SST SYSTEMS, INC.
The FASTEST Solutions for Piping Design and Analysis

checkSTRESS Examples

EXAMPLE 1 - Using Expansion Loops

DATA: An 8" NB Schedule 80 pipe (see Fig. 1A) connects two equipment at nodes 10 and 30 with an offset of 4' (i.e., equal to distance between nodes 20 and 30). The pipe, made of A53 Grade A carbon steel, is heated to 300° F. This problem illustrates the use of expansion loops to reduce thermal stresses.

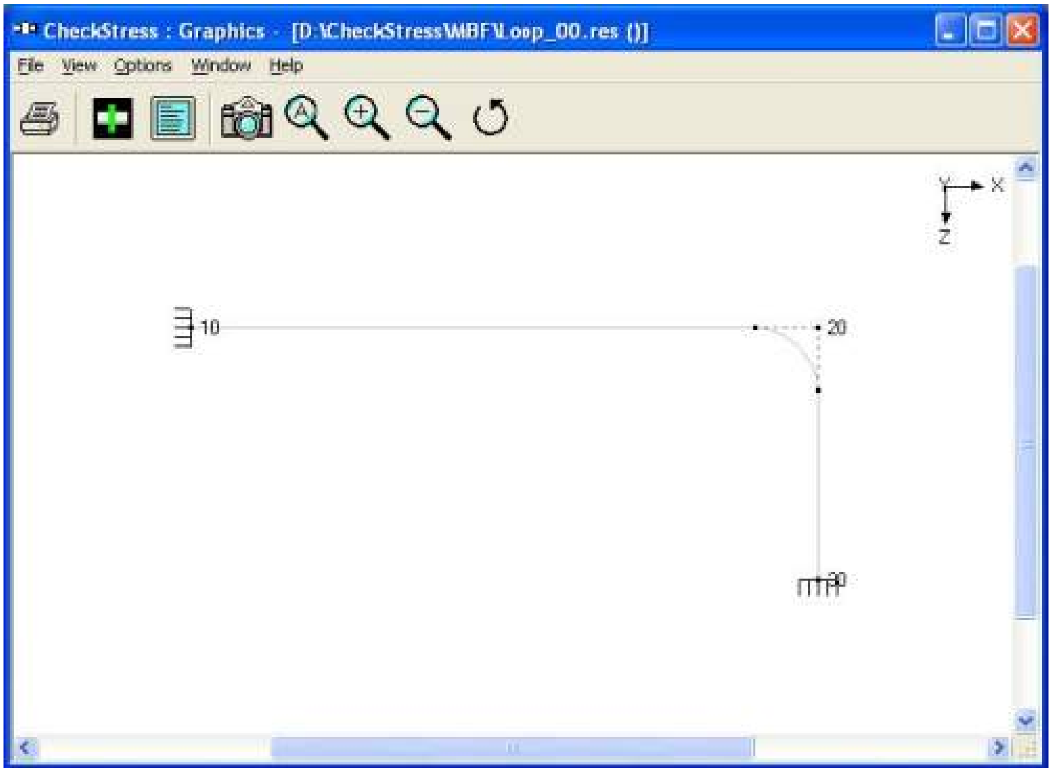

Figure 1A - Layout

Pipe between nodes 10 and 20 grows thermally to the right towards node 20, while pipe between nodes 30 and 20 grows up towards node 20, as illustrated in Fig. 1B.

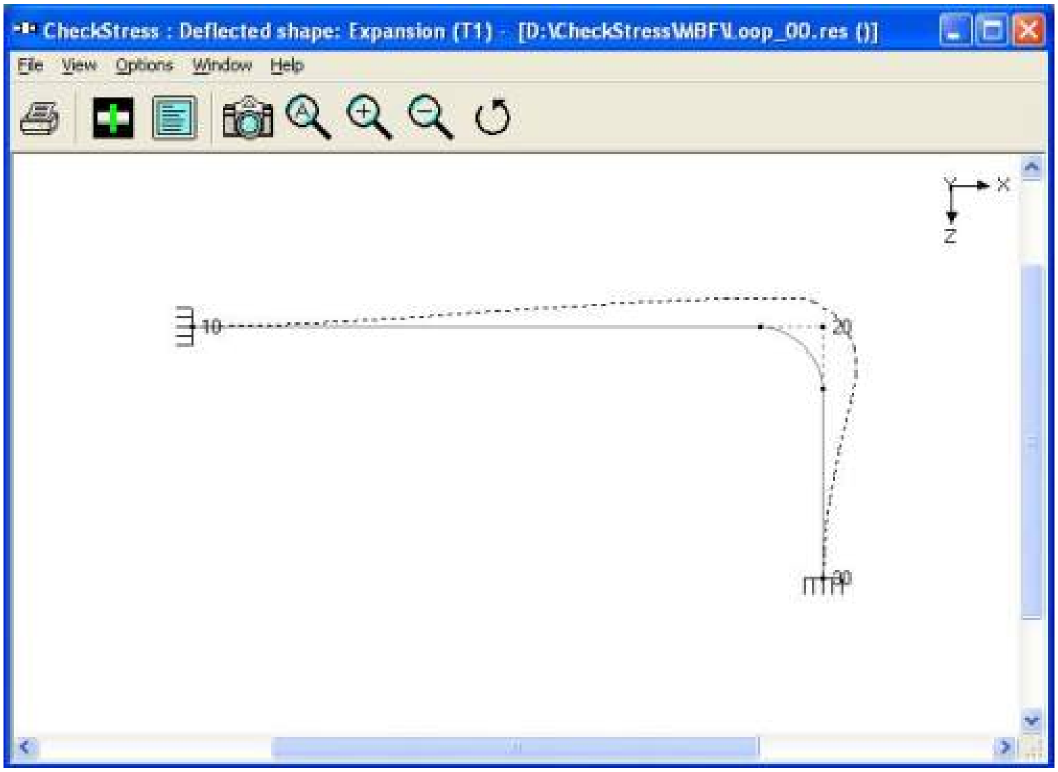

Figure 1B - Thermal Deflection

This thermal deformation generates large thermal stresses (orange and red zones) in the bend at node 20 and at anchor node 30, as shown in Fig. 1C.

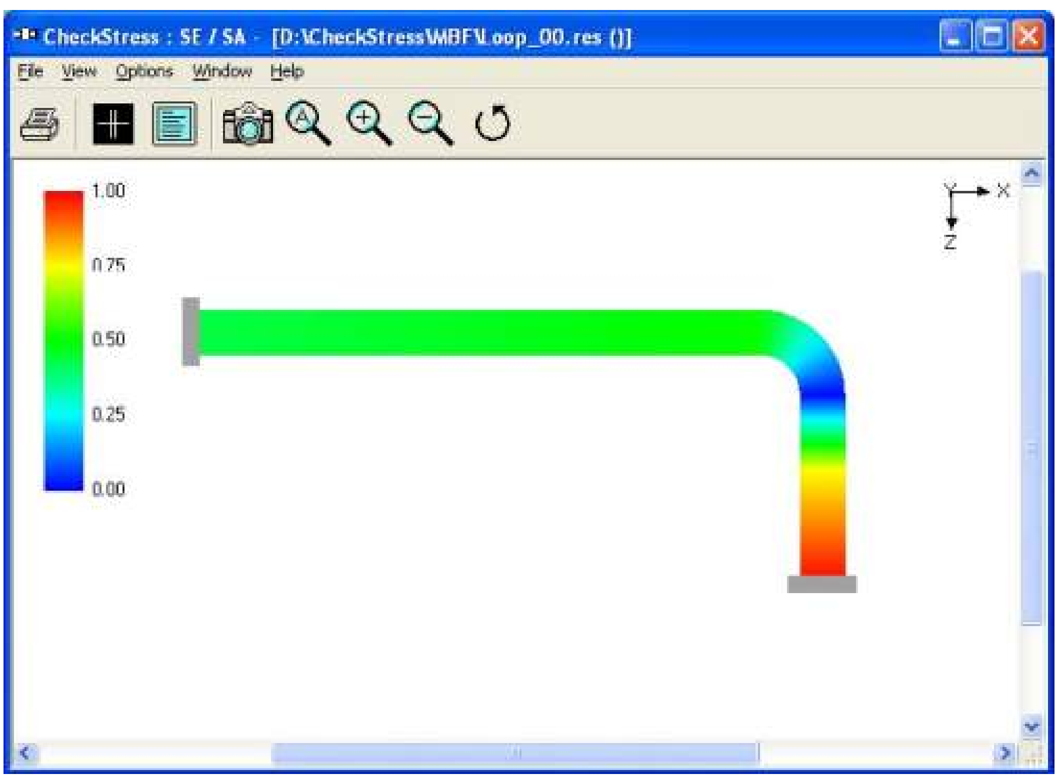

Figure 1C - Non code-compliant (notice the reds)

Now, as a designer, when you use checkSTRESS, you know this layout will be sent back to you by the Stress dept. with suggested rerouting. If you had known beforehand what the engineer discovers, you could have done the rerouting as shown in Fig.1D.

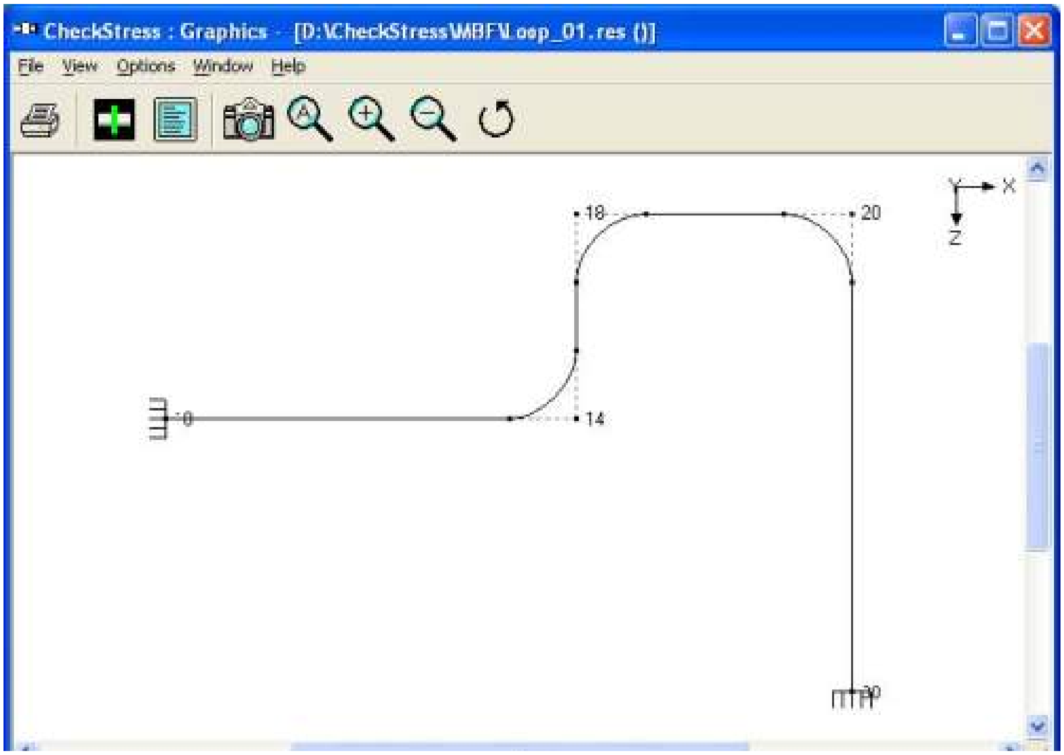

Figure 1D - Avoiding the "back and forth" by rerouting beforehand

Fig. 1D shows a revised layout with a loop, introducing two additional bends at nodes 14 and 18, thereby making the layout more flexible. So, thermal growth of X-directional pipes between nodes 10 and 14 and then between 18 and 20 as well as the growth of Z-directional pipe between nodes 30 and 20 are absorbed by the 3 bends at nodes 14, 18 and 20. The corresponding stress contour plots for thermal and sustained load cases are shown in Fig.1E and Fig. 1F, confirming code compliance. Now, the designer sends this code-compliant model file to the engineer for further detailed analysis, saving his/her valuable time and the engineer's as well.

