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DEVELOPMENT OF A PROTOTYPE PLASTIC SPACE ERECTABLE SATELLITE

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1.0 INTRODUCTION

During this reporting period quantities of Rexwell mesh for the fabrication of the cap section and smaller deliverable items were irradiated to 15 Mrads at High Voltage Engineering, Burlington, Mass. After irradiation, the mesh was heat treated for two hours at 140°C. in a nitrogen atmosphere at GSFC. The irradiated heat treated mesh was then electrolessly plated using essentially the standard Enthone plating cycle. After plating, the mesh was cut to the proper subsegment dimensions in preparation for ultrasonic bonding.

During the heat treatment 28 ft. (7 subsegments) of mesh were degraded due to improper temperature control of the environmental chamber. Consequently it was necessary to reevaluate the inventory of Rexwell mesh and redesign the fabrication plan of the cap section. In conjunction with the new design a $49 \pm .01$ in. x $14.5 \pm .01$ in. steel template for the final cutting of the subsegments was procured.

A testing program has been devised for all phases of the fabrication scheme. A flexural rigidity tester has been constructed. Flexural rigidity and tensile tests in all required directions have been completed on the mesh as received and as irradiated.

2.0 DELIVERABLE ITEMS

The general plan for the construction of the deliverable items is outlined as follows:

a) Irradiation of the mesh.

b) Preliminary cutting of the mesh (with allowance for shrinkage)

c) Heat treatment.

d) Electroless copper plating.

e) Cutting to required subsegment size (with allowances for bonding).

f) Ultrasonic bonding.

g) Final cutting of boundary.

At present, part e) has been completed.

2.1 Spherical Cap Section

The design for the spherical cap section consists of a number of gore segments cut so as to give a circular boundary when bonded together and finally trimmed. A sketch of the construction design can be seen in Figure 1.

The length and width of all gore subsegments (except those on the circular boundary) are 49.00 and 14.50 inches, respectively.

2.1.1 Cap Section Design

It has been shown[1] that the difference between the maximum arc length contained in the cap section surface and the corresponding diameter lying in the cap section base is only 0.01 feet (Figure 2).

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[1] Section 5.1 of Appendix p. 15

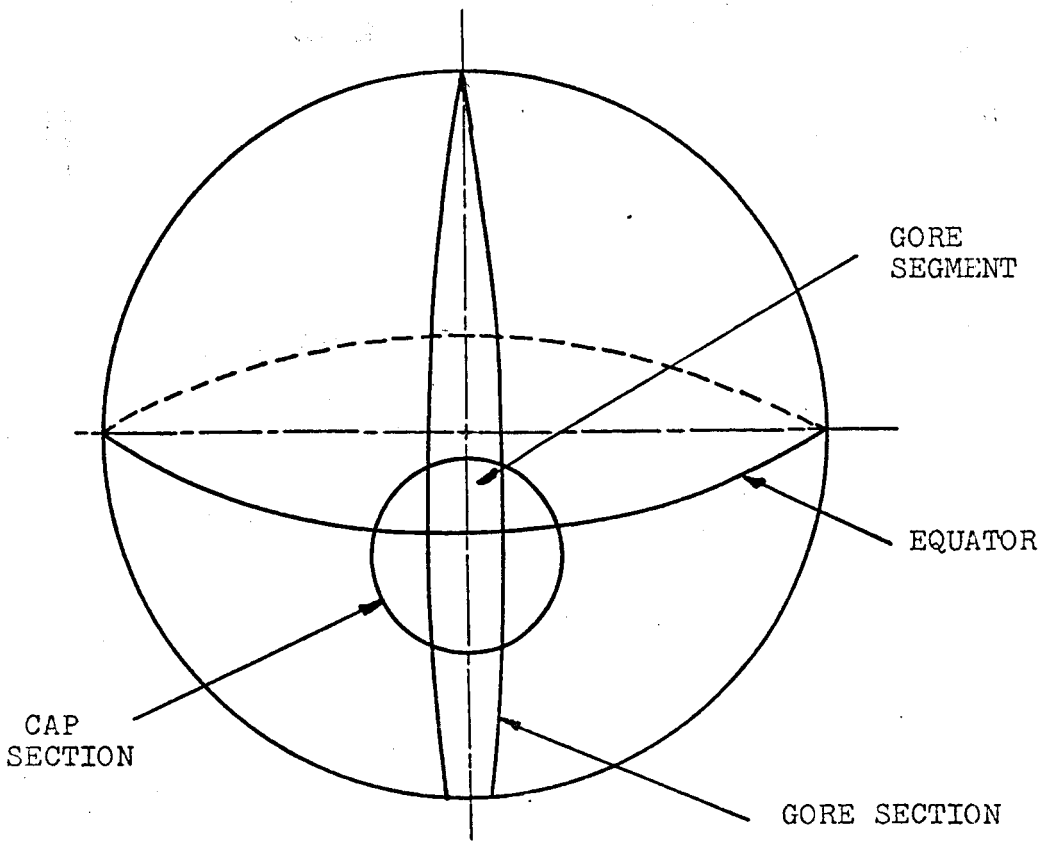

Figure 1 LOCATION OF CAP SECTION WITHIN GORE SECTION CONSTRUCTED SPHERE

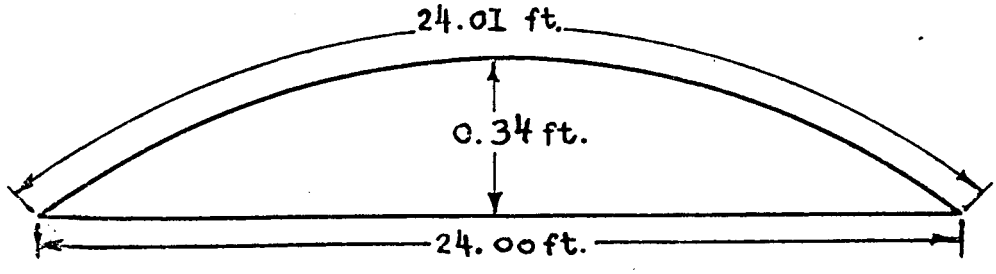

Figure 2 CAP SECTION CROSS-SECTION

This result implies that any arc contained in the cap section surface is approximately, (i.e., within 0.08 inch) equal in length to its projection in the circular base of the cap section.

