Report No. 42

DESIGN OF THE FEED SUPPORT LEGS FOR THE 65-METER HOMOLOGY TELESCOPE

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INTRODUCTION

In order to achieve about a one arc second pointing error under 18 mile/hour lateral wind during observation, the feed support legs of the 65-meter homology telescope requires essentially a deformation governed design (Fig. 1). This structure should also fulfill the survival condition of a wind load of 80 mph, the same as that for the dish back-up structure. With reference to the first requirement, the dimensions of the feed leg structure are larger than those recommended by SVH in Report 22, producing a blockage of 6.4% of telescope aperture.

The cabin is 12' deep and can hold up to 10 tons of front end instruments. An opening of 10' x 10' is provided for a fast change of instruments at the prime focus. This is to be done by pointing the telescope at horizontal position to the service tower, with the floor of the instrument cabin level with that of the service tower. The secondary mirror can be either hoisted up from the front using the feed legs as a boom, or installed from a platform of the service tower.

The legs are guyed at three points in the center portion for increased lateral stiffness. The portion behind the surface plates is a single pipe instead of a built-up structure in order to minimize the clearance problem between panel structures. The joint between the built-up portion and the single tubular section is braced in four directions to the nearest surface points. This bracing produced an insignificant effect on the RMS of the surface deformation of the dish.

Tubular members have been chosed for small shape factor under wind forces. COR-TEN steel with a specified yield stress of 50 ksi is used as in the back-up structure, for the purpose of being consistently with those of the dish structure.

Temperature deformation is also investigated. For a one degree Fahrenheit RMS temperature deviation from the mean of temperature, this feed supporting structure produced a pointing error of 2.04 second of arc RMS.

The lowest natural frequency of the system, by using mean value of frame and truss analysis, is 4.2 cps.



SUMMARY

Performance

Survival wind load		80 mph					
Pointing error under 18 mph wind load	1.08 arc-sec						
RMS pointing error with 1 deg. F temp. diff.	2.04 arc-sec						
Lowest natural frequency	4.2 cps						
Aperture blockage		6.4%					
Gain loss (expressed as an equivalent surfac	ce rms)	Wind -0.17×10^{-3} in.					
		Temp 0.73×10^{-3} in.					
Optics							
Focus and diameter ratio	F/D	0.426					
Focus length, prime focus system	F	1090.56 in.					
Effective focus length, Cassegrain system	f	17,223.529 in.					
Magnification	М	15.793					
Distance, prime focus to vertex of Cassegrain mirror	а	61.367 in.					
Distance, secondary focus to apex of Cassegrain mirror	g	969.193 in.					
Height of secondary focus above the dish	Ъ	60.000 in.					
Diameter of Cassegrain mirror	d	12 ft.					
Dimensions and Weight							
Cabin		10' x 10' x 12'					
Width of leg	Ъ _о	40.00 in.					
Depth of leg	^b 1	97.98 in.					
No. of segments		9					
Weight (portion from surface up)		33,324 1Ъ.					
		16.7 ton					
Capacity of instrument cabin		10 ton					

POINTING ERROR OF THE FEED SUPPORT

Since observations at the short wave-lengths will be performed with Cassegrain optics, the demanded accuracy is governed by the magnitude of the angular rotation and the lateral translation of the secondary mirror. Studies on this subject have been done by several authors (1) (2). Ruze's treatment will be employed in this analysis.

In order to maintain the same notations as shown in Fig. 1, Ruze's formula will be re-stated as follows:

a) Beam movement in radian due to lateral translation, ∆X, of the secondary mirror:

$$\beta = \frac{\Delta X}{F} BDF - \frac{\Delta X}{f} BDf \qquad (1)$$

With reference to the tabulated values in the <u>SUMMARY</u> section for F and f, assuming the illumination function is $I(r) = 1 - .9r^2$, one could obtain BDF = 0.84 with F/D = 0.426; BDf = 1.00 with f/D = 6.725. Substituting all these values into eq (1), one derives the following relation:

$$\beta = 0.786 \frac{\Delta X}{F}$$
 (2)

b) The beam movement α in radians due to the rotation of the secondary mirror ϕ is given by:

$$\alpha = \phi \ge \frac{a}{F} (BDF + BDf)$$
 (3)
Similarly, one again can derive the following relation for the
65-meter telescope:

$$\alpha = 0.104\phi \tag{4}$$

c) The pointing error, consequently, is:

$$PE = \beta - \alpha \tag{5}$$

NUMERICAL RESULTS FOR THE WIND LOAD OF 18 MPH DURING OBSERVATION

From the structural analysis of the feed supporting structure, the lateral translation of the mirror $\Delta X = .0104$ in., and the rotation $\phi = 4.46$ arc-sec. The beam shifts due to these deformations are, by substituting these values into eq. (2) and (4):

$$\beta = 0.786 \times \frac{.0104}{1090.56} \times 2.06 \times 10^5 = 1.54 \text{ arc-sec.}$$

 $\alpha = 0.104 \times 4.46$ = 0.46 arc-sec.

and the pointing error is, by subtracting these two values

PE = 1.54 - 0.46 = 1.08 arc-sec.

NUMERICAL RESULT FOR 1° F TEMPERATURE DIFFERENCE ON ONE LEG

The temperature load is applied on the structure as $\pm 1^{\circ}$ F on two legs, and -1° F on another two. This induced a lateral translation of the mirror .0127 inch, and a rotation of 9.63 arc-sec. Substituting these values into (2) and (4), one can have a peak pointing error, due to one degree temperature difference from the mean, of 2.89 arc-sec. Dividing this value by $\sqrt{2}$, one has a rms value of 2.04 second of arc for a random distribution.

