New

SDC Solenoid
Outer Vacuum Shell R&D

Purpose:

The SDC solenoid is required to be thin in terms of radiation lengths. If this shell were made with conventional techniques (e.g. Welded shell of solid aluminum) then it would be a major contributor to the overall thickness of the coil in terms of radiation lengths. (.3 λ_r) For this reason the SDC magnet group began a program to develop an improved technique to fabricate this shell.

Outer Vacuum Shell Specifications:

outer radius	2.05 m
total length	8.72 m
High Reliability	metallic - welded
Radiation tolerant	> 6 megarads (10 yrs @ 10^{34} cm^{-2} s^{-1})
Safe - predictable	built to ASME/CGA codes

Plan:

The outer vacuum shell thickness for a solid shell is determined by elastic stability criterion for a cylindrical shell under external pressure.

The SDC magnet group evaluated various fabrication techniques intended to achieve the equivalent stiffness of a solid plate but with much less material.

We chose to pursue R&D on two techniques that we judged most likely to lead to a practical shell that would meet the requirements of SDC:

1) Brazed Aluminum Honeycomb

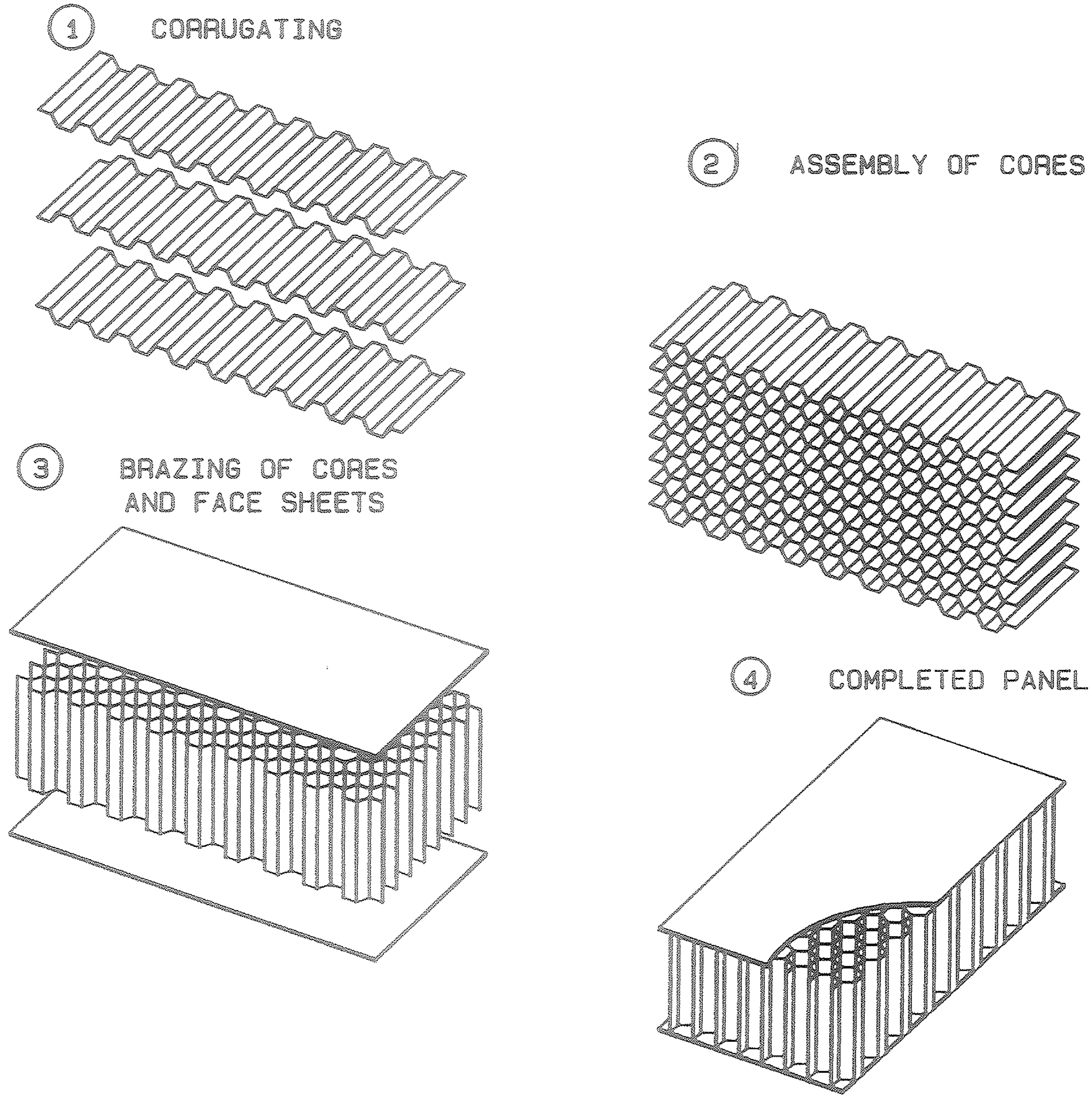
2) Aluminum ISO grid

R&D is in progress at this time on both techniques. I will discuss our progress and plans:

Option 1) <u>Honeycomb</u>

Characteristics of Brazed Aluminum Honeycomb Panels

- Near optimal use of material for high stiffness
- High Thermal Resistance = => Weld able
- High Reliability (no epoxy adhesives)



BRAZING PROCESSES OF HONEYCOMB PANELS

Honeycomb Vacuum Shell
Design Specifications

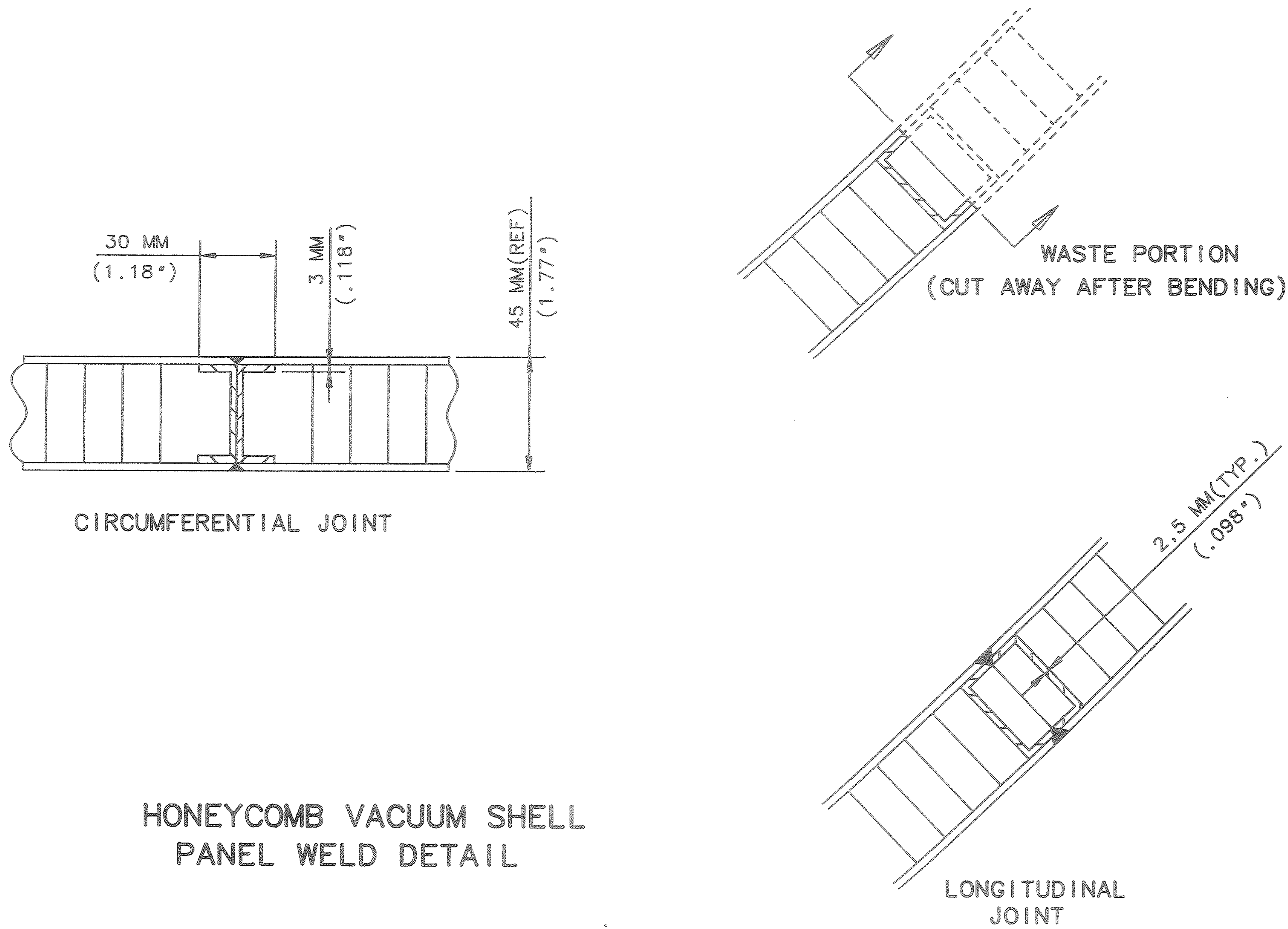
Honeycomb Outer Vacuum Shell

Aluminum alloy	A6951/A4045
Total thickness	45 mm
Skin thickness	3.0 mm + 3.0 mm
Skin layers	double
Node configuration	hexagon
Effective thickness	7.1 mm (Al)
Weight reduction ratio	1/3.83
Radiation thickness	0.08 Xo

Progress with Welding Brazed Honeycomb Panels

- With reinforcement Skin-Skin welding of Honeycomb panels works
- Cores do not melt
- No affect to brazed joints
- Deformation is acceptable (large Stiffness)
- Welded joints are leak tight

Conclusion: Welding seems to have few problems



HONEYCOMB VACUUM SHELL
PANEL WELD DETAIL

R&D on Bending Brazed Honeycomb Panels

(Results of 1st Effort 3 Point Panel Bending)

Panel size - 0.9 mx 1.8 m

Panel thickness - 30 mm <---- ***

Facing thickness - 3 mm and 2 mm

*** note t/R is the same at R = (30 mm/45 mm)x2.05m=1.4 m

RESULTS

Radius Formed To:		Thickness:
Plate 1	1.80 m	29.2 mm
Plate 2	1.36 m	29.0 mm <-------***
Plate 3	1.07 m	28.9 mm
Plate 4	0.69 m	28.5 mm

CONCLUSIONS

1. Decrease of the panel thickness is due to the buckling of the core material.

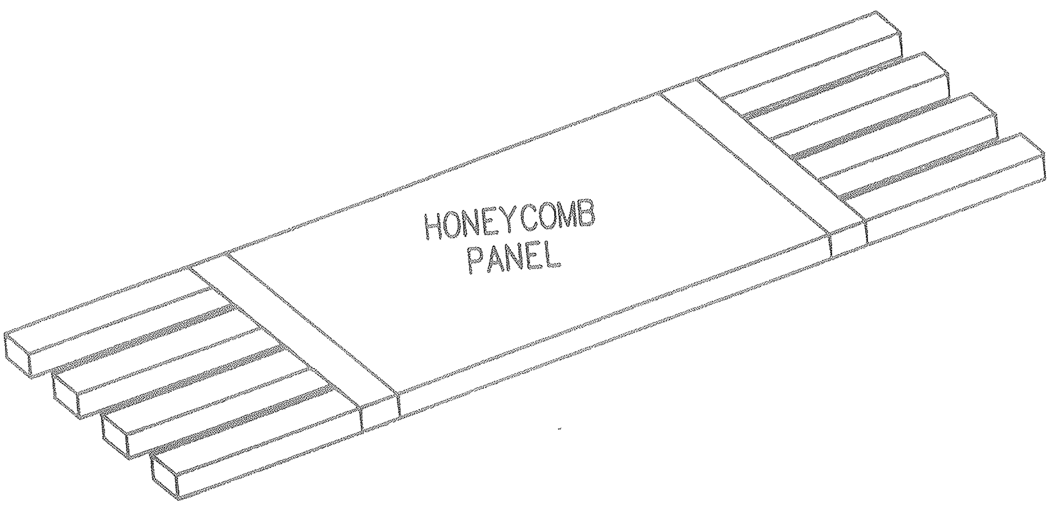
2. Large shearing deformation observed at both ends.