It has also been shown[2] that the width of the center gore segment remains essentially constant. It varies 0.023 in. from a maximum of 14.500 in. at the equator to a minimum of 14.477 in. where the sides of the segment intersect the circular boundary of the cap section.

In view of the small curvature exhibited by the cap section, the individual gore segments can be cut in the form of flat rectangles using a metal template as a guide. Subsequently, one end of each gore segment will be trimmed to provide the required curved boundary.

In actuality, each segment will be composed of a number of 49-inch long subsegments. This is necessary since 4-foot lengths of 14.5-inch wide mesh constitute the most convenient size for plating.

2.1.2 Cap Section Fabrication

2.1.2.1 Irradiation

Sections of mesh were first source irradiated using a Co^{60} gamma source. The properties of the resultant mesh indicated that it was unsuitable for use in the fabrication of the deliverable items due to non-uniformity of absorbed dose. It is for this reason that the Rexwell MX-44 polyethylene mesh was machine irradiated to 15 Mrads with an electron accelerator at High Voltage Engineering, Burlington, Mass. The mesh was irradiated continuously as a flat section by passing it by the electron beam through use of rollers.

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[2] Section 5.1.2 and Table of Appendix p.16 and p. 18

2.1.2.2 Preliminary Cutting

With the procurement of the template and the irradiation of the mesh accomplished, cutting of the subsegments has been completed. A detailed view of the subsegments comprising the cap section is presented in Figure 3. A subsegment numbering system is also indicated in the diagram. The first number represents the quadrant in which the subsegment is located, the second the row, and the third the column. All subsegments were cut to their maximum length dimension with an allowance for shrinkage. Additionally, at least two cell lengths were added to the cutting length to allow for bonding. Table 1 summarizes the cutting length and actual length for all subsegments.

2.1.2.3 Heat Treatment

The heat treatment of the mesh for the deliverable items is intended to insure dimensional stability upon deformation/restoration heating of the fabricated deliverable items. Preliminary tests on small samples of the mesh indicate:

a) Heating temperature should be slightly above the crystalline melting point of the polymer (140°C.).

b) Maximum shrinkage occurs within two hours.

c) Heating in air causes degradation and embrittlement of the mesh which may be eliminated by employing a nitrogen atmosphere.

With these facts considered heat treating operating conditions were chosen as follows:

Operating Temperature: 140-145°C.

Atmosphere: Nitrogen

Heating Time: 2 hours.

In addition, at least one-half hour was allowed for bringing the mesh up to 140°C. from room temperature.

