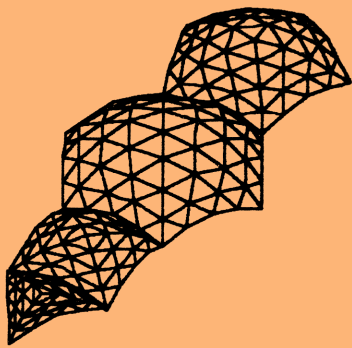
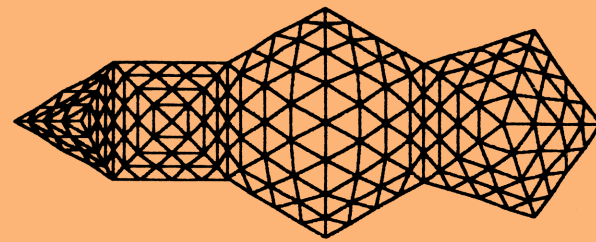




BARF's
Dome Design Tools

This manual plus a Hewlett-Packard Model HP-42S, or equivalent, pocket programmable calculator will enable an architect or engineer to prepare pre-bid documents for technically feasible domes which range in size from a backyard spa cover to ones superior to the New Orleans SuperDome.

Types range from nestable polygons, icosa based to circular edge.

Software provided to calculate geometries, develop structural sections and determine wind loads. Several of the programs are useful for mathematicians or computer scientists who are not directly involved in dome design.

GEORGE ALAN DONALDSON

7/25/97

RICHARD,

I OFTEN THINK OF YOU AS A CONTEMPORARY GALILEO GALILEI, OR ONE WHOSE WORKS WERE UNAPPRECIATED BY HIS ASSOCIATES. I AM NOT ONE OF THE SAME.

GEORGE

To Richard Nelson

As founder of the *PPC*,
he inspired thousands of
personal programmers
to create somewhat
esoteric, tho elegant,
cybernetic blivets.

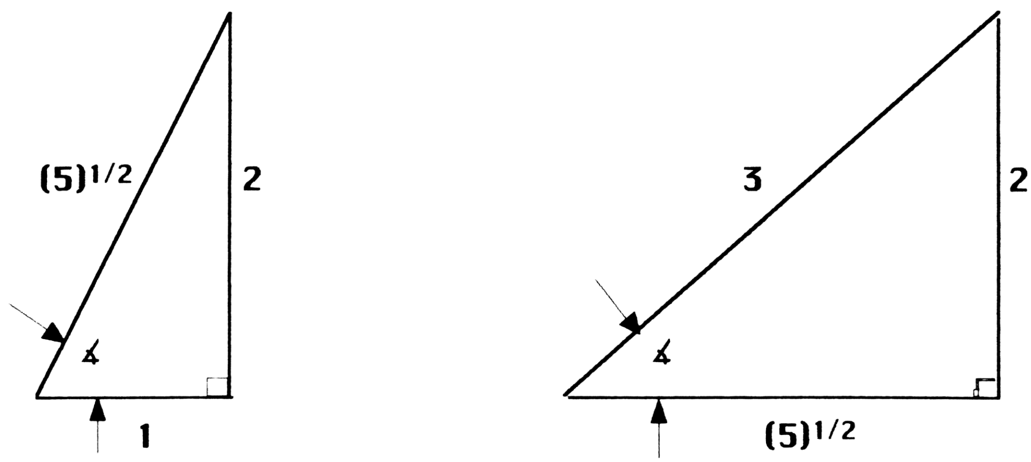
2nd Edition

INTRODUCTION

When the ancients created the various Platonic polyhedra, they could not have envisioned that they were also providing the groundwork for Bucky Fuller patents, defining quasi crystal cookware or configuring the lens orientation within an atomic bomb.

Their vested modesty is appreciated today and will be equally appreciated within the shuffle of time much as with Mozart's and Beethoven's will be, irrespective of the effects of the movies.

BARF's boss once told him that there is no exact expression for the edge of an Icosahedron. For ease of memory, BARF has used the value of arc-sine of the square root of 0.8 and similarly, for the edge of a Dodecahedron: the arc-tangent of the square root of 0.8, as shown below.



Icosahedron edge
63.4349488229 deg.

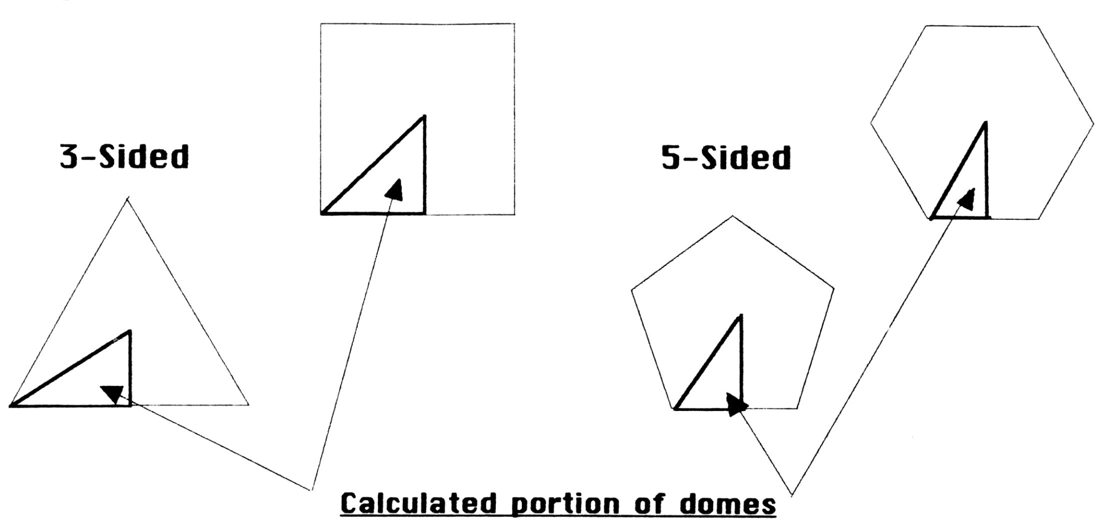
Dodecahedron edge
41.8103148958 deg.

The reader will note that there are six different identities (sine thru cosecant) which may be used to express the central angles of the edges of an Icosahedron and Dodecahedron.

INTRODUCTION

Partial Overview of Manual

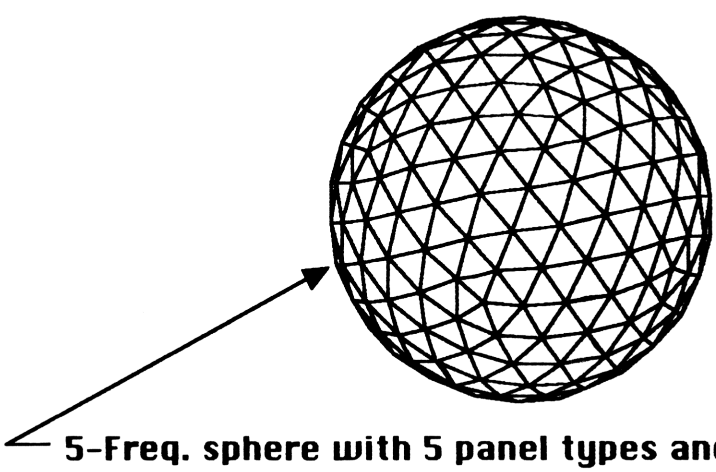
Nesting Domes:



The first four sample geometries do not nest, other than with domes of an identical design. Refer to pages 22 and subs for a fully nesting set of four shapes which have a common edge of 360" or 30'.

Icosa based geometries:

Full sphere: Only one-eighth sphere is required to define all node coordinates if a spherical Icosa is resting on an edge. The symmetry is 180 degree rotational i.e. top to bottom, side to side and end to end. The x-y, y-z and z-x planes are planes of symmetry.

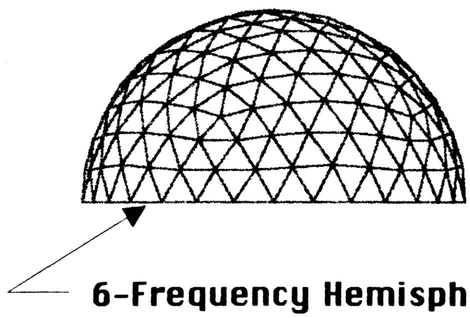


5-Freq. sphere with 5 panel types and 5 strut lengths

Partial Overview of Manual

Icosa based geometries: (Continued)

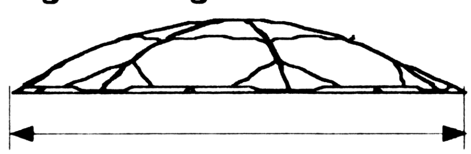
Partial spheres: Orient icosa with point at zenith. A full definition of all node coordinates will require at least one-half dome with side to side symmetry.



6-Frequency Hemisphere
(Sample geometry)

Circular edge domes:

Sample geometry:



408.68' Span w/
Skirt elements to incrementally
extend to 662.20' Span.

Miscellaneous stuff:

Design criteria are presented for architectural approximations. Hopefully, any design changes should be minimal after review by local governing structural engineer. Users are reminded to keep designs within the limits of raw material sizes. This is especially true when factoring unit lengths and coordinates. Where actual exterior finish dimensions are given, BARF has used standard practice from the time of his own experience. This may, or may not, represent current availability. Check, before specifying.

Tool Operation:

To address programs: Key XEQ and make menu selection by keying one of the top row keys. If the desired program does not appear, press either of the ▲ ▼ keys until it does.

Program interruption: Key R/S while output pauses are executing. This is detectable when '((·))' is pulsing and an equal sign '=' is shown. If "Print/On" is in use, the pauses do not normally take place.

Calculator Stack: Hewlett-Packard RPN calculators use a 4-level stack consisting of an x-Register at the bottom and y, z & t registers successively above. When instructed to input up to four different data items, user is to use ENTER after each preceding the last entry and follow the last with either R/S or a 'Letter key' in the top row of keys. This procedure permits up to four data values to be inputted at the same time i.e. Node #, x coordinate, y coordinate and z coordinate.

Disclaimer:

BARF assumes no responsibility for any direct or consequential design, erection or exposure deficiencies. This manual is primarily intended to provide accurate state-of-art geometry data and does not presume to account for user's local building code specifications.

Exclusive of any unknown restraints, BARF permits any desired design usage of material within this manual, without restriction. BARF only wishes that this manual's copyright be respected._

All geometries, in this manual, were calculated with the given software.

Spherical Versions of Regular Polyhedra:

Spherical-	Edge	Surface Angle	Point to face centroid
Tetrahedron	109.471220634°	120°	70.5287793655°
Hexahedron	70.5287793656°	120°	54.7356103173°
Octahedron	90°	90°	54.7356103173°
Dodecahedron	41.8103148958°	120°	37.3773681410°
Icosahedron	63.4349488229°	72°	37.3773681410°

Soccer Ball

Edge Angle: 23.2814462738°	Points:	Spherical Faces:
90 Edges	60	12 Pentagons, 20 Hexagons

Spherical-Pentagon: Surface angle: 111.381279069°
Point to face centroid: 20.0767512748°

Spherical-Hexagon: Surface angle: 124.309360466°
Point to face centroid: 23.8001826025°

Above data calculated with use of SPHR

<u>Design Rationale':</u>

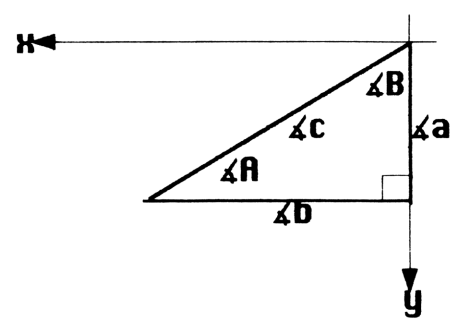
Please refer to TOOL OPERATIONS, GEOM ROUTINE, PAGE 8.

Note that if a <u>generated</u> geometry is rotated back toward the dome center using the same angle as 'G.C.∡', the Great and Minor circle planes will all be vertical. In addition, if 'B1' is equal to 120, 90, 72 or 60 degrees, 3, 4, 5 or 6 sided domes could all have vertical edges which permit lateral nesting. The following samples represent only one each, of possibly infinite, design solutions. Small structures, such as detailed, would make attractive portable kiosks or hospitality huts with aluminum or vinyl tubing frames and fabric covers. Fasteners could be pop-in/out type which bind both the cover and frame.

<u>3-Sided Nesting Domes:</u>

The method of calculation will start by working *backwards.* Refer to TOOL OPERATIONS, SPHR ROUTINE and visualize the spherical right triangle w/ it's 'Angle a' side the y-axis and 'Angle B' at the center. Set 'Angle A' equal to 30 deg. This is determined by: [(180 - <u>120</u>) / 2]. Arbitrarily set 'Angle b' at 20 degrees. The solution is:

∡A = 30 deg., Constant for 3-sided
∡B = 61.9756793262 deg.
∡a = 11.1702294331 deg.
∡b = 20 deg., Arbitrary
∡c = 22.7958772588 deg.

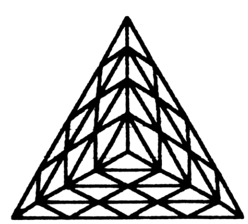


Using GEOM routine: 'G.C.∡' = 11.1702294331 degrees, ∡a
'#Div' = 2, Arbitrary <u>even</u> no., i.e. 2, 4 etc.
'Sides' = 180 / 61.9756793262 (∡B)
= 2.90436509865, varies with ∡b
'Overshoot' = 2, Arbitrary
'Sph. R' = 240 inches, Arbitrary
'Coordinates' = 1 (Yes)
'Inner Level' = 0 (Great Circle)
'Outer Level' = 4 (#Div plus Overshoot)

<u>Note:</u> ∡b, #Div and Overshoot must be held const. for nested shapes.

3-Sided Domes (Continued)

∴ B1 = 120 deg. Q.E.D.
M.C.1. = 5.72510517
a1 = 11.50839337 c.f. = 0.20052188 Length = 48.12525060
b1 = 20 deg. (Not used. Drops out with geometry rotation)
Panel 1 ω = 0.10027629 (Theoretical, final panel shape TBD)
ω x R = 24.06630889 (Ditto, above)
A1 = 30 (Not used. Drops out)
M.C.2. = 11.17022943 (G.C.∡ Ref)
a2 = 11.28748389 c.f. = 0.19668534 Length = 47.20448095
b2 = 19.89922145 c.f. = 0.34556403 Length = 82.93536618
A2 = 28.49099666
C2 = 30.50641180
B2 = 121.00259154
M.C.3. = 16.102111375
a3 = 10.89419027 c.f. = 0.18985320 Length = 45.56476736
b3 = 19.61733628 c.f. = 0.34071715 Length = 81.77211706
A3 = 26.06792180
C3 = 29.98071955
B3 = 123.95135865
M.C.4. = 20.36057488
a4 = 10.40524520 c.f. = 0.18135633 Length = 43.52551907
b4 = 19.20778973 c.f. = 0.33367155 Length = 80.08117085
A4 = 22.85912657
C4 = 28.45869598
B4 = 128.68218745
M.C.5. = 23.85865480 (Not/Applicable)
a5 = 9.89947245 (N/A)
b5 = 18.73878619 c.f. = 0.32559784 Length = 78.14348195
A5 = 19.01037774 (N/A)
C5 = 26.03164649
B5 = 134.95797576



3-Sided Domes (Continued)

Nodes (Excluding unit coordinates and ∡ with zenith)

Node	x	y	z
~~4~~	~~82.084834398~~	~~43.689984410~~	~~221.25384781~~
5	0.000000000	46.493910289	235.453427042
~~6~~	~~119.401434685~~	~~63.551895527~~	~~198.253509351~~
7	41.467683088	69.047004164	226.081716367
8	0.000000000	69.047004164	226.081716367 c/c
~~9~~	~~151.346545561~~	~~80.554809724~~	~~167.943876867~~
10	80.529814864	88.475446130	208.055387698
11	0.000000000	91.226254286	221.985969217
~~12~~	~~176.638006669~~	~~94.016291977~~	~~132.513966972~~
13	115.292270740	103.988302833	183.014002693
14	40.040585426	109.294298982	209.884510454
15	0.000000000	109.294298982	209.884510454 c/c
~~16~~	~~194.860209357~~	~~103.715132905~~	~~94.194851322~~
17	144.630547382	115.311756392	152.922214219
18	76.956306872	122.880914808	191.253778024
19	0.000000000	125.509655938	204.566190428

1) Refer to TOOL OPERATIONS GEOM ,Page 12. The result of rotating node 5 to the dome center is that the first node in each row drops out, therefore: the ~~strike thru~~. Since all diagonals are great circles, the 'B1' angle is carried out to the edge of the generated geometry much like a wedge of a navel orange.
2) 'c/c' denotes center-of-chord, non-spherical surface nodes.
3) Following rotation, nodes will be renumbered, i.e. 5 becomes 1; 7 & 8 become 2 & 3; 10 & 11 become 4 & 5; 13, 14 & 15 become 6, 7 & 8 and 17, 18 & 19 become 9, 10 & 11.

3-Sided Domes (Continued)

Rotated node coordinates:
Using ROTN and x-axis rotation angle of 11.1702294331 degrees.
All coordinates in inches.

Node	x	y	z
1	0.0	0.0	240.0
2	41.46768309	23.94137799	235.17491720
3	0.0	23.94137799	235.17491720 c/c
4	80.52981486	46.49391029	221.25384793
5	0.0	46.49391029	235.45342704
6	115.29227074	66.56402355	199.69207064
7	40.04058543	66.56402355	227.08144417
8	0.0	66.56402355	227.08144417 c/c
9	144.63054738	83.50248546	172.36397444
10	76.95630687	83.50248547	211.43571542
11	0.0	83.50248546	225.00518865

Note: Node #5 is higher than Node #2; the b2 edge is a valley.

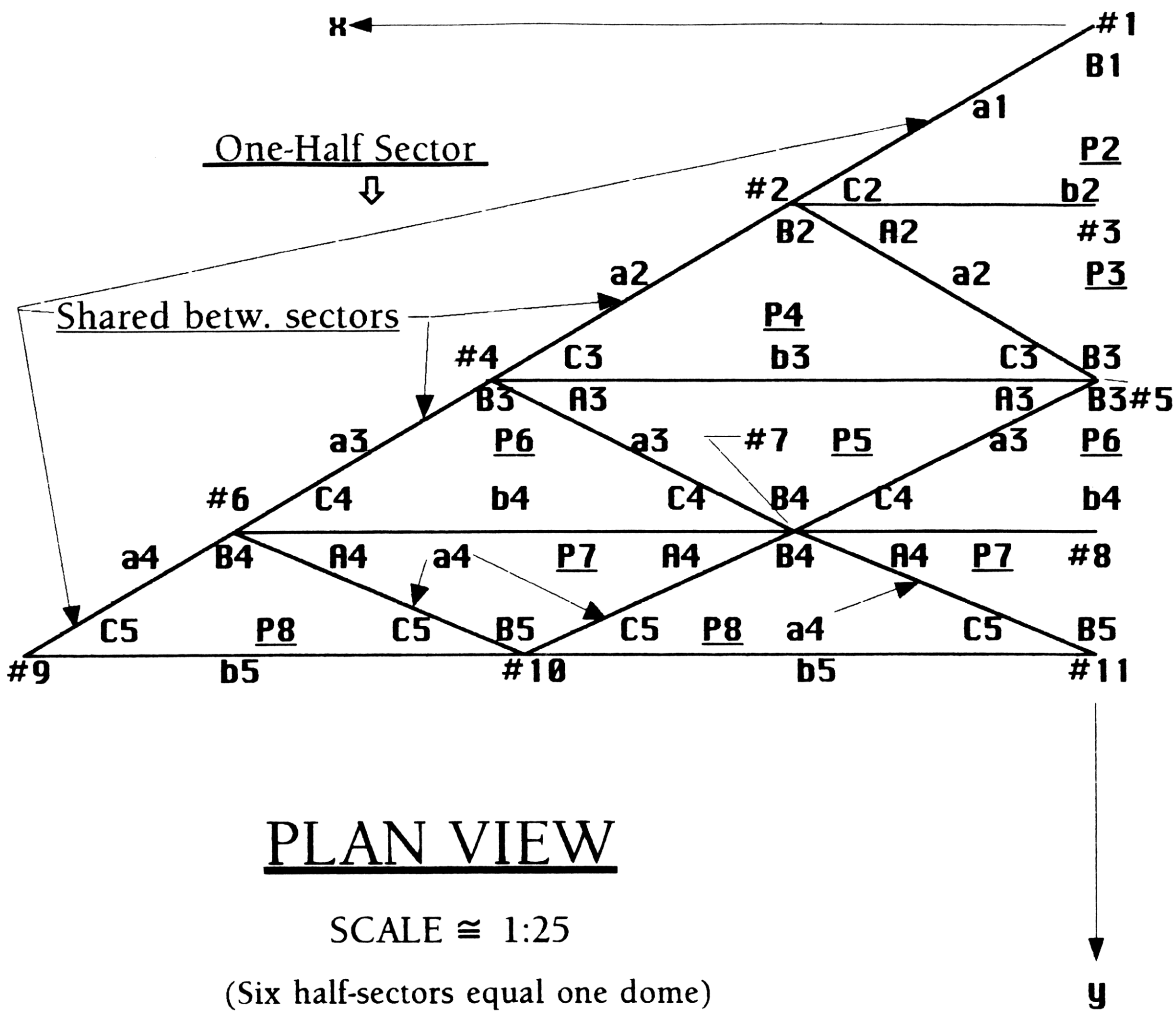
Dome Span, Point to Flat = 20.87562137 feet (20'-10 1/2")
Dome Rise, Node 9 to Zenith = 5.63633546 feet (5'-7 5/8")

Edge Span, Point to Point = 24.10509123 feet (24'-1 1/4")
Edge Rise, Node 9 to Node 11 = 4.38676785 feet (4'-4 5/8")

Dome Center to Point = 13.91708091 feet (13'-11")
Dome Center to Flat = 6.95854046 feet (6'-11 1/2")

All dimensions are to theoretical control points; not necessarily finish dimensions. Tooling documents will control relativity. BARF suggests that control points be at faying surface between struts and skin panels so that theoretical dimensions may be used for fabrication of both. Linear offsets could control hub to strut interface.

3-Sided Domes (Continued)



PLAN VIEW

SCALE ≅ 1:25

(Six half-sectors equal one dome)

LEGEND:

1. ABC denote spherical surface angles.
2. ab denote members.
3. #n denote nodes.
4. Suggested panel couple: (P4 + P5)
   Diamond shape, i.e. Nodes 2→4→7→5→2
   Use NORM to determine crease along 4→5.
5. Panel 1, as determined by a1,a1 & b1, drops out
6. Principal diagonal and y-axis are centerlines of symmetry.

Note: If spherical right triangle side ∡b ,#Div and Overshoot are kept constant for all four shapes, only a variation of spherical radii, to make the edge spans equal, would be required to allow nesting of all four shapes with one another. See pages 22 and subsequent for a fully nesting set which range in span from 25' to 52', each with a common edge of 30'.

Within the first four samples, BARF wished to keep the dome span range around 20'-25' for the purpose of designing either stand-alone structures or nestings of the same size and shape structures. ∡b varied using 20 degrees for the 3 and 4 sided (nestable with radius change), 15 degrees for the 5 sided and 12 deg. for the 6 sided dome.

Although 3, 4, 5 and 6 sided geometries are illustrated, 7 & more sided domes are possible using the same design rationale'. Member intersection angles and raw material considerations would be the only limiting factors. Note that the spans and projected plan areas increase with each increase of the number of edges.

BARF used an even number of edge elements to prevent possible edge ponding which may be encountered with fabric covered domes.

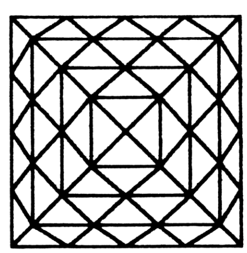
4-Sided Nesting Domes: (Eight half-sectors equal one dome)
Using procedure described in 3-Sided Dome development, set 'Angle A' equal to 45 degrees and set 'Angle b' to an arbitrary 20 deg.
The spherical right triangle solution is:

∡A = 45 deg., Constant for 4-sided
∡B = 48.358856732 deg.
∡a = 18.881721231 deg.
∡b = 20 deg. (Nestable with 3-sided sample with radii control)
∡c = 27.2363134752 deg.

Using GEOM routine: 'G.C.∡' = 18.881721231
'#Div' = Arbitrary 2
'Sides' = 180 / 48.358856732
= 3.72217236229
'Overshoot' = Arbitrary 2
'Sph. R' = Arbitrary 240
'Coordinates' = 1
'Inner Level' = 0
'Outer Level' = 4

4-Sided Domes (Continued)

B1 = 90 deg. Q.E.D.
M.C.1. = 9.85107612
a1 = 14.00194217 c.f. = 0.24377233 Length = 58.50535951
b1 = 20 deg. (Drops Out)
Panel 1 w = 0.17108846 (Panel 1 drops out)
w x R = 41.06122953 (Still useful for estimating material size)
A1 = 30 (Not used)
M.C.2. = 18.88172123
a2 = 13.23437131 c.f. = 0.23047021 Length = 55.31284981
b2 = 19.70215223 c.f. = 0.34217574 Length = 82.12217748
A2 = 42.40808839
C2 = 45.86397054
B2 = 91.72794107
M.C.3. = 26.56505118
a3 = 11.99520701 c.f. = 0.20897373 Length = 50.15369547
b3 = 18.91360201 c.f. = 0.32860787 Length = 78.86588857
A3 = 38.37526406
C3 = 44.90702248
B3 = 96.71771346
M.C.4. = 32.73240721
a4 = 10.64773931 c.f. = 0.18557080 Length = 44.53699313
b4 = 17.87020695 c.f. = 0.31063130 Length = 74.55151285
A4 = 33.25246816
C4 = 42.27001965
B4 = 104.47751219
b5 = 16.79892283 c.f. = 0.29214746 Length = 70.11539007
C5 = 38.24403167
B5 = 114.40449734



4-Sided Domes (Continued)

Nodes (Excluding unit coordinates and angle with zenith)
Users may prefer unit coordinates for proportioning use.

Node	x	y	z	
~~4~~	~~82.084834398~~	~~72.983800750~~	~~213.390357772~~	
5	0.000000000	77.667738509	227.085275601	
~~6~~	~~118.230692918~~	~~105.122041089~~	~~180.473986295~~	
7	41.061088739	114.211573842	207.050002154	
8	0.000000000	114.211573842	207.050002154	c/c
~~9~~	~~145.967601499~~	~~129.783661279~~	~~139.462039916~~	
10	77.667738509	142.544776301	176.773044168	
11	0.000000000	146.976665038	189.731019958	
~~12~~	~~164.441035066~~	~~146.208880438~~	~~95.823323193~~	
13	107.331262920	161.716794143	141.165429522	
14	37.275756426	169.968382675	165.291460378	
15	0.000000000	169.968382675	165.291460378	c/c
~~16~~	~~174.841192717~~	~~155.455936113~~	~~53.516439124~~	
17	129.771888735	172.837815781	104.337655380	
18	69.050179742	184.183031992	137.508848457	
19	0.000000000	188.123184232	149.029082915	

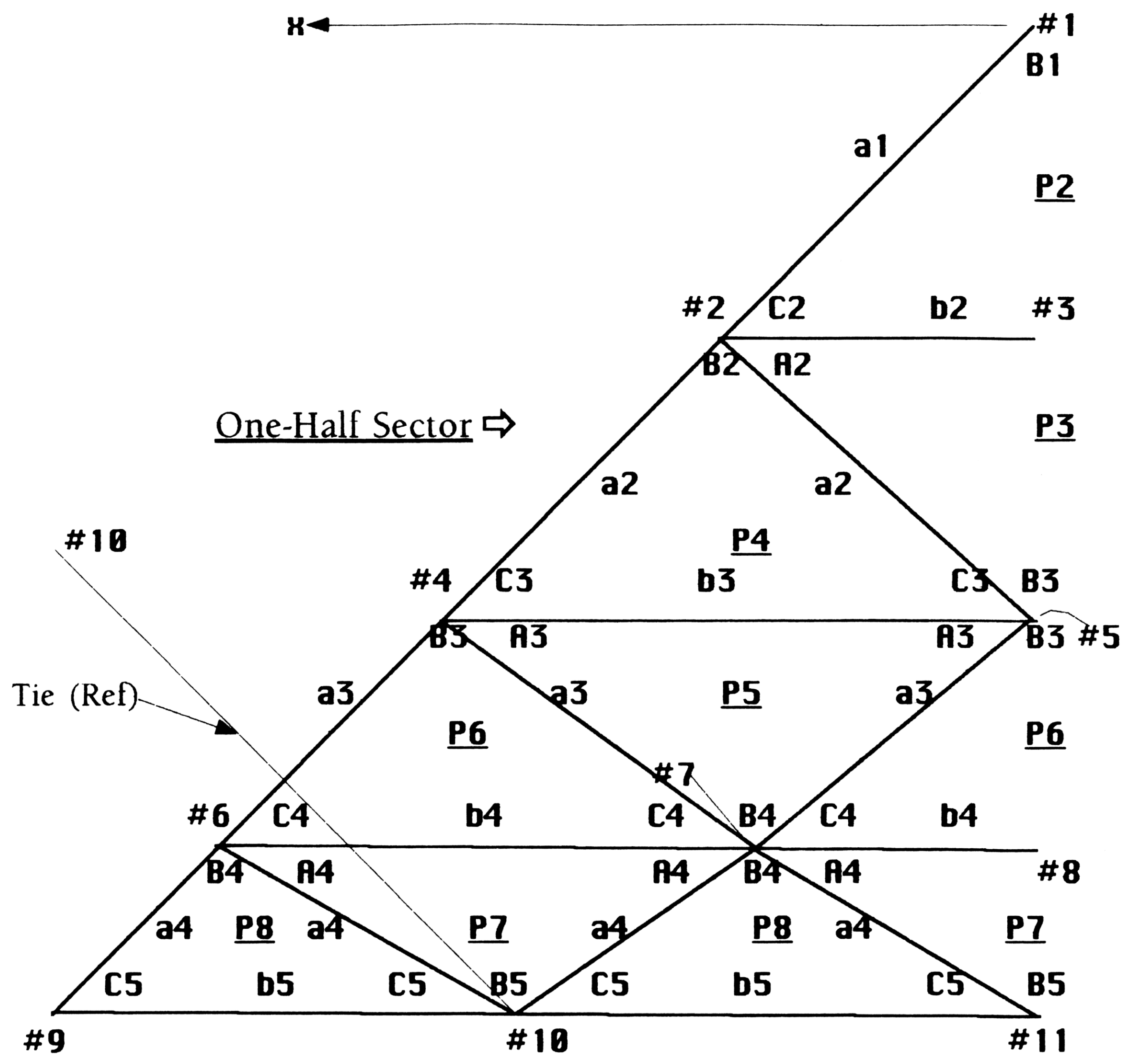
4-Sided Domes (Continued)

Rotated node coordinates:
Using ROTN and x-axis rotation angle of 18.881721231 degrees.
All coordinates in inches.

Node	x	y	z
1	0.0	0.0	240.0
2	41.06108874	41.06108874	232.86900606
3	0.0	41.06108874	232.86900606 c/c
4	77.66773851	77.66773851	213.39035777
5	0.0	77.66773851	227.08527560
6	107.33126292	107.33126292	185.90320062
7	37.27575643	107.33126292	211.40131973
8	0.0	107.33126292	211.40131973 c/c
9	129.77188873	129.77188873	154.65611462
10	69.05017974	129.77188873	189.71380965
11	0.0	129.77188873	201.88921936

Dome Span, Flat to Flat = 21.62864812 feet (21'-7 9/16")
Dome Rise, Node 9 to Zenith = 7.11199045 feet (7'-1 3/8")
Edge Rise, Node 9 to Node 11 = 3.93609206 feet (3'-11 1/4")

4-Sided Domes (Continued)



PLAN VIEW

SCALE 1/2" ≅ 1'-0

LEGEND: (See 3-Sided), except combined pnls may no longer be advised.

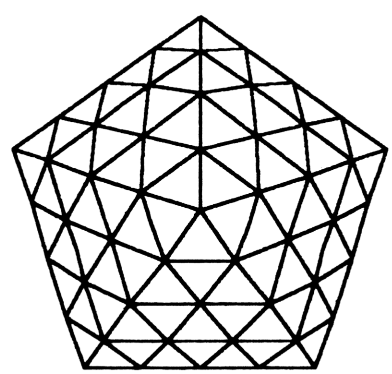
<u>5-Sided Nesting Domes:</u> (Ten half-sectors equal one dome)

Using SPHR set 'Angle A' at 54 degrees and 'Angle b' at 15 degrees
The solution is:
∡A = 54 deg., Constant for 5-sided
∡B = 38.6064340439 deg.
∡a = 19.6076203734 deg.
∡b = 15 deg. (Will not nest with 3, 4 or 6 sided samples)
∡c = 24.5064584438 deg.

Using GEOM , 'G.C.∡' = 19.6076203734
'#Div' = 2 (Must be even integer)
'Sides'= 180 / 38.6064340439
= 4.66243527686
'Overshoot' = 2
'Sph. R' = 240
'Coordinates' = 1
'Inner Level' = 0
'Outer Level' = 4

5-Sided Domes (Continued)

B1 = 72 deg. Q.E.D.
M.C.1. = 10.18476433
a1 = 12.62477883 c.f. = 0.21989848 Length = 52.77563458
Panel 1 w = 0.17696964 (Panel 1 drops out)
w x R = 42.47271362
M.C.2. = 19.60762037
a2 = 11.88167962 c.f. = 0.20700305 Length = 49.68073151
b2 = 14.76231291 c.f. =0.25693889 Length = 61.66533452
A2 = 51.99714094
C2 = 54.66425821
B2 = 73.33860086
M.C.3. = 27.77660868
a3 = 10.66597898 c.f. = 0.18588777 Length = 44.61306514
b3 = 14.12562087 c.f. = 0.24591470 Length = 59.01952686
A3 = 48.86391020
C3 = 53.92322171
B3 = 77.21286809
M.C.4. = 34.53539710
a4 = 9.31443385 c.f. = 0.16238858 Length = 38.97325979
b4 = 13.26329548 c.f. = 0.23097166 Length = 55.43319822
A4 = 44.85771922
C4 = 51.87950114
B4 = 83.26277963
b5 = 12.34525052 c.f. = 0.21504872 Length = 51.61169213
C5 = 48.74591519
B5 = 91.04497563



5-Sided Domes (Continued)

Nodes (Excluding unit coordinates and angle with zenith)

Node	x	y	z
~~4~~	~~62.116570825~~	~~77.794165618~~	~~218.379484899~~
5	0.0	80.538446639	226.083079006
~~6~~	~~90.396806463~~	~~113.212046961~~	~~191.341186899~~
7	30.832667261	118.567908361	206.375865198
8	0.0	118.567908361	206.375865198 c/c
~~9~~	~~113.041539503~~	~~141.572081798~~	~~157.413328540~~
10	58.514606623	149.151352026	178.689437295
11	0.0	151.736499954	185.946321775
~~12~~	~~129.267514768~~	~~161.893329258~~	~~121.162946347~~
13	81.260956900	171.194378584	147.272338289
14	27.716599108	176.008955994	160.787554070
15	0.0	176.008955994	160.787554070 c/c
~~16~~	~~139.799441290~~	~~175.083407609~~	~~86.034391932~~
17	98.853132942	185.626966621	115.631688436
18	51.170146947	192.254924898	134.237326828
19	0.0	194.515598037	140.583363598

5-Sided Domes (Continued)

Rotated node coordinates
Using ROTN and x-axis rotation angle of 19.6076203734 degrees
All coordinates in inches

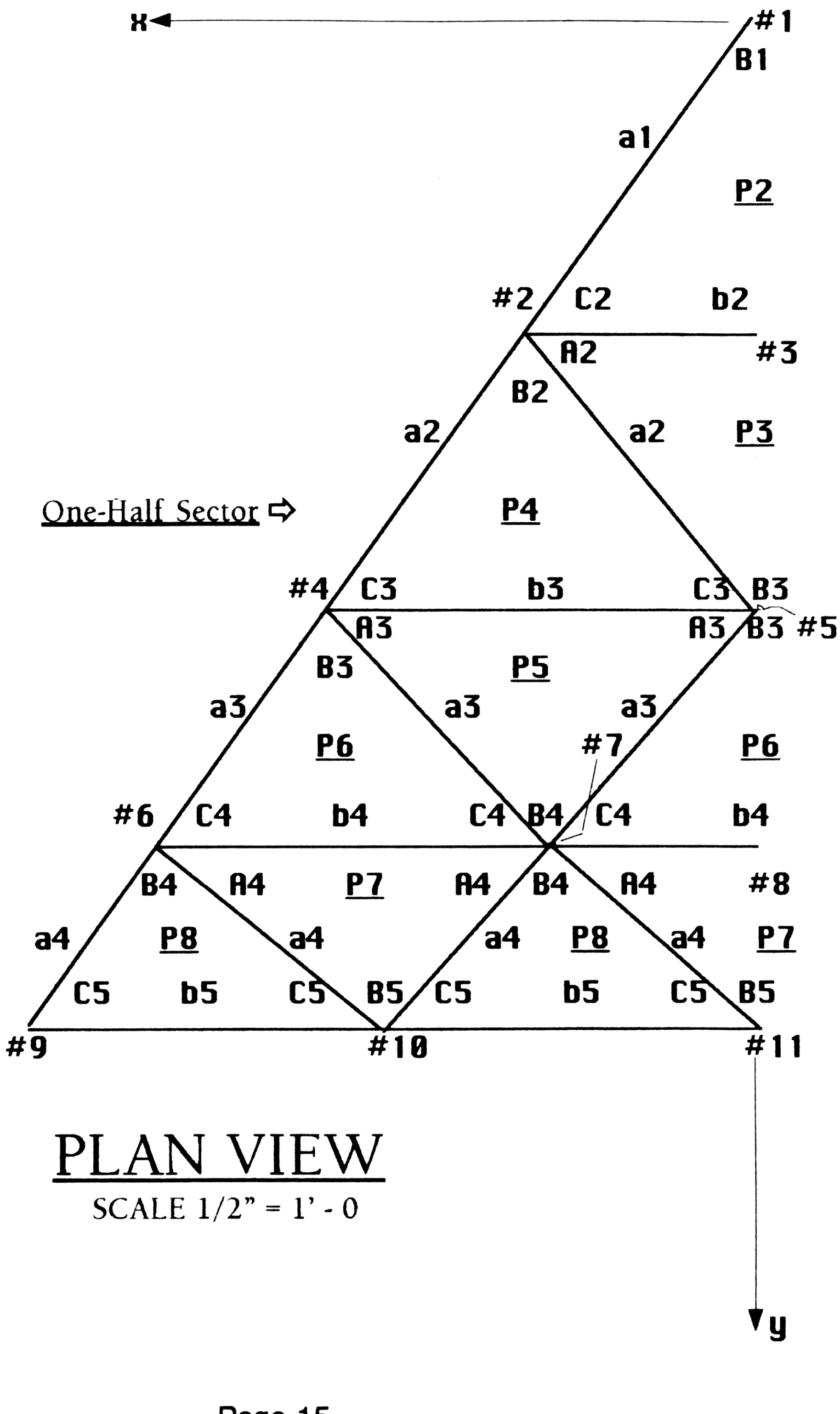
Node	x	y	z
1	0.0	0.0	240.0
2	30.83266726	42.43752578	234.19735915
3	0.0	42.43752578	234.19735915 c/c
4	58.51460662	80.53844664	218.37948490
5	0.0	80.53844664	226.08307901
6	81.26095690	111.84611192	196.18130424
7	27.71659911	111.84611192	210.52847167
8	0.0	111.84611192	210.52847167 c/c
9	98.85313294	136.05966496	171.21864874
10	51.17014695	136.05966496	190.96958824
11	0.0	136.05966496	197.70626588

Dome Span, Point to Flat = 25.35322165 feet (25'-4 1/4")
Dome Rise, Node 9 to Zenith = 5.73177927 feet (5'-8 13/16")

Edge Span, Point to Point = 16.47552216 feet (16'-5 11/16")
Edge Rise, Node 9 to Node 11 = 2.20730143 feet (2'-2 1/2")

Dome Center to Point = 14.01491624 feet (14'-0 3/16")
Dome Center to Flat = 11.33830541 feet (11'-4 1/16")

5-Sided Domes (Continued)



PLAN VIEW

SCALE 1/2" = 1' - 0

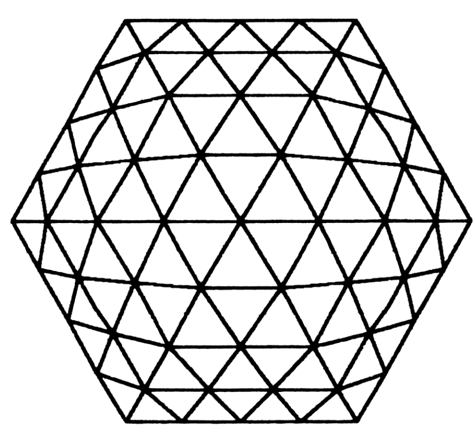
6-Sided Nesting Domes: **(Twelve half-sectors equal one dome)**

Using SPHR ,set 'Angle A' at 60 degrees and 'Angle b" at 12 deg.
The solution is:
∡A = 60 deg., Constant for 6-sided
∡B = 32.1022911705 deg.
∡a = 19.8046387939 deg.
∡b = 12 deg. (Will not nest with 3, 4 or 5 sided samples)
∡c = 23.0309816653 deg.

