Program
Solenoidal Tracker at RHIC
Sub program
Time Projection Chamber - Assembly and Test
Title
Softwall Cleanroom Enclosure

1.0 Introduction

Softwall "cleanrooms" surrounding both ends of the TPC have been constructed to minimize particulate contamination of the active volume of the detector. These cleanrooms consist of a "Unistrut" frame covered by a flame retardant vinyl sheeting, refer to STAR Dwg. 774-E-1-A (LBL 24A9366B). A simplified plan view of the enclosures and TPC is shown in fig.1. The top of these enclosures, also known as tents, may be covered by either vinyl or 0.033 inch thick corrugated polycarbonate sheet. Both materials have been approved for this application by the BNL Fire Safety Engineer. For design calculations only the heavier material has been assumed. In addition to supporting the plastic covering, the frame also supports the weight of the TPC gas plumbing and assorted electronic cables. Since the enclosures are in close proximity to a large roll-up door, wind loading has been suggested as a possible failure mode.

The construction and installation of the east and west end enclosures are nominally identical. Both are bolted to the floor in 6 locations near the floor end of the diagonal braces and to the TPC support frame at two places near mid-height of the "rear" (closest to TPC) frame columns. While these enclosures had been in use at Berkeley Lab for year before they were dismantled and shipped to BNL, documentation supporting the adequacy of the design was lacking. The following note contains a description of the finite element modeling of the enclosure and a summary of the calculated stress and deflection values under a combination of gravity and wind loads. Calculated peak stresses and force and moment values at connection points are compared to manufactures recommended values.

2.0 Loads

2.1 Wind Load

A wind speed of 30 miles per hour was selected as a nominal maximum value. Exposure of the TPC to wind, through opening the roll-up door, is within the control of the BNL-STAR staff so this value can be considered an administrative limit. A plan view of the STAR Detector building showing the location of the TPC is provided in fig.2. Wind loading, or velocity pressure, is covered in Section 7, paragraph 6.5 of the American Society of Civil Engineers (ASCE) manual. A formula for the design wind pressures for buildings and structural elements, derived from the ASCE manual, is given in the Uniform Building Code (UBC Section 1618).

