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INVESTIGATION OF IMPACT LOAD ABSORPTION THROUGH SUSPENSION LINE ELONGATION

E. A. GIMALOUSKI
PIONEER PARACHUTE COMPANY

DECEMBER 1952

WRIGHT AIR DEVELOPMENT CENTER

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E. A. Gimalouski
Pioneer Parachute Company

December 1952

Materials Laboratory
AF Contract No. 33(038)-10401
RDO No. 612-12

Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

McGregor & Werner, Inc., Wakefield, Mass.
Mar. 20, 1953 150

FOREWORD

This report was prepared by Pioneer Parachute Company, Manchester, Connecticut, on USAF Contract No. 33(038)-10401. The contract was initiated under Research and Development Order No. 612-12, "Textiles for High Speed Parachutes", and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Mr. W. A. Corry acting as project engineer, assisted by Mr. J. H. Ross.

We are grateful to the Cheney Brothers, and Mr. Max Schmidhauser, for their cooperation in the study and for the help given in the formic acid treatment of nylon yarns.

We are also grateful to Mr. C. S. Kowalski who handled whirling tower tests, parachute packing, etc., and Mr. C. R. Miller, who interpreted and evaluated the tensiometer film data for the Pioneer Parachute Company.

ABSTRACT

The purpose of this investigation was the study of suspension lines under actual operating conditions, having varying degrees of elongation, energy absorption and elasticity. A secondary purpose of the investigation was the study of fabric porosity, shape and type of canopy, and method of parachute deployment.

The shock absorbing capacity of five different types of parachute suspension line cord were first evaluated for basic physical properties, then were tested by assembling into parachutes and opening the parachute at various speeds - first at 100 mph, then 150 mph, finally 200 mph - on a whirling test tower. The parachutes were evaluated first in standard back type, then in deployment bag openings. Two types of parachutes were used; one being a twenty four foot standard parachute, the other being a 30 foot parachute, with an extended skirt.

The loads were measured and the cords evaluated on the basis of shock absorbing capacity, strength, and durability. Final results of the work indicates that the presently used 550 lb tensile strength cord, Specification MIL-C-5040, Type III, is the best of the cords evaluated. A good correlation was established between line energy absorption and snatch force, but opening shock loads appear to be little affected by line characteristics.

PUBLICATION APPROVAL

This report has been reviewed and is approved.

FOR THE COMMANDING GENERAL:

M. E. SORTE
Colonel, USAF
Chief, Materials Laboratory
Directorate of Research

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A. PURPOSE:

1. To determine the effect of suspension line elongation upon absorbing parachute impact forces.

2. To determine which type of line construction has the greatest impact absorbing capacity.

3. To determine which suspension line material has the greatest impact absorbing capacity.

B. FACTUAL DATA:

4. The static elongation tests show that the Group IV nylon line has the highest percent elongation per unit load.

5. The Group V (Formic Acid Treated Line) has the highest elongation due to its combined unit elongation and higher breaking strength.

6. The Group I (Fortisan Line) had the lowest elongation.

7. The Group III (Nylon Line) had the third highest elongation.

8. The greatest number of failures occurred in the Group IV and Group I lines.

9. Group II line withstood the highest stresses of the five groups tested without any failures.

10. Group III line suffered but a single failure. This was in a main seam of the canopy and was caused by a line over.

11. Group V line suffered but a single failure. This was due to an inversion of the canopy upon opening.

12. The shock loads for the deployment bag 30 ft. canopy launchings were approximately 30% of those for the conventional 24 ft. canopy launchings.

13. Group IV line suffered a large number of failures due to friction burns at low shock loads.

14. Higher loads were registered on the canopies strung with low elongation line than on canopies strung with high elongation line.

CONCLUSIONS:

15. Nylon is superior to fortisan in shock absorbing capacity.

16. The tubular webb line (Group II) registered the highest forces of the five groups of line tested on the whirling tower. (See Paragraph 17.)

17. Had it not been for numerous line breaks, the fortisan line (Group I) may have registered higher loads than the nylon webb (Group II) during the 200 MPH tests using the 24 ft. canopies. The breaking of these lines reduced the snatch and opening forces. Note that the tensile strength of each fortisan line is 30 lbs. less than the nylon webb.

18. The Group IV (320 lb. tensile strength) line suffered the greatest number of failures in the area between the link and the skirt, particularly at lower loads on the 30 ft. canopies. It is concluded that this line has insufficient body to resist failure from friction burning under opening loads. Note the lower number of this type of failure at higher loads with the 24 ft. canopies.

19. The outward tumbling of the deployment bag during the test tower drops with the 30 ft. canopies placed one or more twists in some of the suspension lines, thus creating a source for friction burns as the lines stretched and straightened.

20. Variation in the porosity of the fabric between drop tests was not sufficient to materially affect the results of the investigation.

21. The magnitude of the impact loads is inversely related to the elongation of the suspension line.

22. The Group V and Group III lines exhibited high capacity for absorbing impact loads and resisted failure from stresses and friction burns. On the basis of impact load absorbtion, Group V line is superior.

23. The woven tubular construction is stronger than the braided sleeve with core thread construction but lacks the elongation of the latter.

DISCUSSION OF RESULTS:

24. The gathering of data from a series of personnel canopy tests is apt to turn up some diverse, and possibly contradictory results. This investigation is no exception. Such a contradiction is found in the average opening shock loads for the Type I line from the 150 MPH tests with the 30 ft. canopies. This particular test shows Type I line to have the lowest recorded average load of the five types of line whereas, all other snatch and opening shock loads for this line were highest of all lines for all three speeds with this canopy. Furthermore, the Type V line made the poorest showing in respect to shock load at this speed. A search through the drop test records revealed that a possible cause was an above average shock load for Canopy Number 350250, strung with Type V line. This high shock load was caused by an inversion of the canopy during opening.

25. It was also noted that on many of the individual tests where snatch force was high, the opening shock was relatively low. Similarly, where snatch force was low, opening shock would be higher than average, indicating that the kinetic energy of the dummy was reduced by the combined action of the snatch and opening forces.

26. Speeds at which parachutes were tested during this investigation exceeded those normally used for paratroop drops. Considering that the dynamic pressure varies as the square of the speed, it can be pointed out that the opening forces at the lesser bail out speeds used by paratroops are probably low enough to warrant the use of the Type IV line.

27. A fair comparison between Type I (Fortisan sleeve and core thread) and Type II (Nylon Webb) constructions was difficult because two basic materials were used. A true test of construction should compare the performance of two lines of similar elongation, the same material and differing only in mechanical construction. The nylon webb held up so well under one test in particular (7500 lb. snatch load) that it rates high on strength alone. The fortisan failed at lesser loads because of lower elongation, lower tensile strength, or the difference in construction. It is apparent that the 7.2% difference in tensile strength was not the main reason for the large number of broken lines.

DISCUSSION OF RESULTS (CONT'D):

28. Deployment bag line stowage loops were badly torn during the 200 MPH drop tests due to the rapid deployment of the lines. This also caused some friction burns on the lines.

RECOMMENDATIONS:

1. Investigate the extent to which "Opalwax" will make the Type IV line resistant to friction burns.

2. The 30 ft. extended skirt canopies suffered a large number of line attachment failures at the skirt. These lines did not break but the stitching failed. The method of attaching lines to this shape canopy should be investigated.

3. The flat webb line is better suited to zig-zag sewing than a round line. Investigate the relative strength of the attachment of the two lines.

4. Investigate the braided coreless line construction in fortisan and nylon with respect to elongation.

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MATERIALS TESTED

SECTION I - GENERAL

1. OBJECT OF TESTS: The principle object of this project was to determine what effect suspension line elongation has on the absorbtion of parachute impact forces. A secondary object was to determine what effect canopy shape and size had on impact loads when the canopies were equipped with these lines. A third object was to study the effect of deployment bags as related to suspension line performance and reduction of impact loads.

2. USE OF TERM - "GROUP" vs. "TYPE": Hereafter, the word "Group" will be used in this report instead of the word "Type". "Type" has been used in some of the specifications to indicate different cords. Thus, Group I, Group II, Group III, Group IV and Group V will distinguish the five kinds of cord tested on this contract.

SECTION II - DESCRIPTION OF LINES

1. GROUP I - 420 LB. TENSILE STRENGTH FORTISAN LINE: This cord is similar to Specification 16142, Type II except for its heavier construction and higher breaking strength. It is constructed with an outer cover and an inner core.

Cover (Sleeve)

17.5 Picks/inch
40 Carrier Braider
Yarn 90/120 Fortisan H. T. 1/6
2.5S/2.0Z

Core

4 Ends

Yarn 270/120 Fortisan H. T. 1/2/12
2.4S/4.9S/2.1Z

This line had the lowest elongation of the five tested.

2. GROUP II - NYLON TUBULAR WEBBING, SIMILAR TO SPECIFICATION AN-W-10b (MIL-W-5625): This cord was the only one tested that had no core threads. It is of the woven construction as compared to braided construction in the other four lines.

SECTION II - DESCRIPTION OF LINES (CONT'D)

23 Warp Ends
Yarn 210/68 Nylon 1/8 1S/1.9S

24 Picks/inch Fill
Yarn 210/68 Nylon 1/4 12S/2.1S

3. GROUP III - 550 LB. TENSILE STRENGTH NYLON CORD:

This is probably the best known of the suspension cords. It is used in all sizes and types of canopies and is somewhat of a standard. It is fully described in Specification MIL-C-5040, Type III.

4. GROUP IV - 320 LB. TENSILE STRENGTH NYLON CORD: A quantity of this cord was purchased by Wright Field on Purchase Order 33-097-49-821-E. It is constructed with an outer cover and an inner core.

Cover (Sleeve)

28 Picks/inch
32 Carrier Braider
Yarn 70/34 Nylon 1/2/3 1Z/20.2S/13Z

Core

4 Ends
Yarn 210/34 Nylon 1/5/3.1Z/10.5S/5.9Z

5. GROUP V - 550 LB. T.S. FORMIC ACID TREATED CORD: This cord is the same as Group III except that it is formic acid treated to give 55% ultimate elongation.

(a) The construction of this line is covered in Specification MIL-C-5040 under Type III. The formic acid treatment shrinks the line.

(b) The 700 yd. skeins of nylon shroud line were treated in a solution of 30% formic acid at 150° F. for 15 minutes. The line was removed, washed four times, and remaining traces of formic acid neutralized with soda ash. The line was given a final rinse and allowed to dry.

SECTION II - DESCRIPTION OF LINES (CONT'D)

Laboratory Test Results of Treatment:

	Rupture	Elongation	Picks/inch	Yds/lb.
Untreated	577	42%	26	84.2
30% Formic Acid @ 150°F for 15 minutes	* 591	*55.0	28.5	78.3
	*527	*51.0	28.5	79.5
	*554	*52.0	28.0	78.0

* From Center of (3) Spools.

The above test results from Cheney Brothers Laboratories compared favorably with the line strength and elongation obtained by Pioneer Parachute Company's investigations shown in Appendix "B", Section III.

SECTION III - DESCRIPTION OF CANOPIES

1. 24 FT. DIAMETER STANDARD FLAT CANOPIES: Thirty (30) 24 foot diameter canopies were made to A.F. Drawing X-49J7143 except six (6) canopies were strung with each of the five groups of suspension cord. These cords extended from riser link to skirt, over canopy vent to opposite skirt, then to link on the opposite riser. The canopies were made of 1.1 oz. nylon ripstop, Specification MIL-C-7020, Type I. With the exception of the cord, the canopies were of standard construction.

2. 30 FT. DIAMETER EXTENDED SKIRT CANOPIES: Twenty (20) canopies were made to A.F. Drawing X-49J7141 except four (4) canopies were strung with each of the five groups of suspension cord. These cords were sewed to the skirt for approximately nine (9) inches along the main seam and connected to the drop test riser links at the other end. Canopies were made of 1.1 oz. nylon ripstop, Specification MIL-C-7020, Type I.

3. SERIAL NUMBERS: In order that the identification of the canopies and the test lines might be easily retained, it was decided to relate the last two digits of the serial number with the size of canopy and cord group number as follows:

SECTION III - DESCRIPTION OF CANOPIES (CONT'D)

24 FT. CANOPIES

SERIAL NUMBER	SUSPENSION LINE GROUP
350201 02 03 04 05 06	I Fortisan Line similar to Specification 16142-A, breaking strength, 420 pounds minimum.
07 08 09 10 11 12	II Woven tubular nylon line 450 lbs. minimum breaking strength. Low elongation type construction similar to Specification AN-W-10b Webb.
13 14 15 16 17 18	III Nylon Line, Specification AN-C-63, Type III
19 20 21 22 23 24	IV Nylon Line, 320 lbs. minimum breaking strength, Similar to material furnished to Wright Field on P.O. 33-096-49-821E.
25 26 27 28 29 30	V Nylon Line, Specification AN-C-63, Type III, Formic acid treated to produce approximately 55% elongation.

SECTION III - DESCRIPTION OF CANOPIES (CONT'D)

30 FT. CANOPIES

SERIAL NUMBER	SUSPENSION LINE GROUP
350231 32 33 34	I Fortisan Line similar to Specification No. 16142-A, breaking strength, 420 pounds minimum.
35 36 37 38	II Woven tubular nylon line 450 lbs. minimum breaking strength. Low elongation type construction similar to Specification AN-W-10b webb.
39 40 41 42	III Nylon Line, Specification AN-C-63, Type III.
43 44 45 46	IV Nylon Line, 320 lbs. minimum breaking strength. Similar to material furnished to Wright Field on P.O. 33-096-49-821E.
47 48 49 50	V Nylon Line, Specification AN-C-63, Type III. Formic acid treated to produce approximately 55% elongation.

SECTION IV - TYPES OF DEPLOYMENT

1. DROP TEST FROM SEAT TYPE PACK: The 24 ft. standard canopies were packed into standard A.N. seat type packs modified for test tower use. The suspension lines were tied to four links held by twenty-seven inch drop test cotton risers. Standard A.N. type pilot chutes were used to pull the canopies out of the packs. The ripcords were adapted to the test tower dummy ripcord control device, otherwise pins and spacing were standard.

2. DROP TEST USING DEPLOYMENT BAG: The line elongation tests offered an opportunity to study the effect of a deployment bag launching of the 30 ft. extended skirt canopies as used in the XT-9 type parachutes. The deployment bag design was retained but the shape was changed to correspond with the test tower dummy. The deployment bag was held in a test tower pack fitted with cover and ripcord. (See Figure 4 , Page 215. The bag was pulled from the pack by a twist ring pilot chute, 24 inches projected diameter. The pilot chute was connected to the bag with a 1000 lb. tensile strength bridle cord that extended through the bag to the canopy vent lines. (See Figures 5 and 7 Pages 216and 218.) Twenty-seven inch drop test cotton risers connected the suspension lines to the dummy.

Note that in a conventional launching, the canopy is withdrawn from the pack before the lines, whereas in a deployment bag launching, the lines are withdrawn first followed by the canopy. The bag holds the canopy until the lines are fully stretched, thus preventing a partial canopy opening before the lines are taut.

SECTION V

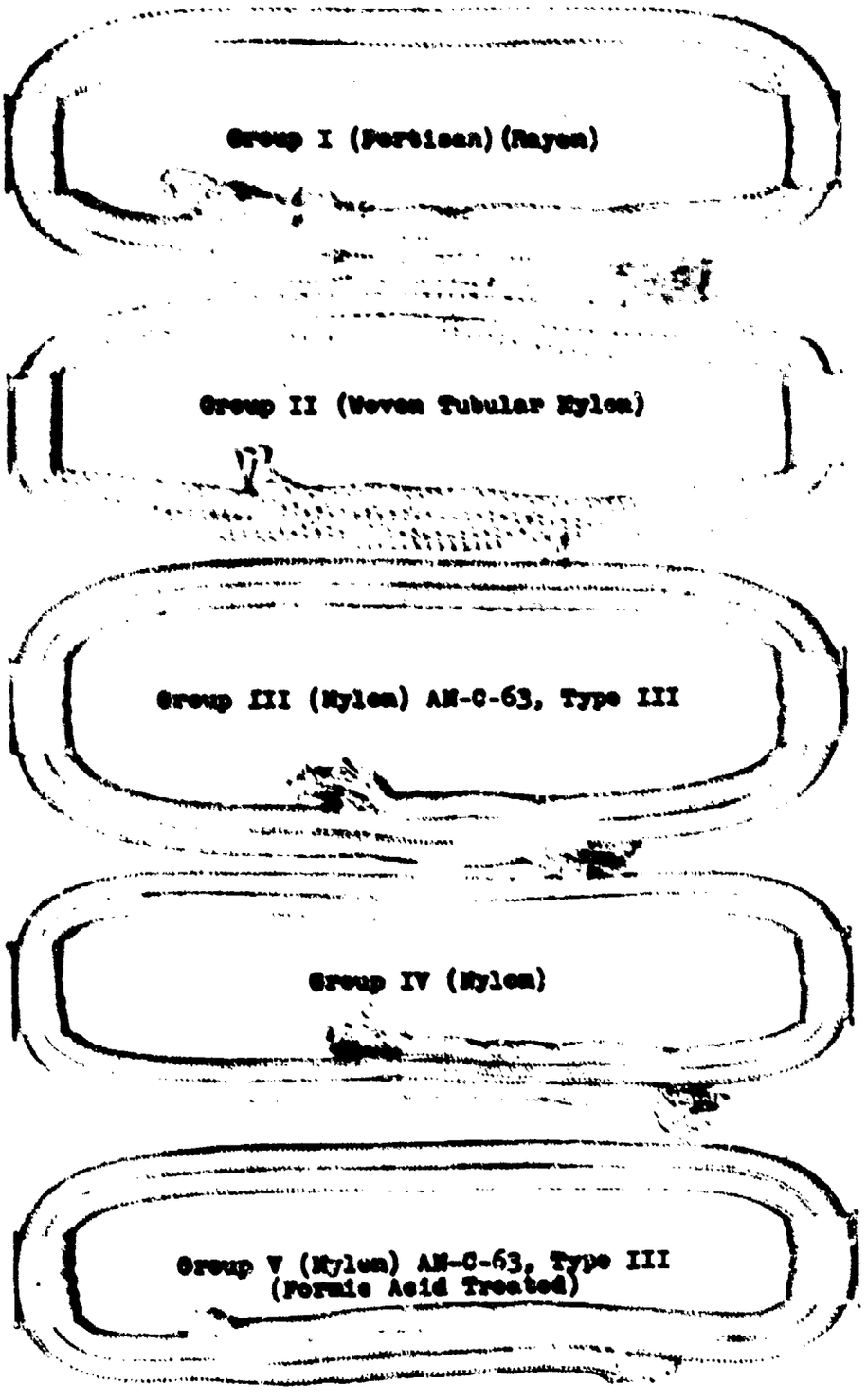

Figure 1. Specimens of Tested Goods

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STATIC LINE TESTS

SECTION I - GENERAL

1. PURPOSE: The static elongation tests were conducted to measure the breaking strengths, elongation and permanent set of the five groups of lines.

2. TESTING OF HIGH ELONGATION CORD: All static line tests were made on the Scott Pendulum Type Tensile Tester having a jaw separation speed of 12 ± 2 inches per minute. (See Page 213, Figure 1.) This machine was equipped with a standard length bed.

It was found that only a five inch gage length, and six inch jaw separation could be used on the high elongation cord and still break the cord before the jaws reached their limit of travel. A similar limitation prevented the continuous recording of high elongation on the autographic recorder. This was overcome by allowing the recorder to graph three or five inches of elongation and quickly returning the platen to zero from where the elongation recording was continued. (See Tensilgrams, Pages 25 to 29.) The two parts were added to obtain total elongation. The autographic recorder was selected for the measurement of elongation because it provided a permanent record convenient for future reference and because it permitted easier reading of intermediate points along the elongation curve. The use of the tensilgrams made by the autographic recorder required that the actual elongation be calculated to correct for jaw penetration effect. (See Page 213, Figure 2.)

The true elongation was measured on a five inch gage length using the Caliper Method. Figure 2, Page 213 shows the method of winding cord around the capstans on the tensile tester. The true elongation for each cord was established from these break tests and measuring the elongation at the breaking point by the Caliper Method. This was followed by five tests on each group of cord to establish the elongation at intermediate points 50%, 70% and 90% of the breaking strength established in the previous tests.

SECTION II - METHOD OF MEASURING LINE ELONGATION

1. CALIPER METHOD: A five inch section is marked off on the cord between the capstans of the testing machine. As the tension is applied and the cord stretches, a pair of calipers is used to measure the distance between the marks. This method is considered the most accurate because the measurement is made on a specific length of cord that stretches uniformly. A slight error, due to separation of the fibers rather than elongation, may take place when the cord reaches the breaking point. This may be seen on the tensilgram made by the autographic recorder. Measurement of elongation at intermediate points is difficult and less accurate because the testing machine cannot be stopped to make these measurements.

2. EFFECTIVE GAGE LENGTH METHOD: This method is fully described in a paper written by W.J. Hamburger and E.R. Kaswell, published in the November 1943 issue of "RAYON TEXTILE MONTHLY". A calculation is made using data from the autograph recorder to obtain the elongation. This calculation takes into account the jaw penetration of cord wrapped around the capstans.