Using GEOM , 'G.C.∡' = 19.8046387939
'#Div' = 2
'Sides' = 180 / 32.1022911705
= 5.60707642467
'Overshoot' = 2
'Sph. R' = 240
'Coordinates' = 1
'Inner Level' = 0
'Outer Level' = 4

6-Sided Domes (Continued)

B1 = 59.999999999 deg. (Q.E.D.?)
M.C.1. = 10.26215842
a1 = 11.87121862 c.f. = 0.20682145 Length = 49.63714771
Panel 1 w = 0.17846263 (Panel 1 drops out)
w x A = 42.83103237
M.C.2. = 19.80463879
a2 = 11.15976305 c.f. = 0.19446687 Length = 46.67204923
b2 = 11.80734711 c.f. = 0.20571263 Length = 49.37103003
A2 = 58.38803133
C2 = 60.53345800
B2 = 61.07851067
M.C.3. = 28.15716535
a3 = 9.98641643 c.f. = 0.17407531 Length = 41.77807401
b3 = 11.28786219 c.f. = 0.19669191 Length = 47.20605786
A3 = 55.85822231
C3 = 59.93719535
B3 = 64.20458234
M.C.4. = 35.16425641
a4 = 8.66630394 c.f. = 0.15111139 Length = 36.26673435
b4 = 10.57555768 c.f. = 0.18431640 Length = 44.23593492
A4 = 52.61133967
C4 = 58.29017806
B4 = 69.09848226
b5 = 9.80408862 c.f. = 0.17090495 Length = 41.01718688
C5 = 55.75744076
B5 = 75.41310839



6-Sided Domes (Continued)

Nodes (Excluding unit coordinates and angles with zenith)

Node	x	y	z	
~~4~~	~~49.898805796~~	~~79.538446574~~	~~220.870425129~~	
5	0.0	81.315382785	225.804801815	
~~6~~	~~72.977669586~~	~~116.326039889~~	~~196.831176864~~	
7	24.685515015	119.803903666	206.488861720	
8	0.0	119.803903666	206.488861720	c/c
~~9~~	~~91.843087080~~	~~146.397420907~~	~~166.531205806~~	
10	46.947458140	151.339862748	180.255879565	
11	0.0	153.011699118	184.898404354	
~~12~~	~~105.798778484~~	~~168.642723123~~	~~134.038242338~~	
13	65.387241071	174.738793602	150.966429101	
14	22.117967461	177.854923763	159.619615363	
15	0.0	177.854923763	159.619615363	c/c
~~16~~	~~115.324079127~~	~~183.826004652~~	~~102.510276494~~	
17	79.802153298	190.774605177	121.805855148	
18	40.792490437	195.069076476	133.731178589	
19	0.0	196.521729545	137.765052958	

6-Sided Domes (Continued)

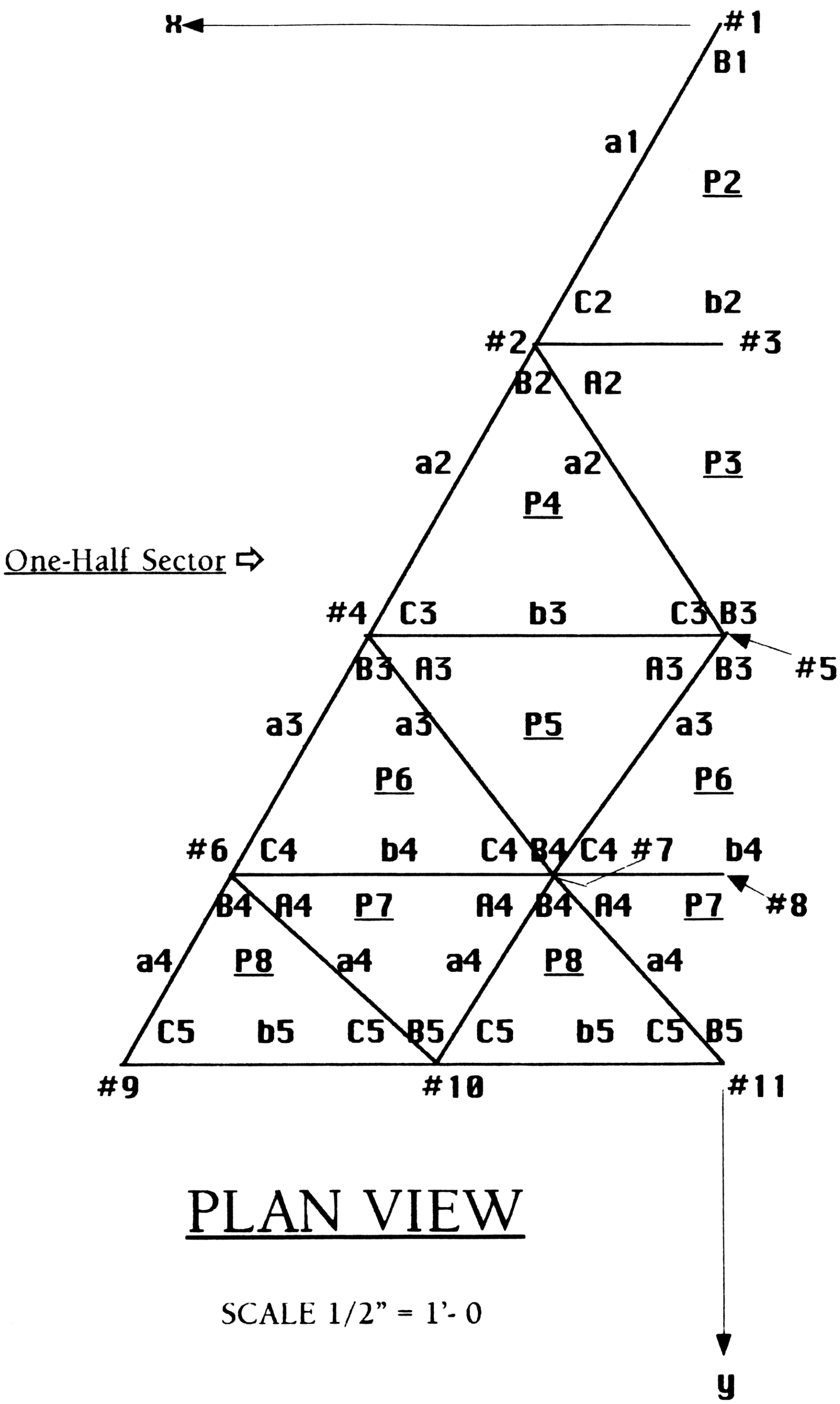
Rotated node coordinates
Using ROTN and x-axis rotation angle of 19.8046387939 degrees.
All coordinates in inches

Node	x	y	z
1	0.0	0.0	240.0
2	24.68551502	42.75656622	234.86698660
3	0.0	42.75656622	234.86698660 c/c
4	46.94745814	81.31538278	220.87042513
5	0.0	81.31538278	225.80480181
6	65.38724107	113.25402370	201.24123539
7	22.11796746	113.25402370	210.43840341
8	0.0	113.25402370	210.43840341 c/c
9	79.80215330	138.22138407	179.23857095
10	40.79249044	138.22138407	191.91357873
11	0.0	138.22138407	196.20104226

Dome Span, Flat to Flat = 23.03689734 feet (23'-0 7/16")
Dome Span, Point to Point = 26.60071777 feet (26'-7 3/16")
Dome Rise, Node 9 to Zenith = 5.06345242 feet (5'-0 3/4")

Edge Span, Point to Point = 13.30035888 feet (13'-3 5/8")
Edge Rise, Node 9 to Node 11 = 1.41353928 feet (1'-4 15/16")

6-Sided Domes (Continued)



PLAN VIEW

SCALE 1/2" = 1'- 0

Parts List:

Sides:	Three	Four	Five	Six
Panels:				
P1	0	0	0	0
P2	3	4	5	6
P3	3	4	5	6
P4	6	8	10	12
P5	6	8	10	12
P6	9	12	15	18
P7	9	12	15	18
P8	12	16	20	24
Struts:				
a1	3	4	5	6
a2	9	12	15	18
a3	15	20	25	30
a4	21	28	35	42
b1	0	0	0	0
b2	3	4	5	6
b3	6	8	10	12
b4	9	12	15	18
b5	12	16	20	24
Hubs (@Nodes)				
'A'(#1)	1	1	1	1
'B'(#2)	3	4	5	6
'C'(#4)	3	4	5	6
'D'(#5)	3	4	5	6
'E'(#6)	3	4	5	6
'F'(#7)	6	8	10	12
Piers (@Nodes)				
'G'(#9)	3	4	5	6
'H'(#10#11)	9	12	15	18

1) Pier 'G' mounted on pedestal(s).
2) Internal ties between Node 10 & Node 10 may be required to contain outer edge thrust (Symm. with Pier 'G').

The following describes a set of triangular, square, pentagonal and hexagonal shapes which fully nest. Angle 'b' within the spherical right triangle is uniformally 15 degrees. The number of divisions and the overshoot are all two (2). The spherical radii are all adjusted to give an common edge width of 30 feet (360 inches).

Three sided dome:

B1 = 120 degrees Sph. R. = 374.699879899 in.
M.C.1 = 4.30962584
a1 = 8.64387836 c.f. = 0.15072111 Length = 56.47518140
b1 = 15.0 c.f. = 0.26105238 Length = 97.81629709
Pnl 1 w = 0.07536422 w x R = 28.23896456
A1 = 30.0
M.C.2 = 8.49878070
a2 = 8.54824537 c.f. = 0.14905669 Length = 55.85152471
b2 = 14.95734498 c.f. = 0.26031426 Length = 97.53972375
A2 = 29.15057985
C2 = 30.28421919
B2 = 120.56520096
M.C.3 = 12.45891019
a3 = 8.36932210 c.f. = 0.14594240 Length = 54.68459848
b3 = 14.83435356 c.f. = 0.25818577 Length = 96.74217718
A3 = 27.76444745
C3 = 29.99374058
B3 = 122.24181197
M.C.4 = 16.10211375
a4 = 8.12862169 c.f. = 0.14175226 Length = 53.11455581
b4 = 14.64480509 c.f. = 0.25490486 Length = 95.51281879
A4 = 2588543455
C4 = 29.13926160
B4 = 124.97530385
b5 = 14.40834803 c.f. = 0.25081102 Length = 93.97885840
C5 = 27.75006578
B5 = 128.68218746

Rotated unit coordinates for three sided dome:

Node	x	y	z
1	0.0	0.0	1.0
2	0.51462555	0.75146256	0.98864157
3	0.0	0.75146256	0.98864157
4	0.25597696	0.14778836	0.95531900
5	0.0	0.14778836	0.98901901
6	0.37367161	0.21573941	0.90212307
7	0.12745243	0.21573940	0.96809730
8	0.0	0.21573940	0.96809730
9	0.48038446	0.27735010	0.83205029
10	0.24866530	0.27735010	0.92803152
11	0.0	0.27735010	0.96076892

Rotated unit coordinates x spherical radius for three sided dome:

Node	x	y	z
1	0.0	0.0	374.69987990
2	48.76986188	28.15729288	370.44387892
3	0.0	28.15729288	370.44387892
4	95.91453445	55.37628228	357.95791574
5	0.0	55.37628228	370.58530375
6	140.01470781	80.83752924	338.02540653
7	47.75640940	80.83752924	362.74594308
8	0.0	80.83752924	362.74594308
9	180.0	103.92304845	311.76914536
10	93.17485624	103.92304845	347.73329746
11	0.0	103.92304845	360.0

Edge span = 30' (360") Edge rise = 4'-0 1/4" (48.2309")
Dome rise = 5'-2 15/16" (62.9307") Span = 25'-11 3/4" (311.7691")
Dome proj. area = 389.7 sq.ft. (All dimensions are theoretical.)

Four sided dome:

B1 = 90.0 degrees   Sph. R. = 402.492235954 in.
M.C.1 = 7.43655768
a1 = 10.54683890   c.f. = 0.18381729   Length = 73.98503028
b1 = 15.0   c.f. = 0.26105238   Length = 105.07155791
Pnl 1 ω = 0.12942839   ω x R = 52.09392129
A1 = 45.0
M.C.2 = 14.51081870
a2 = 10.20673208   c.f. = 0.17790563   Length = 71.60563292
b2 = 14.87311536   c.f. = 0.25885662   Length = 104.18777816
A2 = 43.53569940
C2 = 45.48810020
B2 = 90.97620040
M.C.3 = 20.94102047
a3 = 9.60762242   c.f. = 0.16748826   Length = 67.41272268
b3 = 14.51888492   c.f. = 0.25272490   Length = 101.71981156
A3 = 41.19017380
C3 = 44.96886049
B3 = 93.84096572
M.C.4 = 26.56505118
a4 = 8.87032708   c.f. = 0.15466185   Length = 62.25019334
b4 = 14.00409178   c.f. = 0.24380957   Length = 98.13145870
A4 = 38.09549153
C4 = 43.48345035
B4 = 98.42105812
b5 = 13.40870408   c.f. = 0.23349235   Length = 93.97885840
C5 = 41.13074546
B5 = 104.47751219

Rotated unit coordinates for four sided dome:

Node	x	y	z
1	0.0	0.0	1.0
2	0.12942831	0.12942831	0.98310560
3	0.0	0.12942831	0.98310560
4	0.25056281	0.25056281	0.93511313
5	0.0	0.25056281	0.96810035
6	0.35740674	0.35740674	0.86285621
7	0.12190478	0.35740674	0.92595877
8	0.0	0.35740674	0.92595877
9	0.44721360	0.44721360	0.77459667
10	0.23149479	0.44721360	0.86395032
11	0.0	0.44721360	0.89442719

Rotated unit coordinates x spherical radius for four sided dome.

Node	x	y	z
1	0.0	0.0	402.49223595
2	52.09388908	52.09388908	395.69237223
3	0.0	52.09388908	395.69237223
4	100.84958447	100.84958447	376.37577317
5	0.0	100.84958447	389.65287284
6	143.85343968	143.85343968	347.29292505
7	49.06572935	143.85343968	372.69121549
8	0.0	143.85343968	372.69121549
9	180.0	180.0	311.76914537
10	93.17485624	180.0	347.73329747
11	0.0	180.0	360.0

Edge span and rise same as for three sided dome.
Dome rise = 7'-6 23/32" (90.7231") Span = 30'-0" (360.0")
Dome projected area = 900 sq.ft.

Five sided dome:

B1 = 72.0 degrees   Sph. R. = 437.011945968 in.
M.C.1 = 10.18476433
a1 = 12.62477883   c.f. = 0.21989848   Length = 96.09826153
b1 = 15.0   c.f. = 0.26105238   Length = 114.08301053
Pnl 1 w = 0.17696964   w x R = 77.33784680
A1 = 54.0
M.C.2 = 19.60762037
a2 = 11.88167962   c.f. = 0.20700305   Length = 90.46280481
b2 = 14.76231291   c.f. = 0.25693889   Length = 112.28536599
A2 = 51.99714094
C2 = 54.66425821
B2 = 73.33860086
M.C.3 = 27.77660868
a3 = 10.66597898   c.f. = 0.18588777   Length = 81.23517671
b3 = 14.12562087   c.f. = 0.24591470   Length = 107.46765951
A3 = 48.86391020
C3 = 53.92322171
B3 = 77.21286809
M.C.4 = 34.53539710
a4 = 9.31443385   c.f. = 0.16238858   Length = 70.96575042
b4 = 13.26329548   c.f. = 0.23097166   Length = 100.93737427
A4 = 44.85771922
C4 = 51.87950114
B4 = 83.26277963
b5 = 12.34525052   c.f. = 0.21504872   Length = 93.97885838
C5 = 48.74591519
B5 = 91.04497563

Rotated unit coordinates for five sided dome:

Node	x	y	z
1	0.0	0.0	1.0
2	0.12846945	0.17682302	0.97582233
3	0.0	0.17682302	0.97582233
4	0.24381086	0.33557686	0.90991452
5	0.0	0.33557686	0.94201283
6	0.33858732	0.46602547	0.81742210
7	0.11548583	0.46602547	0.87720197
8	0.0	0.46602547	0.87720197
9	0.41188805	0.56691527	0.71341104
10	0.21320895	0.56691527	0.79570662
11	0.0	0.56691527	0.82377611

Rotated unit coordinates x spherical radius for five sided dome.

Node	x	y	z
1	0.0	0.0	437.01194597
2	56.14268300	77.27377384	426.44601527
3	0.0	77.27377384	426.44601527
4	106.54825878	146.65109705	397.64351523
5	0.0	146.65109705	411.67085961
6	147.96670378	203.65869591	357.22322303
7	50.46868713	203.65869591	383.34773786
8	0.0	203.65869591	383.34773786
9	180.0	247.74874564	311.76914530
10	93.17485622	247.74874564	347.73329740
11	0.0	247.74874564	360.0

Edge span and rise same as for three sided dome.
Dome rise = 10'-5 1/4" (125.2428")   Span = 46'-2" (553.9824")
Dome projected area = 1,548.4 sq.ft.

Six sided dome:

B1 = 60.0 degrees   Sph. R. = 476.235235982 in.
M.C.1 = 12.73915839
a1 = 14.75144492   c.f. = 0.25675078   Length = 122.27376935
b1 = 15.0   c.f. = 0.26105238   Length = 124.32234391
Pnl 1 w = 0.22109699   w x R = 105.29417539
A1 = 60.0
M.C.2 = 24.14610845
a2 = 13.43534052   c.f. = 0.23395406   Length = 111.41716653
b2 = 14.62871600   c.f. = 0.25462634   Length = 121.26203303
A2 = 57.49869881
C2 = 60.82448035
B2 = 61.67682084
M.C.3 = 33.53749799
a3 = 11.45248681   c.f. = 0.19955102   Length = 95.03322556
b3 = 13.68100173   c.f. = 0.23821168   Length = 113.44479525
A3 = 53.69140477
C3 = 59.85671082
B3 = 66.45188441
M.C.4 = 40.89339465
a4 = 9.46733311   c.f. = 0.16504822   Length = 78.60177882
b4 = 12.49191843   c.f. = 0.21759354   Length = 103.62570972
A4 = 48.97982960
C4 = 57.30007664
B4 = 73.72009375
b5 = 11.32500700   c.f. = 0.19733705   Length = 93.97885840
C5 = 53.51634436
B5 = 82.81924422

Rotated unit coordinates for six sided dome:

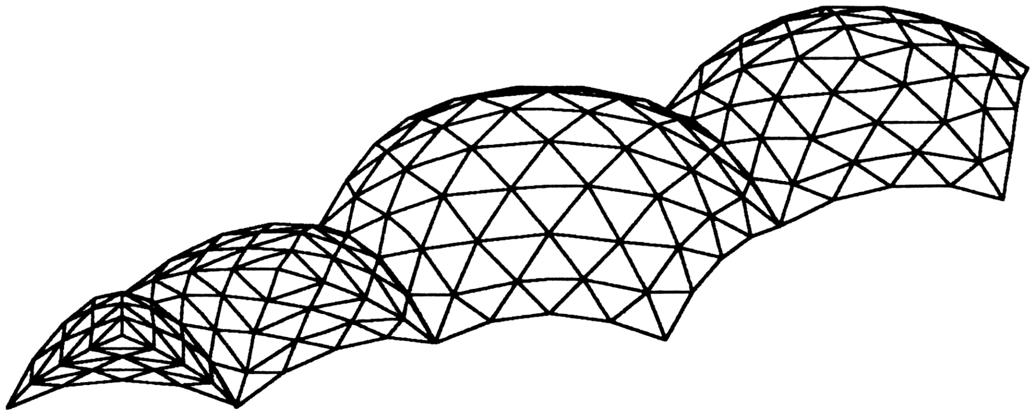
Node	x	y	z
1	0.0	0.0	1.0
2	0.12731317	0.22051288	0.96703952
3	0.0	0.22051288	0.96703952
4	0.23617374	0.40906493	0.88141242
5	0.0	0.40906493	0.91250528
6	0.31897599	0.55248262	0.77007615
7	0.10879677	0.55248261	0.82639350
8	0.0	0.55248261	0.82639350
9	0.37796447	0.65465367	0.65465367
10	0.19564881	0.65465367	0.73017129
11	0.0	0.65465367	0.75592895

Rotated unit coordinates x spherical radius for six sided dome:

Node	x	y	z
1	0.0	0.0	476.23523598
2	60.63101651	105.01600111	460.53829302
3	0.0	105.01600111	460.53829302
4	112.47425930	194.81113165	419.75965024
5	0.0	194.81113165	434.56716739
6	151.90760414	263.11168843	366.73739815
7	51.81285486	263.11168843	393.55770539
8	0.0	263.11168843	393.55770539
9	180.0	311.76914536	311.76914536
10	93.17485624	311.76914536	347.73329746
11	0.0	311.76914536	360.0

Edge span and rise same as for three sided dome.
Dome rise = 13'-8 15/32" (164.4661")
Span = 51'-11 17/32" (623.5380") Flats; 60.0' (720.0") Points
Dome projected area = 2,338.3 sq.ft.

NESTING DOMES Patent Pending



Inline nesting of triangular, square, hexagonal and pentagonal domes.

<u>Miscellaneous notes pertaining to nesting series:</u>

1) If the reader wishes to make the nesting edge different from 30' the Triangular/Square/Pentagonal/Hexagonal Dome Sph.R. = Desired half-edge-span divided by the Node #9 x-axis unit coordinate. Use desired units, i.e. inches. Multiply the 'Unit coordinates' by the new spherical radii of each shape. All radii will vary independently due to the fact that all Node #9 x-axis unit coordinates are different.

Remember to revise strut lengths by the same proportion.

The key factor is the Spherical Right Triangle tangential angle, i.e. 15 degrees, being equal for all shapes and the edge arch being divided by the same number of elements, i.e. 4, which results in the same edge arch included angle of 60 degrees. Any angle, within reason, is acceptable as long as all geometries match.

The theory could apply to large domes as well, with the sub-division frequency being much larger. The overshoot may exceed the given limits.

2) Within the given examples: The maximum panel width = 105.3".
The maximum strut length = 124.3223"
The minimum strut length = 53.1146"
The minimum surface angle = 27.75 deg

3) Refer to views in first part of this section for geometry legend. The scales would no longer be applicable.

Design Variations:

As long as the edge arch element angles are held constant, adjacent domes may be inclined relative to one another. The spherical origin elevation and edge plane normal linearity would be common to both.

In addition, one, two, three, four, five, six or more element arches may mate with one another, with or without mutual plane bases.

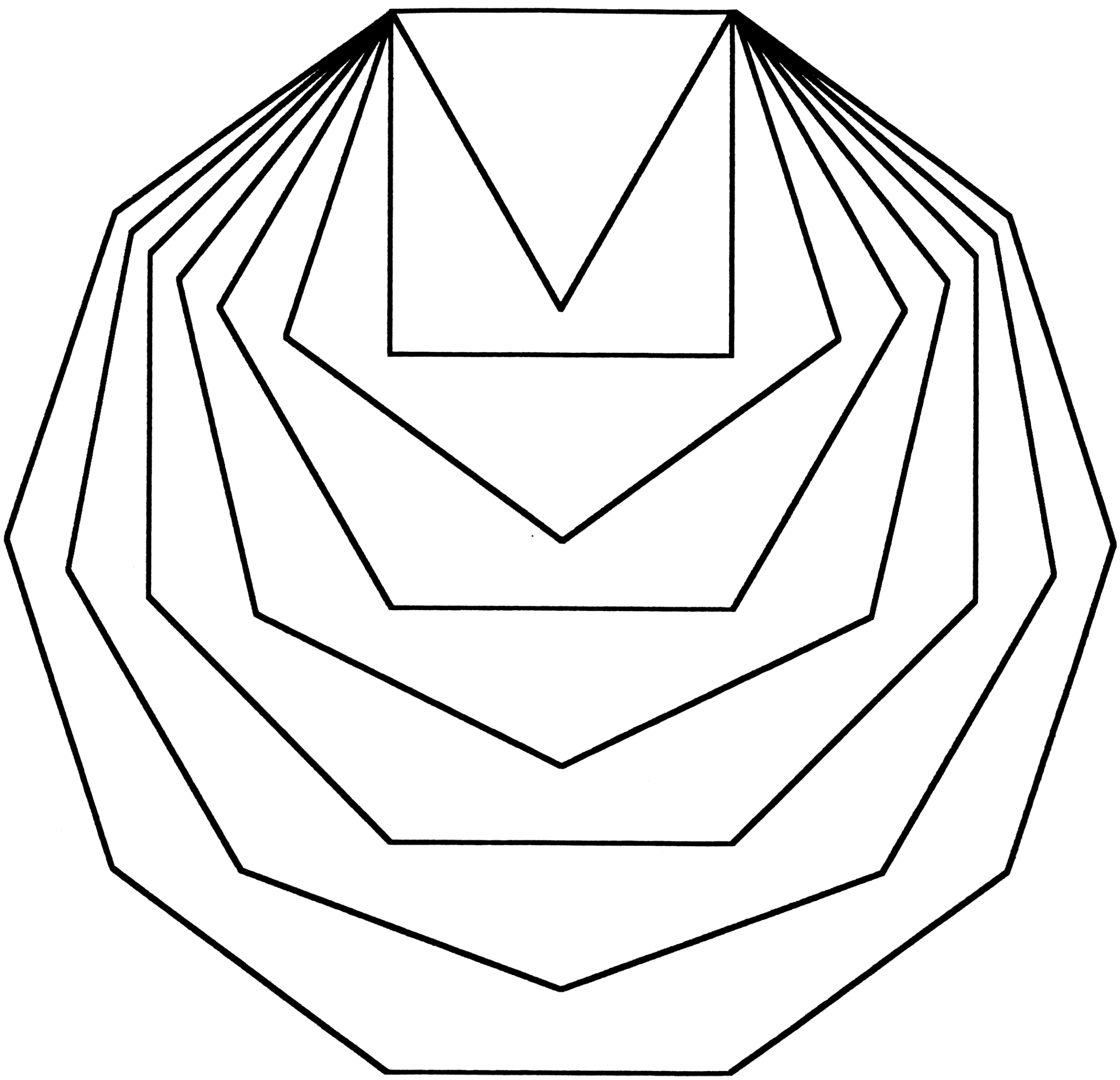
Therefore, a gerrymandered dome complex may vary within any limit of imagination of the architect or engineer. This makes this building system suitable for erection on constant or variable elevation lines in rolling building sites, i.e. coastlines, golf courses, etc.

The author suggests diligent use of CAD software to maintain fit and function when designing complex clusters.

Because of possible complexity of strut joints of multiple dome faying surfaces, the author suggests use of dome edge offsets rather than common edges. Although common edges would have the advantage of diamond, v-shaped, edge panels there would be no provisions for water drainage at the lowest node. Offsets could have benefit of integral rain gutters with low node drain pipe column supports. Note that each shape has its own edge flashing slope. In the given matched set, use "M.C.4" as the relative slope angle. When joining different shapes, the flashing slope planes will not converge at the center of the gutter. Opposite sides of the gutter would not have the same rise for this type of joint, because of the offset between the theoretical node reference point and the vertical side of the gutter. Symmetrical gutters would exist only at faying edges of same shape domes. BARF suggests a nominal offset of strut width plus pipe column I.D., rounded off to the next lower unit of measure. Assume that ponding may occur at the top of the pipe and seal accordingly. For inline clusters, where no internal low nodes exist, the edges could be common with a single edge arch between. The edge panels could be diamond shaped with valleys at edge.

NESTING DOMES Patent Pending

Relative sizes: 3 thru 10 sided nesting domes.



<u>5-Frequency Geometry:</u> This may be the most efficient five-frequency geometry in existence. It utilizes only five member lengths and five panel types.

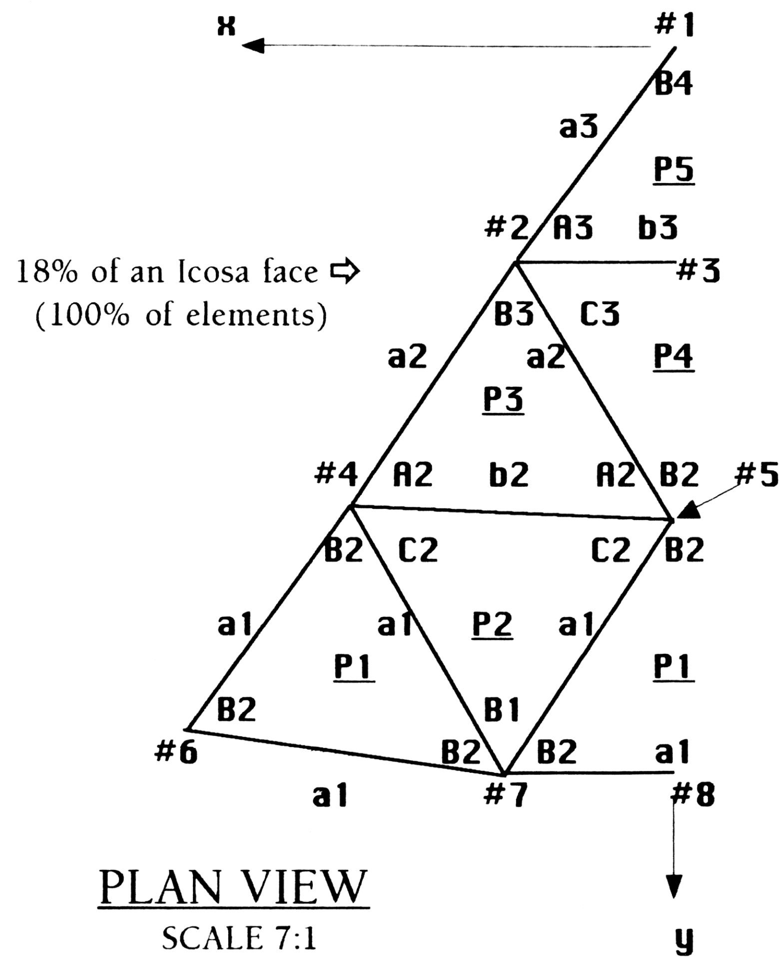
Using **GEOM** , Set 'G.C.∡' = 33.1784876335 deg.
'#Div' = 3
'Sides' = 5
'Overshoot' = 0
'Sph.R' = 1 (Due to the number of subsequent node rotations)
'Coordinates' = 1
'Inner Level' = -3
'Outer Level' = 0 (No fold over)

<u>The Solution:</u>

B1 = 58.938783181
M.C.1. = 12.55201898
a1 = 14.45516845 c.f. = 0.25162172 Length = c.f. (Sph.R=1)
b1 = 14.45516845 c.f. = 0.25162172 (b1 = a1)
Panel 1 ω = 0.21791080
ω x R = 0.21791080
A1 = 60.53060841
M.C.2. = 23.83375894
a2 = 13.19906773 c.f. = 0.22985814
b2 = 14.10789880 c.f. = 0.24560773
A2 = 58.15596926
C2 = 61.31342233
B2 = 60.53060841 (B2 = A1)
M.C.3. = 33.17848763
a3 = 11.29082246 c.f. = 0.19674332
b3 = 13.21670099 c.f. = 0.23016385
A3 = 54.53084810
C3 = 60.39800366
B3 = 65.07114824
M.C.4.,a4,b4,A4 and C4 (N/A)
B4 = 72

5-Frequency Sub-division (Continued)

Node	x	y	z
1	0.0	0.0	1.0
2	0.115081927	0.158396684	0.980646032
3	0.0	0.158396684	0.980646032 c/c
4	0.243656192	0.335363978	0.910034429
5	0.0	0.352274038	0.935896897
6	0.369467051	0.508527769	0.777749054
7	0.125810858	0.542900706	0.830319487
8	0.0	0.542900706	0.830319487 c/c



PLAN VIEW

SCALE 7:1

5-Frequency Sub-division (Continued)

The P1 panels are equilateral with all sides equaling a1 and all angles equaling B2. Panel P4 is within 0.133% of being equilateral.

The next step is to rotate the initially generated geometry to complete half of the Icosa face. Rotate:

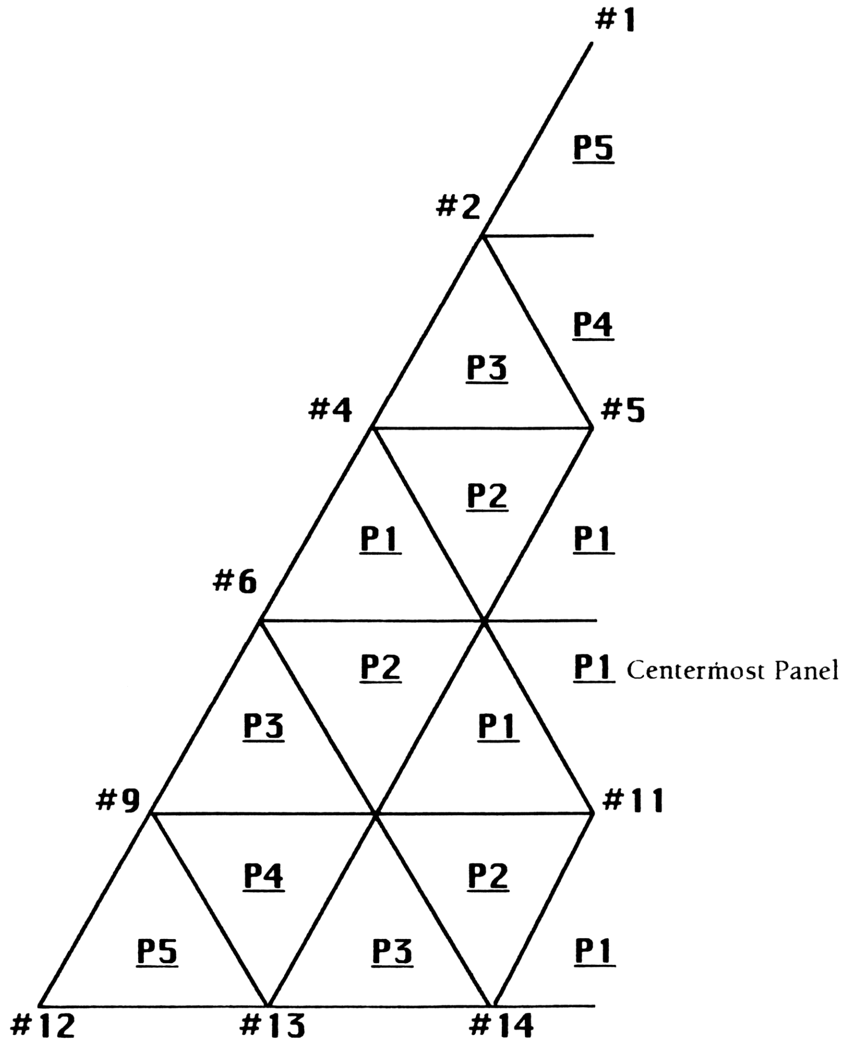
Node (-2) to become Node 9; Node 5 to become Node 10; Node 7 to become Node 11; Node 1 to become Node 12; Node 2 to become Node 13 and Node 4 to become Node 14.

Using ROTN , Rotate 37.377368141 deg. about x-axis;
Rotate 120 deg. about z-axis;
and Rotate -37.377368141 deg. about x-axis.

Node	x	y	z
9	0.464089926	0.638764985	0.613677305
10	0.249598308	0.695816637	0.673453705
11	0.0	0.716064497	0.698034122
12	0.525731112	0.723606798	0.447213596
13	0.349007999	0.797161668	0.492673006
14	0.125810858	0.843891746	0.521553782
15	0.0	0.843891746	0.521553782 c/c

5-Frequency Sub-division (Continued)

NOTE: a1 + (2)a2 + (2)a3 = 63.43494883 deg. Therefore, when the coordinates are rotated, Panel 1 overlaps Panel 1, and the centermost panel = Panel 1, due to edges = a1.



SCHEMATIC VIEW

NOT TO SCALE

5-Frequency Application - Full Sphere:

1) Rest Icosa on an edge;
2) Generate one-eighth sphere coordinates.

The generated coordinates will be all positive: +x, +y & +z.

Section I:

Rotate nodes 1 thru 15, as listed on pages 2 and 3,
-31.7174744114 degrees about x-axis.

Section II:

Rotate nodes 1 thru 15,
37.377368141 deg about x-axis;
120 deg about z-axis;
[180 deg - 63.4349488229 deg - 37.377368141 deg]: x-axis;
108 deg about z-axis;
-31.7174744114 deg about x-axis.

OR Transpose Section I coordinates such that:
Section II x, y and z equal Section I y, z and x

Section III:

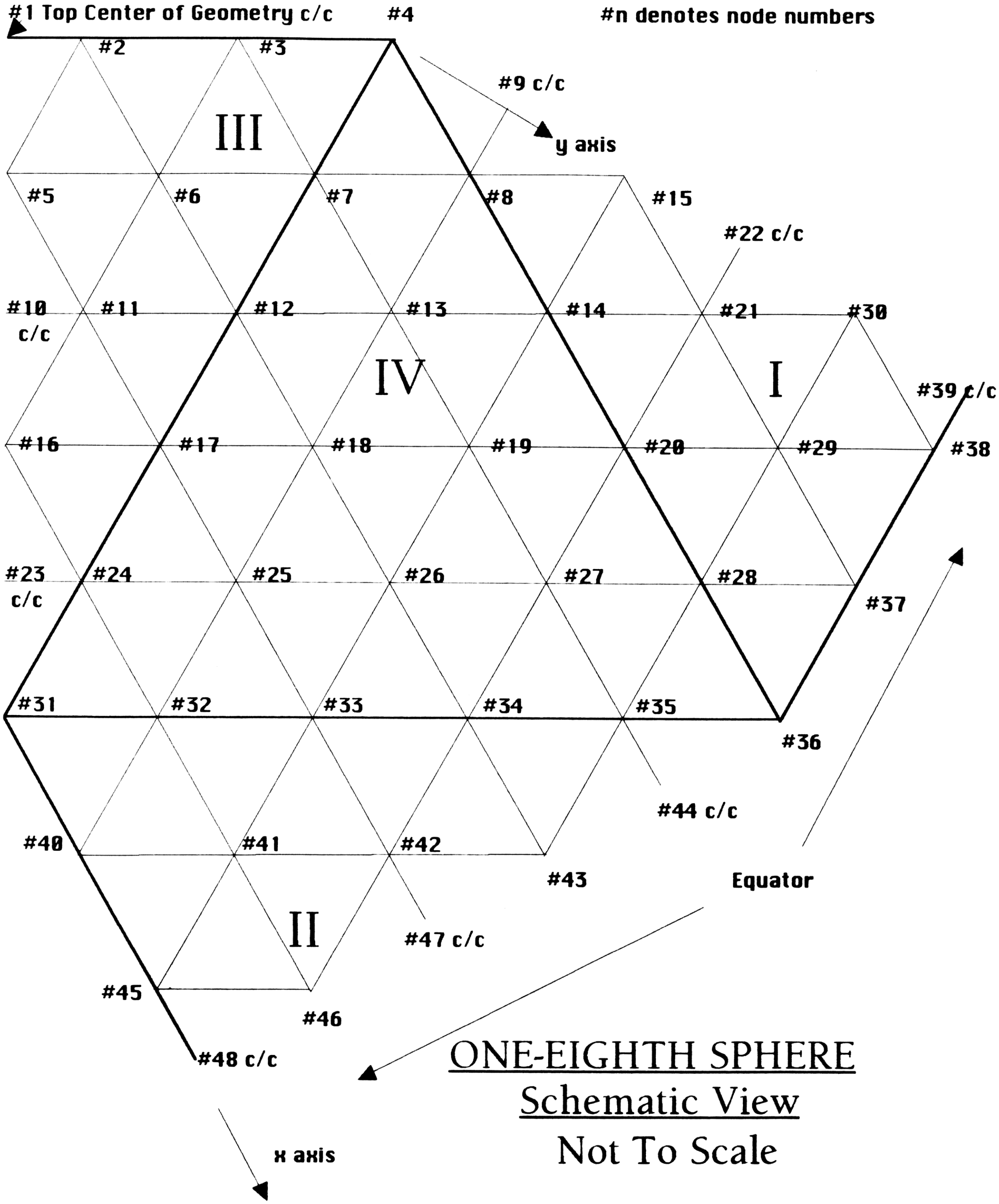
Rotate nodes 1 thru 15,
37.377368141 deg about x-axis;
-120 deg about z-axis;
-37.377368141 deg about x-axis;
-144 deg about z-axis;
-31.7174744114 deg about x-axis.

OR Transpose Section II coordinates such that:
Section III x, y and z equal Section II y, z and x

Section IV:

Rotate nodes 5, 7, -7, 10, -10 and 11,
-72 deg about z-axis;
-31.7174744114 deg about x-axis.