R&D on Bending Brazed Honeycomb Panels

(2nd Effort)

3 point panel bending with constraint fixture
(the fixture was expected to prevent shearing deformation)

Panel size was same as the 1st effort



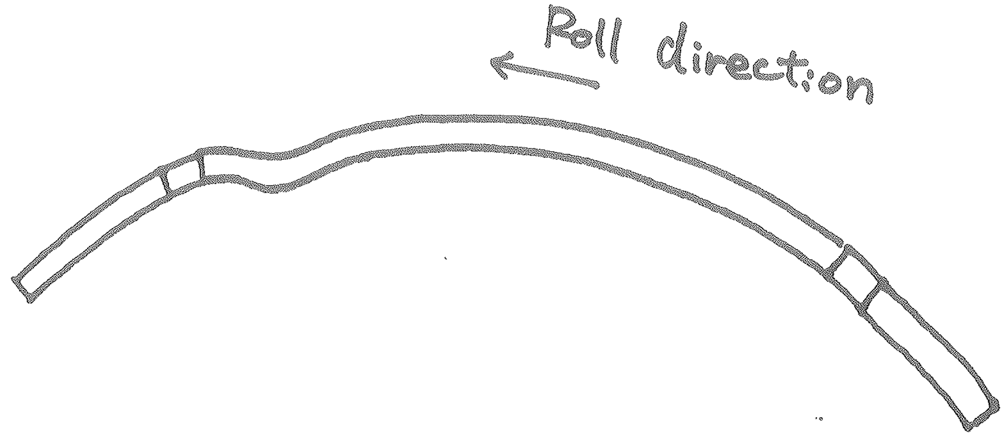
RESULTS

1. A decrease of panel thickness (core material buckling) was found at a relatively large radius.

2. Panel had deformation in the rolling direction and near free edges.

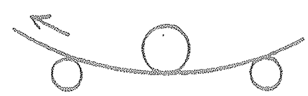
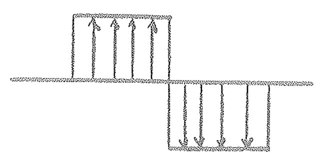
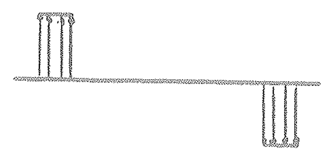
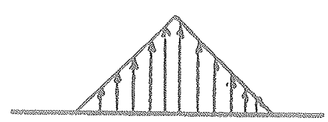
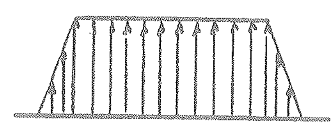
Results

- Decrease of thickness was also found at relatively large radius. (R ≧ 2200 mm)
- Panel has deformed like following figure. Because of forcing to prevent shearing deformations.



Conclusions of Honeycomb Panel Bending R&D

- At this time collapsing (buckling) of the core material is a problem.
- Shearing deformation has to be controlled.
- 3 point bending will probably not work , more R&D is required to develop an alternative technique.
- The next attempt will be to use 4 point bending.

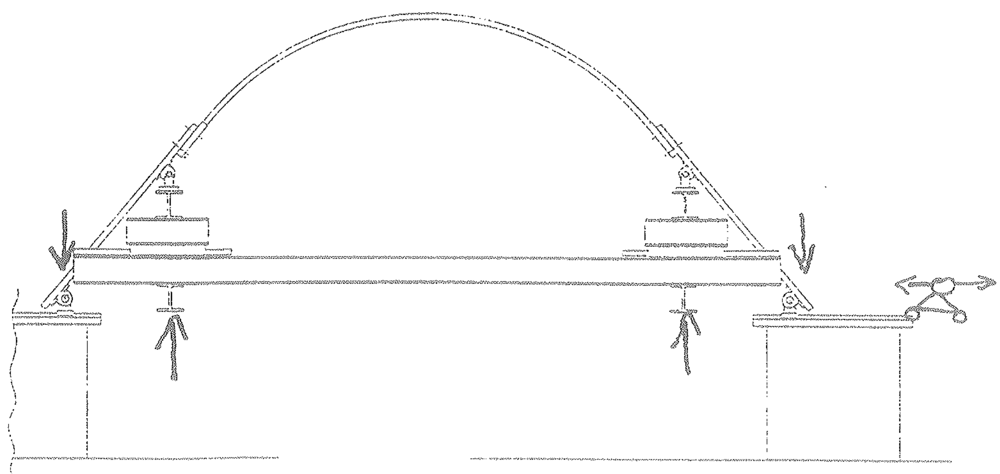
	3 POINT BENDING with Bending Roller	4 POINT BENDING
Concept		
Shearing Force Distribution		
Bending Moment Distribution		
Possibility of Cores Collapsed	Expected	None
Possibility of Shearing Deformation	Expected	None
Bending Size	Long	Limited

HONEYCOMB VACUUM STRUCTURE

RESEARCH AND DEVELOPMENT

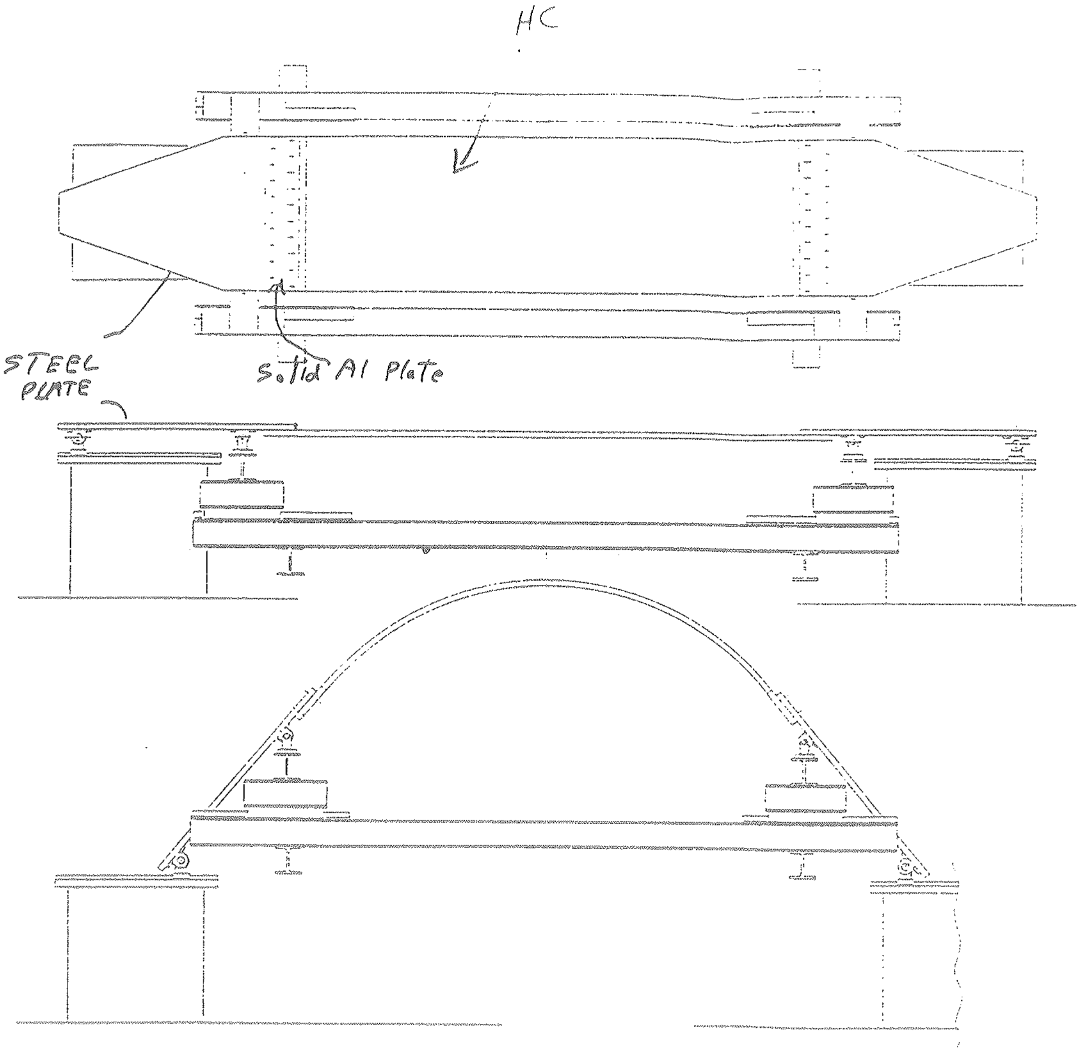
(3RD EFFORT)

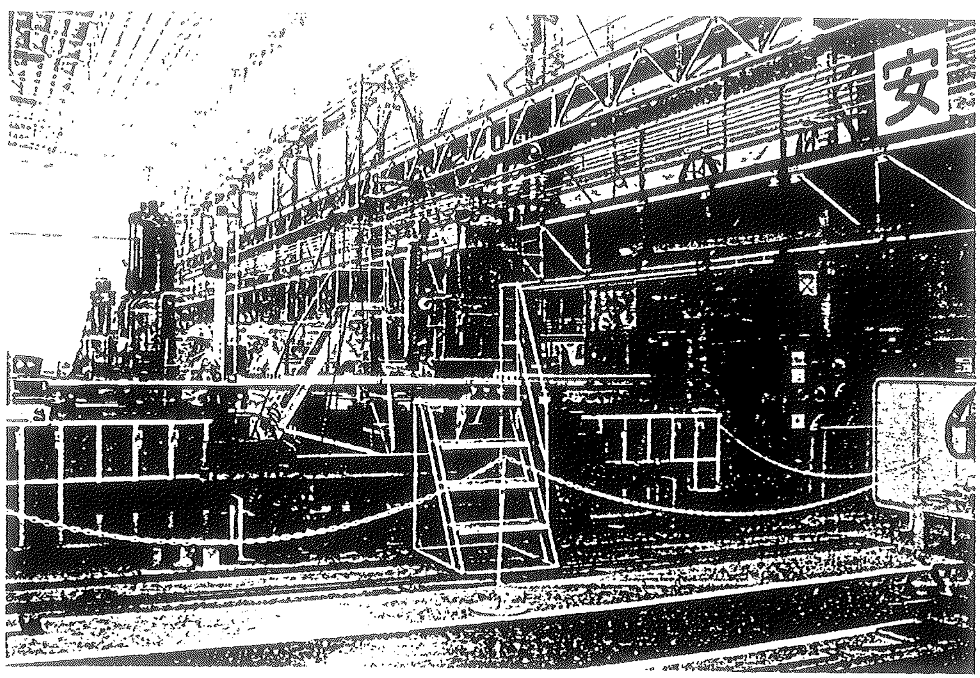
4 POINT PNAEL BENDING WITH CONSTRAINT FIXTURES



RESULTS

1. BENDING SUCESSFUL DOWN TO R/T RATIO OF 46 WITHOUT BUCKLING,
2. RADIAL SPRING BACK OF 10 % OBSERVED AFTER RELEASING,
3. ~~HORSE-BACK~~ (SADDLE) SAGITA OF 15 MM , (IT COULD BE ELIMINATED WITH ANOTHER CONSTRAINT FIXTURE).