3. SEQUENCE OF TESTING: The five groups of lines were tested as follows:

(a) Three (3) break tests were made on each group of lines to determine the average breaking strength and average true elongation by the caliper method.

(b) Five (5) static elongation tests were made on each group of lines. The effective gage length method was used to determine elongation from the tensilgrams.

(c) The elongation was measured at 50%, 70% and 90% of the respective breaking strengths of each group of lines from the autograph records.

(d) The "set" of each group of lines was measured after

5 minutes	**±**	**30 seconds**
1 hour	**±**	**5 minutes**
24 hours	**±**	**1 hour**

SECTION III - STATIC ELONGATION TEST RESULTS

1. CHARTS: The static line elongation test results are tabulated on the charts Pages 18 to 22. The charts show:

a. Average breaking strength and true elongation.

b. "Effective Gage Length" elongation.

c. Permanent set. This measurement is made between original 5 inch gage marks 5 minutes, 1 hour and 24 hours after test.

2. ELONGATION RATING OF LINE GROUPS: The static elongation tests show the lines to have the following percent elongation:

GROUP NO.	BREAKING STRENGTH LBS.	% ELONGATION
V	580	52.8
IV	535	41.8*
III	586	39.3
II	517	23.1
I	464	8.7

*The Group IV lines exhibit elongation qualities superior to all other groups through the static load range 0 to 336 lbs. The Group V lines are rated second highest in the range 0 to 336 lbs. and highest in the static load range 336 to 580 lbs. (See Graph, Page 23.)

3. GRAPHS: The following graphs were made from the data obtained from the static elongation tests:

a. % Elongation vs. Load - Pounds. (See Page 23.)

b. (Permanent Set) Percent Elongation vs. Time - Hours. (See Page 24.)

c. Tensilgrams. The tensilgrams of the E.G.L. tests for each type of line appear on Pages 25 to 29.

SECTION IV - DISCUSSION OF RESULTS

1. ACCURACY OF RESULTS: The percentage of error between the caliper and E.G.L. method was found by dividing the difference between the percent elongation of the two methods by the true elongation of the caliper method. This error was less than 10%, amounting to an error of 3/64 inches in a caliper reading. This is good accuracy considering that the reading is taken in motion just at the rupture point of the line.

2. PERMANENT SET MEASUREMENTS: The permanent set could not be measured 30 ± 5 seconds after the elongation test as this did not allow enough time to return the tensile tester to no load, remove and measure the cord. Instead, the cord was measured 5 minutes ± 30 seconds after the tests. The recovery was rapid during the first hour and slow thereafter. The purpose of this measurement was to determine if a parachute that was used two or more times within an hour would still retain sufficient elongation in the lines to reduce shock loads. Actually, the lines recover much faster after drop tests because the loads are not as high and last only a few seconds as compared to 90% of rated strength loading on the machine and lasting 30 seconds or more.

LINE ELONGATION TESTS

Specimen Group I - Fortisan Nominal T.S. 420 Spec. Similar to 16142-A

CALIPER METHOD

Break Strength Tests in Lbs.

Sample #1 450

#2 477

3 465

464 lbs. @ Aver. Br. Str.

418 lbs. @ 90% of Aver. Br. Str.

True Elongation @ 100% Br. Str.

#1 5.50 -5 in.= .50 in.

#2 5.44 -5 in.= .44 in.

#3 5.50 -5 in.= .50 in.

Aver. True Elong. @ 100% Br. Str.= .48 in.

$\frac{.48}{5} \times 100 = 9.6\%$ True Elongation

EFFECTIVE GAGE LENGTH METHOD

@ 90% of Break Strength

Test No.	L + ΔL	ΔL	ΔSc
1	5.44	.44	2.50
2	5.38	.38	2.60
3	5.38	.38	2.50
4	5.38	.38	2.50
5	5.38	.38	2.80
Average		.39	2.58

True Elong. $\frac{\Delta L}{L} = \frac{.39}{5} \times 100 = 7.8$ % @ 90% of Br. Str.

*E.G.L. $\frac{L \cdot \Delta Sc}{\Delta L} = \frac{5 \times 2.58}{.39} = 33.1$

Elong. by E.G.L. Method $= \frac{\Delta Sc}{E.G.L.} = \frac{2.58}{33.1} \times 100 = 7.8\%$

Elong. @ 100% by E.G.L.= $\frac{7.8}{.9} = 8.7\%$

Sample No.	ΔSc	50% Elong.	ΔSc	70% Elong.	ΔSc	90% Elong.	Permanent Set After 5 min.	1 hr.	24 hrs.
1	2.00	6.0	2.30	6.9	2.50	7.6	5.25	5.25	5.25
2	2.05	6.2	2.35	7.1	2.60	7.9	5.25	5.19	5.19
3	1.95	5.9	2.25	6.8	2.50	7.6	5.25	5.25	5.19
4	2.00	6.0	2.30	6.9	2.50	7.6	5.25	5.19	5.19
5	2.30	6.9	2.60	7.9	2.80	8.5	5.25	5.25	5.19
Aver.	2.06	6.2	2.36	7.1	2.58	7.8	5.25	5.23	5.20

* Effective Gage Length

Date: October 9, 1950 BY L.D.

LINE ELONGATION TESTS

Specimen Group II Woven Tubular Nominal T.S. 450 Spec. Similar to AN-W-10b Webb.

CALIPER METHOD

Break Strength Tests in Lbs.

Sample #1 515

#2 515

3 520

517 lbs. @ Aver. Br. Str.

465 lbs. @ 90% of Aver. Br. Str.

True Elongation @ 100% Br. Str.

#1 6.19 -5 in.= 1.19 in.

#2 6.31 -5 in.= 1.31 in.

#3 6.31 -5 in.= 1.31 in.

Aver. True Elong. @ 100% Br. Str.= 1.27 in.

$\frac{1.27}{5} \times 100 = 25.4\%$ True Elongation

EFFECTIVE GAGE LENGTH METHOD

@ 90% of Break Strength

Test No.	L + ΔL	ΔL	ΔSc
1	6.06	1.06	5.75
2	6.00	1.00	5.75
3	6.06	1.06	5.75
4	6.06	1.06	6.30
5	6.00	1.00	5.75
Average		1.04	5.86

True Elong. $\frac{\Delta L}{L} = \frac{1.04}{5} \times 100 = 20.8\%$ @ 90% of Br. Str.

*E.G.L. $\frac{L \cdot \Delta Sc}{\Delta L} = \frac{5 \times 5.86}{1.04} = 28.17$

Elong. by E.G.L. Method $= \frac{\Delta Sc}{E.G.L.} = \frac{5.86}{28.17} \times 100 = 20.8\%$

Elong. @ 100% by E.G.L.= $\frac{20.8}{.9} = 23.1\%$

Sample No.	ΔSc	50% Elong.	ΔSc	70% Elong.	ΔSc	90% Elong.	Permanent Set After 5 min.	1 hr.	24 hrs.
1	4.45	15.8	5.10	18.1	5.75	20.4	5.31	5.25	5.25
2	4.45	15.8	5.10	18.1	5.75	20.4	5.31	5.25	5.25
3	4.50	16.0	5.15	18.3	5.75	20.4	5.31	5.25	5.19
4	4.85	17.2	5.55	19.7	6.30	22.4	5.38	5.25	5.19
5	4.40	15.6	5.10	18.1	5.75	20.4	5.38	5.25	5.25
Aver.	4.53	16.1	5.20	18.5	5.86	20.8	5.34	5.25	5.23

* Effective Gage Length

Date: October 9, 1950 L.D.

LINE ELONGATION TESTS

Specimen Group III Nylon Line Nominal T.S. 550 Spec. AN-C-63 Type III

CALIPER METHOD

Break Strength Tests in Lbs.

Sample #1 590

#2 565

3 604

586 lbs. @ Aver. Br. Str.

527 lbs. @ 90% of Aver. Br. Str.

True Elongation @ 100% Br. Str.

#1 7.13 -5 in.= 2.13 in.

#2 7.00 -5 in.= 2.00 in.

#3 7.31 -5 in.= 2.31 in.

Aver. True Elong. @ 100% Br. Str.= 2.15 in.

$\frac{2.15}{5} \times 100 = 43.\%$ True Elongation

EFFECTIVE GAGE LENGTH METHOD

@ 90% of Break Strength

Test No.	L+ΔL	ΔL	ΔSc
1	6.75	1.75	9.55
2	6.75	1.75	9.60
3	6.81	1.81	9.70
4	6.81	1.81	9.80
5	6.75	1.75	9.55
Average		1.77	9.64

True Elong. $\frac{\Delta L}{L} = \frac{1.77}{5} \times 100 = 35.4$ % @ 90% of Br. Str.

*E.G.L. $\frac{L \cdot \Delta Sc}{\Delta L} = \frac{5 \times 9.64}{1.77} = 27.23$

Elong. by E.G.L. Method $= \frac{\Delta Sc}{E.G.L.} = \frac{9.64}{27.23} \times 100 = 35.4\%$

Elong. @ 100% by E.G.L.= $\frac{35.4}{.9} = 39.3\%$

Sample No.	ΔSc	50% Elong.	ΔSc	70% Elong.	ΔSc	90% Elong.	Permanent Set After 5 min.	1 hr.	24 hrs.
1	7.05	25.9	8.35	30.7	9.55	35.1	5.75	5.50	5.50
2	7.20	26.4	8.50	31.2	9.60	35.3	5.75	5.56	5.50
3	7.20	26.4	8.50	31.2	9.70	35.6	5.75	5.63	5.56
4	7.35	27.0	8.65	31.8	9.80	36.0	5.75	5.56	5.50
5	7.10	26.1	8.45	31.0	9.55	35.1	5.81	5.56	5.56
Aver.	7.18	26.4	8.49	31.2	9.64	35.4	5.76	5.56	5.52

* Effective Gage Length

Date: October 9, 1950 BY L. D.

LINE ELONGATION TESTS

Specimen Group IV Nylon Line Nominal T.S. 320 Spec. Similar to material furnished Wright Field on P.O. 33-096-49-821E

CALIPER METHOD

Break Strength Tests in Lbs.

Sample #1 338

#2 330

3 340

336 lbs. @ Aver. Br. Str.

302 lbs. @ 90% of Aver. Br. Str.

True Elongation @ 100% Br. Str.

#1 7.32 -5 in.= 2.32 in.

#2 7.13 -5 in.= 2.13 in.

#3 7.25 -5 in.= 2.25 in.

Aver. True Elong. @ 100% Br. Str.= 2.23 in.

$\frac{2.23}{5} \times 100 = 44.6\%$ True Elongation

EFFECTIVE GAGE LENGTH METHOD

@ 90% of Break Strength

Test No.	L+ΔL	ΔL	ΔSc
1	6.88	1.88	9.90
2	6.88	1.88	8.90
3	6.88	1.88	9.00
4	6.88	1.88	8.95
5	6.88	1.88	9.20
Average		1.88	9.19

True Elong. $\frac{\Delta L}{L} = \frac{1.88}{5} \times 100 = 37.6\%$ @ 90% of Br. Str.

*E.G.L. $\frac{L \cdot \Delta Sc}{\Delta L} = \frac{5 \times 9.19}{1.88} = 24.44$

Elong. by E.G.L. Method $= \frac{\Delta Sc}{E.G.L.} = \frac{9.19}{24.44} \times 100 = 37.6\%$

Elong. @ 100% by E.G.L.= $\frac{37.6}{.9} = 41.8\%$

Sample No.	ΔSc	50% Elong.	ΔSc	70% Elong.	ΔSc	90% Elong.	Permanent Set After 5 min.	1 hr.	24 hrs.
1	7.50	30.7	8.70	35.6	9.90	40.5	5.88	5.69	5.56
2	6.60	27.0	7.80	31.9	8.90	36.4	5.88	5.69	5.56
3	6.70	27.4	7.80	31.9	9.00	36.8	5.88	5.69	5.50
4	6.70	27.4	7.80	31.9	8.95	36.6	5.88	5.75	5.56
5	6.90	28.2	8.05	32.9	9.20	37.6	5.88	5.75	5.56
Aver.	6.88	28.1	8.03	32.8	9.19	37.6	5.88	5.71	5.55

PROD
SCHED
SALES
INSP.
ENG

* Effective Gage Length

Date: October 9, 1950 L.D.

LINE ELONGATION TESTS

Specimen Group V, Nylon Line Formic Acid Treated Nominal T.S. 550 Spec. Similar to MIL-C-5040 Type III

CALIPER METHOD

Break Strength Tests in Lbs.

Sample #1 575

#2 585

3 580

580 lbs. @ Aver. Br. Str.

522 lbs. @ 90% of Aver. Br. Str.

True Elongation @ 100% Br. Str.

#1 7.69 -5 in.= 2.69 in.

#2 7.69 -5 in.= 2.69 in.

#3 7.75 -5 in.= 2.75 in.

Aver. True Elong. @ 100% Br. Str.= 2.71 in.

$\frac{2.71}{5} \times 100 = 54.2\%$ True Elongation

EFFECTIVE GAGE LENGTH METHOD

@ 90% of Break Strength

Test No.	L+ΔL	ΔL	ΔSc
1	7.44	2.44	12.30
2	7.19	2.19	12.00
3	7.44	2.44	12.80
4	7.38	2.38	12.10
5	7.44	2.44	12.40
Average		2.38	12.32

True Elong. $\frac{\Delta L}{L} = \frac{2.38}{5} \times 100 = 47.6\%$ @ 90% of Br. Str.

*E.G.L. $\frac{L \cdot \Delta Sc}{\Delta L} = \frac{5 \times 12.32}{2.38} = 25.88$

Elong. by E.G.L. Method $= \frac{\Delta Sc}{E.G.L.} = \frac{12.32}{25.88} \times 100 = 47.6\%$

Elong. @ 100% by E.G.L.= $\frac{47.6}{.9} = 52.8\%$

Sample No.	ΔSc	50% Elong.	ΔSc	70% Elong.	ΔSc	90% Elong.	Permanent Set After 5 min.	1 hr.	24 hrs.
1	9.40	36.3	10.95	42.3	12.30	47.5	6.19	5.94	5.81
2	9.10	35.2	10.60	40.9	12.00	46.3	6.25	5.86	5.75
3	9.90	38.3	11.45	44.2	12.80	49.4	6.25	5.94	5.75
4	9.18	35.5	10.70	41.3	12.10	46.7	6.75	5.88	5.69
5	9.40	36.3	10.95	42.3	12.40	47.9	6.25	5.94	5.75
Aver.	9.39	36.3	10.93	42.2	12.32	47.6	6.34	5.91	5.75

* Effective Gage Length

Date: October 9, 1950 By L.D.

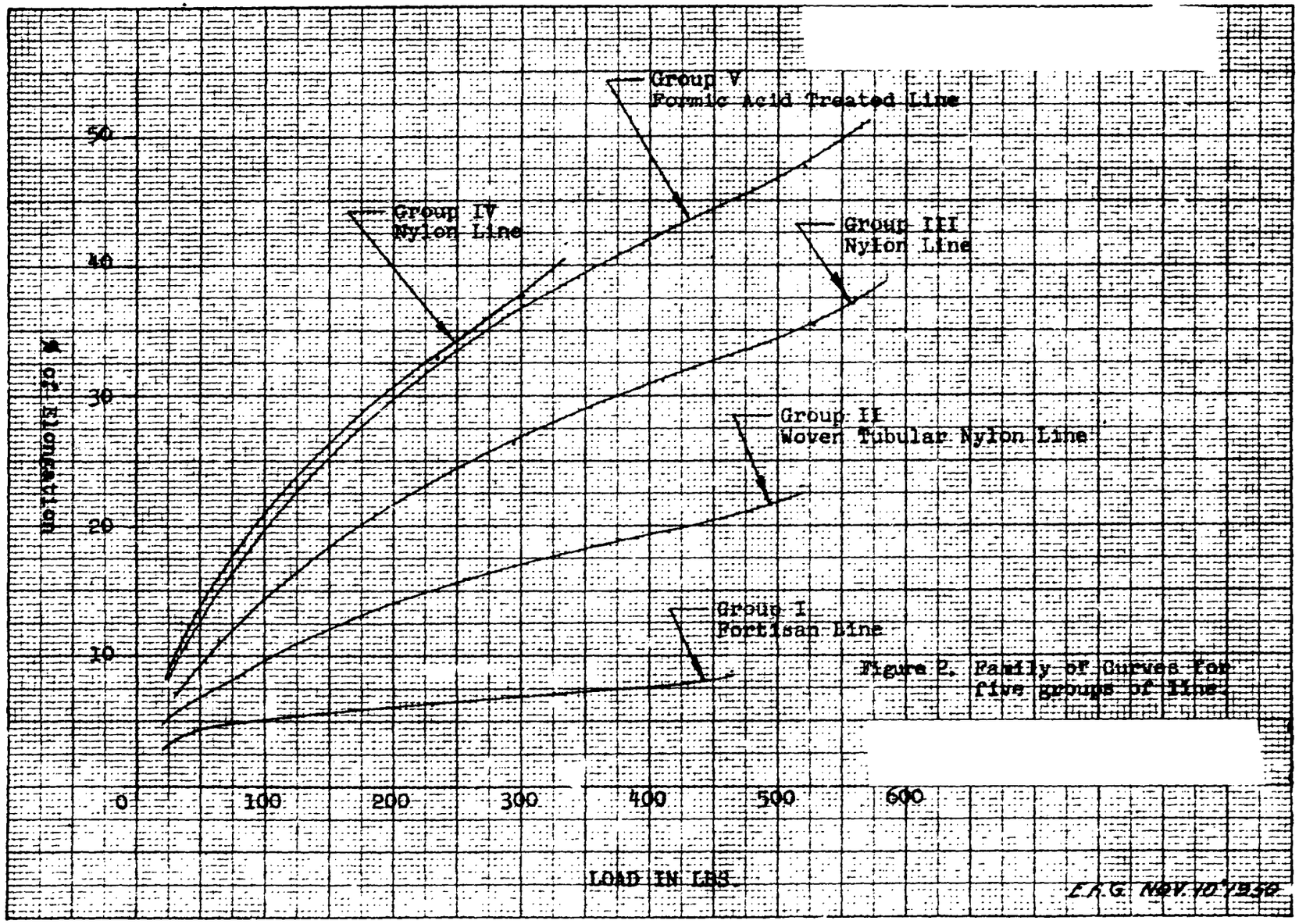
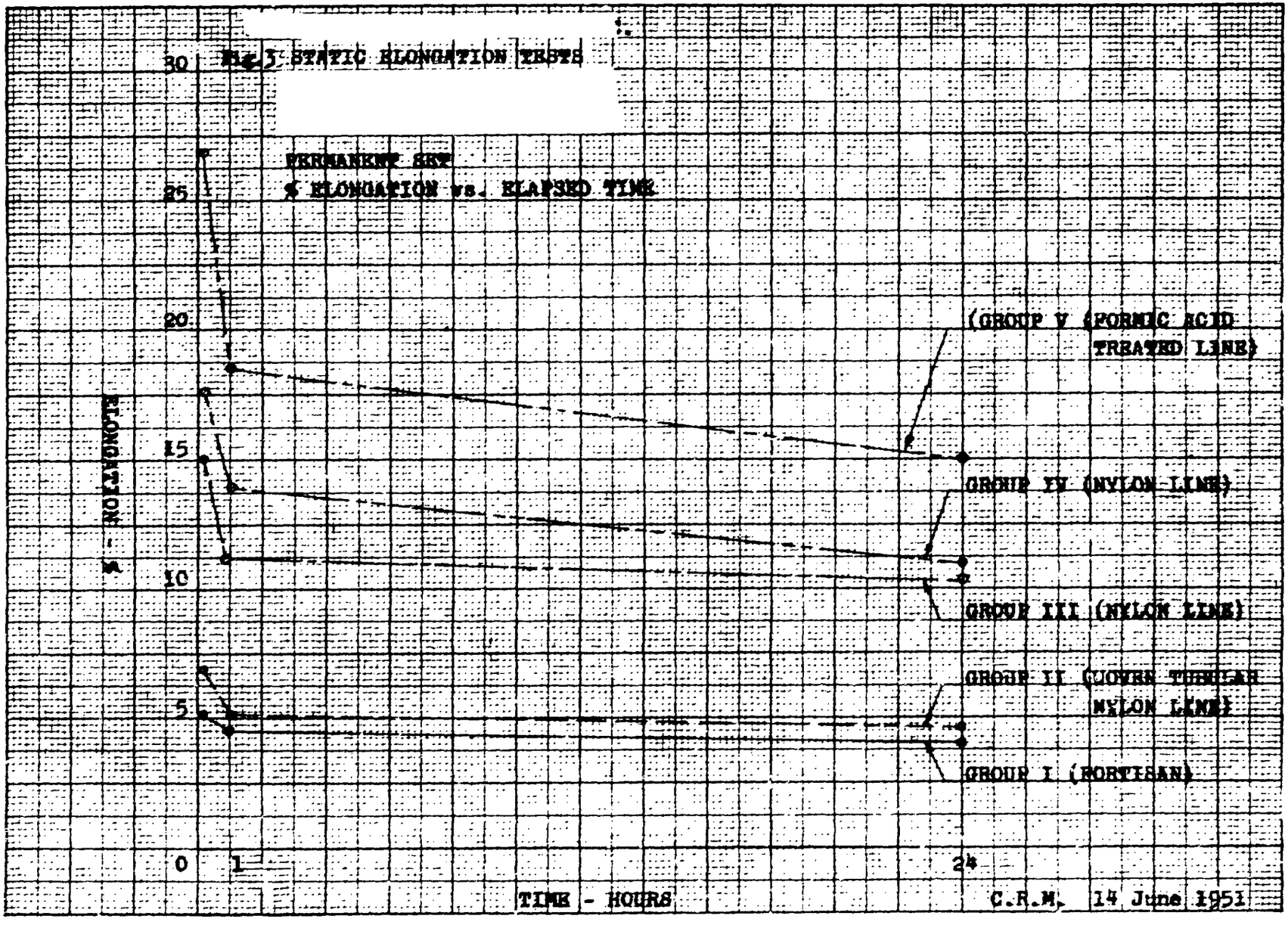


Figure 2. Family of Curves for five groups of line.