5-Frequency Application - Full Sphere: (Continued)

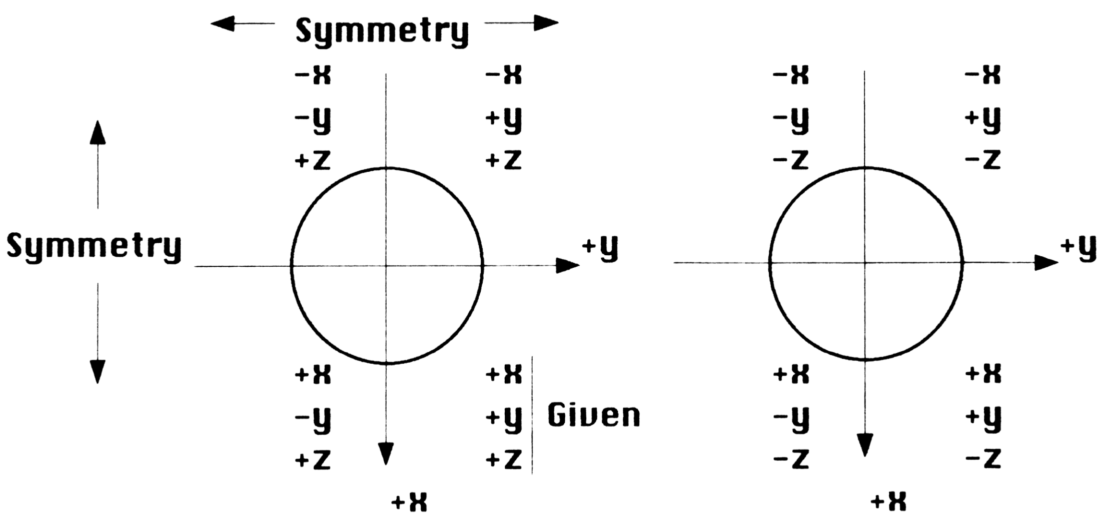


ONE-EIGHTH SPHERE
Schematic View
Not To Scale

5-Frequency Application - Full Sphere: (Continued)

As the reader will note, the total sphere coordinate listing can be calculated with the rotation of only twenty-one nodes: 15 + 6, after calculating one-half of one face. This is accomplished because of the ability to transpose similarly located nodes in Section I into Section II into Section III and rotating the six centermost nodes into Section IV. There is even a relationship amongst these nodes as well.

The balance of the total sphere is accomplished by changing the polarity of the one-eighth sphere node coordinates.



Sphere Top **Sphere Btm**

Notes:

1) No 90 degree rotational symmetry about any axis.
2) 180 degree rotational symmetry, only, about any axis.

5-Frequency Application - Full Sphere: (Continued)

Node No.	x	y	z
1	0.0	0.0	0.992054246 c/c
2	0.0	0.125810858	0.992054246
3	0.0	0.349007999	0.937119745
4	0.0	0.525731112	0.850650809
5	0.217325906	0.0	0.976099098
6	0.207061484	0.249598308	0.945952550
7	0.186206470	0.464089926	0.865995203
8	0.115081927	0.650296396	0.750913275
9	0.0	0.650296396	0.750913275 c/c
10	0.420892151	0.0	0.898343712 c/c
11	0.420892151	0.125810858	0.898343712
12	0.394243992	0.369467051	0.841466433
13	0.335032519	0.584630827	0.738891065
14	0.243656192	0.763711051	0.597810246
15	0.0	0.791692312	0.610920030
16	0.610920030	0.0	0.791692312
17	0.597810246	0.243656192	0.763711051
18	0.555206947	0.477451561	0.681017806
19	0.477451561	0.681017805	0.555206948
20	0.369467051	0.841466433	0.394243992
21	0.125810858	0.898343712	0.420892151
22	0.0	0.898343712	0.420892151 c/c
23	0.750913275	0.0	0.650296396 c/c
24	0.750913275	0.115081927	0.650296396
25	0.738891066	0.335032520	0.584630827
26	0.681017806	0.555206947	0.477451561
27	0.584630828	0.738891065	0.335032519
28	0.464089926	0.865995203	0.186206470
29	0.249598308	0.945952550	0.207061484
30	0.0	0.976099098	0.217325906

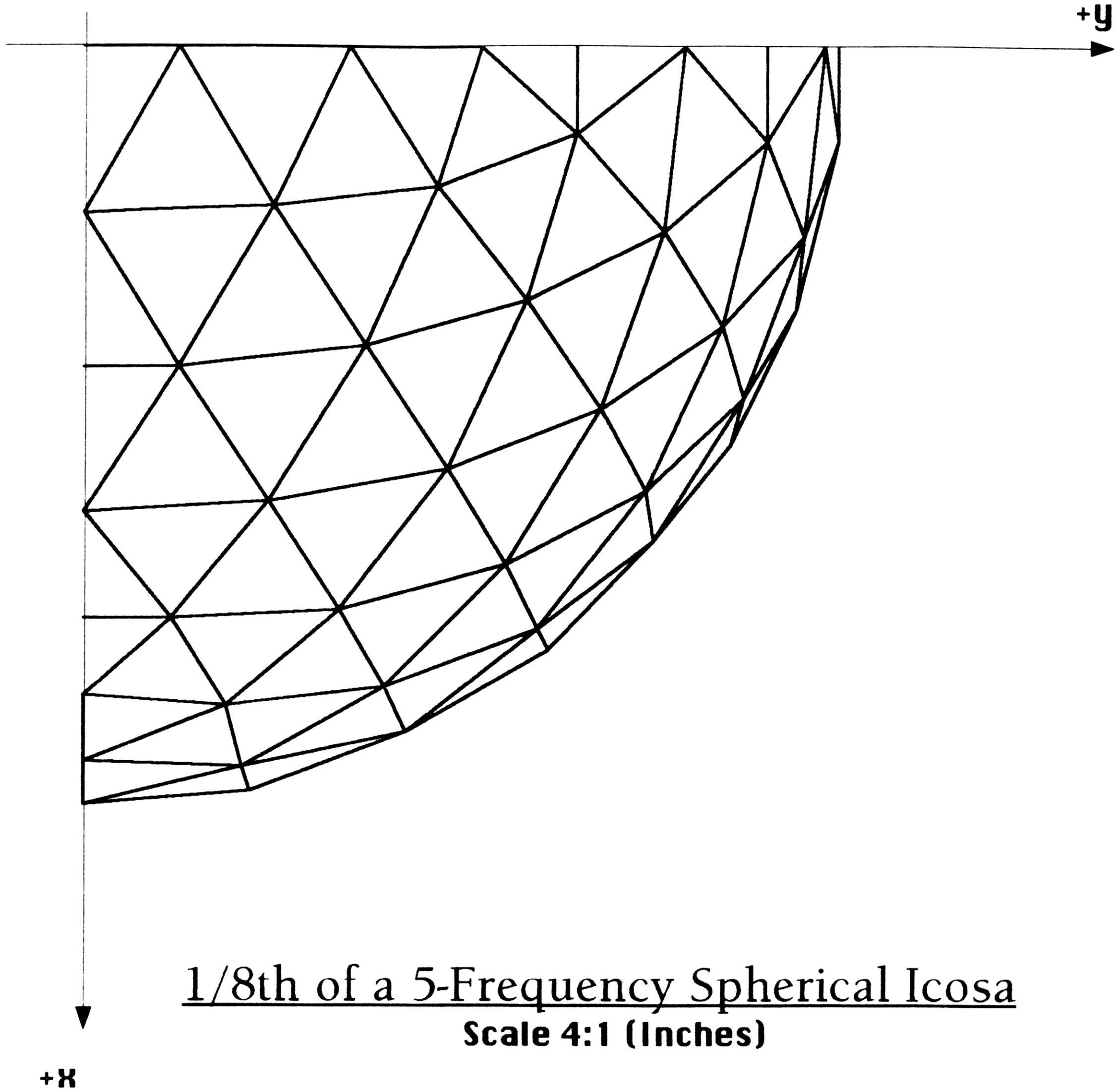
5-Frequency Application - Full Sphere: (Continued)

31	0.850650809	0.0	0.525731112	
32	0.865995203	0.186206470	0.464089926	
33	0.841466433	0.394243992	0.369467051	
34	0.763711051	0.597810246	0.243656192	
35	0.650296396	0.750913275	0.115081927	
36	0.525731112	0.850650808	0.0	
37	0.349007999	0.937119745	0.0	
38	0.125810858	0.992054246	0.0	
39	0.0	0.992054246	0.0	c/c
40	0.937119745	0.0	0.349007999	
41	0.945952550	0.207061484	0.249598308	
42	0.898343712	0.420892151	0.125810858	
43	0.791692312	0.610920030	0.0	
44	0.650296396	0.750913275	0.0	c/c
45	0.992054246	0.0	0.125810858	
46	0.976099098	0.217325906	0.0	
47	0.898343712	0.420892151	0.0	c/c
48	0.992054246	0.0	0.0	c/c

Notes:

1) c/c denotes non-spherical surface center of chord.
2) nn denotes node shared with adjoining balance of sphere.

5-Frequency Application - Full Sphere: (Continued)



1/8th of a 5-Frequency Spherical Icosa

Scale 4:1 (Inches)

5-Frequency Application - Full Sphere: (Continued)

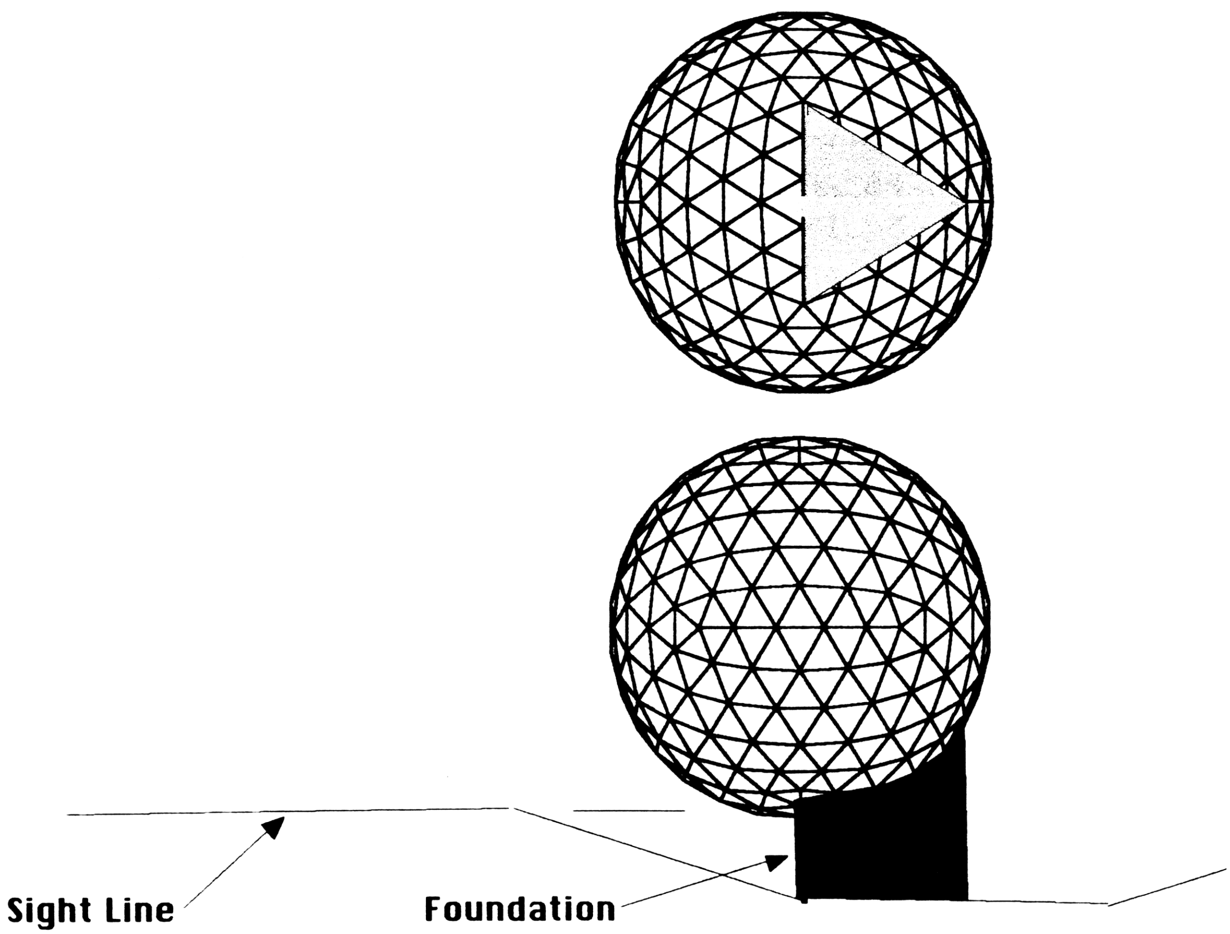
Architectural Uses of Full Sphere:

Design 19/20th Sphere with front of building being a full hemisphere, except for half of a pipe section mast which supports floors within sphere. The bottom icosa face, to the rear of the resting edge, could be balance of foundation for utilities, stairs or elevator containment. The bottom of the front face hemisphere could be at grade, or a sight-line at grade if below grade space is allocated for parking, entry or other non-exposed portions of building site.

The spherical shell could be independent of the usable volume if cylindrically shaped walls are within sphere. This could be determined by tradeoffs amongst architectural details, structural details and weather tightness.

The buildings could be clubhouses for sporting facilities, theme buildings, preschools with the five different panel sizes being five primary colors of the rainbow, offices or private residences.

An external spherical radius of up to 40 feet (12.2 meters) is conceivable with the given panel width factor and aluminum panels.



Hemisphere Geometries:

The Icosa face sub-division should be a even frequency i.e. 2, 4, 6, etc., in order to have a horizontal circular boundary at the dome base. The geometry generation will utilize GEOM to develop two separate arrangements: one five-sided; one three-sided, for the center, if the half-frequency equals 4 or more.

The five-sided geometry will use a half-frequency as the number of divisions and a G.C. angle of 26.5650511771 degrees or (90 - arc sin of square root of 0.8).

The three-sided geometry will use the same number of divisions and a G.C. angle of 10.8123169639 = (37.377368141 - 26.5650511771). Some nodes inside the great circle may be discarded to keep the panels a similar shape. There will be a node at the center-most point of the icosa face if the half-frequency equals a multiple of three.

As a sample, use an Icosa frequency of six (6). Therefore:

5-Sided Geometry Generation:

G.C. angle = 26.5650511771 degrees (Constant for hemispheres)
#Divisions = 3 (Frequency/2)
Sides = 5
Overshoot? = 0
Sph R. = 1
Coordinates= 1
Inner Level = -3
Outer Level = 0 (Great Circle)

3-Sided Geometry Generation: (If required; half freq. greater than 3)

Same as above except G.C. angle = 10.8123169639; Sides = 3

After deletion of unnecessary nodes, rotate (-x) nodes 180 deg. about z-axis and -37.377368141 deg. about x-axis. In addition, rotate +x & -x nodes (-)60.0 degrees about z-axis and (-)37.377368141 deg. about x-axis. This will define half of center quarter of Icosa face. Due to node elimination, SPHO will have to be used to calculate member central angles, chord factors and lengths; and gusset angles.

Hemisphere Geometries: (Continued)

6-Frequency Hemisphere

5-Sided Geometry

B1 = 63.434948823
M.C.1. = 9.59962493
a1 = 11.30553251 c.f. = 0.19699882 Length = c.f. (R=1)
b1 = 12.0 c.f. = 0.20905693 (Equator members)
Panel 1 ω = 0.16698004
ω x R = 0.16698004
A1 = 58.28252559
M.C.2. = 18.59336058
a2 = 10.70827640 c.f. = 0.18662279
b2 = 11.83136159 c.f. = 0.20612953
A2 = 56.77410907
C2 = 58.78239818
B2 = 64.44349275
M.C.3. = 26.56505118
a3 = 9.70366550 c.f. = 0.16915858
b3 = 11.37154275 c.f. = 0.19814528
A3 = 54.39174396
C3 = 58.23054898
B3 = 67.37770706
M.C.4., a4, b4, A4, C4, Ref
B4 = 72

No. of dome piers = 360/12.0 = 30

Hemisphere Geometries: (Continued)

6-Frequency Hemisphere

5-Sided Geometry

Node 1.
x = 0.0
y = 0.0
z = 1.0
∡ w/Top = 0.0

Node 2.
x = 0.099072638
y = 0.136361788
z = 0.985692688
∡ w/Top = 9.703665498

Node 3.
x = 0.0
y = 0.136361788
z = 0.985692688

Node 4.
x = 0.205000330
y = 0.282158748
z = 0.937209318
∡ w/Top = 20.411941898

Node 5.
x = 0.0
y = 0.291794592
z = 0.956481007
∡ w/Top = 16.965426243

Node 6.
x = 0.309016994
y = 0.425325404
z = 0.850650808
∡ w/Top = 31.717474412

Node 7.
x = 0.104528463
y = 0.444763713
z = 0.889527425
∡ w/Top = 27.186076695

Node 8.
x = 0.0
y = 0.444763713
z = 0.889527425

Hemisphere Geometries: (Continued)

6-Frequency Hemisphere

3-Sided Geometry

Since the half-frequency is less than 4, there will not be a GEOM generated geometry for the Icosa center. Because it is a multiple of 3, place a node at the Icosa face center.

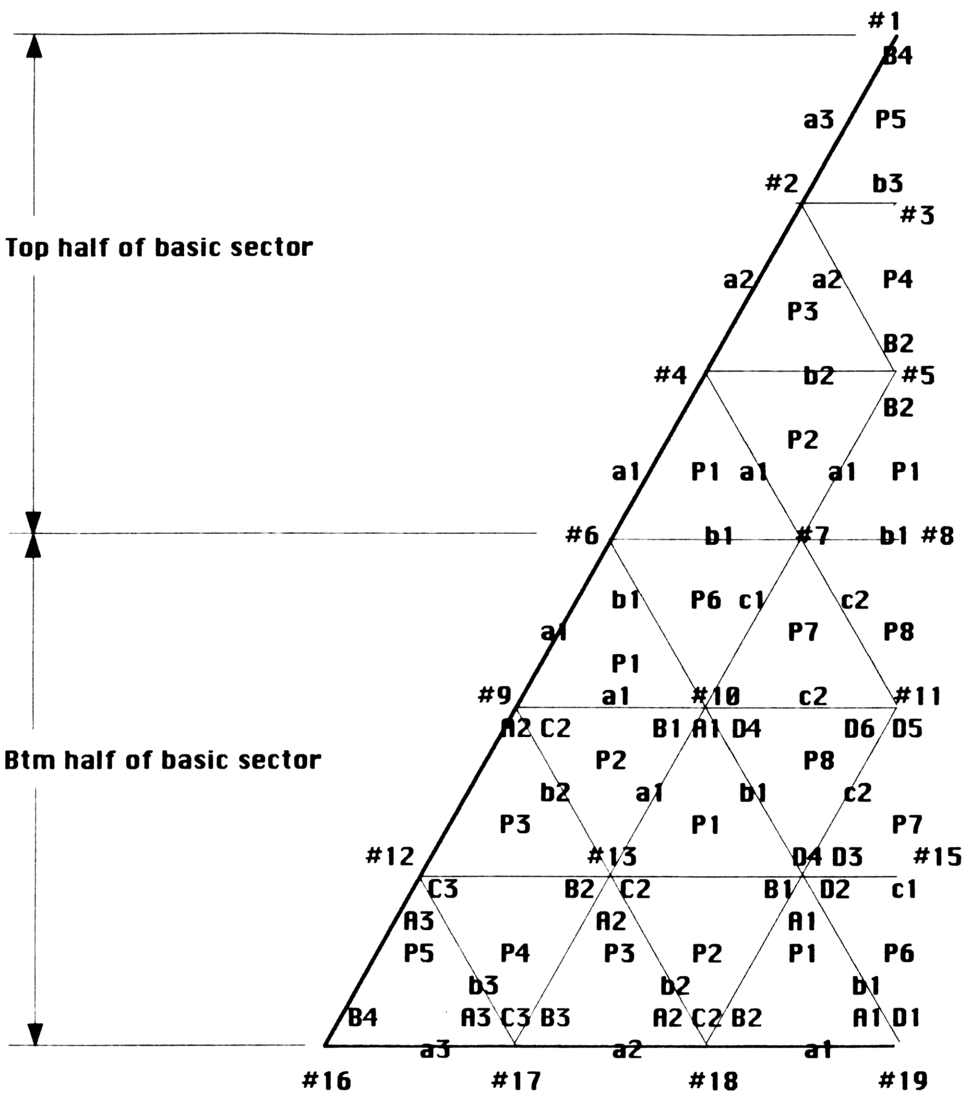
Node 11.
x = 0.0
y = 0.607061998 (Sine 37.377368141)
z = 0.794654472 (Cosine 37.377368141)
∡ w/Top = 37.377368141

The Icosa center geometry will be determined by use of SPHO and the node coordinates.

Rotate nodes 1, 2, -2, 4, -4, 5, 6, 7 and -7 to get the balance of the Icosa face. (-) equals same except with -x coordinate. Rotate 37.377368141 degrees about x-axis, 120 degrees about z-axis and -37.377368141 degrees about x-axis, using ROTN.

Hemisphere Geometries: (Continued)

6-Frequency Hemisphere



<u>6-Frequency Sub-Division of Icosa</u>
<u>Schematic View (N.T.S.)</u>

Hemisphere Geometries: (Continued)

6-Frequency Hemisphere

Half-Face Nodes

Previously Calculated

Node No.	x	y	z
1	0.0	0.0	1.0
2	0.099072638	0.136361788	0.985692688
3	0.0	0.136361788	0.985692688 c/c
4	0.205000330	0.282158748	0.937209318
5	0.0	0.291794592	0.956481007
6	0.309016994	0.425325404	0.850650808
7	0.104528463	0.444763713	0.889527425
8	0.0	0.444763713	0.889527425 c/c
11	0.0	0.607061998	0.794654472

Rotated Coordinates

Node No.	x	y	z
9	0.401041162	0.551985805	0.731079788
10	0.213834107	0.595210025	0.774596669
11	See Above		
12	0.473902682	0.652271084	0.591573056
13	0.302041423	0.707518946	0.638895860
14	0.109305644	0.739081112	0.664688939
15	0.0	0.739081112	0.664688939 c/c
16	0.525731112	0.723606798	0.447213595
17	0.374830044	0.788632872	0.487401920
18	0.196040832	0.834144553	0.515529685
19	0.0	0.850650808	0.525731112

Hemisphere Geometries: (Continued)

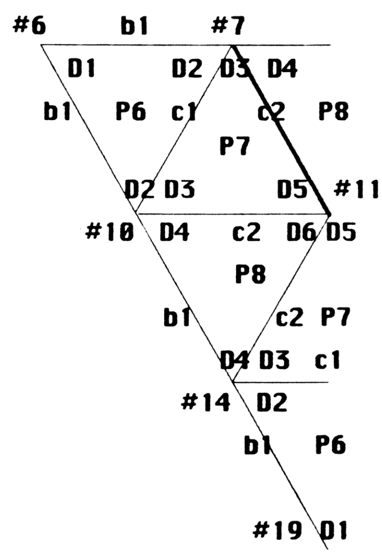
6-Frequency Hemisphere

Central portion calculated using SPHO and Nodes 6,7,10,11 and 14 x, y and z coordinates.

c1= 12.55058110 c.f. = 0.21861129
D1 = 63.434948820
D2 = 58.845843896
c2 = 12.34817916 c.f. = 0.21509954
D3 = 59.846843737
D4 = 61.307312368
D5 = 61.477959836
D6 = 58.522040164

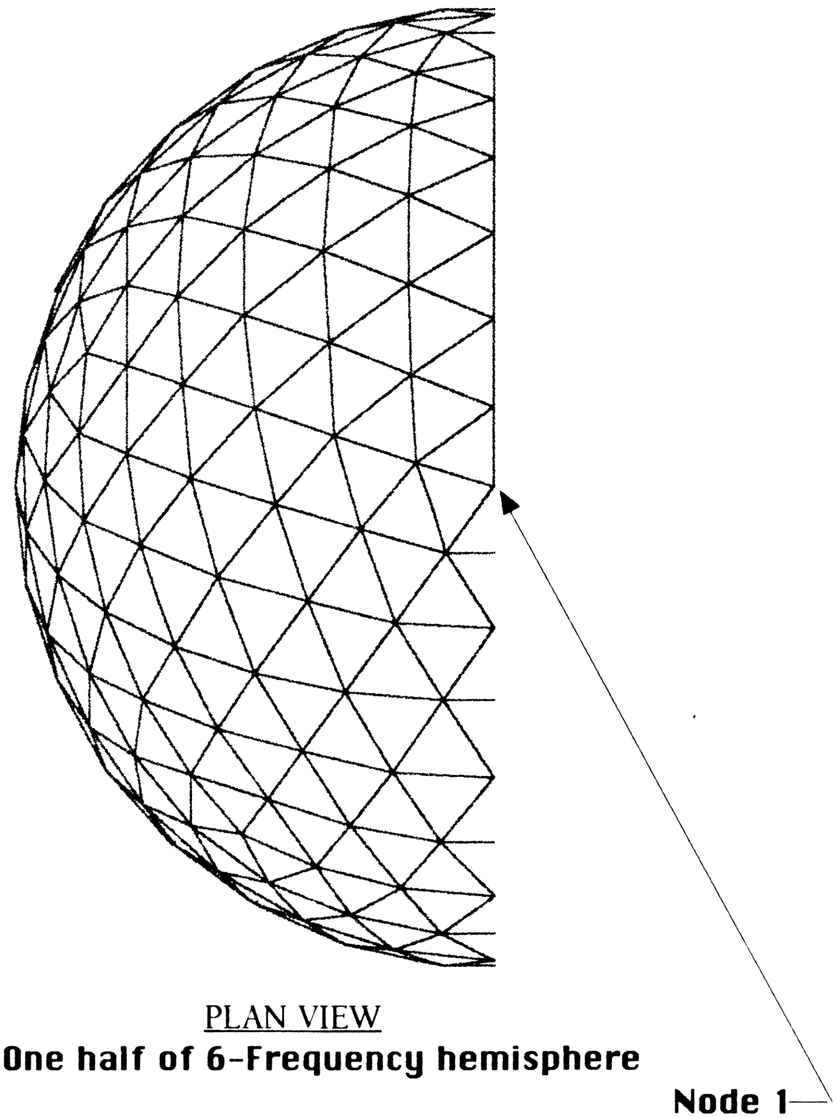
Least altitudes of central panels, using PLTR :
P6 = 0.1782
P7 = 0.1853
P8 = 0.1827

P7 altitude > Panel 1 altitude. Therefore P7 altitude controls the maximum spherical radius. If maximum raw material equals 105", the maximum sph. radius = 105"/0.1853 = 566.65" = 47'-2 5/8".



Hemisphere Geometries: (Continued)

6-Frequency Hemisphere

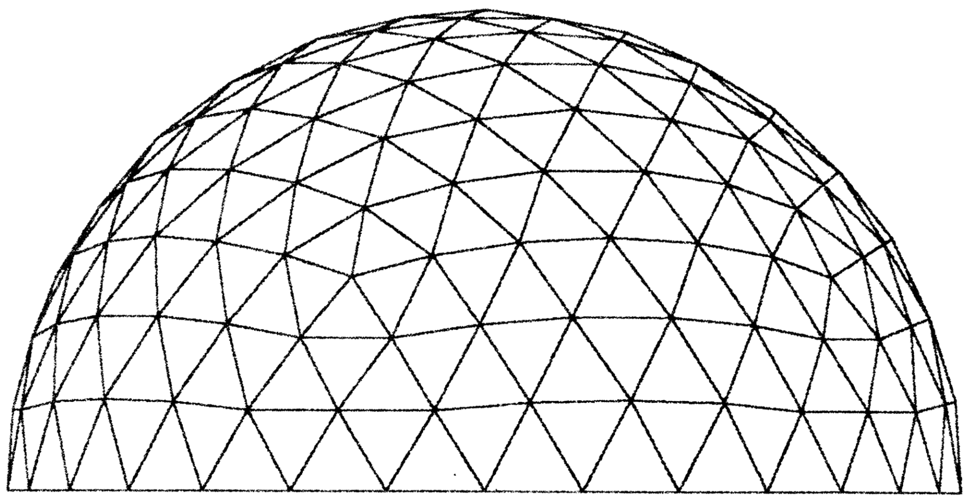


PLAN VIEW
One half of 6-Frequency hemisphere

Node 1
@ Zenith

Hemisphere Geometries: (Continued)

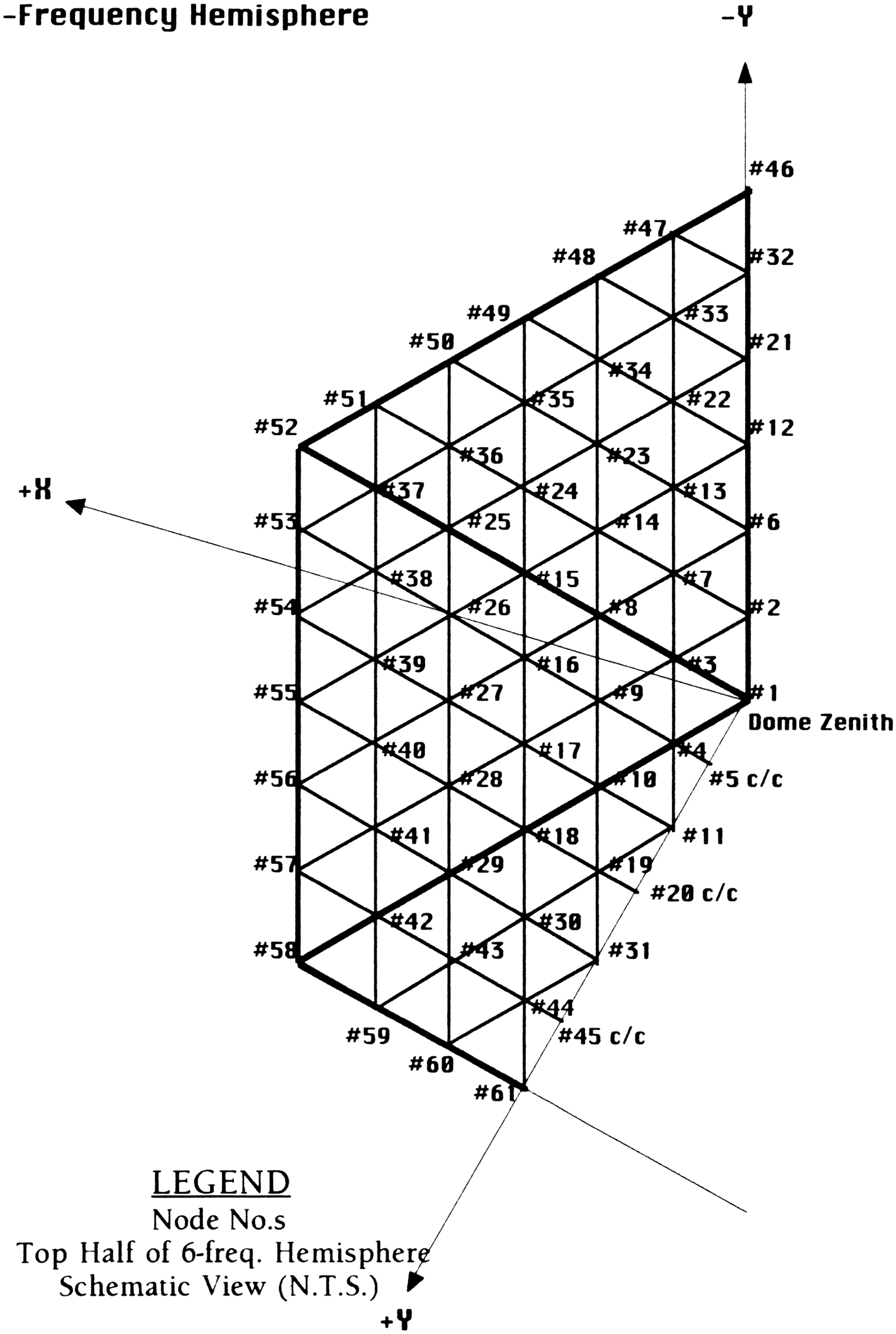
6-Frequency Hemisphere



ELEVATION VIEW
6-Frequency hemisphere

Hemisphere Geometries: (Continued)

6-Frequency Hemisphere



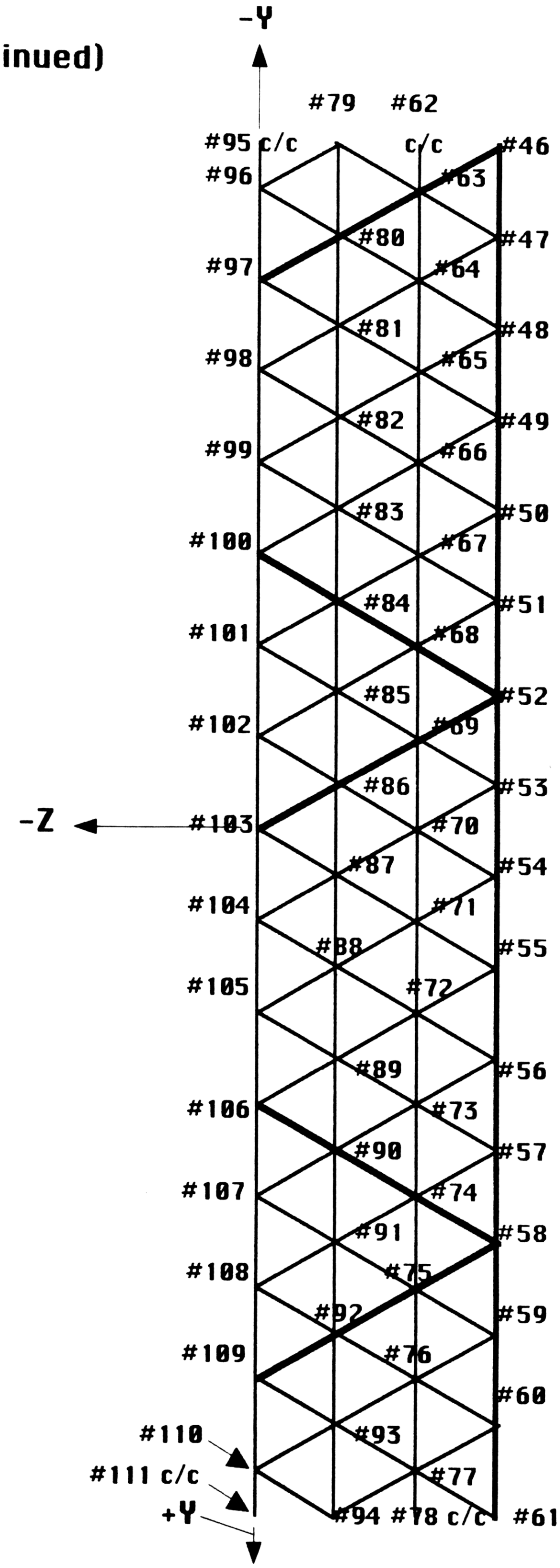
LEGEND
Node No.s
Top Half of 6-freq. Hemisphere
Schematic View (N.T.S.)

Hemisphere Geometries: (Continued)

6-Frequency Hemisphere

Continuation of Legend

Bottom Half of 6-freq. Hemisphere



Hemisphere Geometries: (Continued)

6-Frequency Hemisphere

Legend zone bounded by nodes 1, 58 and 61 is the same as page 16 schematic with nodes renumbered. This is referred to as the basic sector.

Legend zone bounded by nodes 1, 52 and 58 is same as basic sector nodes, both + and - x coordinates, rotated -72.0 degrees about z-axis.

Legend zone bounded by nodes 1, 46 and 52 is same as above except rotation angle is -144.0 degrees.

Legend zone bounded by nodes 58, 61, 109 and 111 is same as bottom half of basic sector, -x half, rotated [180.0 - arc sine of square root of 0.8] degrees about x-axis and 180.0 degrees about z-axis.

Legend zone bounded by nodes 58, 106 and 109 is same as the top half, both + and - x coordinates, of basic sector rotated (minus) [arc sine of the square root of 0.8] degrees about x-axis and -36.0 degrees about z-axis.

Legend zone bounded by nodes 52, 58, 100 and 106 is same as zone bounded by nodes 58, 61, 106 and 111 (both + and - x coordinates) rotated -72.0 degrees about z-axis. Zone bounded by nodes 46, 52, 95 and 100 is similar except rotation angle is -144.0 degrees.

Hemisphere Geometries: (Continued)

6-Frequency Hemisphere

Node No.	x	y	z
1	0.0	0.0	1.0
2	0.0	-0.168552439	0.985692688
3	0.160302896	-0.052085568	0.985692688
4	0.099072638	0.136361788	0.985692688
5	0.0	0.136361788	0.985692688 c/c
6	0.0	-0.348767393	0.937209318
7	0.171512558	-0.236066784	0.956481007
8	0.331697505	-0.107775051	0.937209318
9	0.277513148	0.090169488	0.956481007
10	0.205000330	0.282158748	0.937209318
11	0.0	0.291794592	0.956481007
12	0.0	-0.525731112	0.850650808
13	0.176860248	-0.421261692	0.889527425
14	0.345990854	-0.298381113	0.889527425
15	0.5	-0.162459848	0.850650808
16	0.455296499	0.038027070	0.889527425
17	0.390694356	0.236852022	0.889527425
18	0.309016994	0.425325404	0.850650808
19	0.104528463	0.444763713	0.889527425
20	0.0	0.444763713	0.889527425 c/c
21	0.0	-0.682291977	0.731079788
22	0.176860248	-0.607223560	0.774596669
23	0.356822090	-0.491123473	0.794654472
24	0.522851101	-0.355846491	0.774596669
25	0.648898231	-0.210839816	0.731079788
26	0.632156746	-0.019438308	0.774596669
27	0.577350269	0.187592474	0.794654472
28	0.5	0.387298334	0.774596669
29	0.401041162	0.551985805	0.731079788

Node No.	x	y	z
30	0.213834107	0.595210025	0.774596669
31	0.0	0.607061998	0.794654472
32	0.0	-0.806251399	0.591573056
33	0.171512558	-0.749930345	0.638895860
34	0.345990854	-0.662177425	0.664688939
35	0.522851101	-0.533680934	0.664688939
36	0.660225846	-0.394859357	0.638895860
37	0.766790647	-0.249145384	0.591573056
38	0.766226437	-0.068623085	0.638895860
39	0.736685209	0.124432779	0.664688939
40	0.669130606	0.332344469	0.664688939
41	0.579554571	0.505893842	0.638895860
42	0.473902682	0.652271084	0.591573056
43	0.302041423	0.707518946	0.638895860
44	0.109305644	0.739081112	0.664688939
45	0.0	0.739081112	0.664688939 c/c
46	0.0	-0.894427191	0.447213595
47	0.160302896	-0.858336968	0.487401920
48	0.331697502	-0.790067029	0.515529685
49	0.5	-0.688190960	0.525731112
50	0.648898231	-0.559607209	0.515529685
51	0.766790647	-0.417697824	0.487401920
52	0.850650809	-0.276393202	0.447213595
53	0.865832855	-0.112783596	0.487401920
54	0.853898561	0.071318932	0.515529685
55	0.809016994	0.262865556	0.525731112
56	0.732738664	0.444210753	0.515529685
57	0.634205578	0.600185516	0.487401920
58	0.525731112	0.723606798	0.447213595
59	0.374830044	0.788632872	0.487401920
60	0.196040832	0.834144553	0.515529685
61	0.0	0.850650808	0.525731112

Node No.	x	y	z	
62	0.0	-0.942613188	0.318849480	c/c
63	0.099072639	-0.942613188	0.318849480	
64	0.277513148	-0.895827641	0.347101269	
65	0.455296499	-0.812623738	0.363796313	
66	0.632156746	-0.684127247	0.363796313	
67	0.766226436	-0.540756653	0.347101269	
68	0.865863286	-0.385507173	0.318849480	
69	0.927093544	-0.197059816	0.318849480	
70	0.937738994	-0.012895277	0.347101269	
71	0.913545457	0.181898157	0.363796313	
72	0.845990854	0.389809847	0.363796313	
73	0.751067129	0.561621650	0.347101269	
74	0.634205578	0.704356652	0.318849480	
75	0.473902682	0.820823524	0.318849480	
76	0.302041423	0.887857921	0.347101269	
77	0.109305644	0.925042982	0.363796313	
78	0.0	0.925042982	0.363796313	c/c
79	0.0	-0.985997129	0.166762292	
80	0.205000330	-0.964450726	0.166762292	
81	0.390694356	-0.901540960	0.185961869	
82	0.577350269	-0.794654472	0.187592474	
83	0.736685209	-0.650163891	0.185961859	
84	0.853898561	-0.492998564	0.166762292	
85	0.937738995	-0.304689870	0.166762292	
86	0.980595733	-0.103064764	0.166762292	
87	0.978147600	0.092980935	0.185961869	
88	0.934172359	0.303530999	0.187592474	
89	0.845990854	0.499717577	0.185961869	
90	0.732738664	0.659760857	0.166762292	
91	0.579554571	0.797688434	0.166762292	
92	0.401041162	0.900753198	0.166762292	
93	0.213834107	0.959006338	0.185961869	
94	0.0	0.982246946	0.187592474	

Node No.	x	y	z	
95	0.0	-0.994521896	0.0	c/c
96	0.104528463	-0.994521896	0.0	
97	0.309016994	-0.951056516	0.0	
98	0.5	-0.866025404	0.0	
99	0.669130606	-0.743144825	0.0	
100	0.809016994	-0.587785252	0.0	
101	0.913545458	-0.406736643	0.0	
102	0.978147600	-0.207911691	0.0	
103	1.0	0.0	0.0	
104	0.978147600	0.207911691	0.0	
105	0.913545457	0.406736643	0.0	
106	0.809016994	0.587785252	0.0	
107	0.669130606	0.743144826	0.0	
108	0.5	0.866025404	0.0	
109	0.309016994	0.951056516	0.0	
110	0.104528463	0.994521895	0.0	
111	0.0	0.994521895	0.0	c/c

Mid-Point between:

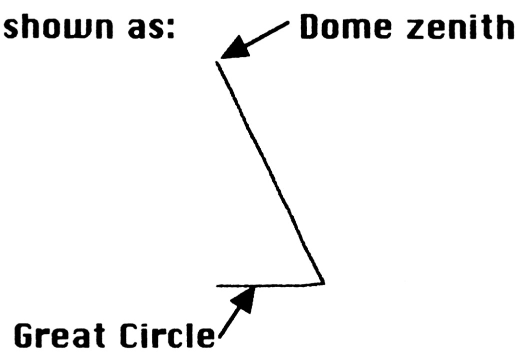
74/75	0.554054130	0.762590088	0.318849480	c/c
107/108	0.584565303	0.804585115	0.0	c/c

This geometry development method minimizes the number of left and right hand panels.