HC
STEEL PLATE
Solid Al Plate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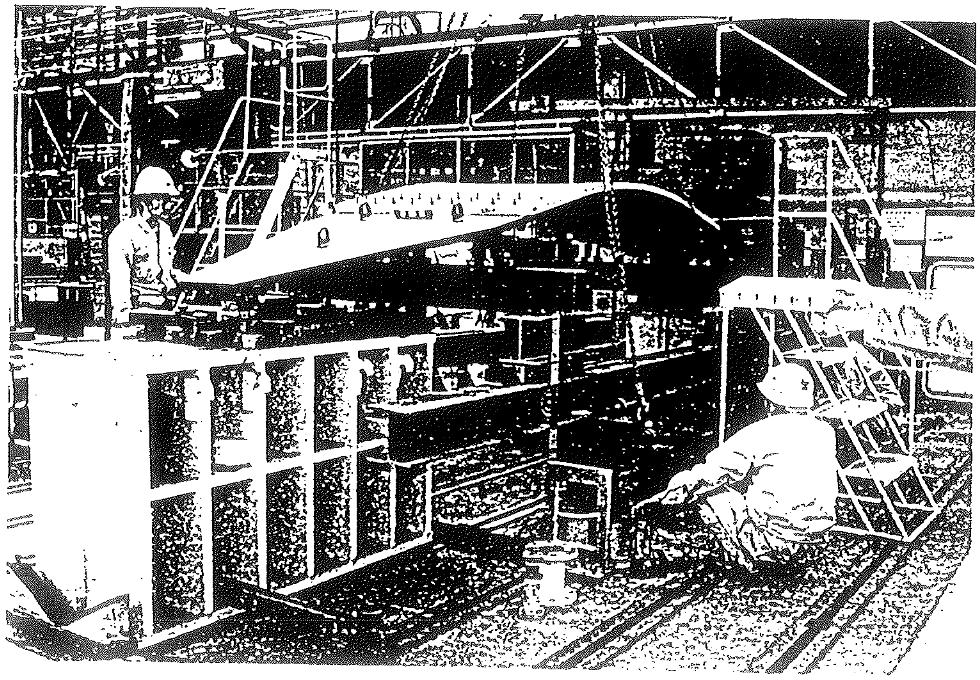
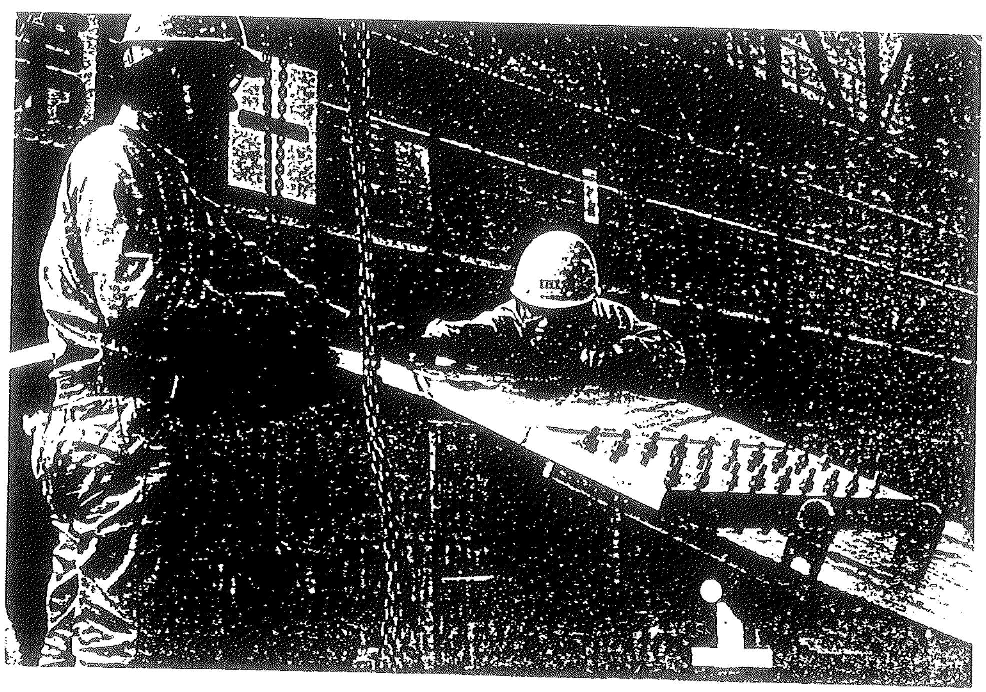
