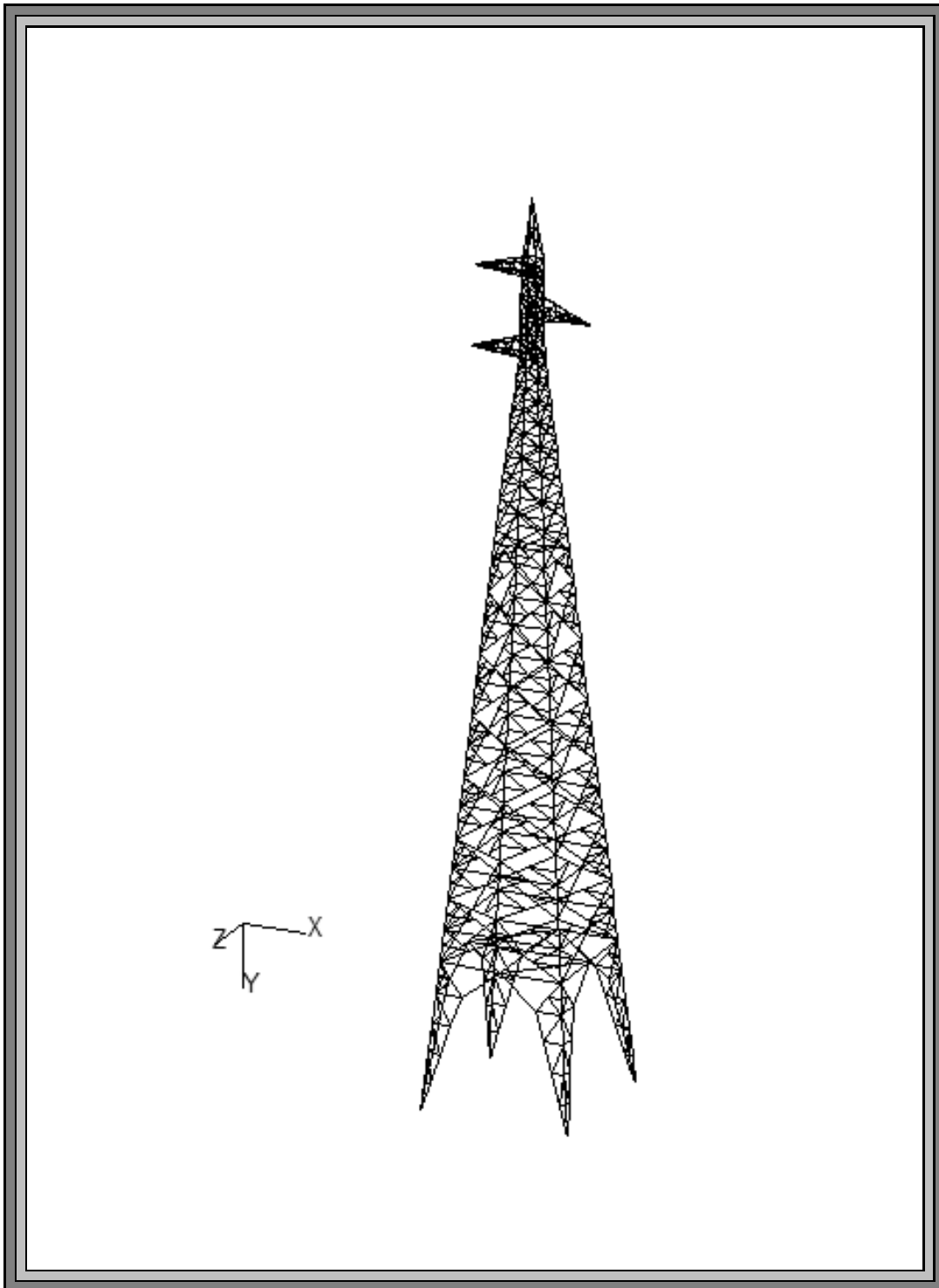


**Summary of a  
Comparison of Static Analysis Results Between  
GTSTRUDL 29 and ZZZ-P for a  
Structure with Initial Rigid Body Instabilities**