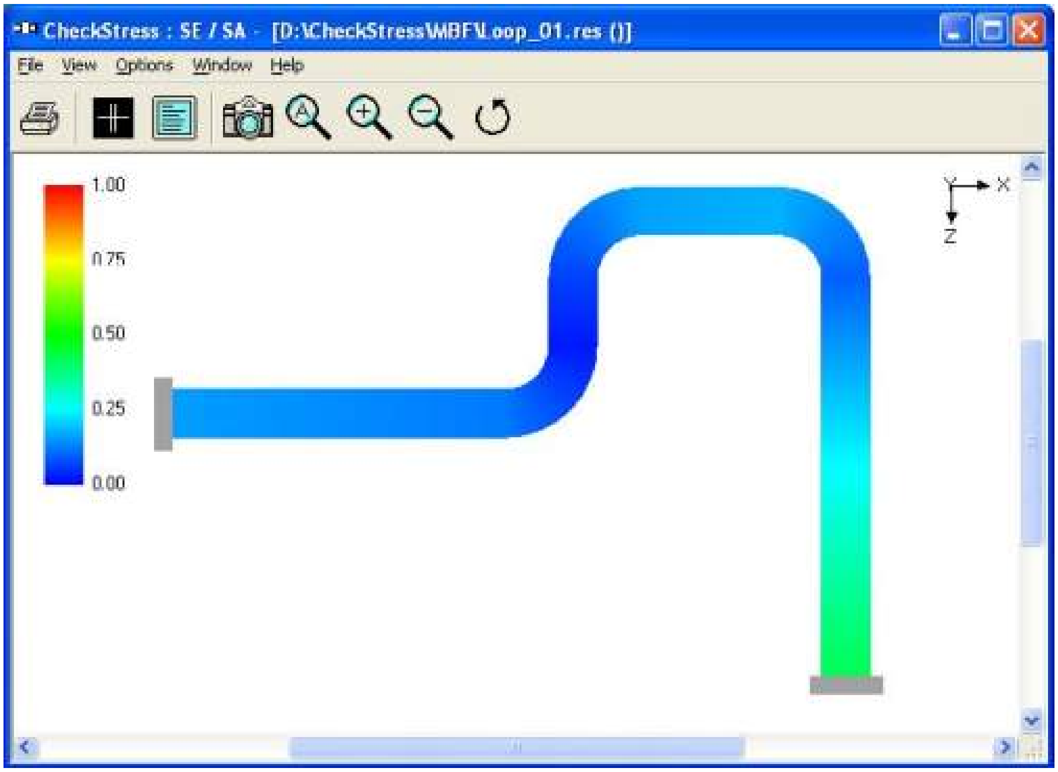

Figure 1E - (Code compliant thermal case)

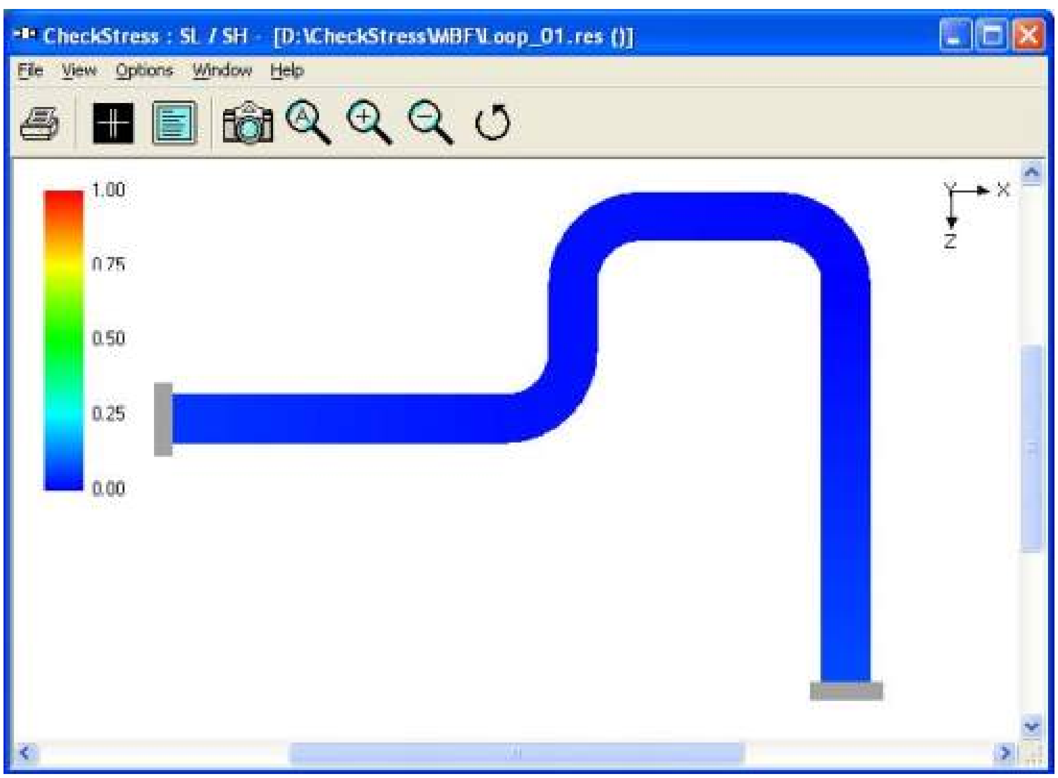

Figure 1F - (Code-compliant sustained case)

EXAMPLE 2 - Splitting Thermal Growth

This system shown in Fig. 2A is made of three pipe sizes:

- 4" NB/Sch. 40: Between nodes 10 and the first reducer
- 6" NB/Sch. 40: Between the first reducer and the second reducer and ending at node 90
- 8" NB/Sch. 40: Between nodes 90 and anchor node 130
- T=470°F

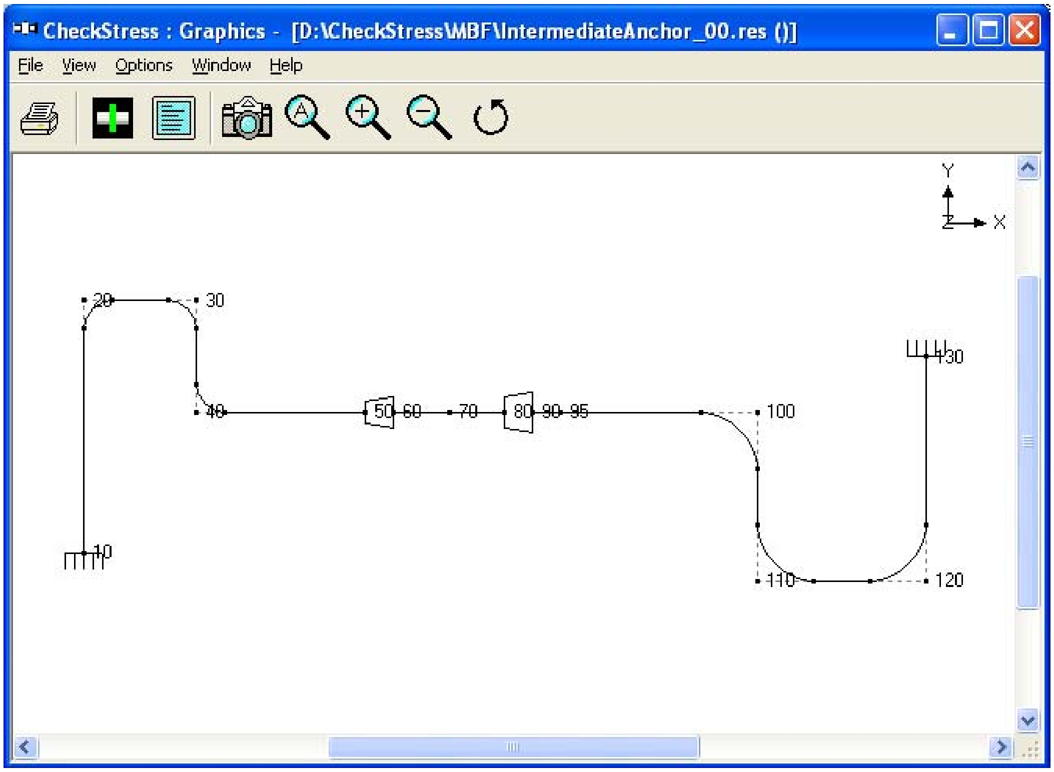

Figure 2A - Layout with Node Numbers

Since the loop between nodes 10 and 40 is much more flexible (as it is made of 4” pipe) than the loop between nodes 100 and 130, the straight pipe between nodes 40 and 100 will thermally grow mostly towards the 4” loop, as shown in Fig. 2B, straining the pipe between nodes 10 and 40.

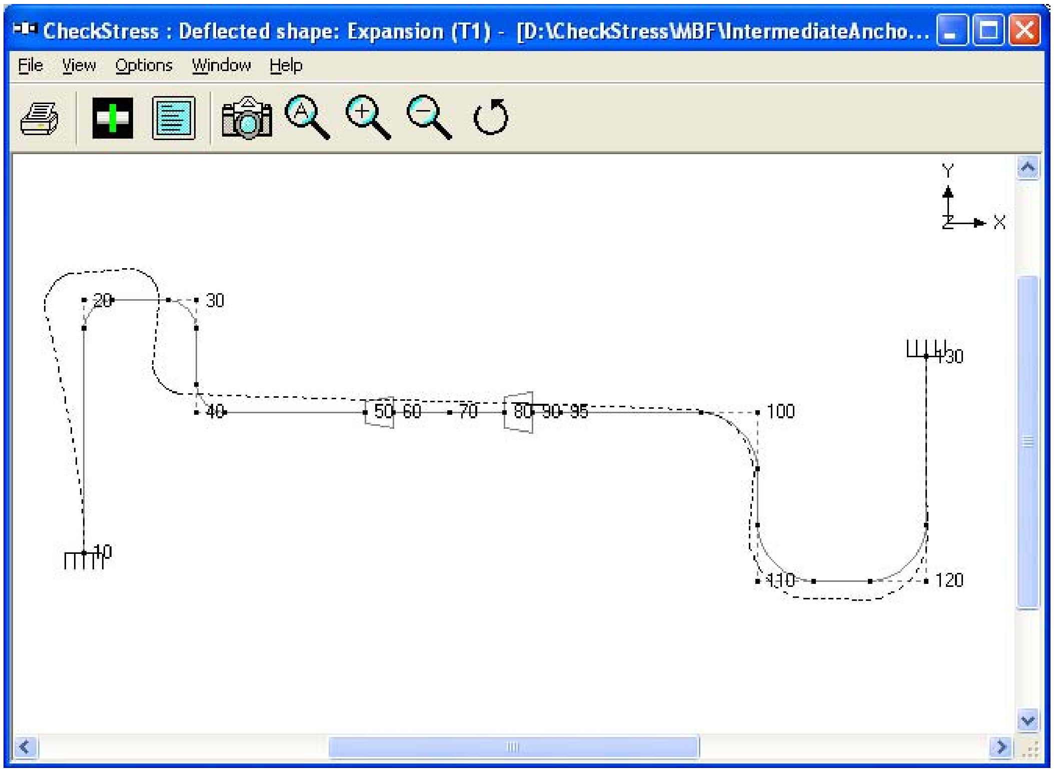

Figure 2B - Thermal Deformation Plot

This, in turn, produces large thermal stresses (i.e., orange and red zones) in the 4" loop and at anchor node 10, as observed in Fig. 2C. In other words, the thermal growth of pipe between nodes 40 and 100 is mostly absorbed by the 4" loop and very little by the 8" loop, defeating the very purpose of the 8" loop.

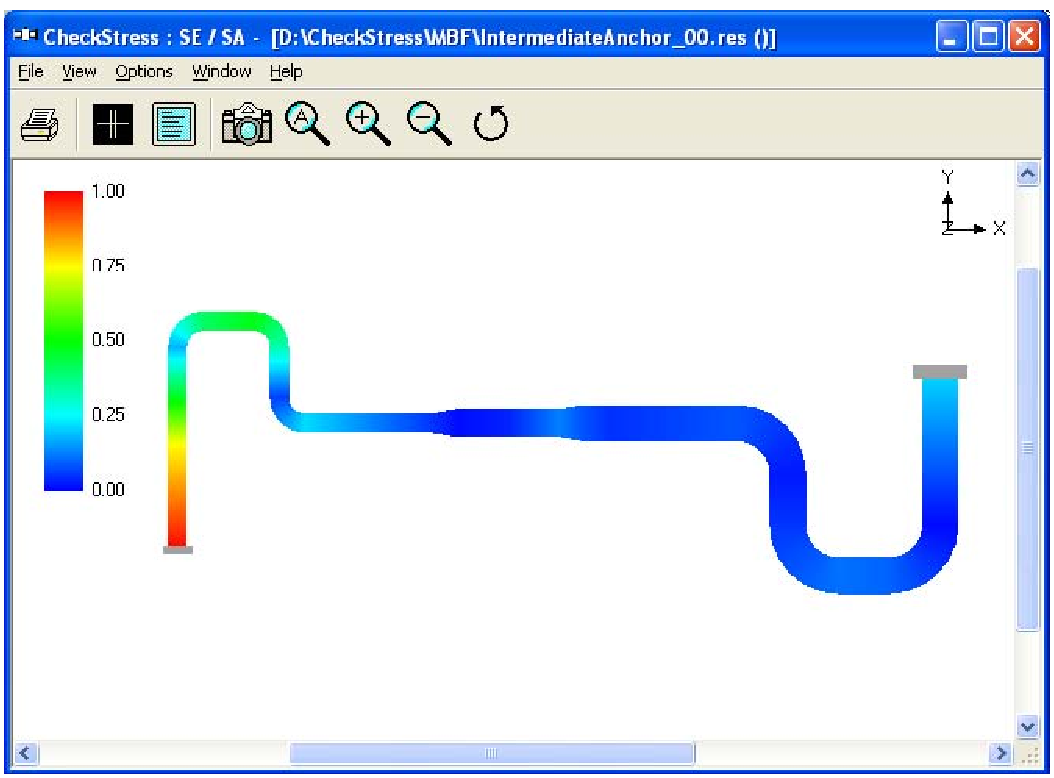

Figure 2C - Thermal Stress Contour Plot

In order to alleviate thermal stresses in the 4" loop, introduce an intermediate anchor at node 95 immediately after the second reducer, so that the thermal growth of straight pipe from node 95 to node 100 is absorbed by the 8" loop, while the thermal expansion of straight pipe between nodes 40 and 95 is absorbed by the 4" loop, thereby making both loops achieve their intended purpose. The corresponding thermal displacement and thermal stress contour plots are given in Fig. 2D and Fig. 2E respectively.