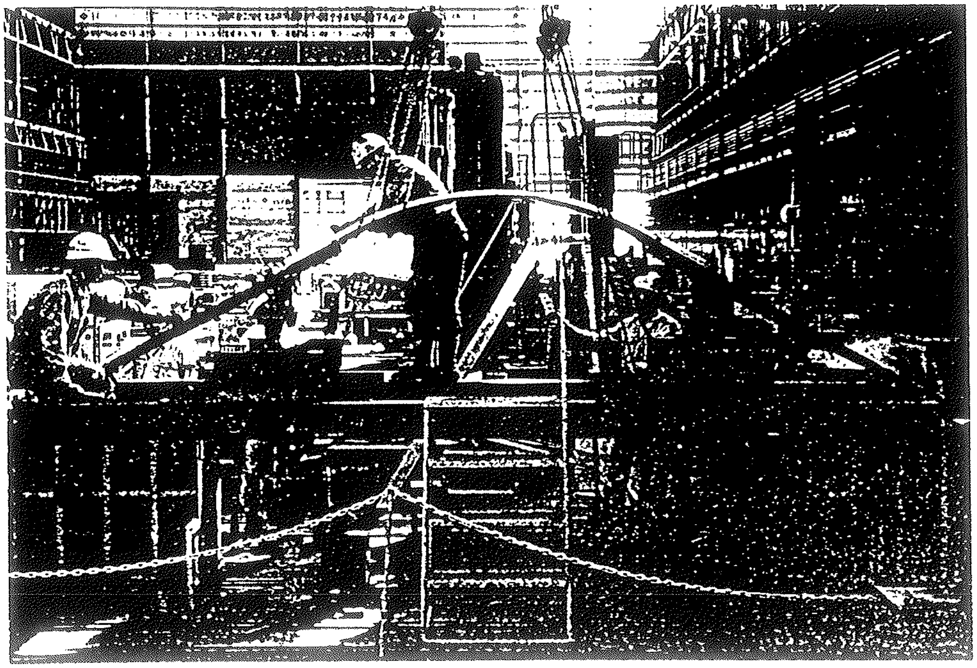
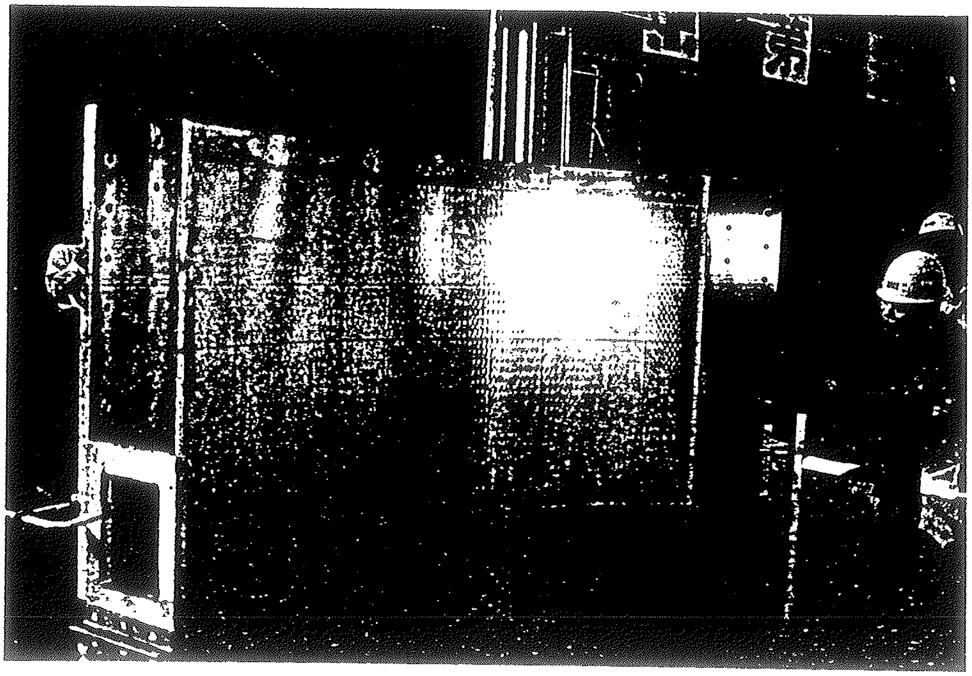
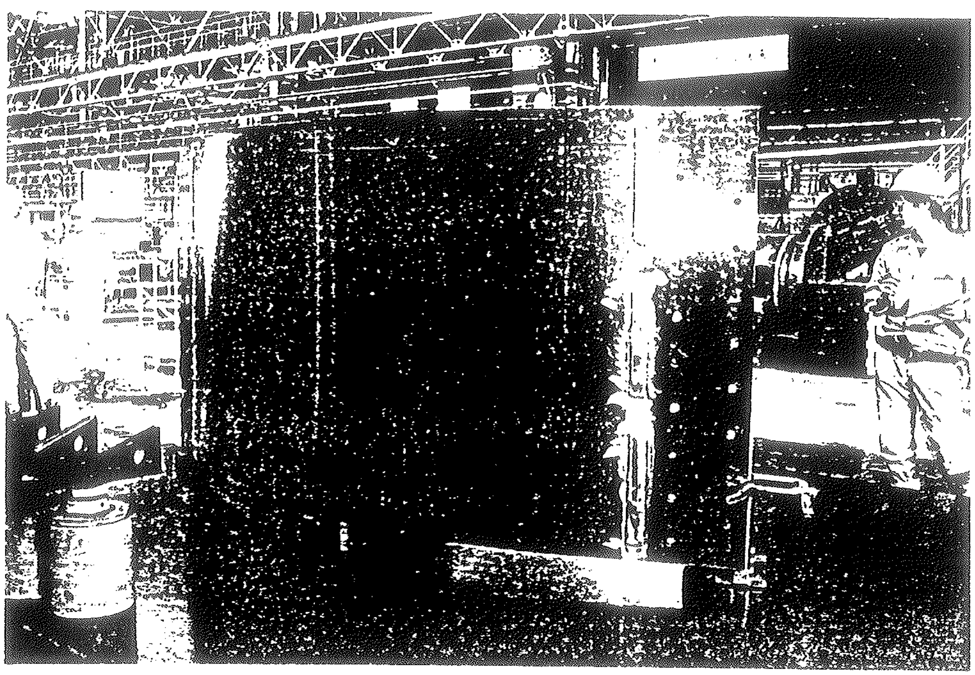
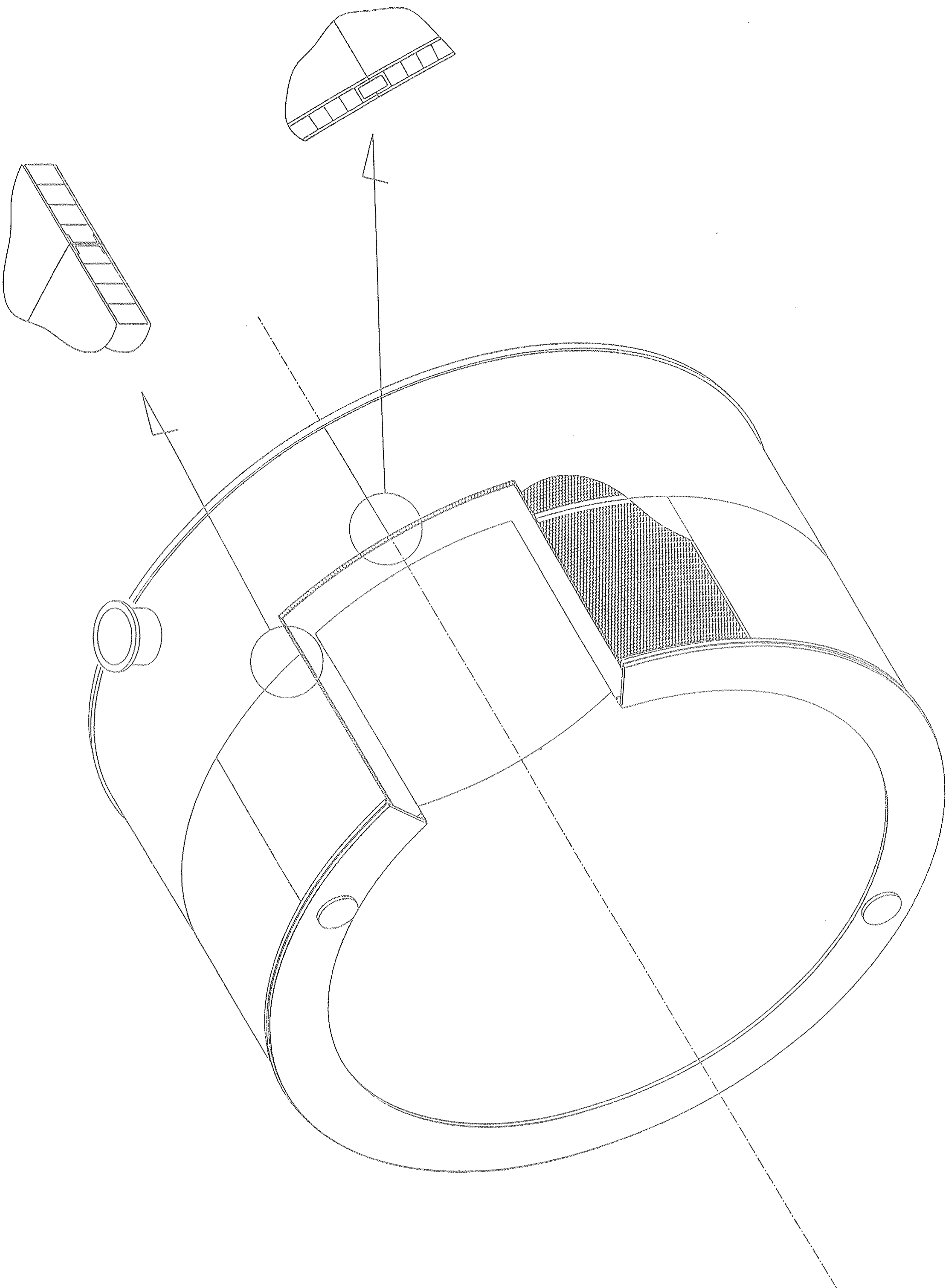