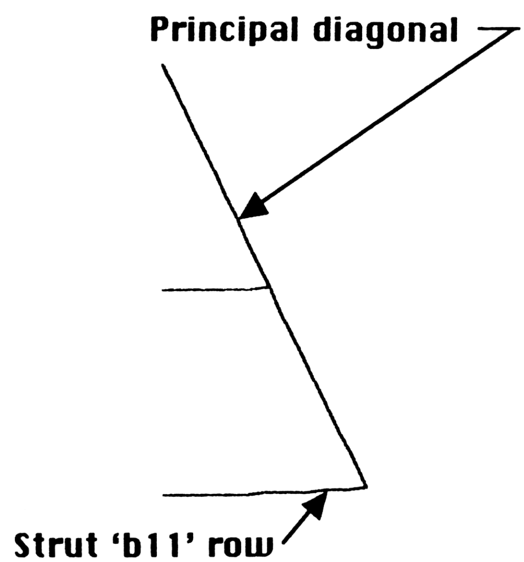
The example for this section of the manual is a 200 meter (656 ft) span dome, which should be suitable for most stadium applications. Experience has shown that a seven sided geometry gives the best results for utilization of raw material and the minimum number of part types, while not degrading the structural integrity.

Using GEOM, set G.C.∡ at 17.0 degrees, #Div at 10 and Sides at 7;
Overshoot equals 0, Sph.R. equals 4,200 (inches);
Coordinates equals 1, Inner and Outer Levels equal -10 and +10.

The resulting generation can be shown as:



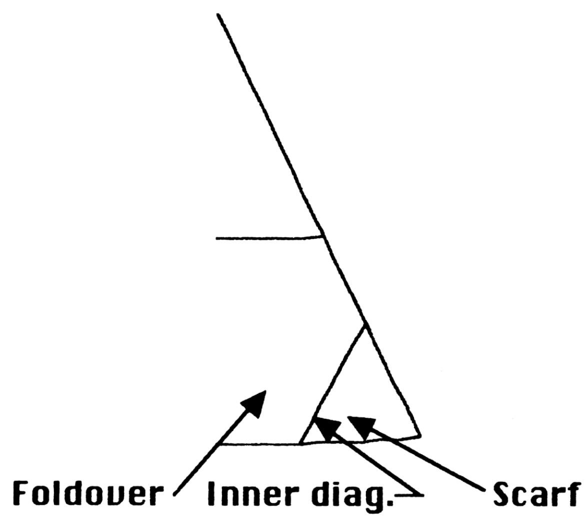
Assuming 100% Foldover:



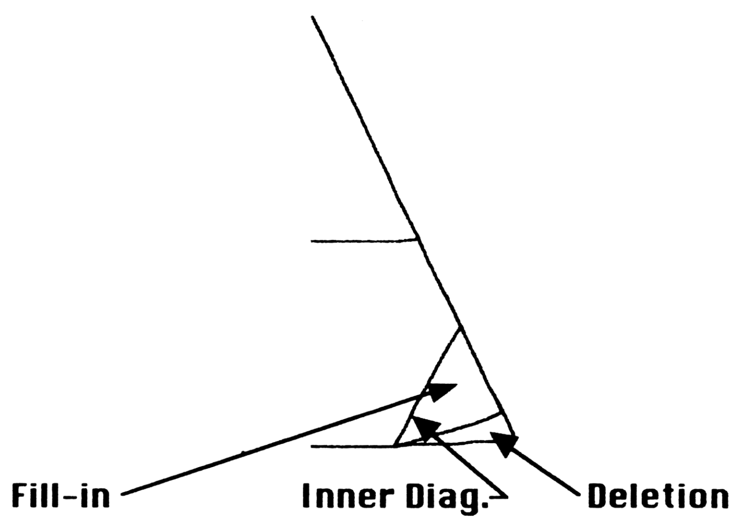
Now is the time to determine the outer edge scarf, which will be replaced by the 'fill-in' portion. The purpose is to blend the crown top of the dome with the circular dome skirt. The geometry portion between the crown/fill-in portion and the skirt is the 'transition'.

The size of the scarf is generally 2/3rds of the outer strut count. The outer edge in this example is the 'b11' row. BARF selected 60% of the 10 element row. In validating both Murphy and Peter, he probably should have selected 70% although this would have added 13 additional panel types.

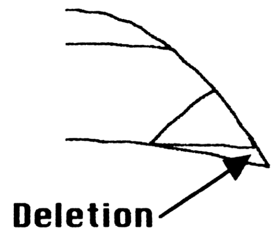
The 60% scarf is shown as:



The net effect of the 'fill-in' is:



Above views are PLAN. FRONT view is:



All panels within the 'fill-in' portion are isosceles triangles, with the bases generally parallel with the inner diagonal and the sides of the triangles equal amongst those in the same row. The rationale' being: as the base edges progressively become shorter, while moving radially outward, the triangle heights become larger, thereby making the outer edge of the fill-in nearly circular in PLAN. BARF developed this method in the mid-70's.

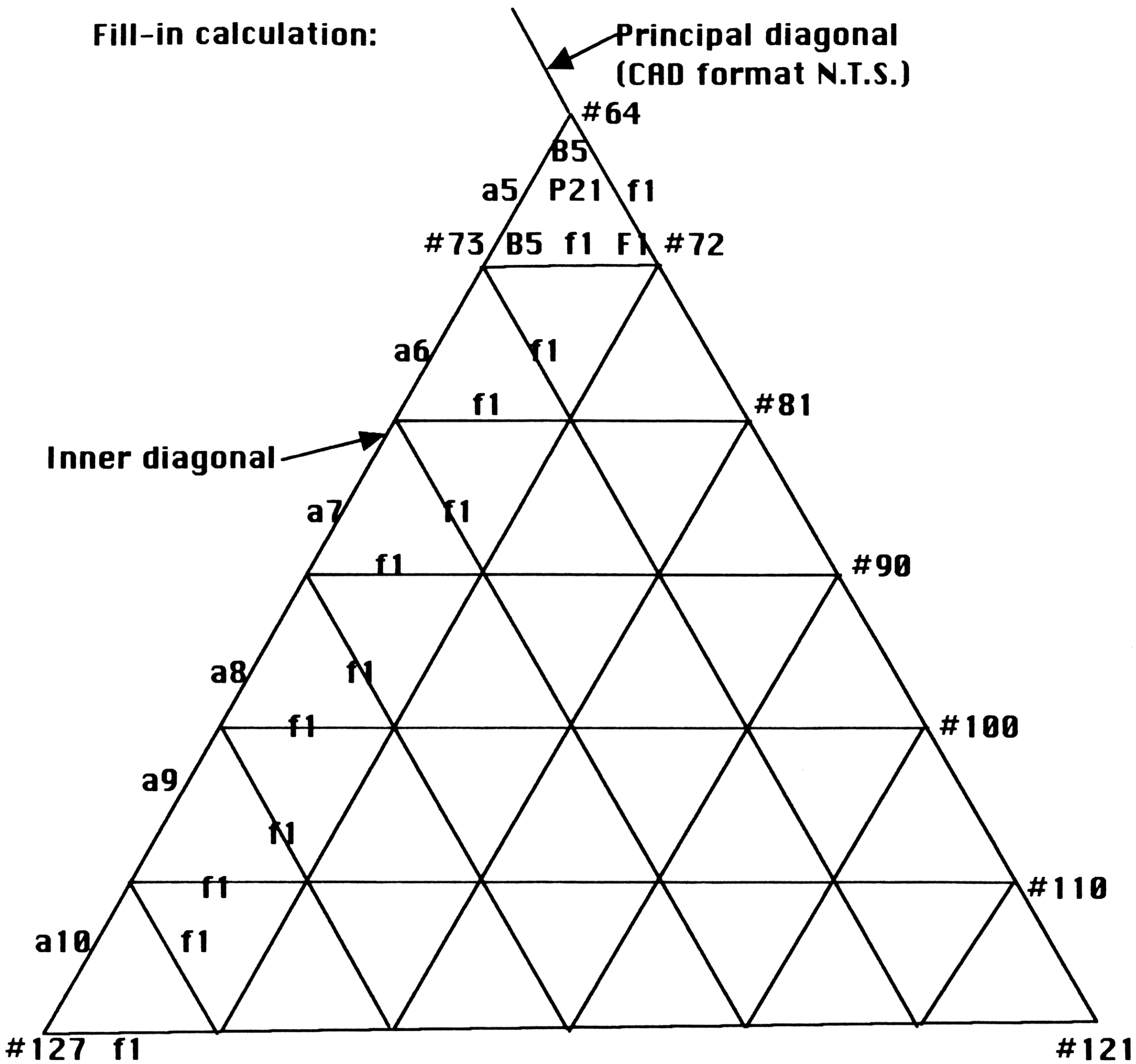
Please note that the above views do not portray this manual's typical x,y,z system in a cyclical manner. BARF's vertical axis is the z-axis. The CAD routine used the y-axis as the 3D vertical due to the 2D orientation being the x,y axes. The CAD routine required a negative polarity for vertical dimensions. This was a very minor anomaly when considering that the while working in the TOP view, the FRONT, SIDE and ISOMETRIC views were automatically generated. BARF used the TOP view because it allowed him to enter data in the same order as this manual's program outputs.

<u>Discard</u> GEOM generated coordinates of nodes:

#72
#81,#82
#90,#91,#92
#100,#101,#102,#103
#110,#111,#112,#113,#114
#121,#122,#123,#124,#125,#126

CIRCULAR EDGE

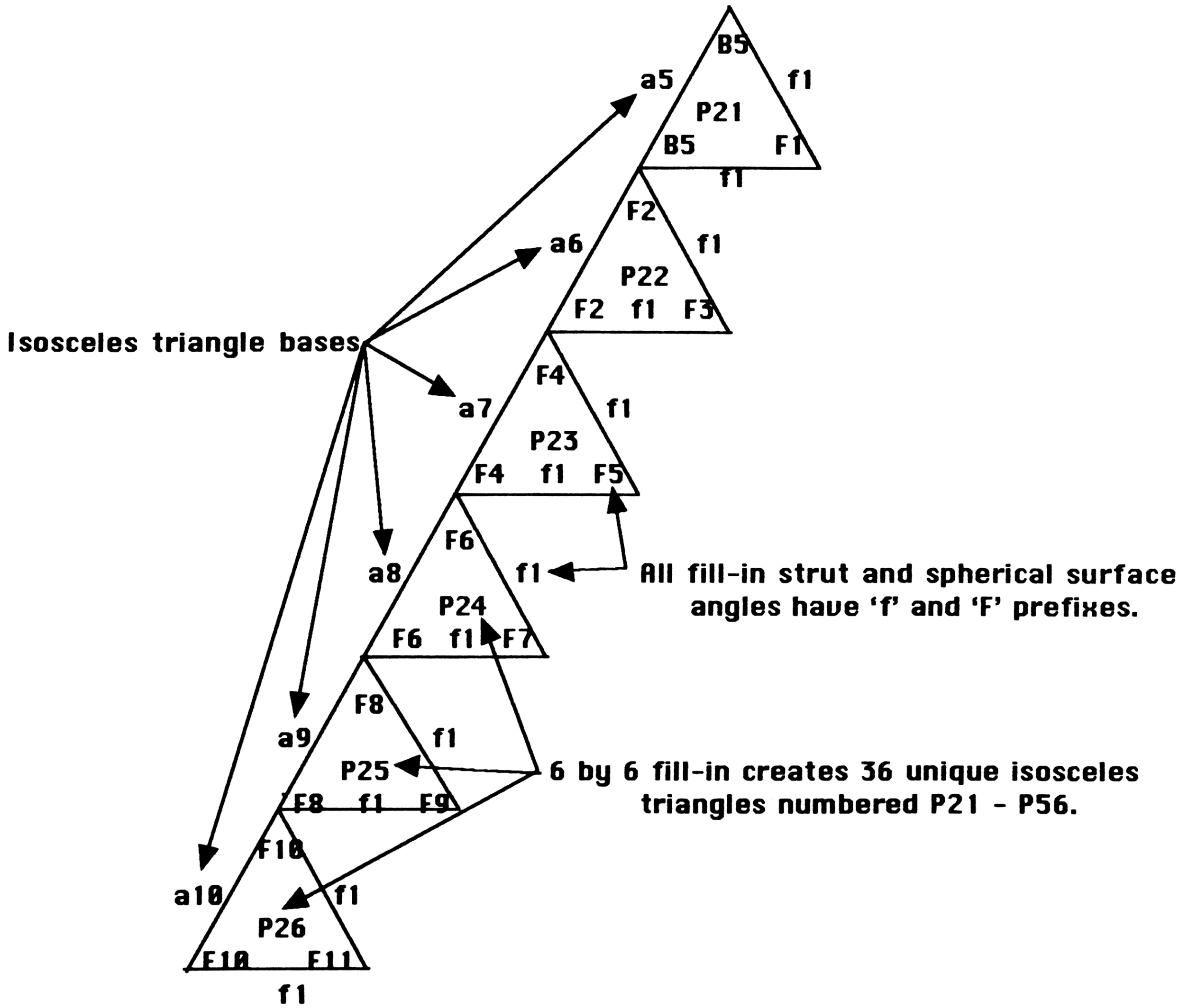
Fill-in calculation:



Visualize Sph. Right Triangle SPHR with ∡a as half of 'a5' and ∡B as 'B5'. ∡c = 'f1' and 2 times ∡A = 'F1'. Carry 'f1' to outer edge of fill-in. Add 'f1' to Node #64 ∡ w/ Top and enter together with 'Sides','R?' and 'Node# ?' into PDGN to calculate replacement #72 coordinates.

Note: 'f1' and 'F1' are both in degrees.
'f1' = strut central angle (Lower Case)
'F1' = spherical surface angle (Upper Case)

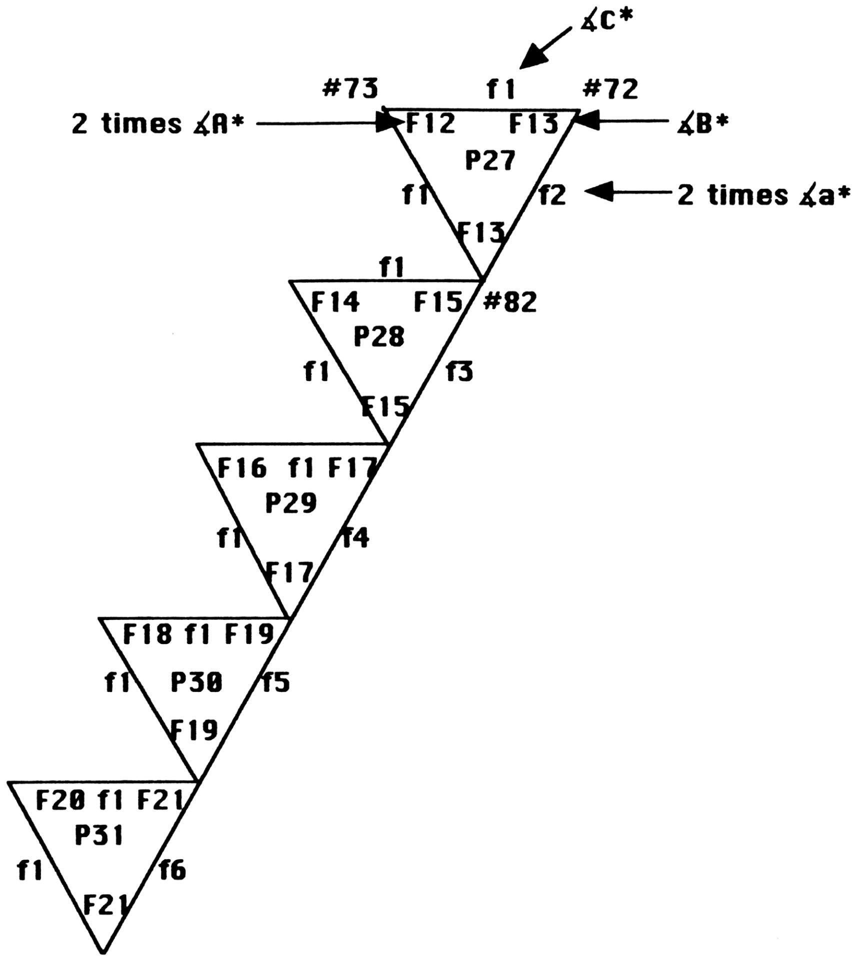
Once 'f1' and the isosceles triangle bases are known, one can use SPHR to calculate the balance of triangle data within the first row. Begin by visualizing ∡a as half of 'a6' and ∡c as 'f1'.



The principal diagonal and the inner diagonal lie on Great Circles. Therefore all fill-in spherical surface angles adjoining them add up to 180 degrees.

Note that this does not hold true for angles between these two diagonals. Internal node spherical surface angles add up to 360 degrees. Of course, this holds true for any dome geometry internal node.

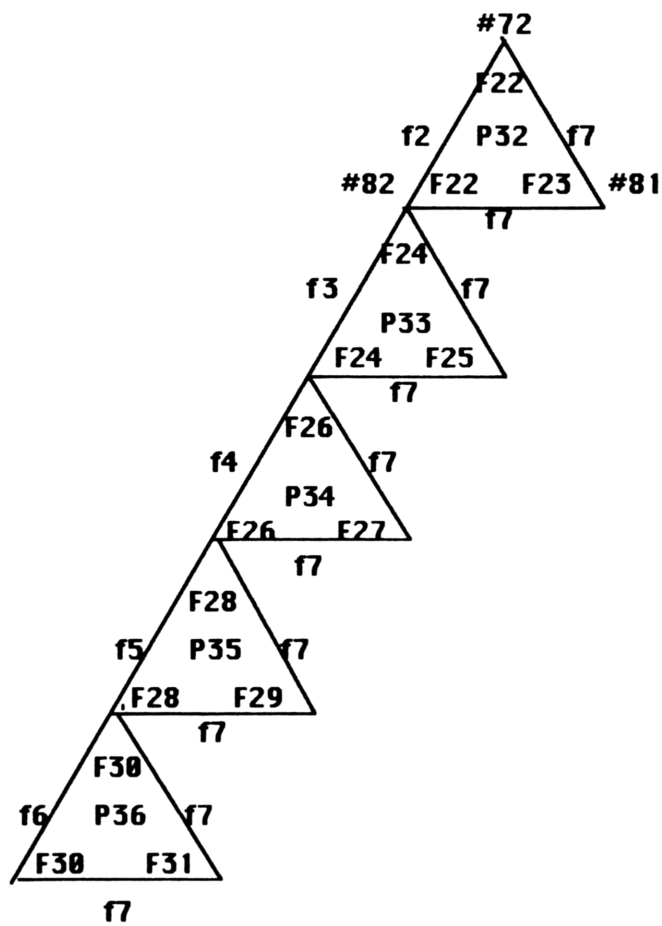
Calculate the adjoining panels P27 thru P31 by subtracting the previous isosceles triangle base angles from 180 degrees and using half of the difference as ∡A and 'f1' as ∡c within SPHR *.



'F22' equals 180 degrees minus 'F1' and 'F13'. Using SPHR with ∡B equaling 'F22' and ∡a equaling half of 'f2', calculate 'f7' and 'F23'.

Carry 'f7' to outer edge of fill-in.

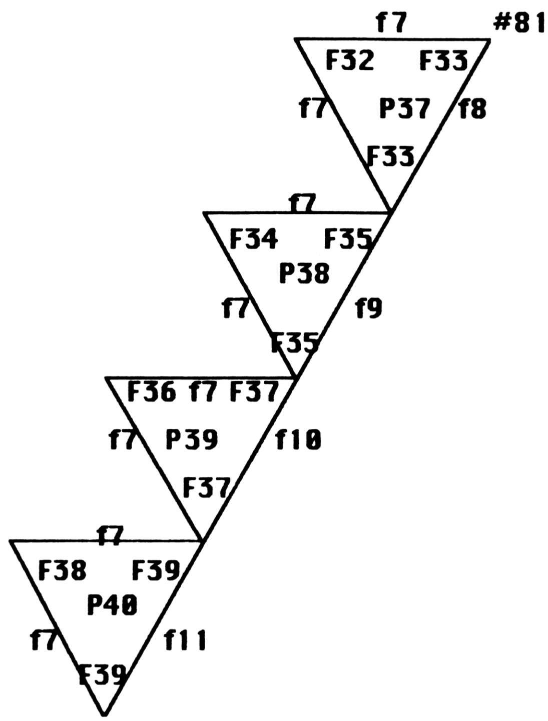
Add 'f7' to ∡ w/Top of Node #72 and input it with 'Sides', 'R? and 'Node #' to calculate coordinates of Node #81. BLND may be used to calculate coordinates of 'blind' Node #82 by inputting 'Sph.R', 'f2','f7', 'Node#' and unit coordinates of Nodes #72 and #81.



CIRCULAR EDGE

Following generation of P32 thru P36, subtract F3, F13, F15, F22 and F24 from 360 degrees to get F32. Use half of F32 as ∡A and f7 as ∡c to calculate panel P37 angles f8 and F33 within SPHR.

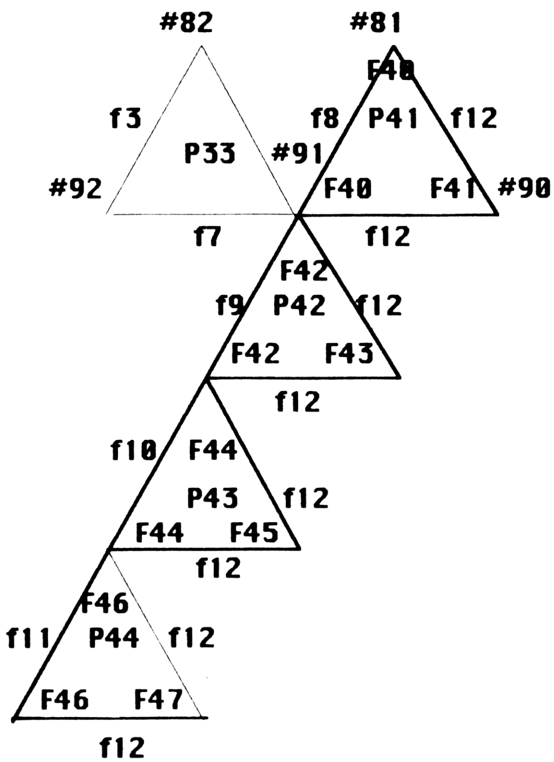
Use similar procedure to calculate panels P38 thru P40.



F40 equals 180 degrees minus F23 and F33. Use F40 as ∡B and half of f8 as ∡a to calculate f12 and F41 within SPHR. Carry f12 to outer edge of fill-in.

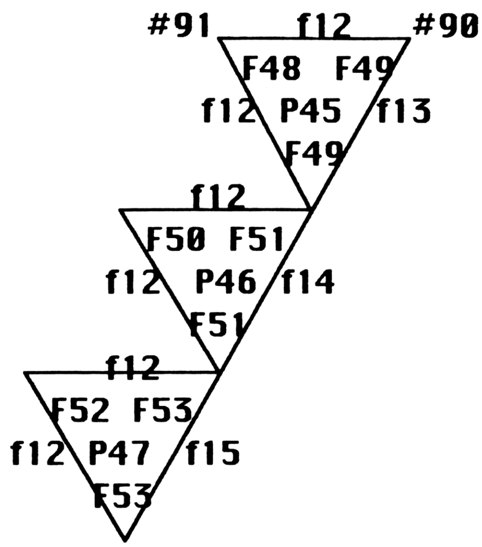
Add f12 to ∡w/Top of node #81 and using PDGN calculate Node #90 coordinates. Calculate 'blind' Node #91 using 'Sph.R.', 'f8', 'f12', coordinates of Nodes #81 and #90 in BLND. Calculate 'blind' Node #92 using similar procedure with 'f3', 'f7', and coordinates of Nodes #82 and #91. Remember to use unit coordinates.

Using isosceles triangle bases f8 thru f11 plus f12 side angle, calculate panels P41 thru P44.



Subtract F25, F33, F35, F40 and F42 from 360 degrees to produce F48. Using half of F48 as ∡A and f12 as ∡c in SPHR calculate F49 and f13 within panel P45.

Using similar procedure, calculate panels P46 and P47.

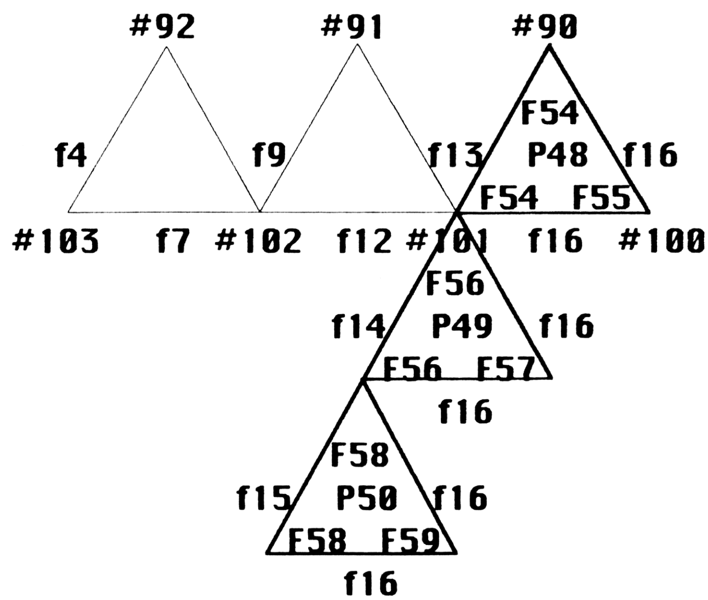


Subtract F41 and F49 from 180 degrees to calculate F54. Using F54 as ∡B and half of f13 as ∡a within SPHR, calculate f16 and F55 (2 x ∡A) in panel P48. Carry f16 to outer edge of fill-in.

Adding f16 to #90 ∡ w/Top, calculate #100 using PDGN.

Calculate 'blind' nodes using BLND: (use unit coordinates)

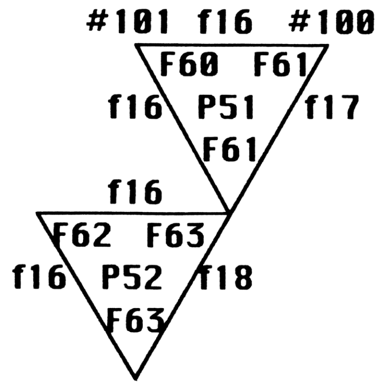
Sph.R	Diag ∡	Tang ∡	Node#	x,y,z	x,y,z
4,200	f13	f16	101	#90	#100
4,200	f9	f12	102	#91	#101
4,200	f4	f7	103	#92	#102



Using half of f14 plus f16, calculate panel P49. Using half of f15 and f16, calculate panel P50.

Subtract F43, F49, F51, F54 and F56 from 360 deg. to calculate F60. Using half of F60 as ∡A and f16 as ∡c, calculate f17 and F61 of panel P51 within SPHR.

Using similar procedure, calculate panel P52.

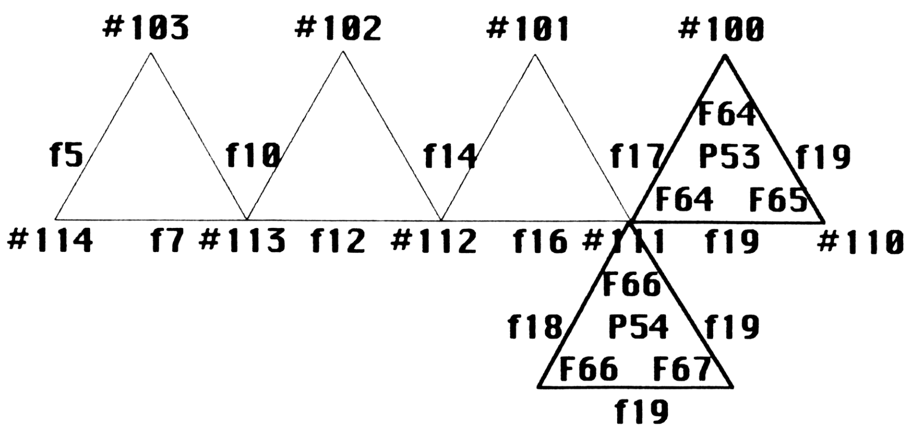


Subtract F55 and F61 from 180 deg. to calculate F64. Using F64 as ∡B and half of f17 as ∡a, calculate f19 and F65 of panel P53 using SPHR.

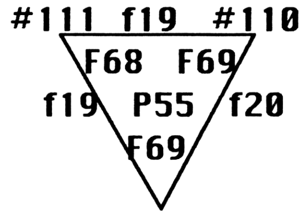
Adding f19 to #100 ∡ w/Top, calculate #110 using PDGN.

Calculate 'blind' nodes using BLND: (use unit coordinates)

Sph.R	Diag ∡	Tang ∡	Node#	x,y,z	x,y,z
4,200	f17	f19	111	#100	#110
4,200	f14	f16	112	#101	#111
4,200	f10	f12	113	#102	#112
4,200	f5	f7	114	#103	#113



Subtract F57, F61, F63, F64 and F66 form 360 deg. to calculate F68. Using half of F68 as ∡A and f19 as ∡c, calculate f20 and F69 of panel P55 within SPHR.

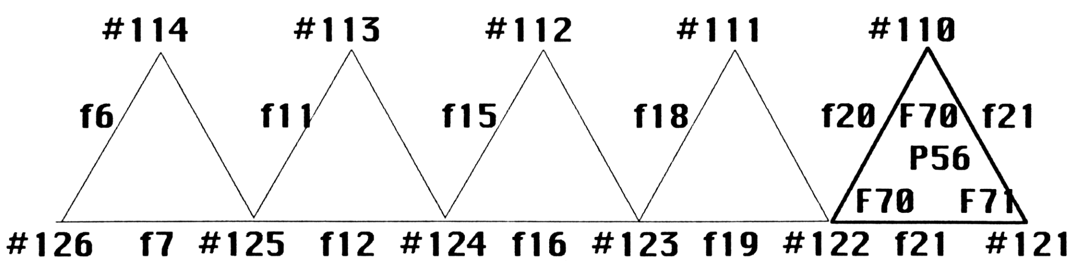


Subtract F65 and F69 from 180 deg. to calculate F70. Using F70 as ∡B and half of f20 as ∡a, calculate f21 and F71 of panel P56 using SPHR.

Adding f21 to #110 ∡ w/Top, calculate #121 using PDGN.

Calculate 'blind' nodes using BLND: (use unit coordinates)

Sph.R	Diag ∡	Tang ∡	Node#	x,y,z	x,y,z
4,200	f20	f21	122	#110	#121
4,200	f18	f19	123	#111	#122
4,200	f15	f16	124	#112	#123
4,200	f11	f12	125	#113	#124
4,200	f6	f7	126	#114	#125



Calculate #127 and compare with GEOM #127, to verify #126:

'Blind' #127: x = 448.5205", y = 2,341.2653", z = 3,457.9338"
GEOM #127: x = 448.5204", y = 2,341.2653", z = 3,457.9338"

Therefore, 'blind' node calculations are valid.

For sake of brevity, BARF will not duplicate results which are straight forward relative to fixed program inputs resulting in fixed program outputs.

With exception of inner diagonal GEOM generated nodes, the fill-in principal diagonal and outer edge node coordinates will be listed.

Node 72
x = 0.202949336
y = 0.421428639
z = 0.883860549

∡ w/Top = 27.888375444

x = 852.387211339
y = 1770.00028251
z = 3712.21430441

Node 81
x = 0.212538490
y = 0.441340721
z = 0.871806032

∡ w/Top = 29.330804775

x = 892.661656152
y = 1853.63102889
z = 3661.58533649

Node 90
x = 0.221879846
y = 0.460738248
z = 0.859354177

∡ w/Top = 30.755852974

x = 931.895353717
y = 1935.10064136
z = 3609.28754154

CIRCULAR EDGE

Node 100
x = 0.230954542
y = 0.479582049
z = 0.846558360

∡ w/Top = 32.160712285

x = 970.009078240
y = 2014.24460583
z = 3555.54511376

Node 110
x = 0.239747534
y = 0.497840884
z = 0.833472000

∡ w/Top = 33.542933987

x = 1006.93964201
y = 2090.93171168
z = 3500.58239932

Node 121
x = 0.248247527
y = 0.515491302
z = 0.820147476

∡ w/Top = 34.900440594

x = 1042.63961471
y = 2165.06346886
z = 3444.61939983

Node 122
x = 0.22615842
y = 0.52400074
z = 0..82114286

∡ w/Top = 34.80063731

x = 949.86534854
y = 2200.80309641
z = 3448.80001602

Node 123
x = 0.20339836
y = 0.53195240
z = 0.82198282

∡ w/Top = 34.71622334

x = 854.27312787
y = 2234.20007832
z = 3452.32782815

Node 124
x = 0.18001755
y = 0.53930579
z = 0.82264387

∡ w/Top = 34.64966178

x = 756.07369278
y = 2265.08433433
z = 3455.10427186

Node 125
x = 0.15607559
y = 0.54602487
z = 0.82310221

∡ w/Top = 34.60344598

x = 655.51746222
y = 2293.30444133
z = 3457.02930218

Node 126
x = 0.13164103
y = 0.55207902
z = 0.82333432

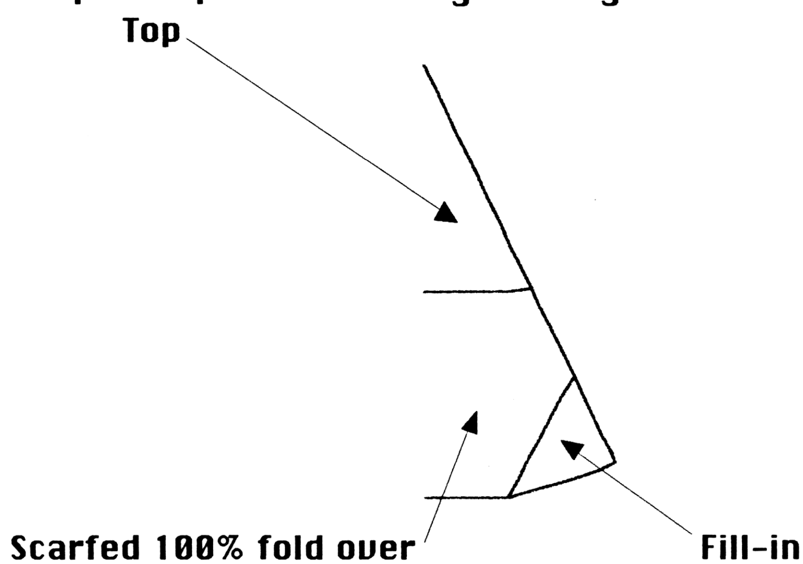
∡ w/Top = 34.58002197

x = 552.89233167
y = 2318.73188133
z = 3458.00412552

Following completion of the top, scarfed 100% fold over and fill-in portions of the geometry, the transition portion should now be addressed.

The lower circular boundary of the transition is more or less arbitrary, with primary considerations being panel width and gusset spherical surface angles. The transition portion has the only left hand and right hand panel details, excluding the panel centered on the sector symmetrical centerline and the panel centered on the principal diagonal.

In review, the completed portion of the geometry is:



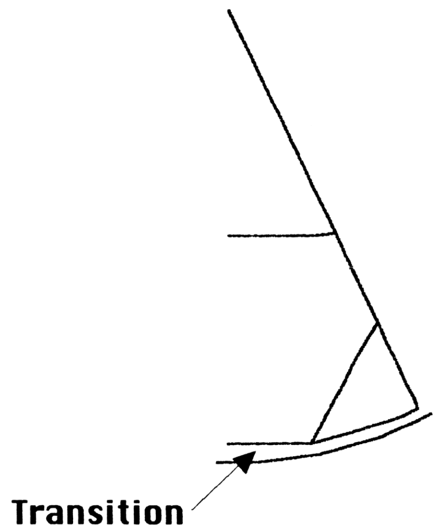
BARF selected a lower boundary angle, from zenith, of: 35.72°. This resulted in a maximum strut length of 137.6059", a minimum gusset angle of 46.34° and maximum panel width of 102.7212", within the transition. The last node number from GEOM was #131.

Using CRCL routine:

		---1st Node:---		
# Nodes/360°	Sph.R?	#?	Pos.Fr.Ctr.	∡Fr.Zenith
140	4,200	132	10.5	35.72

Last generated node number from CRCL: 143

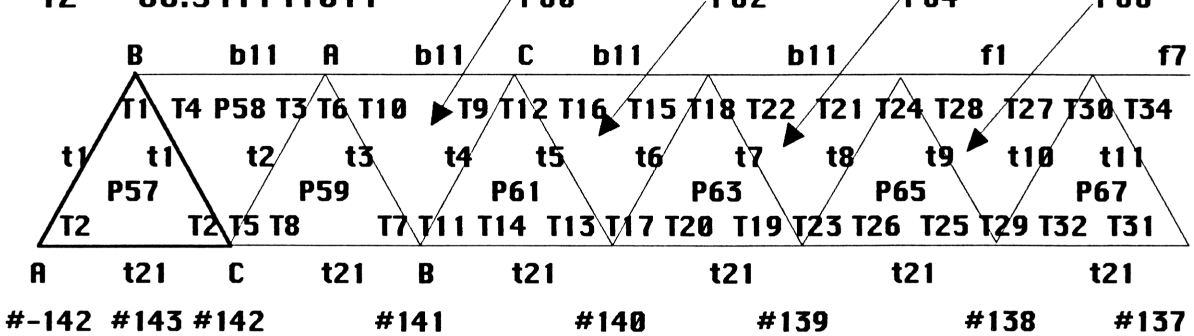
After adding lower boundary of transition:



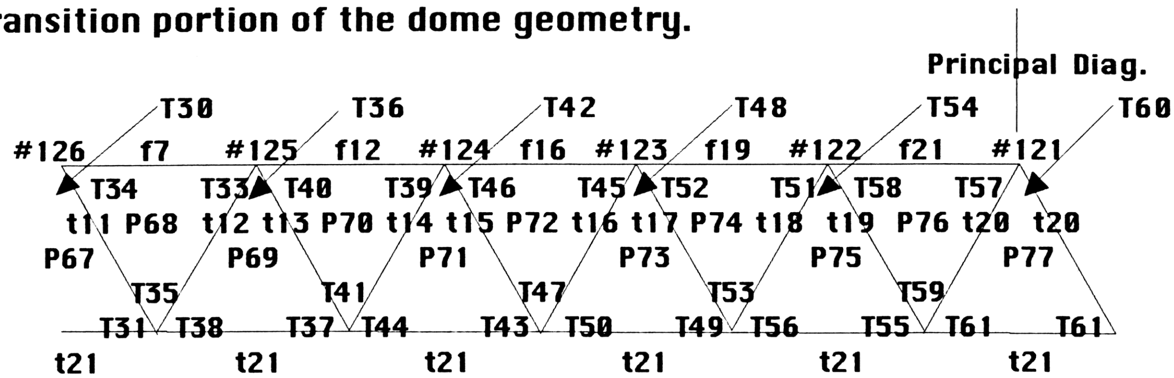
Starting with the centerline panel, P57, bounded by nodes 131, 142 and (-) 142, use SPHO to calculate struts t1, t1, t21 and spherical surface angles T1 and T2. Sph.R and coordinates to be in same units.
Transition struts and spherical surface angles are 't' and 'T'.
"R=?" = 4,200 Following 'A','B' and 'C' inputs, Key 'E'.

	Node 131 B	Node 142 C	Node -142 A
	0.0	55.01955881	-55.01955881
	2348.61019458	2451.44617108	2451.44617108
	3481.95780473	3409.89508907	3409.89508907
t1	**1.870331976**	**0.032642002**	**137.0964**
t21	**1.501180324**	**0.026199790**	**110.0391**

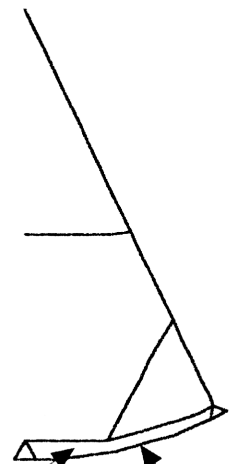
T1 47.328162775
T2 66.347141077



Following the calculation of P57, input node #130 coordinates and key 'A' and key 'E' to execute panel P58 data. You may 'daisy-chain' nodes in a similar manner to calculate the balance of the transition portion of the dome geometry.



With the transition portion now complete:



Using LATT, calculate the successive ∡ w/Top rows of the skirt.
From GEOM: Use the P1 width factor as Target w.

Target w?	# PIERS	Top ∡	Btm ∡
0.02545142	140	35.72	Arbitrarily 37.44

Because of the size of spherical surface angle, S2, BARF selected an arbitrary bottom angle of 37.42 degrees. Current standard practice dictates that when the gusset angle goes below a certain value, the strut flange must be mitered beyond what is reasonable for typical flange widths and hole patterns.

The following lists the successive skirt boundary angles selected by BARF.