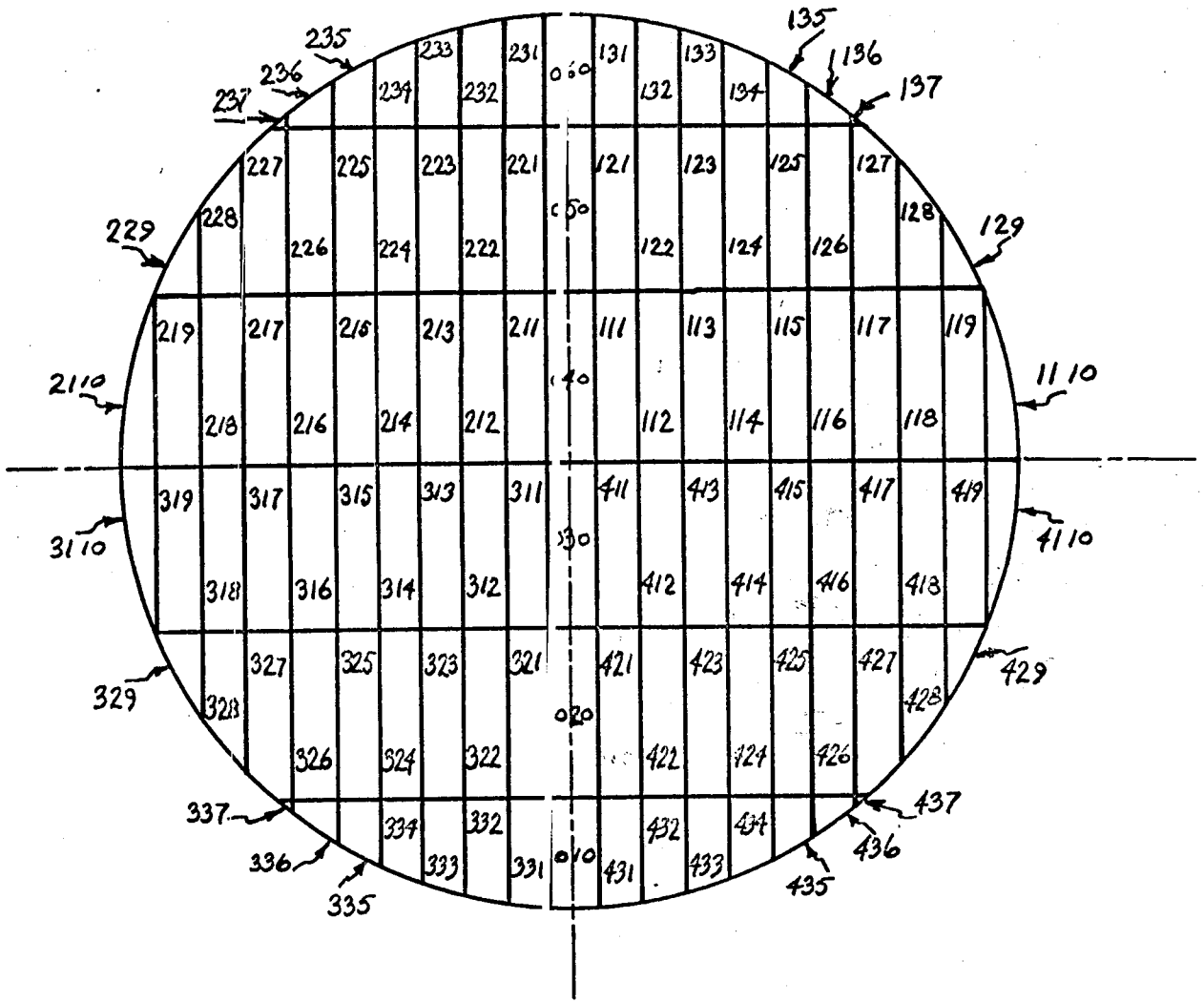


Figure 3

DETAILED ARRANGEMENT OF CAP SECTION SUBSEGMENTS

Table 1

Cutting Lengths for All Subsegments

Subsegment	Actual Maximum Length (in.)	Cutting Length (in.)*	Number
1-3-1	45.88	50.41	4
1-3-2	44.10	48.97	4
1-3-3	41.42	46.04	4
1-3-4	36.83	41.56	4
1-3-5	30.44	35.32	4
1-3-6	21.97	27.12	4
1-3-7	11.19	16.51	4
1-2-8	45.48	50.53	4
1-2-9	25.59	34.94	4
0-1-0	46.00	50.00	1
0-6-0	46.00	50.00	1
1-1-10**	42.17	50.53	4
The remainder are all complete rectangles	49.00	50.53	68

* With two additional cells for bonding

** The width of these boundary pieces is 6.31 inch.

The same minimum time interval was employed for returning the mesh to room temperature after the 2-hour heat treatment period has elapsed. This procedure insured against thermal shock.

During the heat treating process, the mesh subsegments lay on flat, horizontal aluminum trays to insure flatness.

The heat treatment was conducted at Goddard Space Flight Center in an environmental control chamber. Except for the treatment of seven subsegments of the cap section, the heat treatment of the mesh was successful. During the first run the temperature controls of the environmental chamber were improperly connected. This caused a temperature in excess of 145°C. and resulted in the thermal degradation of the seven subsegments. Consequently, it was necessary to reconstruct these subsegments out of scrap material as well as some of the degraded material. These imperfect segments will be placed on the periphery of the cap section in order that as much of it as possible will be cut away.

2.1.2.4 Electroless Plating

Successful electroless copper plating of the deliverable items was accomplished. The plating was carried out in 16-gallon Teflon lined baths of a size necessary to plate the largest subsegments (50 in. x 14.5 in.). The basic plating cycle and operating conditions are given on page 2 of the July 1965 Progress Report. Modifications of the cycle were necessary in order to achieve a satisfactory plate. They are as follows:

1. In the conditioning step (5) in order to achieve thorough oxidation, it was necessary to increase the operating temperature to 30°-40°C. range and increase the immersion time to 25 minutes. The heating was accomplished by use of a chemically-pure lead sheathed immersion heater.

2. In the plating step (11), moderate air dispersion and operating temperatures in the range of 65°-75°F. were necessary so as to deactivate the bath. This was required for two reasons: to preserve the bath and to prevent the excess formation of poorly conductive copper oxide in the plated copper. It must also be pointed out that an excess of dissolved air deactivates the solution so as no plating occurs.

The immersion time in the plating step was held to 10 minutes, so as to give a nominal plating thickness of 10×10^{-6} inch. This is in accordance with information received from Enthone stating that the plating rate in a bath at the stated concentrations is 1×10^{-6} in./min.

3. Agitation of the mesh in the following baths was necessary to insure proper liquid contact (and removal of adhering gases) in the following steps:

Conditioner (5)

Sensitizer (7)

Activator (9)

Plating (11)

4. After each step a very thorough (but gentle) spray rinsing was applied to the treated mesh to prevent "drag in" from one processing solution to the next. This was necessary to preserve each bath as well as to insure proper contact of solution with the mesh.

5. In order to protect the copper surface an antioxidant treatment step (13) has been added to the plating cycle. Treatment consisted of immersing the plated mesh in a solution of 1 part Entek Cu55 and 99 parts deionized water for a minimum of 15 minutes. The mesh was then washed and dried rapidly.

During the course of the plating operation quality control tests[3] and adjustments were executed to insure proper bath composition.

Additionally, electrical resistance measurements were run on the plated subsegments to insure that the resistance of each piece was less than 2 ohms/square. The resistance in ohms/square of most of the subsegments is reported in Table 5 pp. 28-30. The average resistance is 0.34 ohms/square with an average deviation of 0.12 ohms/square.

2.2 Flats and Cylinders

Sections of Rexwell MX-46 mesh were subjected to Co^{60} gamma irradiation for use in construction of the flats and cylinders.

Post-irradiation mesh properties indicated an intolerable degree of irradiation dose non-uniformity.

Additional sections of Rexwell MX-46 mesh suitable for cylinder fabrication have been subjected to machine irradiation (i.e., 1.5 Mev electron accelerator).

Uniformly acceptable mesh properties have been obtained and heat treatment of the cylinders prior to plating and bonding was initiated. It was found that the heat treatment

[3] Section 5.2 of Appendix p. 19

in air at 140°C. degraded the polyethylene mesh by oxidation causing embrittlement. In light of this fact it was necessary to heat treat mesh in an inert nitrogen atmosphere.

