPT ON VENTS)
DENS = 0.00021 kg/cm
FLUID = STEAM
B31.1 CODE



GASTRANS

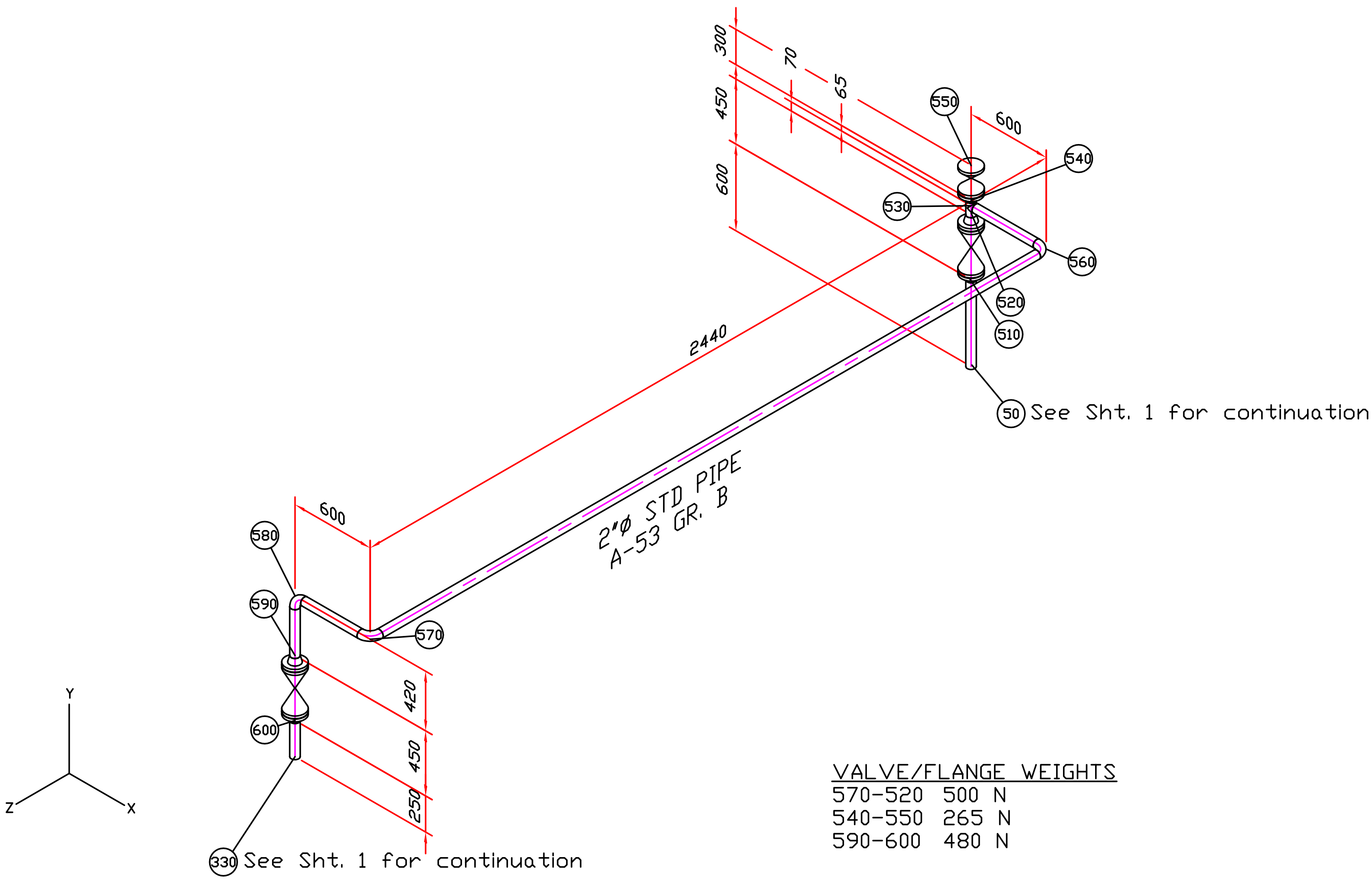
TEMP: -5 - 50 C. (AG)
10 - 30 C. (UG)
PRESS: 80 BAR
FLUID: NATURAL GAS
CODE: TD 12
WELDOLETS @ 30, 50, 330
MILL TOL. +10, -0