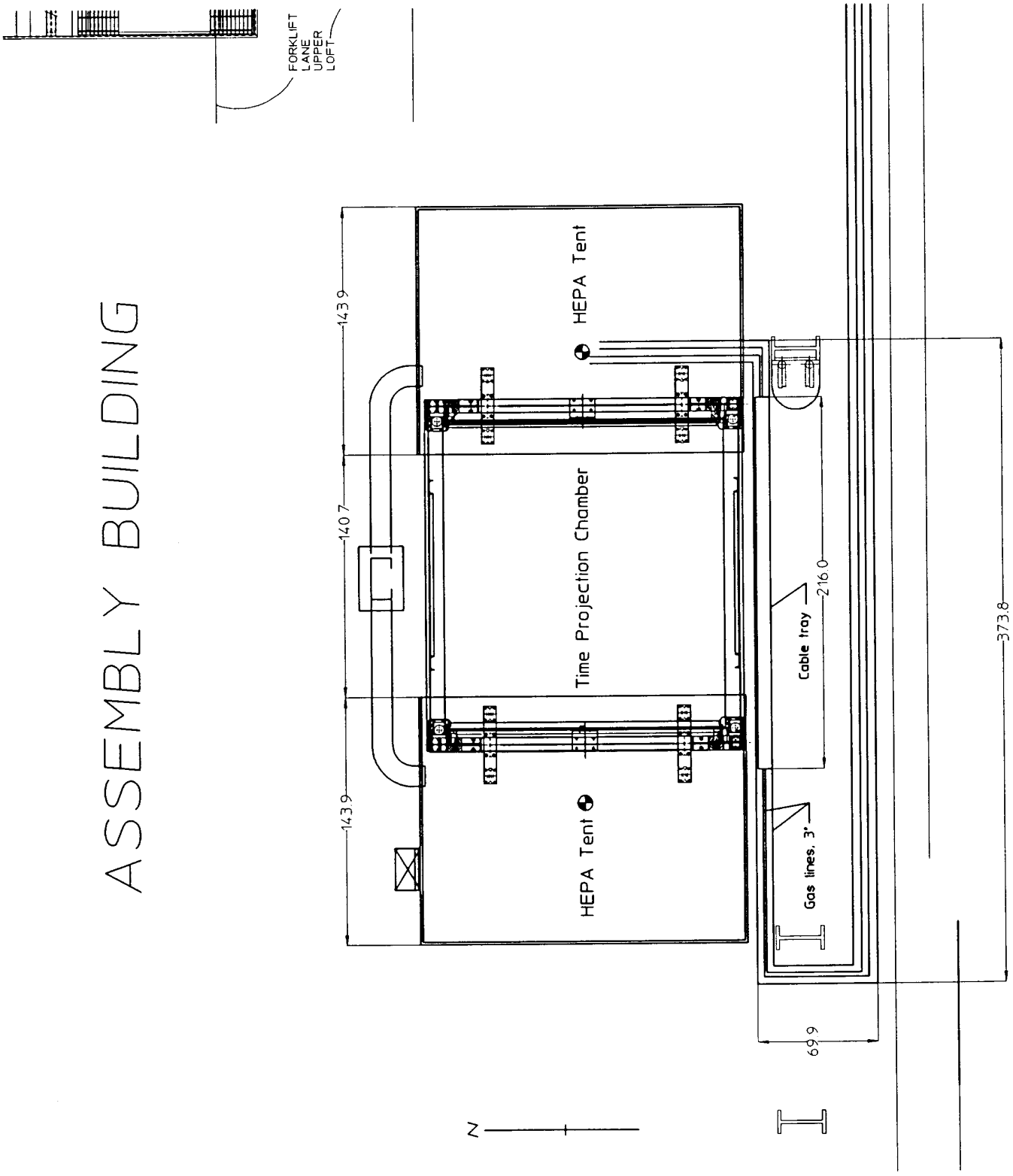


Fig. 1 TPC with Cleanroom Tents in BNL STAR Assembly Building

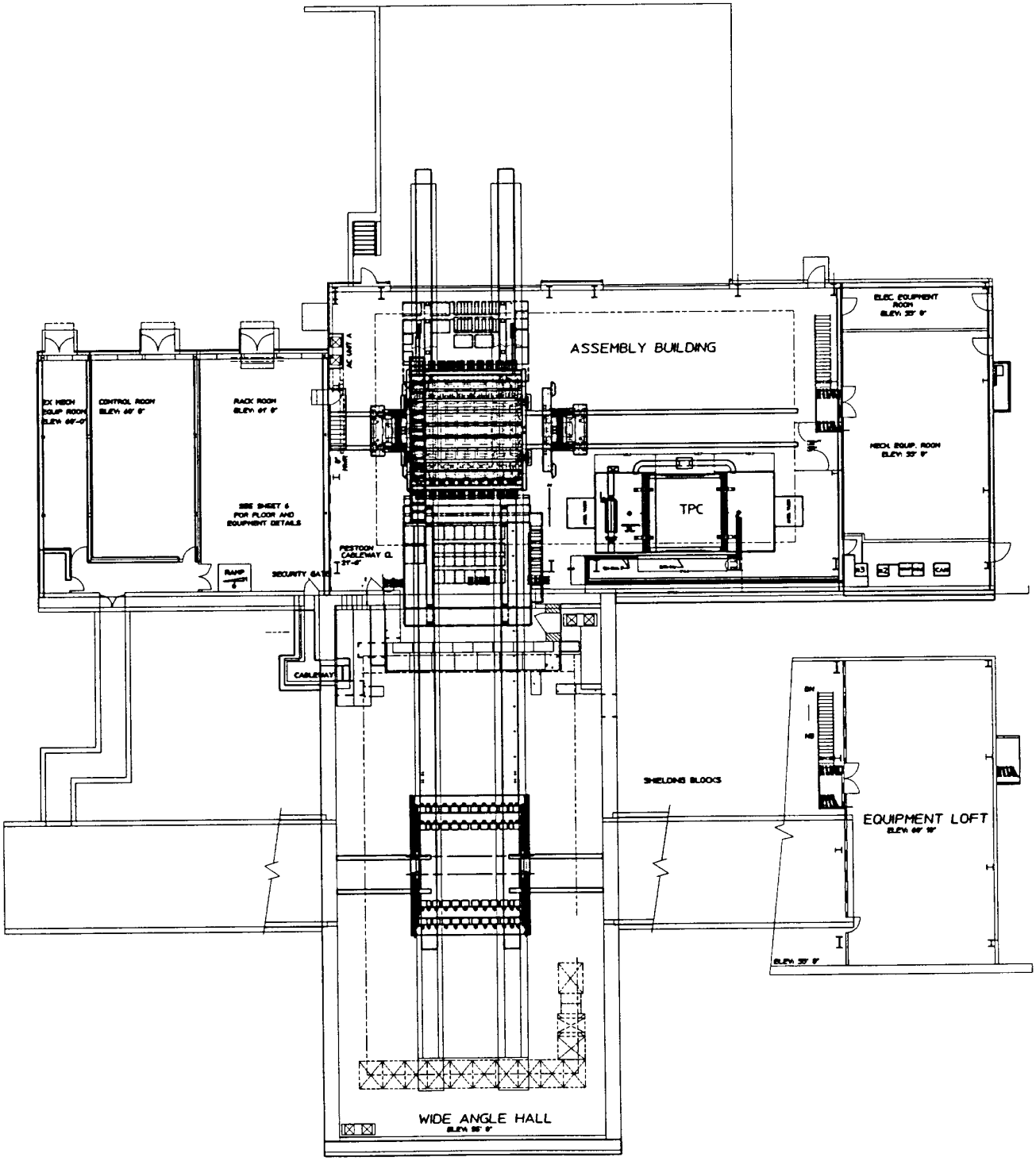


Fig.2 STAR Detector Building in Plan View

From ASCE Section 7 para 6.5, the velocity pressure at height z, is given by the following:

$$q_z := 0.00256 \cdot K_z \cdot \left(I \cdot V_w\right)^2$$

For buildings in exposed areas near a hurricane oceanline: $I := 1.11$

The exposure coefficient for an exposed structure at 20 feet above ground is: $K_z := 0.87$

Assuming a 30 mph wind; $V_w := 30$

Using the given values: $q_z := 0.00256 \cdot K_z \cdot \left(I \cdot V_w\right)^2$ $q_z = 2.47$

From UBC Section 1618 the wind pressure is given by the following:

$P := C_e \cdot C_q \cdot q_s \cdot I_w$

gust factor $C_e := 1.064$

pressure coefficient, inward $C_{qi} := 0.8$