This is a brief summary of a comparison of static analysis results between GTSTRUDL 29 and another popular structural analysis program hereinafter referred to as ZZZ-P for the following structure:



## Summary of Results

1. The structure shown on the previous page was initially modeled and analyzed by ZZZ-P. The ZZZ-P input file was then used to develop a GTSTRUDL command file for the purpose of performing a static analysis. Various results computed by GTSTRUDL and by ZZZ-P for the static analysis are compared herein.
2. The structure model was determined to have initial rigid body instabilities. Although ZZZ-P detected the initial instabilities, ZZZ-P proceeds as follows:

- a. ZZZ-P reports that it detected "instabilities" in the model, and then outputs warning messages similar to the following:

```
### - AN INSTABILITY WAS DETECTED AS A NEGATIVE ON THE DIAGONAL DURING THE SOLUTION  
●●●●●●●●
```

```
### - A SMALL POSITIVE NUMBER IS ADDED IN SUBSTITUTION FOR THE NEGATIVE VALUE
```

```
### - AN INSTABILITY WAS DETECTED AS A ZERO ON THE DIAGONAL DURING THE SOLUTION  
●●●●●●●●
```

```
### - A SMALL POSITIVE NUMBER IS ADDED IN SUBSTITUTION FOR THE ZERO VALUE
```

- b. The ZZZ-P warning messages appear to say that if the governing equations (i.e., the Stiffness Equatins) that are assembled for structure models contain initial rigid body instabilities, and during the equation solving procedures when such an instability is detected, the equations are automatically changed by ZZZ-P so that the solution can proceed, and analysis results are subsequently output.

For example, if ZZZ-P detects a negative number, or a zero value, or a sufficiently small positive number on the diagonal of the reduced stiffness equations during its equation solving, ZZZ-P changes such values to a small positive number, and then continues the solution processing.

3. GTSTRUDL detects the initial rigid body instabilities in the model of the structure. GTSTRUDL then outputs information regarding the conditions existing during its equation solving that resulted in a determination that instabilities exist, and then terminates the equation solving. It should be noted that except for various *trivial* cases, such a determination by any structural analysis program during the equation solving cannot identify the rigid body instabilities. Rather, GTSTRUDL includes an alternate analytical procedure that the engineer may use to compute and identify the locations of the non-trivial instabilities. The engineer must then correct such instabilities (which can ONLY be corrected by the engineer, and can never, nor should be, corrected by a computer program) prior to a subsequent correct analysis.
4. Following the correction by the engineer of the rigid body instabilities in the model, GTSTRUDL was used to perform the static analysis on the initially stable model.

5. Static analysis results computed by GTSTRUDL for the model corrected by the engineer were then compared to the analysis results computed by ZZZ-P for the unstable model where the equations were changed by ZZZ-P. The comparison results are shown in Tables 1 and 2, and are described as follows:
  - a. Table 1 compares support joint reactions for support joints 123 and 223. Differences in the reaction forces range in absolute value from around 4% to 1,829,228%, where the average percent difference in the reaction force values is 35,872%. !!! The reaction forces as computed by ZZZ-P are incorrect when compared to the reaction forces computed by GTSTRUDL for the model where the initial rigid body instabilities were corrected by the engineer.
  - b. Table 2 compares member end forces for members 10255, 12201, and 135197. Differences in the member end forces range in absolute value from around 4% to 170,127%, where the average percent difference in the member end force values is 3,122%. !!! The member end forces as computed by ZZZ-P are incorrect when compared to the member end forces computed by GTSTRUDL for the model where the initial rigid body instabilities were corrected by the engineer.
6. Conclusions:
  1. ZZZ-P's procedure of changing negative numbers, and zero values, and sufficiently small positive numbers on the diagonal of the reduced stiffness equations during its equation solving is not correct since there is no solution for a structure with initial rigid body instabilities (i.e., the governing equations are not solvable for those cases where such negative or zero values are encountered during the solution process). Changing negative, zero, or very small positive numbers to small positive numbers DOES NOT fix initial rigid body instabilities. Rather, such changes create a new system of governing equations that, in general, have no relationship to the corrections that must be made in order to correct the modeling errors that caused the initial rigid body instabilities.
  2. After such changes are made by ZZZ-P, ZZZ-P continues to solve the modified equations and outputs joint displacement, support joint reaction, and member end force analysis results. Unfortunately, such results should have no relationship to the correct results that would be obtained by analyzing a model where the initial rigid body instabilities are first corrected by the engineer prior to the analysis equation solving.
  3. During the linear elastic solution of the governing equations of structural behavior (i.e., the stiffness equations), if conditions are encountered that indicate rigid body instabilities exist in the model, the solution process must terminate and issue appropriate warning messages to the engineer. The engineer must then correct the model by removing the rigid body instabilities prior to the next attempt to perform an analysis of the structure model.