It should be noticed that the pointing error in this case is the sum of the two due to different form of deformation.

GAIN LOSS

The gain losses are derived from the study of Zarghamee (3). Lateral displacement and angular tilt loss coefficients are extracted from Table 2 for a tapering law $1-r^2$ expressed as an equivalent surface error rms we obtain:

$$\varepsilon_{1ateral} = 0.016 \Delta X$$

$$\varepsilon_{tilt} = 0.0016 \cdot f \cdot \Delta \alpha$$

where ΔX is the lateral displacement

 $\Delta \alpha$ is the secondary mirror tilt in radians

f is the focal distance

These expressions are somewhat conservative since they apply to an optical system with a magnification of 10 (losses decrease with increasing magnification). The gain degradation for axial displacements of the secondary mirror is approximately computed as recommended by Ruze by using his equation (5) with the axial loss factor for very large f/D and 0.9 tapering.

We obtain

 $\epsilon_{axial} = 0.154 \ \Delta Z$ where ΔZ is the axial displacement.

STRUCTURAL DATA

The feed supporting structure is being analyzed in only one quadrant due to its symmetrical configuration in X-Z and Y-Z planes. Joint coordinates and member incidences are listed in Table 2, and also are illustrated in Fig. 3. All dimensions are expressed in inches and forces in pounds if not specified. The holding condition to simulate the symmetrical character is listed in Table 1.

Mode	SS	AS	SA	AA
Point	ХҮZ	XYZ	XYZ	хүг
2	111	111	101	101
3	$1 \ 1 \ 1$	$0\ 1\ 1$	$1 \ 1 \ 1$	011
4	010	010	101	101
5	010	010	101	101
6	100	011	100	011
7	100	011	100	011
8	$1 \ 1 \ 1$	$1 \ 1 \ 1$	101	101
9	$1 \ 1 \ 1$	011	$1 \ 1 \ 1$	011
40	$1 \ 1 \ 1$	111	$1 \ 1 \ 1$	111
41	$1 \ 1 \ 1$	$1 \ 1 \ 1$	$1 \ 1 \ 1$	111
42	$1 \ 1 \ 1 \ 1$	$1 \ 1 \ 1 \ 1$	$1 \ 1 \ 1 \ 1$	111
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TABLE 1

Constraints for supporting points, 0-free, 1-fixed

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The structural analysis considered only in SS and AS modes, representing zenith and horizontal positions. For dynamic analysis, however, four modes are being studied for the lowest frequency.

The demand for the structural stability is that the combined stress ratio

$$\frac{S_{m}}{S_{\Lambda}} + \frac{.85}{1 - \frac{S_{m}}{S_{A}}} \times \frac{S_{g}}{.66S_{y}} < 1$$
(6)

where

 $S_m = Max. \{S_{zw}, S_t\}$ $S_{zw} = Survival wind in stow position = |S_1+S_2+S_5|+|S_6|+|(WF-1) \times S_3|$ $S_{t} = Tilted position = \sqrt{(S_{1}+S_{2})^{2}+(S_{3}+S_{4})^{2}+|S_{5}|+|S_{6}|}$ S_1 = Dead load in zenith position S_2 = Instrument load in zenith position, 10 tons per 8 structural pts $S_3 = Dead load in horizontal position$ S_{L} = Instrument load in horizontal position, 10 tons per 8 structural pts $S_5 = Stress$ due to tensil forces from cables, 7000 lbs each for cables S_6 = Max. force on feed support from telescope design: 22,300 lbs WF = Value weight factor to combine the dead load of the structure with the survival wind load of 80 mph. This is derived from the assumption that each member has the same wall thickness of 0.156", and the wind force apply to every member disregarding the possible shadowing effects. Value used in this analysis equals 1.8. S_{Λ} = Axial stress permitted if axial force alone existed $S_e = Euler stress = \frac{149,000,000}{\Lambda^2} psi$ S_{α} = Bending stress of the extreme fibre due to its own dead weight $S_v =$ Specified yield stress: 50 ksi Λ = K1/r, slenderness ratio K = Effective length factor 1 = Length of members

r = Radius of gyration

The design data and analylical results are listed in Table 3. Member size is selected from tubular COR-TEN steel table. The stresses of the six loading conditions as well as the stress ratio are also listed. The analysis is performed in STRUDL. The structure is analyzed in truss model. Joint deformations between a truss model and a frame model is comparable.

DYNAMICAL BEHAVIOR

The structure has a lowest natural frequency of 4.2 cps, when the structure is oscillating around the Z-axis. One must note that this is not the lowest mode for the back-up structure.

The cross-section of the guy cables are 0.5 sq. in. In order to maintain a 2.5 cps vibration to the cable, it would be necessary to stress the cable to 26 ksi. This is too high a stress and a better alternative is to maintain a 14 ksi stress in the cable, which produces only a 10% loss of effective elasticity. In this case the lowest natural frequency of the cable itself is 1.7 cps. It is acceptable since the mass of the cable is small compared with that of the whole telescope structure.

Again the feed legs structure is being analyzed in both truss and frame models. The lowest frequency in truss analysis yields 4.6 cps, whereas in frame analysis, it yields 3.9 cps. Taking the average as the representative natural frequency of the telescope, one obtains 4.2 cps.