pressure coefficient, outward $C_{qo} := 0.5$

The qs value is the wind stagnation pressure assigned to a particular geographic area. To adapt this analysis to the present situation, qz is substituted for qs x Iw. The formula for qz includes the wind importance factor.

Pressure on windward side: $P_{ww} := C_e \cdot C_{qi} \cdot q_z \cdot \frac{lbf}{ft^2}$

Pressure on leeward side: $P_{wl} := C_e \cdot C_{qo} \cdot q_z \cdot \frac{lbf}{ft^2}$

Side load on tent, windward and leeward

Tent dimensions $h := 192 \cdot in$ $w := 192 \cdot in$ $d := 144 \cdot in$

$W_{ww} := P_{ww} \cdot h \cdot d$ $W_{ww} = 403.627 \cdot lbf$

$W_{wl} := P_{wl} \cdot h \cdot d$ $W_{wl} = 252.267 \cdot lbf$

Divide into 12 discrete loads on 2 vertical members for modeling.

$F_{ww} := \frac{W_{ww}}{12 \cdot 2}$ $F_{ww} = 16.818 \cdot lbf$

$F_{wl} := \frac{W_{wl}}{12 \cdot 2}$ $F_{wl} = 10.511 \cdot lbf$

2.2 Static Loads

The tent frame is loaded by its own weight and that of the plastic sheeting it supports. In addition the frame also supports a pair of 3" stainless steel tube runs and one cable tray containing numerous electronic cables. The location of these latter items is shown in the fig.1. A summary of the weights follows.

Weight of plastic "wall" material

Softwall cleanroom plastic sheet

thickness $t := 1.0 \cdot mm$

density $\rho := 1.38 \cdot \frac{gm}{cm^3}$

Tent dimensions $h := 192 \cdot in$ $w := 192 \cdot in$ $d := 144 \cdot in$

Weight of plastic sheet on end wall

$W_{ep} := h \cdot w \cdot t \cdot \rho$

$W_{ep} = 72.357 \cdot lb$

Weight of plastic on side wall

$W_{sp} := h \cdot d \cdot t \cdot \rho$

$W_{sp} = 54.268 \cdot lb$

Weight of plastic sheet on roof.