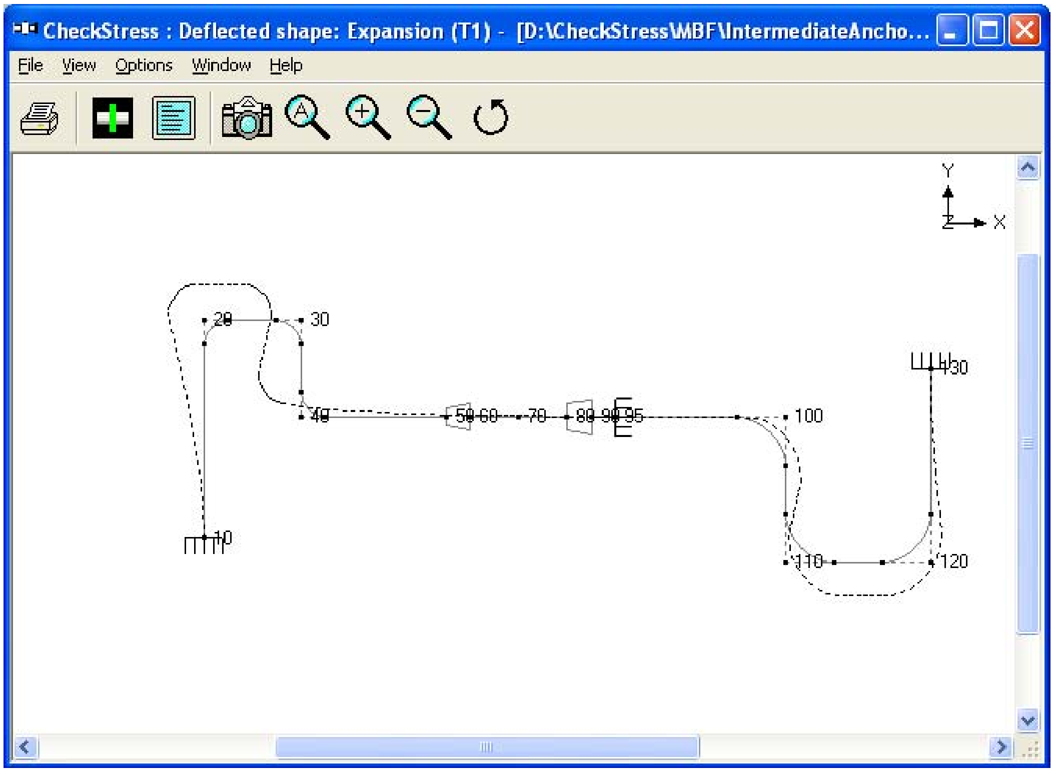

Figure 2D - Thermal Deformation Plot for Layout with Intermediate Anchor

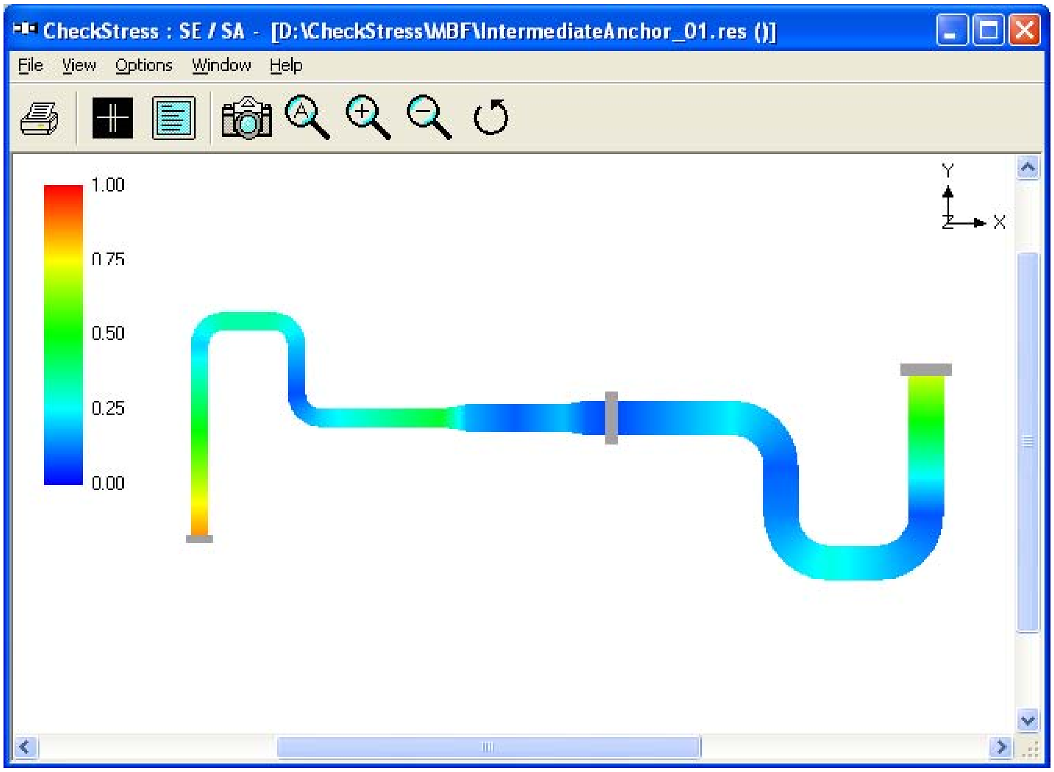

Figure 2E - Thermal Stress Contour Plot for Layout with Intermediate Anchor

Fig. 2F confirms that the present configuration with only two equipment nozzles at nodes 10 and 130 and an intermediate anchor at node 95 safely meet the code stress requirement for sustained load.

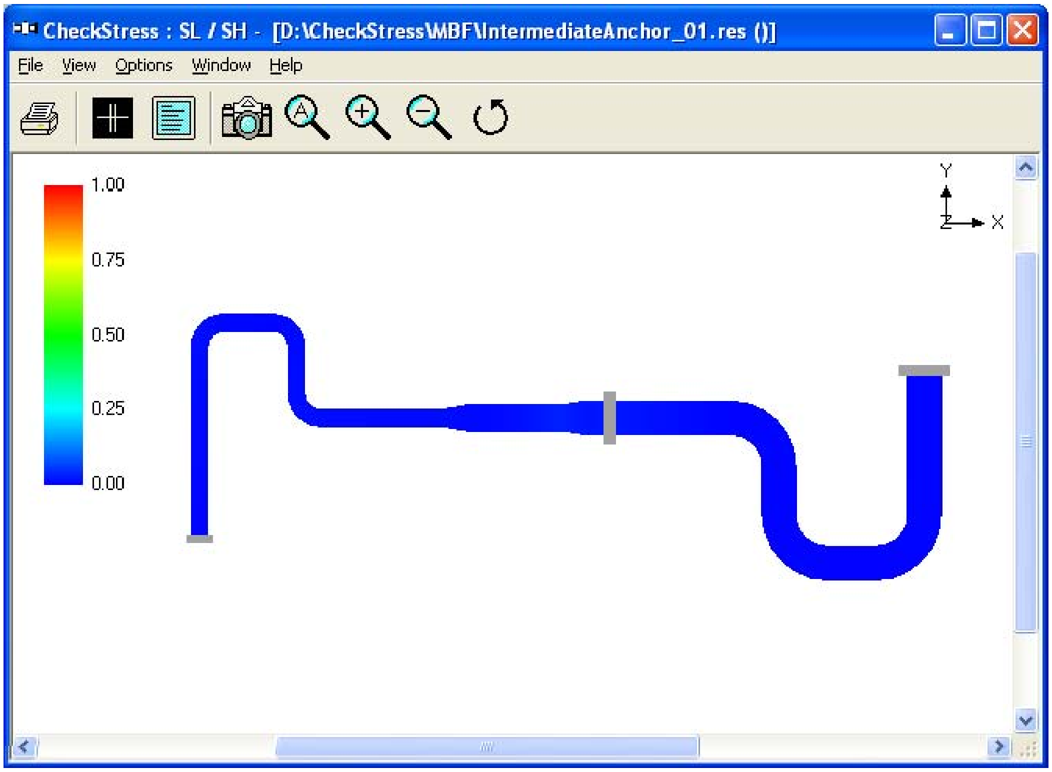

Figure 2F - Sustained Stress Contour Plot for Layout with Intermediate Anchor

EXAMPLE 3 - Axial Restraints to Direct Thermal Growth

This problem shows how axial restraints (i.e., pipe supports that prevent movement along a pipe's axis) can be effectively used to direct thermal growth towards expansion loops and split thermal growth in a line such that the two piping portions grow in opposite directions.

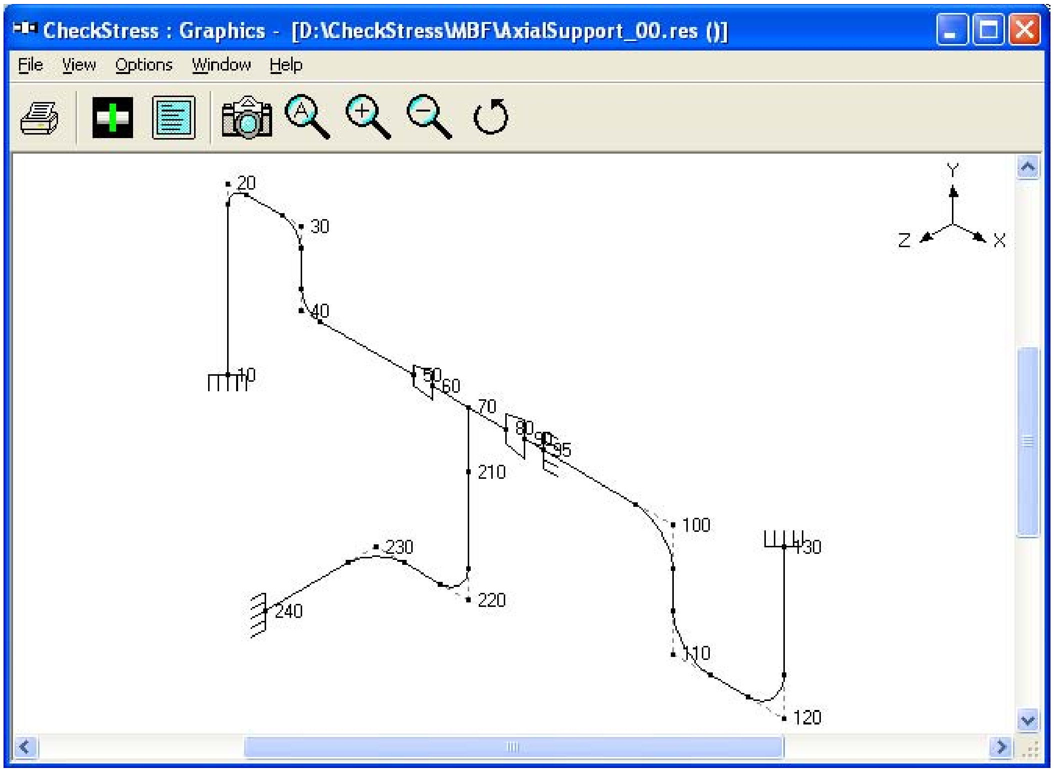

Figure 3A - Layout with Intermediate Anchor at Node 95

Fig. 3A shows the same problem as in Example 2 but with a 6" NB branch line added at the welding tee at node 70 (i.e., from node 70 to node 240).