Due to the non-uniform Co^{60} irradiation of Rexwell MX-46 intended for the fabrication of cylinders, it was necessary to fabricate all remaining smaller deliverable items out of Rexwell MX-47 (a very similar mesh, see Quarterly Report, RAI 356, page 31). A sufficient quantity of MX-47 mesh has been machine irradiated for the construction of the cylinders and flat sections. After irradiation the mesh for the cylinders and flat sections was cut, heat treated and electrolessly plated using the same methods and procedures as for the cap section.

2.2.1 Flat Section

The 4 ft. x 6 ft. flat section will be fabricated out of twelve (12) 25 in. x 14.5 in. smaller flat sections bonded together and then cut to the required 4 ft. x 6 ft. dimensions.

2.2.2 Cylinders

One foot (1 ft.) by 7.5 in. flat sections were machine irradiated while wrapped around a 7.5 in. steel cylinder; thereby imparting a cylindrical shape (and memory) to the mesh. Bonding the 1 ft. edges together will yield the completed cylinder of required size.

3.0 MECHANICAL TESTING

Tensile tests were performed on both virgin and irradiated Rexwell MX-44 mesh. The tests were performed on 1 inch wide samples using an Instron tensile tester. Grip separation on the jaws of the tensile tester was 1 inch. Tensile tests were pulled in the 0°, 45° and 90° directions.

In addition, flexural rigidity tests were performed on the unirradiated and irradiated mesh in the 0°, 45° and 90° directions.

Tables 2 and 3 below summarize the results of these tests.

3.1 Discussion of Results

In general there was little trend in the change of strength in the mesh with 15 Mrads of radiation. On the other hand the mesh has become less elastic as can be seen by the decrease in the strain (yield ultimate and maximum) of the irradiated material compared to the unirradiated. Additionally, the material showed an approximate increase of 25% in flexural rigidity when irradiated. These results are in accord with theory. The radiation induces crosslinking in the polyethylene rendering it less elastic and more rigid.

Table 2

Tensile Test Results of Unirradiated and Irradiated Rexwell MX-44 Mesh

Direction	σ_y psi x 10^{-3}	σ_u psi x 10^{-3}	ϵ_y %	ϵ_u %	ϵ_m %	E psi x 10^{-5}
UNIRRADIATED						
0°	4.96 ± 0.14	8.45 ± 0.49	7 ± 0.8	807 ± 67	827 ± 63	0.72 ± .08
45°	12.0 ± 0.4*	13.7 ± 0.4*	27.7 ± 3.8	591 ± 75	723 ± 60	-
90°	4.59 ± 0.27	5.37 ± 0.44	3.4 ± 1.0	778 ± 69	798 ±120	0.59 ± .07
IRRADIATED						
0°	4.59 ± 0.13	5.53 ± 0.18	7.2 ± 1.2	353 ± 15	411 ± 23	0.66 ± .09
45°	11.9 ± 0.3*	13.8 ± 0.8*	25 ± 1.5	306 ± 36	469 ± 53	-
90°	4.73 ± 0.83	4.73 ± 0.83	7.2 ± 1.8	7.2 ± 1.8	253 ± 71	0.70 ± .14

*Reported in lbs.-force per inch due to complex cross-sectional area of sample in 45° direction.

Table 3

Flexural Rigidity Results of Unirradiated and Irradiated Rexwell MX-44 Mesh

Direction	G lb.ft. x 10^{+5} Unirradiated	Irradiated (15 Mrads)
0°	83.0 ± 10.9	122.1 ± 16.7
45°	104.1 ± 26.4	129.0 ± 17.0
90°	193.0 ± 55.6	221.7 ± 67.3

4.0 FUTURE WORK

During the next reporting period the cap section and other deliverable items will be ultrasonically bonded and then finally cut to their required dimensions. Additionally, the testing program on the mesh will be completed.

5.0 APPENDIX

5.1 Cap Section Design Calculations

The cap section considered is radius of curvature R = 212.5 ft. and diameter D = 24 ft.

5.1.1 Maximum Arc Length

From Figure 4 below it can be seen that 1/2 the maximum central angle (Q_{max}) is equal to:

$$Q_{max} = \sin^{-1}\frac{D}{R} = \sin^{-1}\frac{12.00}{212.50} \qquad (1)$$

$$= 3.237^{o}$$

The maximum arc length is then equal to:

$$2(212.50 \text{ ft.})(3.237^{o})(0.017453 \tfrac{\text{rad}}{\text{deg}}) = 24.01 \text{ ft.}$$

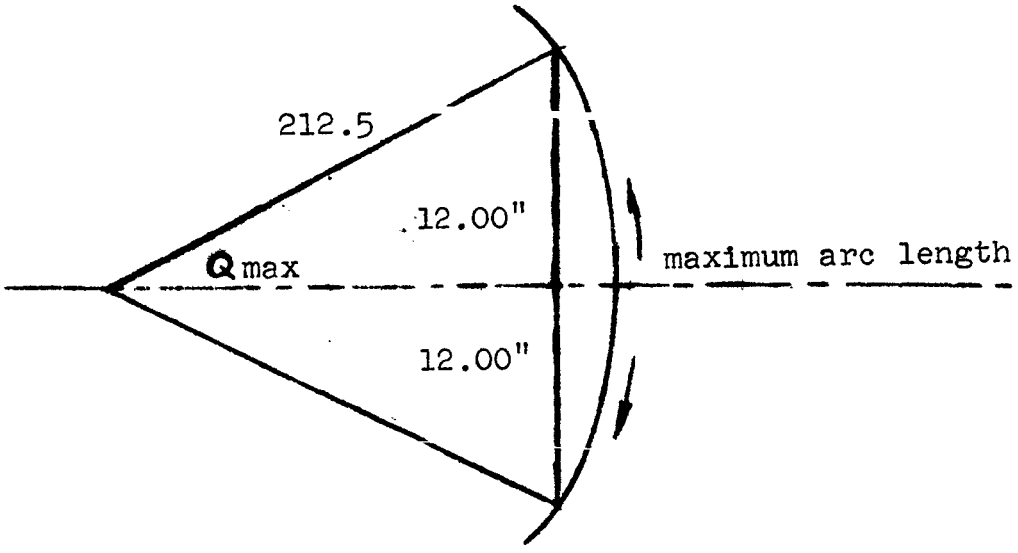


Figure 4 SIDE VIEW OF CAP SECTION

5.1.2 Variations in Gore Width

The maximum variation in the gore width (b) of a gore in the cap section is dependent on the angle Q (see Figure 5) measured from the plane defining the equator of the 212.5 radius sphere. Its dependence can be found as follows:

The length of an arc length b within a gore segment is equal to

$$b = R_1 \phi \tag{2}$$

with $\phi = \frac{14.5}{212.5}\ (12)$

From right triangle OAC

$$R_1 = R \cos Q \tag{3}$$

with $R = 212.5$

Combining equations 2 and 3:

$$b = \frac{14.5}{12} \cos Q \tag{4}$$

A tabulation of the half gore width ($\frac{1}{2}$ b) versus the angle Q from Q=0 at the equator to $Q = Q_{max}$ at the upper boundary is presented in Table 4. It can be seen from the table that the difference between the maximum gore width at the equator to the minimum gore width near the upper boundary is 0.002 ft., so for all practical purposes the lengths of all the gores can be considered parallel within the cap section. It is for this reason that the flat sections have been used in the construction of the cap section.

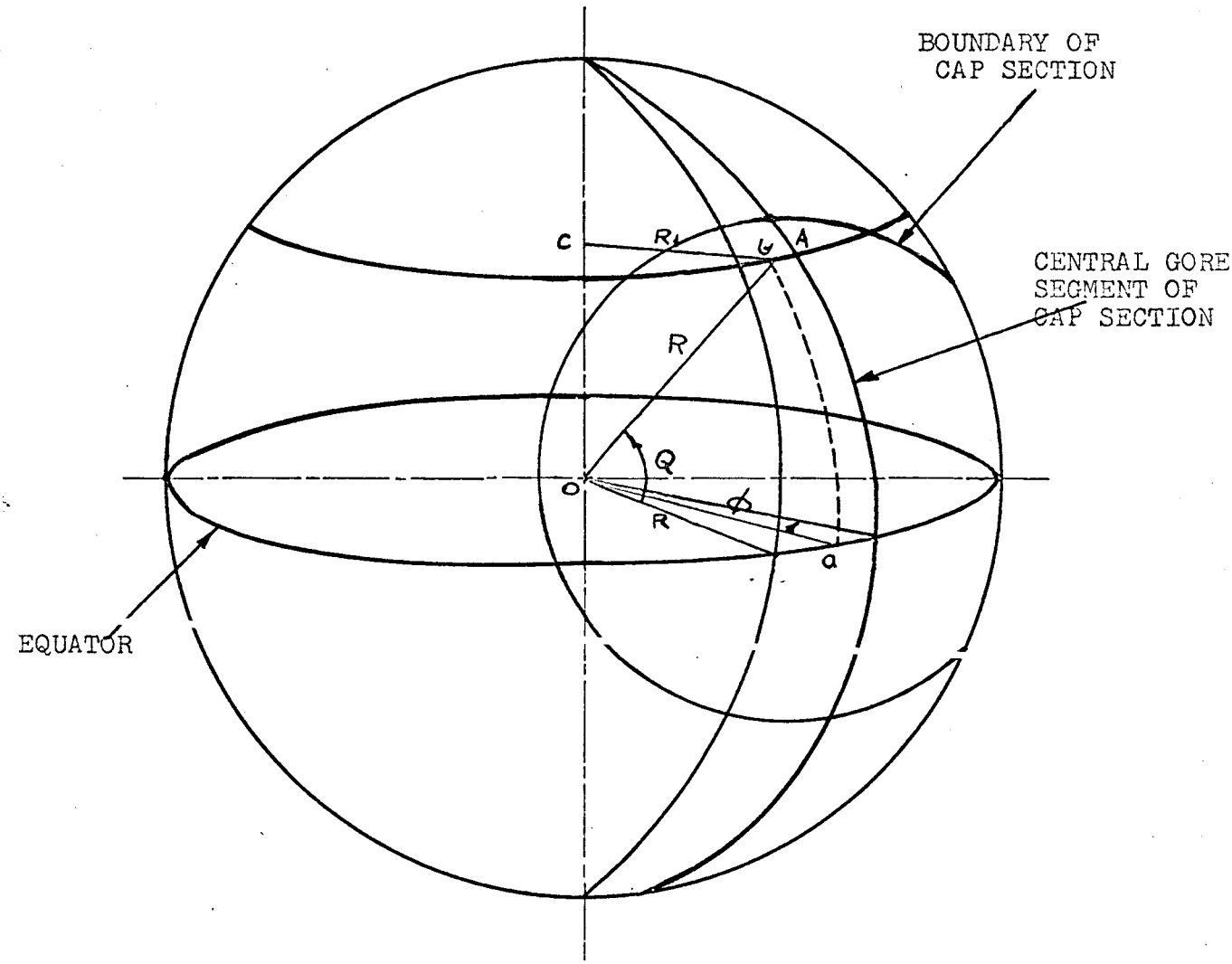


Figure 5 ARC LENGTH WITHIN CAP SECTION

Table 4

Variation of Gore Width with Angle Q in Center of Cap Section

Q (°)	½ Gore Width 0.60416 Cos Q (ft.)	½ Gore Height 3.70876 (ft.)
0	.60416	0
.18	.60416	0.66757
.40	.60415	1.48350
.60	.60413	2.22525
.80	.60410	2.96700
.99	.60407	3.67167
1.08	.60405	4.00546
1.20	.60403	4.45051
1.40	.60398	5.19226
1.62	.60392	6.00819
1.89	.60383	7.00956
2.00	.60377	7.41752
2.20	.60371	8.15927
2.40	.60363	8.90102
2.60	.60354	9.64278
2.80	.60344	10.38452
2.90	.60339	10.75540
2.95	.60336	11.94084
3.00	.60333	11.12628
3.05	.60330	11.31177
3.10	.60327	11.49715
3.15	.60324	11.68259
3.20	.60322	11.86803
3.22	.60321	11.94220
3.23	.60320	12.0100
3.25	.60319	12.05347
3.27	.60318	12.12764
3.29	.603163	12.20182
3.30	.603157	12.23890
3.304	.6031546	12.25374