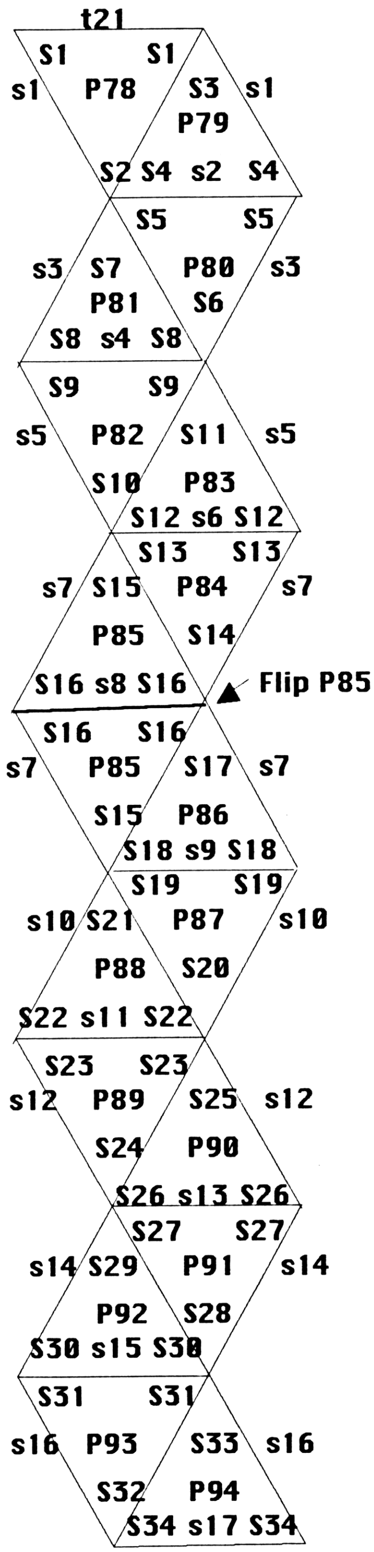
Skirt row	∡ w/Top	Max. Panel w (Target = 0.02545142)	
Top	35.72° Ref	0.0244574286	↓
2nd	37.42° Ref	0.024760023	
3rd	39.09°	0.025434748	
4th	40.580000430°	0.025426867	
5th	42.045541841°	0.025451421	Btm panel controls
Flip P85			
6th	43.496733197°	0.025451421	Top panel controls
7th	44.947898973°	0.025451419	↓
8th	46.399057705°	0.025451420	
9th	47.850227751°	0.025451419	
10th	49.301427520°	0.025451419	
11th	50.752675365°	0.025451420	
12th	52.203989444°	0.025451420	
13th	53.655387783°	0.025451420	
14th	55.106888185°	0.025451420	
15th	56.558508245°	0.025451420	
16th	58.010265228°	0.025451420	
17th	59.462176060°	0.025451420	
18th	60.914257288°	0.025451420	
19th	62.366525002°	0.025451420	
20th	63.818994938°	0.025451420	
21st	65.271682166°	0.025451420	
22nd	66.724601330°	0.025451420	
23rd	68.177766468°	0.025451420	
24th	69.631190976°	0.025451420	
25th	71.084887621°	0.025451420	

Skirt struts and spherical surface angles are ‘s’ and ‘S’.

CIRCULAR EDGE

The skirt legend is:

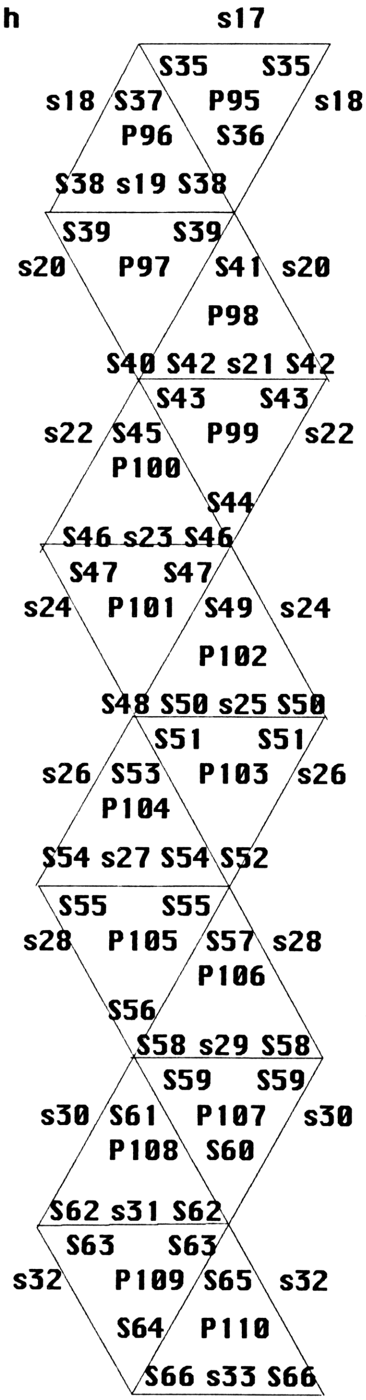
Top



∡ w/Top	Span	Rise
35.72°	408.68'	65.84'
37.42°	425.36'	72.03'
39.09°	441.38'	78.35'
40.58000043°	455.36'	84.18'
42.04554184°	468.80'	90.09'
43.49673320°	481.82'	96.11'
44.94789897°	494.52'	102.29'
46.39905771°	506.91'	108.63'
47.850227751°	518.98'	115.13'
49.30142752°	530.71'	121.77'

Skirt legend: (Cont.)

10th

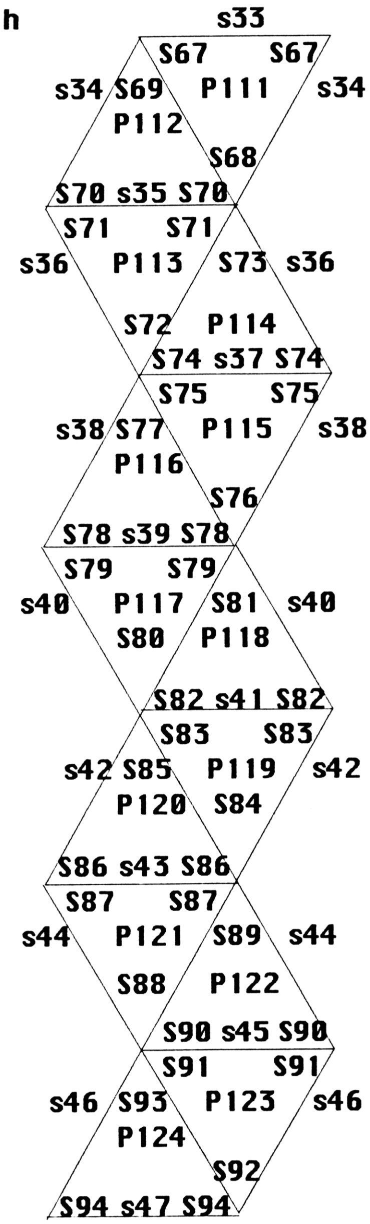


∡ w/Top	Span	Rise
49.30142752 °(Ref)	530.71’(Ref)	121.77’(Ref)
50.752675365°	542.10’	128.57’
52.203989444°	553.14’	135.50’
53.655387783°	563.83’	142.58’
55.106888185°	574.15’	149.78’
56.558508245°	584.11’	157.12’
58.010265228°	593.70’	164.58’
59.462176060°	602.91’	172.16’
60.914257288°	611.73’	179.86’

CIRCULAR EDGE

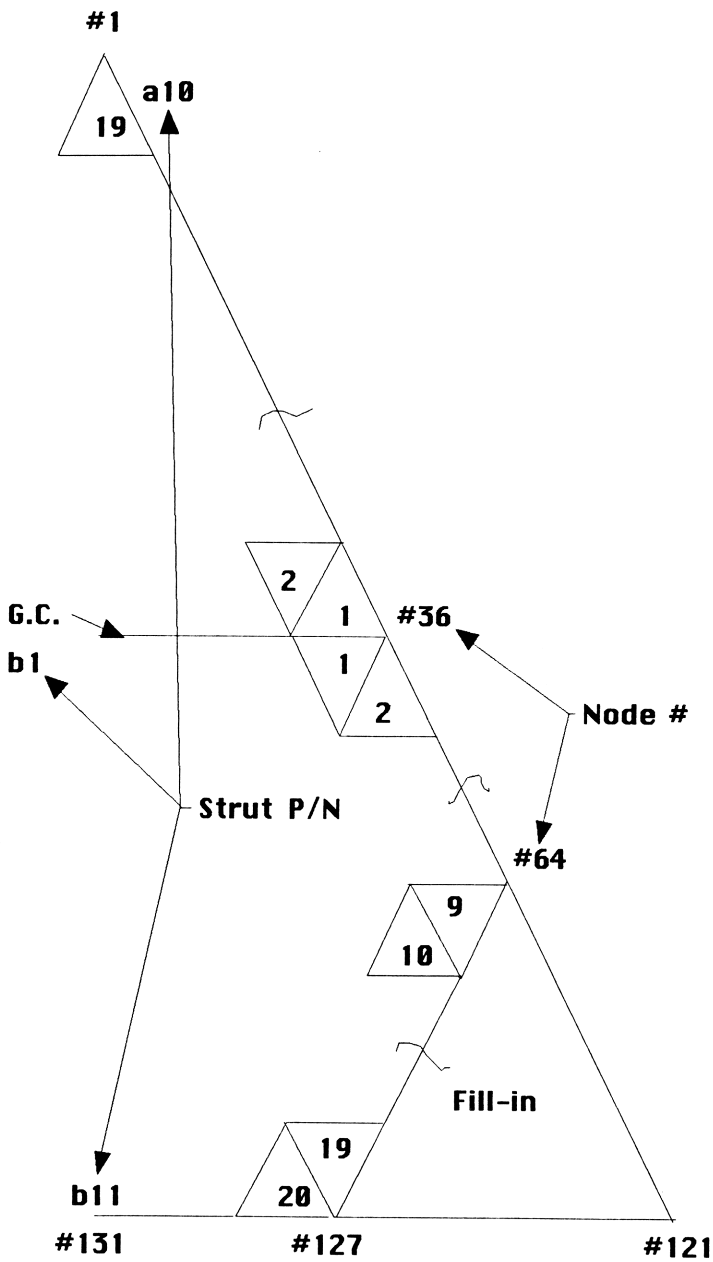
Skirt legend: (Cont.)

18th



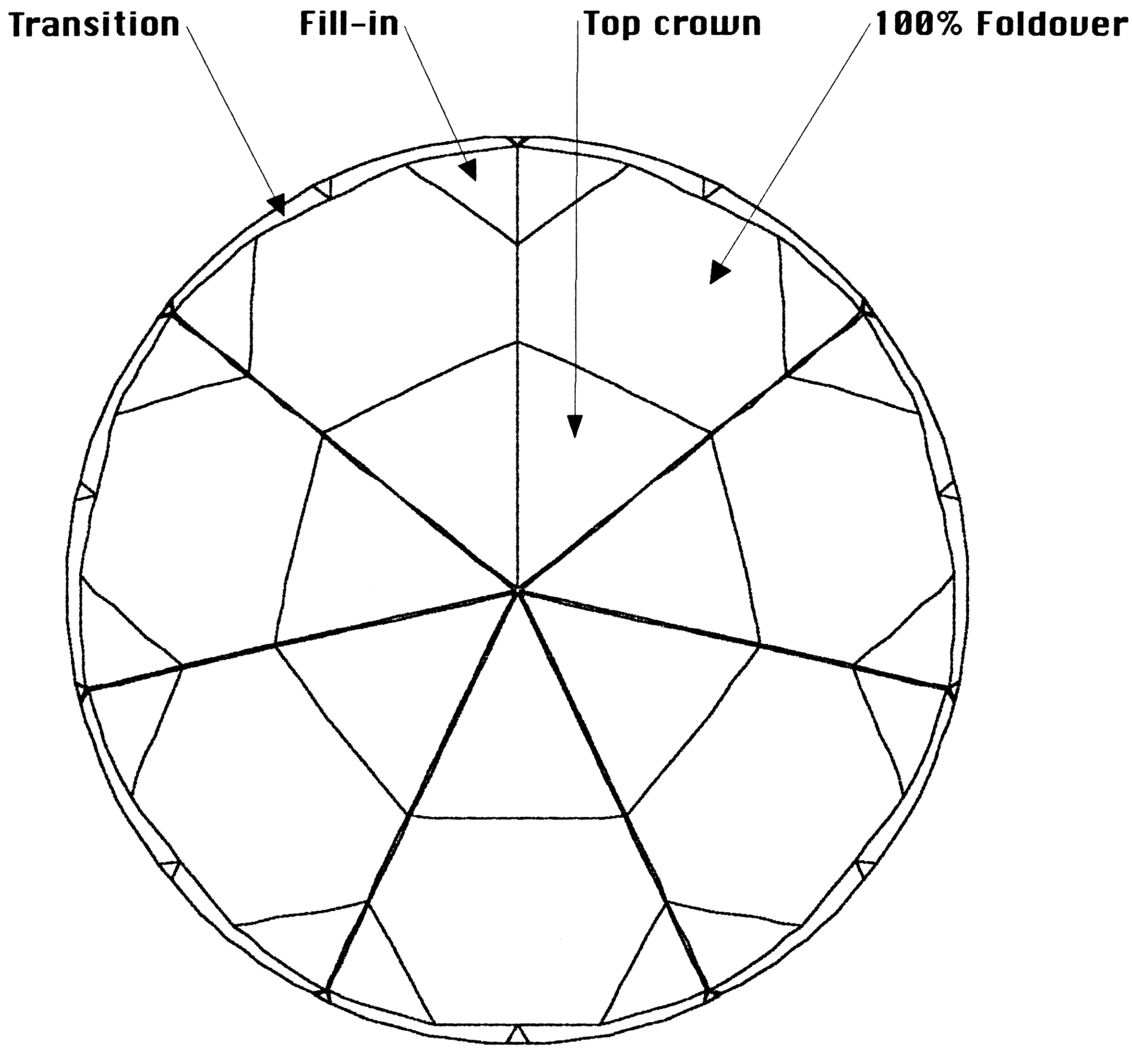
∡ w/Top	Span	Rise
60.914257288°(Ref)	611.73'(Ref)	179.86'(Ref)
62.366525002°	620.15'	187.67'
63.818994938°	628.18'	195.58'
65.271682166°	635.81'	203.59'
66.724601330°	643.03'	211.70'
68.177766468°	649.84'	219.90'
69.631190976°	656.23'/200m	228.18'/69.5m
71.084887621°	662.20'	236.54'

CIRCULAR EDGE



GEOM generated panels

Full dome less skirt:



Skirt node generation using CRCL:

		---1st Node:---		
# Nodes/360°	Sph.R?	#?	Pos.Fr.Ctr.	∡Fr.Zenith
140	4200.	144	10.	37.42°
140	4200.	155	10.5	39.09°
140	4200.	167	10.	40.58000043°
140	4200.	178	10.5	42.045541841°
140	4200.	190	10.	43.496733197°
140	4200.	201	10.5	44.947898973°
140	4200.	213	10.	46.399057705°
140	4200.	224	10.5	47.850227751°
140	4200.	236	10.	49.30142752°
140	4200.	247	10.5	50.752675365°
140	4200.	259	10.	52.203989444°
140	4200.	270	10.5	53.655387783°
140	4200.	282	10.	55.106888185°
140	4200.	293	10.5	56.558508245°
140	4200.	305	10.	58.010265228°
140	4200.	316	10.5	59.46217606°
140	4200.	328	10.	60.914257288°
140	4200.	339	10.5	62.366525002°
140	4200.	351	10.	63.818994938°
140	4200.	362	10.5	65.271682166°
140	4200.	374	10.	66.72460133°
140	4200.	385	10.5	68.177766468°
140	4200.	397	10.	69.631190976°
140	4200.	408	10.5	71.084887621°

CIRCULAR EDGE

Parts List: Panels 200 Meter Span Geometry

I.D.	QTY	SIDES	I.D.	QTY	SIDES	I.D.	QTY	SIDES
1	140	b1 a1 a1	43	14	f10 f12 f12	84	140	s6 s7 s7
2	140	b2 a1 a1	44	14	f11 f12 f12	85	280	s8 s7 s7
3	140	b2 a2 a2	45	14	f13 f12 f12	86	140	s9 s7 s7
4	140	b3 a2 a2	46	14	f14 f12 f12	87	140	s9 s10 s10
5	140	b3 a3 a3	47	14	f15 f12 f12	88	140	s11 s10 s10
6	140	b4 a3 a3	48	14	f13 f16 f16	89	140	s11 s12 s12
7	140	b4 a4 a4	49	14	f14 f16 f16	90	140	s13 s12 s12
8	140	b5 a4 a4	50	14	f15 f16 f16	91	140	s13 s14 s14
9	140	b5 a5 a5	51	14	f17 f16 f16	92	140	s15 s14 s14
10	126	b6 a5 a5	52	14	f18 f16 f16	93	140	s15 s16 s16
11	126	b6 a6 a6	53	14	f17 f19 f19	94	140	s17 s16 s16
12	112	b7 a6 a6	54	14	f18 f19 f19	95	140	s17 s18 s18
13	112	b7 a7 a7	55	14	f20 f19 f19	96	140	s19 s18 s18
14	98	b8 a7 a7	56	14	f20 f21 f21	97	140	s19 s20 s20
15	98	b8 a8 a8	57	7	t21 t1 t1	98	140	s21 s20 s20
16	84	b9 a8 a8	58	7L 7R	b11 t1 t2	99	140	s21 s22 s22
17	84	b9 a9 a9	59	7L 7R	t21 t2 t3	100	140	s23 s22 s22
18	70	b10 a9 a9	60	7L 7R	b11 t3 t4	101	140	s23 s24 s24
19	70	b10 a10 a10	61	7L 7R	t21 t4 t5	102	140	s25 s24 s24
20	56	b11 a10 a10	62	7L 7R	b11 t5 t6	103	140	s25 s26 s26
21	14	a5 f1 f1	63	7L 7R	t21 t6 t7	104	140	s27 s26 s26
22	14	a6 f1 f1	64	7L 7R	b11 t7 t8	105	140	s27 s28 s28
23	14	a7 f1 f1	65	7L 7R	t21 t8 t9	106	140	s29 s28 s28
24	14	a8 f1 f1	66	7L 7R	f1 t9 t10	107	140	s29 s30 s30
25	14	a9 f1 f1	67	7L 7R	t21 t10 t11	108	140	s31 s30 s30
26	14	a10 f1 f1	68	7L 7R	f7 t11 t12	109	140	s31 s32 s32
27	14	f2 f1 f1	69	7L 7R	t21 t12 t13	110	140	s33 s32 s32
28	14	f3 f1 f1	70	7L 7R	f12 t13 t14	111	140	s33 s34 s34
29	14	f4 f1 f1	71	7L 7R	t21 t14 t15	112	140	s35 s34 s34
30	14	f5 f1 f1	72	7L 7R	f16 t15 t16	113	140	s35 s36 s36
31	14	f6 f1 f1	73	7L 7R	t21 t16 t17	114	140	s37 s36 s36
32	14	f2 f7 f7	74	7L 7R	f19 t17 t18	115	140	s37 s38 s38
33	14	f3 f7 f7	75	7L 7R	t21 t18 t19	116	140	s39 s38 s38
34	14	f4 f7 f7	76	7L 7R	f21 t19 t20	117	140	s39 s40 s40
35	14	f5 f7 f7	77	7	t21 t20 t20	118	140	s41 s40 s40
36	14	f6 f7 f7	78	140	t21 s1 s1	119	140	s41 s42 s42
37	14	f8 f7 f7	79	140	s2 s1 s1	120	140	s43 s42 s42
38	14	f9 f7 f7	80	140	s2 s3 s3	121	140	s43 s44 s44
39	14	f10 f7 f7	81	140	s4 s3 s3	122	140	s45 s44 s44
40	14	f11 f7 f7	82	140	s4 s5 s5	123	140	s45 s46 s46
41	14	f8 f12 f12	83	140	s6 s5 s5	124	140	s47 s46 s46
42	14	f9 f12 f12						

CIRCULAR EDGE

Parts List: Struts

I.D.	QTY	Central Angle°	Chord Factor	Length(in.)	Panels
a1	280	1.93094645	0.03369978	141.5391	1 2
a2	280	1.92732285	0.03363654	141.2735	3 4
a3	280	1.92011910	0.03351083	140.7455	5 6
a4	280	1.90942078	0.03332414	139.9614	7 8
a5	273	1.89535314	0.03307864	138.9303	9 10 21
a6	245	1.87807744	0.03277717	137.6641	11 12 22
a7	217	1.85778654	0.03242307	136.1769	13 14 23
a8	189	1.83469967	0.03202018	134.4048	15 16 24
a9	161	1.80905688	0.03157269	132.6053	17 18 25
a10	133	1.78111332	0.03108504	130.5572	19 26
b1	70	1.60289862	0.02797495	117.4948	1
b2	140	1.60214512	0.02796180	117.4395	2 3
b3	140	1.59989157	0.02792247	117.2744	4 5
b4	140	1.59615864	0.02785732	117.0008	6 7
b5	140	1.59098020	0.02776695	116.6212	8 9
b6	126	1.58440251	0.02765216	116.1391	10 11
b7	112	1.57648309	0.02751395	115.5586	12 13
b8	98	1.56728945	0.02735351	114.8847	14 15
b9	84	1.55689753	0.02717215	114.1230	16 17
b10	70	1.54539013	0.02697133	113.2796	18 19
b11	56	1.53285530	0.02675257	112.3608	20 58 60 62 64
f1	161	1.45667007	0.02542300	106.7766	21->31 66
f2	14	1.88637552	0.03292198	138.2723	27 32
f3	14	1.86759567	0.03259425	136.8959	28 33
f4	14	1.84591024	0.03221582	135.3064	29 34
f5	14	1.82154868	0.03179068	133.5209	30 35
f6	14	1.79475846	0.03132316	131.5573	31 36
f7	133	1.44242933	0.02517448	105.7328	32->40 68
f8	14	1.87525297	0.03272788	137.4571	37 41
f9	14	1.85508428	0.03237591	135.9788	38 42
f10	14	1.83212954	0.03197533	134.2964	39 43
f11	14	1.80662536	0.03153025	132.4271	40 44
f12	105	1.42504820	0.02487114	104.4588	41->47 70
f13	14	1.86216200	0.03249943	136.4976	45 48
f14	14	1.84072774	0.03212538	134.9266	46 49
f15	14	1.81663353	0.03170491	133.1606	47 50

CIRCULAR EDGE

Parts List: Struts

I.D.	QTY	Central Angle°	Chord Factor	Length(in.)	Panels
f16	77	1.40485931	0.02451881	102.9790	48->52 72
f17	14	1.84729713	0.03224002	135.4081	51 53
f18	14	1.82472450	0.03184610	133.7536	52 54
f19	49	1.38222170	0.02412373	101.3197	53 54 55 74
f20	14	1.83086384	0.03195324	134.2036	55 56
f21	21	1.35750661	0.02369241	99.5081	56 76
t1	14	1.87033198	0.03264200	137.0964	57 58
t2	14	1.87728377	0.03276332	137.6059	58 59
t3	14	1.80057360	0.03142465	131.9835	59 60
t4	14	1.82370541	0.03182832	133.6789	60 61
t5	14	1.66711566	0.02909563	122.2016	61 62
t6	14	1.71402804	0.02991432	125.6401	62 63
t7	14	1.47034557	0.02566167	107.7790	63 64
t8	14	1.55676703	0.02716988	114.1135	64 65
t9	14	1.21269826	0.02116518	88.8938	65 66
t10	14	1.55611554	0.02715850	114.0657	66 67
t11	14	1.21523175	0.02120940	89.0795	67 68
t12	14	1.52705963	0.02665143	111.9360	68 69
t13	14	1.19972508	0.02093877	87.9428	69 70
t14	14	1.46825304	0.02562515	107.6256	70 71
t15	14	1.17159601	0.02044785	85.8810	71 72
t16	14	1.37877542	0.02406359	101.0671	72 73
t17	14	1.13864366	0.01987275	83.4656	73 74
t18	14	1.25811257	0.02195777	92.2226	74 75
t19	14	1.11196144	0.01940708	81.5098	75 76
t20	14	1.10628381	0.01930800	81.0936	76 77
t21	140	1.50118032	0.02619979	110.0391	57odd>77 78
s1	280	1.86454147	0.03254095	136.6720	78 79
s2	140	1.56245384	0.02726912	114.5303	79 80
s3	280	1.84995767	0.03228645	135.6031	80 81
s4	140	1.62130750	0.02829621	118.8441	81 82
s5	280	1.70241029	0.02971157	124.7886	82 83
s6	140	1.67265682	0.02919233	122.6078	83 84
s7	560	1.69353041	0.02955661	124.1378	84 85 86
s8	140	1.72206023	0.03005449	126.2289	85
s9	140	1.76987010	0.03088883	129.7331	86 87
s10	280	1.70580824	0.02977087	125.0377	87 88

CIRCULAR EDGE

Parts List: Struts

I.D.	QTY	Central Angle°	Chord Factor	Length(in.)	Panels
s11	140	1.81654403	0.03170335	133.1541	88 89
s12	280	1.71803063	0.02998417	125.9335	89 90
s13	140	1.86205272	0.03249752	136.4896	90 91
s14	280	1.73016772	0.03019598	126.8231	91 92
s15	140	1.90636752	0.03327086	139.7376	92 93
s16	280	1.74219068	0.03040579	127.7043	93 94
s17	140	1.94946049	0.03402286	142.8960	94 95
s18	280	1.75407151	0.03061313	128.5751	95 96
s19	140	1.99130443	0.03475307	145.9629	96 97
s20	280	1.76578297	0.03081751	129.4335	97 98
s21	140	2.03187285	0.03546101	148.9363	98 99
s22	280	1.77729882	0.03101847	130.2776	99 100
s23	140	2.07114000	0.03614624	151.8142	100 101
s24	280	1.78859368	0.03121558	131.1054	101 102
s25	140	2.10908089	0.03680833	154.5950	102 103
s26	280	1.79964312	0.03140841	131.9153	103 104
s27	140	2.14567131	0.03744684	157.2767	104 105
s28	280	1.81042362	0.03159654	132.7055	105 106
s29	140	2.18088783	0.03806138	159.8578	106 107
s30	280	1.82091257	0.03177958	133.4742	107 108
s31	140	2.21470780	0.03865154	162.3365	108 109
s32	280	1.83108834	0.03195716	134.2201	109 110
s33	140	2.24710941	0.03921694	164.7112	110 111
s34	280	1.84093020	0.03212891	134.9414	111 112
s35	140	2.27807164	0.03975723	166.9804	112 113
s36	280	1.85041847	0.03229449	135.6369	113 114
s37	140	2.30757436	0.04027205	169.1426	114 115
s38	280	1.85953423	0.03245357	136.3050	115 116
s39	140	2.33559822	0.04076106	171.1964	116 117
s40	280	1.86825970	0.03260584	136.9445	117 118
s41	140	2.36212481	0.04122394	173.1405	118 119
s42	280	1.87657795	0.03275100	137.5542	119 120
s43	140	2.38713655	0.04166038	174.9736	120 121
s44	280	1.88447299	0.03288878	138.1329	121 122
s45	140	2.41061676	0.04207010	176.6944	122 123
s46	280	1.89192980	0.03301890	138.6794	123 124
s47	140	2.43254969	0.04245281	178.3018	124

Gusset Angle Listing: (Rounded; do not use in geometry calculations)
To be used for gusset layout only

I.D.	Degrees	I.D.	Degrees	I.D.	Degrees	I.D.	Degrees
A1	65.49	F1	81.18	F36	78.86	F71	84.81
A2	65.45	F2	49.87	F37	50.58	T1	47.33
A3	65.39	F3	80.28	F38	77.55	T2	66.35
A4	65.30	F4	50.39	F39	51.23	T3	65.63
A5	65.19	F5	79.24	F40	48.86	T4	66.10
A6	65.06	F6	50.97	F41	82.29	T5	48.29
A7	64.90	F7	78.07	F42	49.40	T6	48.13
A8	64.72	F8	51.62	F43	81.22	T7	68.62
A9	64.52	F9	76.78	F44	50.00	T8	63.27
A10	64.30	F10	52.32	F45	80.01	T9	64.21
B1	49.03	F11	75.38	F46	50.67	T10	65.77
B2	49.05	F12	80.71	F47	78.68	T11	50.04
B3	49.13	F13	49.65	F48	81.60	T12	50.70
B4	49.25	F14	79.75	F49	49.21	T13	70.07
B5	49.42	F15	50.14	F50	80.46	T14	59.25
B6	49.64	F16	78.64	F51	49.78	T15	61.50
B7	49.91	F17	50.69	F52	79.20	T16	64.62
B8	50.22	F18	77.41	F53	50.41	T17	53.90
B9	50.58	F19	51.31	F54	48.50	T18	55.63
B10	50.98	F20	76.06	F55	83.03	T19	70.45
B11	51.43	F21	51.98	F56	49.08	T20	53.94
C2	65.50	F22	49.17	F57	81.86	T21	56.84
C3	65.49	F23	81.68	F58	49.72	T22	62.41
C4	65.45	F24	49.66	F59	80.57	T23	60.77
C5	65.39	F25	80.69	F60	82.22	T24	64.25
C6	65.30	F26	50.22	F61	48.90	T25	69.07
C7	65.19	F27	79.57	F62	81.00	T26	46.69
C8	65.06	F28	50.85	F63	49.51	T27	47.33
C9	64.90	F29	78.32	F64	48.07	T28	70.65
C10	64.72	F30	51.53	F65	83.87	T29	62.03
C11	64.52	F31	76.95	F66	48.70	T30	64.23
		F32	81.09	F67	82.62	T31	68.98
		F33	49.46	F68	82.96	T32	46.80
		F34	80.04	F69	48.53	T33	48.21
		F35	49.99	F70	47.60	T34	69.54

CIRCULAR EDGE

Gusset Angle Listing: (Rounded; do not use in geometry calculations)

I.D.	Degrees	I.D.	Degrees	I.D.	Degrees	I.D.	Degrees
T35	62.26	S1	66.27	S33	68.05	S64	74.43
T36	65.54	S2	47.48	S34	55.99	S65	75.71
T37	67.81	S3	49.55	S35	56.25	S66	52.16
T38	46.67	S4	65.24	S36	67.53	S67	52.40
T39	48.97	S5	65.03	S37	69.18	S68	75.23
T40	67.40	S6	49.97	S38	55.42	S69	76.46
T41	63.64	S7	51.99	S39	55.69	S70	51.79
T42	68.25	S8	64.02	S40	68.65	S71	52.02
T43	65.29	S9	61.57	S41	70.26	S72	75.99
T44	46.46	S10	56.88	S42	54.88	S73	77.16
T45	49.77	S11	58.85	S43	55.15	S74	51.44
T46	63.96	S12	60.58	S44	69.73	S75	51.66
T47	66.28	S13	60.41	S45	71.29	S76	76.71
T48	72.51	S14	59.19	S46	54.37	S77	77.82
T49	61.16	S15	61.13	S47	54.63	S78	51.11
T50	46.34	S16	59.45	S48	70.77	S79	51.32
T51	50.83	S17	63.01	S49	72.26	S80	77.39
T52	58.94	S18	58.50	S50	53.88	S81	78.43
T53	70.24	S19	58.76	S51	54.14	S82	50.80
T54	78.34	S20	62.51	S52	71.75	S83	51.01
T55	55.17	S21	64.35	S53	73.20	S84	78.02
T56	46.51	S22	57.84	S54	53.42	S85	79.00
T57	52.46	S23	58.09	S55	53.67	S86	50.51
T58	52.08	S24	63.84	S56	72.69	S87	50.71
T59	75.47	S25	65.64	S57	74.08	S88	78.61
T60	85.45	S26	57.19	S58	52.97	S89	79.53
T61	47.28	S27	57.45	S59	53.22	S90	50.25
		S28	65.12	S60	73.58	S91	50.44
		S29	66.87	S61	74.92	S92	79.16
		S30	56.58	S62	52.55	S93	80.02
		S31	56.84	S63	52.80	S94	50.00
		S32	66.35				

Parts List: Gussets (Top & Btm)

Nodes	QTY	Spherical Surface Angles						
1	2	B11	B11	B11	B11	B11	B11	B11
2	14	A10	C10	B10	B10	C10	A10	
4	14	A9	C9	B9	B9	C9	A9	
5 105->109	140	B9	A9	C9	B9	C9	A9	
6	14	A8	C8	B8	B8	C8	A8	
7 94->98	168	B8	A8	C8	B8	C8	A8	
9	14	A7	C7	B7	B7	C7	A7	
10 11 84->89	196	B7	A7	C7	B7	C7	A7	
12	14	A6	C6	B6	B6	C6	A6	
13 14 74->79	224	B6	A6	C6	B6	C6	A6	
16 64	28	A5	C5	B5	B5	C5	A5	
17->19 65->71	252	B5	A5	C5	B5	C5	A5	
20 56	28	A4	C4	B4	B4	C4	A4	
21->23 57->62	252	B4	A4	C4	B4	C4	A4	
25 49	28	A3	C3	B3	B3	C3	A3	
26->29 50->55	252	B3	A3	C3	B3	C3	A3	
30 42	28	A2	C2	B2	B2	C2	A2	
31->34 43->47	252	B2	A2	C2	B2	C2	A2	
36	14	A1	A1	B1	B1	A1	A1	
37->41	126	B1	A1	A1	B1	A1	A1	
72	14	F1	F13	F22	F22	F13	F1	
73	14L 14R	B6	C6	A6	F2	F12	B5	
81	14	F23	F33	F40	F40	F33	F23	
82	14L 14R	F13	F3	F15	F24	F32	F22	
83	14L 14R	B7	C7	A7	F4	F14	F2	
90	14	F41	F49	F54	F54	F49	F41	
91	14L 14R	F33	F25	F35	F42	F48	F40	
92	14L 14R	F15	F5	F17	F26	F34	F24	
93	14L 14R	B8	C8	A8	F6	F16	F4	
100	14	F55	F61	F64	F64	F61	F55	
101	14L 14R	F49	F43	F51	F56	F60	F54	
102	14L 14R	F35	F24	F37	F44	F50	F42	
103	14L 14R	F17	F7	F19	F28	F36	F26	
104	14L 14R	B9	C9	A9	F8	F18	F6	
110	14	F65	F69	F70	F70	F69	F65	
111	14L 14R	F61	F57	F63	F66	F68	F64	
112	14L 14R	F51	F45	F53	F58	F62	F56	

CIRCULAR EDGE

Parts List: Gussets

Nodes	QTY	Spherical Surface Angles					
113	14L 14R	F37	F29	F39	F46	F52	F44
114	14L 14R	F19	F9	F21	F30	F38	F28
115	14L 14R	B10	C10	A10	F10	F20	F8
116->119	112	B10	A10	C10	B10	C10	A10
121	14	F71	T57	T60	T57	F71	
122	14L 14R	F69	F67	T51	T54	T58	F70
123	14L 14R	F63	F59	T45	T48	T52	F66
124	14L 14R	F53	F47	T39	T42	T46	F58
125	14L 14R	F39	F31	T33	T36	T40	T46
126	14L 14R	F21	F11	T27	T30	T34	F30
127	14L 14R	B11	C11	T21	T24	T28	F10
128	14L 14R	B11	C11	T15	T18	T22	C11
129	14L 14R	B11	C11	T9	T12	T16	C11
130	14L 14R	B11	C11	T3	T6	T10	C11
131	14	B11	C11	T4	T1	T4	C11
133	14L 14R	T59	T55	S1	S3	S1	T61
134	14L 14R	T53	T49	S1	S3	S1	T56
135	14L 14R	T47	T43	S1	S3	S1	T50
136	14L 14R	T41	T37	S1	S3	S1	T44
137	14L 14R	T35	T31	S1	S3	S1	T38
138	14L 14R	T29	T25	S1	S3	S1	T32
139	14L 14R	T23	T19	S1	S3	S1	T26
140	14L 14R	T17	T13	S1	S3	S1	T20
141	14L 14R	T11	T7	S1	S3	S1	T14
142	14L 14R	T5	T2	S1	S3	S1	T8
144->154	280	S2	S4	S5	S7	S5	S4
156->165	280	S6	S8	S9	S11	S9	S8
167->177	280	S10	S12	S13	S15	S13	S12
179->188	280	S14	S16	S16	S17	S16	S16
190->200	280	S15	S18	S19	S21	S19	S18
202->211	280	S20	S22	S23	S25	S23	S22
213->223	280	S24	S26	S27	S29	S27	S26
225->234	280	S28	S30	S31	S33	S31	S30
236->246	280	S32	S34	S35	S37	S35	S34
248->257	280	S36	S38	S39	S41	S39	S38

CIRCULAR EDGE

Parts List: Gussets

Nodes	QTY	Spherical Surface Angles					
259->269	280	S40	S42	S43	S45	S43	S42
271->280	280	S44	S46	S47	S49	S47	S46
282->292	280	S48	S50	S51	S53	S51	S50
294->303	280	S52	S54	S55	S57	S55	S54
305->315	280	S56	S58	S59	S61	S59	S58
317->326	280	S60	S62	S63	S65	S63	S62
328->338	280	S64	S66	S67	S69	S67	S66
340->349	280	S68	S70	S71	S73	S71	S70
351->361	280	S72	S74	S75	S77	S75	S74
363->372	280	S76	S78	S79	S81	S79	S78
374->384	280	S80	S82	S83	S85	S83	S82
386->395	280	S84	S86	S87	S89	S87	S86
397->407	280	S88	S90	S91	S93	S91	S90
409->418	280	S94	S92	S94			

BLND <u>BLIND NODE GENERATION:</u>

<u>Function</u>: Calculates the unknown x,y and z coordinates of a spherical surface node terminated by two known central angles anchored at two known spherical nodes.

When GEOM generated nodes are replaced within the 'Fill-In' portion of circular based geometries, there is no direct way to calculate the replacement node coordinates. This routine uses an iterative process to determine the x,y and z coordinates of the replacement nodes. The direction of generation is to start with nodes on the principal diagonal and work inward toward the symmetrical centerline of the geometry sector.

The time to execute is variable, with the size of the known central angles being proportional to the time required.

<u>Accuracy</u>: As listed, to ten (10) decimal places. May be revised by changing "1E10" to "1Enn" six places.

<u>Inputs</u>:

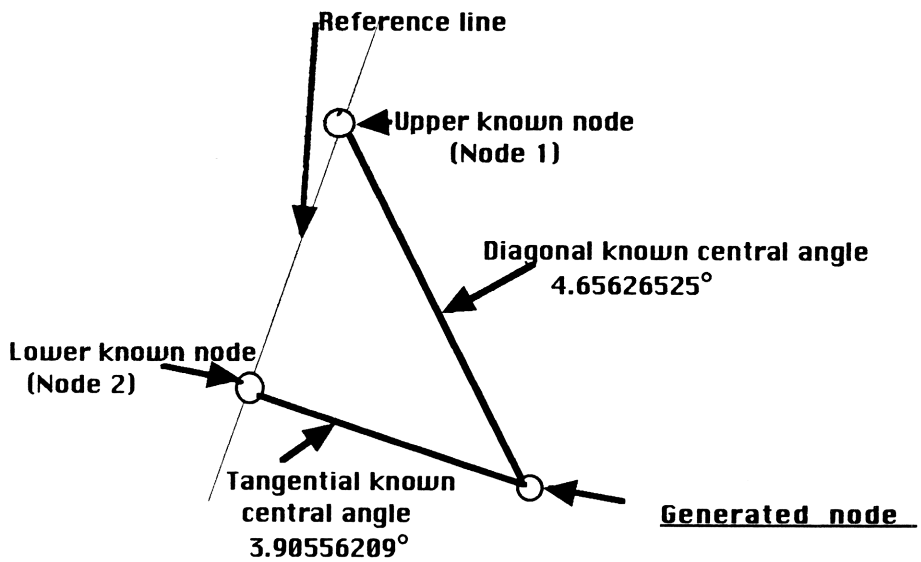
1) Non-unity spherical radius;
2) Diagonal known central angle, tangential known central angle; (Degrees)
3) Generated node number;
4) Unit coordinates of upper known node (Node 1);
5) Unit coordinates of lower known node (Node 2).

<u>Outputs</u>:

1) Generated node number;
2) Unit x,y and z coordinates of generated node;
3) Elevation angle between geometry zenith and generated node (Degrees);
4) Non-unity radius x,y and z coordinates of generated node.

BLND BLIND NODE GENERATION:

Sample:



Inputs:

(Prompt:)	(Data:	(Key:)
"Sph.R?"	120.	R/S
"Diag ∡, Tang ∡ R/S"	4.65626525	ENTER
	3.90556209	R/S
"GEN. NODE #"	21.	R/S
"USE UNIT COORD."		
"Node 1 x,y,z R/S"	0.20587956	ENTER
	0.42751331	ENTER
	0.88025336	R/S
"Node 2 x,y,z R/S"	0.23620410	ENTER
	0.49048287	ENTER
	0.83882905	R/S

(1 minute, 27 seconds)

Outputs:

"BEEP"
Node #21.
x =0.1695470384
y =0.4946330386
z =0.8524036361

∡ w/Top =31.5259274735

x =20.3456446108
y =59.3559646325
z =102.288436335

BMCL **BEAM COLUMN:**

Function: Calculates the maximum Axial Stress, f_a , in a dome strut which is effectively a beam column, to confirm that an adequate strut section has been selected. If a custom section is required, it's properties may be calculated using SECT.

Logic: Within the combined stress formula, the Bending Stress, f_b , was replaced with Bending Moment over Section Modulus, M_c/S, so that the only variable would be f_a. The maximum Axial Load, P_c , may be determined by multiplying the max. f_a by the Strut Cross Sectional Area.