No other approach is correct.



| Table 2: Comparison of Member End Forces                     |      |          |          |          |         |           |           |           |   |          |          |          |          |          |           |           |           |
|--|------|----------|----------|----------|---------|-----------|-----------|-----------|---|----------|----------|----------|----------|----------|-----------|-----------|-----------|
| GTSTRUDL Member End Forces (Units: m, kn)                    |      |          |          |          |         |           |           |           | Absolute Value %Difference, (GTSTRUDL - ZZZ-P) / GTSTRUDL |          |          |          |          |          |           |           |           |
| [Initial Rigid Body Instabilities Corrected by the Engineer] |      |          |          |          |         |           |           |           |   |          |          |          |          |          |           |           |           |
| Member   | Load | Joint    | Axial    | Shear Y  | Shear Z | Torsional | Bending Y | Bending Z | Member  | Load     | Joint    | Axial    | Shear Y  | Shear Z  | Torsional | Bending Y | Bending Z |
| 10255  | 1    | 818      | 23.651   | -1.655   | -0.085  | 0.000     | 0.101     | 0.401     | 10255   | 1        | 818      | 36.2%    | 46.2%    | 124.2%   | 100.0%    | 18.5%     | 27.6%     |
|  |      | 819      | -23.651  | 1.655    | 0.085   | 0.000     | 0.020     | -2.778    |   |          | 819      | 36.2%    | 46.2%    | 124.2%   | 100.0%    | 632.4%    | 35.4%     |
|  | 2    | 818      | 347.227  | -26.018  | -1.186  | 0.003     | 0.821     | 5.274     | 2   | 818      | 49.0%    | 73.0%    | 82.9%    | 277.4%   | 53.5%     | 94.5%     |           |
|  |      | 819      | -347.227 | 26.018   | 1.186   | -0.003    | 0.883     | -42.652   |   |          | 819      | 49.0%    | 73.0%    | 82.9%    | 277.4%    | 110.6%    | 50.9%     |
|  | 3    | 818      | -34.458  | 1.979    | -0.032  | 0.000     | -0.128    | -1.285    | 3   | 818      | 97.8%    | 4.6%     | 1104.8%  | 100.0%   | 21.6%     | 119.5%    |           |
|  |      | 819      | 34.458   | -1.979   | 0.032   | 0.000     | 0.174     | 4.128     |   |          | 819      | 97.8%    | 4.6%     | 1104.8%  | 100.0%    | 164.4%    | 96.4%     |
|  | 4    | 818      | -19.560  | 0.909    | -0.033  | 0.000     | -0.155    | -1.004    | 4   | 818      | 17.4%    | 334.5%   | 1188.3%  | 100.0%   | 41.9%     | 173.8%    |           |
|  |      | 819      | 19.560   | -0.909   | 0.033   | 0.000     | 0.202     | 2.310     |   |          | 819      | 17.4%    | 334.5%   | 1188.3%  | 100.0%    | 157.7%    | 26.4%     |
|  | 5    | 818      | 22.848   | -2.255   | -0.089  | 0.000     | -0.163    | -0.343    | 5   | 818      | 278.5%   | 322.6%   | 506.9%   | 100.0%   | 26.6%     | 698.1%    |           |
|  |      | 819      | -22.848  | 2.255    | 0.089   | 0.000     | 0.291     | -2.896    |   |          | 819      | 278.5%   | 322.6%   | 506.9%   | 100.0%    | 123.2%    | 278.1%    |
|  | 6    | 818      | 22.154   | -0.546   | 0.087   | 0.000     | 0.276     | 1.658     | 6   | 818      | 163.5%   | 1521.6%  | 705.2%   | 100.0%   | 49.3%     | 203.9%    |           |
|  |      | 819      | -22.154  | 0.546    | -0.087  | 0.000     | -0.401    | -2.443    |   |          | 819      | 163.5%   | 1521.6%  | 705.2%   | 100.0%    | 114.4%    | 214.8%    |
| 7  | 818  | 98.508   | -7.123   | -0.704   | 0.001   | 0.946     | 1.709     | 7         | 818   | 463.7%   | 47363.6% | 33471.4% | 33471.4% | 25972.8% | 14436.1%  |           |           |
|  | 819  | -98.520  | 7.222    | 0.803    | -0.001  | 0.136     | -12.014   |           |   | 819      | 463.7%   | 47170.8% | 41466.2% | 33471.4% | 170726.6% | 4110.2%   |           |
| 12201  | 1    | 222      | 17.128   | 12.881   | 2.140   | -0.002    | -1.293    | 7.168     | 12201   | 1        | 222      | 63.7%    | 60.1%    | 62.2%    | 100.0%    | 84.1%     | 81.8%     |
|  |      | 813      | -17.128  | -12.881  | -2.140  | 0.002     | -0.767    | 5.235     |   |          | 813      | 63.7%    | 60.1%    | 62.2%    | 100.0%    | 25.1%     | 30.5%     |