5.2 Analytical Procedures for Plating Baths in Enthone Plating Cycle

5.2.1 Plating Bath 5: Analysis for Enplate G-H053

Equipment Required:

1 - 10 ml. graduate

1 - 250 ml. graduate

1 - 1.400 - 1.620 hydrometer

1 - 2 ml. pipette

2 - 250 ml. stoppered Erlenmeyer flasks

1 - 50 ml. burette

Solutions Required:

50% HCl (6N)

20% KI (Wt.)

1% Starch solution (Wt.)

0.1N $Na_2S_2O_3$

Procedure:

1. Cool the sample to 75°F.
2. Measure the S.G of the sample. The S.G should be 1.590-1.608; if it is lower the solution should be heated and the excess water driven off.
3. Pipette a 2 ml. sample into a 250 ml. flask and dilute with 100 ml. of deionized water.
4. Add 10 ml. of a 20% KI solution.
5. Add 2 ml. of 6N HCl.
6. Stopper the flasks immediately and store in a dark place for 5-10 minutes.
7. Titrate the sample with 0.1N $Na_2S_2O_3$ to a straw color; then add 2 ml. of starch solution and titrate to a clear end point (greenish blue).

Calculation:

$$\frac{\text{ml } 0.1\text{N } Na_2S_2O_3}{30} \times 100 = \% \text{ activity of GH053}$$

For each 10% low add 3/4 oz./gal. of Enplate Conditioner 470 Additive.

5.2.2 Plating Bath 7

5.2.2.1 Analysis of Sensitizer 432 Working Solution

Apparatus Needed:

3 ml. pipette

25 ml. pipette

250 ml. Erlenmeyer Flask

25 ml. graduated cylinder

5 ml. graduated cylinder

Eye dropper

Hot plate

50 ml. burette

Reagents Needed:

EDTA Solution (EDTA Disodium Salt) 0.0575 M

Zinc Solution (Zinc Metal) 0.0575 M

A.R. Hydrochloric acid (HCl)

Ammonium Acetate ($NH_4C_2H_3O_2$) solution 30%

Hydrogen Peroxide (H_2O_2) 30%

Xylenol Orange Indicator Mix (0.1% by weight in sugar) (Fisher-Scientific Xylenol Orange Tetrasodium Salt)

Procedure:

1. Pipette 3 ml. sample into 250 ml. Erlenmeyer flask.
2. Add 5 ml. concentrated HCl.
3. Add 5 drops H_2O_2 (30%) or 2.5 ml. H_2O_2 (3%).
4. Heat on hot plate to boiling, remove and allow to cool.
5. Pipette 25 ml. Standard EDTA into cooled solution.
6. While swirling add 25 ml. $NH_4C_2H_3O_2$ solution.
7. Add 1.5 g. indicator mix and dissolve.
8. Titrate with standard 0.0575 M zinc solution. Color changes from yellow to red.

Calculations:

0.55 x (25 -ml. zinc sol.) = % (Vol.) of Enplate Sensitizer 432 in solution.

Replenishment:

Maintain the desired level of sensitizer 432 by adding 38 ml. (1.3 fl. oz.) of concentrate per gallon of solution for each 1% low.

5.2.2.2 Analytical Procedure for Acidity of Sensitizer 432 Working Solution

Apparatus Needed:

2 ml. pipette

250 ml. Erlenmeyer Flask

Eye-dropper

50 ml. burette

Reagents Needed:

0.1N Sodium Hydroxide (NaOH) solution

Phenolphthalein Indicator

Procedure:

1. Pipette 2 ml. of sample into 250 ml. Erlenmeyer flask.
2. Dilute with approximately 100 ml. distilled water.
3. Add 3 drops of phenolphthalein indicator.
4. Titrate with 0.1N NaOH. Color change is from clear to pink.

Calculations:

0.42 x mls titrated = % (Vol.) Conc. HCl in solution.

Replenishment:

Maintain the desired level of acidity adding:

For each 1% low add 75 ml. (2.2 fl. oz.) of 6N HCl (50% by Vol.) for each gallon of solution.

If necessary, the acidity can be reduced adding for

each 1% high, 75 ml. (2.5 fl.oz.) of 6N NaOH (2 lb./gal.) for each gallon of solution.

A solution made up using 1 part Sensitizer 432 and 15 parts of water contains approximately an equivalent of 8% (by Vol.) of conc. HCl.

A solution made up using 1 part of Sensitizer 432 and 30 parts of water contains approximately an equivalent of 4% (by Vol.) of conc. HCl.

A solution made up using 1 part of Sensitizer 432, 1 part of conc. HCl and 14 parts of water contains approximately an equivalent of 14% (by Vol.) of HCl.

5.2.3 Plating Bath 9

5.2.3.1 Analysis of Activator 440 Working Solution - Colorimetric Procedure

Apparatus Needed:

Set of clean dry test tubes (or Nessler tubes)

2 ml. pipette - 0.1 ml. graduations

10 ml. graduate

Procedure:

1. Set up standards ranging from 1% to 10% (Vol.) by pipetting 0.1 ml. increments of Activator 440 concentrate into the tubes and adding water with the graduate to make 10 ml. of standard. (These standards may be sealed and kept permanently.)