STATIC ELONGATION TESTS
PERMANENT SET
% ELONGATION vs. ELAPSED TIME
ELONGATION - %
30
25
20
15
10
5
0
1
24
TIME - HOURS
GROUP V (FORMIC ACID TREATED LINE)
GROUP IV (NYLON LINE)
GROUP III (NYLON LINE)
GROUP II (COVERN TUBULAR NYLON LINE)
GROUP I (FORTISAN)
C.R.M. 14 June 1951

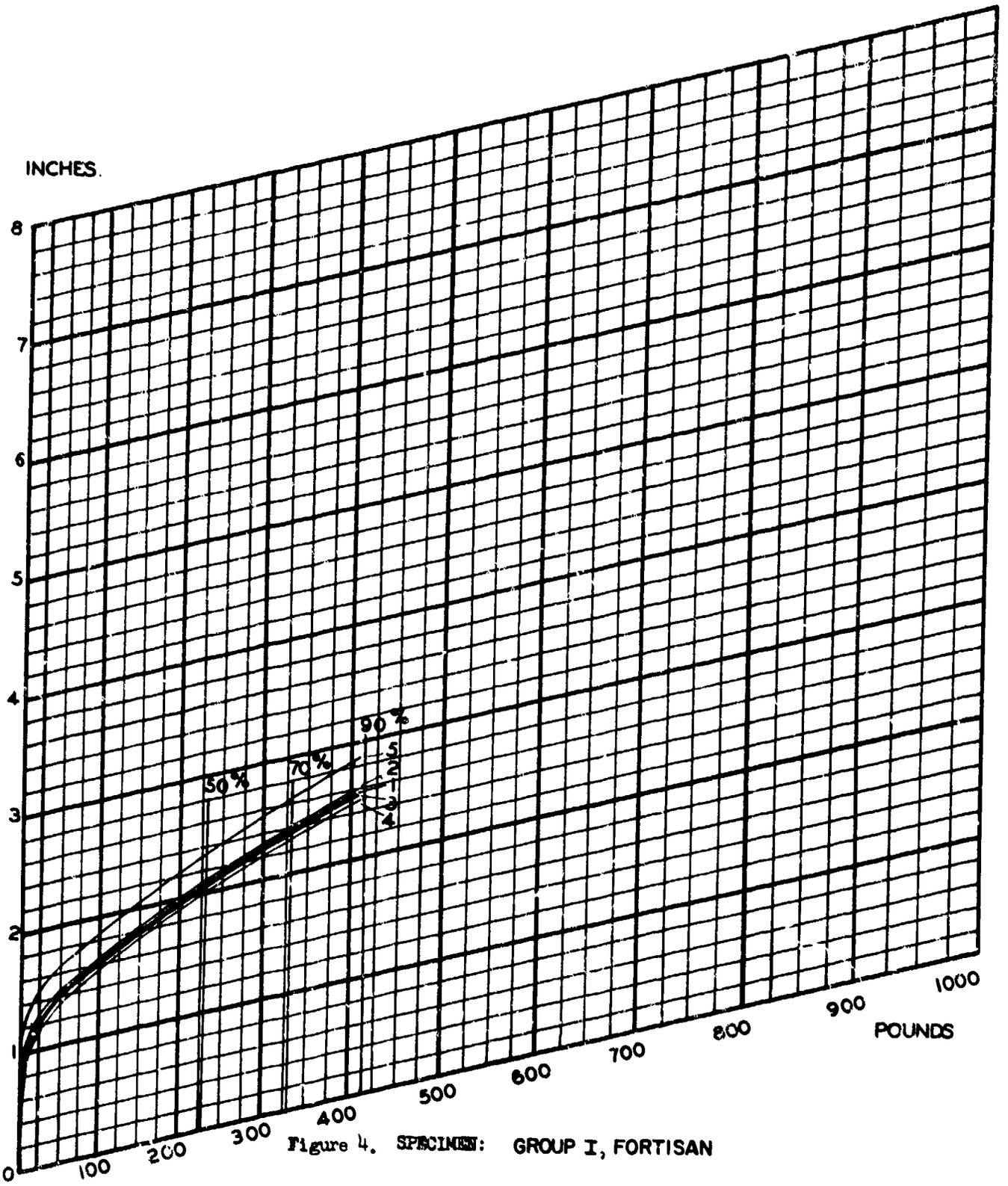


Figure 4. SPECIMEN: GROUP I, FORTISAN

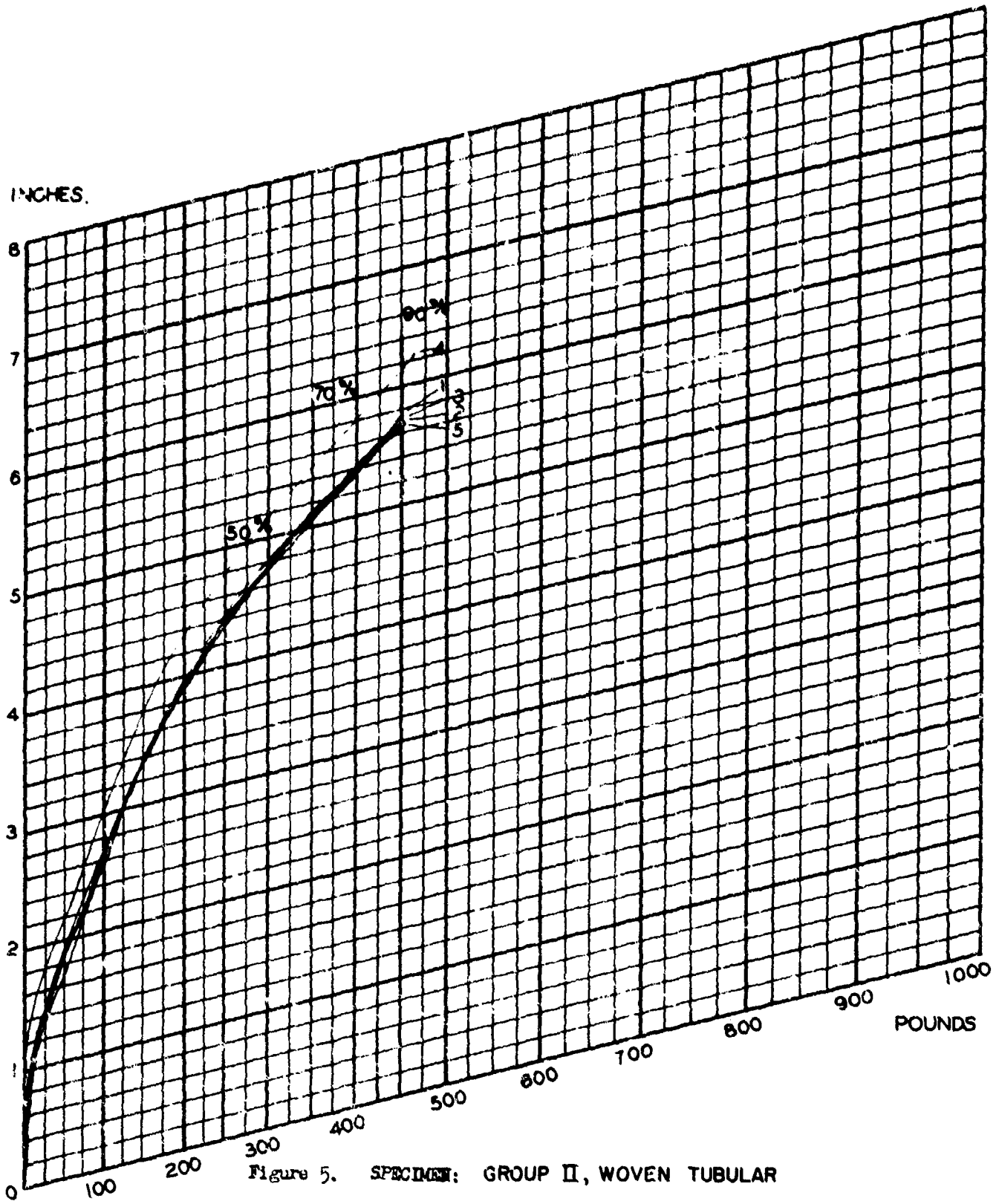


Figure 5. SPECIMEN: GROUP II, WOVEN TUBULAR

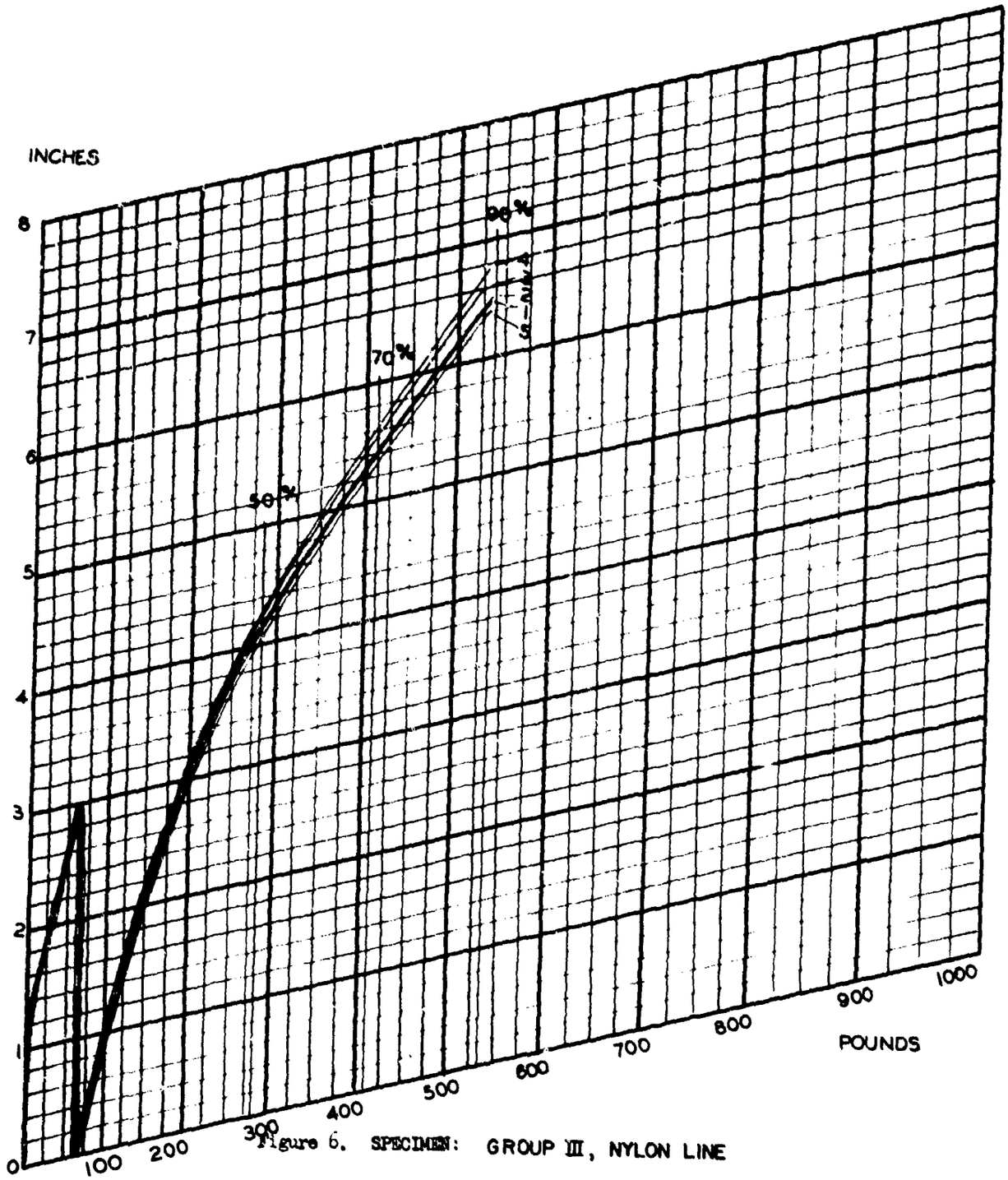


Figure 6. SPECIMEN: GROUP III, NYLON LINE

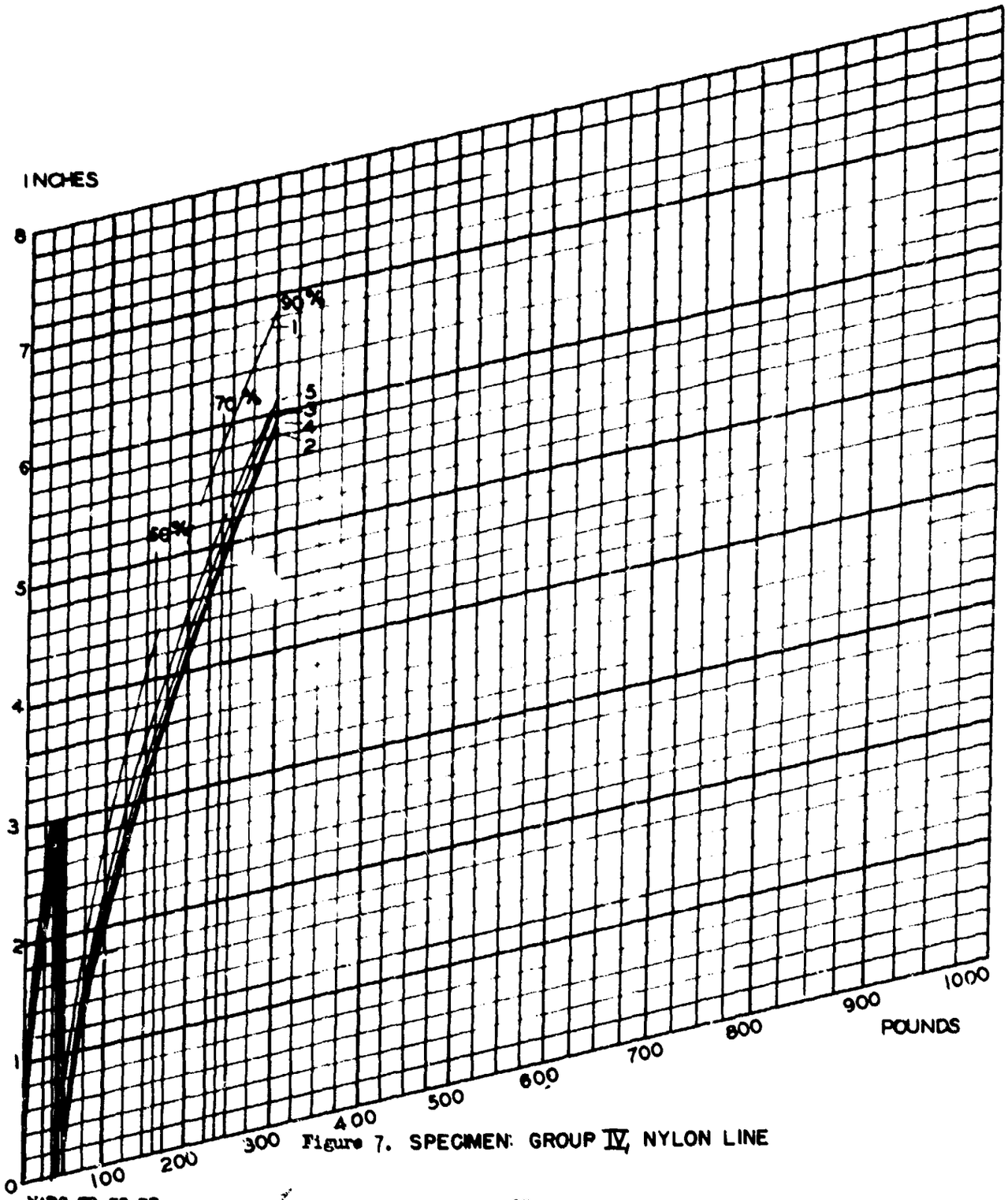


Figure 7. SPECIMEN: GROUP IV, NYLON LINE

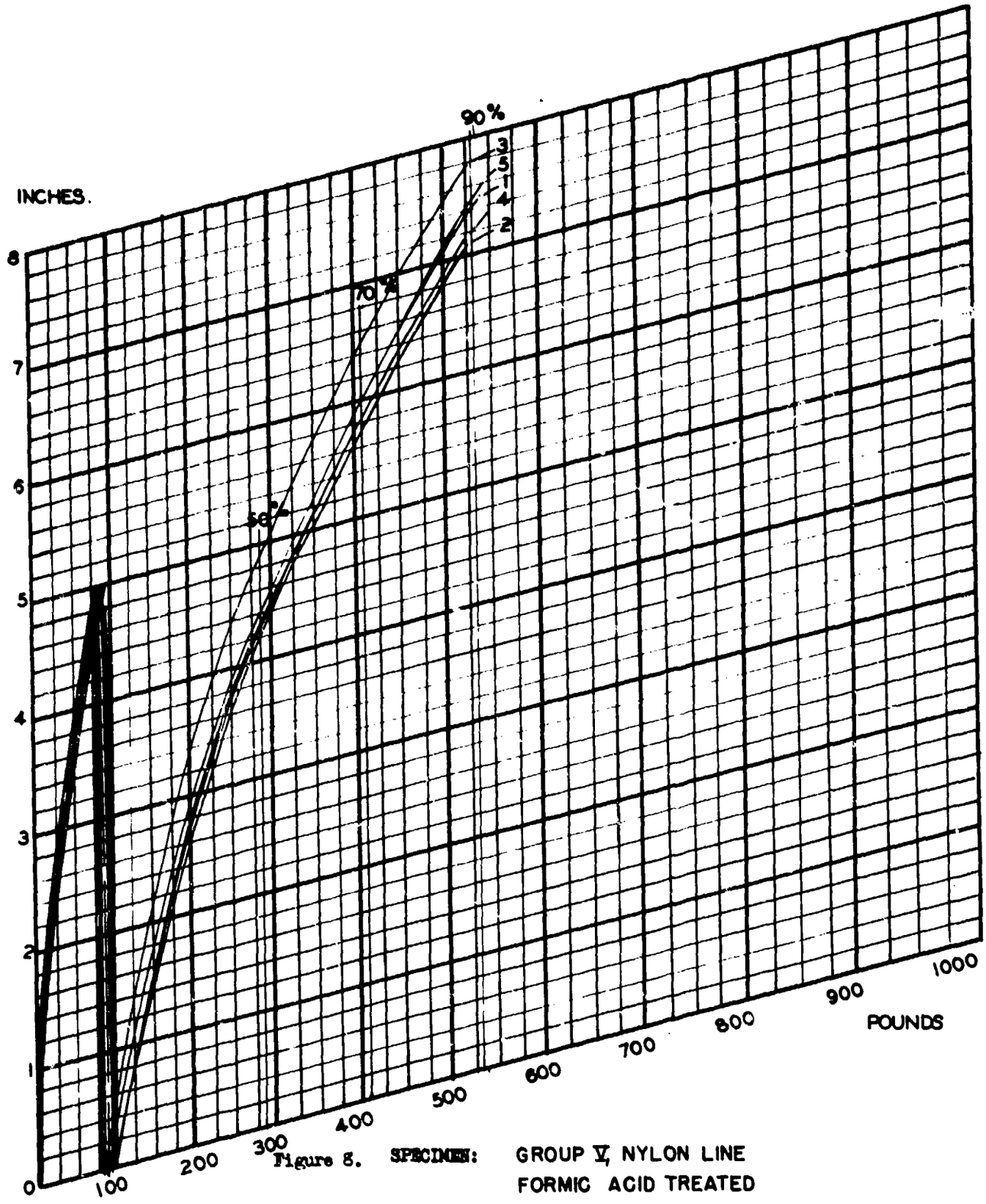


Figure 8. SPECIMEN: GROUP V, NYLON LINE FORMIC ACID TREATED

INDEX TO APPENDIX III

POROSITY

SECTION PAGE

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1. Significance of Porosity

II - POROSITY MEASUREMENTS----------31

1. Porosity Machine
2. Sequence of Measurement
3. Humidity
4. Average Porosity and Variation of Porosity
5. Effects of Porosity on Results

III - CHARTS----------33

1. Porosity Charts Before and After Tower Tests
2. Average Porosities by Line Groups

POROSITY

SECTION I - GENERAL

1. SIGNIFICANCE OF POROSITY: The permeability of the fabric has considerable effect on the opening time and opening shock forces of a parachute. Its action is two fold, a high porosity increases the opening time, thus reducing opening shock by distributing it over a longer period of time; it also reduces opening shock directly by permitting more air to escape through the fabric. In this investigation, porosity of the fabric was carefully checked to find any changes that would be of sufficient magnitude to appreciably affect canopy loads.