The deformed geometry, due to the thermal load (Fig. 3B), shows that the tee at node 70 does not move up in +Y-direction. The intermediate anchor at node 95 restrains the vertical riser (between nodes 220 and 70) from thermally growing upward towards node 70. As a result, this riser grows downward producing large bending moments and stresses at and around equipment nozzle at node 240.

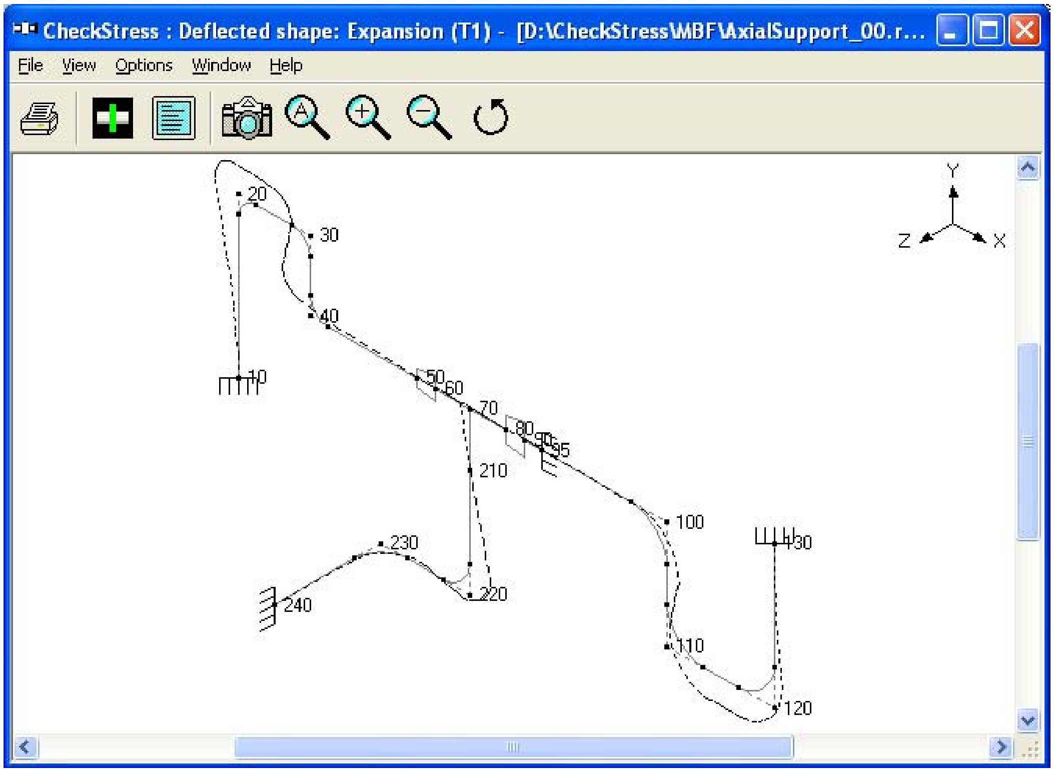

Figure 3B - Thermal Deformation Plot

Since the intermediate anchor effectively restrains upward growth of this vertical riser node 70, we see large localized thermal stress at the welding tee. See thermal stress contour plot shown in Fig. 3C.

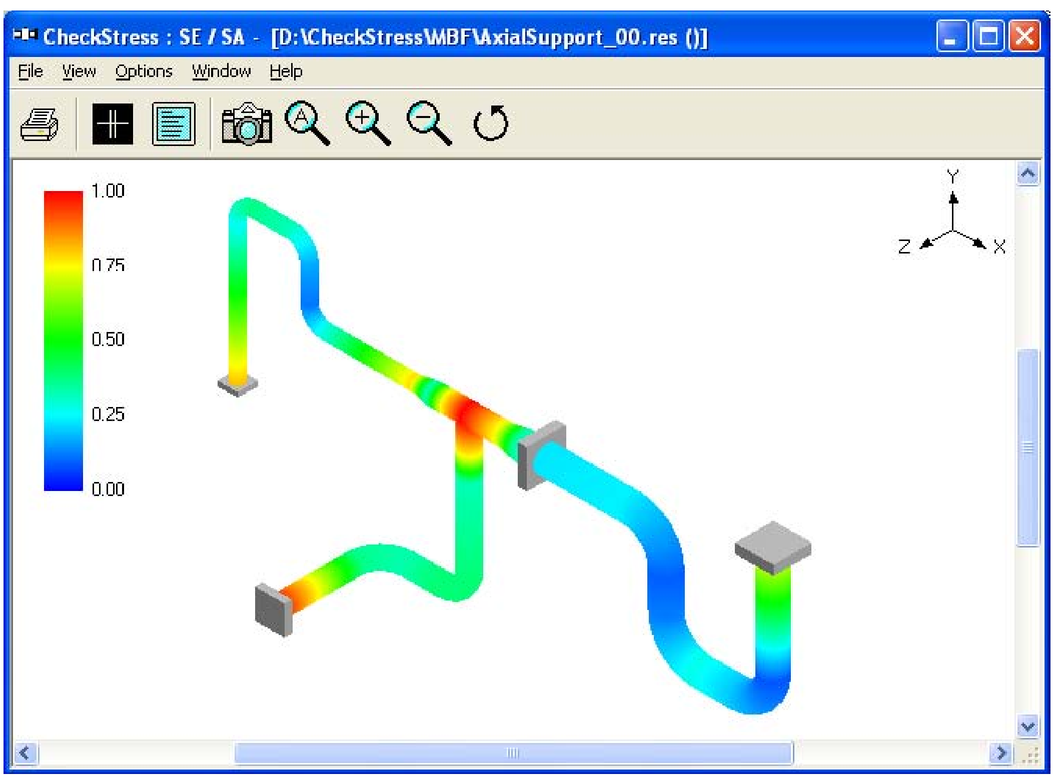

Figure 3C - Thermal Stress Contour Plot

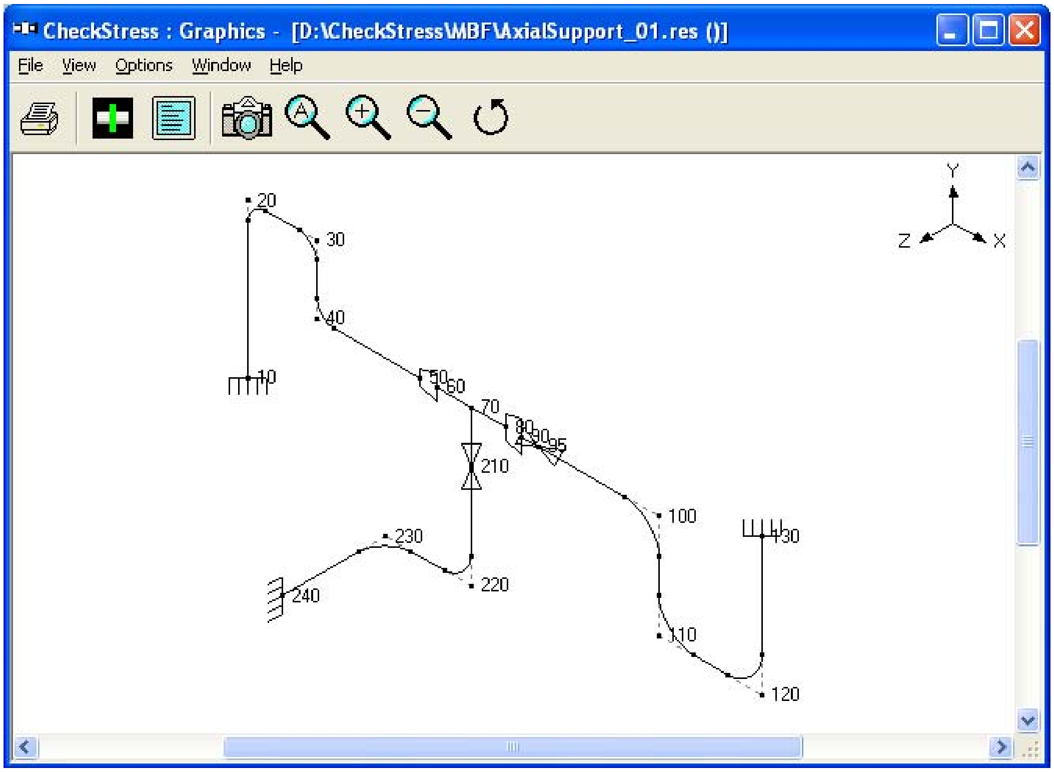

Figure 3D - Layout with Axial Restraints at Node 95 and 210

Fig. 3D shows the same piping system with one axial restraint at 95 (replacing the intermediate anchor at node 95) and another at node 210 — the one at node 95 splits and directs thermal growth towards the 4" and 8" loops and permits the horizontal line to move up in +Y-direction at node 70; the second one at node 210 splits the thermal growth of the vertical riser (between nodes 220 and 70). The resulting deformed geometry plot in Fig. 3E shows a more flexible system, which produces smaller forces and moments, and hence stresses at the equipment nozzle node 240 and welding tee node 70.

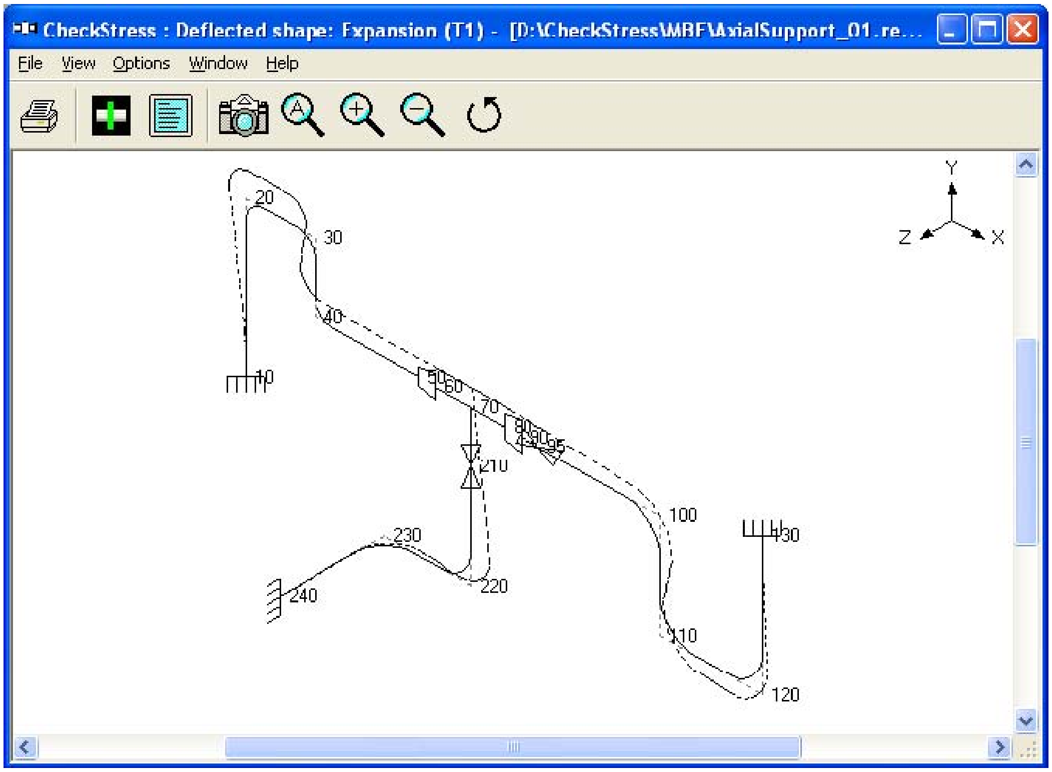

Figure 3E - Thermal Deformation Plot for Layout with Axial Restraints

Figures 3F and 3G show the thermal and sustained stress contour plots (in this case sustained stress is due to only deadweight as pressure is zero), confirming a code-compliant system for both load cases.