APERTURE BLOCKAGE

The shaded area in Fig. 1 shows the shadow cast by one feed leg. This shadow can be considered the sum of A_1 , the shadow of the subreflector; A_2 , the shadow of the feed leg, with width $b_0 = 40.5$ inches; A_3 , the fan shape area caused by the diverging spherical wave from the focal point; and

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 ${\rm A}_4,$ the shadow of the cables on the surface.

With the geometry of the present design, eq. (15) of Report 22 by SVH has to be adjusted to

$$\alpha$$
(rad) = 0.670 b_o/h + 0.423 x 10⁻³ x b_o

Also, by using the same illumination function as suggested in the same report, $I(r) = 1 - .776 r^2$, one could derive the quartered effective aperture, A_0 :

$$A_{o} = \frac{\pi}{2} \int_{0}^{1} I(r) r dr = .4807$$

shadow of subreflector, A_1 :

$$A_1 = \frac{\pi}{2} \int_0^{12/213} I(r) r dr = .0025$$

shadow of feed leg, A₂:

$$A_2 = \int_{12/213}^{1} I(r) \frac{b_0}{R} dr = .0217$$

fan shaped area, A_3 , which is approximated with straight line:

$$A_3 = \int_{.477}^{1} I(r) (\alpha - b_0/R) \frac{r - .477}{1 - .477} r dr = .0110$$

and finally, the shadow of the cables, A_4 , with the measured length above the surface equals 2280"; diameter equals .8":

$$A_4 = \frac{2280 \times .8}{R^2} = .0011$$

The weighted aperture blockage:

$$f_{s} = \frac{A_{1} + A_{2} + A_{3} + A_{4}}{A_{o}} = 7.5\%$$

when it is considered completely opaque.

For considering the opacity equals .83, the aperture blockage becomes:

$$f_s = \frac{A_1 + (A_2 + A_3) \times .83 + A_4}{A_0} = 6.4\%$$

For the sake of comparison, the following table lists the blockage of various telescopes:

Antenna Diameter (ft)	<u>Spars (%)</u>	Randome (%)	Total (%)
JPL 210	6.55		6.55
Rosman 85	18.37		18.37
Proposed NEROC 440	1.11	8.6	9.71
Proposed NRAO 213	6.4	600 km	6.4



FIGURE 3 - Cabin and Feed-Support

₹ 2

Fig. 3 (cont.)

Fig. 3. (cont.)

