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FACILITY FORM 602

DEVELOPMENT OF A 425 FOOT DIAMETER PASSIVE COMMUNICATION SATELLITE WITH SELF ERECTING PROPERTIES

Submitted to:

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

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1.0 INTRODUCTION

The objective of this program is to develop a material with the following properties:

1. Ability to erect without external aids.
2. Open mesh configuration, transparent to 90 per cent solar radiation.
3. Weight less than 20 per cent that of ECHO II material.
4. Rigidity to withstand 5 times solar pressure.
5. RF reflectivity 95 to 98 per cent that of a similar solid surface.

This report describes operation of the equipment and in turn production of self-erecting material. From this material two spherical segments were fabricated.

2.0 SUMMARY

During this quarter, three production plating runs were made, one in December 1965, and two in February 1966. The run in December constituted a shakedown run for the plating equipment. The runs in February were made after the modifications dictated by the December run were completed. The deliverable items shipped during this period were:

1. A 30-inch sphere;
2. Two 4-ft by 6-ft panels;
3. Two 27-ft diameter spherical segments.

3.0 DISCUSSION

3.1 MACHINE MODIFICATIONS

During this quarter the processing equipment was extensively modified as dictated by the results from the start-up run in December. Major additions to the equipment were:

1. Auxiliary drive to facilitate machine threading.
2. Web control rollers at tank bottoms for proper tensioning.
3. Additional heat lamps in curing tunnel to increase cure temperature.
4. Additional unwind station for final RTV silicone rubber sheath coating operation.
5. An exhaust hood to remove fumes from plating tanks and solvent vapors from the silicone rubber solution.
6. Another plating tank, bringing total immersion time to 10 minutes.

Details of this equipment are depicted on drawing No. 1.

The equipment has the following operating features:

1. Web width: 48 in maximum
2. Web speed: 1.0 ft/min
3. Amount of material required to thread machine: 130 ft
4. Residence times:

Sensitizer solution	1.7	min
Activator solution	1.7	min
Plating solution	10	min
Drying tower	10	min
Curing tower	10	min

5. Process Control Temperatures:

Sensitizer and activator	18 to 22 C
Plating	20 to 23 C

Rinse tanks	40 to 50 C
Curing tower	65 to 70 C

6. Operating facilities requirements:

Air pressure	70 psi
Water	deionized
Gas	for water heater
Electrical	110 v. 60 Hz

Under normal operation this equipment can deposit copper electrolessly, and prime coat a mesh with RTV silicone rubber. The resistance of mesh produced on this machine has been in the 0.1 to 4.0 Ω/sq. range. The copper is coated immediately to prevent oxidation.

3.2 PRODUCTION RUNS

During this quarter, three production runs were made, one in December and two in February. The one in December was a start-up and preconditioning run, and was described in detail in the December progress report. The majority of the equipment modifications were prompted by process observations and materials properties measurements during and after this run. The material was plated, primed, and sheath-coated using the equipment as originally designed. The quality of the copper deposit was quite good in certain areas, but there was not enough material to fabricate a spherical segment as had been planned. Portions of this material were fabricated into a 30-inch sphere and two 4- by 6-ft panels.

The material processed during January and February is to be used in fabricating two spherical segments to be tested at NASA-Goddard in July.

3.3 GLASS FIBER PROCUREMENT AND PREPARATION

In December of 1965, yarn was purchased from Owens Corning Fiberglass with the description of ECD 900 1/0 1.0 Z yarn. This yarn was shipped to the Alta Vista Company, a division of Hess Goldsmith, to be woven into a fabric with a 10 by 20 leno weave. 260 yards of this material were received from the weaver; however, there were many flaws in the fabric. These flaws, consisting of areas where there were no yarns in the fill direction, were not detrimental to processing operations, as the machine direction yarns had enough strength so that adequate web control was maintained. Woven material, as received, was rerolled onto three-inch diameter aluminum cores for the heat treatment step. Material was rolled onto four cores as follows:

Roll No. 1	100 ft of good fabric w/200 ft scrap.
Roll No. 2	220 ft of good fabric
Roll No. 3	220 ft of good fabric
Roll No. 4	360 ft of good fabric

Roll No. 1 was to be used as leader in the GT-201 coating operation. Rolls No. 2 and 3 were to be used in the segments. Roll No. 4 has been set aside to be used for future development work. Good fabric is defined as material that is essentially free of flaws.