|  | 2    | 222      | 290.939  | -222.430 | -38.442 | -0.073    | -23.147   | 137.189   | 2   | 222      | 81.1%    | 77.6%    | 78.0%    | 51.5%    | 107.0%    | 98.7%     |           |
|  |      | 813      | -290.939 | 222.430  | 38.442  | 0.073     | -13.869   | 76.986    |   |          | 813      | 81.1%    | 77.6%    | 78.0%    | 51.5%     | 29.5%     | 39.9%     |
|  | 3    | 222      | -8.231   | 5.984    | 0.575   | -0.001    | -0.746    | 2.392     | 3   | 222      | 416.6%   | 416.0%   | 891.5%   | 1049.4%  | 685.1%    | 1215.3%   |           |
|  |      | 813      | 8.231    | -5.984   | -0.575  | 0.001     | 1.300     | -8.154    |   |          | 813      | 416.6%   | 416.0%   | 891.5%   | 1049.4%   | 71.5%     | 78.8%     |
|  | 4    | 222      | 4.554    | -3.651   | -1.113  | -0.004    | -1.733    | 8.362     | 4   | 222      | 1338.4%  | 1217.3%  | 683.5%   | 370.6%   | 358.7%    | 419.2%    |           |
|  |      | 813      | -4.554   | 3.651    | 1.113   | 0.004     | 0.661     | -8.446    |   |          | 813      | 1338.4%  | 1217.3%  | 683.5%   | 370.6%    | 33.5%     | 39.9%     |
|  | 5    | 222      | 40.727   | -30.931  | -5.856  | -0.013    | -4.562    | 25.283    | 5   | 222      | 222.8%   | 215.7%   | 197.0%   | 123.4%   | 208.6%    | 208.3%    |           |
|  |      | 813      | -40.727  | 30.931   | 5.856   | 0.013     | -1.076    | 4.500     |   |          | 813      | 222.8%   | 215.7%   | 197.0%   | 123.4%    | 147.1%    | 256.9%    |
|  | 6    | 222      | -19.325  | -15.068  | -3.480  | 0.012     | 3.926     | -20.355   | 6   | 222      | 601.6%   | 566.1%   | 421.8%   | 234.4%   | 307.7%    | 331.7%    |           |
|  |      | 813      | 19.325   | 15.068   | 3.480   | -0.012    | -0.575    | 5.846     |   |          | 813      | 601.6%   | 566.1%   | 421.8%   | 234.4%    | 155.5%    | 49.8%     |
| 7  | 222  | 62.865   | -49.616  | -7.727   | -0.011  | -3.945    | 25.375    | 7         | 222   | 10444.4% | 10280.3% | 13637.0% | 8303.4%  | 28338.5% | 21019.0%  |           |           |
|  | 813  | -62.868  | 49.612   | 7.769    | 0.011   | -3.515    | 22.398    |           |   | 813      | 10443.9% | 10281.1% | 13562.9% | 8303.4%  | 2743.6%   | 1684.7%   |           |
| 135197   | 1    | 2500     | -14.435  | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 135197  | 1        | 2500     | 32.2%    |          |          |           |           |           |
|  |      | 103      | 14.435   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      | 32.2%    |          |          |           |           |           |
|  | 2    | 2500     | 13.027   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 2   | 2500     | 38.6%    |          |          |          |           |           |           |
|  |      | 103      | -13.027  | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      | 38.6%    |          |          |           |           |           |
|  | 3    | 2500     | 8.621    | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 3   | 2500     | 10.7%    |          |          |          |           |           |           |
|  |      | 103      | -8.621   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      | 10.7%    |          |          |           |           |           |
|  | 4    | 2500     | 12.723   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 4   | 2500     | 4.0%     |          |          |          |           |           |           |
|  |      | 103      | -12.723  | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      | 4.0%     |          |          |           |           |           |
|  | 5    | 2500     | 7.134    | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 5   | 2500     | 14.1%    |          |          |          |           |           |           |
|  |      | 103      | -7.134   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      | 14.1%    |          |          |           |           |           |
|  | 6    | 2500     | -31.817  | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 6   | 2500     | 13.0%    |          |          |          |           |           |           |