SECTION II - POROSITY MEASUREMENTS

1. POROSITY MACHINE: All porosity measurements were made on the Frazier Air Porosity Tester, an orifice-type flowmeter. (See Figure 3, Page 214 .) Pressure differential across the orifice is converted to porosity reading by the use of calibration charts. (See Bibliography, Page 223 , No. 2.

2. SEQUENCE OF MEASUREMENT: During the fabrication of the canopies, the material underwent sufficient manipulation to stabilize the porosity. Hence, there was little variation in porosity due to subsequent handling. After fabrication, porosity measurements were taken on all canopies. On the 24 ft. canopies, porosity measurements were taken on all panels of each gore with the exception of the top panels. The top width of the panel was too small to fit over the fabric orifice. Porosity measurements were taken on all panels of each gore of the 30 ft. canopies.

Porosity measurements were taken after each tower test of the 24 ft. and 30 ft. parachutes. After the 100 MPH test, porosity was measured on all panels of each gore of the 24 ft. canopies with the exception of the top panels. All panels of each gore on the 30 ft. canopies were measured for porosity after the 100 MPH tests. After the 150 MPH tests, random porosity measurements were taken on the 24 ft. and 30 ft. canopies. After the 200 MPH tests, all panels of each gore on the 24 ft. canopies were measured for porosity, with the exception of the top panels. Random porosity measurements were taken on the 30 ft. canopies after the 200 MPH tests. For porosity measurements at the various launching speeds, see the porosity charts, Pages 34 to 188.

SECTION II - POROSITY MEASUREMENTS (CONT'D)

3. HUMIDITY: The effects of humidity on the results of porosity measurements were considered and, wherever possible, measurements were taken at times when there was but small deviation from the ideal condition; 65% relative humidity and a temperature of 70°F being recommended as the ideal condition for the taking of porosity measurements.

4. AVERAGE POROSITY AND VARIATIONS OF POROSITY: The average porosity of the 24 ft. canopies was 98.88 (ft.^{3}/min.)/ft.^{2} for the entire range of launching speeds. The average porosity for the 30 ft. canopies was 90.46 (ft.^{3}/min.)/ft.^{2} for the entire range of launching speeds. The maximum variation of the 24 ft. canopies over the entire range of launching speeds was 15.30 (ft.^{3}/min.)/ft.^{2}, while for the 30 ft. canopies the variation was 11.13 (ft.^{3}/min.)/ft.^{2}.

5. EFFECTS OF POROSITY ON RESULTS: It was found that the variation in porosity was not of sufficient magnitude to materially affect the results of the investigation.

TABLE I

EFFECT OF POROSITY ON OPENING SHOCK*

For the porosity range, 86.0 to 110.0 (ft.^{3}/min.)/ft.^{2}, the following table gives the proportional increase in opening shock per unit decrease in porosity at the designated launching speeds.

Launching Speed MPH	Δ Opening Shock lbs.
100	3.33
150	6.66
200	11.05

*See Bibliography, Page 223 , No. 3.

SECTION II - POROSITY MEASUREMENTS (CONT'D)

Referring to Appendix "D", Page 203 , Table V , the average opening shock of Groups III and IV are equal (550 lbs.) The variation in porosity is 1.85 units. From Table I , Appendix "C", Opening Shock at 100 MPH is 3.33 lbs., hence, Group III must be decreased by the amount (1.85 x 3.33 = 6.161 lbs.). This would make the Group III opening shock equal to (550 - 6.161 = 543.839 lbs. or 544 lbs.). Group III in this case would be rated superior to Group IV in shock absorbing capacity. In all other cases, the effect of porosity on the opening shock bears out the tabulated ratings, thus, necessitating no corrections.

SECTION III - CHARTS

1. POROSITY CHARTS BEFORE AND AFTER TESTS: All porosity measurements taken are recorded on the porosity charts for the 24 ft. and 30 ft. canopies. (See Pages 34 to 188.)

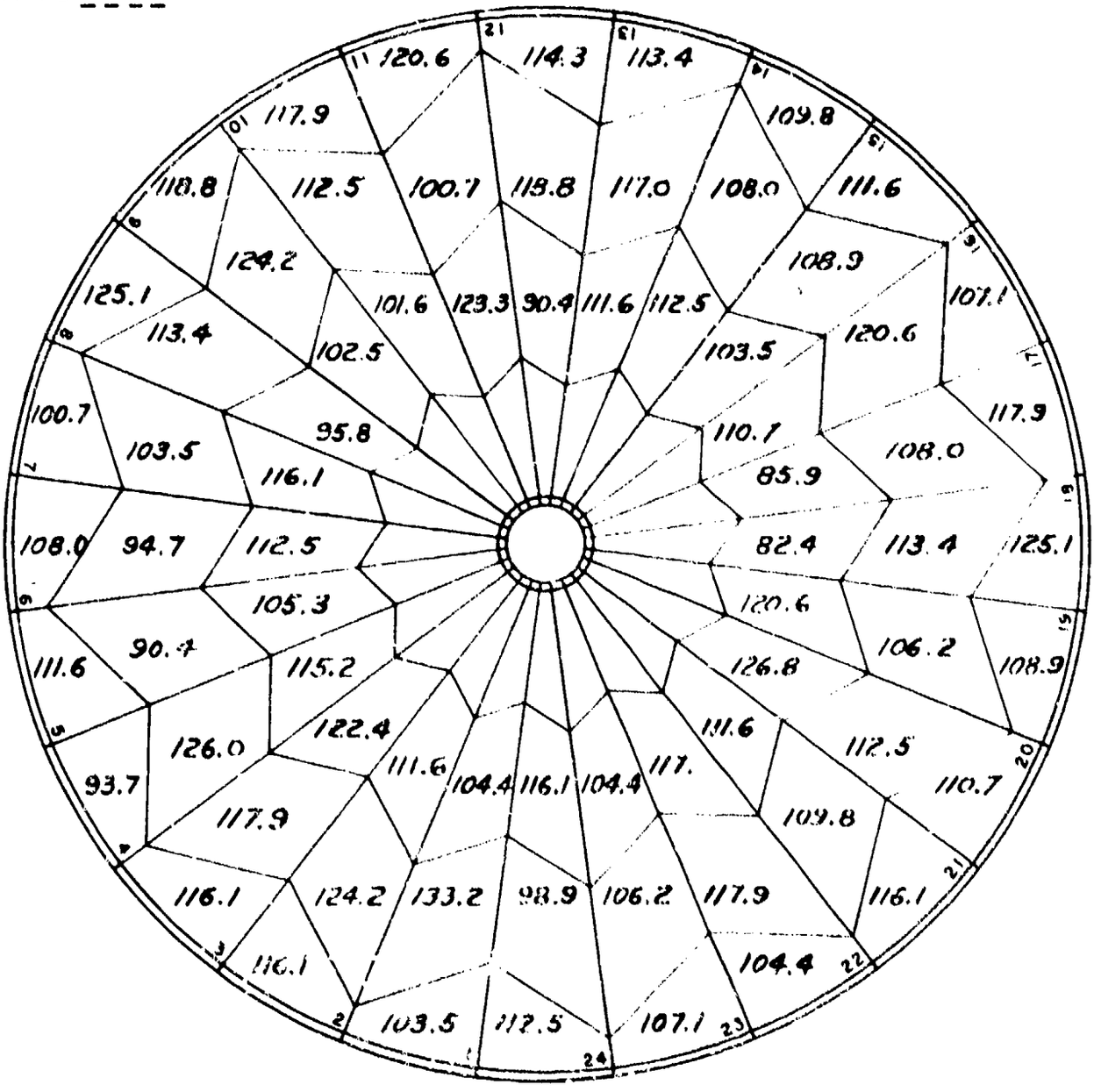
2. AVERAGE POROSITIES BY LINE GROUPS: Average porosities for each group at the various launching speeds appear on the charts in Appendix "D", Pages 194 to 203.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350201

TEMP. 75 °F

HUMID 56 %



AVERAGE POROSITY: 110.9

DATE 6/26/60

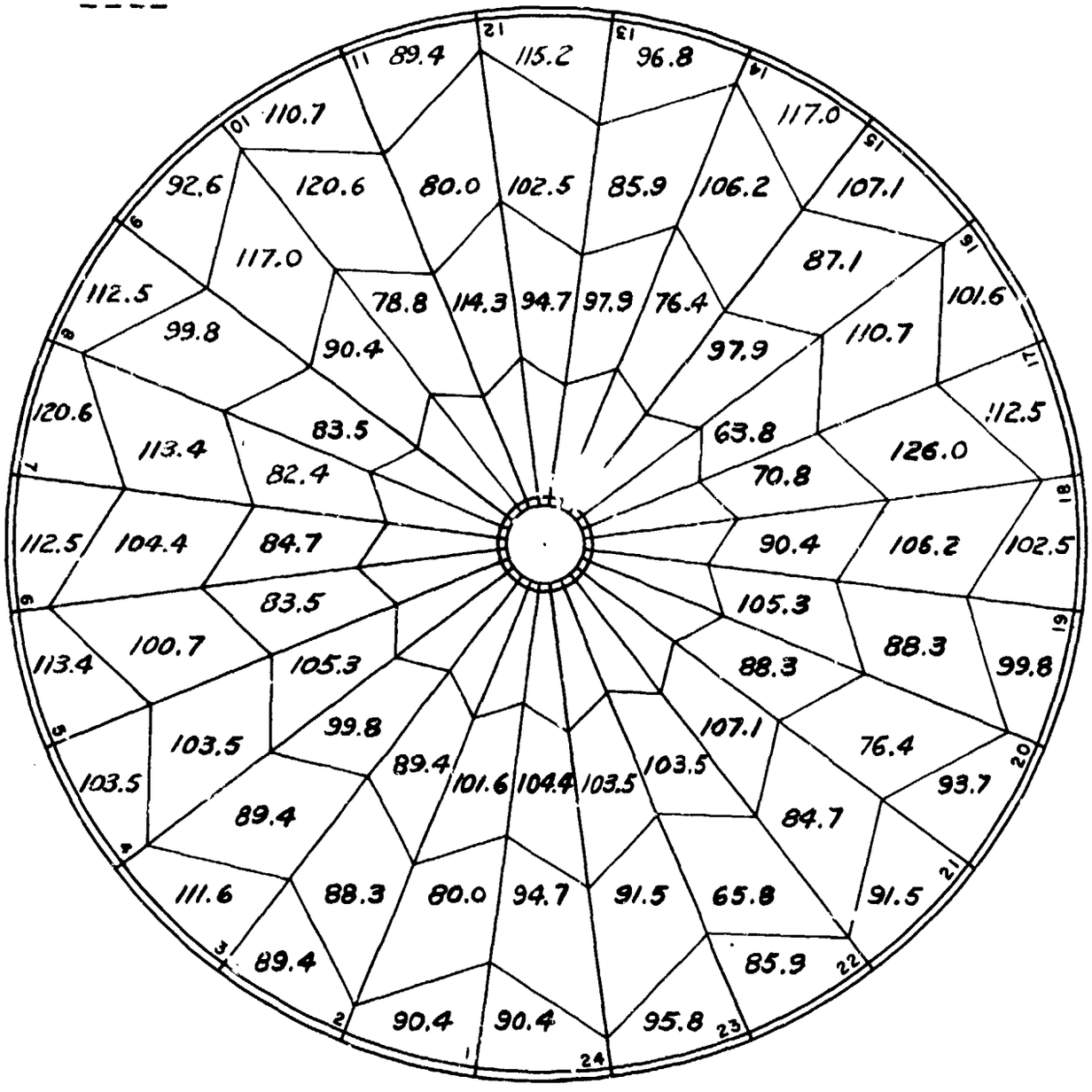
BY L.D

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350202

TEMP. 81 °F

HUMID. 56 %



AVERAGE POROSITY: 97.2

DATE 6/26/50

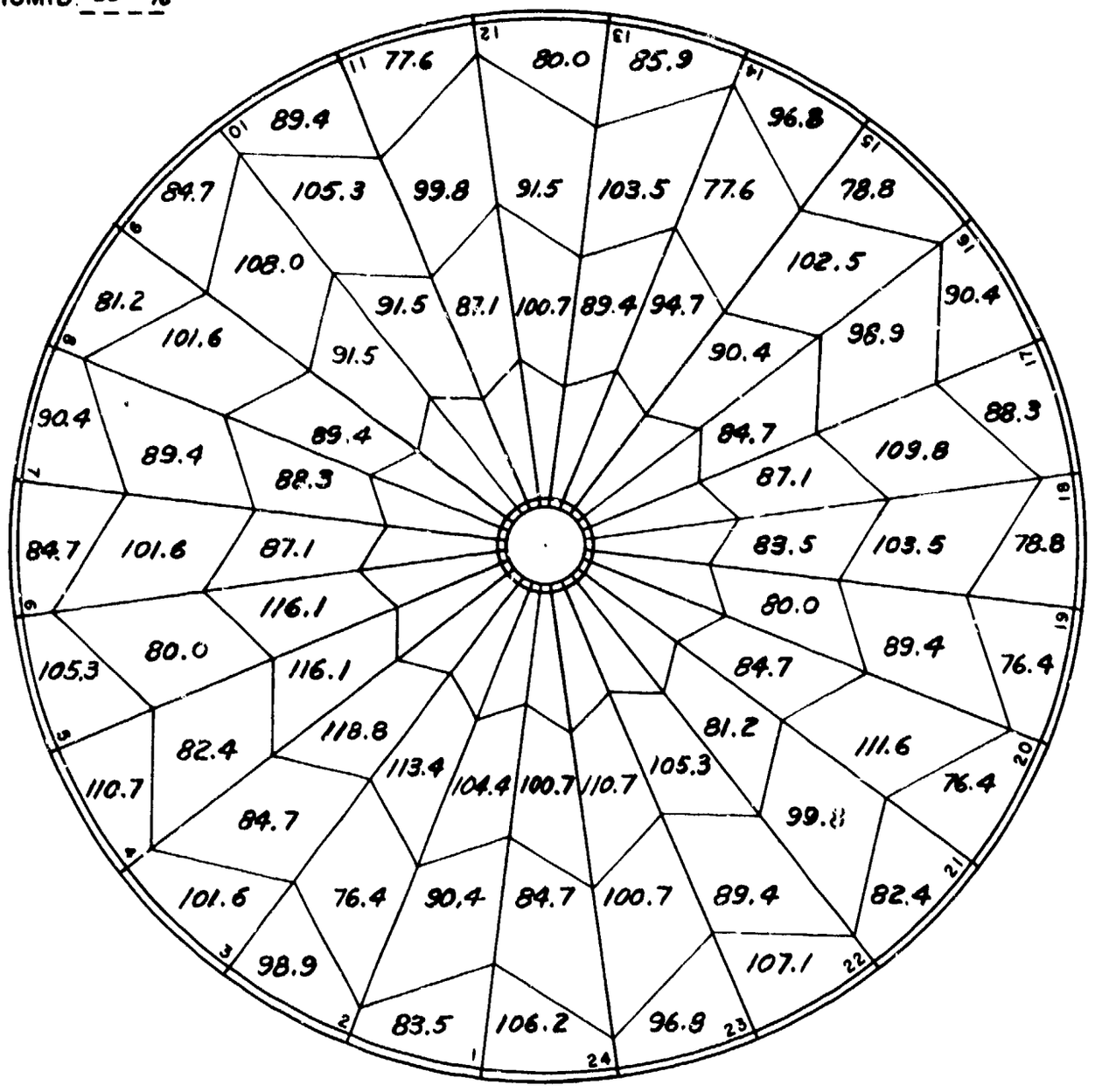
BY L.D

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350203

TEMP. 75 °F

HUMID. 65 %



AVERAGE POROSITY: 93.5

DATE 6/27/50

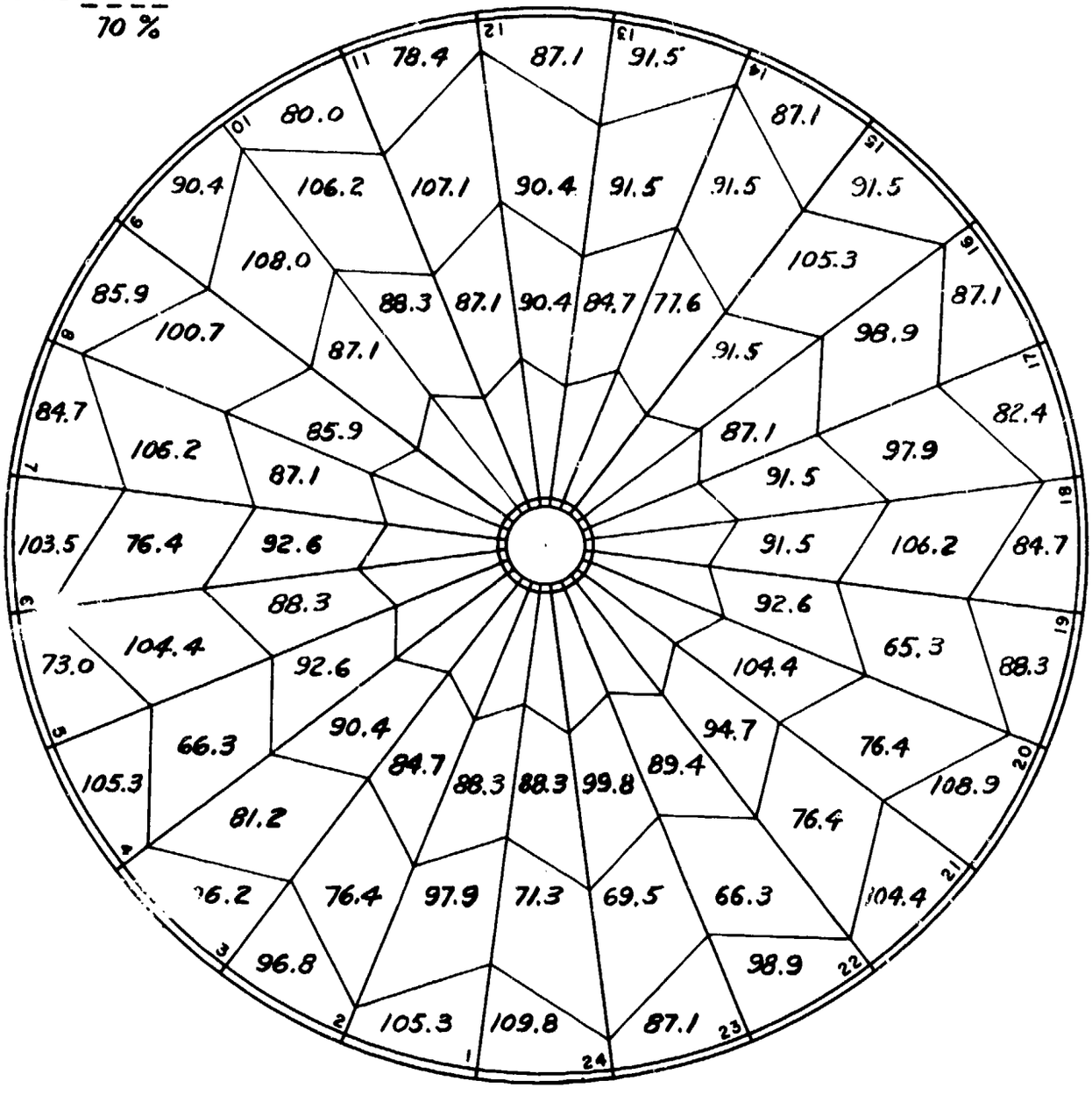
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350204