The glass fabric as received weighed 5.7 grams per square yard. Preliminary testing of this fabric in the "as-received" condition showed that the rigidity in the machine direction was 13.4 milligram centimeters, the transverse direction was 2.2 milligram centimeters and at a 45 degree angle it was 5.9 milligram centimeters. The technique used to measure rigidity is described in the monthly prorgress report for January.

3.4 HEAT TREATMENT

The heat treatment step performs a two-fold purpose: (1) it heat cleans the fabric by driving off weaving lubricants, and by caramelizing the fabric sizing so that subsequent coating will wet the surface more uniformly; and (2) it increases the intrinsic rigidity of the fabric. A laboratory oven was used for the charring process. Since diagonal dimension of the oven was approximately 47 inches, the door had to be left slightly ajar and the opening packed with fiberglass insulation. Because of space available, the amount of fabric treated at any given time was limited to 2 rolls. Roll 1 was heat treated for thirty minutes. The equilibrium temperature reached during this treatment was 565 F.

Rolls 2 and 3 were heat treated together since the two deliverable end caps are to be made out of these two rolls. During the heat treatment of rolls 2 and 3, the oven door had to be more ajar than in the case of roll No. 1. Even though the opening was packed with insulation, the maximum equilibrium temperature during the heat treating process only reached 520 F. Because of this lower equilibrium temperature, rolls 2 and 3 were heat treated ninety instead of thirty minutes. After heat treatment, the fabric weight for all three rolls was found to be 5.6 grams per square yard (a 1.8 per cent reduction).

From the above weight loss data, it was determined that all three rolls of material had been heat cleaned to the same degree.

The rigidity of the fabric at this stage was measured and found to be markedly increased. An apparent side effect due to heat treatment noted at this point was that there appeared to be some permanent set or curvature of the fabric. It is felt that this was due to wrapping on the three inch core. This has caused an apparent wide variation in the rigidity of a material sample if it is inverted on the test fixture and remeasured. A factor of 10 difference in the rigidity measured in this manner was observed when testing to ASTMD-1388 procedures. This effect was marked in the machine direction but was negligible in the transverse direction. The samples taken at 45 degrees did not appear to exhibit this characteristic curl. Further tests will be made to determine whether or not this deformation caused by wrapping on the core will affect the fold resistance and/or the erection properties of the material.

3.5 GT-201 COATING

The next phase in processing consisted of coating the heat treated fabric with GT®-201 adhesive. This coating was applied with the Schjeldahl 64-inch laminator. After coating, the adhesive is cured to alleviate blocking.

As it is intended to use this run of material to fabricate and test two spherical segments, it was jointly agreed by Schjeldahl and NASA engineers that the two assemblies should be different in some way. It was determined that the most logical step was to vary the GT-201 coating weight. This was done by applying a heavy coating to roll No. 2 and a relatively light coating to roll No. 3. Roll No. 2 was coated to a finished material weight of 6.8 to 7.8 grams per square yard. Roll No. 3 was coated to a finished material weight of 6.0 to 7.0 grams per square yard.

The coating on this particular run was dyed a faint pink to facilitate inspection for proper penetration and coating of the yarn bundles. The December run used a green dyed coating; however, it was found that too much dye had been used as evidenced by a gross discoloration of the silicone rubber which masked the copper lustre desired.

This particular run on the laminator proceeded very smoothly. The heat-treated rolls were coated in numerical order. This allowed adjustment of the machine so that few problems in machine control were encountered in coating rolls No. 2 and 3. During this coating operation the mesh openings remained relatively square and very little yarn wandering was noted. Microscopic examination of the coated material revealed that the yarns were adequately encapsulated.