VALVE/FLANGE WEIGHTS

10	- 20	5780 N
90	- 100	130300 N
340	- 350	4600 N
420	- 430	5850 N

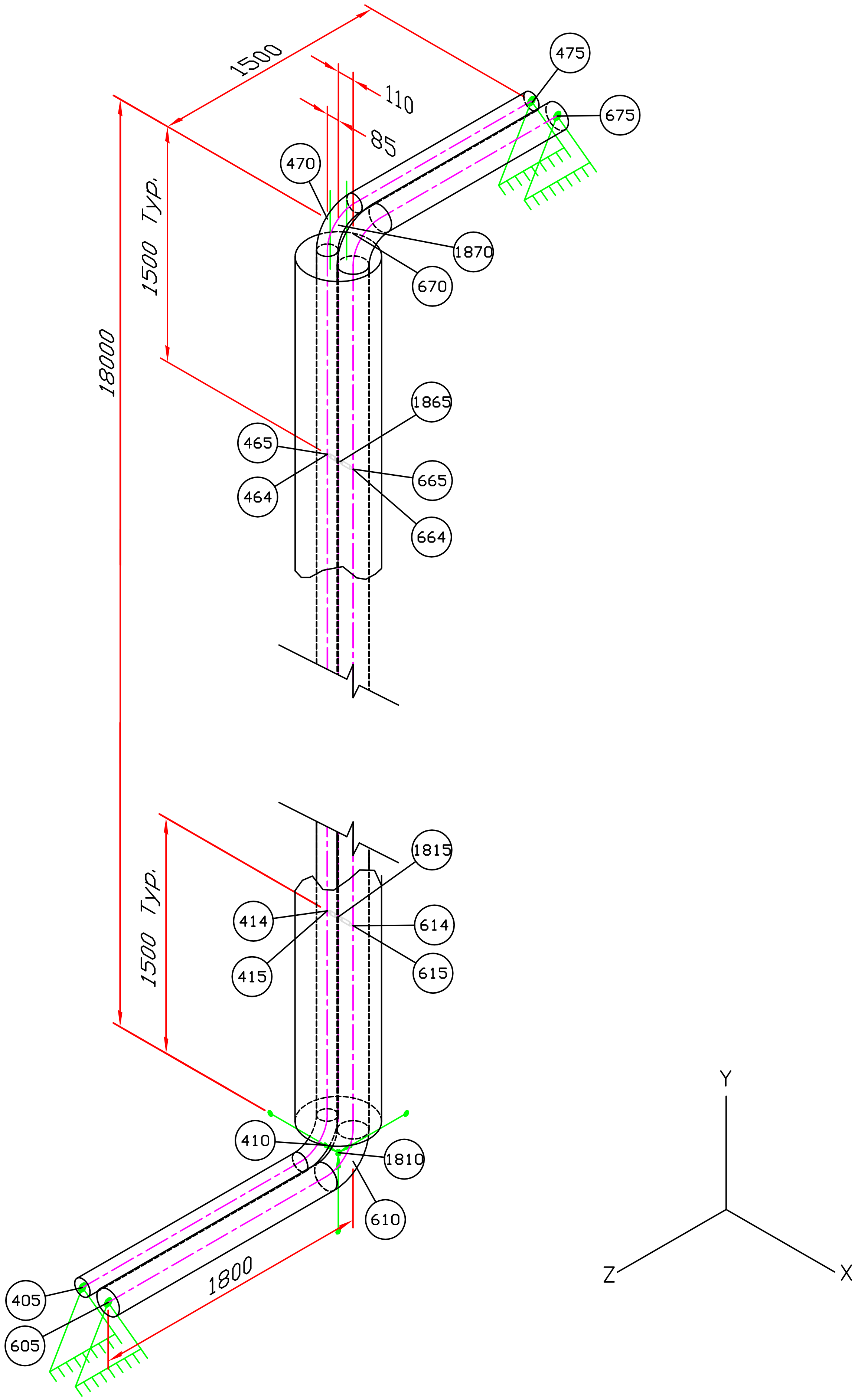
GASTRANS



VALVE/FLANGE WEIGHTS

570-520	500 N
540-550	265 N