$W_{rp} := w \cdot d \cdot t \cdot \rho$

$W_{rp} = 54.268 \cdot lb$

Weight of plumbing

The piping is supported at either end by a section of P1001 unistrut running from the top of the north wall to the top of the south wall. The return runs are clamped directly to the cross member
whereas the supply run hangs from the crossmember by a single rod.

Weight of piping hung from P1001 cross member

Triclamp elbows, 2 ea

$W_{tc90} := 2 \cdot 2 \cdot lb$

Weight of 3" tube x .065" wall

$w_3 := 2.037 \cdot \frac{lb}{ft}$

Weight of 4" x 0.120" wall

$w_4 := 4.973 \cdot \frac{lb}{ft}$

Point load from vertical tube run and half of horizontal run of supply line

$W_{pt} := W_{tc90} + 7 \cdot ft \cdot w_3 + 6 \cdot ft \cdot w_4 + 4 \cdot ft \cdot w_3$

$W_{pt} = 56.245 \cdot lb$

Distributed load is the weight of the 3" tube over south half of the P1001 span.

$W_{dis} := w_3 \cdot 8 \cdot ft$ $W_{dis} = 16.296 \cdot lb$

Weight of 3" tube on side of tent
A pair of 3" x .065" wall tubes run along the south side of the tent and are supported by the tent. A 18 ft. long cable tray is immediately above the tube runs and is supported by the same unistrut, Refer to fig. 1.

$$W_{tube} := w_3 \cdot 2 \cdot 31 \cdot ft$$

$$W_{tube} = 126.294 \cdot lb$$

Weight of cable and cable tray

$$W_{tray} := 350 \cdot lb$$

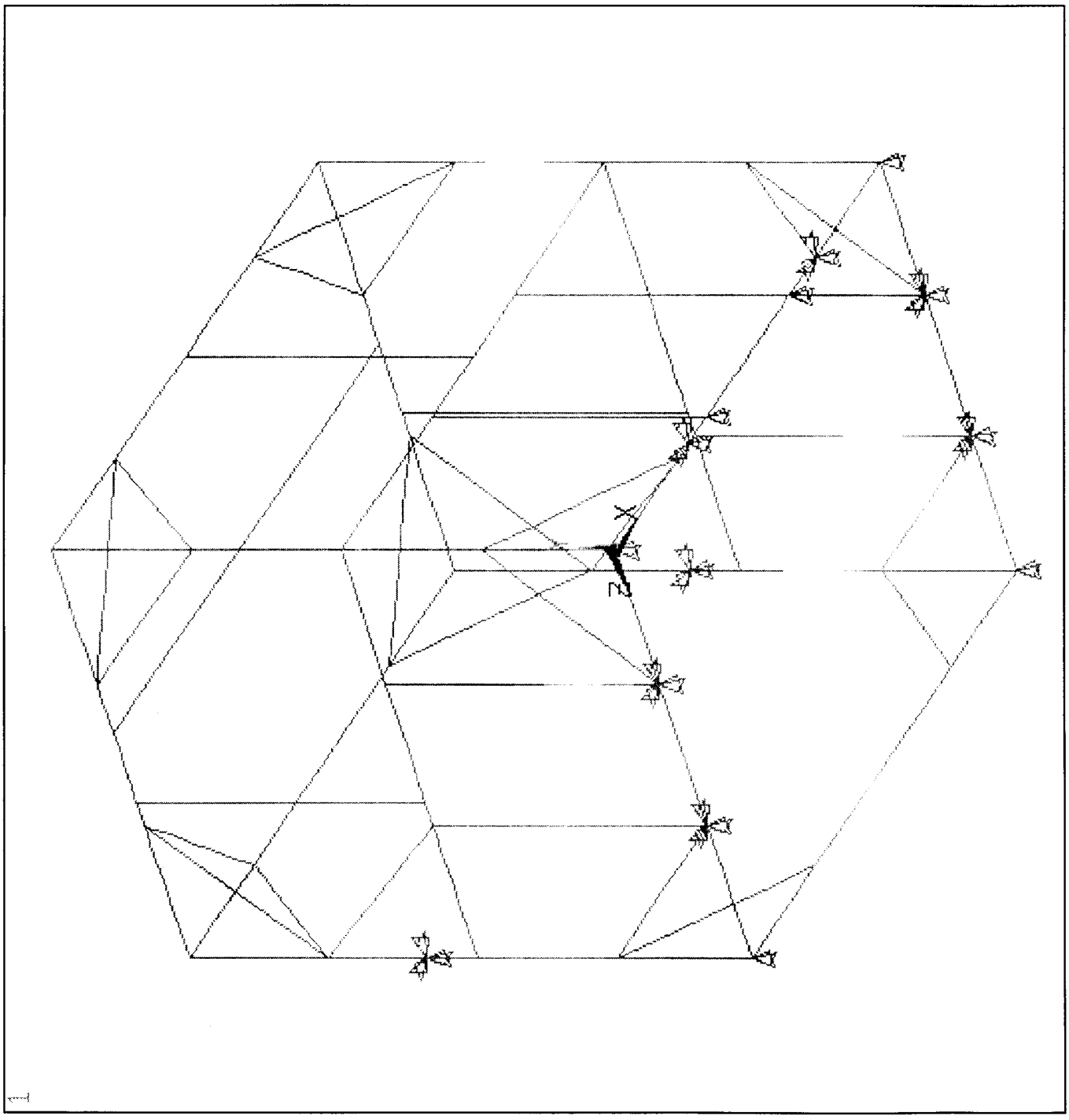
$$w_{tr} := \frac{W_{tray}}{18 \cdot ft} \qquad w_{tr} = 19.444 \cdot \frac{lb}{ft}$$