3.6 PLATING

The equipment described in earlier reports was used to deposit copper electrolessly on the GT-201 coated material. The plating operation was scheduled so that only one roll of material was processed on a given day. The December run showed that for the two plating runs that would be made, only one charge of sensitizer solution and one charge of activator solution would have to be made. The plating solutions, however, would have to be made up fresh each day. It has been determined that storage of these plating solutions overnight is virtually impossible.

The supplier suggested the use of air agitation and a more dilute plating bath to increase stability. These procedures did not help appreciably. It was found that pH was a significant factor in controlling the quality of plating. Therefore, a pH meter was used for process control. During these runs, care was taken to keep the pH of the plating solutions between 12.2 and 12.8 as recommended by the plating chemicals supplier. This was verified by laboratory experiments conducted by Schjeldahl. The pH was adjusted by adding sodium hydroxide flake in a dry form to the tanks. The air agitation in the tanks dissolved the caustic quickly, thus there was no need for the caustic to be predissolved. The machine ran very well at the prescribed speed of 1 foot per minute. The addition of the rollers in the bottom of all the tanks resulted in better operation of the equipment. During the December run, it was found that when using a free floaing web the residence time could not be held constant.

During the plating run, the material resistance of a one-inch wide sample was periodically checked. On the first run this was done at approximately 28-foot intervals. However, it was found that web strength was reduced to a point of potential web breakage when a sample was cut out of the center. On the second run the resistance of the material was checked by taking samples at the beginning, in the center, and at the end. By this means of sampling more material could be utilized for the fabrication of an end cap.

On the first run, that is roll No. 2, it was found that the resistance of the copper-plated mesh ranged from 1/2 Ω per square to approximately 2 Ω per square. This was felt to be acceptable and the material was primed with a silicone primer. Roll No. 3, our second run, was plated to a point where the resistance of the mesh was between 0.1 and 1 Ω per square.

3.7 DRYING

The web travels from the plating section to the silicone coating section through a drying tower. The drying tower prepares the plated material for the subsequent sheath layer by removing any remaining water. The residence time of the tower is 12 minutes and it is heated to between 110 and 125 F by heat lamps. The plated material was dried adequately in this section during the runs in February.

3.8 SILICONE PRIME COAT

After drying, the material was rinsed with toluene containing a wetting agent (Rohm & Haas X100), and then primed with a dilute solution of silicone rubber as described in the last quarterly report. This affords an interim protection to the copper plate until the final coating can be done.

3.9 SILICONE SHEATH

After primer curing, the material was coated with a final RTV silicone rubber sheath coating. The total weight gain of the prime coat and sheath was approximately 30 to 40 per cent. This part of the process ran satisfactorily.

It was necessary to introduce a new unwind station between the drying towers to coat the material. During this operation, the curing tunnel temperature reached approximately 160 F. The residence time in the tunnel was approximately 12 minutes. One pass through the curing tower was not sufficient to completely cure the RTV rubber. Therefore, to eliminate any future surface blocking in the roll, the material was passed through the drying tunnel twice.