JUINTxyZCCNDITION160.001 mm 60.000 -1280.1600 SUPPORT2 60.000 60.000 -1280.1600 SUPPORT3 0.00 60.000 -1280.1600 SUPPORT5 60.000 0.0 -1208.1600 SUPPORT6 0.000 60.0000 -1208.1600 SUPPORT7 0.0000 $60.00000000000000000000000000000000000$	JOINT	(JULAUINATES			/
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16176.448 234.733 -954.243 19160.383160.283 $-F05.330$ 20233.194 200.909 $-F43.967$ 21209.909238.194 $-F05.674$ 22193.844103.844 -695.054 23271.654 243.370 -713.661 24243.370271.654 -733.661 25227.305 227.305 -584.778 26305.115 276.621 -623.415 27276.831305.115 -623.415 28260.765 260.765 260.745 29338.576 310.291 336.576 31294.226294.226 -364.227 32372.037343.752 -402.864 33343.752 372.687 -253.951 35 -405.467 377.213 -292.587 36 377.213 405.497 -292.587 37 361.148 361.148 -143.675 39 47.678 437.678 -192.312 40 437.678 437.678 -56.114 538.102 -538.102 230.000 $SUPPORT$	17	-204.733	176.448	-954.243	
19 160.383 160.383 -F05.320 20 233.194 200.909 -E43.967 21 209.909 234.194 -E43.967 22 193.844 192.844 -E95.054 23 271.654 243.370 -733.691 24 243.370 271.654 -634.778 25 227.305 227.305 -584.778 26 305.115 276.821 -623.415 26 260.765 260.765 -474.502 29 338.576 310.291 -513.139 30 310.291 338.576 -613.139 31 294.226 294.226 -364.227 32 372.037 343.752 -402.864 33 343.752 372.027 -402.864 34 327.687 -292.587 -292.587 35 -405.467 377.213 -292.587 36 377.213 405.497 -292.587 37 361.148 '361.148 -143.675 39 410.674 438.558 -182.312 <td>18</td> <td>175.448</td> <td>204.723</td> <td>-954 242</td> <td></td>	18	175.448	204.723	-954 242	
20 233.104 200.909 -E43.667 21 209.909 238.164 -E43.667 22 193.844 103.644 -E95.054 23 271.654 243.370 -733.691 24 243.370 271.654 -733.691 25 227.305 227.305 -684.778 26 305.115 276.821 -623.415 26 305.115 260.765 260.765 29 338.576 310.291 365.76 30 310.291 336.576 -613.139 31 294.226 294.226 -364.227 32 372.037 343.752 -402.864 33 343.752 372.037 -432.864 34 327.687 -292.587 -35 35 -405.467 377.213 -292.587 36 377.213 405.467 -272.587 37 361.148 -143.675 -438.658 40 438.558 410.674 -192.312 40 437.578 437.578 -56.114 SUPPORT	10	160.383	160, 283	-805,330	
21 209.909 235.194 -E43.967 22 193.844 103.844 -73.661 23 271.654 243.370 -733.661 24 243.370 271.654 -733.661 25 227.305 227.305 -584.778 26 305.115 276.831 -623.415 26 260.765 280.745 -474.502 29 338.576 310.291 -513.136 30 310.291 338.576 -513.139 31 294.226 294.226 -364.227 32 372.037 343.752 -412.864 33 343.752 372.637 -412.864 34 327.687 292.587 -56.361.14 36 377.213 405.467 -292.587 36 377.213 405.467 -292.587 37 361.148 361.148 -143.675 39 410.674 438.558 -182.212 40 437.578 -56.114 SUPPORT 41 538.102 -638.102 230.000 S	20	233-104	200,000	-143.967	
22 193.844 193.844 -655.054 23 271.654 243.370 -733.651 24 243.370 271.654 -733.651 25 227.305 227.305 -584.778 26 305.115 276.831 305.115 -623.415 26 260.765 280.745 -474.502 29 338.576 310.291 -513.139 30 310.291 338.576 -564.227 32 372.037 343.752 -402.864 34 327.687 227.2037 -402.864 34 327.687 229.587 -551.3139 35 -405.467 377.213 -292.587 36 377.213 405.467 -232.587 37 361.148 361.148 -143.675 36 377.213 405.467 -192.587 37 361.148 361.148 -143.675 39 410.674 438.558 -182.312 40 437.578 437.578 -56.114 SUPPORT 41 538.102	20	209.909	238,104	- 843 - 867	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	22	193,844	133.844	-695-054	
24 243.370 271.654 -733.691 25 227.305 227.305 -584.778 26 305.115 276.831 -623.415 27 276.831 305.115 -623.415 26 260.765 260.745 -474.502 29 338.576 310.291 338.576 30 310.291 338.576 -513.139 31 294.226 294.226 -364.227 32 372.037 343.752 -402.864 33 343.752 372.027 -402.864 34 327.687 -292.587 35 -405.467 377.213 -292.587 36 377.213 405.497 -292.587 37 361.148 361.148 -143.675 38 438.558 410.674 -192.312 39 410.674 438.558 -182.312 40 437.578 437.578 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT 42 -533.102 538.102 23	22	271.654	243.270	-733.691	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	23	243.370	271.654	-733.691	
26 $305 \cdot 115$ $276 \cdot 621$ $-623 \cdot 415$ 27 $276 \cdot 831$ $305 \cdot 115$ $-623 \cdot 415$ 26 $260 \cdot 765$ $260 \cdot 745$ $-474 \cdot 502$ 29 $338 \cdot 576$ $310 \cdot 291$ $-513 \cdot 139$ 30 $310 \cdot 291$ $338 \cdot 576$ $-513 \cdot 139$ 31 $294 \cdot 226$ $294 \cdot 226$ $-364 \cdot 227$ 32 $372 \cdot 037$ $343 \cdot 752$ $-402 \cdot 864$ 33 $343 \cdot 752$ $372 \cdot 037$ $-402 \cdot 864$ 34 $327 \cdot 687$ $-292 \cdot 587$ 35 $-405 \cdot 467$ $377 \cdot 213$ $-292 \cdot 587$ 36 $377 \cdot 213$ $405 \cdot 467$ $-292 \cdot 587$ 37 $361 \cdot 148$ $361 \cdot 148$ $-143 \cdot 675$ 38 $438 \cdot 558$ $410 \cdot 674$ $-192 \cdot 312$ 40 $437 \cdot 578$ $437 \cdot 578$ $-56 \cdot 114$ SUPPORT 41 $538 \cdot 102$ $-538 \cdot 102$ $230 \cdot 000$ SUPPORT $+2$ $-533 \cdot 102$ $538 \cdot 102$ $230 \cdot 000$ SUPPORT	25	227.305	227.205	-584.778	