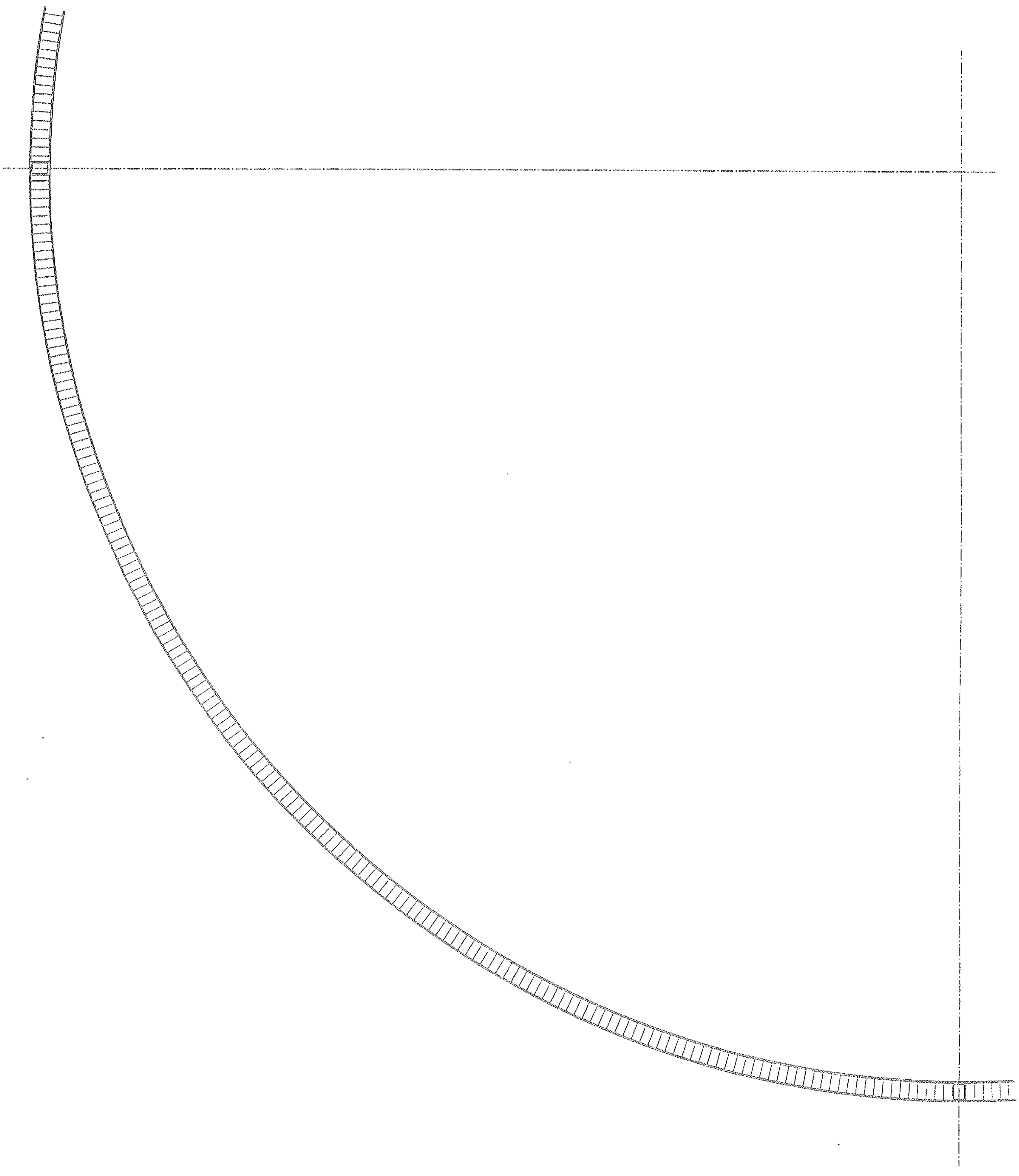


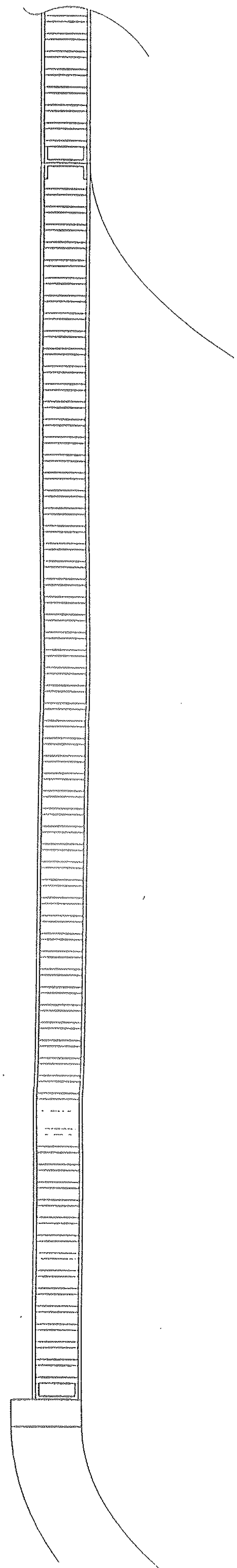


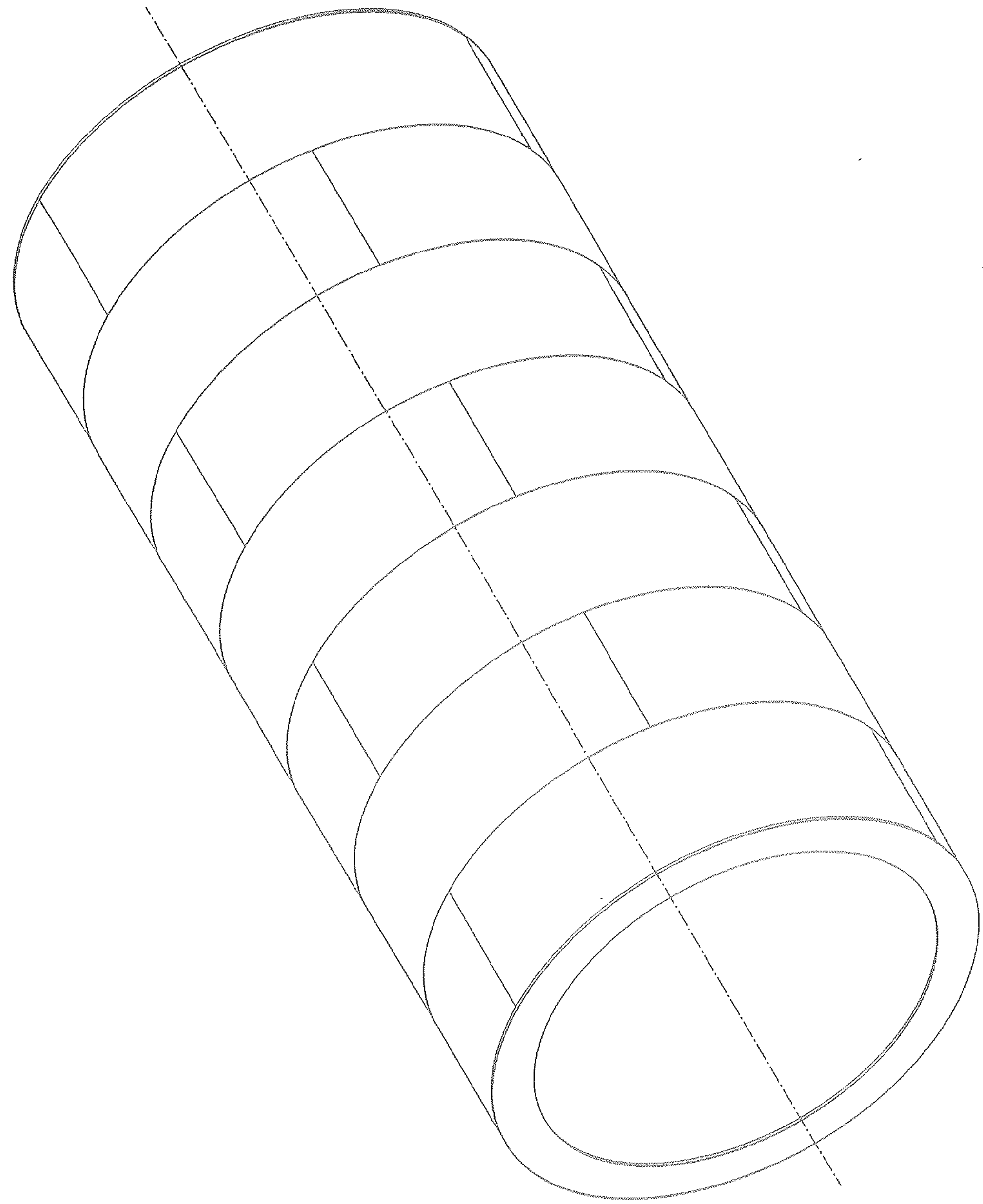












Option 2) ISO grid Shell

Characteristics of Aluminum ISO grid construction

- A lattice of intersecting ribs forming an array of equilateral triangles.

- Isotropic (no directions of instability or weakness)

- Efficient use of material for either compression and/or bending

  - Lightweight

  - Proven analysis techniques

  - Can be optimized for wide range of loading intensities

  - Readily reinforced for concentrated loads and cutouts

  - Regular pattern of nodes provides attach points for other structures

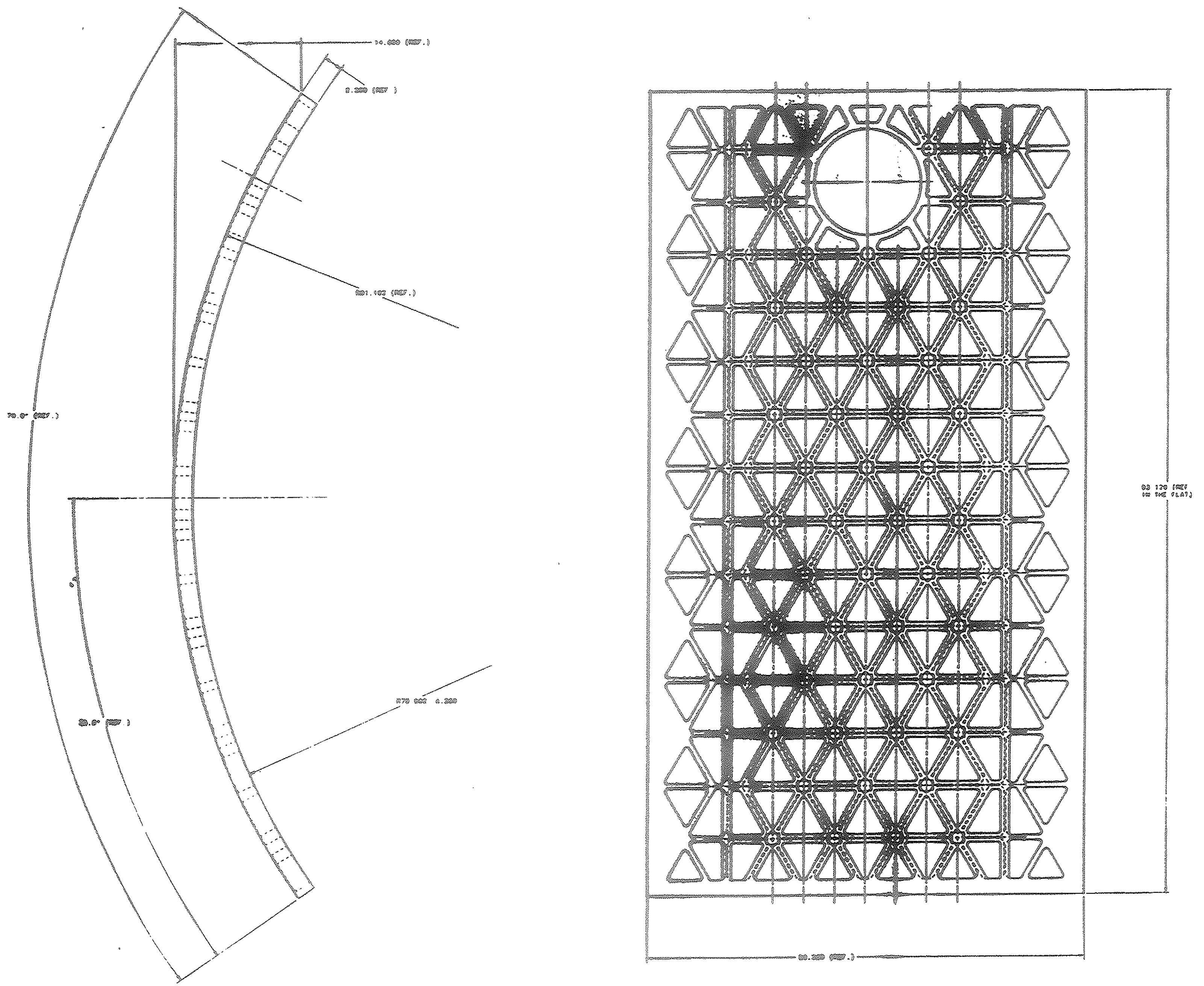
- Easily fabricated from solid Al plate with NC machine tools yielding a very reliable material of known costs.

- Large experience base :

  In use on major space programs, extensively investigated by NASA, military, and industry.

  Fermilab has received structural analysis and engineering design assistance from P.S. Associates

  Companies with ISO grid construction experience are available for R&D and for production of final shell. (e.g. machining, welding, bending)



FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

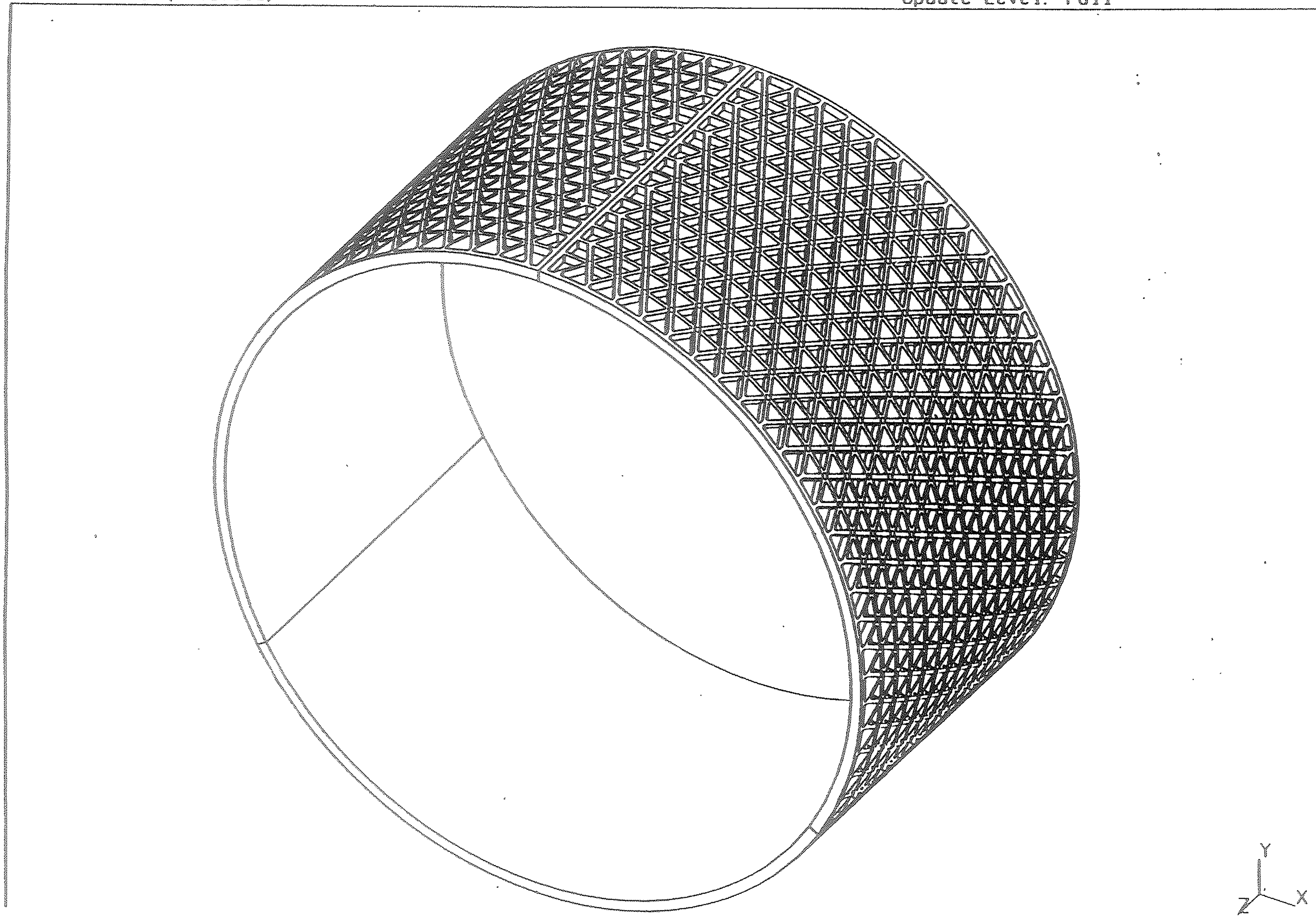
SOLENOIDAL DETECTOR COLLABORATION
SUPERCONDUCTING SOLENOID

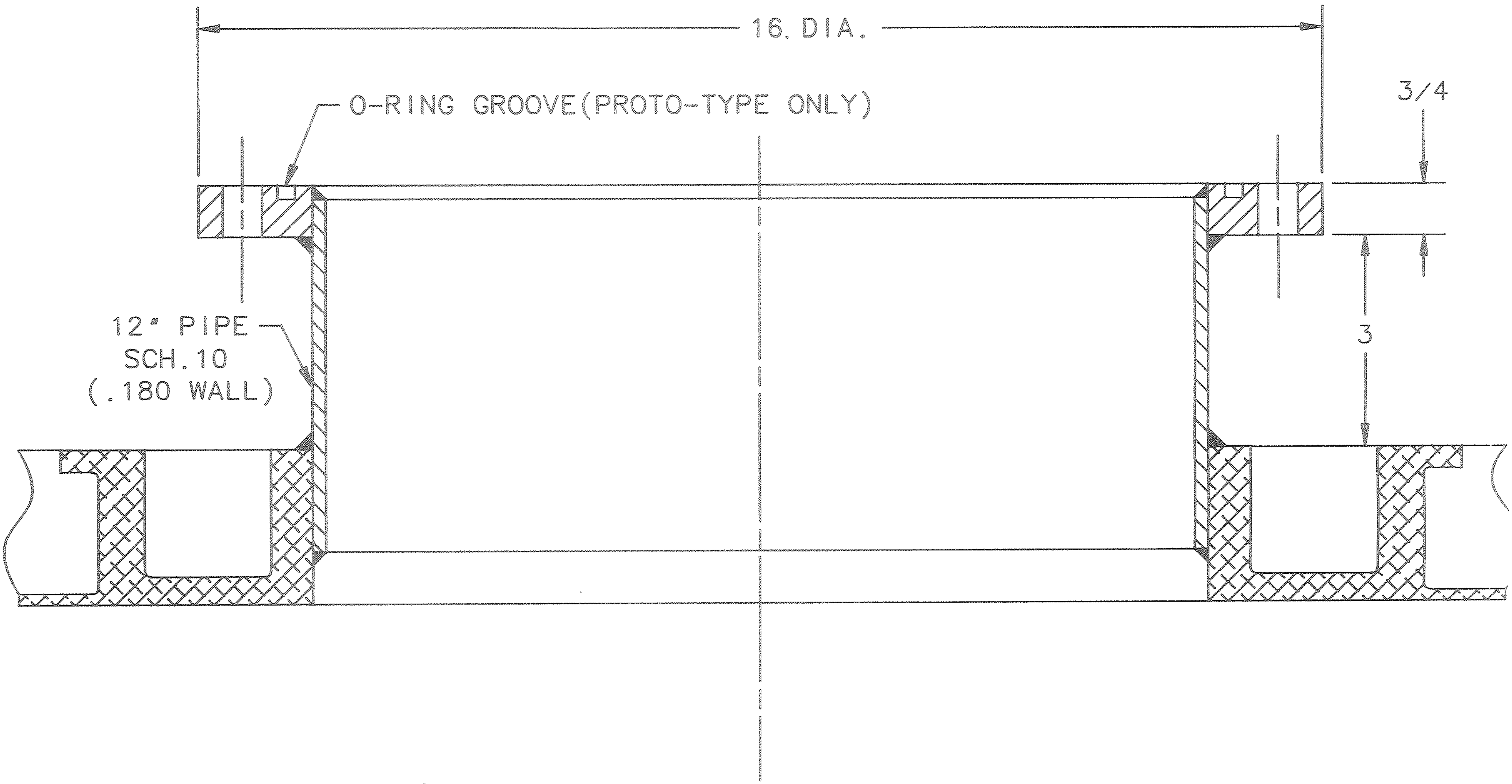
SSC-SDD-00001P

SDRC I-DEAS VI: Solid_Modeling 14-NOV-91 11:59:

Database: isogrid tank
View : No stored View
Task: Assembly
System: 3-RING1 (modified)

Units
Display : No stored Op
Bin: 1-MAIN
Update Level: Full

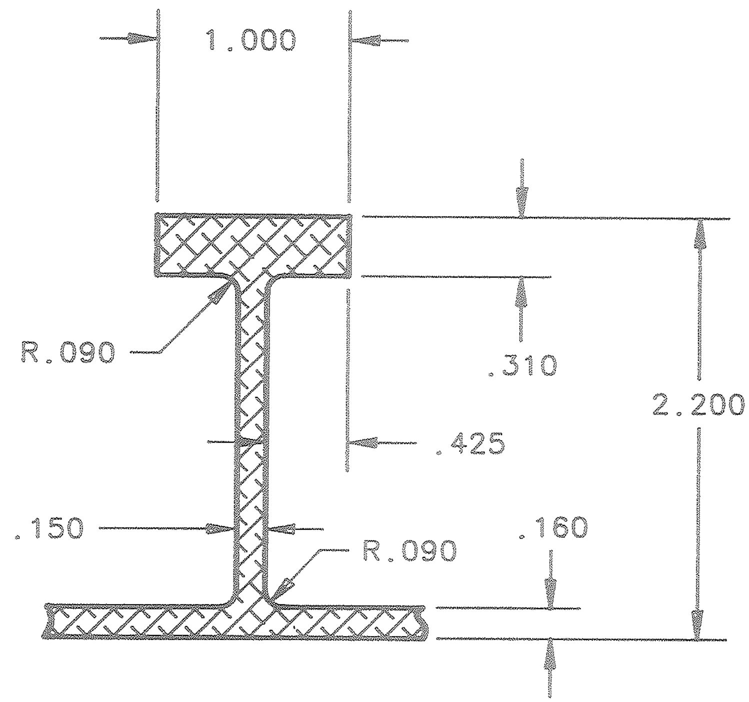




SUPERCONDUCTING SOLENOID

OUTER VACUUM SHELL

ISOGRID(CHIMNEY PENETRATION)

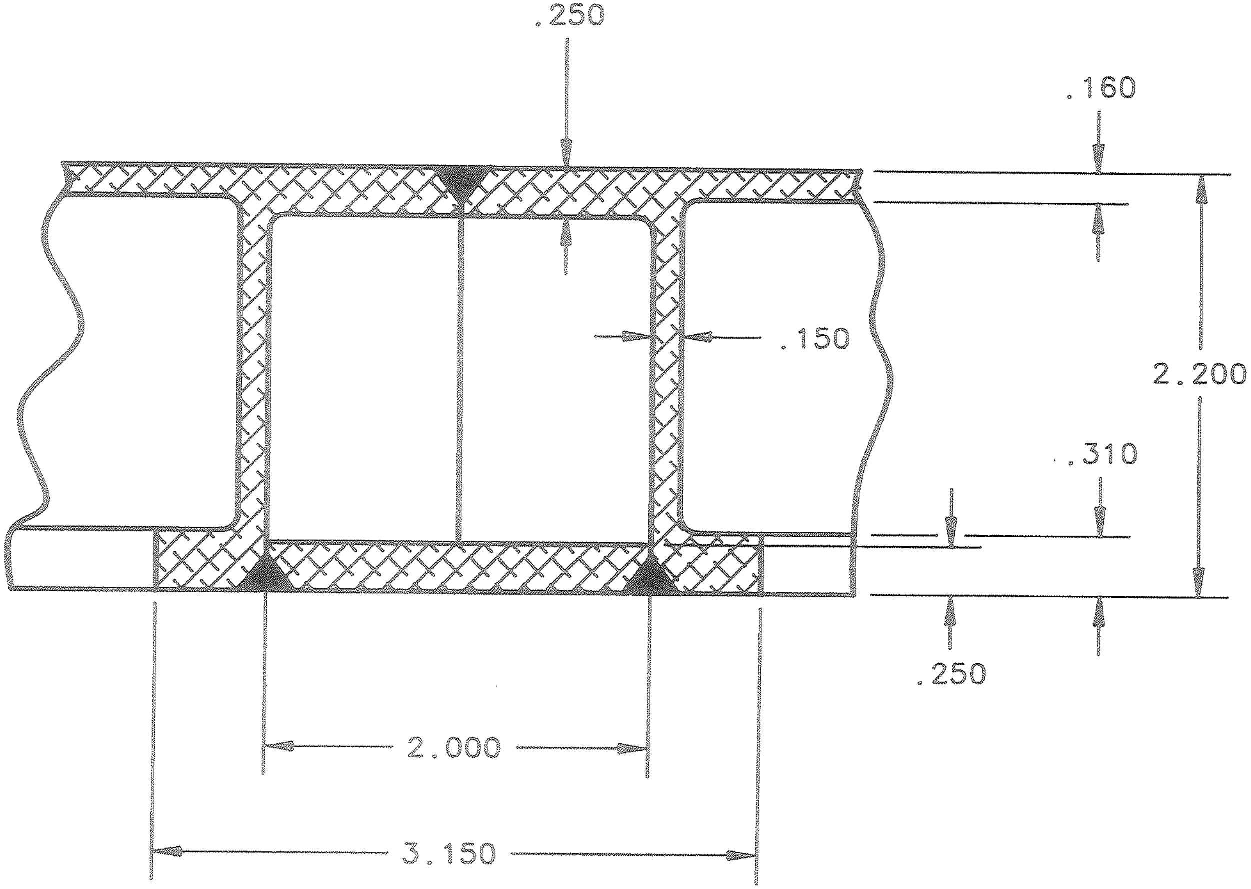


NOTE:

1. NODE SPACING IS 7.092 IN
2. EFFECTIVE THICKNESS IS 0.407 IN.
3. MATERIAL-ALUM. 5083-H321

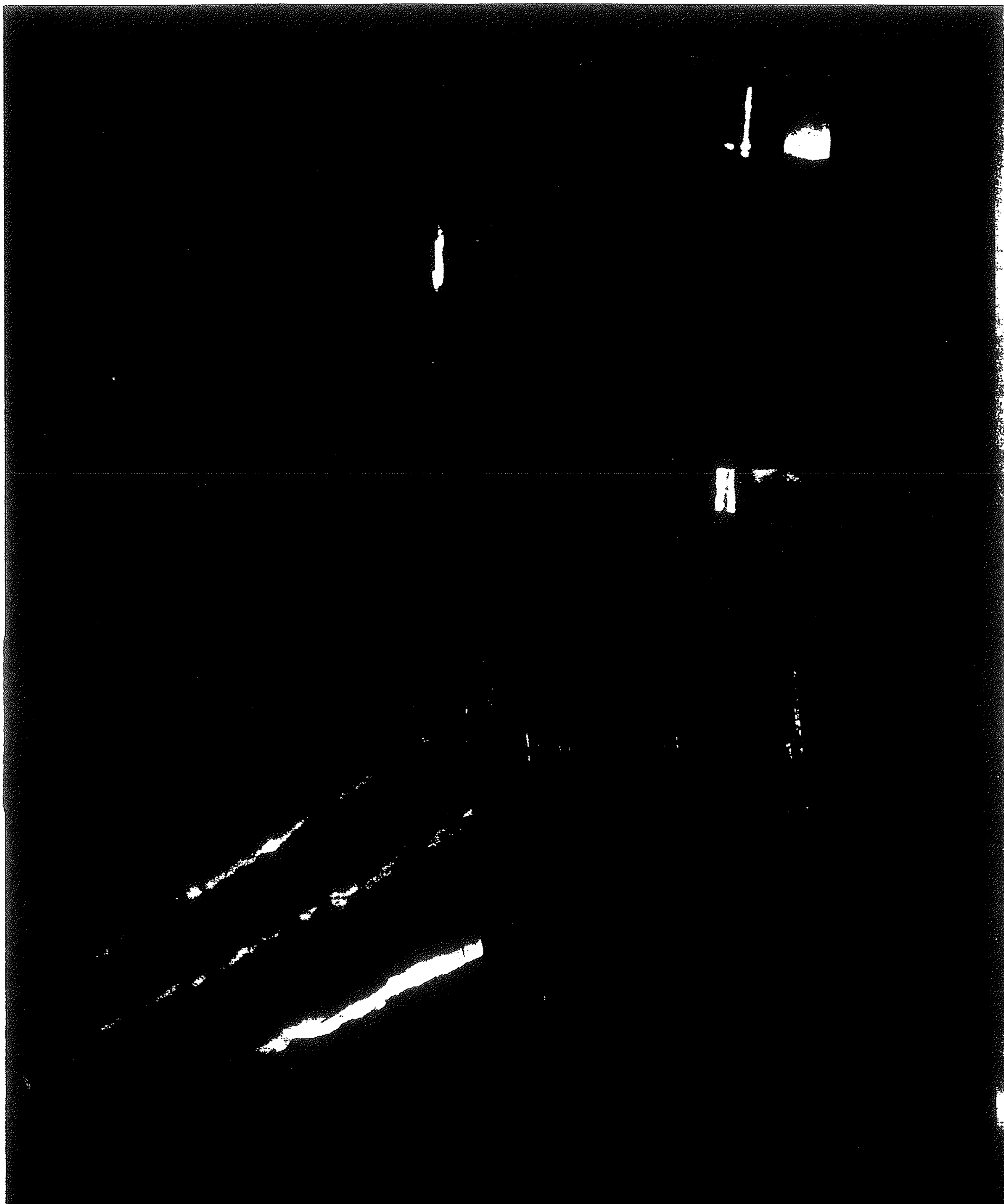
SUPERCONDUCTING SOLENOID
OUTER VACUUM SHELL
ISOGRID TYPICAL RIB CROSS SECTION

4/16/92

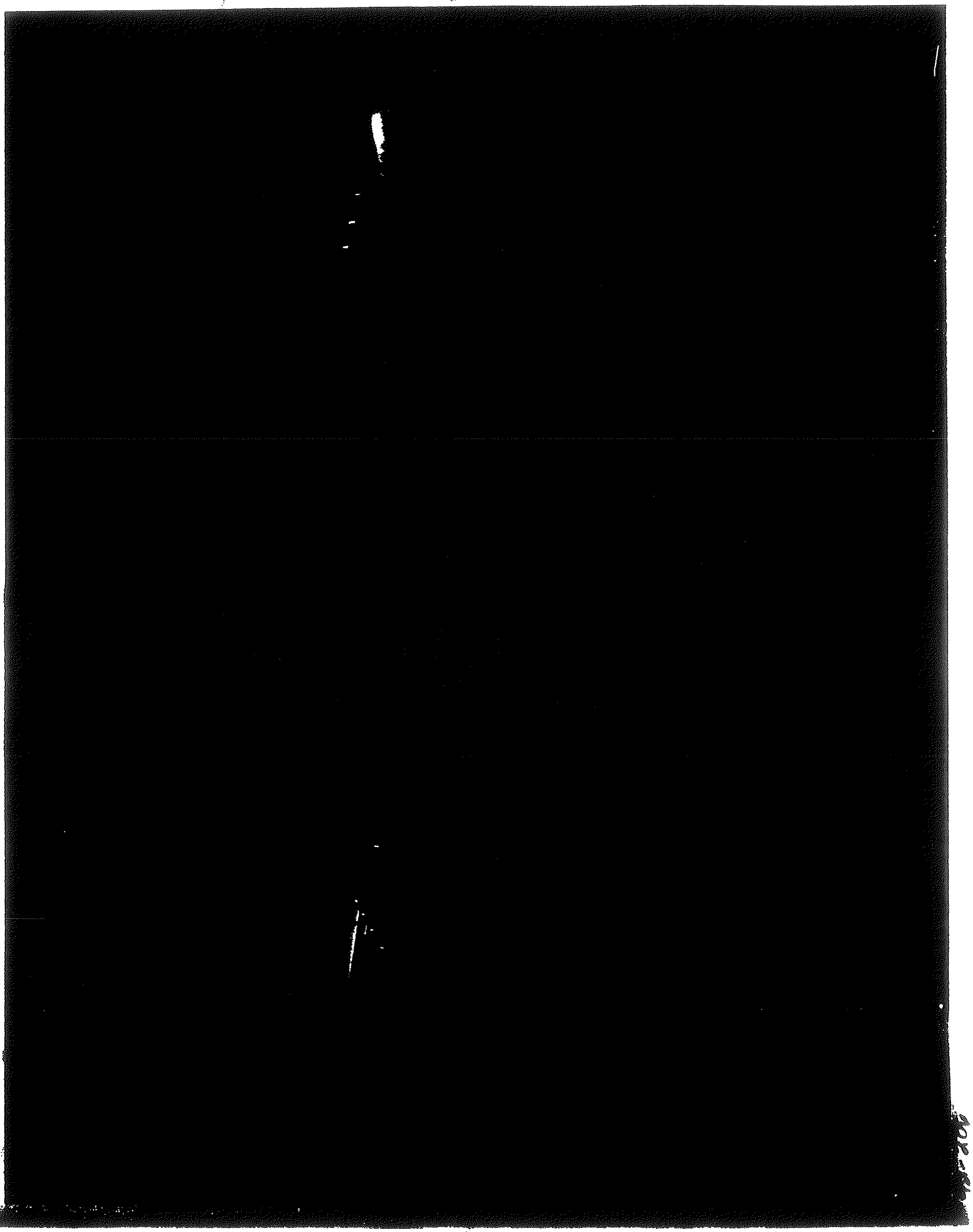


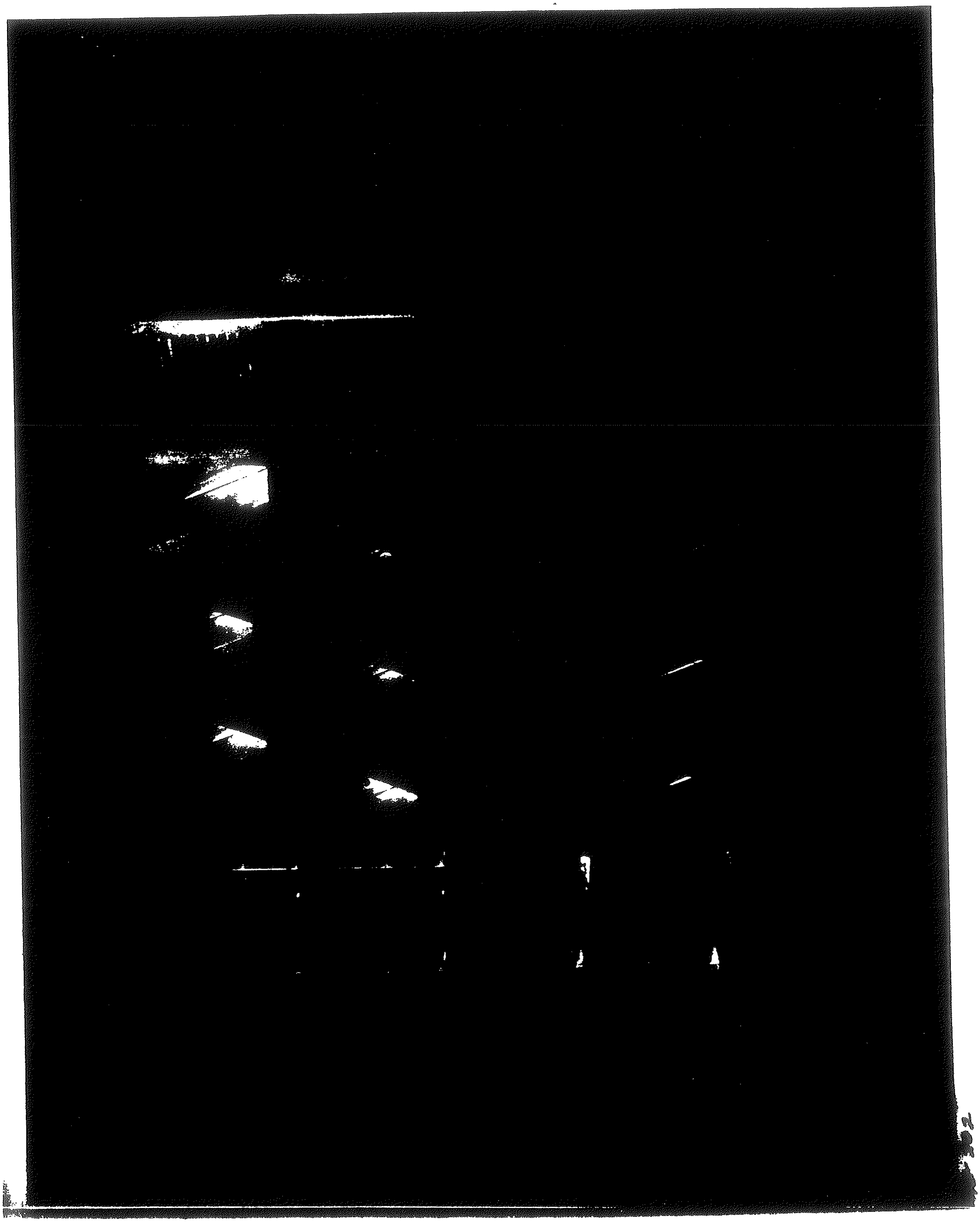
SUPERCONDUCTING SOLENOID
OUTER VACUUM SHELL
ISOGRID PANEL TO PANEL WELD DETAIL

4/16/92



92-209





ISO grid Vacuum Shell
Design Specifications

ISO grid Outer Vacuum Shell

Aluminum alloy	5083
Total thickness	46 mm
Skin thickness	4.0 mm
Skin layers	single
Node configuration	triangle
Effective thickness	11 mm (Al)
Weight reduction ratio	1/2.5
Radiation thickness	0.12 Xo

Progress with Welding Aluminum ISO grid Panels

- Weld samples of Panel to Panel joints have been made using 2219-T351 material. (5083 soon)
- No detectable leaks
- Possible to leak check main welded joints before cryostat assembly (probably true with Honeycomb also)
- Deformation at joint is very small (large Stiffness)

Conclusion: Welding ISO grid panels seems also to have few problems

R&D on Machining and Bending ISO grid Panels

Machining

Panel size -	0.63 m x 1.1 m (two panels)
Panel thickness -	46 mm
Sin thickness -	4 mm