Inputs:

1) Allowable Axial Stress, F_a (ksi);
2) Allowable Euler Stress, F_e' (ksi);
3) Allowable Bending Stress, F_b (ksi);
4) Beam Center Moment, M_c (in-kips);
5) Section Modulus, S_x (in^3);
6) Reduction Factor, c_m (non-dimensional).
   (Use unity factor, if aluminum)

Output:

1) Maximum Axial Stress, f_a (ksi)

BMCL BEAM COLUMN:

Sample:

Inputs:

(Prompt:)	(Data:)	(Key:)
"BEAM COLM"		
"Calcs max fa as func of"		
"Fa,Fb,Fe',S,Mc & cm"		
"If alum., cm=1"		
"INPUT ksi,in↑3,in-kips"		
"Fa=?"	14.345	R/S
"Fe'=?"	23.567	R/S
"Fb=?"	19.	R/S
"Mc=?"	17.012	R/S
"S=?"	5.123	R/S
"cm=?"	1.	R/S

Output:

"max fa=9.992" (ksi)

CRCL CIRCLE GENERATION:

Function: Calculates horizontal circular locus of equally spaced nodes, typically within a geometry half-sector, to determine the pier locations of circular based geometries and the nodes within any lattice boundary, as determined by LATT.

Inputs:

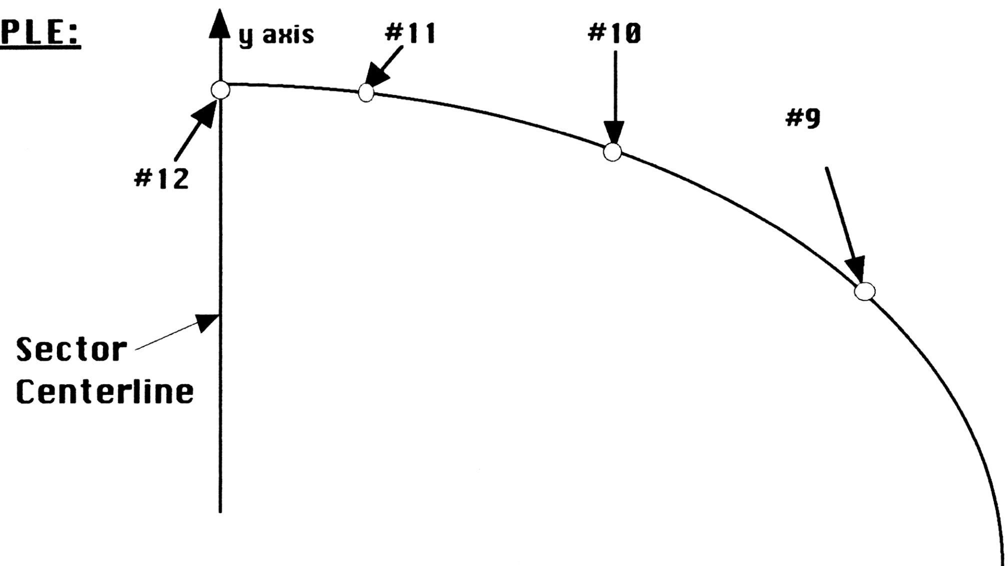
1) Number of nodes per 360°;
2) Spherical radius;
3) First node #;
4) Furthest. from sector centerline, node position, i.e.: 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5 ..... node spaces;
5) Elevation angle from dome zenith. (degrees)

Outputs:

1) Generated node number(s);
2) Unit x,y and z coordinates of generated node(s);
3) Elevation angle between geometry zenith and generated node(s); (Degrees)
4) Non-unity radius x,y and z coordinates of generated node(s).

CRCL CIRCLE GENERATION:

SAMPLE:



Inputs:

(Prompt:)	(Data:)	(Key:)
"# NODES/360°"	28.	R/S
"Sph.R?"	120.	R/S
"1st NODE:"		
"#?"	9.	R/S
"Pos.Fr.Ctr.i.e.4,3.5"	2.5	R/S
"∡ FR.ZENITH"	33.567	R/S

Outputs:

Node 9.	Node 10.	Node 11.	Node 12.
x = 0.29416678	x = 0.18261517	x = 0.06190647	x = 0.0
y = 0.45816374	y = 0.52188416	y = 0.54943514	y = 0.54943514
z = 0.83323983	z = 0.83323983	z = 0.83323983	z = 0.83323983
∡ w/Top = 33.567	∡ w/Top = 33.567	∡ w/Top = 33.567	-
x = 35.30001306	x = 21.91382008	x = 7.42877665	x = 0.0
y = 56.17964895	y = 62.62609973	y = 65.93221637	y = 65.93221637
z = 99.98877998	z = 99.98877998	z = 99.98877998	z = 99.98877998

GEOM DOME CROWN GEOMETRY:

Function: Calculates strut central angles and chord factors, spherical surface angles, minor circle locations and node x,y & z coordinates of uppermost portion of a dome geometry, to produce the fewest possible types of different parts of a dome. Fold over capabilities permit a quadrupling of upper geometry configuration. Overshoot capabilities permit an extrapolation of geometric progression past the fold over.

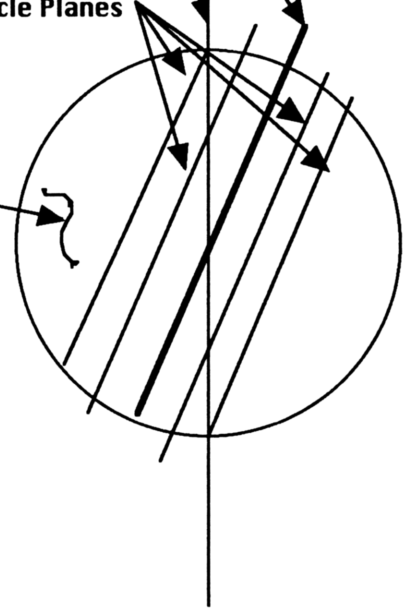
Inputs:

1) Angle between dome zenith and geometry great circle;
2) Number of sub-divisions or frequency of basic sector;
3) Number of symmetrical sides of dome geometry; (May be mixed number. See Nesting and Sinus Geometries)
4) Geometry overshoot; (0,1,2,3 or 4)
5) Spherical radius;
6) Optional: Portion of dome geometry where node coordinates are desired. Mid-chord nodes are given a node number if they fall on sector centerline.

Outputs:

1) Minor circle locations, relative to great circle;
2) Strut central angles, chord factors, lengths;
3) Spherical surface angles;
4) Width factor of largest generated panel; (Panel #1)
5) Optional. x,y & z coordinates of requested nodes.

GEOM DOME CROWN GEOMETRY:



Sample:

Inputs:

(Prompt:)	(Data:)	(Key:)
"G.C.∡, #Div, Sides R/S"	15.0	ENTER
	2.	ENTER
	6.	R/S
"Overshoot? 0→4"	0.	R/S
"Sph. R"	120.0	R/S

Outputs:

(See Next Sheet; "Ref" output is superfluous result of program looping)

GEOM DOME CROWN GEOMETRY:

Outputs:

B1 = 57.758188035 [deg]

M.C.1. = 7.65152628 [deg]

a1. = 8.74617976 [deg]
c.f. = 0.15250147 [chord factor]
Length = 18.30017609 [c.f. x R]

b1. = 8.49878070
c.f. = 0.14819576
Length = 17.78349098

Panel 1 w = 0.12952662
w x R = 15.54319490

A1. = 61.12090598

M.C.2. = 15.00000000

a2. = 8.44594397
c.f. = 1.14727610
Length = 17.67313232

b2. = 8.42297207
c.f. = 0.14687625
Length = 17.62515035

A2. = 60.26979489
C2. = 61.40343073
B2. = 58.32677438

M.C.3. = 21.80542378 (Ref)

a3. = 7.90855560 (Ref)
c.f. = 0.13792079 (Ref)
Length = 16.55049421 (Ref)

b3. = 8.20868661
c.f. = 0.14314611
Length = 17.17753322

A3. = 58.89829165 (Ref)
C3. = 61.10170835
B3. = 60.00000000 ("Sides"= 6)

"Coordinate? Yes=1 No=0"
1. R/S
"Inner Level?"
-2. R/S
"Outer Level?"
2. R/S

Level is relative to Great Circle. Use negative integer for M.C.'s toward geom center & positive integer for M.C.'s away fr. ctr. Use 0 for nodes on Great Circle. Order of output is inner most to outer most with Node 1. at geometry center and 1st node of each next outer level using progression of 2, 4, 6, 9, 12, 16 or square of integers and square of integer-plus-half. If inner level is not at center of geom., 1st node is not #1; it is that of progression.

GEOM DOME CROWN GEOMETRY:

Outputs: (Continued)

Node 1.
x = 0.000000000
y = 0.000000000
z = 1.000000000

∡ w/Top = 0.000000000

x = 0.000000000
y = 0.000000000
z = 120.000000000

Node 2.
x = 0.073438126
y = 0.127198566
z = 0.989154875

∡ w/Top = 8.445943974

x = 8.812575174
y = 15.263827947
z = 118.698584976

Node 3.
x = 0.000000000
y = 0.127198566
z = 0.989154875

(Angle w/Top not given for mid-chord non-spherical surface nodes)

x = 0.000000000
y = 15.263827947
z = 118.698584976

Node 4.
x = 0.147788364
y = 0.255976955
z = 0.955319003

∡ w/Top = 17.192123734

x = 17.734603393
y = 30.717234648
z = 114.638280375

Node 5.
x = 0.000000000
y = 0.258819045
z = 0.965925826

∡ w/Top = 15.0

x = 0.000000000
y = 31.058285412
z = 115.911099155

Node 6.
x = 0.218701532
y = 0.378802166
z = 0.899265566

∡ w/Top = 25.938303494

x = 26.244183898
y = 45.456259914
z = 107.911867958

GEOM DOME CROWN GEOMETRY:

Outputs: (Continued)

Node 7.
x = 0.073438126
y = 0.384420248
z = 0.920232533

∡ w/Top = 23.039899631

x = 8.812575174
y = 46.130429727
z = 110.427903955

Node 8.
x = 0.000000000
y = 0.384420248
z = 0.920232533

x = 0.000000000
y = 46.130429727
z = 110.427903955

Node 9.
x = 0.282370065
y = 0.489079300
z = 0.825268795

∡ w/Top = 34.384247468

x = 33.884407842
y = 58.689515966
z = 99.032255457

Node 10.
x = 0.142752598
y = 0.497254752
z = 0.855779999

∡ w/Top = 31.153987134

x = 17.130311726
y = 59.670570259
z = 102.693599923

Node 11.
x = 0.0
y = 0.5
z = 0.8660254404

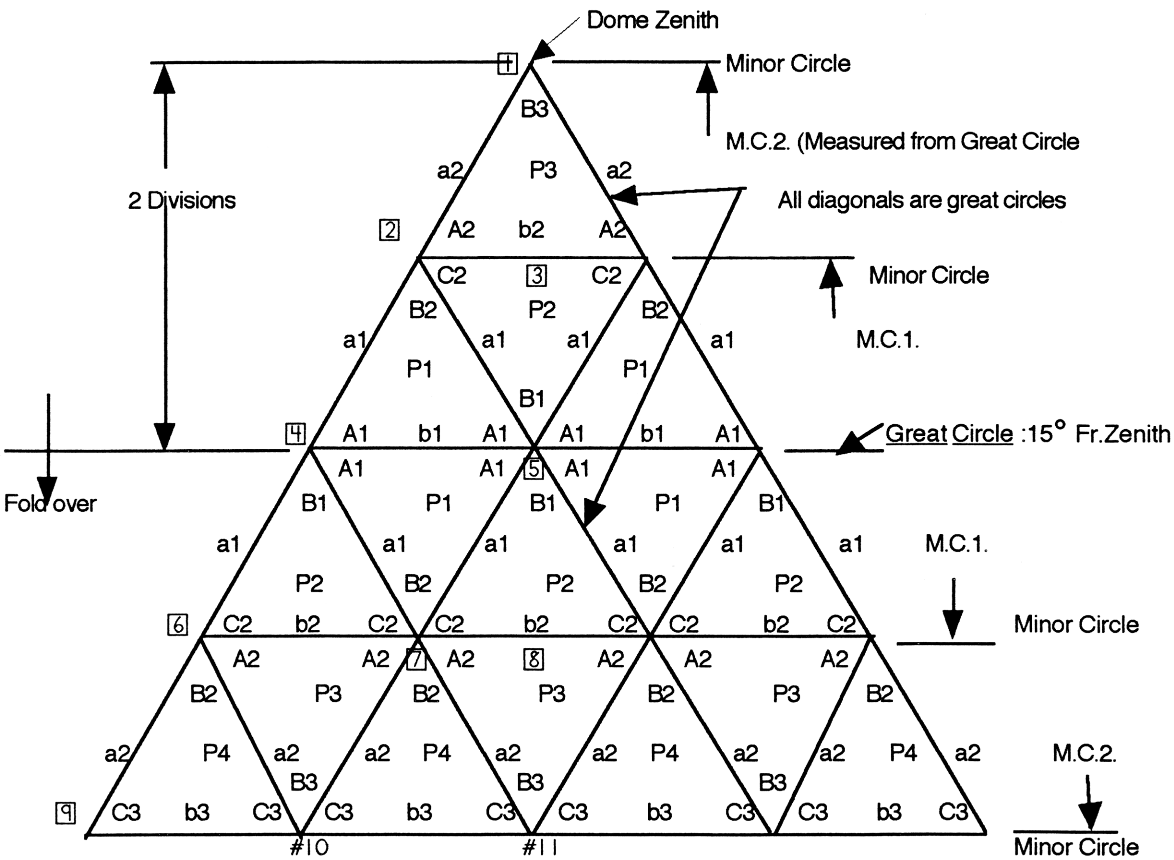
∡ w/Top = 30.0

x = 0.0
y = 60.0
z = 103.923048454

(Program returns to "Coodinate?" Prompt) Individual levels may be outputted by using same number for both levels.

GEOM DOME CROWN GEOMETRY:

Outputs: (Continued)



LEGEND:

Lower case: a,b = Sides
Upper case: A,B,C = Surface Angles
□ and #: Nodes
Pn = Panel Number
A1 + A1 + B1 = 180 deg
A2 + C2 + B2 = 180 deg
Three Great Circles intersect at Nodes 4 and 5

All generated triangles are isosceles with the sides on great circles and the bases on either a great circle or a minor circle parallel with a great circle. In this example, the first overshoot level would have node numbers: 12, 13, 14 & 15.

Schematic View (N.T.S.)

LATT LATTICE SKIRT GENERATION:

FUNCTION: Using iterative methods,a target panel width factor and an upper horizontal node location, program calculates the lower horizontal node location for use in CRCL program to define x,y and z coordinates. This program uses PLTR and SPHO as subroutines. This routine is to be used only for circular base geometries which have a lattice extension below the nominal transition portion of dome.

The reason for using the "Panel 1 w" factor is to maximize the possible dome span so that neither the upper nor lower geometry controls span through maximum use of panel raw material width.

Experience has shown that the lower point up panel will control until the upper point down panel controls, from then on. When the crossover occurs, the adjoining panels, at base edge, may be identical to reduce the quantity of panel types.

The HP-42S has a "Printer On" and "Printer Off" command. The iterations will speed up if "Printer On" is used with a turned off printer, or no printer at all. The calculator will operate at a faster speed because the "Pause" instructions are ignored when there is an assumption that a printer is linked with the calculator. The user will have to closely monitor the iterated panel width presentation in the calculator display to determine when satisfactory iterations have passed to finalize the program operation. Normally, four or five loops will be sufficient. This procedure will also lessen paper tape waste during iterations, if user has a printer in his possession.

The iterations are not automatic. The user determines when sufficient loops have occurred. Adjustments to lower horizontal node locations may be either program controlled or user controlled, to create a more manageable Angle-From-Top, relative to significant digits.

The principal advantage of using a lattice skirt is that a whole family of dome geometries may be created using a common crown portion, for tooling standardization. Each level of a lattice requires only two panel types, as opposed to many panel types within the transition portion of a circular based geometry. The transition portion has the only non-isosceles triangular panels within a circular based geometry, excluding intentionally modified panels,i.e. doors.

LATT LATTICE SKIRT GENERATION:

Inputs:

1) Target w: Transcribe from GEOM "Panel 1 w"
   Purpose: To make panels within lattice the same theoretical width as maximum size panels in dome crown geometry. Do not use "w x R".
2) Total dome piers:
   Number of piers will remain constant throughout the lattice as determined by number of nodes at the bottom of transition zone.
3) Angle of upper level of nodes relative to top of dome.
4) Initial angle of lower level of nodes (Arbitrary value)
   User could approximate same differential between previous upper/lower levels. Does not have to be accurate since value is revised during program.

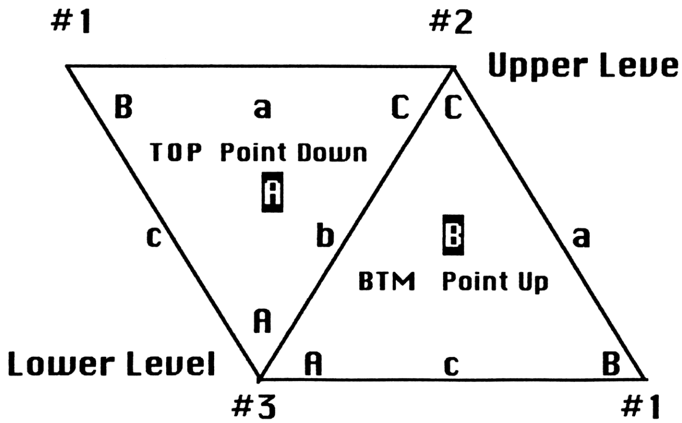
Operational Keys and Desired Output:

A Calculation of upper, point down , panel SPHO & PLTR data.
B Calculation of lower, point up, panel " " "
C Calculate new lower level angle (program generated)
D Disable printer operation (to save paper tape)
E Enable printer operation (to record final lattice data)
F View ratio of target and current widths (to check state of program progression)
G View current lower level angle
H To input specific lower level angle (user generated)
   A and B must still be run to calculate panel data.

As noted on previous page, the lower point up panel will generally control until crossover occurs. After optimizing panel, check the adjacent, same lattice level panel, to confirm that it has a lesser width. If not, finalize it, rather than previous. After finalizing lower level angle, use CRCL to generate node x,y and z coordinates of lattice bottom boundary. Remember to stagger, integer and, integer + half positions. When crossover occurs, use previous differential.

LATT LATTICE SKIRT GENERATION:

Sample:



Inputs:

(Prompt:)	(Data:)	(Key:)
"TOP:A BTM:B PRT,OFF:D"		
"ON:E CORR∡:C"		
"USER ∡ CHG:H"		
"LAST∡:G ω/ω:F"		
"TARGET ω?"	0.025451420	R/S
"# Piers"	140.	R/S
"TOP∡"	44.947898973	R/S
"BTM∡"	46.5	R/S

(Initiate program) A TOP Point Down Panel Solve

LATT LATTICE SKIRT GENERATION:

Outputs:

SPH. DATA
Sides, Chord Factors
1-2 = 0.031703347
2-3 = 0.031493144
3-1 = 0.031493144

Sides, Cent. ∡
1-2 = 1.816544033
2-3 = 1.804498809
3-1 = 1.804498809

Surface ∡'s
Node 1 = 59.787182725
Node 2 = 59.787182725
Node 3 = 60.450355377

Area = 0.000431460

Sph Excess= 0.024720827

Linear Data:
Side 1-2 = 0.031703347
Side 2-3 = 0.031493144
Side 3-1 = 0.031493144

(Plane Triangle Data follows:)
∡A= 60.442078137
∡B= 59.778960931
∡C= 59.778960932
a= 0.031703347
b= 0.031493144
c= 0.031493144

LATT LATTICE SKIRT GENERATION:

(Plane Triangle Data - Continued)

a Height= 0.027212912
b Height= 0.027394546
c Height= 0.027394546
Area= 0.000431370
Outside D.=0.036446600
Inside d.=0.018222488
Perim.= 0.094689634

Following initial solution, minimum height = "a Height"; Key C and A
Following 1st iteration, minimum height = 0.025459705; Key C and A
Following 2nd iteration, minimum height = 0.025451462; Key C and A
Following 3rd iteration, minimum height = 0.025451420 = "Target w"

Key G; Lower Level Angle = 46.399057720 degrees

Key B (Point Up △) to confirm that point down triangle controls:

- a Height= 0.027312075
- b Height= 0.027312075
- c Height= 0.025199764 or less than "Target w". Therefore Point Down Panel controls.

Rerun A and B to record strut lengths, chord factors & surface angles.
Use Lower Level Angle in CRCL to generate node x,y & z coordinates.

Note: Because the initial solution and all but final data is garbage, it is best to wait until after optimizing Plane Triangle " a/b/c Height" before recording data.

If you found that the bottom, point up panel controlled, repeat keying C and B until optimizing Height and then key A to confirm that bottom, point up panel controlled.

Key C only when a new Lower Level Angle is desired.

NORM NORMAL TO PLANE:

FUNCTION: To calculate the direction cosines of a normal to a plane and the dihedral angle between the current plane and the previous plane. Routine useful for determining the relative angle between panel and strut or panel and adjacent panel as well as the curb angle of any panel penetrations, i.e. sanitary vents, HVAC ducts. Strut plane may be determined by both ends & the spherical origin.

When confusion exists, relative to whether or not the desired angle or it's complementary angle is presented, one is encouraged to shift one node a very small amount and notice the effect.

Inputs:

(For a plane determined by three nodes)

1) Node 1 x,y & z coordinates; (x&y horizontal;z vertical)
2) Node 2 x,y & z coordinates;
3) Node 3 x,y & z coordinates.

Outputs:

1) l_x: x-axis direction cosine of normal; (l_x is "EL" sub x)
2) l_y: y-axis direction cosine of normal;
3) l_z: z-axis direction cosine of normal. (Use for curb angle of vertical penetrations)

Secondary Input:

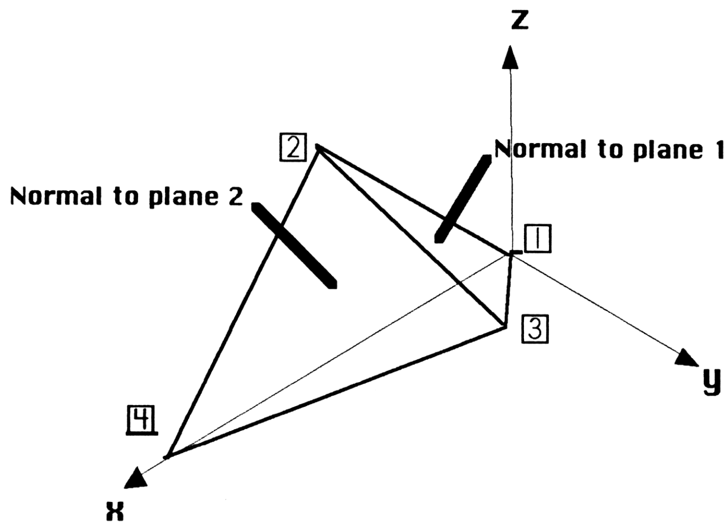
1) Node 1 replacement x,y & z coordinates
   When dihedral angles are desired, the prior two most recently inputted nodes should be common to both planes, i.e. Nodes 2 & 3 of first input should be common to both planes. Use similar progression for additional planes.

Secondary Output:

1) l_x, l_y and l_z direction cosines of normal to second plane
2) Dihedral angle betw. first and second planes. (Degrees)

NORM NORMAL TO PLANE:

Sample:



Inputs:

(Prompt:)	(Data:)	(Key:)
"NORM TO PL"		
"IF 2 PL,MAKE 2→3 COMM"		
"Node 1: x, y, z R/S"	0.0	ENTER
	0.0	ENTER
	0.0	R/S
"Node 2 x,y,z"	10.0	ENTER
	0.0	ENTER
	10.0	R/S
"Node 3 x,y,z"	10.0	ENTER
	10.0	ENTER
	10.0	R/S

NORM NORMAL TO PLANE:

Outputs:

I_x = -0.707107

I_y = 0.000000

I_z = 0.707107 (Curb angle = 45°)

Secondary Inputs:

(Prompt:)	(Data:)	(Key:)
"Next pt x,y,z?"		
" YES = 1 NO = 0"	1.0	R/S
(If YES) "x,y,z"	20.0	ENTER
	0.0	ENTER
	0.0	R/S

Secondary Outputs:

I_x = -0.707107

I_y = 0.000000

I_z = -0.707107 (Curb angle = 45°)

∡ Bet pl = 90.000°

PDGN PRINCIPAL DIAGONAL NODE:

Function: To calculate the principal diagonal 'fill-in' node coordinates and present them in same format as used in other routines. The 'fill-in' nodes replace lower, outer, nodes which are generated within the GEOM routine when it is desirable to blend the dome crown geometry with a circular base.

The coordinates of the non-principal diagonal nodes within a 'fill-in' are calculated using the BLND routine.

Inputs:

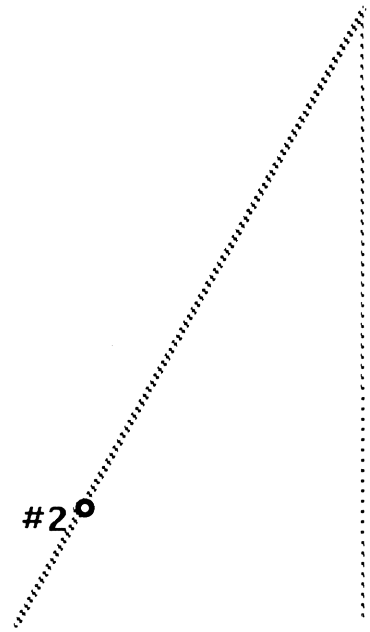
1) Number of dome sides; (Same as used in GEOM)
2) Spherical radius; (Same as used in GEOM)
3) Node number; (Same as node which is replaced)
4) Angle from geometry zenith. (Degrees)

Outputs:

1) Node #
2) x,y and z unit coordinates;
3) Angle from top;
4) x, y and z coordinates in same units as Spherical R.

PDGN PRINCIPAL DIAGONAL NODE:

Sample:



Inputs:

(Prompt:)	(Data:)	(Key:)
"Sides?"	6.	R/S
"R?"	120.	R/S
"NODE#?"	2.	R/S
"∡ w/Top"	35.6789	R/S

Outputs:

Node 2.
x = 0.291621055
y = 0.505102484
z = 0.812298369

∡ w/Top = 35.678900000

x = 34.994526617
y = 60.612298087
z = 97.475804318

PLTR PLANE TRIANGLE SOLUTIONS:

Function: To calculate all nineteen solvable types of plane triangles, including both solutions, where applicable. The three angle case is not solvable (Unlike sph. triangles) due to infinite results.

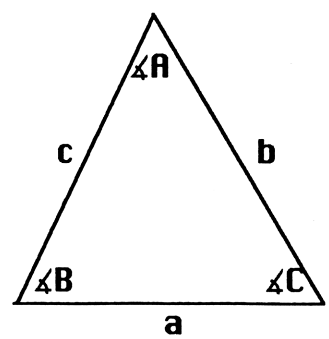
The program uses binary sum addressing and does not recalculate any input data. Program execution is automatic, following third input, and the results are not saved, due to the number of outputs being double the number of registers used.

There are extensive uses of 'domino' register roll technique and flag sets/tests.

This program is used as a subroutine within the LATI program.

Inputs:

1) thru
3) Any three of the three angles, A/B/C, and their corresponding opposite sides, a/b/c.



Outputs:

1) ∡A (Angle A)
2) ∡B (Angle B)
3) ∡C (Angle C)
4) a (Side a)
5) b (Side b)
6) c (Side c)
7) Height relative to side a
8) Height relative to side b
9) Height relative to side c
10) Area
11) Circumscribed circle diameter: D
12) Inscribed circle diameter: d
13) Perimeter (Redundant, though useful if exact solution is desired)

PLTR PLANE TRIANGLE SOLUTIONS:

Sample:

Inputs: Angles are in degrees

(Prompt:)	(Data:)	(Key:)	(Display:)
"PL TRI-∡"			
"∡'s: ABC"			
"Side's: GOLD ABC"	36.5	A	∡A= 36.5000
	37.	GOLD A	a= 37.0000
	50.	GOLD C	c= 50.0000

Outputs: Angles are in degrees

2 SOL

1st	2nd
∡A= 36.5000	∡A= 36.5000
∡B= 90.0041	∡B= 16.9959
∡C= 53.4959	∡C= 126.5041
a= 37.0000	a= 37.0000
b= 62.2034	b= 18.1823
c= 50.0000	c= 50.0000
a Height= 50.0000	a Height= 14.6152
b Height= 29.7411	b Height= 29.7411
c Height= 37.0000	c Height= 10.8152
Area= 925.0000	Area= 270.3809
Outside D.=62.2034	Outside D.=62.2034
Inside d.=24.7984	Inside d.=10.2824
Perim.= 149.2034	Perim.= 105.1823

ROTN <u>NODE ROTATION:</u>

<u>Function:</u> To complete a total dome geometry by using only a small symmetrical portion, thereof.

Examples would be: completing an Icosa based geometry using one-sixth of one face to completing a circular based geometry using one-half of one sector. This is the reason for GEOM defining only half of a geometry sector's nodes. The other half would require only that the polarity of the x coordinate be changed.

All routines in this manual use the 3-axes convention of the x and y axes being in a horizontal plane and the z-axis is vertical. The relationship of one axis, to the others, follows the Right Hand Rule, where the direction of the z-axis would align with the thumb when the fingers point in the direction of going from the x-axis to the y-axis. Correspondingly, the y-axis and going from z to x.

The orientation of the direction of rotation, relative to plus or minus, follows the same rule, with plus being the direction of the fingers with the thumb pointing in the direction of a positive axis.

The program permits four sequential sets of z,x & y rotations. Please note that the z-axis rotation is first. This is due to the writer's perception that most rotations are in the horizontal plane.

<u>Inputs:</u>

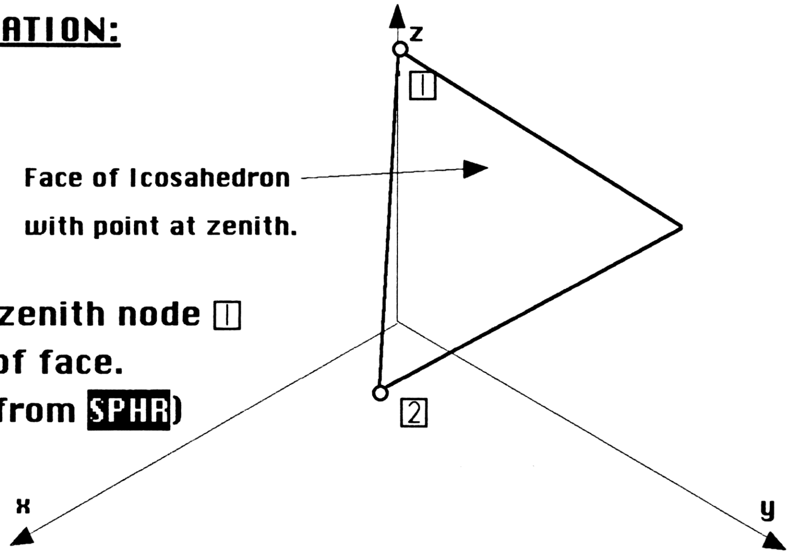
1) thru
12) The desired sequential rotations. Fill non-rotations with zeros. Key R/S with no angle inputs when all rotations within a set of three are zero. Begin w/ z;
13) Node number;
14) Initial x coordinate;
15) Initial y coordinate;
16) Initial z coordinate.

<u>Outputs:</u>

1) Node #
2) thru
4) x, y and z coordinates of fully rotated node

ROTN NODE ROTATION:

Sample:



Operation: To rotate zenith node 1
to lower point of face.
(x-axis rotation ∡ from SPHR)

Inputs:

(Prompt:)	(Data:)	(Key:)
"ROTATE NODE xy&z COORD"		
"KEEP ∡'s CYCLICAL:"		
" Z>X>Y>Z>X>Y..."		
"USE 0 ∡'s WHERE"		
" APPLICABLE AS FILL."		
"+/- ∡'s:USE RH RULE"		
"INPUT 12 ROTATION ∡'s"		
"KEY "R/S" IF ALL 0's"		
"1st Set: z,x,y R/S"	0.0	ENTER
	37.377368141	ENTER
	0.0	R/S
"2nd Set: z,x,y R/S"	120.0	ENTER
	-37.377368141	ENTER
	0.0	R/S
"3rd Set: z,x,y R/S"	-	R/S
"4th Set: z,x,y R/S"	-	R/S
"INPUT NODE:"		
" NODE#, x, y, z R/S"	2.	ENTER
	0.0	ENTER
	0.0	ENTER
	100.	R/S

Outputs:

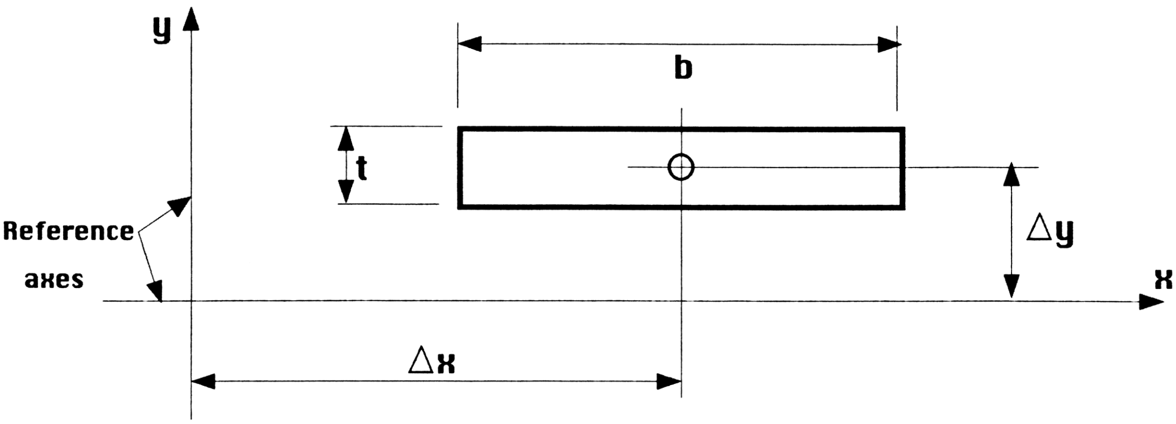
Node 2.
x = 52.5731112123
y = 72.3606797753
z = 44.721359549

SECT **SECTION PROPERTIES:**

Function: To do a complete calculation of the properties of a given section. Elements may be rectangular, fillet or triangular. The rectangular elements may be at any angle relative to the reference x and y axes. The fillet and triangular are to be oriented so as to be in any of the four mathematical quadrants. Torsion constant, J, is ignored due to shape factors. For rectangular elements, $J \approx bt^3/3$.

Inputs:

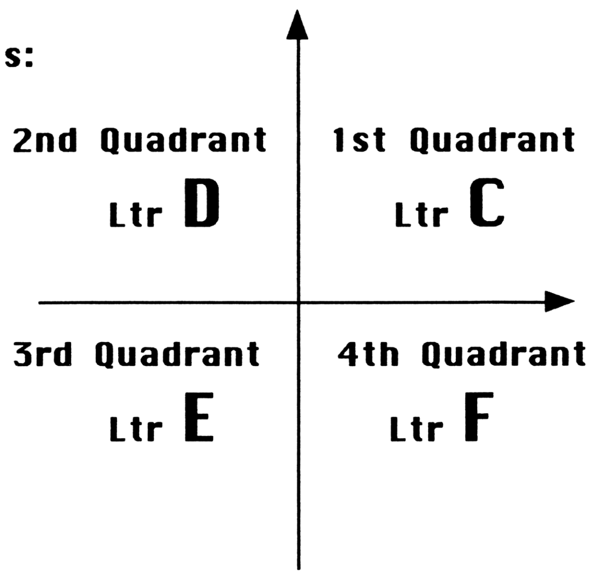
Rectangular elements:

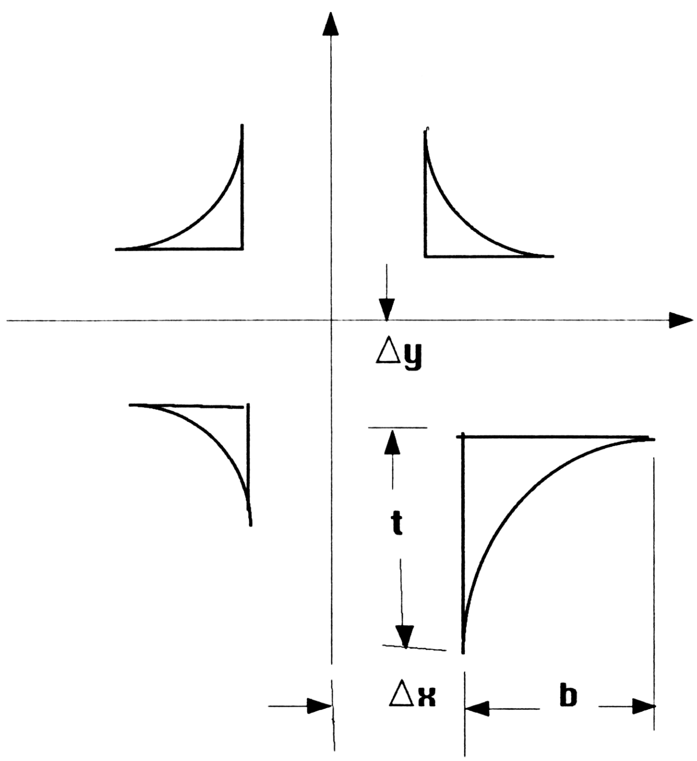


1) Long dimension of element, ‘b’
2) Narrow dimension of element, ‘t’
3) Element centroid location relative to y-axis, ‘Δx’
4) Element centroid location relative to x-axis, ‘Δy’
5) Angle between ‘b’ dimension and x-axis.
   (If ‘b’ dimension were vertical, angle = 90 deg)

SECT SECTION PROPERTIES:

Fillet Elements:





b = t = radius

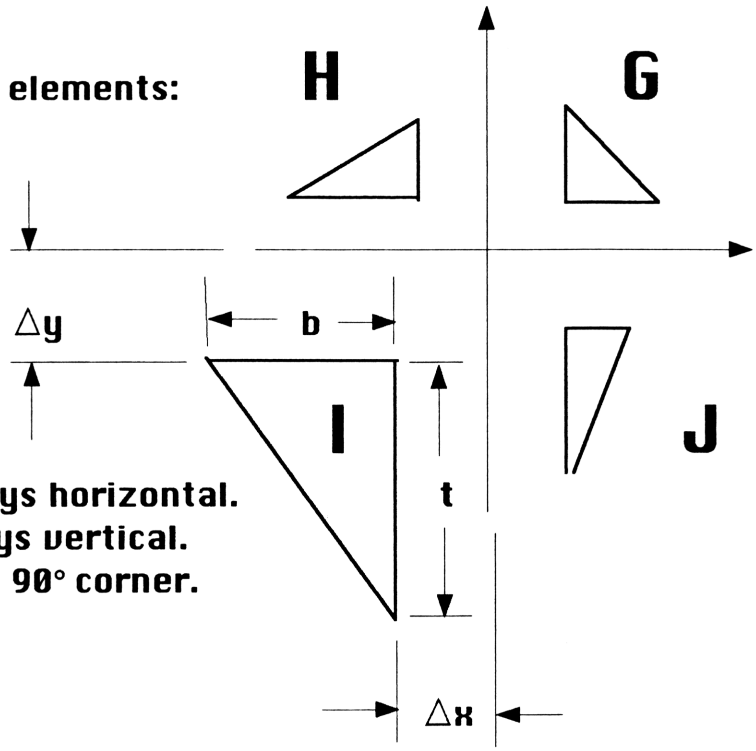
Δx and Δy always to

90 degree corner.

Dimensions from reference axes to fillet element centroid will be recalculated automatically by program, when user properly orients element relative to quadrants 1,2,3 & 4. Note that dimensions presented by program differ from inputted dimensions, if user transcribes data to chart.

SECT SECTION PROPERTIES:

Triangular elements:



'b' dimension is always horizontal.
't' dimension is always vertical.
Δx and Δy always to 90° corner.

Fillet or triangular inputs:

1) 'b' (Fillet radius or triangle horizontal edge)
2) 't' (Fillet radius or triangle vertical edge)
3) Δx, Dimension from ref y-axis to 90 degree corner
4) Δy, Dimension from ref x-axis to 90 degree corner
5) Quadrant Ltr C,D,E & F for fillets; G,H,I & J for triangles.