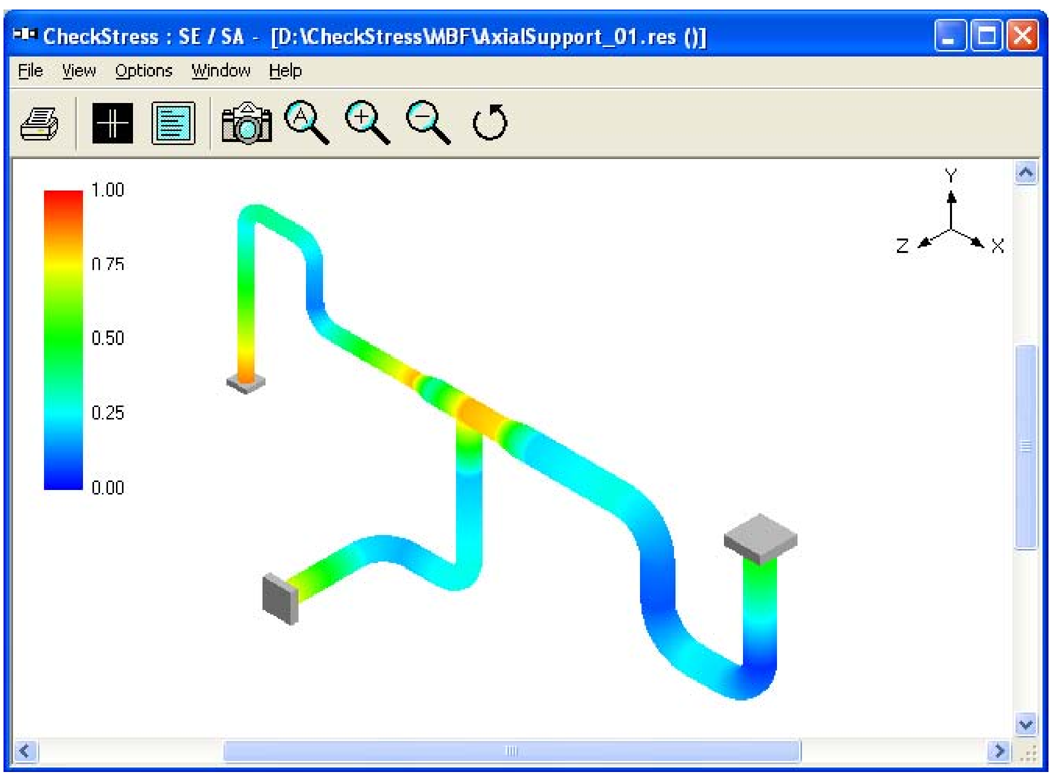

Figure 3F - Thermal Stress Contour Plot for Layout with Axial Restraints

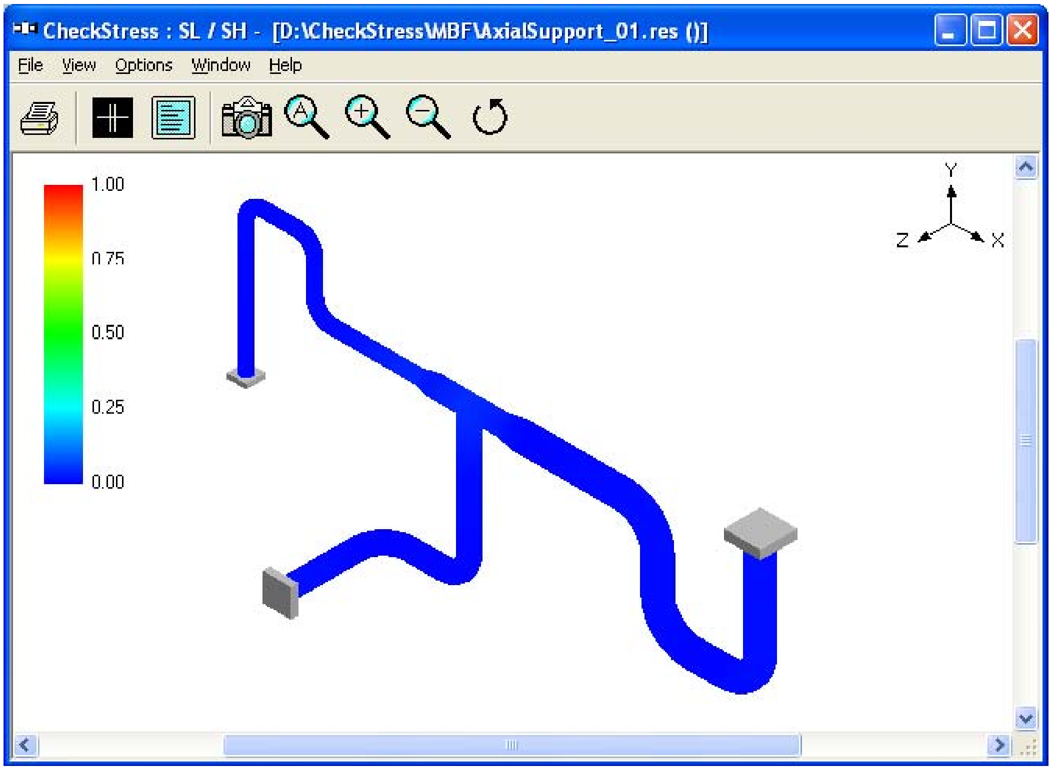

Figure 3G - Sustained Stress Contour Plot for Layout with Axial Restraints

EXAMPLE 4 - Locating Supports For Deadweight Analysis

This problem illustrates how to select and locate vertical supports to carry piping deadweight in the operating condition.

Fig. 4A shows a practical problem with 10" NB Standard schedule pipe from equipment nozzle at node 5 up to the reducer at node 30, 8" NB Standard schedule pipe from this reducer to the pump nozzle at node 40, and a 6" NB Standard schedule branch line from the welding tee at node 25 to the equipment nozzle at node 125.

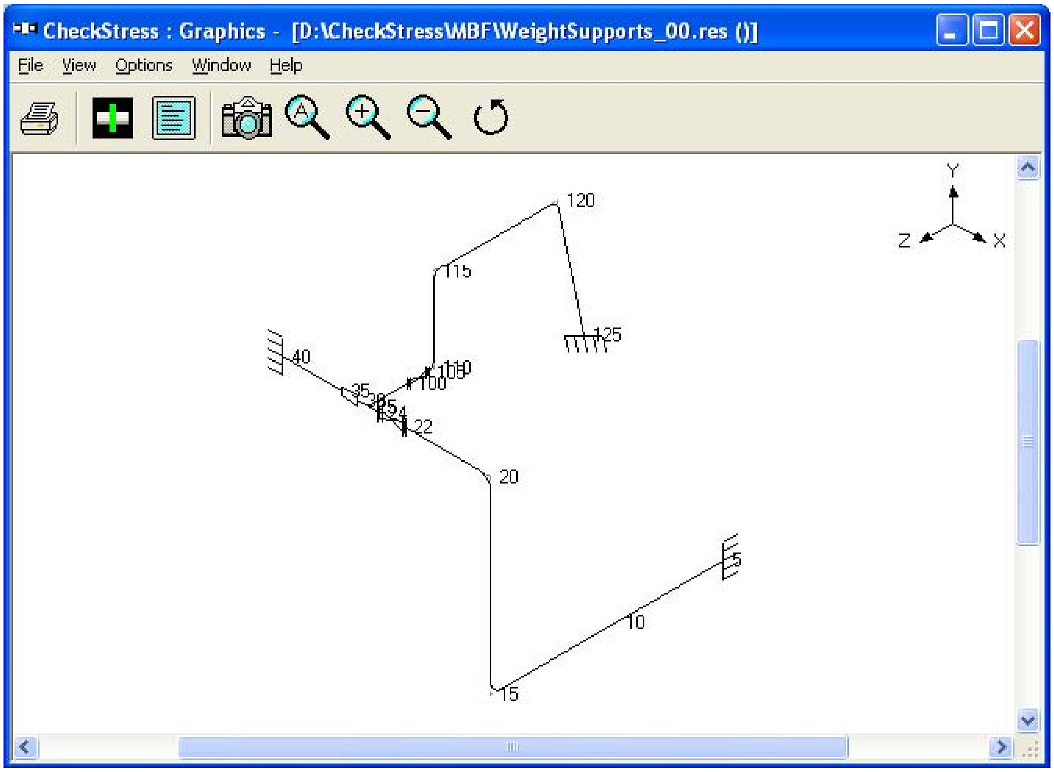

Figure 4A - Layout with Node Numbers

The thermal stress contour plot given in Fig. 4B confirms that the piping system is highly flexible and hence meets the code requirement for thermal load.

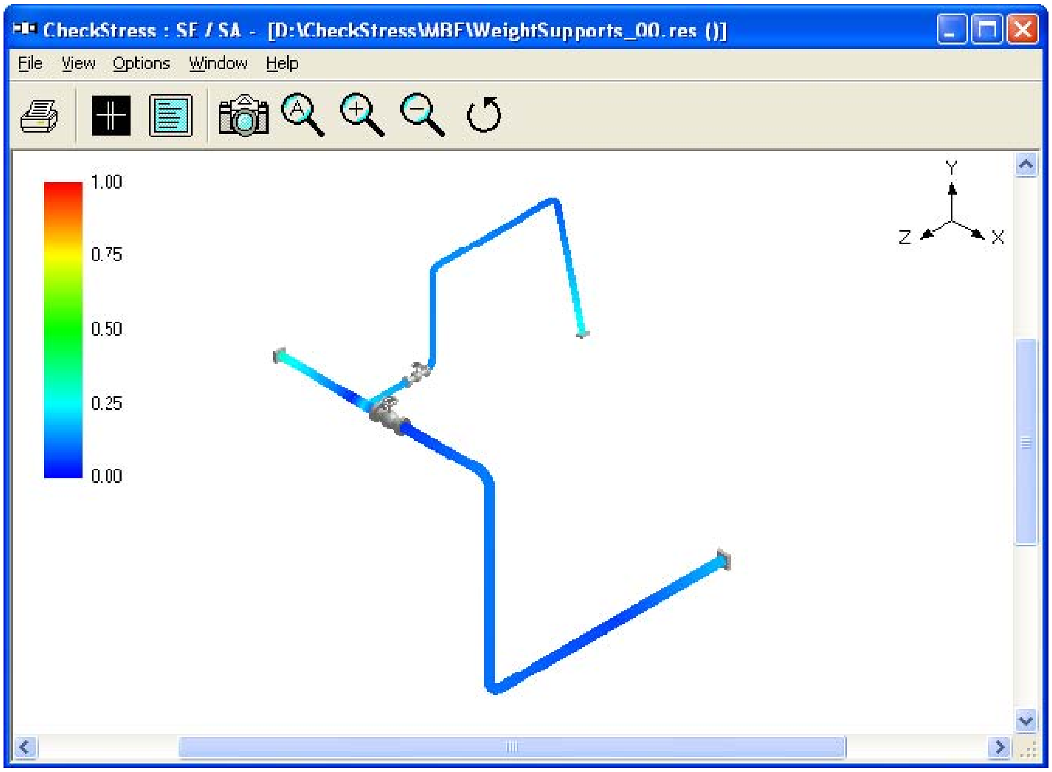

Figure 4B - Thermal Stress Contour Plot

Fig. 4C shows the deflected shape for sustained load (i.e., mainly deadweight). It is observed that the weight of (i) the horizontal line from node 5 to node 15 and (ii) a major portion of the vertical riser from node 15 to node 20 is carried by the equipment nozzle at node 5; on the other hand, the pump nozzle at node 40 carries the weight of (i) the horizontal line from node 20 to node 40, (ii) the valve portion of the branch line from node 25 to node 125 and (iii) a small portion of the vertical riser from node 15 to node 20.

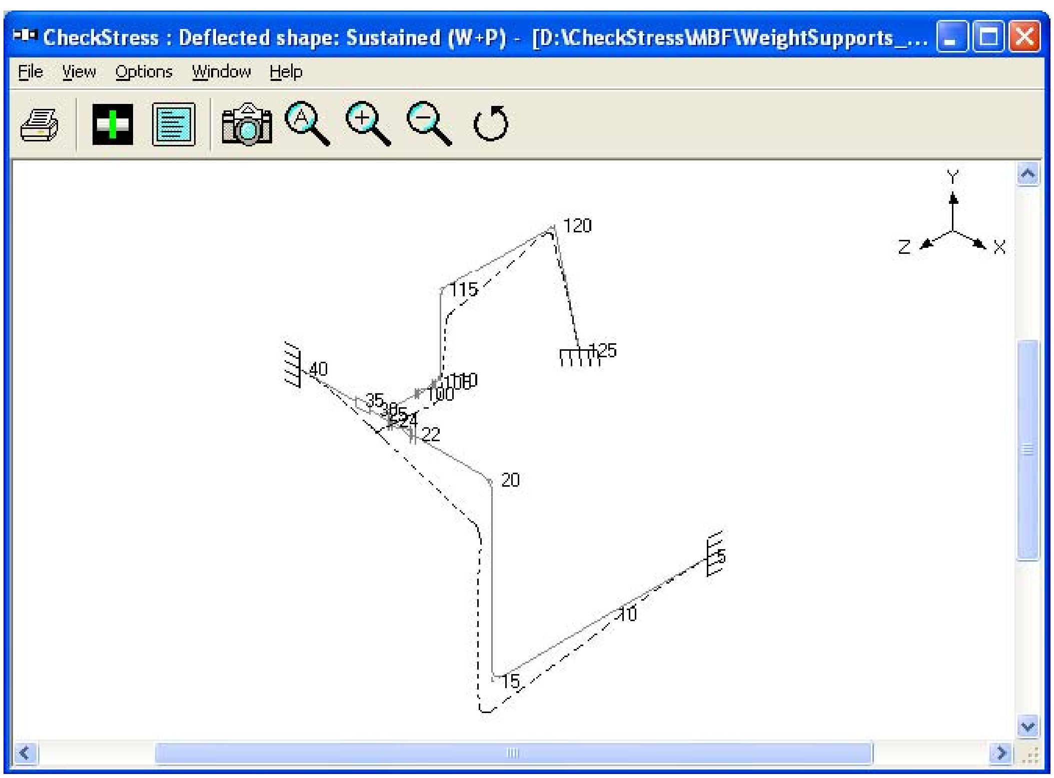

Figure 4C - Sustained Load Deflected Shape

The deformation response for deadweight, in turn, generates large forces and moments and hence large sustained stresses at nozzle nodes 5 and 40 as shown in Fig. 4D for sustained stress contour plot.