27 276.831 305.115 -623.415 26 260.765 $2c0.745$ -474.502 29 338.576 310.291 -513.139 30 310.291 338.576 -513.139 31 294.226 294.226 -364.227 32 372.037 343.752 -402.864 33 343.752 277.687 -253.951 35 -405.467 377.213 -292.587 36 377.213 405.467 -292.587 37 361.148 361.148 -143.675 38 438.558 410.674 -192.312 40 437.578 437.578 -56.114 41 538.102 -538.102 230.000 42 -533.102 538.102 230.000	26	305,115	276 . 821	-622,415	
26 260.765 260.745 -474.502 29 338.576 310.291 -513.139 30 310.291 338.576 -513.139 31 294.226 294.226 -364.227 32 372.037 343.752 -402.864 33 343.752 972.037 -402.864 34 327.687 227.687 -253.951 35 -405.467 377.213 -292.587 36 377.213 405.467 -272.587 37 361.148 361.148 -143.675 38 438.558 410.674 -192.312 39 410.674 438.958 -182.212 40 437.578 437.578 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT $+2$ -533.102 538.102 230.000 SUPPORT	27	276.831	305,115	-623.415	
29 338.576 310.291 -513.139 30 310.291 $33F.57E$ -513.139 31 $294.22E$ 294.226 -364.227 32 372.037 343.752 -472.864 33 343.752 372.037 -412.864 34 327.687 -253.951 35 -495.467 377.213 -292.587 36 377.213 $40F.497$ -232.587 37 361.148 361.148 -143.675 39 410.674 438.558 -182.212 40 437.578 437.578 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT	20	260.765	200.745	-474.502	
30 310.291 $33E.57E$ -513.139 31 $294.22E$ 294.226 -364.227 32 372.037 343.752 -402.864 33 343.752 372.037 -402.864 34 327.687 -253.951 35 -405.467 377.213 -292.587 36 377.213 405.497 -232.587 37 361.148 361.148 -143.675 38 438.558 410.674 -192.312 39 410.674 438.958 -182.212 40 437.578 437.578 -56.114 41 538.102 -538.102 230.000 42 -533.102 538.102 230.000	29	338.576	310.291	-512.139	
31 294.226 294.226 -364.227 32 372.037 343.752 -402.864 33 343.752 372.037 -402.864 34 327.687 -253.951 35 -405.467 377.213 -292.587 36 377.213 405.497 -292.587 36 377.213 405.497 -292.587 36 377.213 405.497 -292.587 36 377.213 405.497 -292.587 37 361.148 361.148 -143.675 38 438.958 410.674 -182.312 49 410.674 438.958 -182.312 40 437.978 437.978 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT +2 -533.102 538.102 230.000 SUPPORT	30	310.291	338.576	-513.139	
32 372.037 343.752 -402.864 33 343.752 372.037 -402.864 34 327.687 -253.951 35 -495.467 377.213 -292.587 36 377.213 405.497 -292.587 36 377.213 405.497 -292.587 36 377.213 405.497 -292.587 36 377.213 405.497 -292.587 37 361.148 361.148 -143.675 38 438.558 410.674 -192.312 39 410.674 438.958 -182.312 40 437.978 437.978 -56.114 41 538.102 -538.102 230.000 42 -533.102 538.102 230.000	31	294.226	294.226	-364.227	
33 343.752 372.037 -4.)2.864 34 327.687 227.687 -253.951 35 -405.467 377.213 -292.587 36 377.213 405.497 -232.587 36 377.213 405.497 -232.587 37 361.148 361.148 -143.675 38 438.558 410.674 -192.312 39 410.674 438.558 -182.312 40 437.578 437.578 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT +2 -533.102 538.102 230.000 SUPPORT	32	372.037	343.752	-472.864	
34 327.687 327.687 -253.951 35 -495.467 377.213 -292.587 36 377.213 405.497 -292.587 37 361.148 361.148 -143.675 38 438.558 410.674 -192.312 39 410.674 438.958 -182.212 40 437.978 437.978 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT +2 -533.102 538.102 230.000 SUPPORT	33	343+752	272.027	-4)2.864	
35 -405.467 377.213 -292.587 36 377.213 405.497 -292.587 37 361.148 -361.148 -143.675 38 438.558 410.674 -192.312 39 410.674 438.958 -182.212 40 437.578 437.578 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT +2 -533.102 538.102 230.000 SUPPORT	34	327.687	327.687	-253.951	
36 377.213 405.497 -292.587 37 361.148 361.148 -143.675 38 438.958 410.674 -192.312 39 410.674 438.958 -182.312 40 437.978 437.978 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT +2 -533.102 538.122 230.000 SUPPORT	35	495.497	377.213	-292.587	
37 361.148 361.148 -143.675 38 438.558 410.674 -192.312 39 410.674 438.558 -182.312 40 437.578 437.578 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT +2 -533.102 538.122 230.000 SUPPORT	30	377.213	405.497	-292.587	
30 438.558 410.674 -192.312 39 410.674 438.558 -182.312 40 437.578 437.578 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT +2 -538.102 538.102 230.000 SUPPORT	37	361.148	361.148	-143.675	
39 410.674 438.958 -182.212 40 437.978 437.978 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT +2 -538.102 538.102 230.000 SUPPORT	30	438.558	410.674	-192.312	
40 437.578 437.578 -56.114 SUPPORT 41 538.102 -538.102 230.000 SUPPORT +2 -538.102 538.102 230.000 SUPPORT	39	419.674	438.558	-182.312	
41 538.102 -538.102 230.000 SUPPORT +2 -538.102 538.102 230.000 SUPPORT	40	437.578	437.578	-56.114	SUPPORT
42 -538.102 538.102 230.000 SUPPORT	41	538.102	-538.102	230.000	SUPPORT
	42	-533.102	538.102	230.000	SUPPORT