TEMP. 75 °F

HUMID. 67 %
70 %



AVERAGE POROSITY: 90.4

DATE 6/27/50

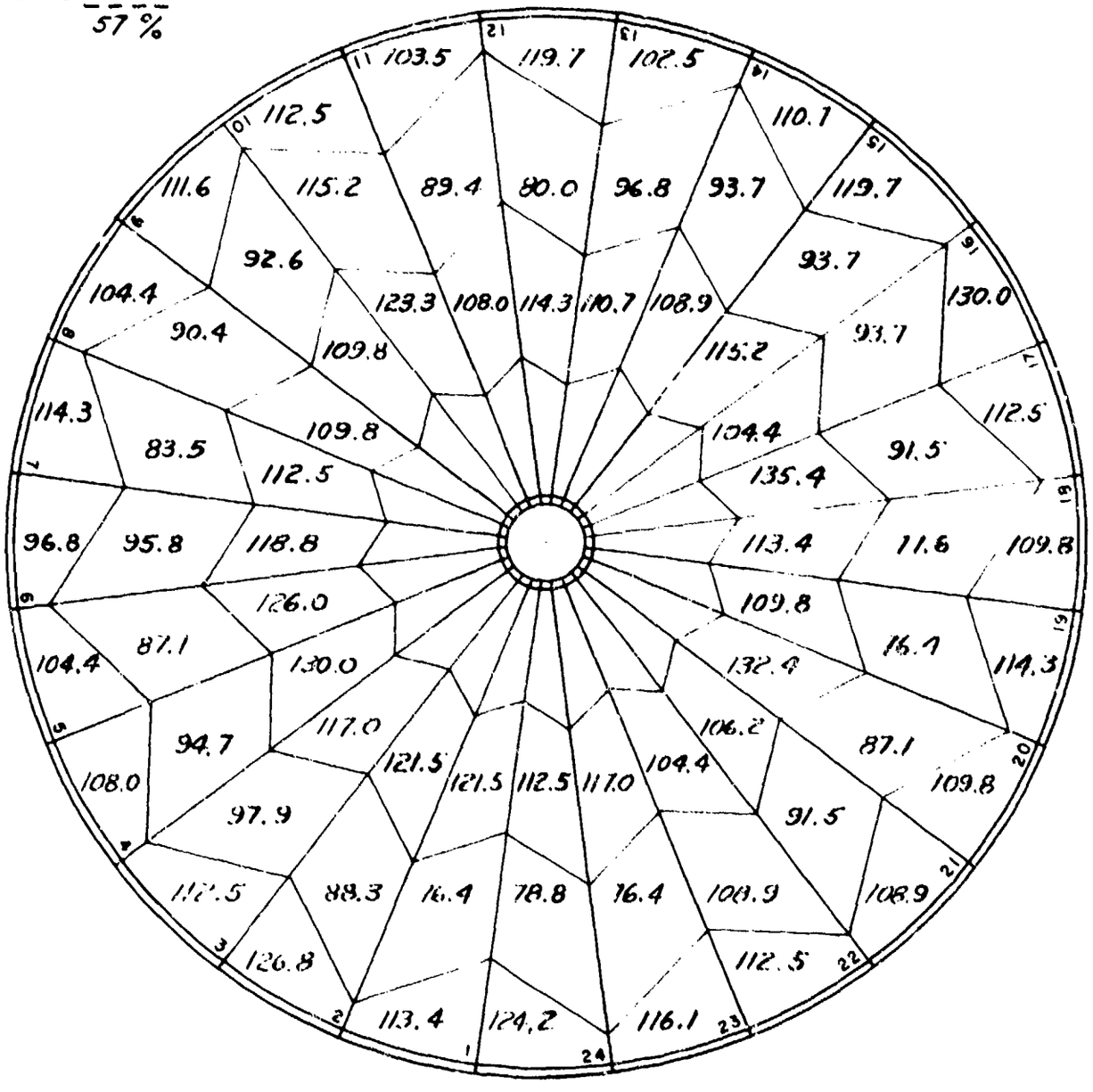
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350205

TEMP. 81 °F

HUMID 70 %
57 %



AVERAGE POROSITY: 106.1

DATE 6/2/50

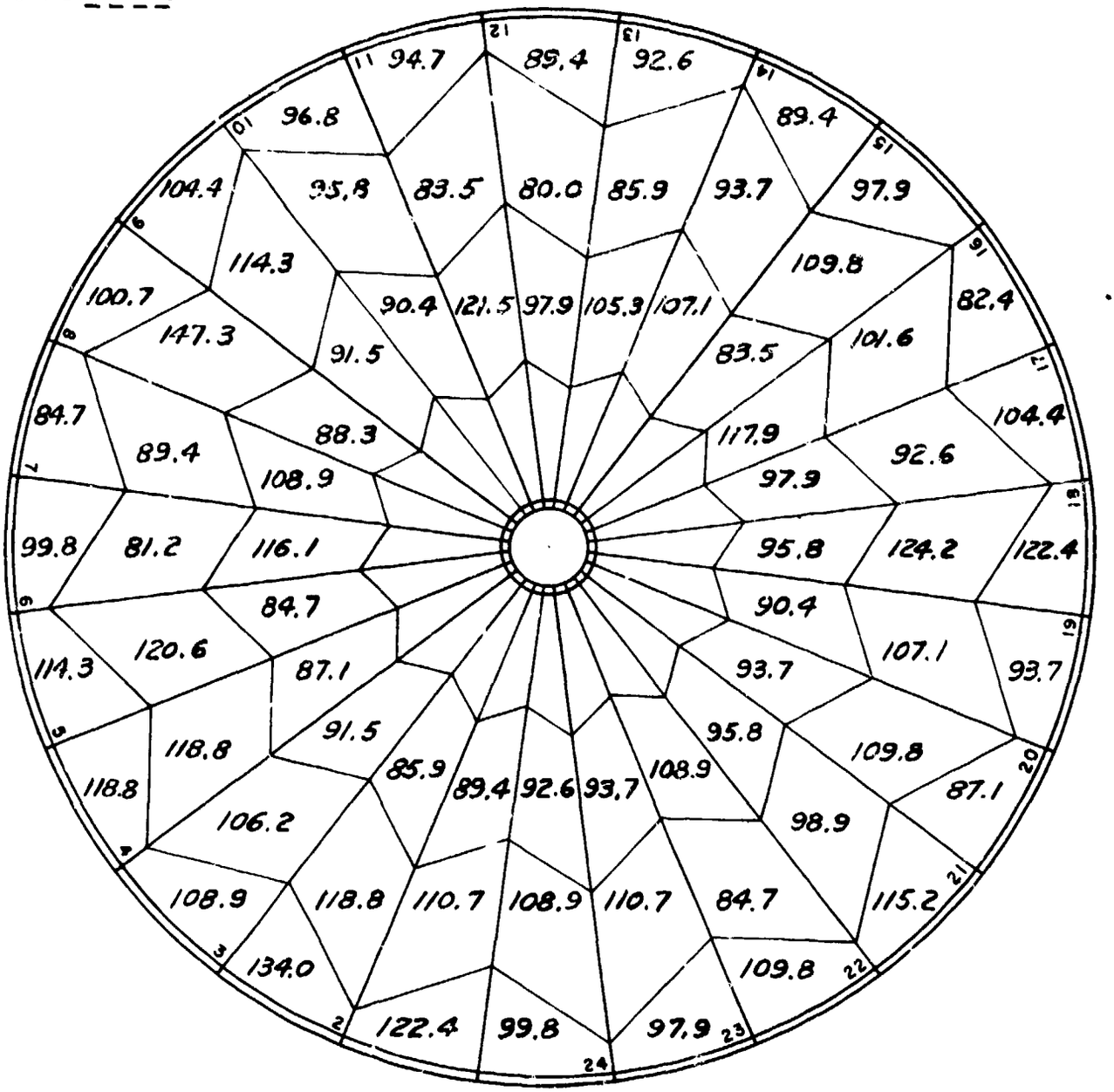
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. [illegible]

TEMP. [illegible] °F

HUMID. [illegible] %



AVERAGE POROSITY: 101.3

DATE 6/28/50

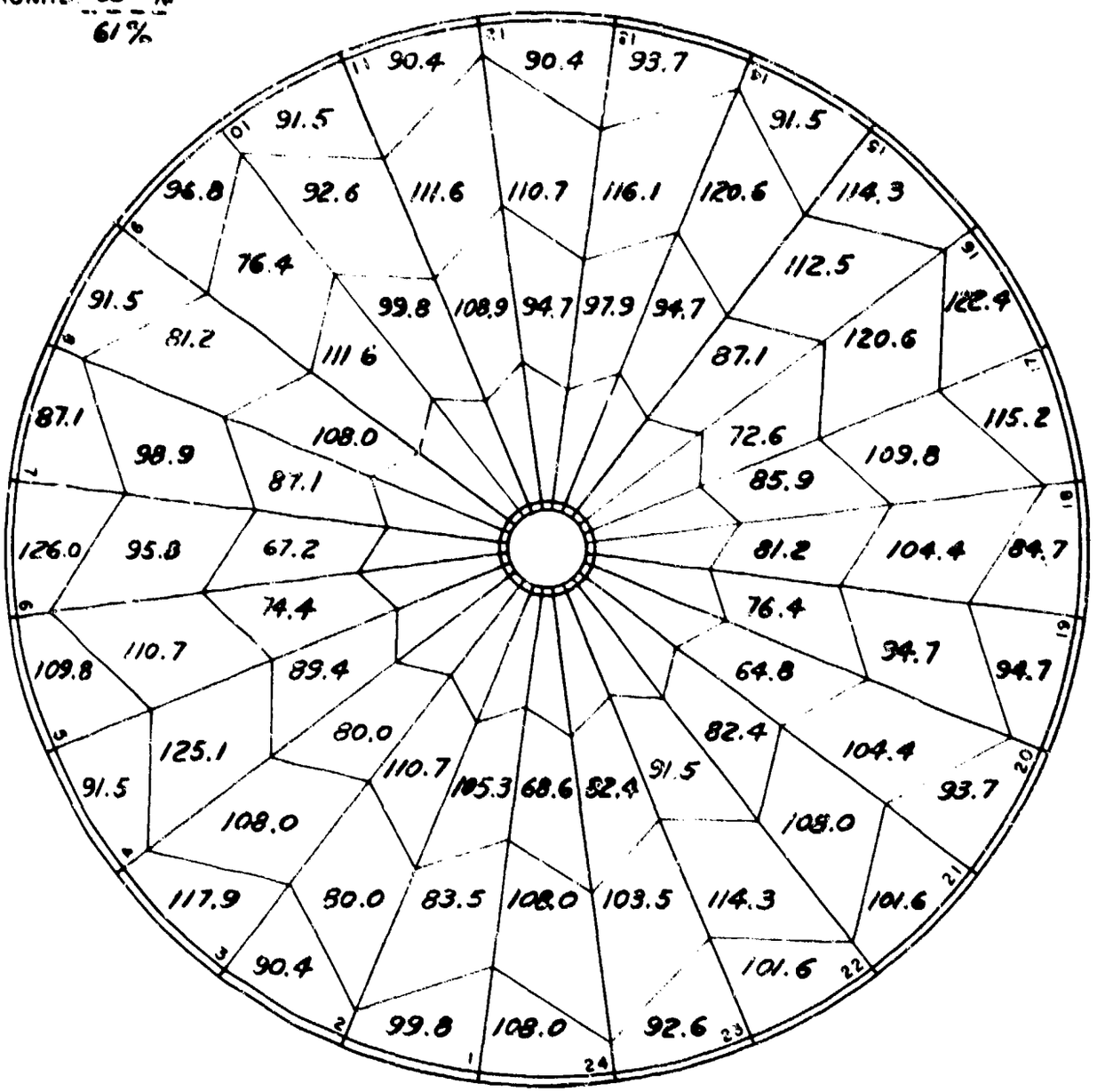
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350207

TEMP. 73 °F

HUMID. 65 %
61%



AVERAGE POROSITY: 97.4

DATE 6/29/50

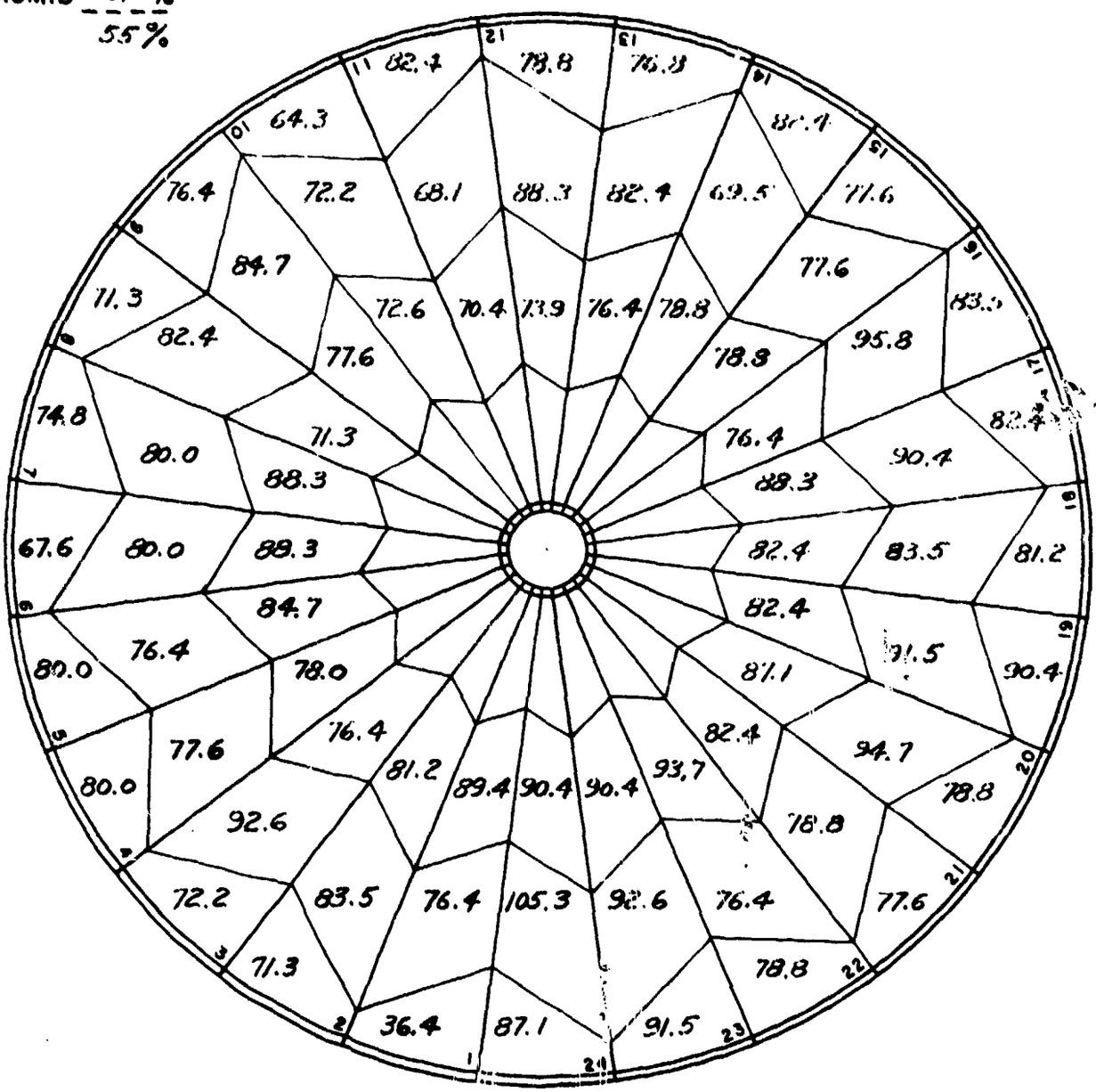
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350208

TEMP. 78 °F

HUMID 61 %
55%



AVERAGE POROSITY: 80.6

DATE 6/29/50

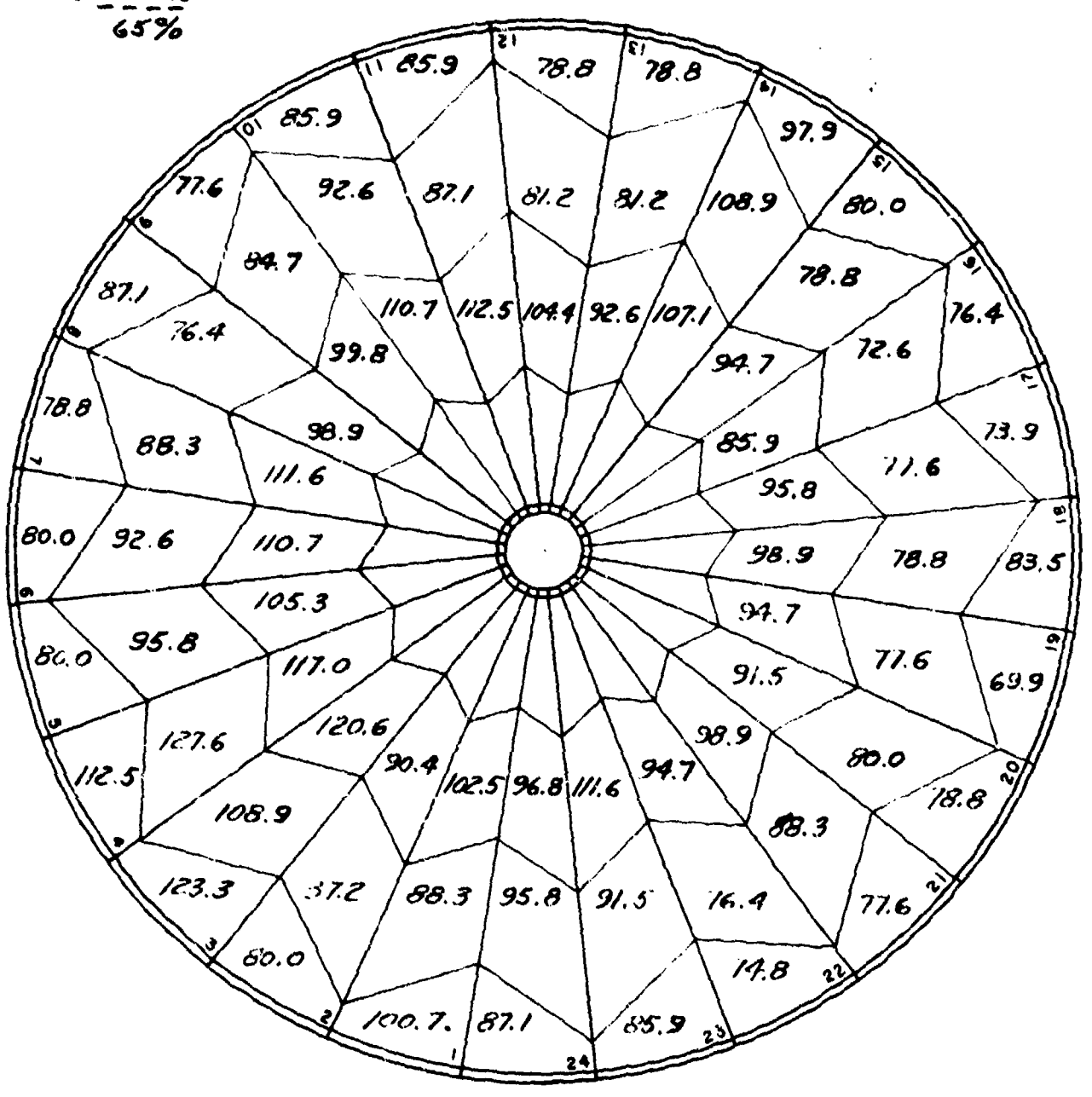
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350209

TEMP. 76 °F

HUMID 67 %
65%



AVERAGE POROSITY: 91.0

DATE 6/30/50

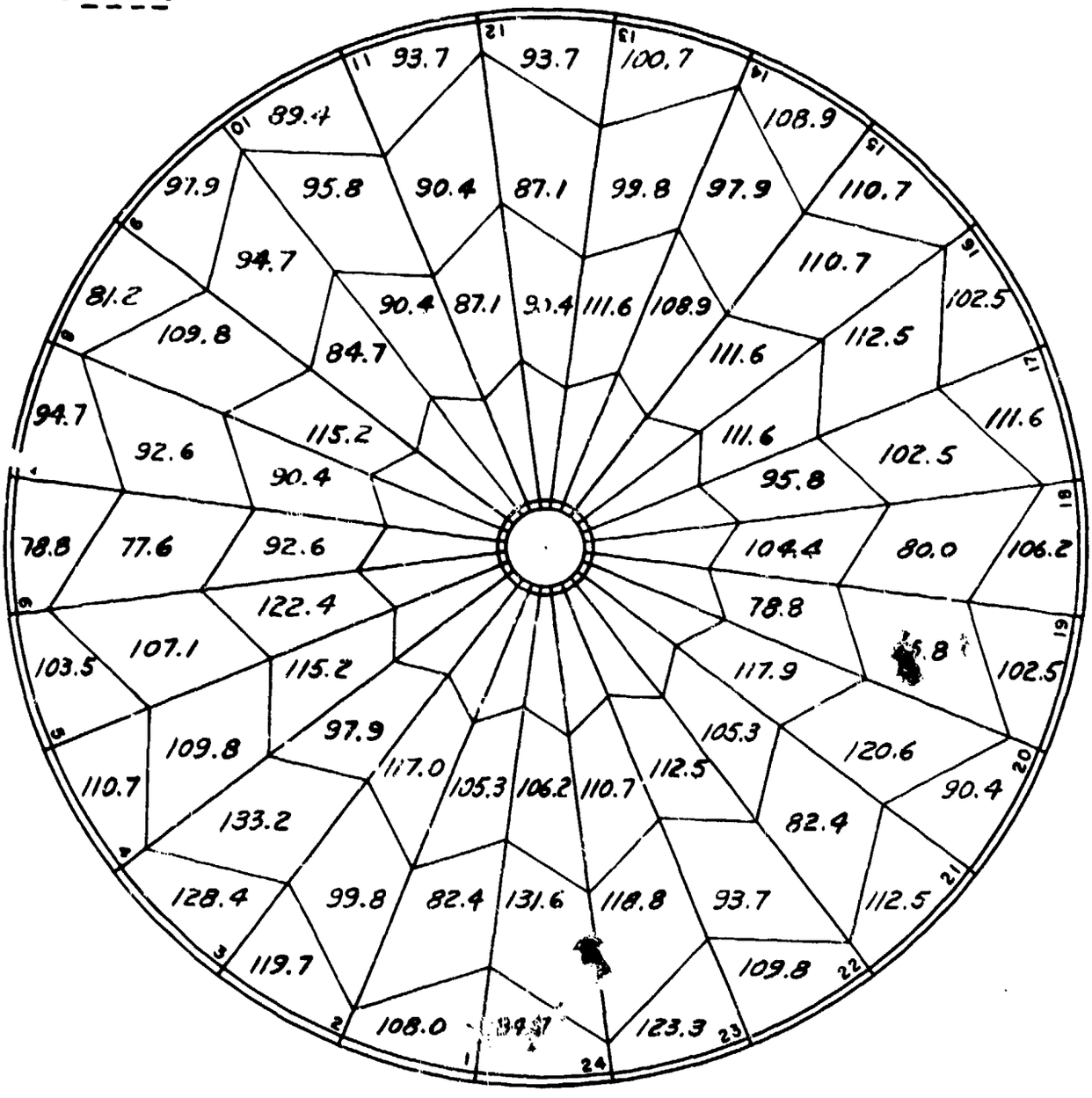
BY I. D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350210