590-600	480 N

RISER-J3



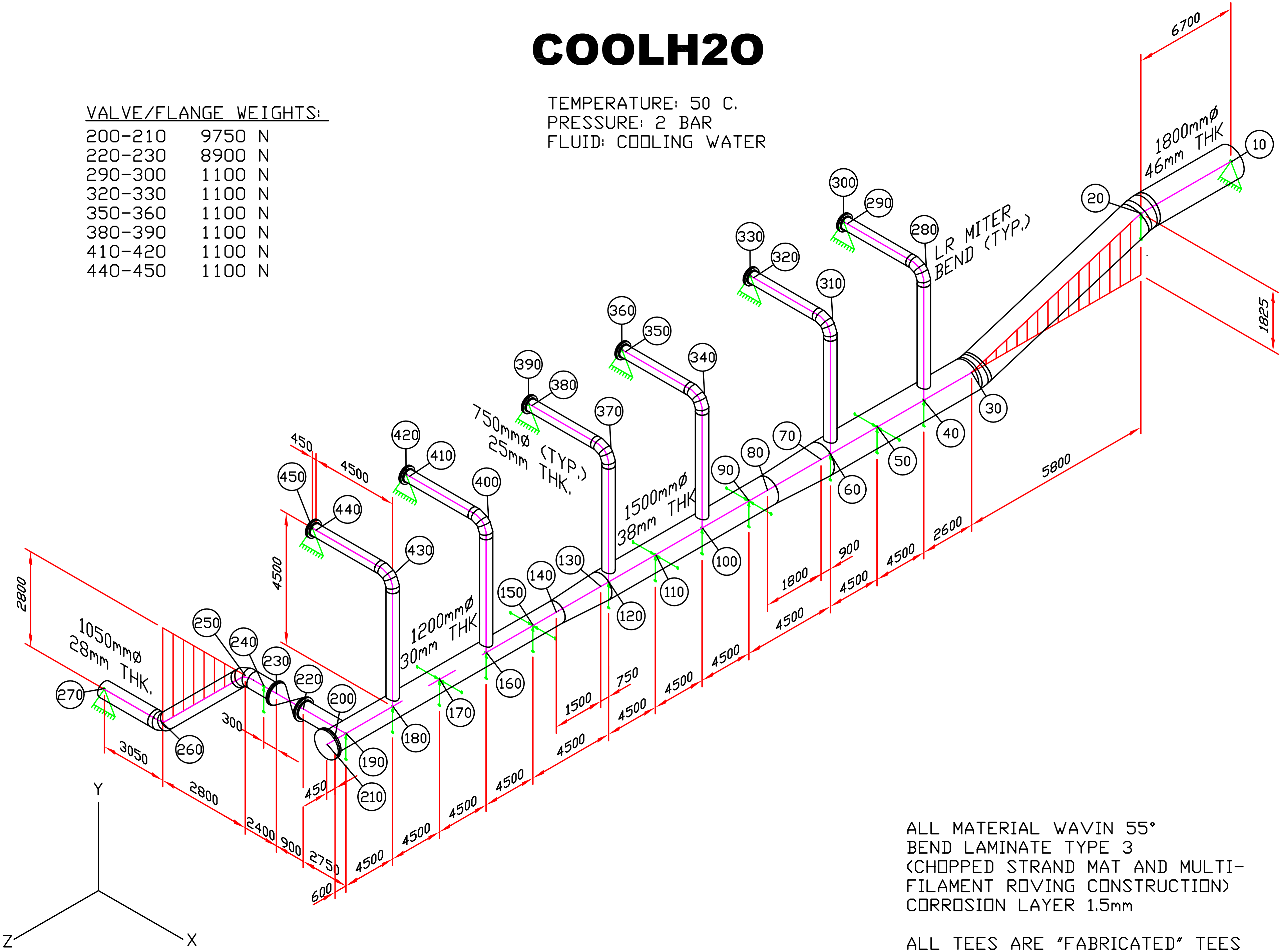
1500
110
85
475
675
470
1870
670
Typ.
1500
18000
1865
465
464
665
664
1815
414
614
415
615
Typ.
1500
410
1810
610
1800
405
605
Y
Z
X