ME	МВЕК	AREA	ƙ.G.	LENGTH	L/R	1	?	3	4	5	6	RATIO
1	1 2	2.515	1.369	60.00	35.	0.25	-0.45	-C.69	-1.01	2.80	1.19	C.26
2	1 3	2.515	1.369	60.0C	35.	C.25	-0.45	0.0	0.0	2.80	1.19	0.19
3	1 10	2.515	1.369	144.OC	84.	-0.25	-0.01	1.17	2.07	-1.79	0.35	0.28
4	8 10	2.515	1.369	60.CC	35.	-0.56	0.05	1.23	2.29	4.60	-0.39	0.39
5	9 10	2.515	1.369	60.00	35.	-0.56	0.09	0.0	0.0	4.60	-0.39	0.25
6	15	1.439	0.928	93.72	81.	-0.20	-0.CE	0.80	1.49	-1.00	-0.93	0.20
7	17	1.439	0.928	93.72	81.	-0.20	-C.08	-1.41	-2.90	-1.00	-0.93	0.29
8	5 10	1.439	0.928	93.72	81.	-0.23	-0.08	0.80	1.49	-1.86	1.67	0.27
9	7 10	1.439	0.928	93.72	81.	-0.23	30.2-	1.45	2.90	-1.86	1.67	0.36
10	1 4	1.439	0.928	105.32	91.	0.04	-0.13	-0.14	-0.42	-1.52	-1.05	0.19
11	16	1.439	0.928	105.32	91.	0.04	-0.13	-0.42	-1.85	-1.52	-1.05	0.28
12	1 11	1.516	1.149	140.03	ç7.	C.32	-C.89	-1.47	-2.44	4.26	1.43	C.66
13	1 12	1.516	1.149	140.03	97.	C•32	-0.89	-0.05	1.20	4.26	1.43	0.48
14	4 10	1.439	0.928	105.32	91.	-0.03	-0.02	-0.09	-0.06	-0.28	1.43	0.12
15	4 11	C•960	0.641	118.30	148.	0.02	-C.40	-0.22	-1.31	1.78	0.99	0.70
16	6 IU	1.439	0.928	105.32	91.	-0.03	-0.02	1.34	1.88	-0.28	1.43	0.29
17	6 12	0.960	0.641	118.30	148.	C.02	-0.4C	-0.79	-0.02	1.78	0.99	0.59
18	10 11	0.960	0.641	100.00	125.	-0.38	0.76	0.30	2.01	-4.29	-1.43	C•95
19	10 12	C•960	0.641	100.00	125.	-C.38	0.76	0.16	-0.81	-4.29	-1.43	0.73
20	11 12	0.960	0.641	40.0C	50.	-0.03	-0.03	-0.06	-0.22	0.10	0.24	0.04
21	4 5	0.103	0.220	48.05	175.	C•O	0.0	0.38	0.0	0.0	0.0	0.09
22	67	0.103	0.220	48.05	175.	C•O	0.0	0.0	0.0	0.0	0.0	0.01
23	10 13	3.290	1.770	120.00	54.	-C.42	-0.68	2.10	3.49	-2.72	1.89	0.67
24	11 14	3.290	1.770	120.00	54.	C.03	-0.34	-0.83	-1.07	1.41	0.60	0.26
25	12 15	3.290	1.770	120.00	54.	0.03	-0.34	-0.01	0.39	1.41	0.60	0.17
26	14 15	0.291	0.262	40.00	122.	C.17	0.61	0.78	0.29	-1.39	-1.17	C.40
27	13 14	C.720	0.575	100.00	139.	C.22	0.30	-0.43	-1.43	1.21	-0.78	0.55
28	13 15	C.720	0.575	100.00	139.	C.22	0.30	-1.18	-1.43	1.21	-0.78	0.65
29	11 15	1.074	0.840	126.49	120.	C.04	-0.28	0.06	-0.74	1.20	0.50	0.26
30	12 14	1.074	0.840	126.49	120.	C.04	-0.28	-C.74	0.14	1.20	0.50	C.25
31	10 14	1.394	1.061	156.21	118.	-0.45	-0.09	0.24	1.63	-3.21	0.46	0.57
32	10 15	1.394	1.061	156.21	118.	-0.45	-0.09	0.53	1.10	-3.21	0.46	0.55
33	11 13	1.394	1.061	156.21	118.	0.15	-0.05	0.46	0.03	1.17	0.10	0.19
34	12 13	1.394	1.061	156.21	118.	C.15	-0.05	0.29	0.27	1.17	0.10	0.20
35	13 16	3.290	1.770	120.00	54.	-0.22	-0.63	2.13	2.94	-0.56	1.61	0.48
36	14 17	3.290	1.770	120.00	54.	-0.18	-0.34	-0.85	-0.22	0.01	0.70	C.13
37	15 18	3.290	1.770	120.00	54.	-0.18	-C.34	0.17	0.34	0.01	0.70	0.10
38	17 18	0.291	0.262	40 • C C	122.	C•49	0.58	C.56	-0.39	1.02	-1.27	0.39
39	16 17	C.720	0.575	100.00	139.	C.11	C.36	-0.38	-0.90	-0.21	-0.83	0.34