TEMP. 78 °F

HUMID. 65 %



AVERAGE POROSITY 102.4

DATE 6/30/50

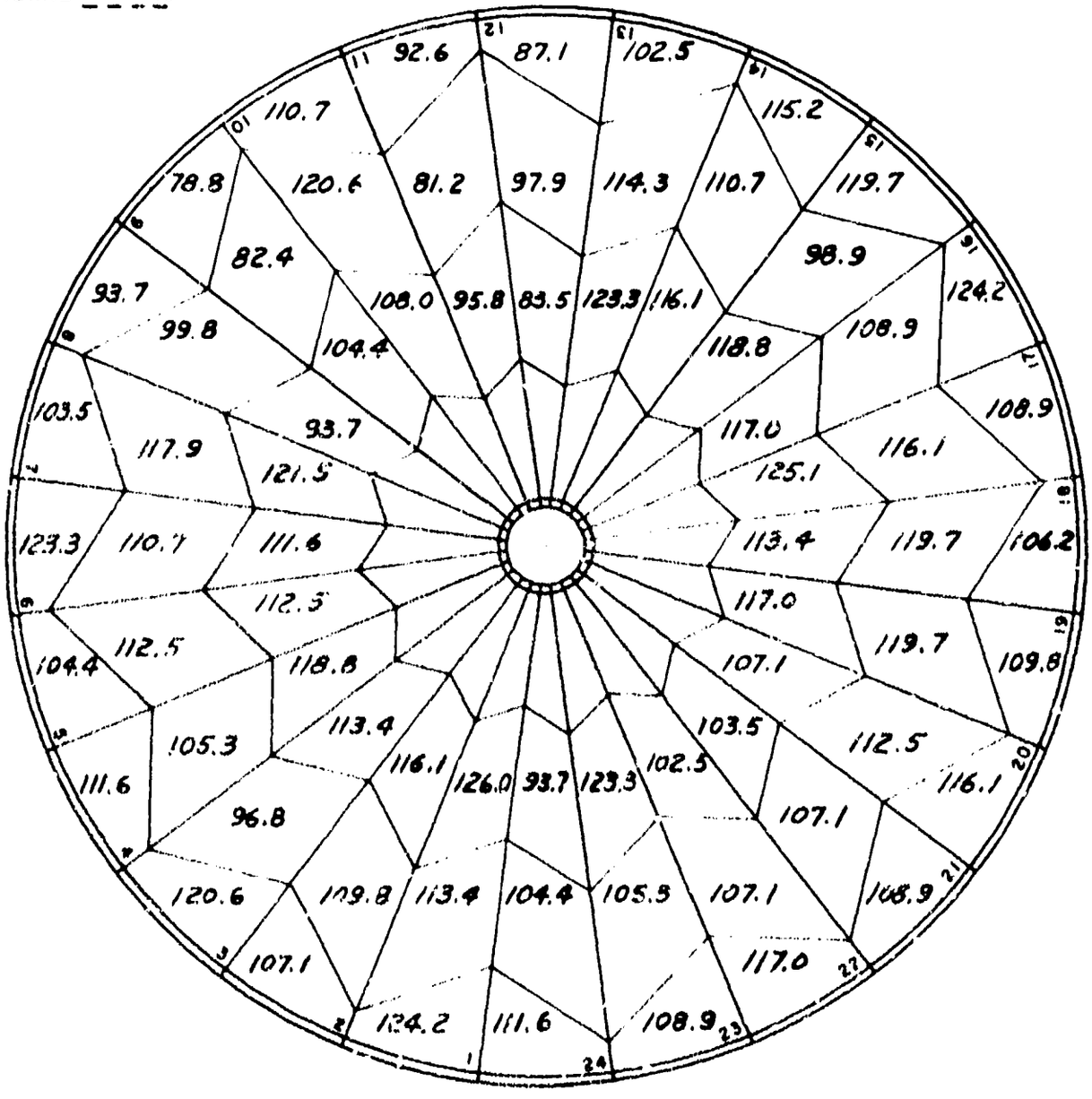
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350211

TEMP. 80 °F

HUMID 65 %



AVERAGE POROSITY: 109.0

DATE 6/30/50

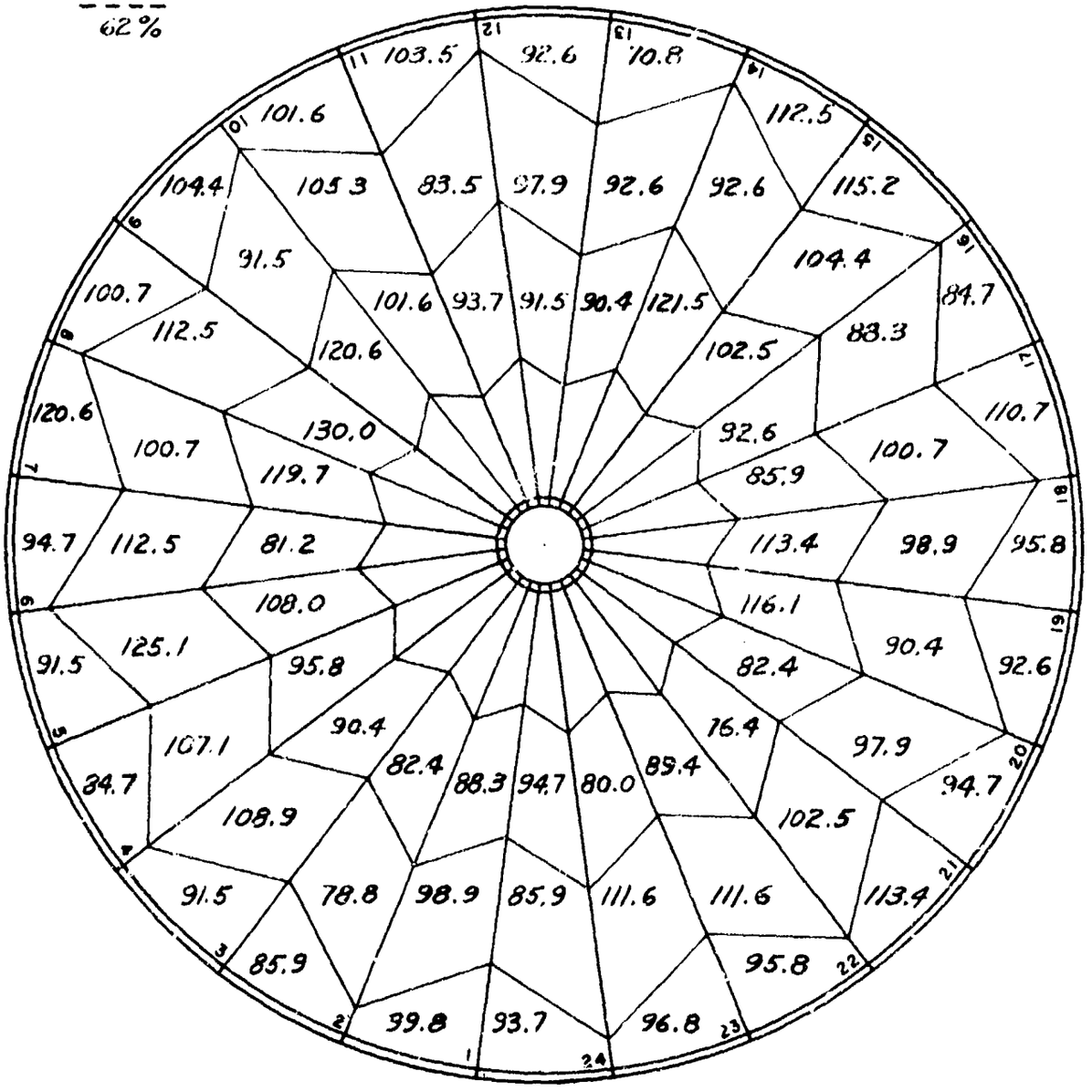
BY L.J.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350212

TEMP. 80 °F

HUMID 65 %
62 %



AVERAGE POROSITY: 98.6

DATE 6/30/50

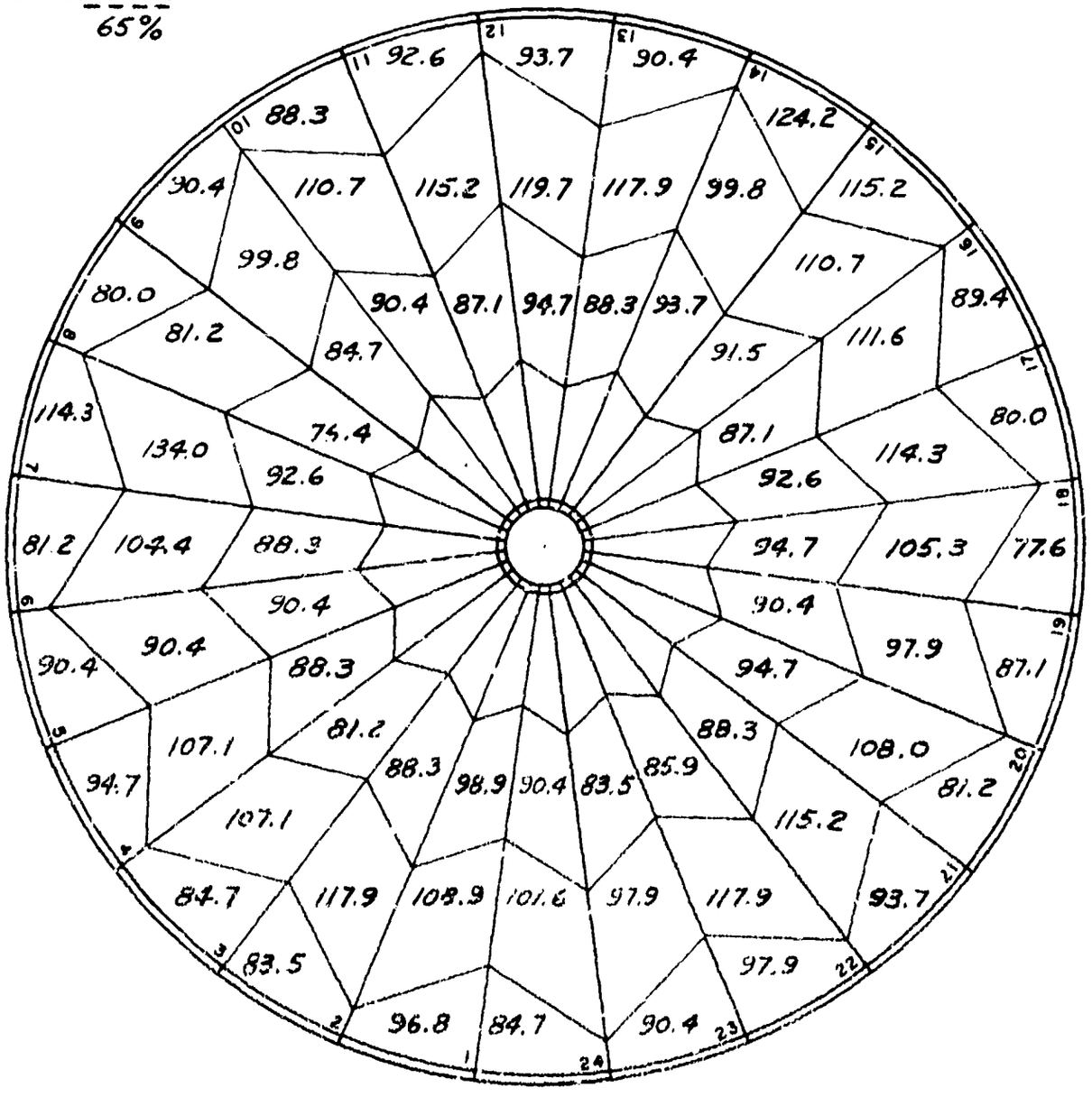
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350213

TEMP. 80 °F

HUMID. 62 %
65%



AVERAGE POROSITY: 96.4

DATE 6/30/50

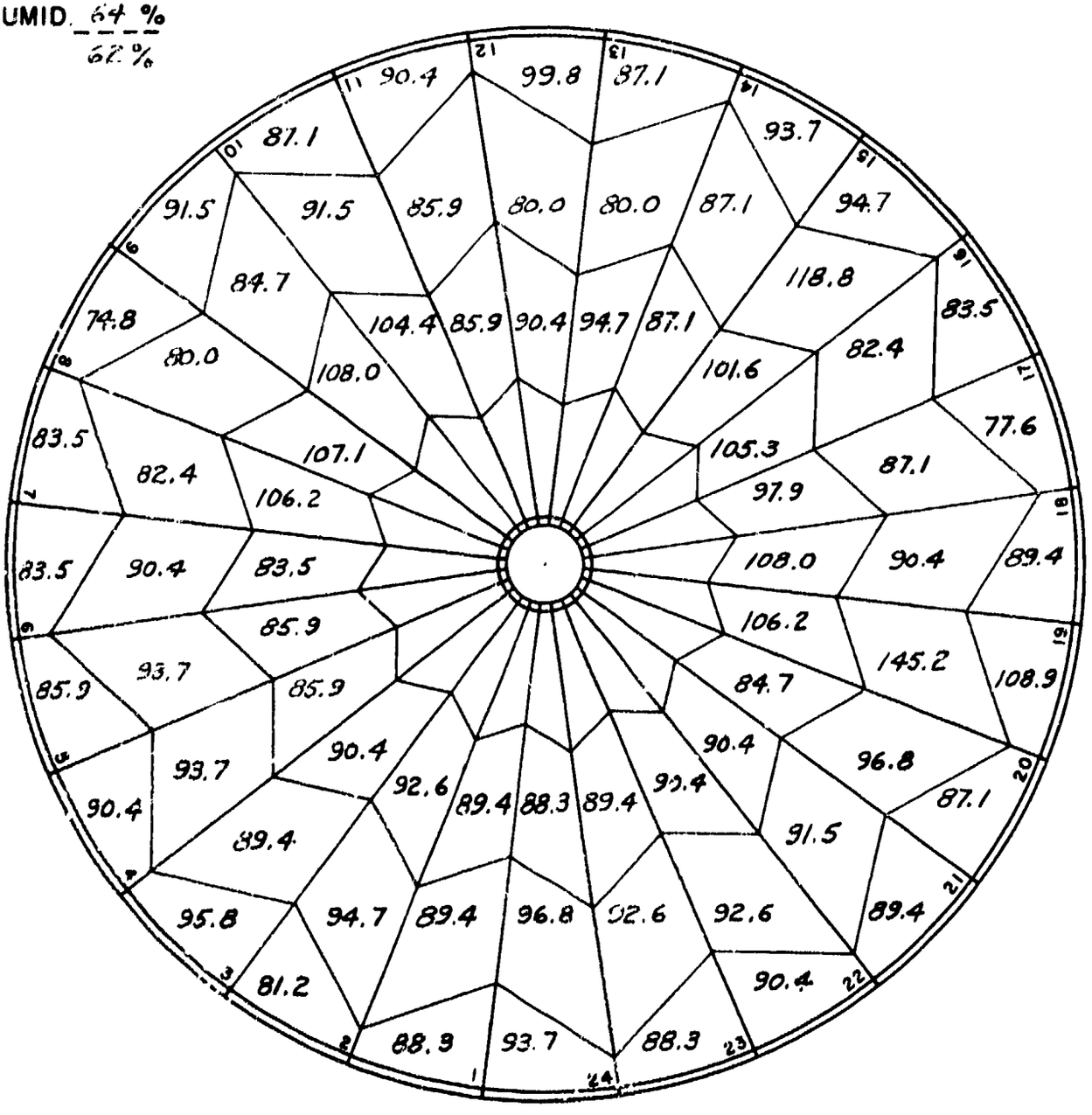
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350214

TEMP. 19 °F

HUMID. 64 %
62 %



AVERAGE POROSITY: 92.0

DATE 7/19/50

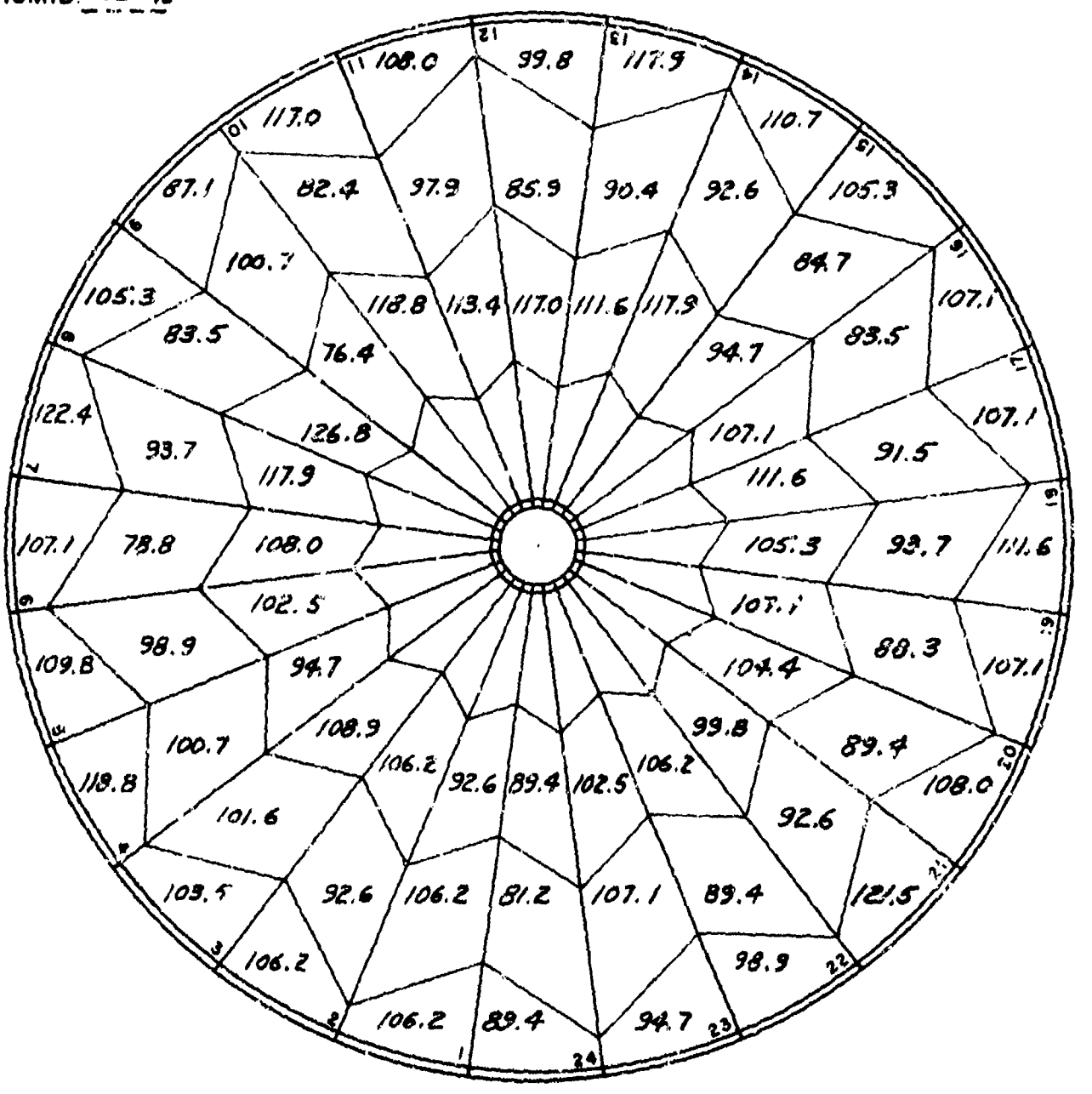
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350215