|  |      | 103      | 31.817   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      | 13.0%    |          |          |           |           |           |
| 7  | 2500 | -10.632  | 0.000    | 0.000    | 0.000   | 0.000     | 0.000     | 7         | 2500  | 16.2%    |          |          |          |          |           |           |           |
|  | 103  | 10.632   | 0.000    | 0.000    | 0.000   | 0.000     | 0.000     |           |   | 103      | 16.2%    |          |          |          |           |           |           |
| ZZZ-P Member End Forces (Units: m, kn)                       |      |          |          |          |         |           |           |           |   |          |          |          |          |          |           |           |           |
| [ZZZ-P Changes Diagonal Values from - to +]                  |      |          |          |          |         |           |           |           |   |          |          |          |          |          |           |           |           |
| Member   | Load | JT       | Axial    | Shear-Y  | Shear-Z | Torsion   | MOM-Y     | MOM-Z     |   |          |          |          |          |          |           |           |           |
| 10255  | 1    | 818      | 32.220   | -2.420   | -0.190  | 0.000     | 0.120     | 0.290     | 10255   | 1        | 818      |          |          |          |           |           |           |
|  |      | 819      | -32.220  | 2.420    | 0.190   | 0.000     | 0.150     | -3.760    |   |          | 819      |          |          |          |           |           |           |
|  | 2    | 818      | 517.210  | -45.000  | -2.170  | 0.010     | 1.260     | 0.290     | 2   | 818      |          |          |          |          |           |           |           |
|  |      | 819      | -517.210 | 45.000   | 2.170   | -0.010    | 1.860     | -64.360   |   |          | 819      |          |          |          |           |           |           |
|  | 3    | 818      | 0.770    | -2.070   | -0.390  | 0.000     | 0.100     | -2.820    | 3   | 818      |          |          |          |          |           |           |           |
|  |      | 819      | -0.770   | 2.070    | 0.390   | 0.000     | 0.460     | -0.150    |   |          | 819      |          |          |          |           |           |           |
|  | 4    | 818      | 22.960   | -3.950   | -0.420  | 0.000     | 0.090     | -2.750    | 4   | 818      |          |          |          |          |           |           |           |
|  |      | 819      | -22.960  | 3.950    | 0.420   | 0.000     | 0.520     | -2.920    |   |          | 819      |          |          |          |           |           |           |
|  | 5    | 818      | 86.480   | -9.530   | -0.540  | 0.000     | 0.120     | -2.740    | 5   | 818      |          |          |          |          |           |           |           |
|  |      | 819      | -86.480  | 9.530    | 0.540   | 0.000     | 0.650     | -10.950   |   |          | 819      |          |          |          |           |           |           |
|  | 6    | 818      | -58.380  | 8.860    | 0.700   | 0.000     | -0.140    | 5.040     | 6   | 818      |          |          |          |          |           |           |           |
|  |      | 819      | 58.380   | -8.860   | -0.700  | 0.000     | -0.860    | 7.690     |   |          | 819      |          |          |          |           |           |           |
| 7  | 818  | 555.310  | -524.990 | 334.030  | -0.470  | -246.680  | -248.490  | 7         | 818   |          |          |          |          |          |           |           |           |
|  | 819  | -555.330 | 525.090  | -333.930 | 0.470   | -233.110  | -505.790  |           |   | 819      |          |          |          |          |           |           |           |
| 12201  | 1    | 222      | 28.04    | 20.62    | 3.47    | 0         | -2.38     | 13.03     | 12201   | 1        | 222      |          |          |          |           |           |           |