TABLE 3 - RESULTS OF STRUCTURAL ANALYSIS

-17-

ME	MBER		ARFA	R.G.	LENGTH	L/R	1	2	3	4	5	6	RATIO
40	16	18	0.720	0.575	100.00	139.	C.11	0.36	-0.88	-1.02	-0.21	-0.83	0.42
41	14	18	1.074	0.840	126.49	120.	-0.13	-0.24	-0.31	-0.39	-0.01	0.50	0.15
42	15	17	1.074	0.840	126.49	120.	-C.13	-0.24	-0.17	0.49	-0.01	0.50	0.12
43	13	17	1.394	1.061	156.21	118.	-0.27	-0.16	0.48	1.13	-2.15	0.53	0.44
44	13	18	1.394	1.061	156.21	118.	-C.27	-0.16	0.25	0.88	-2.15	0.53	0.40
40	14	16	1.394	1.061	156.21	118.	C.17	-0.15	-0.06	-0.48	2.23	0.17	0.31
46	15	16	1.394	1.061	156.21	118.	0.17	-0.15	0.26	0.06	2.23	0.17	C.29
47	16	19	3.290	1.770	120.00	54.	-C.04	-0.63	1.89	2.16	2.23	1.40	0.51
48	17	20	3.290	1.770	120.00	54.	-0.33	-C.34	-C.4C	0.48	-1.18	0.80	0.20
49	18	21	3.290	1.770	120.00	54.	-0.33	-0.34	-0.04	0.30	-1.18	C.80	0.18
50	20	21	0.291	0.262	40 • C C	122.	C.73	0.60	C.33	-0.97	3.06	-1.48	0.63
51	19	20	C.72C	0.575	100.00	139.	C.13	0.36	-0.22	-0.93	-0.71	-0.78	0.38
52	19	21	C.720	0.575	100.00	139.	C.13	0.36	-0.99	-0.80	-0.71	-0.78	0.47
53	17	21	1.074	0.840	126.49	120.	-0.23	-0.25	-C.69	-0.16	-0.86	0.58	0.27
54	18	20	1.074	0.840	126.49	120.	-C.23	-0.25	C.38	0.73	-0.86	0.58	0.28
55	16	20	1.394	1.061	156.21	118.	-C.20	-0.15	C.97	1.21	-2.07	0.50	0.49
56	16	21	1.394	1.061	156.21	118.	-C.20	-0.15	0.04	0.76	-2.07	0.50	0.36
57	17	19	1.394	1.061	156.21	118.	C.C8	-0.13	-0.34	-0.40	2.31	0.14	0.33
58	18	19	1.394	1.061	156.21	118.	C•08	-0.13	0.29	-0.06	2.31	0.14	0.28
59	19	22	3.290	1.770	120.00	54.	0.02	-0.62	1.50	1.41	4.88	1.17	0.59
60	20	23	3.290	1.770	120.00	54.	-C.42	-0.34	0.69	1.22	-2.43	0.89	0.35
61	21	24	3.290	1.770	120.00	54.	-C.42	-0.34	-0.70	0.24	-2.43	0.89	0.31
62	23	24	0.873	0.685	40.CC	47.	C.03	0.20	-1.06	-1.27	5.47	-0.78	0.47
63	22	23	0.873	0.685	100.00	117.	C.12	0.25	-2.55	-1.18	-C.64	-0.65	0.49
64	22	24	0.873	0.685	100.00	117.	C.12	0.25	1.51	-0.17	-0.64	-0.65	0.27
65	20	24	1.074	0.840	126.49	120.	-C.34	-0.26	-1.C4	0.10	-1.76	0.69	0.41
66	21	23	1.074	0.840	126.49	120.	-0.34	-C.26	0.95	0.98	-1.76	0.69	0.47
67	19	23	1.394	1.061	156.21	118.	-C.13	-0.16	1.12	1.15	-1.74	0.49	0.46
68	19	24	1.394	1.061	156.21	118.	-C.13	-0.16	0.09	0.70	-1.74	0.49	0.32
69	20	22	1.394	1.061	156.21	118.	-C.00	-0.14	-0.96	-0.46	2.64	0.13	0.43
70	21	22	1.394	1.061	156.21	118.	-C.00	-0.14	0.59	-0.12	2.64	0.13	0.34
71	22	25	3.290	1.770	120.00	54.	0.15	-0.59	1.80	1.33	4.20	1.15	0.56
72	23	26	3.290	1.770	120.00	54.	-C.50	-0.34	0.57	1.60	3.39	0.97	0.44
73	24	27	3.290	1.770	120.00	54.	-0.50	-0.34	-0.12	0.43	3.39	0.97	0.35
74	26	27	C.720	0.575	40.00	56.	C.42	C.25	-0.08	-0.72	2.20	-0.69	0.27
75	25	26	0.720	0.575	100.00	139.	C.12	0.35	-C.26	-1.03	-0.15	-0.79	0.33
76	25	27	C.720	0.575	100.00	139.	C.12	0.35	-1.39	-0.74	-0.15	-0.79	0.44
77	23	27	1.074	0.840	126.49	120.	-C.40	-0.27	1.41	0.88	-2.50	0.75	C•59
78	24	20	1.074	0.840	126.49	120.	-C.40	-0.27	-1.13	0.64	-2.50	0.75	C.51
79	22	26	1.394	1.061	156.21	118.	-C.20	-0.16	-C.83	0.37	0.86	0.33	0.19

TABLE 3 - (CONT.)