SECT SECTION PROPERTIES:

Outputs: (For each element)

1) b
2) t
3) x (May be recalculated for fillet and triangle elements)
4) y Do
5) ∡ (Degrees or quadrant letter)

6) A (Area)
7) Axy (Product of element area, program x & program y)
8) Ax (Product of element area and prgm x)
9) Ax^2 (Product of element area and square of prgm x)
10) I_{oy} (Element moment of inertia about centroid y-axis)
11) Ay (Product of element area and prgm y)
12) Ay^2 (Product of element area and square of prgm y)
13) I_{ox} (Element moment of inertia about centroid x-axis)

Outputs: (Following entry of all elements)

1) ΣA
2) ΣAxy
3) ΣAx
4) ΣAx^2
5) ΣI_{oy}
6) ΣAy
7) ΣAy^2
8) ΣI_{ox}

9) x bar = $\Sigma Ax / \Sigma A$
10) y bar = $\Sigma Ay / \Sigma A$

11) $I_x = \Sigma Ay^2 + \Sigma I_{ox} - \Sigma A(y\ bar)^2$
12) $r_x = (I_x / \Sigma A)^{1/2}$

13) $I_y = \Sigma Ax^2 + \Sigma I_{oy} - \Sigma A(x\ bar)^2$
14) $r_y = (I_y / \Sigma A)^{1/2}$

SECT SECTION PROPERTIES:

Additional Outputs: If I_{xy} does not equal zero (or near zero)

15) $I_{xy} = \Sigma Axy - (\Sigma A)(x\ bar)(y\ bar)$

16) $I_p = (I_x + I_y)/2 + \{ [(I_x - I_y)/2]^2 + (I_{xy})^2 \}^{1/2}$
17) $I_q = (I_x + I_y)/2 - \{ [(I_x - I_y)/2]^2 + (I_{xy})^2 \}^{1/2}$

18) $r_p = (I_p/\Sigma A)^{1/2}$
19) $r_q = (I_q/\Sigma A)^{1/2}$

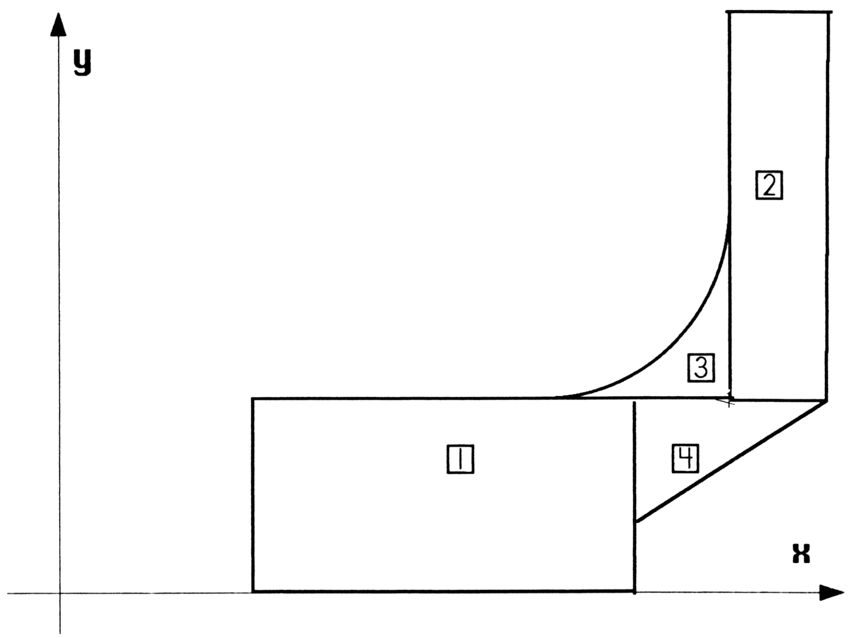
20) ∡ between centroid y-axis and principal p-axis,
where: $\tan 2\varnothing = 2\ I_{xy}/(I_y - I_x)$
Positive angle is CCW

Options:

1) Use Negative 'b' dimension to remove an element, i.e. a circular hole could be a removed square, with four added fillets at the four corners.
2) Following summation output, elements may be added, one at a time. After each addition (or subtraction), the summation is presented, to show effect on total section.

SECT SECTION PROPERTIES:

Sample:



Inputs:

(Prompt:)	(Data:)	(Key:)
"FILLET QUAD 1234: CDEF"		
"b=t=Radius"		
"TRI∡ QUAD 1234: GHIJ"		
"b:Horiz t:Vert"		
"Delta x,y @ 90°"		
"x&y Recalc:F1>4, T1>4"		
"KEY LTR @ "∡""		
"If delete: -b"		
"# ELEMENTS"	4.	R/S
"EL.1.:b,t,x,y R/S"	2.	ENTER
	1.	ENTER
	2.	ENTER
	0.5	R/S
"∡ w/ x-Axis"	0.0	R/S

SECT SECTION PROPERTIES:

Sample:

Single element output:

Element 1.
b = 2.000000
t = 1.000000
x = 2.000000
y = 0.500000
∡ = 0.000000 Deg

A = 2.000	
Axy = 2.000	
Ax = 4.000	
A(x)E2 = 8.000	(E is symbol for exponent)
Ioy = 0.667	(oy is a subscript)
Ay = 1.000	
A(y)E2 = 0.500	
Iox = 0.167	(ox is a subscript)

"EL.2.:b,t,x,y R/S"	2.	ENTER
	0.5	ENTER
	3.75	ENTER
	2.	R/S
"∡ w/ x-Axis"	90.0	R/S

Element 2.
b = 2.000000
t = 0.500000
x = 3.750000
y = 2.000000
∡ = 90.000000 Deg

SECT SECTION PROPERTIES:

A = 1.000
Axy = 7.500
Ax = 3.750
A(x)E2 = 14.063
Ioy = 0.021
Ay = 2.000
A(y)E2 = 4.000
Iox = 0.333

"EL.3.:b,t,x,y R/S"	1.	**ENTER**
	1.	**ENTER**
	3.5	**ENTER**
	1.	**R/S**
"∡ w/ x-Axis"	-	**D**

Element 3.
b = 1.000000
t = 1.000000
x = 3.276600 Note recalculation
y = 1.223400 Note recalculation
∡ = F2 Quad Fillet in 2nd quadrant

A = 0.215
Axy = 0.860
Ax = 0.703
A(x)E2 = 2.304
Ioy = 0.008
Ay = 0.263
A(y)E2 = 0.321
Iox = 0.008

"EL.4.:b,t,x,y R/S"	1.	**ENTER**
	0.625	**ENTER**
	3.	**ENTER**
	1.	**R/S**
"∡ w/ x-Axis"	-	**J**

SECT SECTION PROPERTIES:

Element 4.
b = 1.000000
t = 0.625000
x = 3.333333 Note recalculation
y = 0.791667 Note recalculation
∡ = T4 Quad Triangle in 4th quadrant

A = 0.313
Axy = 0.825
Ax = 1.042
A(x)E2 = 3.472
Ioy = 0.017
Ay = 0.247
A(y)E2 = 0.196
Iox = 0.007

SUMMATION
ΣA = 3.527
ΣAxy = 11.185
ΣAx = 9.495
ΣA(x)E2 = 27.839
ΣIoy = 0.712
ΣAy = 3.510
ΣA(y)E2 = 5.017
ΣIox = 0.514

x Bar = 2.692 Dim. betw. ref. y-axis and section centroid
y Bar = 0.995 Dim. betw. ref. x-axis and section centroid

Ix = 2.039 Moment of Inertia about centroid x-axis
rx = 0.760 Radius of Gyration about centroid x-axis

Iy = 2.991
ry = 0.921

SECT **SECTION PROPERTIES:**

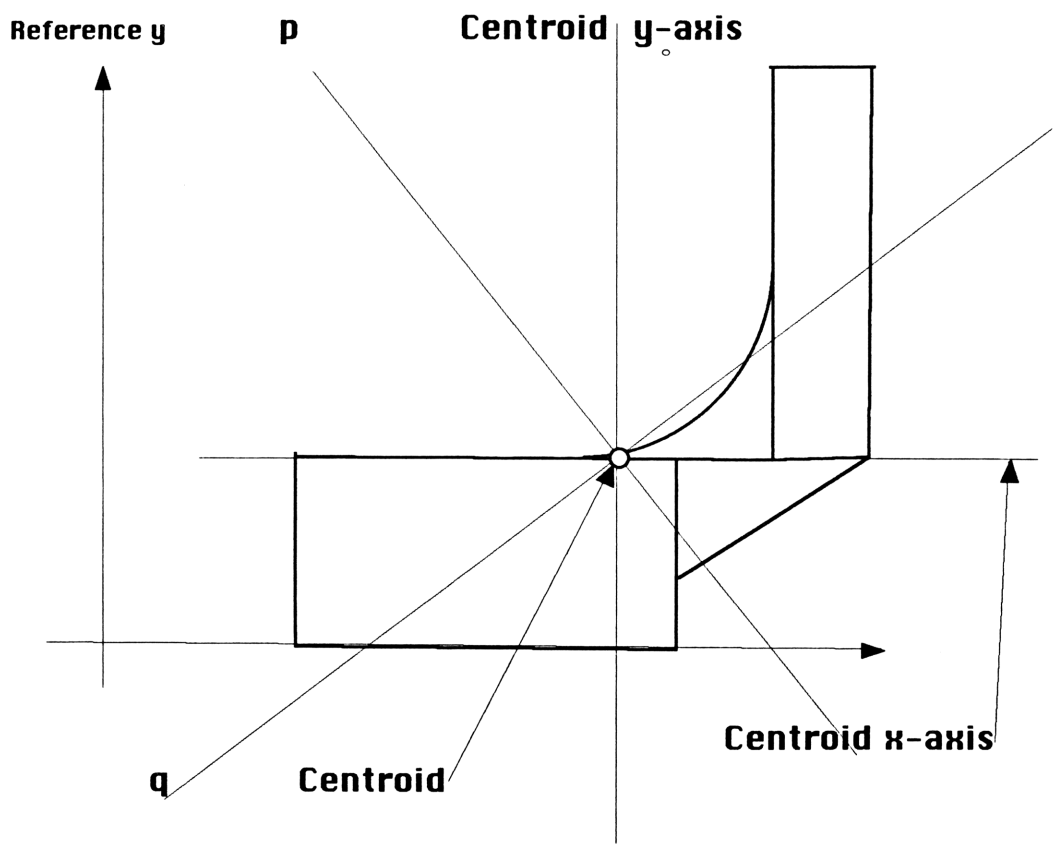
Ixy = 1.736

Ip = 4.315 Moment of Inertia about principal axis p
Iq = 0.714

rp = 1.106 Radius of Gyration about principal axis p
rq = 0.450

∡ = 37.328 Deg. Angle between centroid y and p axes

"Add:"A" New:"B"" Key "A" to modify existing section; "B" for new section.



Detail of Section with Principal Axes

SPHO SPHERICAL OBLIQUE TRIANGLES:

Function: Solves oblique triangles defined by three spherical nodes. Inputs are saved in order to minimize inputs when adjacent triangles are to be solved in a daisy chain manner by inputting only one additional node for each additional triangle.

This routine is used as a subroutine within the LATT routine and is of principal value while calculating the circular based geometry transition portion where the only non-isosceles triangles occur, excluding special cases when some triangles must be modified.

Inputs:

1) Spherical radius; in same units as coordinates;
2) x,y and z coordinates of 1st spherical node;
3) x,y and z coordinates of 2nd spherical node;
4) x,y and z coordinates of 3rd spherical node.

Outputs: (Following keying E)

1) thru 3) Chord factors of the three sides;
4) thru 6) Central angles of the three sides;
7) thru 9) Spherical surface angles of the three corners;
10) Spherical surface area of triangle;
11) Spherical excess of sum of three angles;
12) thru 14) Node to node linear data; will be same as chord factors if Sph R = 1.0 and coordinates are unit coordinates. PLTR may be used to get additional plane triangle data.

Secondary, Tertiary and Subsequent Inputs:

1) thru 3) x,y and z coordinates of additional spherical node, while retaining two of previous three nodes.

SPHO SPHERICAL OBLIQUE TRIANGLES:

Sample: (Use same coordinates as developed in ROTN routine, except as spherical Icosahedron)

Inputs:

(Prompt:)	(Data:)	(Key:)
"SPH.OBLIQUE TRI-∡"		
"INPUT 3 NODES ON SPH.SURF."		
"R & COORD: SAME UNITS"		
"Nodes 1,2,3: Key A,B,C"		
"Execute: Key E"		
"R=? R/S"	100.	R/S
	0.0	ENTER
(1st Node)	0.0	ENTER
	100.	A
	52.5731112123	ENTER
(2nd Node)	72.3606797753	ENTER
	44.721359549	B
	-52.5731112123	ENTER
(3rd Node)	72.3606797753	ENTER
	44.721359549	C
(To execute)	-	E

SPHO SPHERICAL OBLIQUE TRIANGLES:

Outputs:

SPH. DATA
Sides, Chord Factors
1-2 = 1.05146222425
2-3 = 1.05146222425
3-1 = 1.05146222425

Sides, Cent. ∡
1-2 = 63.4349488238
2-3 = 63.4349488238
3-1 = 63.4349488238

Surface ∡'s
Node 1 = 72.0000000004
Node 2 = 72.0000000004
Node 3 = 72.0000000004

Area = 6,283.18530733 ($4\pi R^2/20$ = 6,283.1853072)

Sph Excess= 36.000000001

Linear Data:
Side 1-2 = 105.146222425
Side 2-3 = 105.146222425
Side 3-1 = 105.146222425

SPHR SPHERICAL RIGHT TRIANGLES:

Function: To solve all ten cases of spherical right triangles. This routine uses binary sum logic and does not recalculate input data. Results are saved to ease calculation of 'fill-in' portion of circular based geometries. Program logic is used within GEOM routine and is useful for determining start criteria for nesting geometries.

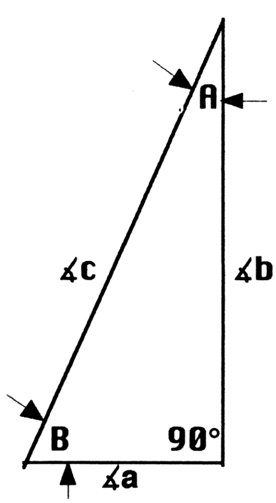
Program execution is automatic following 2nd of two inputs, if annunciator is allowed to stop pulsing between entries. (If not, key R/S)

Inputs:

1) and 2) Any two of the two variable surface angles and the three edges. All are expressed in degrees since the sides represent central angles. Angle opposite hypotenuse is a constant 90°.

Outputs:

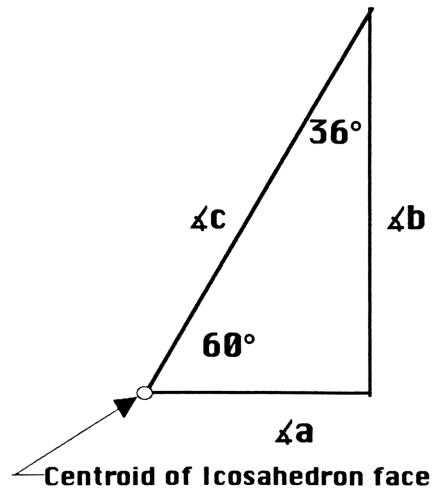
1) Surface angle A; (Saved in register 01)
2) Surface angle B; (Saved in register 02)
3) Side central angle a, opposite A; (Saved in register 03)
4) Side central angle b, opposite B; (Saved in register 04)
5) Side central angle c, hypotenuse; (Saved in register 05)



SPHR SPHERICAL RIGHT TRIANGLES:

Sample:

One-sixth of one face of
a spherical Icosahedron.



Inputs:

(Prompt:)	(Data:)	(Key:)
"SPHERICAL RT. TRI-∡"		
"USE A,B KEYS FOR SURFACE ANGLES"		
"USE GOLD/a,b,c KEYS FOR CENTRAL ∡s"		
	36	A
	60	B

Outputs:

∡A = 36	(Reg 01)	Applicable to sph. Icosa only
∡B = 60	(Reg 02)	Spherical/plane Icosahedron
∡a = 20.905157448	(Reg 03)	Dodecahedron edge / 2
∡b = 31.7174744117	(Reg 04)	Icosahedron edge / 2
∡c = 37.377368141	(Reg 05)	Icosahedron pt. to face centroid

WIND WIND LOADING:

Function: To calculate wind lift, drag and overturning moment coefficients on a dome and calculate the dynamic pressure.

The applicable range is a 0 degree thru 90 degree base angle relative to the dome zenith. Angles greater than 90 degrees may be estimated by addition and subtraction, where applicable, of portions of a hemisphere below the dome equator,i.e. for a 5/8th sphere: Lift would equal that of a 3/8 sphere, drag would equal 2 x Hemisphere drag minus 3/8 sphere drag. Calculating overturning moment may require special effort regarding center of pressure height above dome base times total drag. Experience has shown that the wind O.T.M. has a minimal effect on dome pier loads, relative to shallow domes, but a 9/10th sphere could present a sizable value. A conservative approach would be to use a full sphere drag times the spherical radius.

Input:

1) Dome base angle,as measured from dome zenith; (Deg.)

Outputs:

1) Lift coefficient: C_L;
2) Drag coefficient: C_D;
3) Overturning moment coefficient: C_M.

Secondary Inputs:

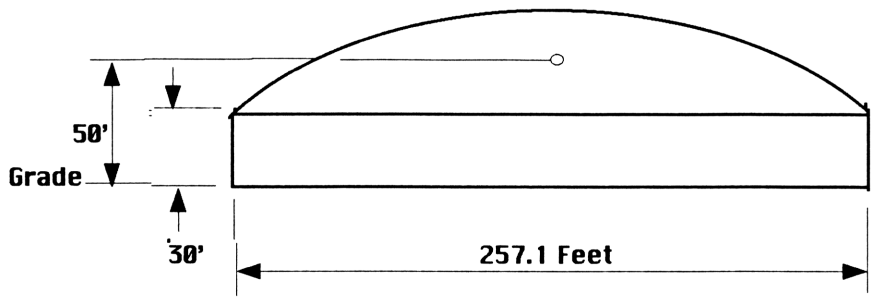
1) Wind exposure factor (From table);
2) Wind velocity, 'N', in mph;
3) Mean height above ground, 'h', in feet.

Secondary Output:

1) Dynamic pressure, 'q', in psf.

WIND **WIND LOADING:**

Sample: (Data is applicable to dome portion only)



Base Angle = 34.5678 deg. Sph. R = 257.1/2/sine 34.5678 deg. = 226.567 feet
h = 30 feet + (1- cosine 34.5678 deg)(Sph. R)(0.5) = 50 feet
Exposure Factor is for open country = 0.925 at 50 foot elevation
Specified Wind Velocity, N = 100 mph

Input:

(Prompt:)	(Data:)	(Key:)
"BASE ∡"	34.5678	R/S

Outputs:

"COEFF's:"
LIFT = 0.637
DRAG = 0.139
MOM. = 0.0042

Secondary Inputs:

(Prompt:)	(Data:)	(Key:)
"EXP.FACTOR?"	0.925	R/S
"N?"	100.	R/S
"h?"	50.	R/S

Secondary Output:

q = 27.6 (psf)

WIND LOADING:

Exposure Factor Chart:

	Elev. \ Exp.	A	B	C
Ordinary Structures	<30'	0.336	0.633	1.000
	30'	0.416	0.796	1.295
	50'	0.517	0.925	1.475
	≥100'	0.720	1.169	1.710
For Areas <200 sq.ft.	30'	0.495	0.920	1.490
	50'	0.625	1.064	1.660
	≥100'	0.830	1.320	1.905
Exposure:	A = Metropolitan, rolling terrain, sheltered B = Open suburban, plains, exposed C = Coastal			

American National Standards Institute

Applicable Formulae:	Using Sample Data:
Dome Lift = C_L (R^2) q →	0.637 (51,332.6) 27.6 = 902.5 kips
Dome Drag = C_D (R^2) q	0.139 (51,332.6) 27.6 = 196.9 kips
Dome OTM = C_M (R^3) q	0.0042 (11,630,274.4) 27.6 = 1,348.2 kip-ft

where: kip = 1,000 pounds

PROGRAM LISTINGS:

LEGEND:

+ denotes 'plus'
-- denotes 'minus'
x denotes 'multiply'
/ denotes 'divide'
↑ denotes 'exponent'
↓ denotes 'down'
→ denotes 'convert to:'
≠ denotes 'not equal'
≤ denotes 'less than or equal to"

WITHIN ALPHA ONLY:

" " denotes '1 space'
_ denotes '1 space'
_3_ denotes '3 spaces'
l-- denotes 'append'
∡ denotes 'angle'

The HP-42S appears to be cumbersome to program but once program is entered, this handheld is ideal for ease of use and fitting into one's pocket.

All programs will fit into the HP-42S concurrently. One possible revision would be to label the 'Print/Pause' subroutine with a 'global' rather than a 'local' label, and have only one subroutine for all programs. The author wanted to give all programs a 'stand alone' potential.

To enter program step "x<> nn" in NORM & PLTR use following sequence: XEQ ALPHA X <=> < <=> > ENTER Followed with "nn". This is less involved than CATALOG.

```
{ 466-Byte Prgm }
LBL   "BLND"
ADV
SIZE  25
"Sph.R?"
PROMPT
STO  01
LBL  00
"Diag ∡ ,Tang ∡ "
l--"  R/S"
PROMPT
STO  03
X<>Y
STO  02
XEQ  06
STO  13
STO  15
X<>Y
XEQ  06
STO  14
STO  16
"NODE #?"
PROMPT
STO  24
"USE UNIT COORD"
XEQ  04
"NODE 1 x,y,z R/"
l--"S"
PROMPT
STO  06
ACOS
STO  19
R↓
STO  05
R↓
STO  04
"NODE 2 x,y,z R/"
l--"S"
PROMPT
STO  09
ACOS
STO  20
STO  21
R↓
STO  08
R↓
STO  07
RCL  20
SIN
/
ASIN
```

"BLND" CONTINUED

```
51  STO 22
52  RCL 03
53  0.8
54  x
55  STO 18
56  RCL 20
57  RCL 19
58  --
59  STO 17
60  LBL 01
61  0.003
62  STO 00
63  LBL 14
64  ISG 00
65  GTO 13
66  GTO 02
67  LBL 13
68  RCL 16
69  RCL 14
70  /
71  RCL 18
72  x
73  STO 18
74  RCL 22
75  RCL 18
76  --
77  STO 23
78  XEQ 08
79  XEQ 07
80  RCL 14
81  1E10
82  x
83  RCL 16
84  1E10
85  x
86  --
87  IP
88  X=0?
89  GTO 02
90  GTO 14
91  LBL 02
92  0.003
93  STO 00
94  LBL 15
95  ISG 00
96  GTO 09
97  GTO 01
98  LBL 09
99  RCL 15
100 RCL 13
101 /
102 RCL 17
103 x
104 STO 17
105 RCL 19
106 RCL 17
107 +
108 STO 21
109 XEQ 08
110 XEQ 07
111 RCL 15
112 1E10
113 x
114 RCL 13
115 1E10
116 x
117 --
118 IP
119 X=0?
120 GTO 10
121 GTO 15
122 LBL 03
123 |--" = "
124 ARCL ST X
125 LBL 04
126 AVIEW
127 FS? 55
128 RTN
129 PSE
130 PSE
131 PSE
132 RTN
133 LBL 06
134 2
135 /
136 SIN
137 2
138 x
139 RTN
140 LBL 07
141 RCL 04
142 RCL 10
143 --
144 X↑2
145 RCL 05
146 RCL 11
147 --
148 X↑2
149 +
150 RCL 06
151 RCL 12
152 --
153 X↑2
154 +
155 SQRT
156 STO 13
157 RCL 07
158 RCL 10
159 --
160 X↑2
161 RCL 08
162 RCL 11
163 --
164 X↑2
165 +
166 RCL 09
167 RCL 12
168 --
169 X↑2
170 +
171 SQRT
172 STO 14
173 RTN
174 LBL 08
175 RCL 21
176 SIN
177 RCL 23
178 SIN
179 x
180 STO 10
181 RCL 21
182 SIN
183 RCL 23
184 COS
185 x
186 STO 11
187 RCL 21
188 COS
189 STO 12
190 RTN
191 LBL 10
192 RCL 14
193 1E10
194 x
195 RCL 16
196 1E10
197 x
198 --
199 IP
200 X=0?
201 GTO 11
```

"BLND" CONTINUED

```
202  GTO  01
203  LBL  12
204  FIX 10
205  RCL  10
206  "x"
207  XEQ  03
208  RCL  11
209  "y"
210  XEQ  03
211  RCL  12
212  "z"
213  XEQ  03
214  ADV
215  RTN
216  LBL  11
217  ADV
218  FIX  00
219  BEEP
220  "NODE  #"
221  ARCL  24
222  XEQ  04
223  XEQ  12
224  RCL  12
225  ACOS
226  "∡ w/Top"
227  XEQ  03
228  ADV
229  RCL  01
230  STO X  10
231  STO X  11
232  STO X  12
233  XEQ  12
234  ADV
235  ADV
236  GTO  00
237  END
```

```
00  { 251-Byte Prgm }
01  LBL  "BMCL"
02  LBL  00
03  SIZE  10
04  CLX
05  "BEAM COLM"
06  XEQ  01
07  "Calcs max  fa as"
08  I--"  func    "
09  I-- "of  Fa,Fb,Fe',S"
10  I--",Mc  &  cm"
11  XEQ  01
12  "INPUT  ksi  "
13  I--"in↑3  in-kips"
14  XEQ  01
15  FIX  03
16  ADV
17  "Fa=?"
18  CLX
19  PROMPT
20  STO  01
21  CLX
22  "Fe'=?"
23  PROMPT
24  STO  02
25  CLX
26  'Fb=?"
27  PROMPT
28  STO  03
29  CLX
30  "Mc=?"
31  PROMPT
32  STO  05
33  CLX
34  "S=?"
35  PROMPT
36  STO  04
37  1
38  "cm=?"
39  PROMPT
40  STO  06
41  RCL  03
42  RCL  06
43  /
44  RCL  01
45  /
46  RCL  02
47  /
48  STO  07
49  RCL  01
50  RCL  02
```

```
51  +
52  RCL  03
53  x
54  RCL  06
55  /
56  RCL  01
57  /
58  RCL  02
59  /
60  STO  08
61  RCL  03
62  RCL  06
63  /
64  RCL  05
65  RCL  04
66  /
67  --
68  STO  09
69  RCL  08
70  ENTER
71  X ↑ 2
72  RCL  07
73  RCL  09
74  x
75  4
76  x
77  --
78  SQRT
79  --
80  2
81  /
82  RCL  07
83  /
84  ADV
85  BEEP
86  "max  fa="
87  ARCL  ST  X
88  I--"  ksi____10_____"
89  XEQ  01
90  ADV
91  ADV
92  ADV
93  GTO  00
94  LBL  01
95  AVIEW
96  FS?  55
97  RTN
98  PSE
99  PSE
100  PSE
101  PSE
```

PROGRAM LISTINGS:

"BMCL" CONTINUED

```
102  END
```

```
00  { 296-Byte Prgm }
01  LBL "CRCL"
02  SIZE 11
03  "# NODES/360°"
04  PROMPT
05  STO 01
06  360
07  X<>Y
08  /
09  STO 02
10  "Sph.R?"
11  PROMPT
12  STO 03
13  LBL 00
14  "1st NODE:"
15  XEQ 04
16  " #?"
17  PROMPT
18  STO 04
19  "  Pos.Fr.Ctr.i.e"
20  I--".  4, 3.5"
21  PROMPT
22  STO 05
23  " ∡ FR.ZENITH"
24  PROMPT
25  STO 06
26  RCL 02
27  RCL 05
28  x
29  STO 07
30  ADV
31  LBL 01
32  ADV
33  XEQ 08
34  XEQ 09
35  RCL 05
36  0.5
37  --
38  X<0?
39  GTO 00
40  X=0?
41  GTO 12
42  1
43  STO + 04
44  STO -- 05
45  RCL 02
46  STO -- 07
47  GTO 01
48  LBL 08
49  RCL 07
50  SIN
51  RCL 06
52  SIN
53  x
54  STO 08
55  RCL 06
56  SIN
57  RCL 07
58  COS
59  x
60  STO 09
61  RCL 06
62  COS
63  STO 10
64  RTN
65  LBL 09
66  ADV
67  FIX 00
68  "Node "
69  ARCL 04
70  XEQ 04
71  FIX 08
72  RCL 08
73  FS? 01
74  CLX
75  "2_x "  (2 spaces, x)
76  XEQ 03
77  RCL 09
78  "2_y "
79  XEQ 03
80  RCL 10
81  "2_z"
82  XEQ 03
83  ADV
84  FS? 01
85  GTO 10
86  ACOS
87  " ∡ w/Top"
88  XEQ 03
89  LBL 10
90  FS? 01
91  0
92  FC?C 01
93  1
94  STO X 08
95  1
96  RCL 03
97  X=Y?
98  RTN
99  ADV
100 RCL 08
101 RCL 03
```

"CRCL" CONTINUED

```
102 x
103 "2_x "
104 XEQ 03
105 RCL 09
106 RCL 03
107 x
108 "2_y "
109 XEQ 03
110 RCL 10
111 RCL 03
112 x
113 "2_z "
114 XEQ 03
115 ADV
116 ADV
117 RTN
118 LBL 03
119 l--" = "
120 ARCL ST X
121 LBL 04
122 AVIEW
123 FS? 55
124 RTN
125 PSE
126 PSE
127 PSE
128 PSE
129 RTN
130 LBL 12
131 SF 01
132 1
133 STO + 04
134 XEQ 09
135 END
```

```
00 { 761-Byte Prgm }
01 LBL "GEOM"
02 "GEOM"
03 XEQ 04
04 ADV
05 FIX 09
06 SIZE 35
07 ADV
08 LBL 00
09 ADV
10 ADV
11 CLX
12 "G.C.∡ ,#Div,"
13 l--"Sides R/S"
14 CLRG
15 PROMPT
16 STO 01
17 R↓
18 STO 02
19 R↓
20 STO 03
21 0
22 "OverShoot? 0→4 "
23 PROMPT
24 RCL 02
25 +
26 1
27 +
28 1E3
29 /
30 1
31 +
32 STO 00
33 1
34 "Sph. R"
35 PROMPT
36 STO 19
37 RCL 03
38 COS
39 180
40 RCL 01
41 /
42 SIN
43 x
44 ACOS
45 STO 04
46 TAN
47 1/x
48 RCL 03
49 TAN
50 x
```

```
51 ASIN
52 RCL 02
53 /
54 STO 05
55 RCL 04
56 ENTER
57 +
58 180
59 X<>Y
60 --
61 ADV
62 "B1"
63 XEQ 03
64 ADV
65 LBL 01
66 1
67 RCL 00
68 IP
69 X=Y?
70 SF 00
71 RCL 05
72 STO + 06
73 RCL 00
74 20
75 +
76 RCL 06
77 SIN
78 RCL 04
79 TAN
80 x
81 ATAN
82 "M.C."
83 FIX 00
84 ARCL 00
85 FIX 08
86 XEQ 03
87 ADV
88 STO IND ST Y
89 COS
90 RCL 06
91 COS
92 x
93 ACOS
94 STO 08
95 RCL 07
96 --
97 STO 09
98 "a"
99 FIX 00
100 ARCL 00
101 FIX 08
```

"GEOM" CONTINUED

```
102 XEQ 03
103 XEQ 02
104 RCL 04
105 SIN
106 RCL 06
107 COS
108 x
109 ACOS
110 STO 10
111 RCL 10
112 SIN
113 RCL 09
114 SIN
115 x
116 ASIN
117 ENTER
118 +
119 FS? 00
120 STO 14
121 "b"
122 FIX 00
123 ARCL 00
124 FIX 08
125 XEQ 03
126 XEQ 02
127 FS?C 00
128 XEQ 14
129 RCL 10
130 TAN
131 RCL 09
132 COS
133 x
134 1/x
135 ATAN
136 STO 01
137 FIX 00
138 "A"
139 ARCL 00
140 FIX 08
141 XEQ 03
142 1
143 RCL 00
144 IP
145 X=Y?
146 GTO 05
147 180
148 RCL 01
149 --
150 RCL 11
151 --
152 FIX 00
153 "C"
154 ARCL 00
155 FIX 08
156 XEQ 03
157 RCL 11
158 FIX 00
159 "B"
160 ARCL 00
161 FIX 08
162 XEQ 03
163 LBL 05
164 ADV
165 ADV
166 ADV
167 RCL 10
168 ENTER
169 +
170 STO 11
171 RCL 08
172 STO 07
173 ISG 00
174 GTO 01
175 GTO 06
176 RTN
177 LBL 14
178 RCL 14
179 2
180 /
181 SIN
182 ENTER
183 +
184 2
185 /
186 RCL 09
187 2
188 /
189 SIN
190 ENTER
191 +
192 /
193 ACOS
194 SIN
195 ENTER
196 ENTER
197 RCL 09
198 2
199 /
200 SIN
201 ENTER
202 +
203 x
204 X<>Y
205 RCL 14
206 2
207 /
208 SIN
209 ENTER
210 +
211 x
212 X>Y?
213 X<>Y
214 "Panel 1 w "
215 XEQ 03
216 RCL 19
217 x
218 " w x R"
219 XEQ 03
220 ADV
221 RTN
222 LBL 02
223 2
224 /
225 SIN
226 ENTER
227 +
228 "c.f."
229 XEQ 03
230 ENTER
231 RCL 19
232 x
233 X=Y?
234 GTO 13
235 "Length"
236 XEQ 03
237 LBL 13
238 ADV
239 RTN
240 LBL 03
241 |--" = "
242 ARCL ST X
243 LBL 04
244 AVIEW
245 FS? 55
246 RTN
247 PSE
248 PSE
249 PSE
250 PSE
251 RTN
252 LBL 06
```

"GEOM" CONTINUED

```
253  "Coordinate?  "
254  |--"Yes=1  No=0"
255  PROMPT
256  X=0?
257  GTO 00
258  "Inner  Level?"
259  PROMPT
260  STO 12
261  "Outer  Level?"
262  PROMPT
263  STO 13
264  LBL 07
265  RCL 02
266  RCL 12
267  +
268  2
269  /
270  STO 18
271  1
272  +
273  X↑2
274  IP
275  STO 15
276  RCL 18
277  RCL 05
278  x
279  ENTER
280  +
281  STO 16
282  RCL 12
283  ABS
284  20
285  +
286  RCL IND ST X
287  STO 17
288  LBL 15
289  XEQ 08
290  XEQ 09
291  RCL 18
292  0.5
293  --
294  X<0?
295  GTO 11
296  X=0?
297  GTO 12
298  1
299  STO + 15
300  RCL 05
301  ENTER
302  +
303  STO -- 16
304  1
305  STO -- 18
306  GTO 15
307  LBL 11
308  RCL 12
309  1
310  +
311  RCL 13
312  X<Y?
313  GTO 06
314  1
315  STO + 12
316  GTO 07
317  LBL 12
318  SF 01
319  1
320  STO + 15
321  XEQ 09
322  GTO 11
323  LBL 08
324  RCL 17
325  COS
326  RCL 16
327  SIN
328  x
329  STO 08
330  RCL 17
331  COS
332  RCL 16
333  COS
334  x
335  RCL 03
336  SIN
337  x
338  RCL 17
339  SIN
340  RCL 03
341  COS
342  x
343  RCL 12
344  SIGN
345  x
346  +
347  STO 09
348  RCL 17
349  COS
350  RCL 16
351  COS
352  x
353  RCL 03
354  COS
355  x
356  RCL 17
357  SIN
358  RCL 03
359  SIN
360  x
361  RCL 12
362  SIGN
363  +/--
364  x
365  +
366  STO 10
367  RTN
368  LBL 09
369  ADV
370  FIX 00
371  "NODE  "
372  ARCL 15
373  XEQ 04
374  FIX 09
375  RCL 08
376  FS? 01
377  CLX
378  "2_x "
379  XEQ 03
380  RCL 09
381  "2_y "
382  XEQ 03
383  RCL 10
384  "2_z "
385  XEQ 03
386  ADV
387  FS? 01
388  GTO 10
389  ACOS
390  "∡  w/Top"
391  XEQ 03
392  LBL 10
393  FS? 01
394  0
395  FC?C 01
396  1
397  STO X 08
398  1
399  RCL 19
400  X=Y?
401  RTN
402  ADV
403  RCL 08
```

"GEOM" CONTINUED

```
404  RCL  19
405  x
406  "2_x "
407  XEQ  03
408  RCL  09
409  RCL  19
410  x
411  "2_y "
412  XEQ  03
413  RCL  10
414  RCL  19
415  x
416  "2_z "
417  XEQ  03
418  ADV
419  END
```

```
00  { 365-Byte Prgm }
01  LBL  "LATT"
02  SIZE  33
03  SF  27
04  LCLBL
05  "Top:A  Btm:B Prt"
06  I--",OFF:D  ON:E"
07  I--"  Corr ∡:C"
08  AVIEW
09  PSE
10  PSE
11  "User  ∡  Chg:H"
12  AVIEW
13  PSE
14  PSE
15  "Last  ∡ :G   w/w:F"
16  AVIEW
17  PSE
18  PSE
19  "Target  w?"
20  PROMPT
21  STO  31
22  "# Piers"
23  PROMPT
24  STO  30
25  "Top  ∡  "
26  PROMPT
27  STO  28
28  "Btm  ∡  "
29  PROMPT
30  LBL  00
31  STO  29
32  360
33  RCL  30
34  /
35  RCL  28
36  SIN
37  STO  05
38  →REC
39  STO  02
40  X<>Y
41  STO  01
42  RCL  28
43  COS
44  STO  03
45  STO  06
46  0
47  STO  04
48  180
49  RCL  30
50  /
51  RCL  29
52  SIN
53  →REC
54  STO  08
55  X<>Y
56  STO  07
57  RCL  29
58  COS
59  STO  09
60  RTN
61  LBL  B
62  RCL  09
63  STO  03
64  RCL  08
65  STO  02
66  RCL  07
67  +/--
68  STO  01
69  XEQ  A
70  RTN
71  LBL  C
72  RCL  31
73  RCL  32
74  /
75  RCL  29
76  RCL  28
77  --
78  x
79  RCL  28
80  +
81  AVIEW
82  PSE
83  GTO  00
84  LBL  A
85  1
86  STO  00
87  XEQ  " SPH "
88  RCL  10
89  STO  25
90  RCL  11
91  STO  26
92  RCL  12
93  STO  27
94  XEQ  02
95  0
96  STO  01
97  STO  02
98  STO  03
99  RCL  25
100  STO  04
101  RCL  26
```

PROGRAM LISTINGS:

"LATT" CONTINUED

```
102 STO 05
103 RCL 27
104 STO 06
105 180
106 STO 07
107 SF 07
108 XEQ " PLT "
109 XEQ 04
110 RTN
111 LBL 02
112 1
113 STO 19
114 11
115 STO 20
116 7
117 STO 18
118 LBL 03
119 RCL IND 19
120 STO IND 20
121 1
122 STO + 19
123 STO + 20
124 DSE 18
125 GTO 03
126 RTN
127 LBL 04
128 1.007
129 STO 18
130 1
131 STO -- 19
132 STO -- 20
133 LBL 05
134 RCL IND 20
135 STO IND 19
136 1
137 STO -- 19
138 STO -- 20
139 ISG 18
140 GTO 05
141 RTN
142 LBL D
143 PROFF
144 RTN
145 LBL E
146 PRON
147 RTN
148 LBL F
149 RCL 31
150 1E5
151 x
152 IP
153 RCL 32
154 1E5
155 x
156 IP
157 /
158 PRX
159 RTN
160 LBL G
161 RCL 29
162 PRX
163 RTN
164 LBL H
165 XEQ 00
166 END
```

```
00 { 477-Byte Prgm }
01 LBL "NORM"
02 SIZE 28
03 0
04 STO 25
05 STO 26
06 STO 27
07 LBL 00
08 "NORM TO PL"
09 XEQ 02
10 FIX 06
11 "IF 2 PL, MAKE "
12 I--"2→3 COMM"
13 XEQ 02
14 ADV
15 "Node 1:x ,y , z "
16 I--" R/S"
17 PROMPT
18 STO 03
19 R↓
20 STO 02
21 R↓
22 STO 01
23 "Node 2 x,y,z"
24 PROMPT
25 STO 06
26 R↓
27 STO 05
28 R↓
29 STO 04
30 "Node 3 x,y,z"
31 PROMPT
32 STO 09
33 R↓
34 STO 08
35 R↓
36 STO 07
37 LBL 01
38 RCL 01
39 RCL 04
40 --
41 X↑2
42 RCL 02
43 RCL 05
44 --
45 X↑2
46 +
47 RCL 03
48 RCL 06
49 --
50 X↑2
```

"NORM" CONTINUED

```
51  +
52  SQRT
53  STO 00
54  RCL 01
55  RCL 04
56  --
57  RCL 00
58  /
59  STO 13
60  RCL 02
61  RCL 05
62  --
63  RCL 00
64  /
65  STO 14
66  RCL 03
67  RCL 06
68  --
69  RCL 00
70  /
71  STO 15
72  RCL 04
73  RCL 07
74  --
75  X↑2
76  RCL 05
77  RCL 08
78  --
79  X↑2
80  +
81  RCL 06
82  RCL 09
83  --
84  X↑2
85  +
86  SQRT
87  STO 00
88  RCL 04
89  RCL 07
90  --
91  RCL 00
92  /
93  STO 16
94  RCL 05
95  RCL 08
96  --
97  RCL 00
98  /
99  STO 17
100 RCL 06
101 RCL 09
102 --
103 RCL 00
104 /
105 STO 18
106 RCL 14
107 RCL 18
108 x
109 RCL 15
110 RCL 17
111 x
112 --
113 X↑2
114 RCL 15
115 RCL 16
116 x
117 RCL 13
118 RCL 18
119 x
120 --
121 X↑2
122 +
123 RCL 13
124 RCL 17
125 x
126 RCL 14
127 RCL 16
128 x
129 --
130 X↑2
131 +
132 SQRT
133 STO 00
134 RCL 14
135 RCL 18
136 x
137 RCL 15
138 RCL 17
139 x
140 --
141 RCL 00
142 /
143 STO 22
144 ADV
145 FIX 06
146 "Ix = "
147 ARCL ST X
148 XEQ 02
149 RCL 15
150 RCL 16
151 x
152 RCL 13
153 RCL 18
154 x
155 --
156 RCL 00
157 /
158 STO 23
159 "Iy = "
160 ARCL ST X
161 XEQ 02
162 RCL 13
163 RCL 17
164 x
165 RCL 14
166 RCL 16
167 x
168 --
169 RCL 00
170 /
171 STO 24
172 "Iz = "
173 ARCL ST X
174 XEQ 02
175 ADV
176 RCL 25
177 ABS
178 RCL 26
179 ABS
180 +
181 RCL 27
182 ABS
183 +
184 X ≠ 0?  (X .NE. 0 ?)
185 XEQ 05
186 "Next pt x,y,z?"
187 I--"______11____"
188 I--" YES = 1_3__"
189 I-- " NO = 0"
190 PROMPT
191 X=0?
192 GTO 00
193 " x,y,z"
194 PROMPT
195 STO 12
196 R↓
197 STO 11
198 R↓
199 STO 10
200 RCL 10
```