COOLH2O

TEMPERATURE: 50 C.
PRESSURE: 2 BAR
FLUID: COOLING WATER

VALVE/FLANGE WEIGHTS:

200-210	9750 N
220-230	8900 N
290-300	1100 N
320-330	1100 N
350-360	1100 N
380-390	1100 N
410-420	1100 N
440-450	1100 N



ALL MATERIAL WAVIN 55°
BEND LAMINATE TYPE 3
(CHOPPED STRAND MAT AND MULTI-
FILAMENT ROVING CONSTRUCTION)
CORROSION LAYER 1.5mm

ALL TEES ARE "FABRICATED" TEES
ALL BENDS ARE LONG RADIUS MITERS
90° MITERS ARE 4 CUT - ALL OTHERS 2 CUT

COURSE EVALUATION

We would appreciate your taking a moment to let us know how we did, and what we can do to improve our presentation in the future.

Course Name	Date	Location
______________________________	______________________________	______________________________

Background:

1. What competing products have you used? ____

2. How did you hear about this course? ____

3. Is the subject matter of this course used in the performance of your current or near future job assignments? ____ Yes ____ No

Content:

Circle the label that most closely represents your opinion about the course and add any comments you may care to make.

4. How would you rate the overall value of this course regardless of how much or how often you personally might use it?

HIGH	MODERATE	LITTLE	NONE

What could be added to make the course more valuable? ______________________________

In your opinion, what could be dropped? ______________________________

5. How logical was the order of the course subject matter:

VERY LOGICAL	LOGICAL	SOMEWHAT LOGICAL	NOT LOGICAL

Comments: ____

6. The value of the student handouts and/or reading materials used in this class was/is/will be:

HIGH	MODERATE	LITTLE	NONE

Comments: ____

Presentation

7. The instructors' knowledge of the subject matter seemed to be:

VERY GOOD MODERATE LITTLE POOR

Comments: ____

8. The instructors' ability to answer questions clearly was:

VERY GOOD MODERATE LITTLE POOR

Comments: ____

9. To what extent were you satisfied with the opportunity to participate?

HIGHLY MODERATELY LITTLE NONE

Comments: ____

10. To what degree did the instructors' lecture/discussion contribute to your understanding of the course material?

HIGH MODERATE LITTLE NONE

Comments: ____

Overall Impression:

11. What in your opinion were the strong points?

____

____

Weak points?

____

____

12. General comments or suggestions for improving the course (e.g. regarding format, location, personnel, documentation, size, length, lecture / workshop balance, etc.):

____

____

____

13. If you have attended other, similar, courses, how would you rate this course in comparison?

EXCELLENT GOOD FAIR POOR

14. Would you recommend this course to others? ____Yes ____No

15. In general, did the seminar:

____ Exceed your expectations

____ Meet your expectations

____ Not meet your expectations

Learning Outcome:

16. To what degree did the course meet the stated objectives?

HIGH MODERATE LITTLE NONE

Comments: ____

17. To what degree are the stated objectives for this course appropriate?

HIGH MODERATE LITTLE NONE

Comments: ____

Our brochure promotes certain learning outcomes through your attendance of this seminar. Please let us know if you gained this knowledge by reviewing the list below and checking the appropriate box.

		Y	N	N/A
18.	Did you learn problem-solving principles that you can apply to real piping systems?	☐	☐	☐
19.	Were you able to gain any insights by talking with classmates and the program authors?	☐	☐	☐
21.	Were you exposed to recent analytical techniques in dynamic analysis?	☐	☐	☐
22.	Did you learn the underlying principles used in evaluating piping systems?	☐	☐	☐
23.	Did you receive adequate “hands on” experience using CAESAR II?	☐	☐	☐
24.	Did the theory improve your confidence and speed in modeling?	☐	☐	☐
25.	During this course, were you able to devote time to focus on this field of analysis?	☐	☐	☐
26.	Did you learn our approach to reducing loads and stresses in piping systems?	☐	☐	☐
27.	Can you now handle a wider range of analysis?	☐	☐	☐
28.	Can you now address piping problems more efficiently and accurately?	☐	☐	☐
29.	Will you be able to keep more analysis “in house”?	☐	☐	☐

30. Any Additional Comments?

Printed Name (optional):