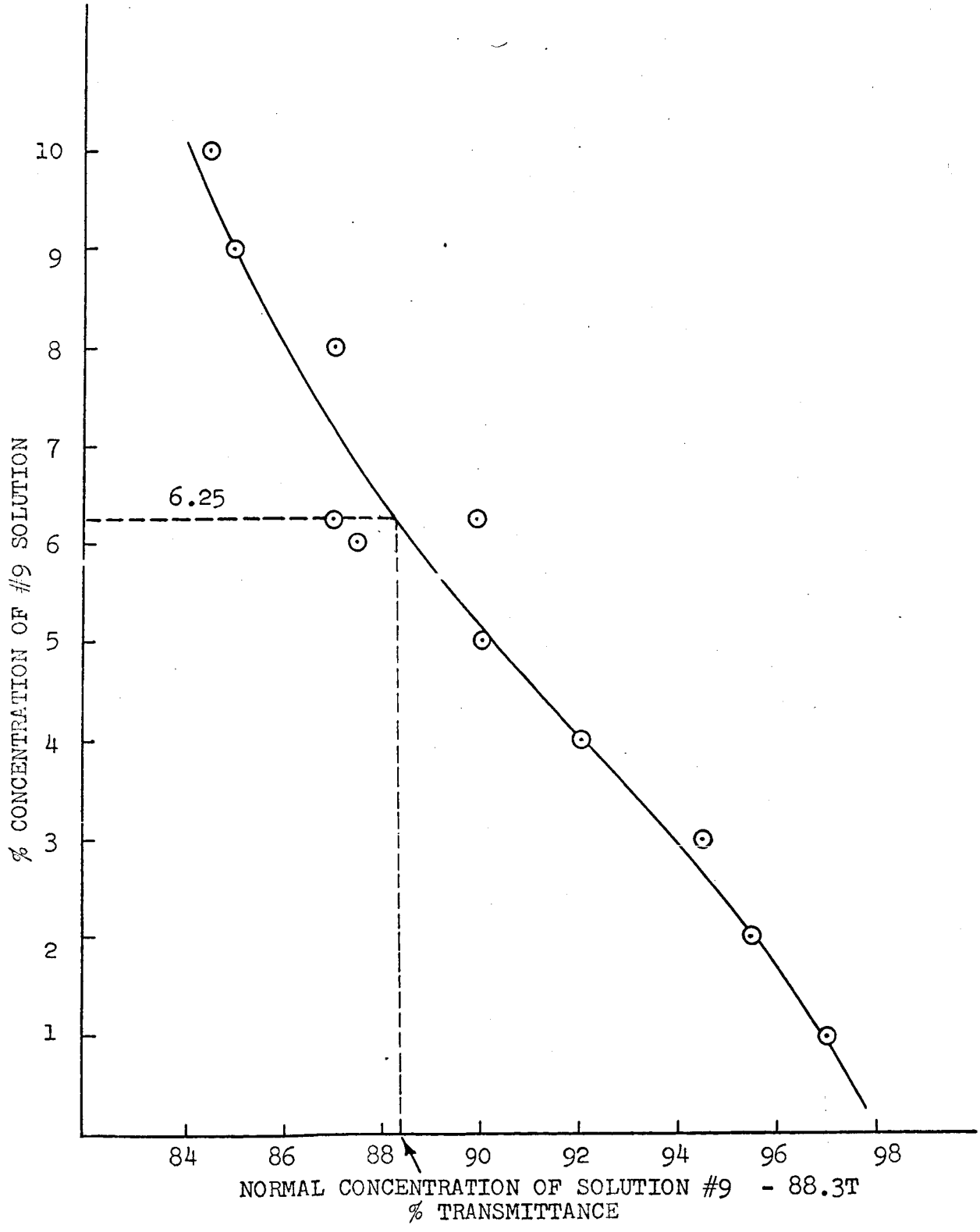
2. Place 10 ml. of filtered sample of Activator 440 working solution into the sample test tube.

3. Obtain concentration versus transmittance curve using colorimeter at set wave length and temperature. (See Figure 6 below.)

Replenishment:

Maintain the desired level of Activator 440 by adding 38 ml. (1.3 fl.oz.) of concentrate per gallon of solution for each 1% low.

Figure 6 ACTIVATOR CONCENTRATION VS. TRANSMITTANCE
at 535 x 10^{-9} cm. and 24°C.
wavelength



5.2.3.2 Analytical Procedure for Acidity of Activator 440 Working Solution

Apparatus Needed:

20 ml. pipette

250 ml. Erlenmeyer flask

Eye dropper

Reagents Needed:

0.1N Sodium Hydroxide (NaOH) solution.

Phenolphthalein Indicator

50 ml. burette

Procedure:

1. Pipette 20 ml. of sample of Activator 440 into the Erlenmeyer flask.
2. Dilute with approximately 100 ml. distilled water.
3. Add 2 to 3 drops of phenolphthalein indicator.
4. Titrate with 0.1N NaOH. Color change is from clear to pink.

Calculations:

0.042 x mls. titrated = % of conc. HCl in solution.

Replenishment:

Maintain the desired level of acidity by adding:

For each 0.1% low, add 7.5 ml. (0.25 fl.oz.) of 6N HCl (50% by Vol.) for each gallon of solution.

For each 0.1% high add 7.5 ml. (0.25 fl.oz.) of 6N NaOH (2 lb./gal.) for each gallon of solution.

A solution made up using 1 part of activator and 15 parts water contains approximately 0.5% (by Vol.) conc. HCl.

A solution made up using 1 part of Activator and 30 parts water contains approximately 0.25% (by Vol.) conc. HCl.

NOTE: The concentration of acid in Activator 440 working solution is always under 1% (by Vol.)