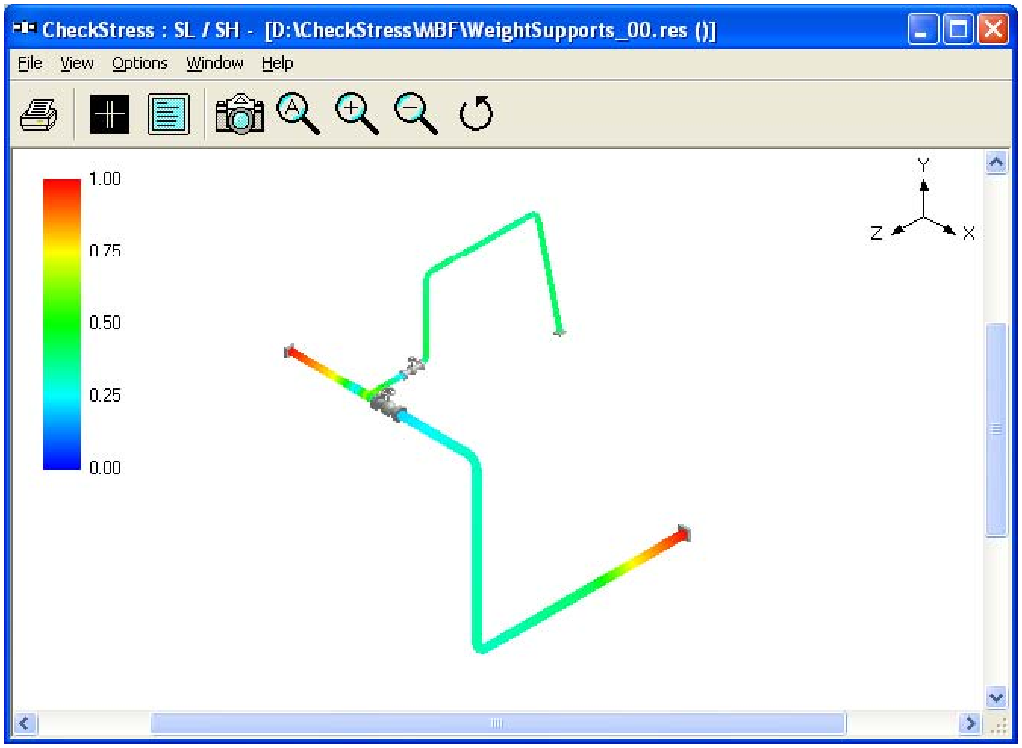

Figure 4D - Sustained Stress Contour Plot

Fig. 4E shows the same layout with variable spring hangers at the bends at nodes 20 and 115, which carry piping deadweight and provide negligible restraint to thermal movement from cold to hot condition and vice versa.

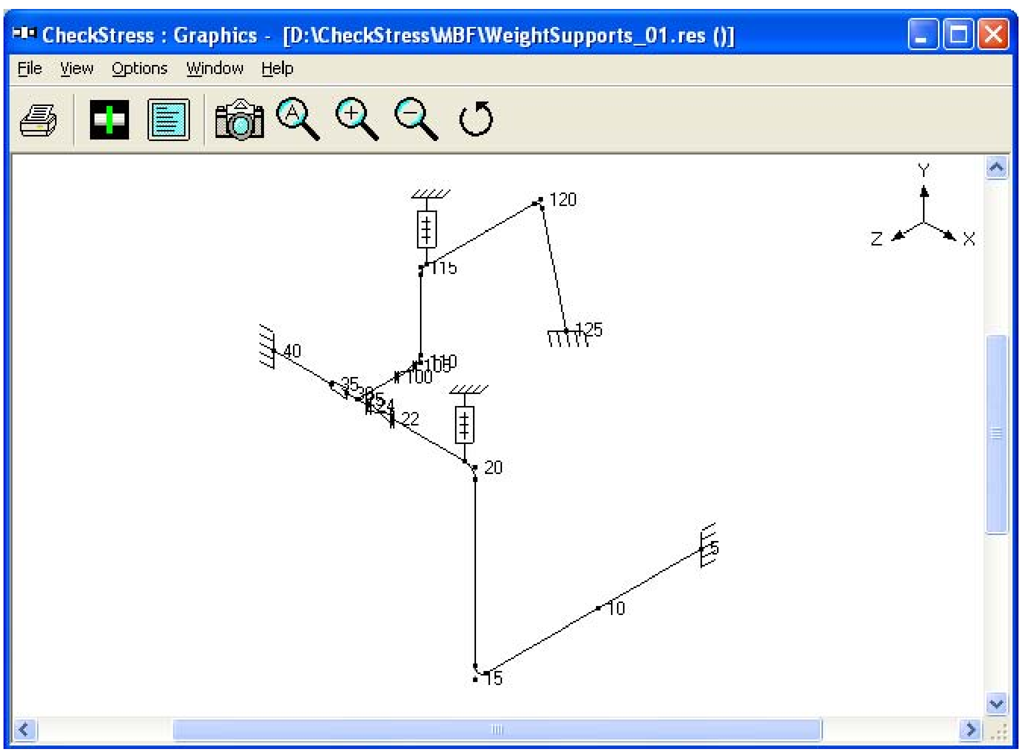

Figure 4E - Layout with Hangers

The thermal and sustained stress contour plots given in Fig. 4F and Fig. 4G confirm that the piping system with hangers is code-complaint for both sustained and thermal load cases.

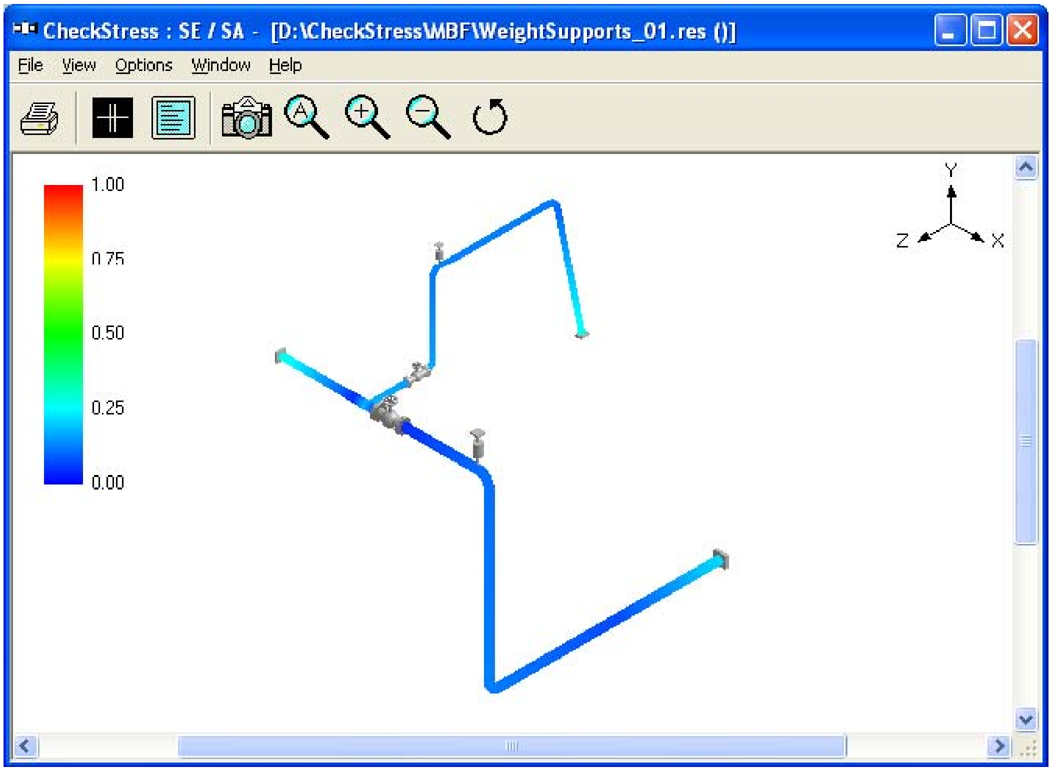

Figure 4F - Thermal Stress Contour Plot for Layout with Hangers

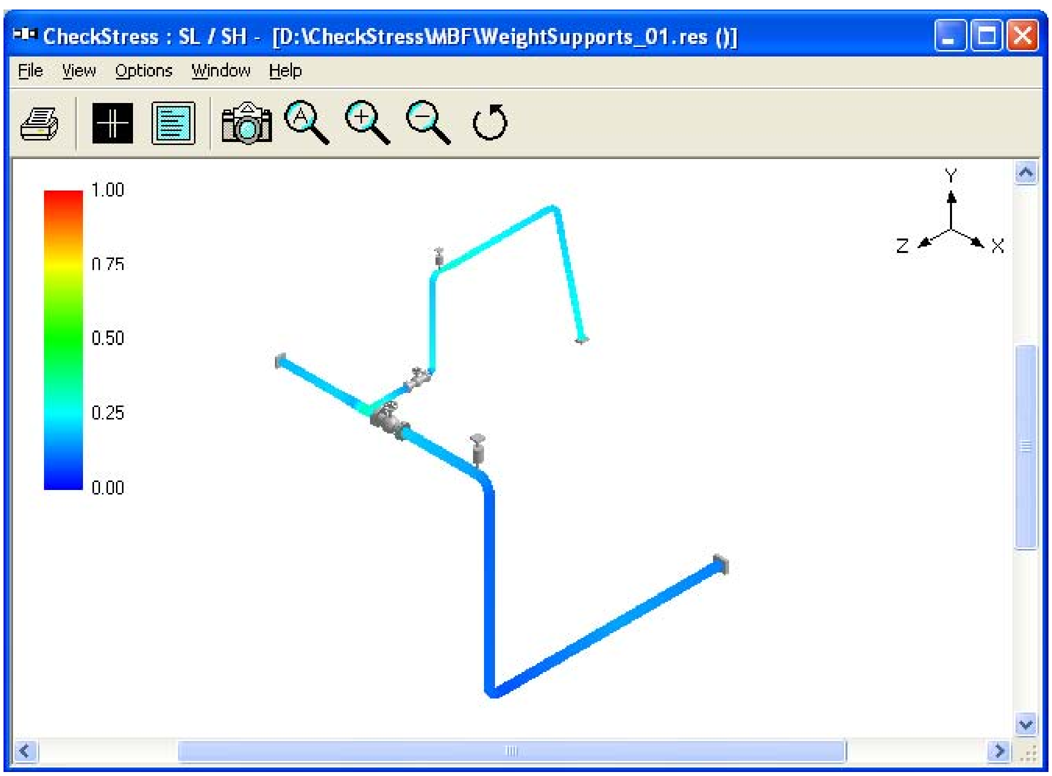

Figure 4G - Sustained Stress Contour Plot for Layout with Hangers

EXAMPLE 5 - Layout Changes to Lower Thermal Stresses

This practical problem illustrates how to place resting steel supports to carry the weight of the system with operating fluid and modify the layout in order to re-direct thermal growth to comply with code stress requirements. Fig. 5A shows the initial layout where condensate from a tank (node 10) is extracted by the pump suction lines. When one pump is operating, the other one is on standby.