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ME	MBER		ΔΡΕΔ	R.G.	LENGTH	L/R	1	2	3	4	5	6	RATIO
80	22	27	1.394	1.061	156.21	118.	-0.20	-0.16	1.08	0.40	0.86	0.33	0.28
81	23	25	1.394	1.061	156.21	118.	0.09	-0.13	1.08	0.45	-0.70	0.32	0.27
82	24	25	1.394	1.061	156.21	118.	C.09	-0.13	-0.03	0.26	-0.70	0.32	0.14
83	25	28	3.290	1.770	120.00	54.	C.22	-0.57	2.01	1.32	3.22	1.15	0.50
84	26	29	3.290	1.770	120.00	54.	-0.62	-0.36	-0.61	1.50	-2.97	0.99	0.36
85	27	30	3.290	1.770	120.00	54.	-C.62	-C.36	C•94	0.57	-2.97	0.99	0.38
86	29	30	0.720	0.575	40.00	56.	0.47	C.25	-0.08	-0.72	1.90	-0.68	0.25
87	28	29	C.720	0.575	100.00	139.	C•14	0.34	-0.31	-1.00	-0.00	-0.77	0.31
88	28	30	C.720	0.575	100.00	139.	C.14	0.34	-1.32	-0.69	-0.00	-0.77	0.40
89	26	3Ú	1.074	0.840	126.49	120.	-C.45	-C.26	0.93	0.87	-2.17	0.72	0.51
90	27	29	1.074	0.840	126.49	120.	-C.45	-0.26	-0.68	0.64	-2.17	0.72	0.44
91	25	29	1.394	1.061	156.20	118.	-0.13	-0.16	-0.27	0.38	0.82	0.32	0.16
92	25	3û	1.394	1.061	156.20	118.	-C.13	-0.16	0.75	0.34	0.82	0.32	C.24
93	26	28	1.394	1.061	156.21	118.	C.01	-0.12	C.87	0.45	-0.74	0.31	0.25
94	27	28	1.394	1.061	156.21	118.	C.01	-0.12	-0.12	0.19	-0.74	0.31	0.14
95	28	31	3.290	1.770	120.00	54.	C.20	-0.55	2.03	1.30	2.26	1.15	0.44
96	29	32	3.290	1.770	120.00	54.	-C.68	-0.37	-1.15	1.41	-2.54	0.99	0.36
97	30	33	3.290	1.770	120.00	54.	-C.68	-0.37	1.50	0.68	-2.54	0.99	0.39
98	32	33	0.291	0.262	40.00	122.	1.23	C.64	-0.28	-1.78	3.95	-1.69	0.88
99	31	32	C.720	0.575	100.00	139.	C.19	0.34	-0.14	-0.98	0.21	-0.79	0.32
100	31	33	C.720	0.575	100.00	139.	C.19	0.34	-1.53	-0.75	0.21	-0.79	0.47
101	29	33	1.074	0.840	126.49	120.	-C.49	-0.27	0.47	0.88	-1.85	0.72	0.44
102	30	32	1.074	0.840	126.49	120.	-0.49	-0.27	-C.21	0.65	-1.85	0.72	0.37
103	28	32	1.394	1.061	156.21	118.	-0.06	-0.15	-0.02	0.36	0.74	0.32	0.16
104	28	33	1.394	1.061	156.21	118.	-0.06	-0.15	0.77	0.36	0.74	0.32	0.24
105	29	31	1.394	1.061	156.20	118.	-C.C8	-C.11	C.36	0.43	-0.82	0.31	0.21
106	30	31	1.394	1.061	156.20	118.	-0.08	-0.11	0.15	0.22	-0.82	0.31	0.17
107	31	34	3.290	1.770	120.00	54.	C.08	-0.52	1.89	1.26	1.30	1.13	0.37
108	32	35	3.290	1.770	120.00	54.	-C.70	-0.38	-1.21	1.31	-2.10	0.99	0.34
109	33	36	3.290	1.770	120.00	54.	-0.70	-0.38	1.72	0.79	-2.10	0.99	0.38
110	35	36	0.291	0.262	40.0C	122.	1.26	0.69	-0.53	-1.87	3.29	-1.75	0.85
111	34	35	C.720	0.575	100.00	139.	C.19	0.28	-0.08	-0.79	0.30	-0.66	0.28
112	34	36	C.720	0.575	100.00	139.	C.19	0.28	-1.28	-0.65	0.30	-0.66	0.41
113	32	36	1.074	0.840	126.49	120.	-C.50	-C.28	0.07	0.88	-1.53	0.72	0.37
114	33	35	1.074	0.840	126.49	120.	-C.50	-0.28	0.32	0.65	-1.53	0.72	0.37
115	31	35	1.304	1.061	156.21	118.	-C.01	-0.16	0.35	0.36	0.65	0.33	0.19
116	31	30	1.394	1.061	156.21	118.	-C.01	-C.16	0.67	0.39	0.65	0.33	0.22
117	32	34	1.394	1.061	156.21	118.	-C.19	-0.12	-0.04	0.43	-0.91	0.32	0.19
118	33	34	1.394	1.061	156.21	118.	-C.19	-0.12	0.30	0.25	-0.91	0.32	C.20
119	34	37	3.290	1.770	120.00	54.	-C.18	-0.53	1.66	1.33	0.27	1.21	0.30

TABLE 3 - (CONT.)

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ME	MBER	AREA	R.G.	LENGTH	L/R	1	2	3	4	5	6	RATIO
120	35 38	3.290	1.770	120.00	54.	-C.68	-C.4C	-0.75	1.25	-1.68	1.02	0.29
121	36 39	3.290	1.770	120.00	54.	-0.68	-C.4C	1.63	0.93	-1.68	1.02	0.36
122	38 39	0.873	0.685	40.CC	47.	C.57	C.34	-0.4C	-0.91	1.26	-0.84	0.20
123	37 38	0.873	0.685	100.00	117.	C.70	C.65	-0.64	-1.77	1.21	-1.56	0.54
124	37 39	C.873	0.685	100.00	117.	C.70	C.65	-2.18	-1.62	1.21	-1.56	0.66
125	35 39	1.074	0.840	126.49	120.	-C.52	-0.31	-0.24	0.96	-1.29	0.78	0.34
126	36 38	1.074	0.840	126.49	120.	-C.52	-0.31	C.94	0.72	-1.29	0.78	0.41
127	34 38	1.394	1.061	156.21	118.	C.10	-0.1C	0.70	0.20	0.67	0.21	0.19
128	34 39	1.394	1.061	156.21	118.	C.10	-C.1C	0.32	0.28	0.67	0.21	0.17
129	35 37	1.394	1.061	156.20	118.	-0.24	-0.07	-0.46	0.27	-0.88	0.20	0.19
130	36 37	1.394	1.061	156.20	118.	-C.24	-0.07	0.20	0.13	-0.88	0.20	0.17
131	37 40	3.730	1.768	139.54	63.	-C.39	-0.57	1.59	1.46	-0.30	1.33	0.14
132	38 40	3.730	1.768	129.12	58.	-0.80	-0.49	-0.20	1.42	-1.72	1.22	0.35
133	39 40	3.730	1.768	129.12	58.	-C.80	-C.49	1.54	1.21	-1.72	1.22	0.44
134	22 41	0.500	0.045	1228.81	****	-0.63	-0.07	0.09	-1.58	-4.49	-0.59	****
135	22 42	0.500	0.045	1228.81	****	-0.63	-0.07	-5.18	-2.36	-4.49	-0.59	****
136	23 41	C.500	0.045	1269.01	****	-0.71	-0.02	0.18	-1.36	-5.26	-0.57	****
137	24 42	0.500	0.045	1269.01	****	-0.71	-0.02	-5.53	-2.44	-5.26	-0.57	****

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