TEMP. 80 °F

HUMID. 62 %



AVERAGE POROSITY: 101.6

DATE 7/12/50

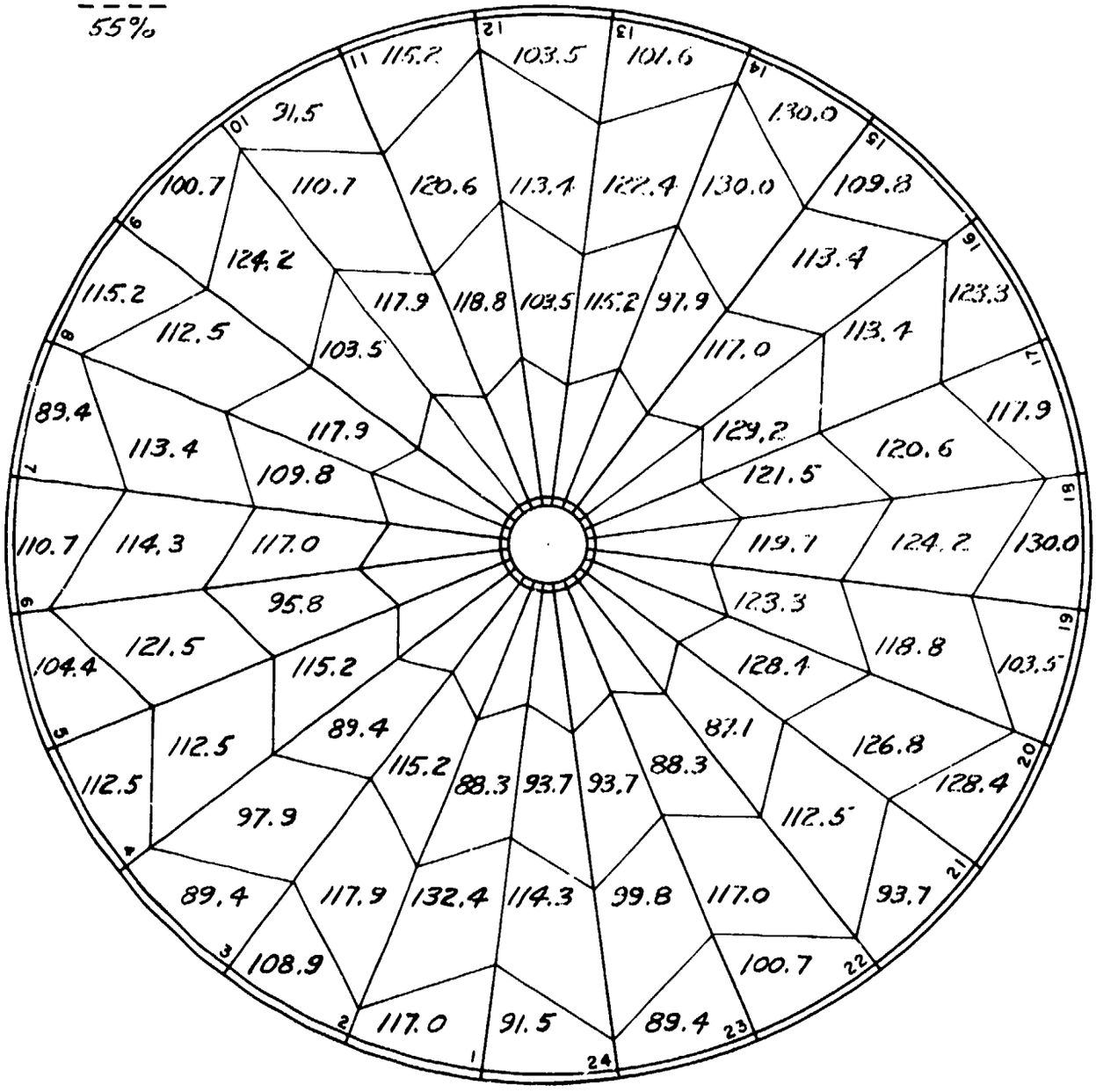
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350216

TEMP. 80 °F

HUMID. 57 %
55%



AVERAGE POROSITY: 111.0

DATE 7/19/50

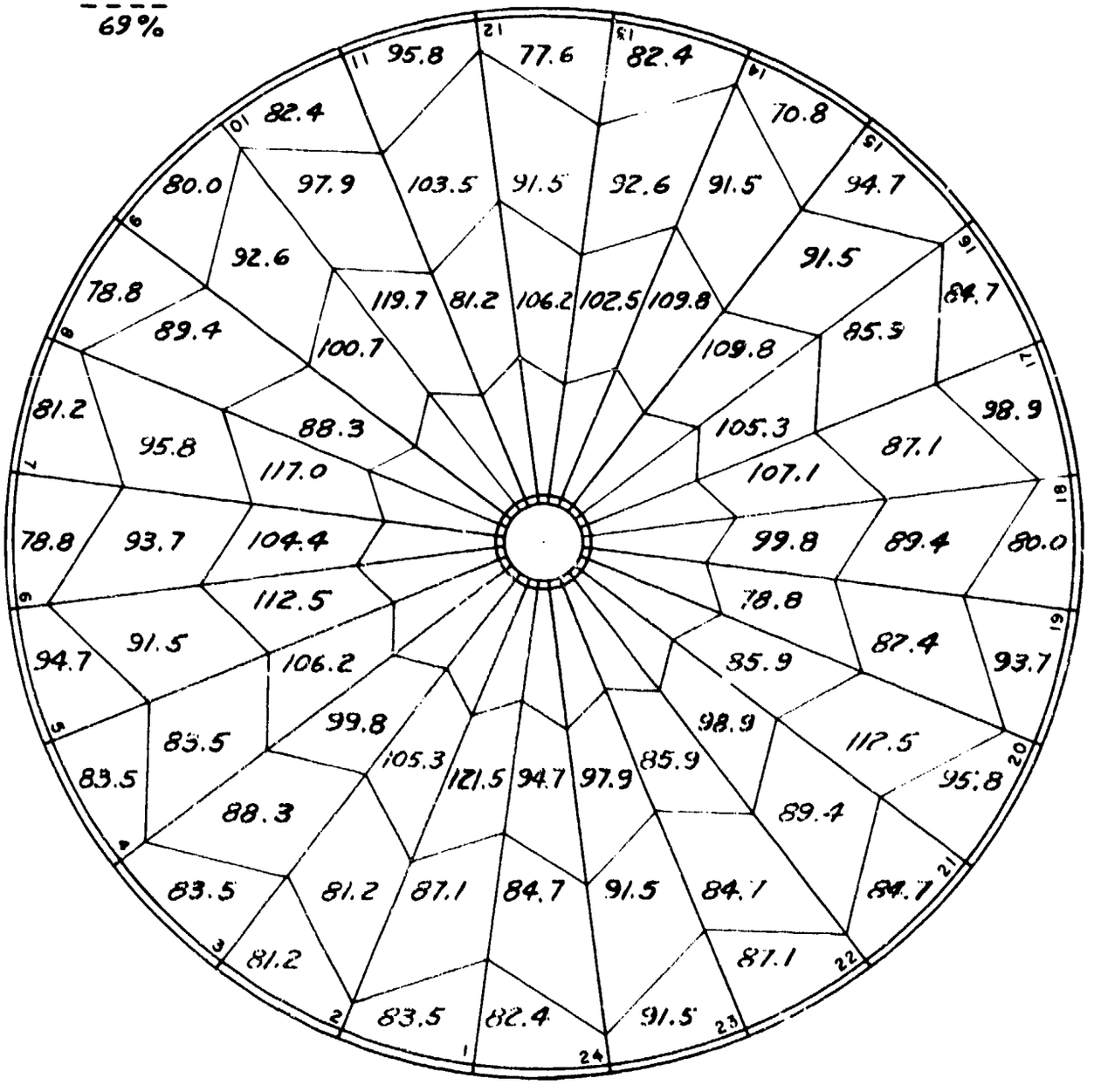
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350217

TEMP. 79 °F

HUMID 66 %
69 %



AVERAGE POROSITY: 92.6

DATE 7/20/50

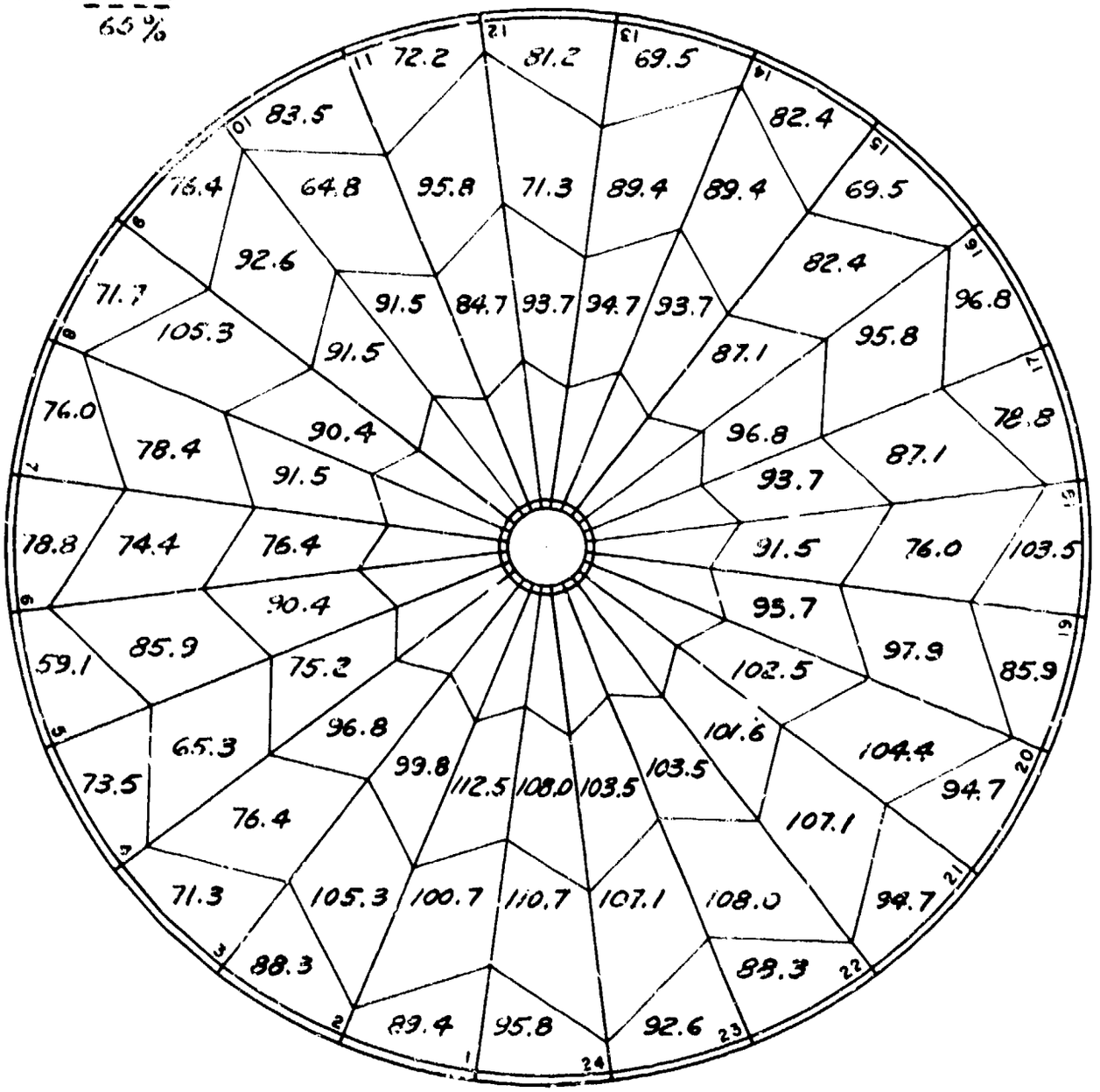
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 300218

TEMP. 79 °F

HUMID 63 %
65 %



AVERAGE POROSITY: 89.0

DATE 7/20/50

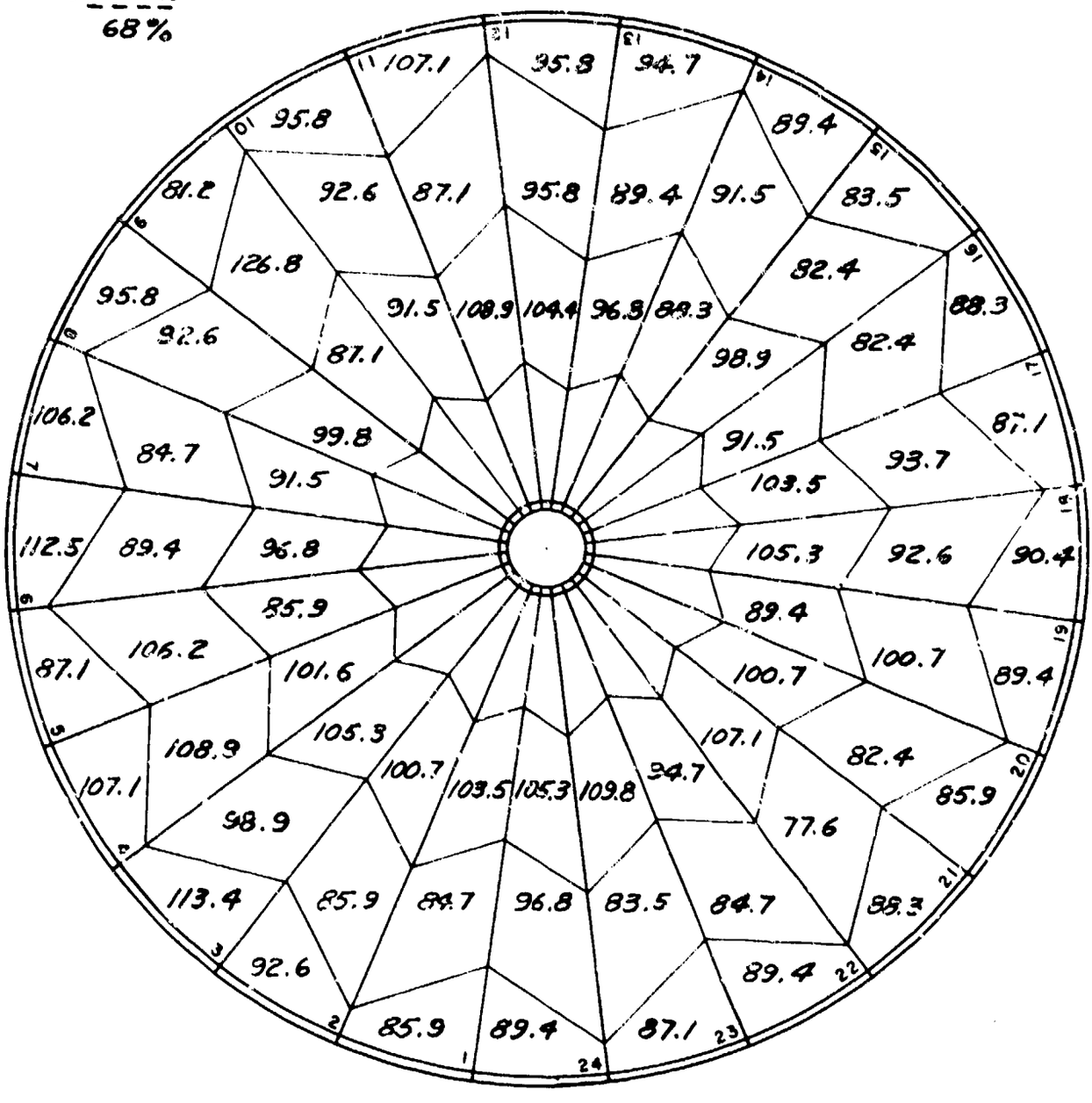
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350219

TEMP. 76 °F

HUMID. 65 %
68 %



AVERAGE POROSITY: 94.8

DATE 7/20/50

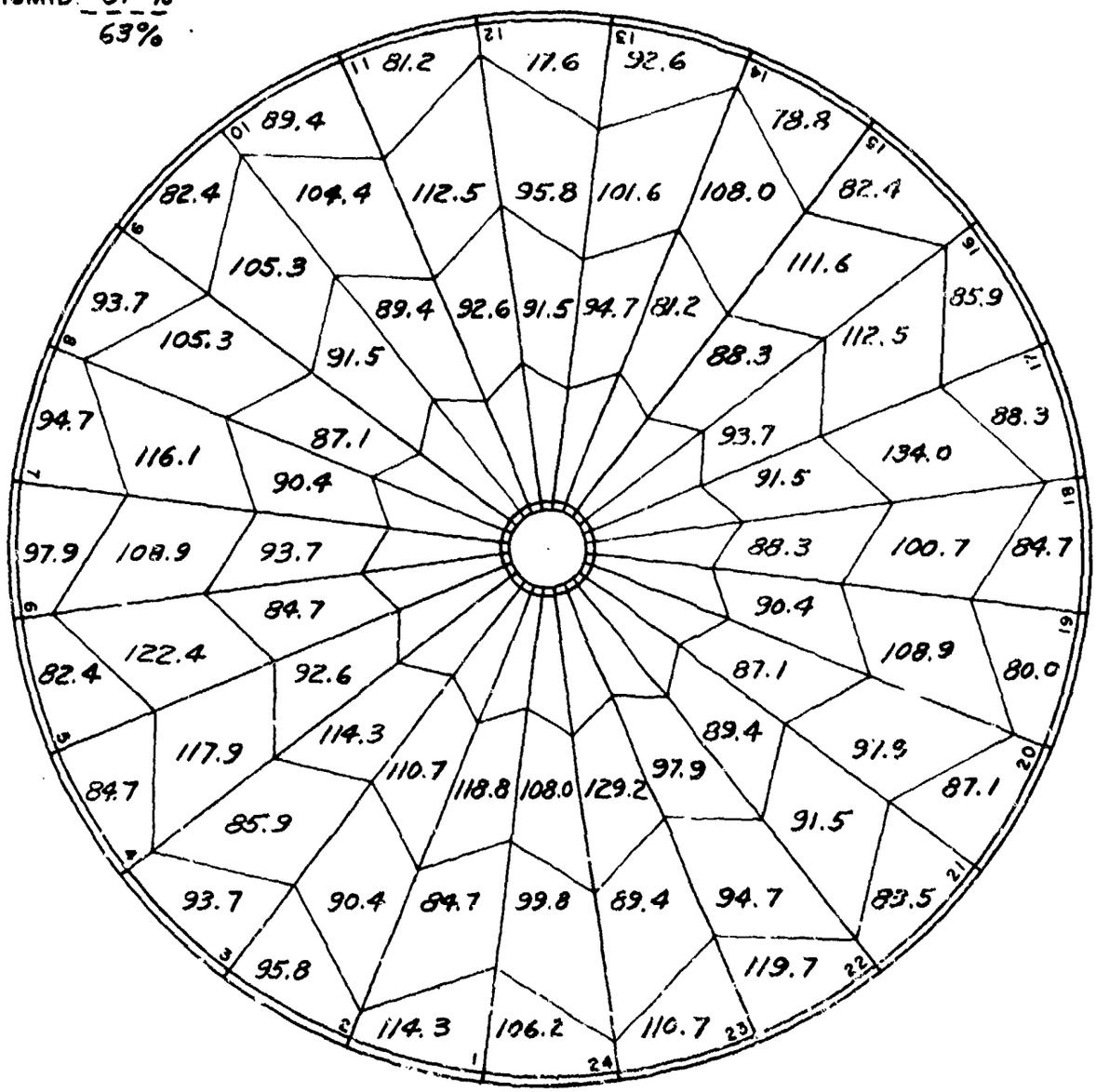
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350220

TEMP. 76 °F

HUMID. 67 %
63%



AVERAGE POROSITY: 97.0

DATE 7/21/50

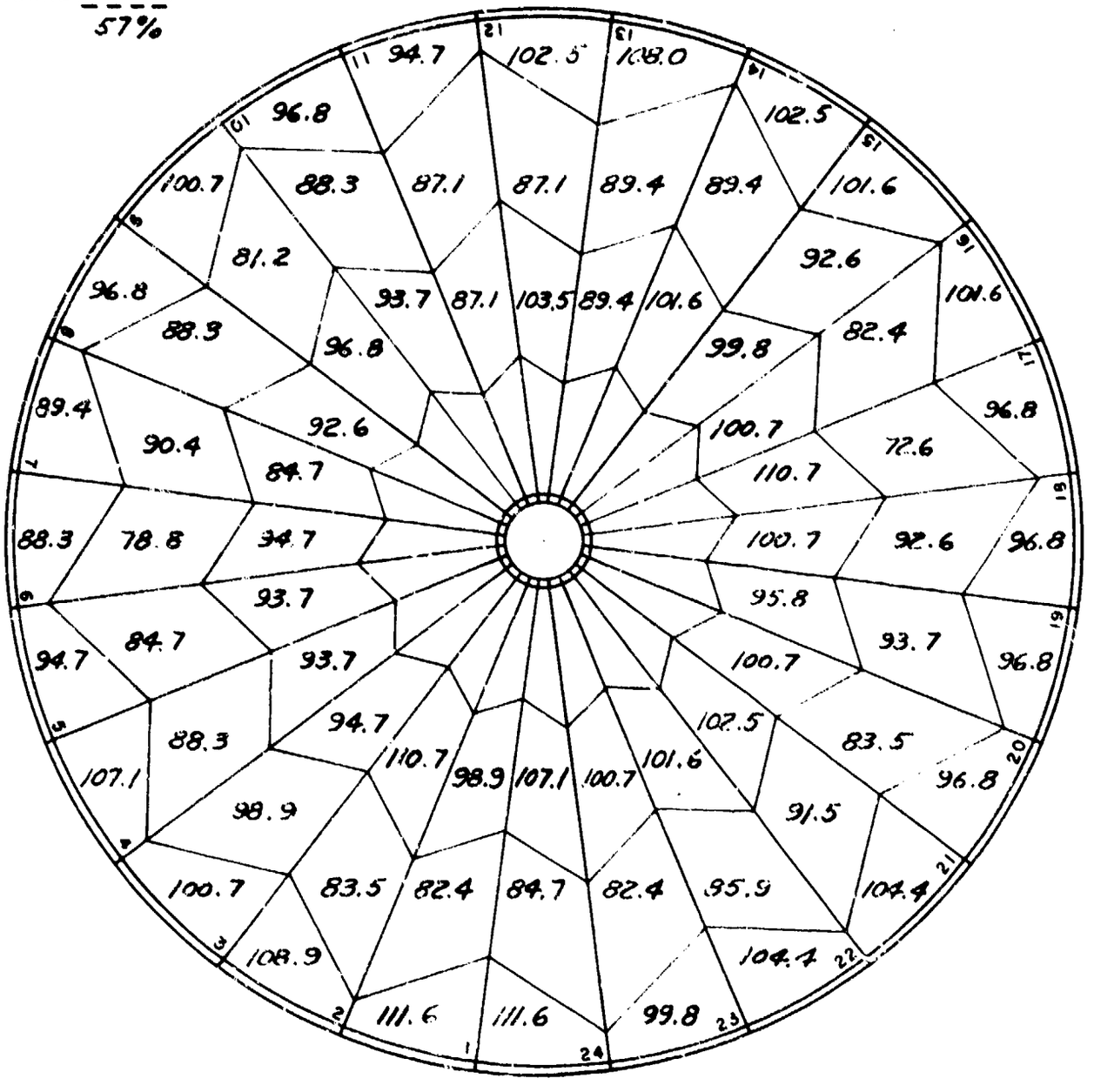
BY L.A.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350221