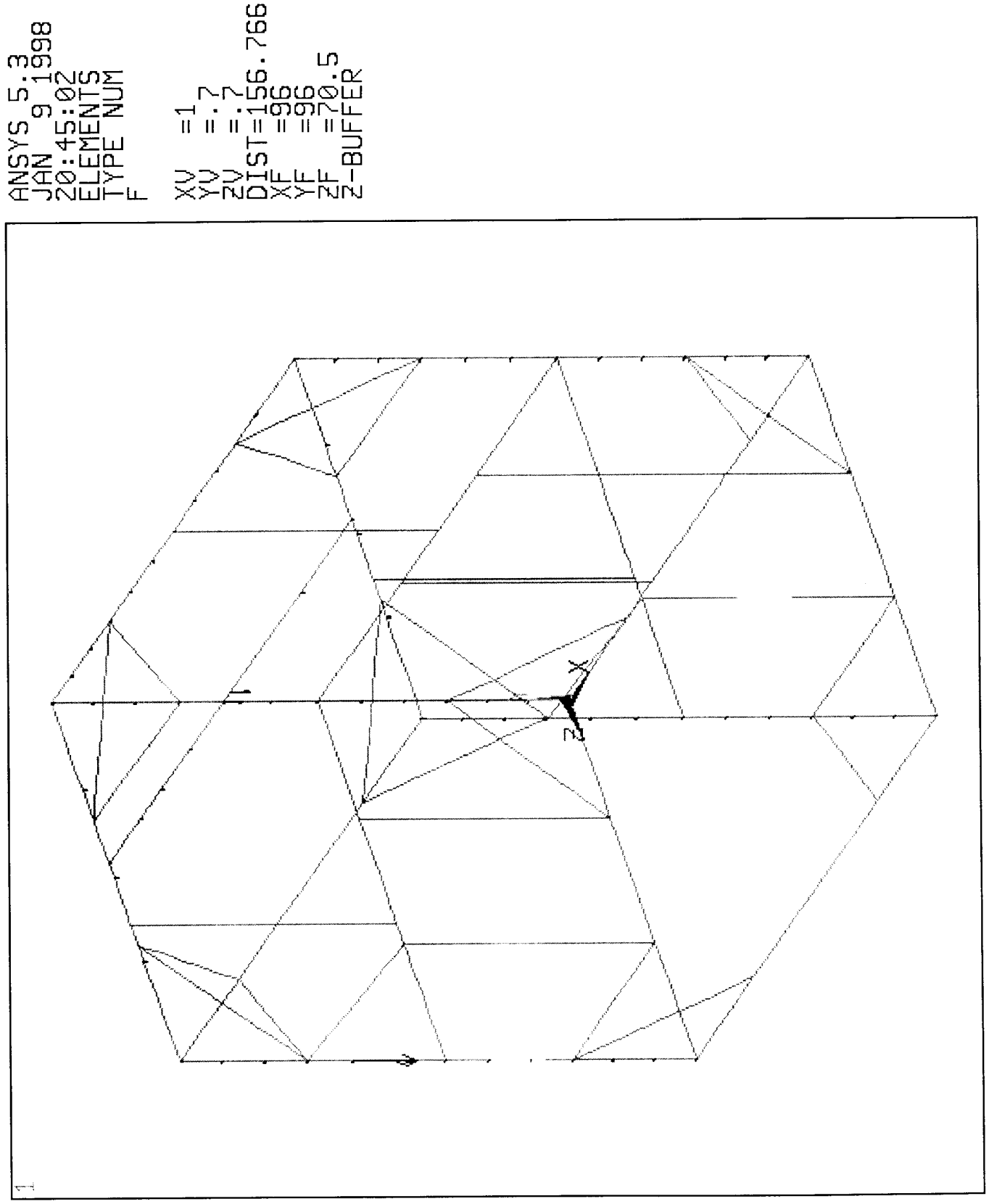
3.0 Finite Element Model

The finite element program ANSYS v5.3 was used calculate the stress and deflection of the tent frame under load. Unistrut members were modeled by 3D beam 4 elements. The cross sectional area, thickness and moment of inertia for the P1000, P1001 and P5000 Unistrut channels were taken from the Unistrut General Engineering Catalog 12.

The geometry of the model is close to, but not an exact copy of, the actual structure. For ease, where connections between members are close (within 6 inches), they have been modeled as joining at a common node. The displacement boundary conditions are shown in fig.4. Translation in all three directions has been eliminated at the 8 locations where the frame is either bolted to the floor or TPC Supports. In addition, vertical displacement is not allowed where the frame contacts the floor at the corner columns and at the door opening.

The static and wind loads have been modeled by multiple discrete nodal loads, shown in fig.5 and tabulated in the appendix, distributed over the appropriate nodes. For example the weight of the plastic sheet on the end wall is modeled as a series of 13 point loads along the top front edge of the model pointed in the negative y-direction. The central eleven loads are set to 1/12 the total weight and the outer two loads include 1/24 the weight. The weight of the side wall plastic is similarly distributed only over a smaller number of nodes. The weight of the roof plastic is assumed to be carried entirely by the P1001 cross member. Wind loads are summed into line loads and distributed evenly over the corner columns. The direction of loading is consistent with gusts blowing into the building through the roll-up door, from north to south (x direction). Input files are included in the appendix for reference.