5.2.4 Plating Bath 11

5.2.4.1 Analysis for CU-400A in CU-400 Operating Solution

Apparatus Needed:

50 ml. pipette

50 ml. burette

500 ml. Erlenmeyer flask

25 ml. graduated cylinder

Reagents Needed:

Glacial Acetic Acid

Potassium iodide (KI) reagent grade

Starch solution (10% soluble starch solution)

0.1N Sodium thiosulfate ($Na_2S_2O_3$)

Procedure:

1. Pipette 50 ml. sample into 500 ml. Erlenmeyer flask.
2. Add 100 ml. distilled water.
3. Add 15 ml. glacial acetic acid (color should change to light blue-green)
4. Add 15 g. KI (about 1 teaspoon), swirl until completely dissolved. (Color changes from light blue-green to dark brown.)

   NOTE: It is important to add KI as solid, not as liquid concentrate.

5. Titrate with 0.1N $Na_2S_2O_3$ until color changes from dark brown to light brown or yellow.
6. Add 5 ml. starch indicator solution.(Color will change to dark purple or black.)
7. Continue titrating with 0.1N $Na_2S_2O_3$ until color changes to white and remains clear for 1 minute.

   NOTE: With some starch solutions the white may be tinged with a faint pink color which cannot be made to disappear.

8. Record ml. of 0.1N $Na_2S_2O_3$ used.

Calculations:

(0.883)(ml. 0.1N $Na_2S_2O_3$ used) = % (by Vol.) CU-400A present.

Replenishment:

Maintain at desired level of CU-400A by adding 38 ml. (1.3 fl.oz.) of CU-400A per gallon of solution for each 1% low. CU-400B is maintained by adding an equal volume of CU-400B for each volume of CU-400A replenished.

5.2.4.2 Free Alkalinity Control

The free alkalinity of a 2-5-9 bath should be controlled by the following titration. This test should only be run after proper additions of both CU-400A and B have been made.

Apparatus Needed:

50 ml. pipette

250 ml. Erlenmeyer flask

50 ml. burette

Eye dropper

Reagents Needed:

1N sulfuric acid (H_2SO_4) solution.

Phenolphthalein indicator.

Procedure:

1. Pipette 50 ml. sample of CU-400 into a 250 ml. flask.
2. Add 50 ml. deionized water.
3. Add 3-4 drops of phenolphthalein indicator.
4. Titrate with 1N H_2SO_4 until all red color disappears. (Clear blue)

Calculations:

For a bath made-up using 2 parts A, 5 parts B, 9 parts water.

(221-13 x ml. of 1N H_2SO_4 used) = ml. of a 2 lb./gal. (6N) solution of NaOH needed per gallon of made-up CU-400 bath. (30 ml. = approximately 1 fl.oz.)

Table 5

Resistance of Various Subsegments of Cap Section

Subsegment	Resistance (ohms/square)
0-1-0	-
0-2-0	.27
0-3-0	.24
0-4-0	.24
0-5-0	.30
0-6-0	-
1-1-1	.45
1-1-2	.30
1-1-3	.63
1-1-4	.27
1-1-5	.24
1-1-6	.30
1-1-7	.30
1-1-8	.30
1-1-9	.27
1-1-10	.30
1-2-1	.30
1-2-2	.24
1-2-3	.30
1-2-4	.2
1-2-5	.39
1-2-6	.48
1-2-7	.30
1-2-8	-
1-2-9	.8
1-3-1	.43
1-3-2	.30
1-3-3	.33
1-3-4	.41
1-3-5	.24
1-3-6	.5
1-3-7	.60
2-1-1	.18
2-1-2	.30
2-1-3	.24
2-1-4	.30
2-1-5	.30
2-1-6	.24
2-1-7	.46
2-1-8	.18
2-1-9	.60
2-1-10	-

continued

Table 5 (Continued)

Subsegment	Resistance (ohms/square)
2-2-1	.20
2-2-2	.21
2-2-3	.24
2-2-4	.18
2-2-5	.24
2-2-6	.30
2-2-7	.30
2-2-8	-
2-2-9	.96
2-3-1	-
2-3-2	.27
2-3-3	.60
2-3-4	.20
2-3-5	.48
2-3-6	.50
2-3-7	.90
3-1-1	.30
3-1-2	.24
3-1-3	.10
3-1-4	.24
3-1-5	.30
3-1-6	.24
3-1-7	.30
3-1-8	.30
3-1-9	.30
3-1-10	-
3-2-1	.24
3-2-2	.24
3-2-3	.30
3-2-4	.30
3-2-5	.18
3-2-6	.30
3-2-7	.24
3-2-8	-
3-2-9	.60
3-3-1	.30
3-3-2	.24
3-3-3	.30
3-3-4	.27
3-3-5	.23
3-3-6	.31
3-3-7	.38

continued

Table 5 (Continued)

Subsegment	Resistance (ohms/square)
4-1-1	.24
4-1-2	.30
4-1-3	.30
4-1-4	.20
4-1-5	.61
4-1-6	.15
4-1-7	.30
4-1-8	.60
4-1-9	.60
4-1-10	-
4-2-1	.18
4-2-2	.30
4-2-3	.24
4-2-4	.49
4-2-5	.24
4-2-6	.48
4-2-7	.42
4-2-8	.24
4-2-9	.23
4-3-1	.60
4-3-2	.37
4-3-3	.60
4-3-4	.62
4-3-5	.20
4-3-6	.30
4-3-7	.38

Table 6

Resistance of Various Subsegments of Flat Section

Subsegment	Resistance (ohms/square)
1	0.51
2	1.70
3	0.34
4	0.68
5	0.51
6	0.56
7	0.68
8	1.98
9	1.58
10	1.13
11	4.0
12	0.45

Table 7

Resistance of Cylinders

Cylinders	Resistance (ohms/square)
1	0.57
2	1.41
3	1.70
4	1.80