3.10 END CAP ASSEMBLY

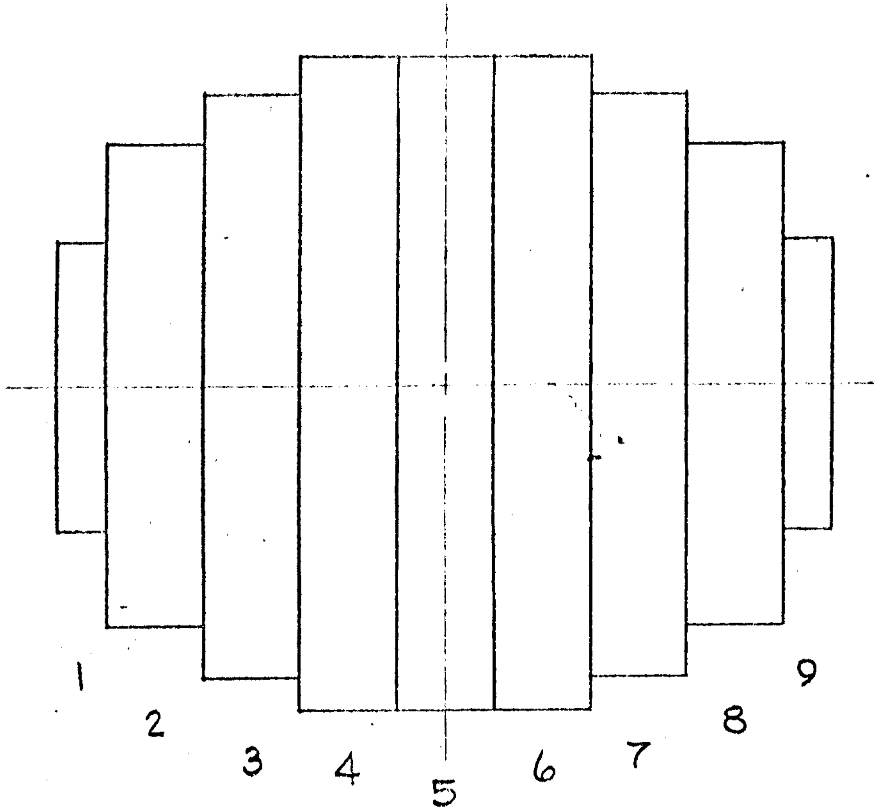
Two spherical segments were made from the material processed during the month of January and February. Figure 2 is a drawing of these end caps. Their approximate dimensions are 26 feet in diameter. These were shipped to NASA Goddard and will be tested on a fixture in July for RF reflectivity characteristics.

These end caps were made utilizing a bitape seam configuration as shown in Figure 2 using 2/8-inch wide GT-300 tape. The tape was 0.15-mil Mylar by 1-mil adhesive.

4.0 FUTURE PLANS

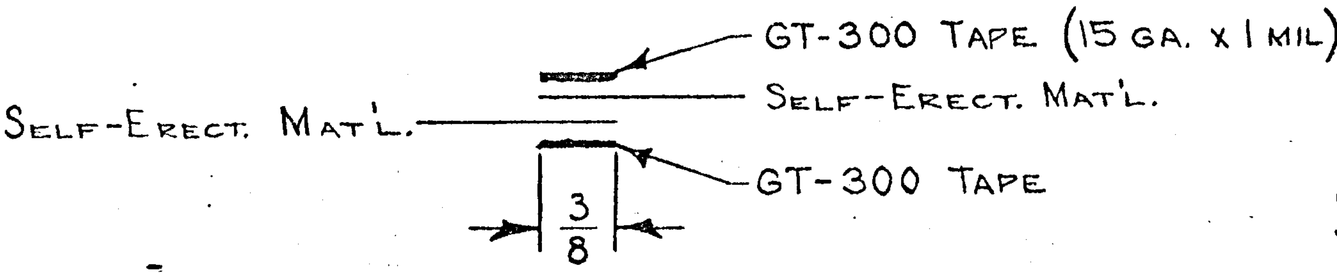
A thorough examination of the heat treatment step will be made to determine optimum processing conditions. An investigation of other types of weave styles will be made to determine applicability to this program. Weave set will be studied to determine if it is possible to introduce a resin or coating of some nature that will effectively eliminate or negate the necessity of a charring step. A seam study will be started to examine the means of fabricating hardware. This study will explore the use of conductive seams. Further tests will be made on the material used during this run, such as tensile, rigidity, bend-radius, and tensile tests.

Calculations have begun to determine a more accurate definition of the design criteria for a 425 ft. diameter sphere.