ANSYS 5.3
JAN 9 1998
20:40:39
ELEMENTS
TYPE NUM
XV =1
YV =.7
ZV =.7
DIST=156.766
XF =96
YF =96
ZF =70.5
Z-BUFFER
Y
Z


ANSYS 5.3
JAN 9 1998
20:45:02
ELEMENTS
TYPE NUM
F
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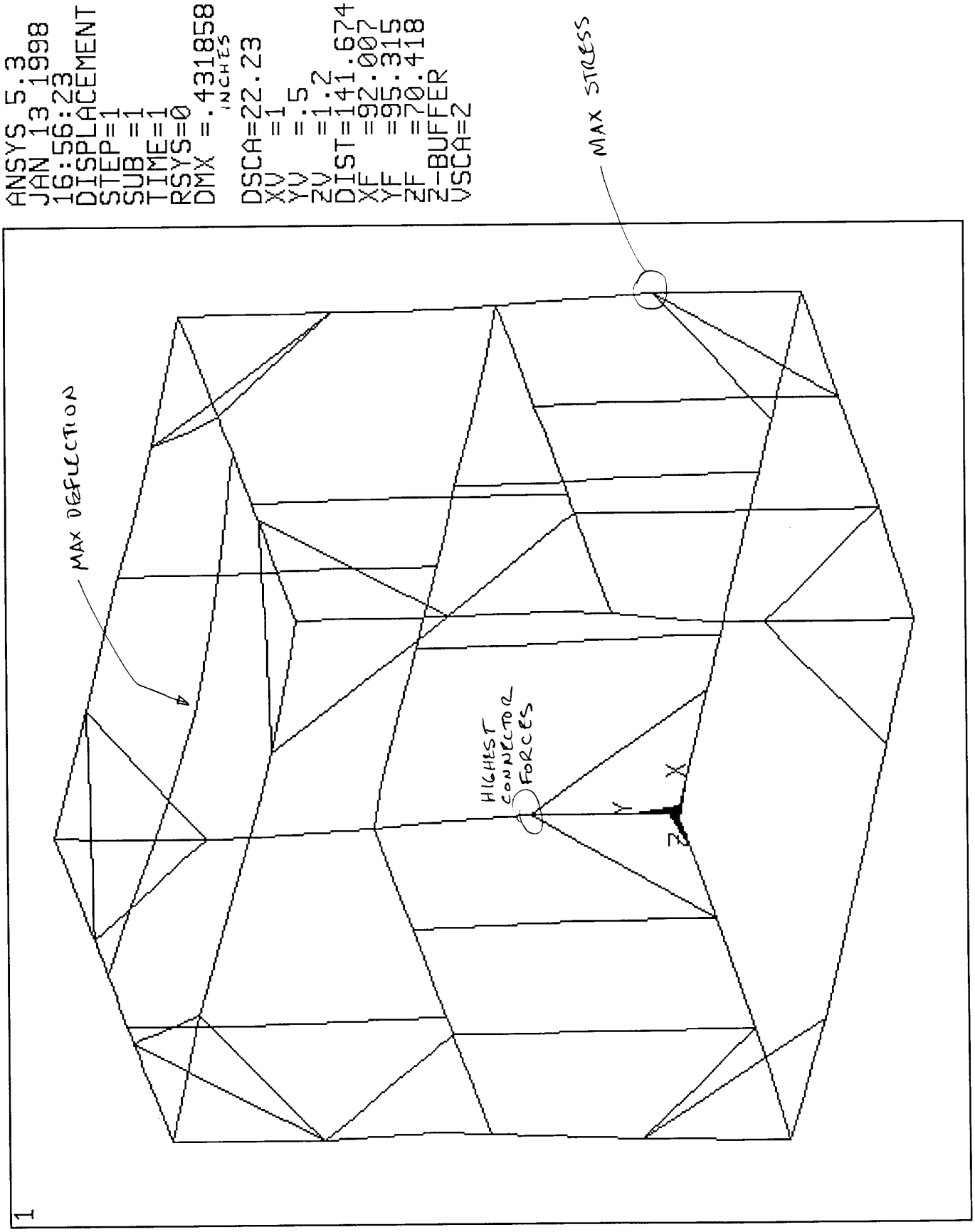
YV =.7
ZV =156.766
DIST=96
XF =96
YF =70.5
ZF =BUFFER

4.0 Calculated Force, Stress and Deflection Values

The maximum deflection of 0.43 inches, shown on the ANSYS plot in fig.6, occurs at the top cross member supporting the water/gas heat exchanger. This deflection is 1/440 th of the span dimension. The peak stress of 7016 psi occurs in the front corner column at the junction of the diagonal brace on the windward side. The manufacturers maximum recommended stress is 25,000 psi (safety factor of 2.5 on ultimate) so the peak stress in the tent frame is roughly ¼ of the allowable. The maximum force at any connection is 331 lb. This peak force component is located where the lower diagonal braces meet the front leeward corner column and is directed downward in y. The suggest load capacity of the Unistrut connectors, for the geometry used in the frame construction, is 1000 lb. The connectors are bolted to the channel sections using ½-13 steel bolts for which the manufacturer lists a pull-out force of 2000 lb. and a slip load of 1500 lb. Thus the forces on connections throughout the frame are less than 1/3 rd of the rated capacity.

5.0 Conclusion

The stresses, calculated using the actual static loads in combination with a sideways directed pressure load from an assumed 30 mph wind, are well within the manufacturers allowable values. Deflections are relatively low and the forces on the connectors well within the recommended maximums.


ANSYS 5.3
JAN 13 1998
16:56:23
DISPLACEMENT
STEP=1
SUB =1
TIME=1
RSYS=0
DMX = .431858
INCHES
DSCA=22.23
XV =1
YV =.5
ZV =1.2
DIST=141.674
XF =92.3015
YF =70.418
ZF =95.418
VSCA=2
MAX STRESS
MAX DEFLECTION
HIGHEST CONNECTOR FORCES
Y
X
Z
1