|  |      | 813      | -28.04   | -20.62   | -3.47   | 0         | -0.96     | 6.83      |   |          | 813      |          |          |          |           |           |           |
|  | 2    | 222      | 526.92   | -395.04  | -68.42  | -0.11     | -47.92    | 272.64    | 2   | 222      |          |          |          |          |           |           |           |
|  |      | 813      | -526.92  | 395.04   | 68.42   | 0.11      | -17.96    | 107.74    |   |          | 813      |          |          |          |           |           |           |
|  | 3    | 222      | 42.52    | 30.88    | 5.7     | -0.01     | -5.86     | 31.46     | 3   | 222      |          |          |          |          |           |           |           |
|  |      | 813      | -42.52   | -30.88   | -5.7    | 0.01      | 0.37      | -1.73     |   |          | 813      |          |          |          |           |           |           |
|  | 4    | 222      | 65.51    | 48.1     | 8.72    | -0.02     | -7.95     | 43.41     | 4   | 222      |          |          |          |          |           |           |           |
|  |      | 813      | -65.51   | -48.1    | -8.72   | 0.02      | -0.44     | 2.91      |   |          | 813      |          |          |          |           |           |           |
|  | 5    | 222      | 131.48   | 97.64    | 17.39   | -0.03     | -14.08    | 77.95     | 5   | 222      |          |          |          |          |           |           |           |
|  |      | 813      | -131.48  | -97.64   | -17.39  | 0.03      | -2.66     | 16.06     |   |          | 813      |          |          |          |           |           |           |
|  | 6    | 222      | -135.58  | -100.36  | -18.16  | 0.04      | 16.01     | -87.87    | 6   | 222      |          |          |          |          |           |           |           |
|  |      | 813      | 135.58   | 100.36   | 18.16   | -0.04     | 1.47      | -8.76     |   |          | 813      |          |          |          |           |           |           |
| 7  | 222  | 6628.73  | 5150.26  | 1061.41  | -0.9    | -1121.99  | 5358.88   | 7         | 222   |          |          |          |          |          |           |           |           |
|  | 813  | -6628.73 | -5150.26 | -1061.45 | 0.9     | 99.95     | -399.74   |           |   | 813      |          |          |          |          |           |           |           |
| 135197   | 1    | 2500     | -9.780   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 135197  | 1        | 2500     |          |          |          |           |           |           |
|  |      | 103      | 9.780    | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      |          |          |          |           |           |           |
|  | 2    | 2500     | 8.000    | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 2   | 2500     |          |          |          |          |           |           |           |
|  |      | 103      | -8.000   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      |          |          |          |           |           |           |
|  | 3    | 2500     | 9.540    | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 3   | 2500     |          |          |          |          |           |           |           |
|  |      | 103      | -9.540   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      |          |          |          |           |           |           |
|  | 4    | 2500     | 12.210   | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 4   | 2500     |          |          |          |          |           |           |           |
|  |      | 103      | -12.210  | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     |   |          | 103      |          |          |          |           |           |           |
|  | 5    | 2500     | 6.130    | 0.000    | 0.000   | 0.000     | 0.000     | 0.000     | 5   | 2500     |          |          |          |          |           |           |           |
|  |      | 103      | -6.130   | 0.000    |         |           |           |           |   |          |          |          |          |          |           |           |           |