Gore Sealing Configuration

Gore	Length	Width
1	12 feet	21 inches
2	20	41
3	24	41
4	27	41
5	27	41
6	27	41
7	24	41
8	20	41
9	12	21



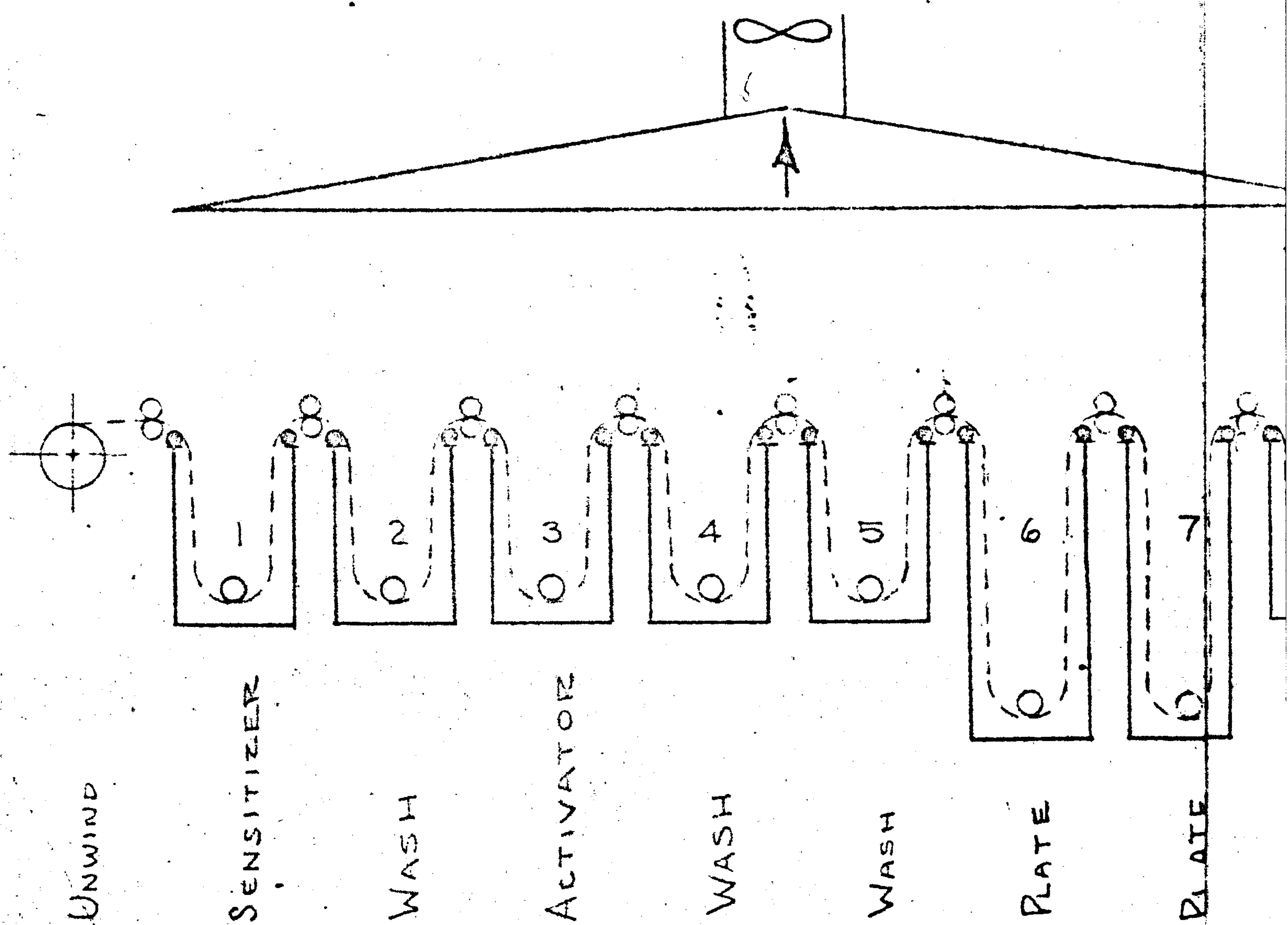
Typical Seal

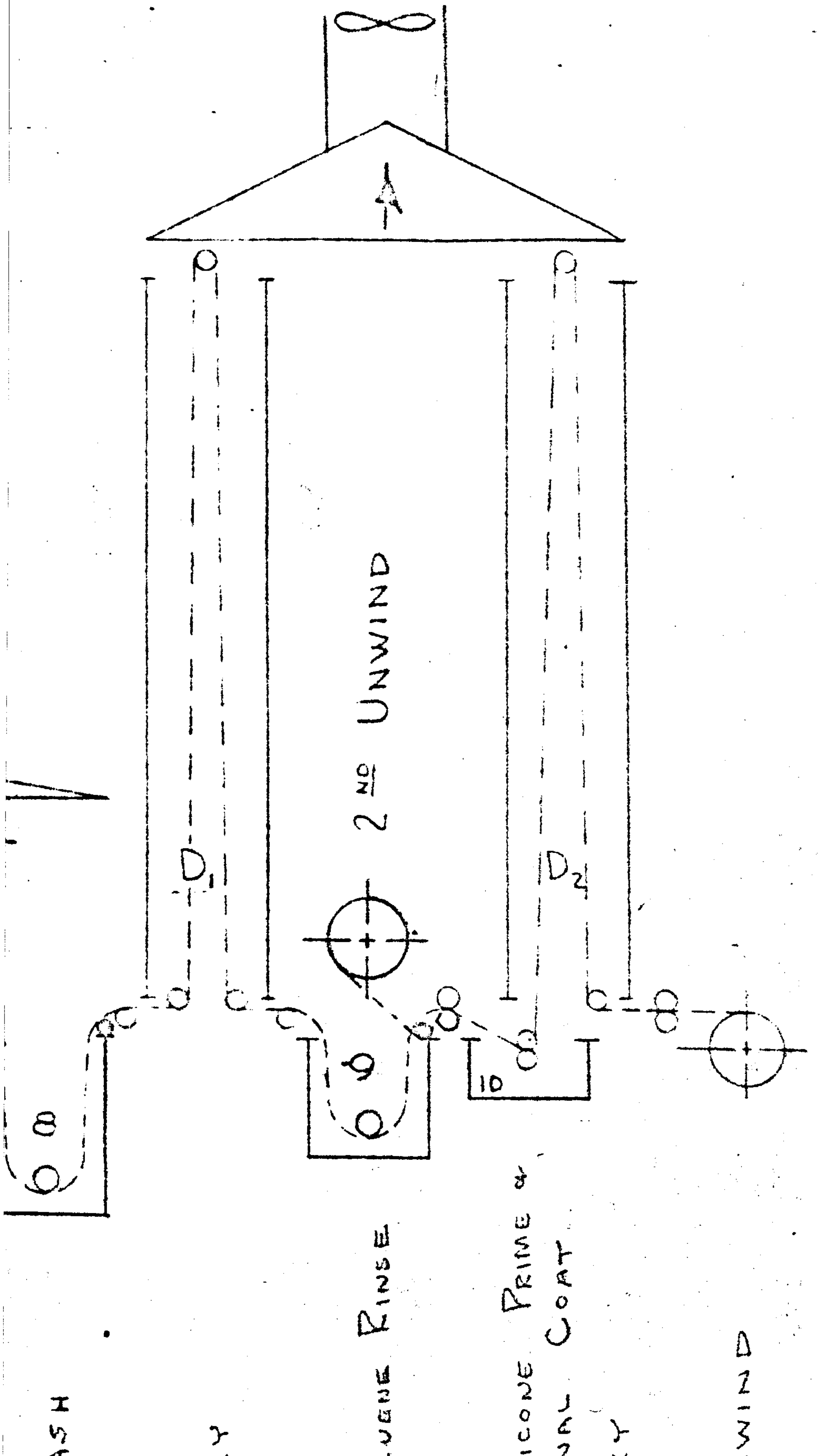
Spherical Segement and Typical Gore Seal

March 24, 1966

TANKS —	1 & 3	— WOOD	12 x 18 x 54
	2, 4, 5 & 8	— SHEET METAL	12 x 18 x 54
	6 & 7	— WOOD	12 x 30 x 54
	9	— SHEET METAL	12 x 12 x 54
	10	— SHEET METAL	12 x 6 x 54

DRYING CHAMBERS — SHEET METAL 12 x 72 x 54





2. MACHINE FOR COPPER PLATING AND SILICONE RUBBER COATING SELF ERECTING MATERIAL $\frac{1}{8}$ IN. = 2 IN. 24456-01 2-25-66