PROGRAM LISTINGS:

"NORM" CONTINUED

```
201  X<> 07
202  X<> 04
203  STO 01
204  RCL 11
205  X<> 08
206  X<> 05
207  STO 02
208  RCL 12
209  X<> 09
210  X<> 06
211  STO 03
212  RCL 22
213  STO 25
214  RCL 23
215  STO 26
216  RCL 24
217  STO 27
218  GTO 01
219  LBL 05
220  RCL 22
221  RCL 25
222  x
223  RCL 23
224  RCL 26
225  x
226  +
227  RCL 24
228  RCL 27
229  x
230  +
231  ACOS
232  FIX 03
233  " ∡ Betw pl = "
234  ARCL ST X
235  I--" ° "
236  XEQ 02
237  ADV
238  ADV
239  ADV
240  RTN
241  LBL 02
242  AVIEW
243  FS? 55
244  RTN
245  PSE
246  PSE
247  PSE
248  PSE
249  END
```

```
00  { 143-Byte Prgm }
01  LBL "PDGN"
02  SIZE 07
03  180
04  "SIDES?"
05  PROMPT
06  /
07  STO 01
08  "R?"
09  PROMPT
10  STO 00
11  LBL 00
12  "NODE#?"
13  PROMPT
14  STO 02
15  " ∡ w/Top"
16  PROMPT
17  STO 03
18  FIX 00
19  ADV
20  "NODE "
21  ARCL 02
22  XEQ 05
23  RCL 01
24  RCL °03
25  SIN
26  → REC
27  FIX 09
28  STO 05
29  X<>Y
30  STO 04
31  RCL 03
32  COS
33  STO 06
34  XEQ 03
35  " ∡ w/Top"
36  RCL 03
37  XEQ 04
38  ADV
39  RCL 00
40  STO X 04
41  STO X 05
42  STO X 06
43  XEQ 03
44  ADV
45  GTO 00
46  LBL 03
47  RCL 04
48  "x"
49  XEQ 04
50  RCL 05
51  "y"
52  XEQ 04
53  RCL 06
54  "z"
55  XEQ 04
56  ADV
57  RTN
58  LBL 04
59  I--" = "
60  ARCL ST X
61  LBL 05
62  AVIEW
63  FS? 55
64  RTN
65  PSE
66  PSE
67  PSE
68  END
```

PROGRAM LISTINGS:

```
00 { 806-Byte Prgm }
01 LBL "PLTR"
02 " PL TRI- ∡ "
03 AVIEW
04 PSE
05 SIZE 08
06 FIX 04
07 LBL E
08 5
09 LBL 13
10 CF IND ST X
11 DSE ST X
12 GTO 13
13 CF 00
14 SF 27
15 CLRG
16 9
17 STO 00
18 3
19 STO 07
20 LCLBL
21 ADV
22 ADV
23 ADV
24 " ∡ 's: ABC"
25 AVIEW
26 PSE
27 PSE
28 PSE
29 PSE
30 "Side's: GOLD "
31 |-- " ABC "
32 AVIEW
33 PSE
34 PSE
35 PSE
36 PSE
37 CLA
38 CLX
39 VIEW ST X
40 LCLBL
41 ADV
42 ADV
43 STOP
44 LBL A
45 STO 01
46 " ∡A"
47 0
48 GTO 00
49 LBL B
50 STO 02
51 " ∡B"
52 1
53 GTO 00
54 LBL C
55 STO 03
56 " ∡C"
57 2
58 GTO 00
59 LBL a
60 STO 04
61 " a "
62 4
63 GTO 00
64 LBL b
65 STO 05
66 " b "
67 8
68 GTO 00
69 LBL c
70 STO 06
71 " c "
72 16
73 LBL 00
74 STO + 00
75 |-- "= "
76 ARCL ST Y
77 AVIEW
78 DSE 07
79 RTN
80 ADV
81 PI (π)
82 →DEG
83 RCL 01
84 --
85 RCL 02
86 --
87 RCL 03
88 --
89 STO 07
90 X>0?
91 GTO IND 00
92 LBL 12
93 "NO SOLUTION"
94 AVIEW
95 ADV
96 GTO E
97 LBL 14
98 LBL 15
99 LBL 16
100 17
101 GTO 06
102 LBL 18
103 LBL 19
104 LBL 20
105 21
106 SF 01
107 GTO 06
108 LBL 26
109 LBL 27
110 LBL 28
111 29
112 SF 03
113 LBL 06
114 RCL 00
115 --
116 X<>Y
117 STO IND ST Y
118 FS? 01
119 XEQ 04
120 FS? 03
121 XEQ 05
122 RCL 02
123 SIN
124 RCL 04
125 RCL 01
126 SIN
127 /
128 x
129 STO 05
130 LASTX
131 RCL 03
132 SIN
133 x
134 STO 06
135 FS?C 01
136 XEQ 05
137 FS?C 03
138 XEQ 04
139 LBL 01
140 2
141 0.1
142 " ∡A "
143 XEQ IND ST Y
144 " ∡B "
145 XEQ IND ST Y
146 " ∡C "
147 XEQ IND ST Y
148 "_a "
149 XEQ IND ST Y
150 "_b "
151 XEQ IND ST Y
152 "_c "
```

"PLTR" CONTINUED

```
153 XEQ IND ST Y
154 3
155 RCL 02
156 SIN
157 RCL 06
158 x
159 " a "
160 XEQ IND ST Y
161 RCL 01
162 SIN
163 x
164 " b "
165 XEQ IND ST Y
166 RCL 05
167 x
168 " c "
169 XEQ IND ST Y
170 RCL ST Z
171 2
172 /
173 RCL 06
174 x
175 "Area=  "
176 ARCL ST X
177 XEQ 32
178 ENTER
179 ENTER
180 2
181 x
182 RCL 04
183 /
184 RCL 05
185 /
186 RCL 06
187 /
188 1/x
189 "Outside  D.="
190 ARCL ST X
191 XEQ 32
192 X<>Y
193 RCL 04
194 RCL 05
195 +
196 RCL 06
197 +
198 /
199 4
200 x
201 "Inside  d.="
202 ARCL ST X
203 XEQ 32
204 "Perim.=  "
205 RCL 04
206 RCL + 05
207 RCL + 06
208 ARCL ST X
209 XEQ 32
210 ADV
211 FS? 02
212 RTN
213 FS?C 07
214 GTO 40
215 GTO E
216 LBL 02
217 |-- "=  "
218 ISG ST X
219 ARCL IND ST X
220 GTO 32
221 LBL 03
222 X<>Y
223 LASTX
224 |-- "  Height=  "
225 ARCL ST Z
226 LBL 32
227 AVIEW
228 FS? 55
229 RTN
230 PSE
231 PSE
232 PSE
233 PSE
234 RTN
235 LBL 04
236 XEQ 05
237 LBL 05
238 RCL 03
239 X<> 01
240 X<> 02
241 STO 03
242 RCL 06
243 X<> 04
244 X<> 05
245 STO 06
246 RTN
247 LBL 22
248 SF 01
249 LBL 29
250 SF 04
251 GTO 07
252 LBL 30
253 SF 03
254 LBL 23
255 SF 05
256 GTO 07
257 LBL 31
258 SF 03
259 LBL 21
260 SF 00
261 GTO 07
262 LBL 33
263 SF 01
264 SF 05
265 GTO 07
266 LBL 34
267 SF 00
268 SF 01
269 GTO 07
270 LBL 35
271 SF 03
272 SF 04
273 LBL 07
274 FS? 01
275 XEQ 04
276 FS? 03
277 XEQ 05
278 FS? 05
279 XEQ 08
280 FS? 00
281 XEQ 10
282 FS? 04
283 RCL 06
284 FS?C 04
285 XEQ 11
286 FS?C 03
287 XEQ 04
288 FS?C 01
289 XEQ 05
290 FS?C 05
291 GTO 01
292 FC? 02
293 GTO 01
294 XEQ 01
295 GTO IND 00
296 LBL 08
297 RCL 03
298 RCL 05
299 ->REC
300 +/--
301 RCL 04
302 +
```

"PLTR" CONTINUED

```
303 →POL
304 STO 06
305 X<>Y
306 STO 02
307 +/--
308 RCL 07
309 +
310 STO 01
311 RTN
312 LBL 10
313 RCL 05
314 LBL 11
315 ENTER
316 FS? 02
317 GTO 24
318 RCL 01
319 SIN
320 x
321 RCL 04
322 X<Y?
323 GTO 12
324 RCL ST Z
325 X≤Y? (X .LE. Y?)
326 GTO 17
327 XEQ 17
328 FS? 00
329 RCL 02
330 FC? 00
331 RCL 03
332 90
333 X=Y?
334 RTN
335 " 2 SOL "
336 AVIEW
337 PSE
338 ADV
339 "1st"
340 AVIEW
341 SF 02
342 RTN
343 LBL 17
344 RCL 01
345 SIN
346 x
347 RCL 04
348 /
349 ASIN
350 FS? 00
351 STO 02
352 FC? 00
353 STO 03
354 +/--
355 RCL 07
356 +
357 GTO 25
358 LBL 24
359 CF 02
360 FS? 00
361 RCL 02
362 FC? 00
363 RCL 03
364 COS
365 +/--
366 ACOS
367 FS? 00
368 STO 02
369 FC? 00
370 STO 03
371 "2nd"
372 AVIEW
373 RCL 01
374 +
375 COS
376 +/--
377 ACOS
378 LBL 25
379 FS? 00
380 STO 03
381 FC? 00
382 STO 02
383 SIN
384 RCL 04
385 x
386 RCL 01
387 SIN
388 /
389 FS? 00
390 STO 06
391 FC? 00
392 STO 05
393 RTN
394 LBL 37
395 LBL "PLT"
396 XEQ 09
397 XEQ 05
398 XEQ 09
399 RCL 02
400 +
401 +/--
402 RCL 07
403 +
404 STO 03
405 XEQ 04
406 GTO 01
407 LBL 09
408 RCL 05
409 RCL 06
410 →POL
411 X↑2
412 RCL 04
413 X↑2
414 --
415 2
416 /
417 RCL 05
418 /
419 RCL 06
420 /
421 ACOS
422 STO 01
423 RTN
424 LBL 40
425 RCL 01
426 SIN
427 RCL 05
428 x
429 RCL 03
430 SIN
431 RCL 04
432 x
433 X>Y?
434 X<>Y
435 RCL 02
436 SIN
437 RCL 06
438 x
439 X>Y?
440 X<>Y
441 STO 32
442 END
```

```
00  { 536-Byte Prgm }
01  LBL "ROTN"
02  "Rotate Node xy&"
03  |-- "z Coord"
04  |--"2_"
05  XEQ 05
06  "Keep ∡ 's Cyclic"
07  |-- "al:__5__"
08  |--"_"
09  |--"z>x>y>z>x>y..."
10  XEQ 05
11  "Use 0 ∡ 's Where"
12  |-- '____9____"
13  |--"Applicable As "
14  |--"Fill."
15  XEQ 05
16  "+/- ∡ 's:Use RH "
17  | "Rule__4__"
18  XEQ 05
19  "Input 12 Rotati"
20  |--"on ∡ 's__5__"
21  XEQ 05
22  "KEY "R/S" IF "
23  |--"ALL 0's"
24  XEQ 05
25  SIZE 24
26  CLRG
27  "1st"
28  XEQ 04
29  STO 03
30  R↓
31  STO 02
32  R↓
33  STO 01
34  "2nd"
35  XEQ 04
36  STO 06
37  R↓
38  STO 05
39  R↓
40  STO 04
41  "3rd"
42  XEQ 04
43  STO 09
44  R↓
45  STO 08
46  R↓
47  STO 07
48  "4th"
49  XEQ 04
50  STO 12
51  R↓
52  STO 11
53  R↓
54  STO 10
55  GTO 00
56  LBL 04
57  CLST
58  |--" Set: z ,x ,y "
59  |--"R/S"
60  PROMPT
61  RTN
62  LBL 00
63  1.015
64  STO 13
65  CLST
66  ADV
67  ADV
68  "Input Node:__5__"
69  |-- "_____9_____"
70  |--"Node# ,x ,y ,"
71  |--"z R/S"
72  PROMPT
73  STO 17
74  R↓
75  STO 16
76  R↓
77  STO 15
78  R↓
79  STO 14
80  XEQ 01
81  XEQ 01
82  XEQ 01
83  XEQ 01
84  ADV
85  FIX 00
86  "Node "
87  ARCL 14
88  XEQ 05
89  ALL (Display)
90  "x = "
91  ARCL 15
92  XEQ 05
93  "y = "
94  ARCL 16
95  XEQ 05
96  "z = "
97  ARCL 17
98  XEQ 05
99  GTO 00
100 LBL 01
101 RCL 15
102 STO 19
103 RCL 16
104 STO 20
105 XEQ 02
106 RCL 21
107 STO 15
108 RCL 22
109 STO 16
110 STO 19
111 RCL 17
112 STO 20
113 XEQ 02
114 RCL 21
115 STO 16
116 RCL 22
117 STO 17
118 STO 19
119 RCL 15
120 STO 20
121 XEQ 02
122 RCL 21
123 STO 17
124 RCL 22
125 STO 15
126 RTN
127 LBL 02
128 RCL IND 13
129 STO 18
130 RCL 19
131 RCL 18
132 COS
133 x
134 RCL 20
135 RCL 18
136 SIN
137 x
138 --
139 STO 21
140 RCL 19
141 RCL 18
142 SIN
143 x
144 RCL 20
145 RCL 18
146 COS
147 x
148 +
149 STO 22
150 ISG 13
151 RTN
152 LBL 05
```

PROGRAM LISTINGS:

"ROTN" CONTINUED

```
153  AVIEW
154  FS?  55
155  RTN
156  PSE
157  PSE
158  PSE
159  PSE
160  END
```

```
00  { 1193-Byte Prgm }
01  LBL "SECT"
02  "Section Propert"
03  I--"ies"
04  SIZE 20
05  SF 27
06  LCLBL
07  CF 00
08  CF 02
09  CF 03
10  LBL 00
11  CLRG
12  "Fillet Quad 123"
13  I--"4:  CDEF"
14  AVIEW
15  PSE
16  "b=t=Radius"
17  AVIEW
18  PSE
19  "Tri ∡ Quad 1234"
20  I--": GHIJ"
21  AVIEW
22  PSE
23  "b:Horiz  t:Vert"
24  AVIEW
25  PSE
26  "Delta x,y @ 90    "
27  AVIEW
28  PSE
29  "x&y Recalc:F1->4"
30  I--",  T1->4"
31  AVIEW
32  PSE
33  "Key Ltr @ " ∡ " "
34  AVIEW
35  PSE
36  "If delete:  --b"
37  AVIEW
38  PSE
39  ADV
40  ADV
41  ADV
42  TONE 3
43  FIX 00
44  "# Elements?"
45  PROMPT
46  1E3
47  /
48  1
49  +
50  STO 14
```

```
51  LBL 01
52  ADV
53  "EL. "
54  FIX 00
55  ARCL 14
56  FIX 06
57  I--":b ,t ,x ,y,R/S"
58  TONE 7
59  PROMPT
60  STO 12
61  Rd
62  STO 11
63  Rd
64  STO 10
65  Rd
66  STO 09
67  " ∡ w/  x-Axis"
68  TONE 1
69  PROMPT
70  LBL 18
71  FS? 00
72  ASTO 13
73  FC? 00
74  STO 13
75  RCL 09
76  SIGN
77  X<0?
78  SF 01
79  FIX 00
80  ADV
81  "Element  "
82  ARCL 14
83  XEQ 06
8 4 FIX 06
85  "b = "
86  ARCL 09
87  XEQ 10
88  "t = "
59  ARCL 10
60  XEQ 10
91  "x = "
92  ARCL 11
93  FC? 00
94  XEQ 10
95  FS? 00
96  PROMPT
97  "y = "
98  ARCL 12
99  FC? 00
100  XEQ 10
101  FS? 00
```

"SECT" CONTINUED

```
PROMPT
" ∡ = "
ARCL 13
FC? 00
|--" Deg"
FS? 00
|--" Quad"
XEQ 10
ADV
RCL 09
RCL 10
x
FC? 00
1
FS? 02
4.66
FS? 03
2
/
STO 00
STO + 01
FIX 03
" A "
XEQ 05
RCL 11
x
RCL 12
x
STO + 02
"Axy "
XEQ 05
RCL 00
RCL 11
x
STO + 03
" Ax "
XEQ 05
LASTX
x
STO + 04
" A(x)E2"
XEQ 05
FC? 00
GTO 00
FS? 02
GTO 01
FS? 03
GTO 02
LBL 01
RCL 10
4
Y↑X
132.536
/
FS? 01
+/-
STO 19
GTO 01
LBL 02
RCL 09
3
Y↑X
RCL 10
x
36
/
GTO 01
LBL 00
RCL 09
X↑2
STO 00
RCL 10
X↑2
STO 19
XEQ 02
LBL 01
STO + 05
"Ioy "
XEQ 05
RCL 09
RCL 10
x
FC? 00
1
FS? 02
4.66
FS? 03
2
/
RCL 12
x
STO + 06
"Ay "
XEQ 05
LASTX
x
STO + 07
"A(y)E2"
XEQ 05
FC?C 00
GTO 00
FS?C 02
GTO 01
FS?C 03
GTO 21
LBL 01
RCL 19
GTO 01
LBL 21
RCL 10
3
Y↑X
RCL 09
x
36
/
GTO 01
LBL 00
RCL 00
RCL 19
STO 00
R↓
STO 19
XEQ 02
LBL 01
STO + 08
"Iox "
XEQ 05
ADV
CF 01
ISG 14
GTO 01
SF 12
"SUMMATION"
BEEP
XEQ 10
CF 12
" ΣA = "
ARCL 01
XEQ 06
" ΣAxy = "
ARCL 02
XEQ 06
" ΣAx = "
ARCL 03
XEQ 06
" ΣA(x)E2 = "
ARCL 04
XEQ 06
" ΣIoy = "
```

"SECT" CONTINUED

```
253  XEQ  06
254  " ΣAy  =  "
255  ARCL  06
256  XEQ  06
257  " ΣA(y)E2  =  "
258  ARCL  07
259  XEQ  06
260  " Σlox  =  "
261  ARCL  08
262  XEQ  06
263  ADV
264  RCL  03
265  RCL  01
266  /
267  STO  09
268  " x-Bar "
269  XEQ  05
270  RCL  06
271  RCL  01
272  /
273  STO  10
274  " y-Bar "
275  XEQ  05
276  ADV
277  RCL  07
278  RCL  08
279  +
280  RCL  01
281  RCL  10
282  X↑2
283  x
284  --
285  STO  11
286  "Ix "
287  XEQ  05
288  RCL  01
289  /
290  SQRT
291  " rx "
292  XEQ  05
293  ADV
294  RCL  04
295  RCL  05
296  +
297  RCL  01
298  RCL  09
299  X↑2
300  x
302  STO  12
303  "Iy "
304  XEQ  05
305  RCL  01
306  /
307  SQRT
308  "ry "
309  XEQ  05
310  ADV
311  RCL  02
312  RCL  01
313  RCL  09
314  x
315  RCL  10
316  x
317  --
318  STO  18
319  1E4
320  x
321  IP
322  X=0?
323  GTO  22
324  RCL  18
325  "Ixy "
326  XEQ  05
327  ADV
328  RCL  11
329  RCL  12
330  +
331  2
332  /
333  RCL  11
334  RCL  12
335  --
336  2
337  /
338  X↑2
339  RCL  18
340  X↑2
341  +
342  SQRT
343  +
344  STO  15
345  "Ip"
346  XEQ  05
347  LASTX
348  2
349  x
350  --
351  STO  16
352  "Iq"
353  XEQ  05
354  ADV
355  RCL  15
356  RCL  01
357  /
358  SQRT
359  "rp"
360  XEQ  05
361  RCL  16
362  RCL  01
363  /
364  SQRT
365  "rq"
366  XEQ  05
367  ADV
368  RCL  18
369  2
370  x
371  RCL  12
372  RCL  11
373  --
374  /
375  ATAN
376  2
377  /
378  " ∡  =  "
379  ARCL  ST  X
380  I--"  Deg. "
381  XEQ  06
382  ADV
383  ADV
384  LBL  22
385  "Add:"A"  New:"B""
386  PROMPT
387  LBL  10
388  AVIEW
389  PSE
390  PSE
391  RTN
392  LBL  A
393  GTO  01
394  LBL  B
395  GTO  00
396  LBL  C
397  XEQ  19
398  STO +  12
399  STO +  11
400  "F1"
401  GTO  18
402  LBL  D
403  XEQ  19
```

"SECT" CONTINUED

```
404 STO + 12
405 STO -- 11
406 "F2"
407 GTO 18
408 LBL E
409 XEQ 19
410 STO -- 12
411 STO -- 11
412 "F3"
413 GTO 18
414 LBL F
415 XEQ 19
416 STO -- 12
417 STO + 11
418 "F4"
419 GTO 18
420 LBL G
421 XEQ 20
422 STO + 11
423 RCL 10
424 3
425 /
426 STO + 12
427 "T1"
428 GTO 18
429 LBL H
430 XEQ 20
431 STO -- 11
432 RCL 10
433 3
434 /
435 STO + 12
436 "T2"
437 GTO 18
438 LBL I
439 XEQ 20
440 STO -- 11
441 RCL 10
442 3
443 /
444 STO -- 12
445 "T3"
446 GTO 18
447 LBL J
448 XEQ 20
449 STO + 11
450 RCL 10
451 3
452 /
453 STO -- 12
454 "T4"
455 GTO 18
456 LBL 19
457 SF 00
458 SF 02
459 RCL 09
460 ABS
461 0.2234
462 X
463 RTN
464 LBL 20
465 SF 00
466 SF 03
467 RCL 09
468 ABS
469 3
470 /
471 RTN
472 LBL 02
473 RCL 19
474 RCL 13
475 SIN
476 X↑2
477 x
478 RCL 00
479 RCL 13
480 COS
481 X↑2
482 x
483 +
484 RCL 09
485 x
486 RCL 10
487 x
488 12
489 /
490 RTN
491 LBL 05
492 " = "
493 ARCL ST X
494 LBL 06
495 AVIEW
496 FS? 55
497 RTN
498 PSE
499 PSE
500 PSE
501 END
```

```
00 { 647-Byte Prgm }
01 LBL "SPHO"
02 "Sph.Oblique Tri"
03 I--"- ∡ "
04 XEQ 04
05 CLX
06 SIZE 27
07 ADV
08 "Input 3 Nodes "
09 I--"on___8___"
10 I-- "Sph.Surf."
11 XEQ 04
12 ""R & Coord: Same"
13 I--" Units"
14 XEQ 04
15 "Nodes 1,2,3: "
16 I--"Key A,B,C"
17 XEQ 04
18 "Execute: Key E"
19 XEQ 04
20 ADV
21 1
22 "R=? R/S"
23 PROMPT
24 STO 00
25 ADV
26 SF 27
27 LCLBL
28 RTN
29 LBL A
30 STO 03
31 R↓
32 STO 02
33 R↓
34 STO 01
35 RTN
36 LBL B
37 STO 06
38 R↓
39 STO 05
40 R↓
41 STO 04
42 RTN
43 LBL C
44 STO 09
45 R↓
46 STO 08
47 R↓
48 STO 07
49 RTN
50 LBL E
```

"SPHO" CONTINUED

```
LBL "SPH"
RCL 01
RCL 04
--
RCL 02
RCL 05
--
→POL
RCL 03
RCL 06
--
→POL
STO 10
RCL 04
RCL 07
--
RCL 05
RCL 08
--
→POL
RCL 06
RCL 09
--
→POL
STO 11
RCL 07
RCL 01
--
RCL 08
RCL 02
--
→POL
RCL 09
RCL 03
--
→POL
STO 12
RCL 10
XEQ 01
STO 16
X<>Y
STO 13
RCL 11
XEQ 01
STO 17
X<>Y
STO 14
RCL 12
XEQ 01
STO 18
X<>Y
STO 15
RCL 13
STO 22
RCL 14
STO 23
RCL 15
STO 24
XEQ 02
STO 21
RCL 14
STO 22
RCL 15
STO 23
RCL 13
STO 24
XEQ 02
STO 19
RCL 15
STO 22
RCL 13
STO 23
RCL 14
STO 24
XEQ 02
STO 20
RCL 21
+
RCL 19
+
180
--
STO 25
RCL 00
X↑2
x
PI
x
180
/
STO 26
ALL      (Display)
ADV
"SPH. DATA"
XEQ 04
" Sides, Chord "
I--"Factors"
XEQ 04
RCL 16
"1-2"
XEQ 03
RCL 17
"2-3"
XEQ 03
RCL 18
"3-1"
XEQ 03
ADV
" Sides, Cent. ∡ "
XEQ 04
RCL 13
"1-2"
XEQ 03
RCL 14
"2-3"
XEQ 03
RCL 15
"3-1"
XEQ 03
ADV
" Surface ∡ 's"
XEQ 04
RCL 19
"Node 1"
XEQ 03
RCL 20
"Node 2"
XEQ 03
RCL 21
"Node 3"
XEQ 03
ADV
"Area = "
ARCL 26
XEQ 04
ADV
"Sph Excess= "
ARCL 25
XEQ 04
ADV
"Linear Data:"
XEQ 04
RCL 10
"Side 1-2"
XEQ 03
RCL 11
"Side 2-3"
XEQ 03
RCL 12
"Side 3-1"
XEQ 03
```

PROGRAM LISTINGS:

"SPHO" CONTINUED

```
202  ADV
203  ADV
204  ADV
205  RTN
206  LBL  01
207  2
208  /
209  RCL  00
210  /
211  STO  22
212  ASIN
213  2
214  x
215  RCL  22
216  2
217  x
218  RTN
219  LBL  02
220  RCL  22
221  COS
222  RCL  23
223  COS
224  RCL  24
225  COS
226  x
227  --
228  RCL  23
229  SIN
230  /
231  RCL  24
232  SIN
233  /
234  ACOS
235  RTN
236  LBL  03
237  I--" = "
238  ARCL  ST  X
239  LBL  04
240  AVIEW
241  FS? 55
242  RTN
243  PSE
244  PSE
245  PSE
246  PSE
247  END
```

```
00  { 510-Byte Prgm }
01  LBL  "SPHR"
02  "Spherical  Rt.  "
03  I--"Tri - ∡ "
04  AVIEW
05  ADV
06  PSE
07  SF  27
08  SIZE  07
09  LBL  07
10  ADV
11  0
12  STO 00
13  2
14  STO  06
15  " Use A,B Keys Fo"
16  I--"r____9_____"
17  I--"Surface  Angles"
18  XEQ  18
19  "Use Gold/a,b,c  "
20  I--"Keys__5__"
21  I--"For Central ∡ s"
22  XEQ  18
23  ADV
24  ADV
25  ALL     (Display)
26  CLX
27  VIEW  ST  X
28  LCLBL
29  STOP
30  LBL  A
31  STO  01
32  "∡A"
33  0
34  GTO  00
35  LBL  B
36  STO  02
37  "∡B"
38  1
39  GTO  00
40  LBL  a
41  STO  03
42  "∡a"
43  2
44  GTO  00
45  LBL  b
46  STO  04
47  "∡b"
48  4
49  GTO  00
50  LBL  c
51  STO  05
52  "∡c"
53  8
54  LBL  00
55  STO +  00
56  I--" = "
57  ARCL  ST  Y
58  XEQ  18
59  ADV
60  DSE  06
61  RTN
62  GTO  IND  00
63  LBL  01
64  RCL  01
65  TAN
66  RCL  02
67  TAN
68  x
69  1/x
70  ACOS
71  STO  05
72  SIN
73  RCL  02
74  SIN
75  x
76  ASIN
77  STO  04
78  SIN
79  RCL  01
80  TAN
81  x
82  ATAN
83  STO  03
84  GTO  11
85  LBL  02
86  RCL  03
87  TAN
88  RCL  01
89  TAN
90  /
91  ASIN
92  STO  04
93  COS
94  RCL  01
95  SIN
96  x
97  ACOS
98  STO  02
99  COS
100  1/x
101  RCL  03
```

"SPHR" CONTINUED

```
102 TAN
103 x
104 ATAN
105 STO 05
106 GTO 11
107 LBL 04
108 RCL 04
109 TAN
110 RCL 01
111 COS
112 /
113 ATAN
114 STO 05
115 COS
116 RCL 04
117 COS
118 /
119 ACOS
120 STO 03
121 TAN
122 RCL 05
123 TAN
124 /
125 ACOS
126 STO 02
127 GTO 11
128 LBL 08
129 RCL 01
130 SIN
131 RCL 05
132 SIN
133 x
134 ASIN
135 STO 03
136 TAN
137 RCL 01
138 TAN
139 /
140 ASIN
141 STO 04
142 COS
143 RCL 01
144 SIN
145 x
146 ACOS
147 STO 02
148 GTO 11
149 LBL 03
150 RCL 03
151 COS
152 RCL 02
153 SIN
154 x
155 ACOS
156 STO 01
157 TAN
158 RCL 02
159 TAN
160 x
161 1/x
162 ACOS
163 STO 05
164 SIN
165 RCL 02
166 SIN
167 x
158 ASIN
169 STO 04
170 GTO 11
171 LBL 05
172 RCL 02
173 COS
174 RCL 04
175 COS
176 /
177 ASIN
178 STO 01
179 TAN
180 RCL 02
181 TAN
182 x
183 1/x
184 ACOS
185 STO 05
186 SIN
187 RCL 01
188 GTO 15
189 LBL 09
190 RCL 02
191 SIN
192 RCL 05
193 SIN
194 x
195 ASIN
196 STO 04
197 TAN
198 RCL 05
199 TAN
200 /
201 ACOS
202 STO 01
203 SIN
204 RCL 05
205 LBL 15
206 SIN
207 x
208 ASIN
209 STO 03
210 GTO 11
211 LBL 06
212 RCL 03
213 COS
214 RCL 04
215 COS
216 x
217 ACOS
218 STO 05
219 SIN
220 1/x
221 RCL 04
222 SIN
223 x
224 ASIN
225 GTO 16
226 LBL 10
227 RCL 03
228 TAN
229 RCL 05
230 TAN
231 /
232 ACOS
233 STO 02
234 SIN
235 RCL 03
236 COS
237 x
238 ACOS
239 STO 01
240 COS
241 RCL 05
242 TAN
243 x
244 ATAN
245 STO 04
246 GTO 11
247 LBL 12
248 RCL 05
249 COS
250 RCL 04
251 COS
252 /
```

"SPHR" CONTINUED

```
253  ACOS
254  STO  03
255  TAN
256  RCL  05
257  TAN
258  /
259  ACOS
260  LBL  16
261  STO  02
262  SIN
263  RCL  03
264  COS
265  x
266  ACOS
267  STO  01
268  LBL  11
269  "∡A"
270  1
271  XEQ  13
272  " ∡B"
273  2
274  XEQ  13
275  "∡a"
276  3
277  XEQ  13
278  "∡b"
279  4
280  XEQ  13
281  "∡c"
282  5
283  XEQ  13
284  GTO 07
285  LBL  13
286  I--" = "
287  ARCL  IND  ST  X
288  XEQ  14
289  XEQ  18
290  RTN
291  LBL  14
292  I--"   "
293  RTN
294  LBL  18
295  AVIEW
296  FS?  55
297  RTN
298  PSE
299  PSE
300  PSE
301  END
```

```
00  { 288-Byte Prgm }
01  LBL  "WIND"
02  "Base ∡ "
03  PROMPT
04  STO  01
05  30
06  X<>Y
07  X>Y?
08  GTO  02
09  RCL  01
10  0.9429
11  Y↑X
12  0.02313
13  x
14  STO  04
15  248
16  1/x
17  RCL  01
18  x
19  STO  05
20  LASTX
21  951
22  /
23  STO  06
24  GTO  06
25  LBL  02
26  60
27  X<Y?
28  GTO  03
29  RCL  01
30  LN
31  2.11
32  /
33  1.042
34  --
35  STO  04
36  RCL  01
37  0.03
38  x
39  E↑X
40  0.0492
41  x
42  STO  05
43  LBL  07
44  RCL  01
45  0.065
46  x
47  E↑X
48  223
49  /
50  STO  06
51  GTO  06
52  LBL  03
53  X<>Y
54  90
55  X<Y?
56  GTO  01
57  RCL  01
58  LN
59  0.258
60  x
61  0.1564
62  --
63  STO  04
64  RCL  01
65  40.1
66  /
67  E↑X
68  15
69  /
70  STO  05
71  GTO  07
72  LBL  04
73  I--" = "
74  ARCL  ST  X
75  LBL  05
76  AVIEW
77  FS?  55
78  RTN
79  PSE
80  PSE
81  PSE
82  PSE
83  RTN
84  LBL  01
85  "NO  SOL."
86  XEQ  05
87  RTN
88  LBL  06
89  FIX  03
90  "COEFF's:"
91  XEQ  05
92  RCL  04
93  "LIFT"
94  XEQ  04
95  RCL  05
96  "DRAG"
97  XEQ  04
98  FIX  04
99  RCL  06
100  0.1
101  x
```

"WIND" CONTINUED

```
"MOM."
XEQ 04
FIX 01
ADV
"EXP.FACTOR?"
PROMPT
"N?"
PROMPT
X↑2
x
391
/
"h?"
PROMPT
30
/
0.3
Y↑X
x
"q"
XEQ 04
ADV
ADV
ADV
END
```

Miscellaneous Stuff

Dome Basics:

A spherical chord is a straight line element whose ends lie on a common spherical surface.

The sphere origin is at x=y=z=0.0

A chord's central angle is the plane angle subtended by the two radials from the sphere origin to the ends of a chord.

An element's chord factor is equal to two times the sine of half of the central angle. It may range in size from 0.0 through 2.0

The chord length is the product of the chord factor and the sphere radius.

A spherical node is the point of intersection of two or more chords. Center points of chords are not spherical, although they are useful for determining boundaries of dome geometries when they lie on planes of symmetry. Chord factors of divided elements do not change from that of total elements.

The sum of spherical angles about a node equals 360 degrees. The spherical angle between two chords is the plane angle between the projections of the chords onto a plane normal to the node radial from the sphere origin. The plane angles between two chords is always less than the spherical angle. The spherical angles are required for the purpose of designing the node elements which are referred to as hubs or gussets.

A great circle lies on a plane which intersects the sphere origin. The sum of spherical angles on either side of a great circle node equals 180 degrees. A minor circle lies on a plane which does not pass through the sphere origin. The sum of spherical angles which lie on either side of a minor circle node is either greater than or less than 180 degrees as a function of being either toward or away from the sphere origin. Within the GEOM program, the outboard basic sector node locus is a great circle and the parallel inner node loci define minor circles. The geometry diagonals are all great circles. The geometry generation logic is based on the solution of progressively larger spherical right triangles and subtracting the value of the previous hypotenuse from the current hypotenuse. One edge of of the spherical triangle is the outboard great circle angle subdivided by the number of the divisions. Two times this subdivision equals the “b1” central angle. The spherical angle, "A1", between the outboard edge and the principal diagonal is constant during the successive solutions.The other required input is the progressive summation of the outboard subdivisions. Do not confuse the outboard minor circle edge of the fold over with the generation outboard great circle which defines the “b1” strut elements.

Miscellaneous Stuff

<u>Areas:</u>

Dome surface area = $2\pi Rh$

where: R = Spherical radius

h = Dome height

Therefore, area calculations are directly proportional to height, The bottom half of a dome has the same area as the top half. This relationship is useful for estimating construction joint locations, when matching crane pick limits.

When using a helicopter pick, the rotor down wash must be taken into account. It is most efficient to omit dome skin and pick frame only. Use a drag coefficient of 2.0 for dome strut projected areas. The down wash reaction and dead weight are additive and can affect picking cable load allowable. Calculate down wash per unit area as (helicopter weight plus pick weight) divided by area of rotor wiped circle. Helicopter pick cables typically must be much longer than nominal crane pick cables, to move the down wash off the picked object to reduce effect.

Node tributary area equals the summation of each adjoining panel area divided by the number of corners of each area. For dead load areas, use the above calculation. For live load area approximations, multiply the above calculation by the node z-axis unit coordinate.

Member tributary area equals the summation of each, of the two adjoining panels, area divided by the number of corners of each of the two panels. Member dead load calculations may be handled similar to node loads and live load areas may be multiplied by the cosine of the member slope. This is the average of the two end node z-axis unit coordinates.

When using a stiffness matrix structural analysis program which uses node loads, the calculation of member loads, due to tributary areas, may be useful for detail empirical calculations only. The actual node live loads are reduced by additional slope factors. The American National Standards Institute uses factors, for areas greater than 200 square feet, of 80% of ground snow for slopes up to 30 degrees, a factor of 80% through 0% between 30 degrees and 70 degrees and 0% on slopes greater than 70%. ANSI load factors, though generally accepted, are not universal. The State of New York has its own unique snow load profile which is conic with graduated slope changes. Mother Nature has to mind her manners in New York. There are other snow load factors which are related to wind exposure, inside temperature, insulation and importance relative to life support i.e. hospitals and emergency response facilities.

Miscellaneous Stuff

Dome behavior:

It is useful to visualize an elevation view of a dome with a horizontal line at the mid-height location. This may be considered to be a line of inflection.

When loaded with either dead or live weights, the upper portion of the dome, above the inflection line, will deflect inward with all struts in the upper zone generally loaded in compression. Below the inflection line, the dome will deflect outward, with the radial struts continuing to be loaded in compression and the tangential struts progressively carrying increasing tension loads after going through an axial load reversal at the inflection line. The above criteria applies to domes with a base angle of less than 90 degrees. Above this angle, the ring forces reverse from tension to compression.

Under dominant unbalanced live loading, the inflection line may lie in a vertical plane at the dome center, with the loaded side deflecting inward and the unloaded side deflecting outward. Dominant is condition of live load exceeding dead weight.

Under dominant wind loading, one may visualize a reversal of the above symmetrical loading behavior.

The member loads derived from a stiffness matrix program come from the relative displacement and node rotations at both ends of the members. A general rule to remember is: Loads follow stiffness.

Because most domes have a very low shell thickness to spherical radius ratio, any sudden radial load application may cause the dome to effect a wave motion similar to a wire held in tension with an abrupt force applied near one end.

Miscellaneous Stuff

Program translation:

Because access to an HP-42S may be limited, the user of this manual may have to translate the program logic to that of another machine.

As an example, the logic within the Spherical Right Triangle routine uses binary sum addressing where Spherical Surface Angles A and B use binary values of 0 and 1. The 0 value is permissible because a fixed number of inputs is used. In this case, after two inputs are made, the program executes automatically. The side Spherical Central Angles a, b and c use values of 2, 4 and 8. A translated program could use a variable list where 'var1' through 'var5' represent the possible inputs. If surface angle B and side angle 'a' are inputted, the binary sum would be 3. A translation could include a conditional test i.e.:

IF (((var2).AND.(var3)).NE.(0.0)) GOTO LBL xxx; (1 of 10 possible input combos)
would be equivalent to GTO IND (binary sum 3) or GTO LBL 03
At xxx continue given solution logic. Flag sets and clears could be handled by:
FLAG1=1 or FLAG1=0 for set or clear, as example.

If user would like to be recognized for his/her translation, BARF will include them within a Translated Software section in future editions of this manual. BARF is now facing galloping senility and prefers to not develop all possible program translations. Younger computer scientists are less likely to have cloudy minds. Because this manual is a product of DTP, future editions can be the next copy printed. Please send software to same address as shown on inside rear cover. Include your name, address and phone number so that any other party may critique same.

BARF would also like to receive 5x7 photos of any projects. Include A/E name, address and phone number together with project name and location. Publicity could draw additional business contacts.

Most of this manual's program logic was developed in the mid-70s when one of the best desktop machines was the *Monroe* 1880. Toward the end of the decade the best personal machine was the HP-41. The *PPC* was composed of more than 10,000 members using HP-41s. The HP-42 has more memory and uses less power.

FYI: A blivet is 10 pounds of crap in a 5 pound container.

History

This manual began as the result of BARF having heard that his grandson, Kyle, expressed an interest in becoming an engineer. BARF wanted to document his favorite occupation, that of a dome designer for Kyle's use and the use of any other who may wish to make use of BARF's experience.

George was baptized with the BARF handle in the latter 1950s while he was acting as the engineering flight test instrumentation group design checker at the Columbus (OH) Division of North American Aviation, Inc. He had the habit of expressing his opinion of different designs and his comment stuck.

Following his termination from NAA in 1970, BARF began employment with TEMCOR as a project engineer in their dome division. While developing most of the company's CAD software, BARF was named manager of R & D. He remained in this function until his retirement in 1986.

This manual reflects that earliest CAD software which remains state-of-art in calculating dome geometries. The only difference between the past and today is the hardware used and speed of doing things. The methodology remains the same.

This manual is directed toward engineers and architects in the calculation of dome geometries and relevant technology.

Price: $59.00 (US)

Price includes shipping and handling in the United States. Preferred method of payment is by Money Order.

Foreign orders should include differential (above $3 US) in Global Priority Mail via the United States Postal Service.
Canada, Germany & Great Britain: +$4.00
Japan & Australia: +$6.00(US)

Place orders & send correspondence to:

BARF
P.O.Box 3382
Orange, CA 92857-3382

E-mail address:
<BARFDONALDSON@worldnet.att.net>

Quotes on aluminum domes & flat roofs:

TEMCOR
24724 S. Wilmington Ave.
Carson, CA 90745

P.O.Box 6256
Carson, CA 90749-6256

Ph: (800) 421-2263

http://www.temcor.com/

<102062.2566@compuserve.com>