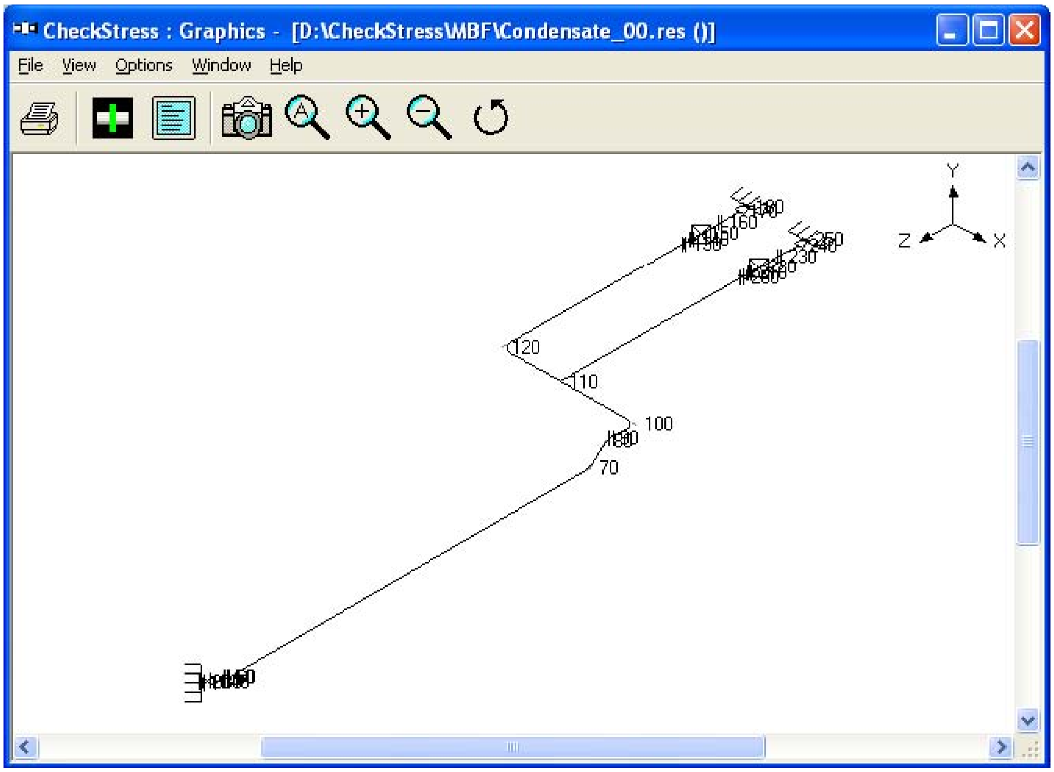

Figure 5A - Layout with Node Numbers

From Fig. 5B, we see that the pipeline from nodes 10 to 220 grows thermally towards the pumps, whereas the two pump suction lines, one from nodes 250 to 580 and the other from nodes 280 to 430, grow in the opposite direction towards the tank. So, the straight pipe between nodes 220 and 280 (with a welding tee at node 250) experiences two opposing deflection patterns - the pipe portion between nodes 250 and 280 is being deflected like a rigid stick towards the tank, while the pipe portion from nodes 250 to 220 is being bent at node 250 to accommodate thermal growth of pipe from nodes 10 to 220.

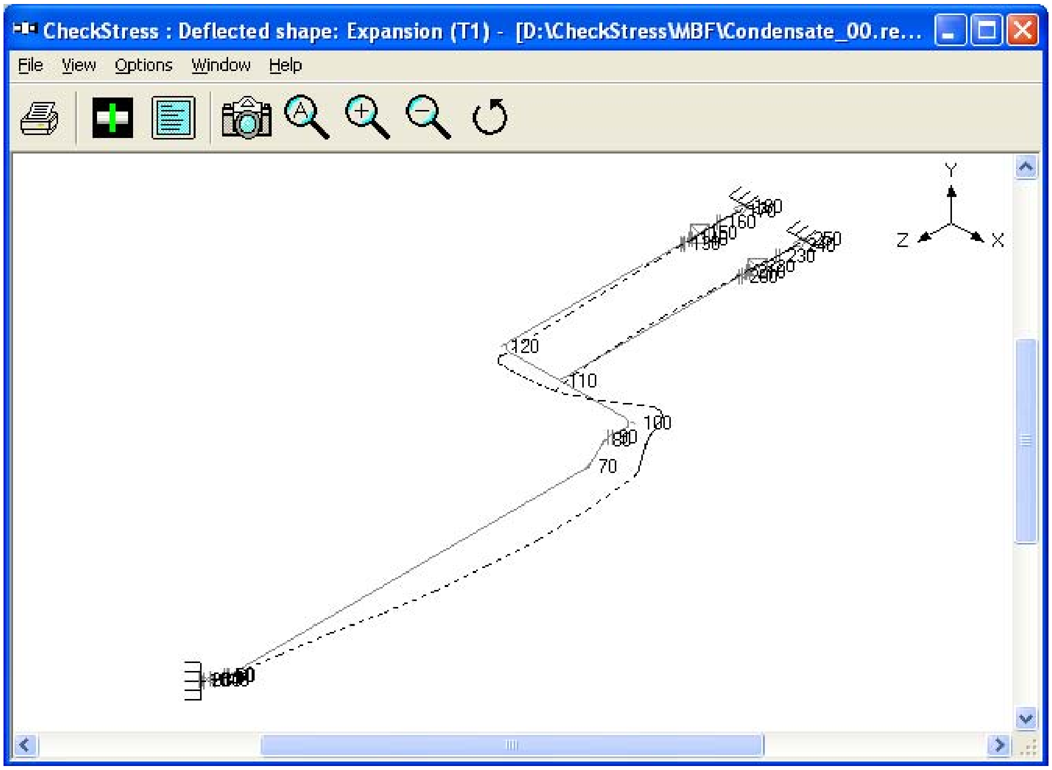

Figure 5B - Thermal Deformation Plot

This produces high strains and hence high thermal stresses locally at the tee node 250, as shown in Fig. 5C.

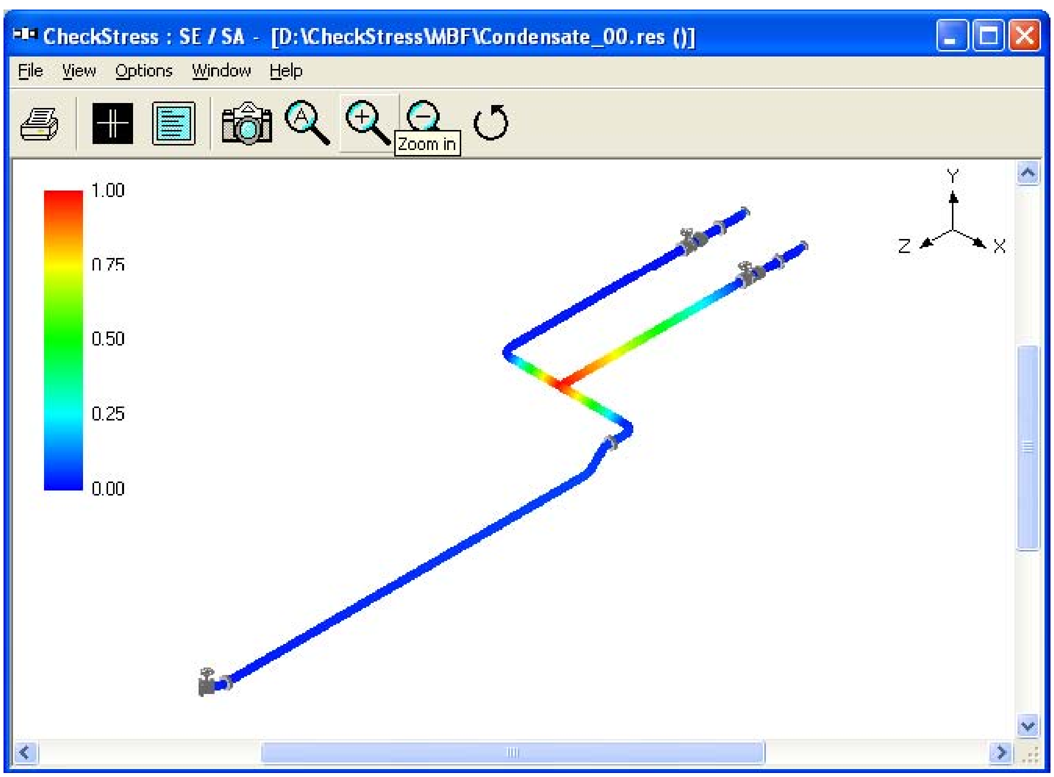

Figure 5C - Thermal Stress Contour Plot

In order to reduce these thermal stresses at node 250, we cut the straight pipe between nodes 220 and 280 (Fig. 5A) into two parts – one part is the pipe from nodes 220 to 250, and the second part from nodes 250 to 280 is shifted downstream towards the two pumps, resulting in the modified layout shown in Fig. 5D, with modified node numbers automatically generated by checkSTRESS.

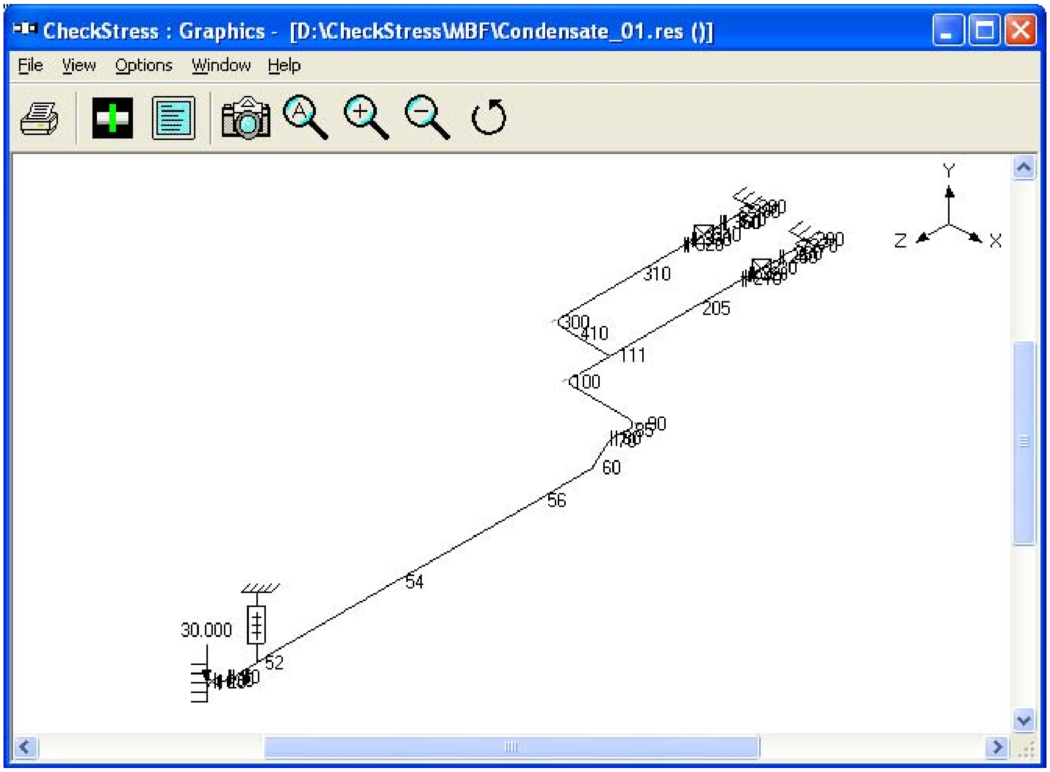

Figure 5D - Revised Layout with Node Numbers

This shift of pipe downstream does not adversely increase the pressure drop between the tank at node 10 and the pump suction nozzles at nodes 430 and 610 in Fig. 5D. From the thermal deformation plot for this revised layout shown in Fig. 5E, we can see that the two pump suction lines from the suction nozzles to the welding tee at node 280 have almost equal thermal growth towards the tank, resulting in lower thermal stresses in that branch pipe as seen in Fig. 5F below.

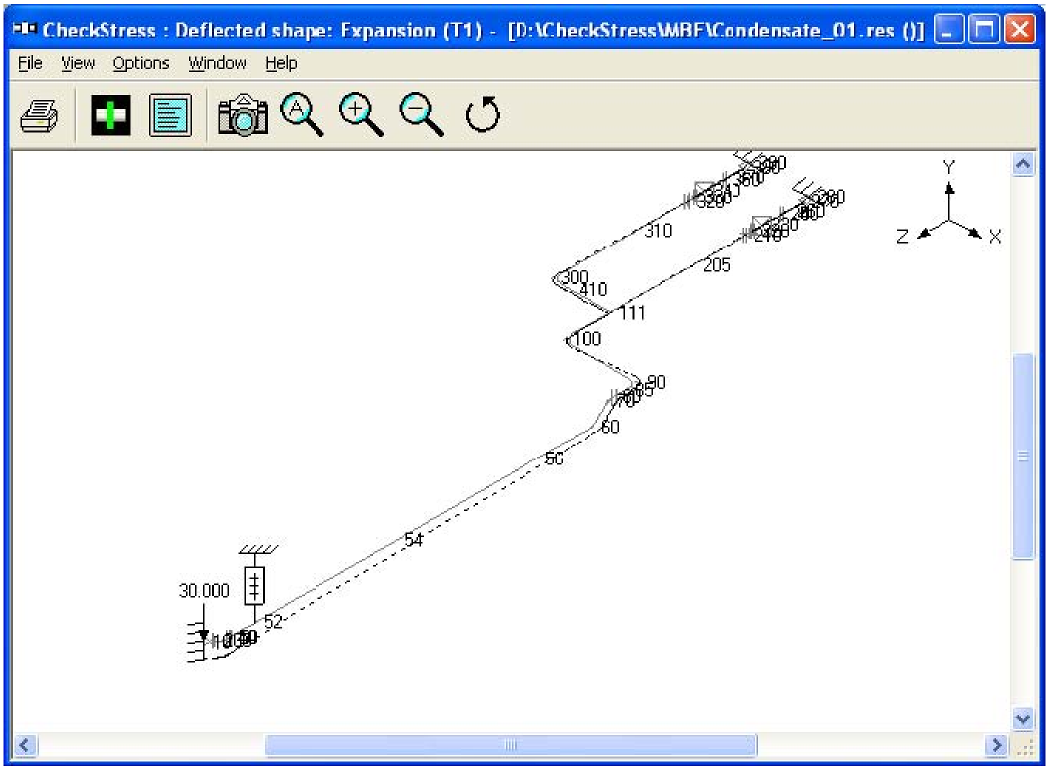

Figure 5E - Thermal Deformation Plot for Revised Layout

In addition, we observe from Fig. 5E that the two pump suction lines make the bend node 250 grow thermally towards the tank, whereas the pipe from the tank node 10 to the bend node 220 grows in the opposite direction. These opposing deflections rotate the interconnecting pipe between nodes 220 and 250 like a (horizontal) "see-saw" in the horizontal XZ plane, resulting in lower thermal stresses in this region, as observed in Fig. 5F.