Bending RESULTS

Radius Formed To:		Thickness:
Plate 1	2.05 m	46 mm
Plate 2	2.05 m	46 mm

CONCLUSIONS

1. No significant problems in brake forming plates if skin is on outside radius. No buckling or web crippling observed.

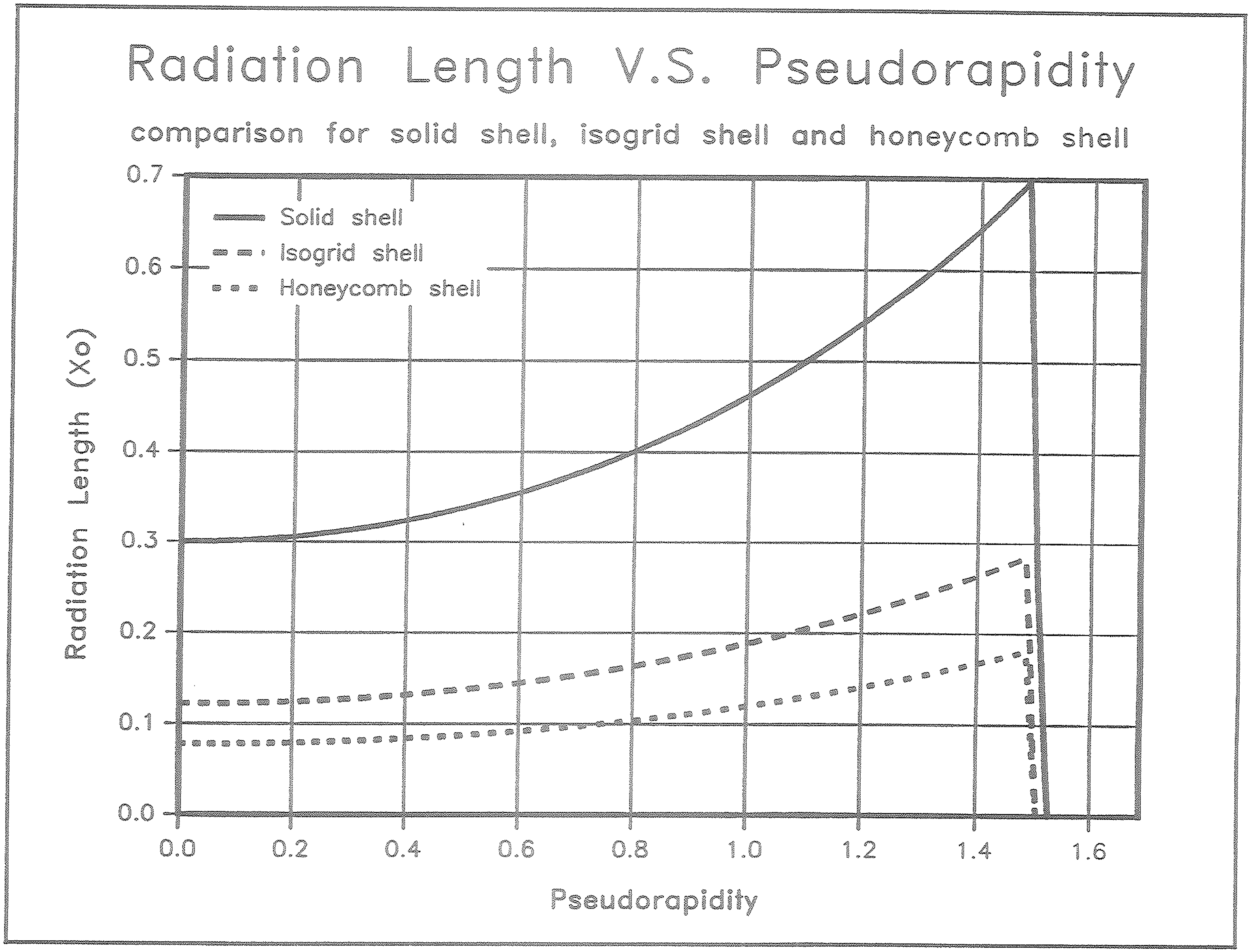
2. Small deformations observed near edge nodes...understood and easily fixed ===> no problems

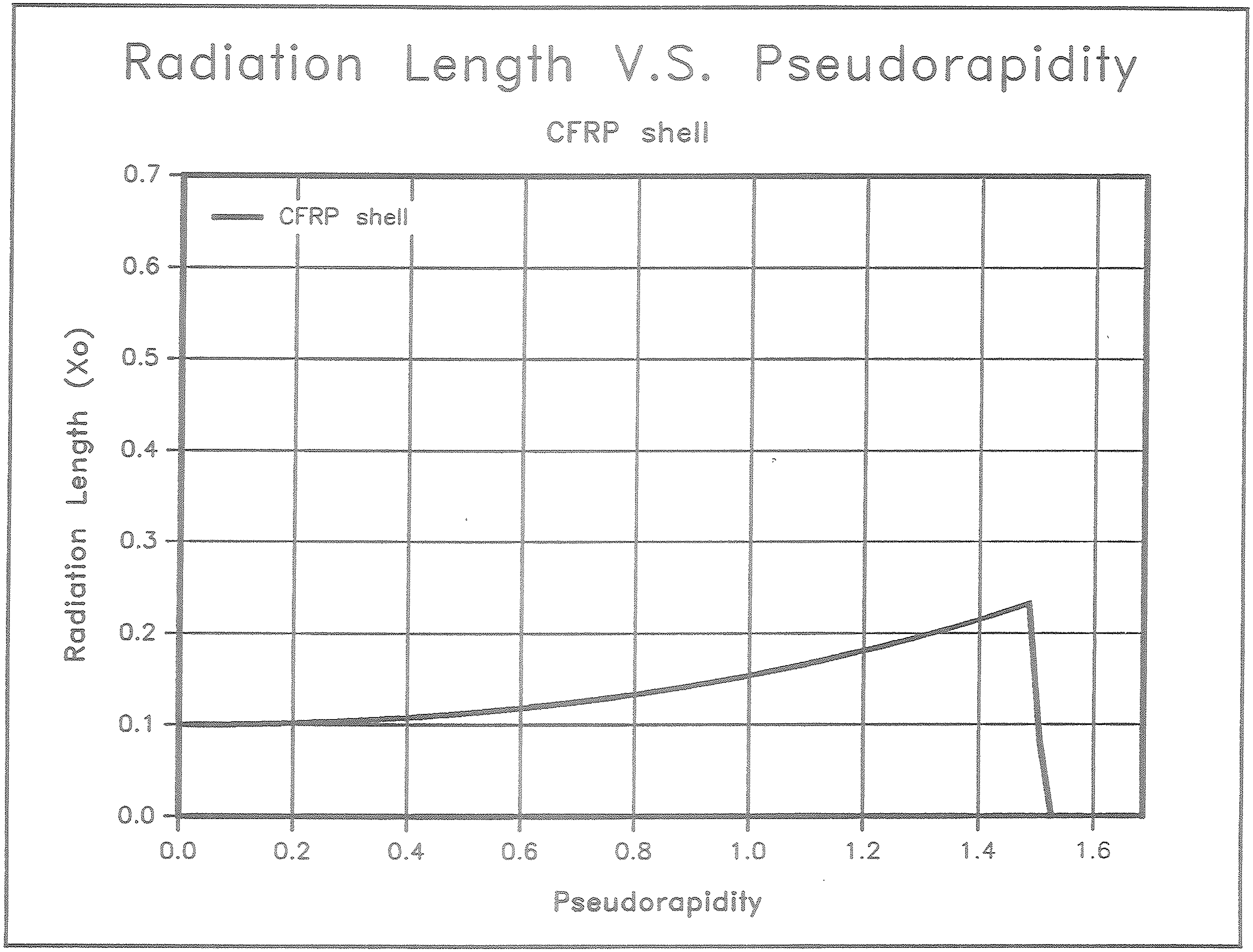
Conclusions of ISO grid R&D and Plans

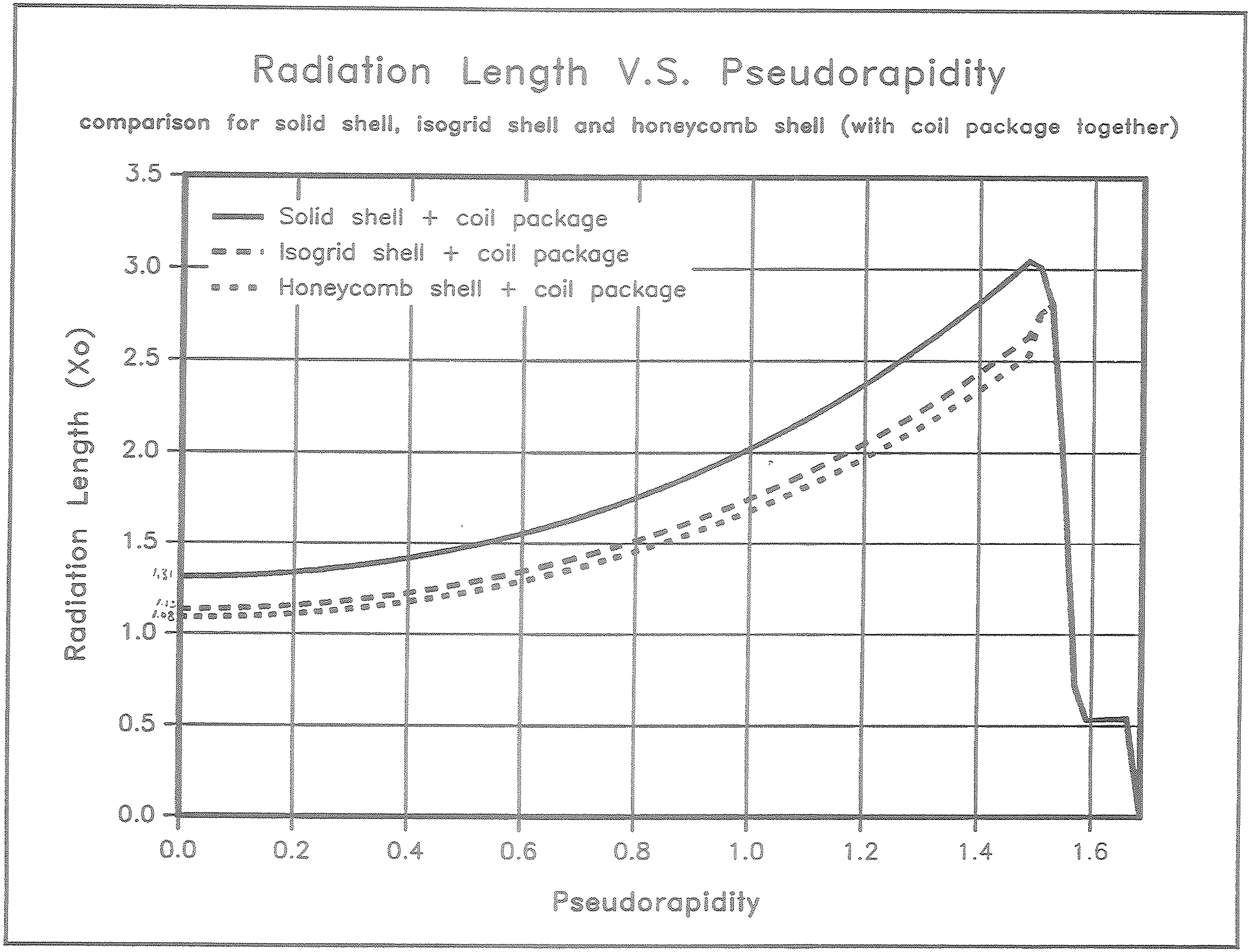
- Technique is likely to be successful but somewhat less efficient than Aluminum honeycomb.
- SDC magnet group decided to fabricate prototype shell using this technique. (3 Al plates 2.5 m x 5 m are on order from Alcoa)
- We will fabricate a large test panel from 5083-H321. This will have exact circumferential and longitudinal weld configurations as Prototype shell. Test panel will be formed to 2.05 m radius.
- More weld joint tests will be done with 5083-H321
- Decision for final shell will depend on outcome of Honeycomb R&D effort.

Expected Performance of SDC Vacuum Shell

(Effective Thickness vs pseudo-rapidity)


Radiation Length V.S. Pseudorapidity
comparison for solid shell, isogrid shell and honeycomb shell
Solid shell
Isogrid shell
Honeycomb shell
Radiation Length (Xo)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Pseudorapidity


Radiation Length V.S. Pseudorapidity
CFRP shell
CFRP shell
Radiation Length (Xo)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Pseudorapidity


Radiation Length V.S. Pseudorapidity
comparison for solid shell, isogrid shell and honeycomb shell (with coil package together)
Solid shell + coil package
Isogrid shell + coil package
Honeycomb shell + coil package
Radiation Length (Xo)
Pseudorapidity
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6