6.0 Apendix

LIST NODAL FORCES FOR SELECTED NODES 1 TO 402 BY 1
CURRENTLY SELECTED NODAL LOAD SET= FX FY FZ MX MY MZ

NODE	LABEL	REAL	IMAG
1	FX	-5.25000000	0.000000000E+00
21	FX	-8.40000000	0.000000000E+00
26	FX	-16.8000000	0.000000000E+00
27	FX	-16.8000000	0.000000000E+00
28	FX	-16.8000000	0.000000000E+00
29	FX	-16.8000000	0.000000000E+00
30	FX	-16.8000000	0.000000000E+00
31	FX	-16.8000000	0.000000000E+00
32	FX	-16.8000000	0.000000000E+00
33	FX	-16.8000000	0.000000000E+00
34	FX	-16.8000000	0.000000000E+00
35	FX	-8.40000000	0.000000000E+00
35	FY	-9.75000000	0.000000000E+00
36	FX	-16.8000000	0.000000000E+00
37	FX	-16.8000000	0.000000000E+00
49	FX	-10.5000000	0.000000000E+00
54	FX	-10.5000000	0.000000000E+00
55	FX	-10.5000000	0.000000000E+00
56	FX	-10.5000000	0.000000000E+00
57	FX	-10.5000000	0.000000000E+00

NODE	LABEL	REAL	IMAG
58	FX	-10.5000000	0.000000000E+00
59	FX	-5.25000000	0.000000000E+00
59	FY	-9.75000000	0.000000000E+00
60	FX	-10.5000000	0.000000000E+00
61	FX	-10.5000000	0.000000000E+00
62	FX	-10.5000000	0.000000000E+00
63	FX	-10.5000000	0.000000000E+00
63	FY	-63.0000000	0.000000000E+00
64	FX	-10.5000000	0.000000000E+00
75	FY	-6.00000000	0.000000000E+00
79	FY	-6.00000000	0.000000000E+00
83	FY	-6.00000000	0.000000000E+00
91	FY	-6.00000000	0.000000000E+00
92	FY	-6.00000000	0.000000000E+00
93	FY	-6.00000000	0.000000000E+00
94	FY	-6.00000000	0.000000000E+00
95	FY	-6.00000000	0.000000000E+00
96	FY	-6.00000000	0.000000000E+00
97	FY	-6.00000000	0.000000000E+00
98	FY	-6.00000000	0.000000000E+00

NODE	LABEL	REAL	IMAG
120	FX	-10.5000000	0.000000000E+00
130	FX	-8.40000000	0.000000000E+00
133	FY	-6.75000000	0.000000000E+00
134	FX	-10.5000000	0.000000000E+00
135	FX	-10.5000000	0.000000000E+00
136	FX	-10.5000000	0.000000000E+00
137	FX	-10.5000000	0.000000000E+00
138	FX	-10.5000000	0.000000000E+00
138	FY	-235.000000	0.000000000E+00
139	FX	-10.5000000	0.000000000E+00
140	FX	-10.5000000	0.000000000E+00
141	FX	-10.5000000	0.000000000E+00
142	FX	-10.5000000	0.000000000E+00
143	FX	-10.5000000	0.000000000E+00
144	FX	-10.5000000	0.000000000E+00
148	FX	-16.8000000	0.000000000E+00
152	FX	-16.8000000	0.000000000E+00
161	FX	-16.8000000	0.000000000E+00
162	FX	-16.8000000	0.000000000E+00
163	FX	-16.8000000	0.000000000E+00

NODE	LABEL	REAL	IMAG
164	FX	-16.8000000	0.000000000E+00
165	FX	-16.8000000	0.000000000E+00
166	FX	-16.8000000	0.000000000E+00
167	FX	-16.8000000	0.000000000E+00
168	FX	-8.40000000	0.000000000E+00
168	FY	-13.5000000	0.000000000E+00
169	FX	-16.8000000	0.000000000E+00
170	FX	-16.8000000	0.000000000E+00
329	FY	-13.5000000	0.000000000E+00
333	FY	-6.75000000	0.000000000E+00
338	FY	-13.5000000	0.000000000E+00
342	FY	-13.5000000	0.000000000E+00
348	FY	-13.5000000	0.000000000E+00
352	FY	-6.75000000	0.000000000E+00
357	FY	-13.5000000	0.000000000E+00
361	FY	-13.5000000	0.000000000E+00
364	FY	-69.5000000	0.000000000E+00
367	FY	-8.00000000	0.000000000E+00
368	FY	-13.5000000	0.000000000E+00
369	FY	-8.00000000	0.000000000E+00

NODE	LABEL	REAL	IMAG
371	FY	-13.5000000	0.000000000E+00