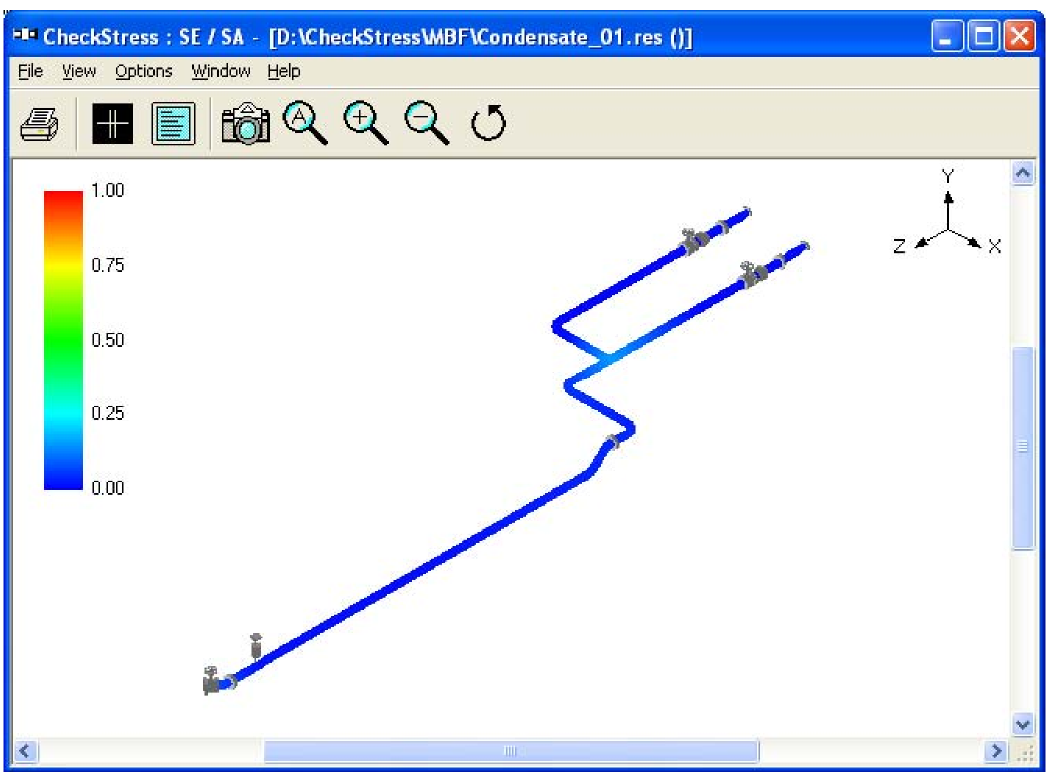

Figure 5F - Thermal Stress Contour Plot for Revised Layout

Although the thermal stress criteria have been met, the weight stresses exceed the sustained stress allowable, as illustrated by many red and orange areas in the sustained stress contour plot given in Fig 5G.

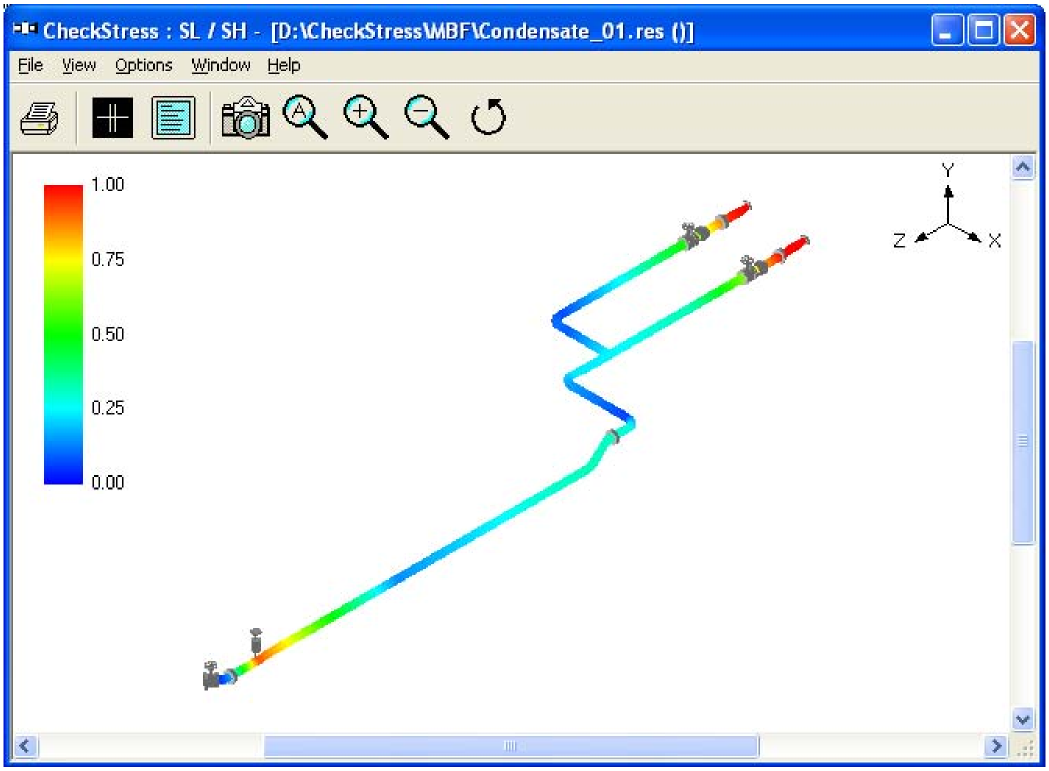

Figure 5G - Sustained Stress Contour Plot for Revised Layout

This is because there are no vertical supports (excluding the 3 nozzles and a variable spring hanger near the tank to accommodate any tank settlement) to carry the weight of the system. Vertical resting supports are therefore introduced as shown in Fig. 5H.

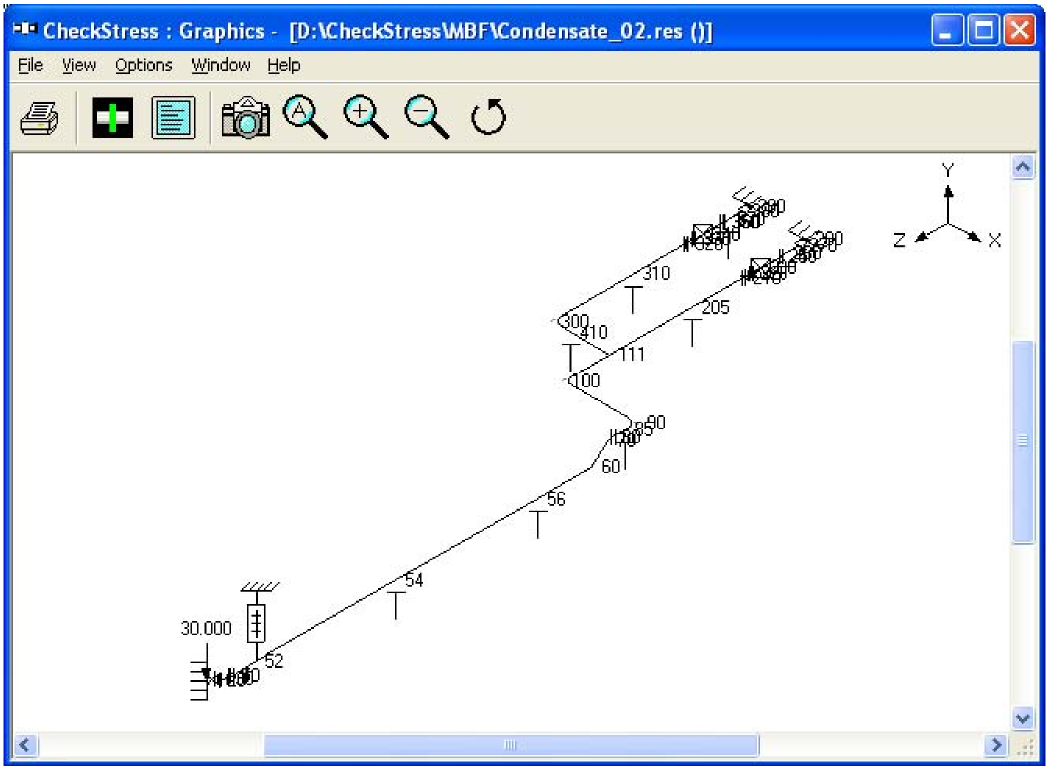

Figure 5H - Revised Layout with Resting Supports

The recalculated sustained stress (i.e., weight + pressure) contour plot (with most areas in blue) shown in Fig. 5I are now well below the allowable stress values, and hence code-compliant.

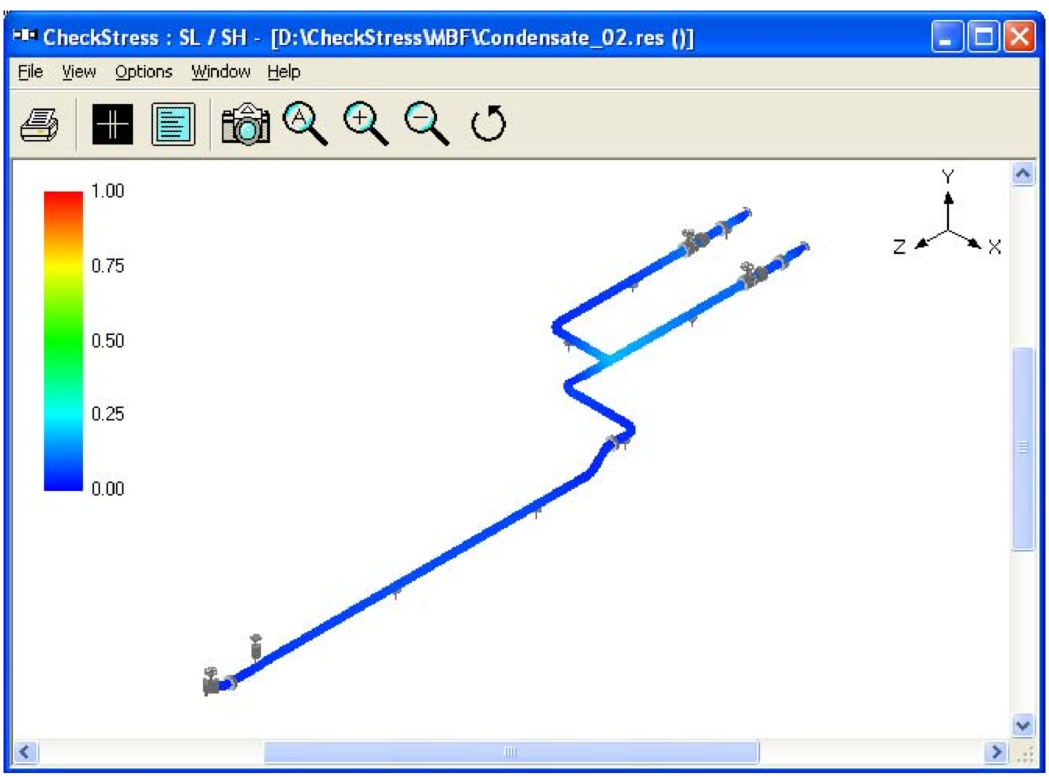

Figure 5I - Sustained Stress Contour Plot for Revised Layout with Resting Supports