TEMP. 78 °F

HUMID. 63 %
57%



AVERAGE POROSITY: 95.1

DATE 7/21/50

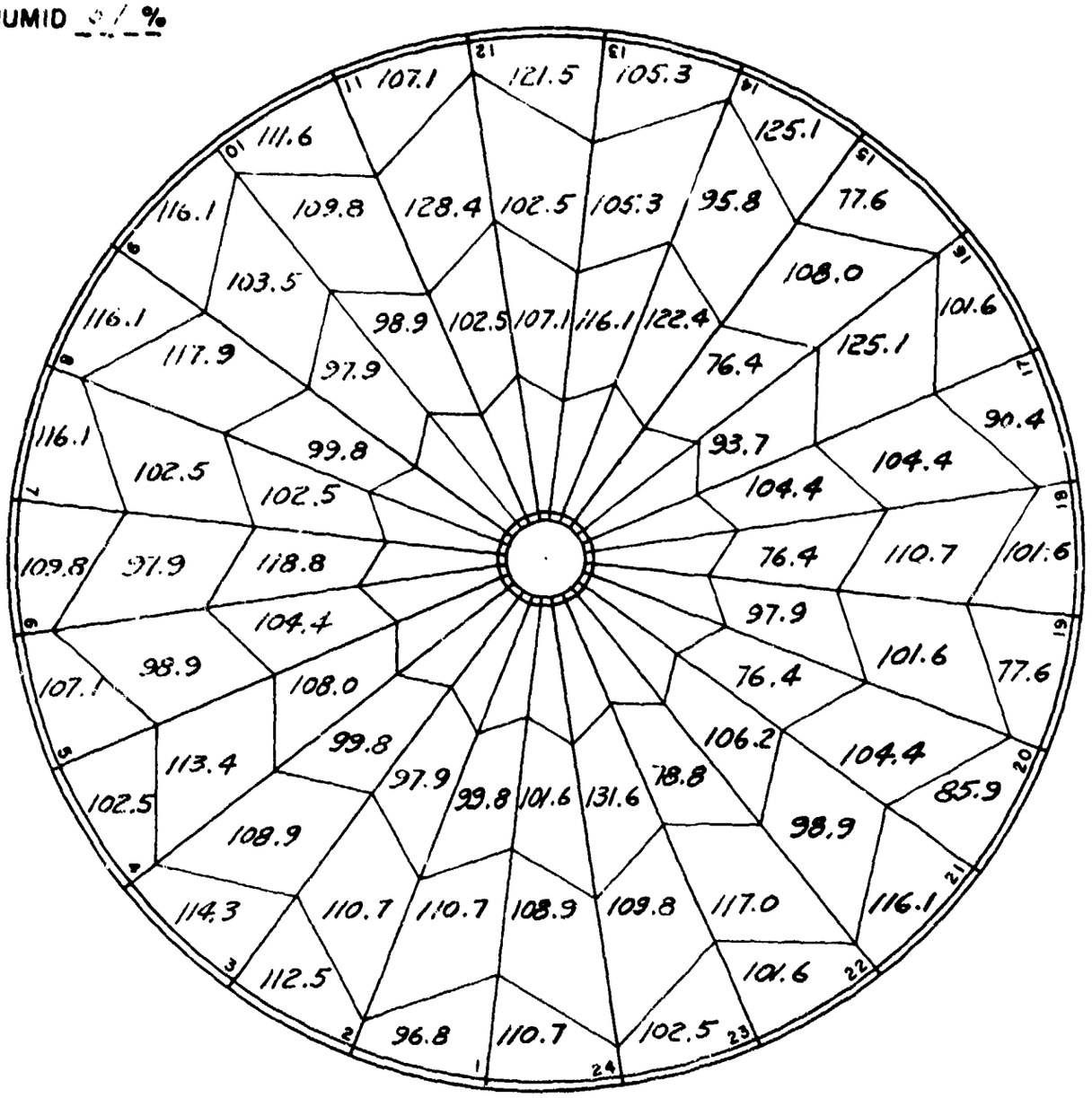
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. [illegible]

TEMP. [illegible] °F

HUMID [illegible] %



AVERAGE POROSITY: 104.7

DATE 7/21/50

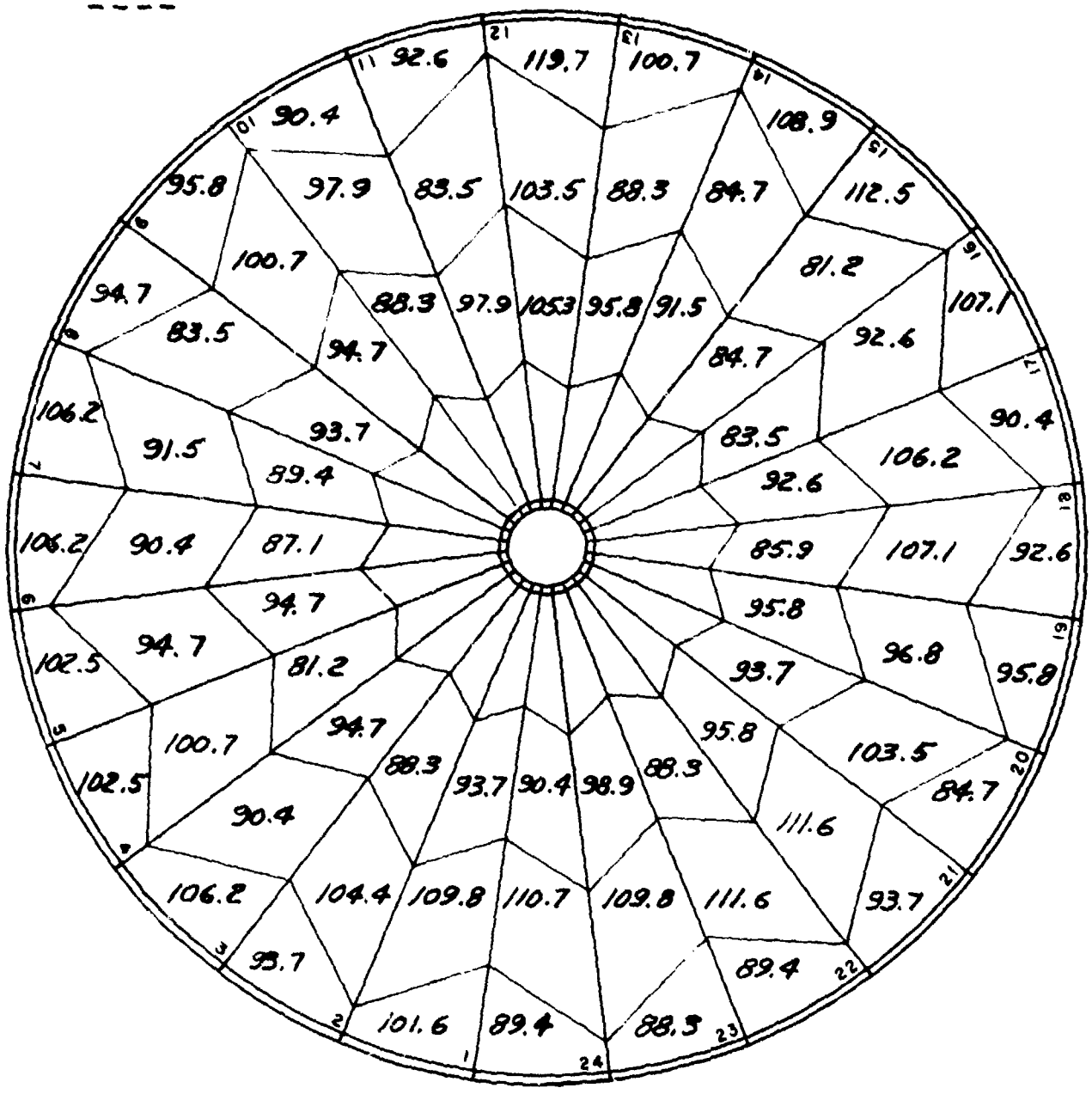
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350223

TEMP. 76 °F

HUMID 65 %



AVERAGE POROSITY: 96.2

DATE 7/24/50

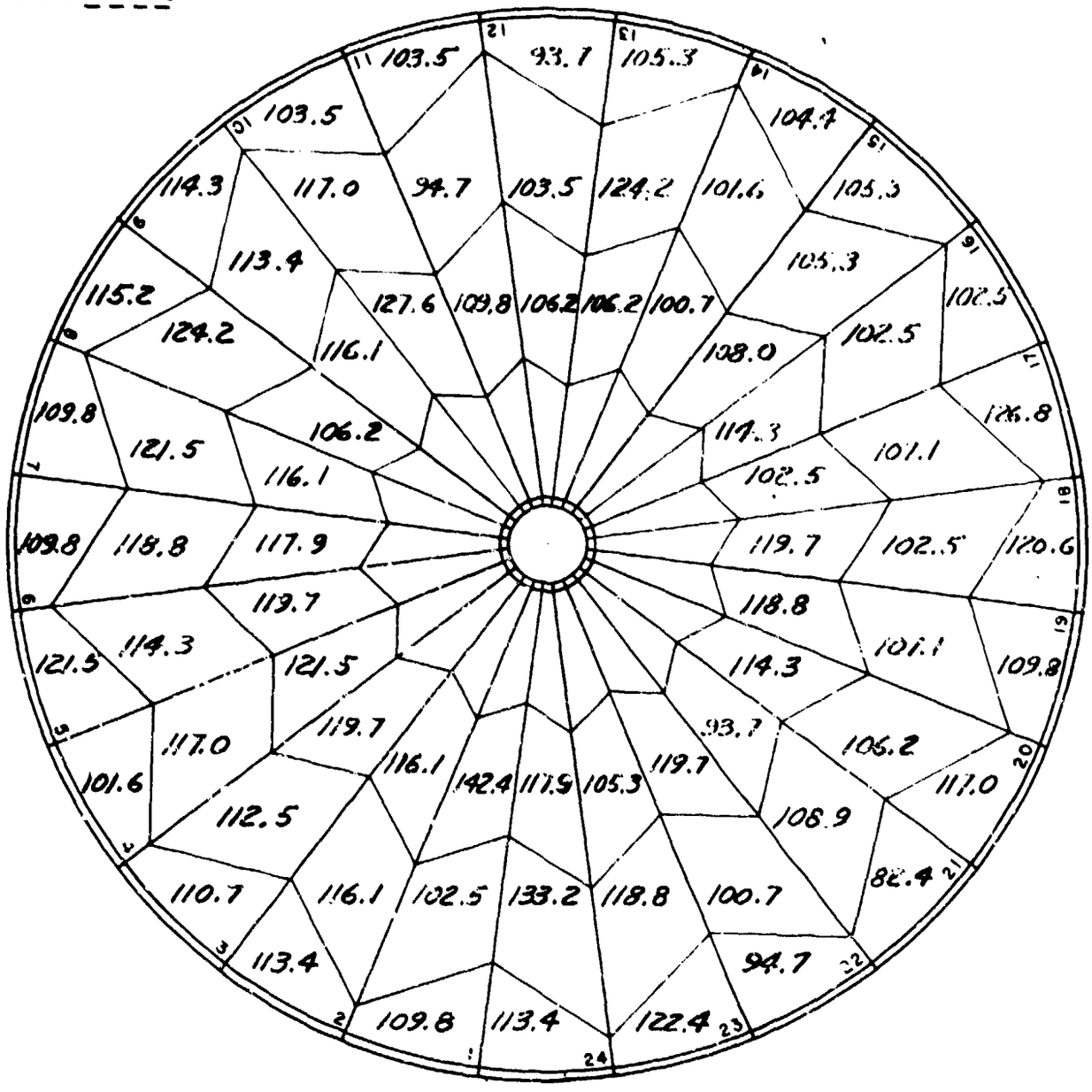
BY L.J.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350224

TEMP. 75 °F

HUMID 65 %



AVERAGE POROSITY: 111.5

DATE 7/24/50

BY L.D.

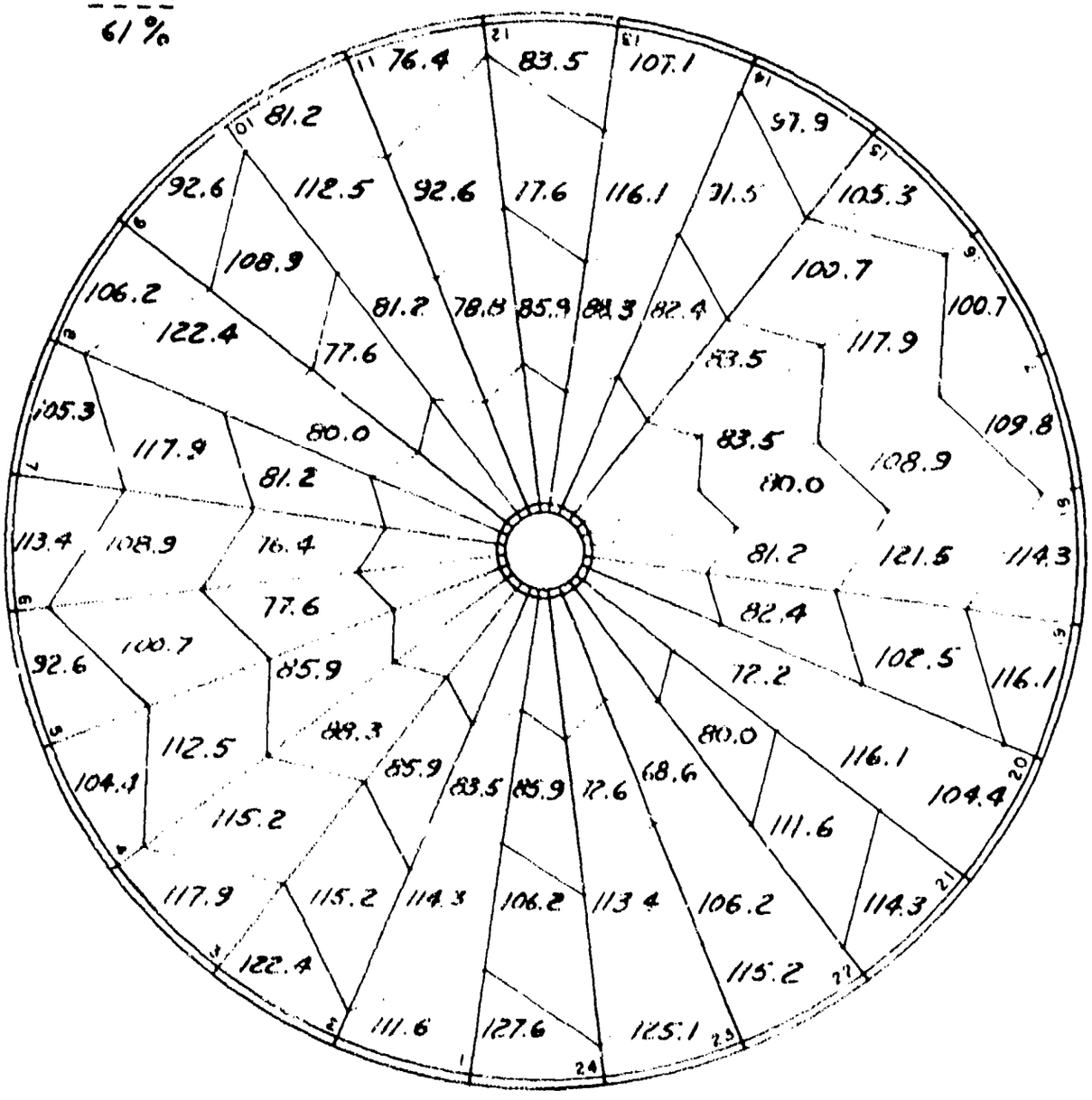
POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350225

TEMP. 76 °F

HUMID 64 %

61 %



AVERAGE POROSITY 98.6

DATE 1/24/50

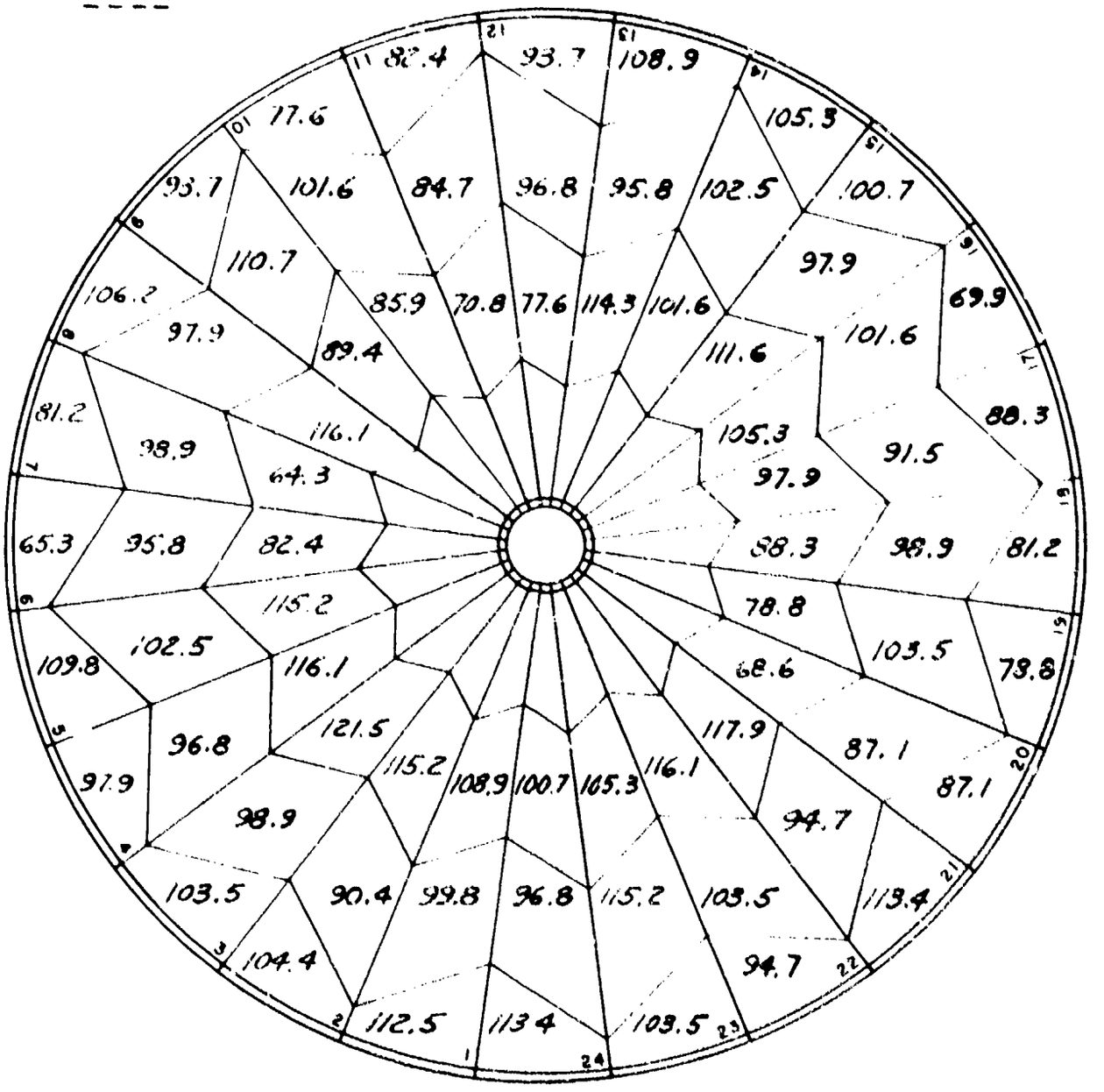
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. [illegible]

TEMP. 78 °F

HUMID 67 %



AVERAGE POROSITY 97.3

DATE 7/24/50

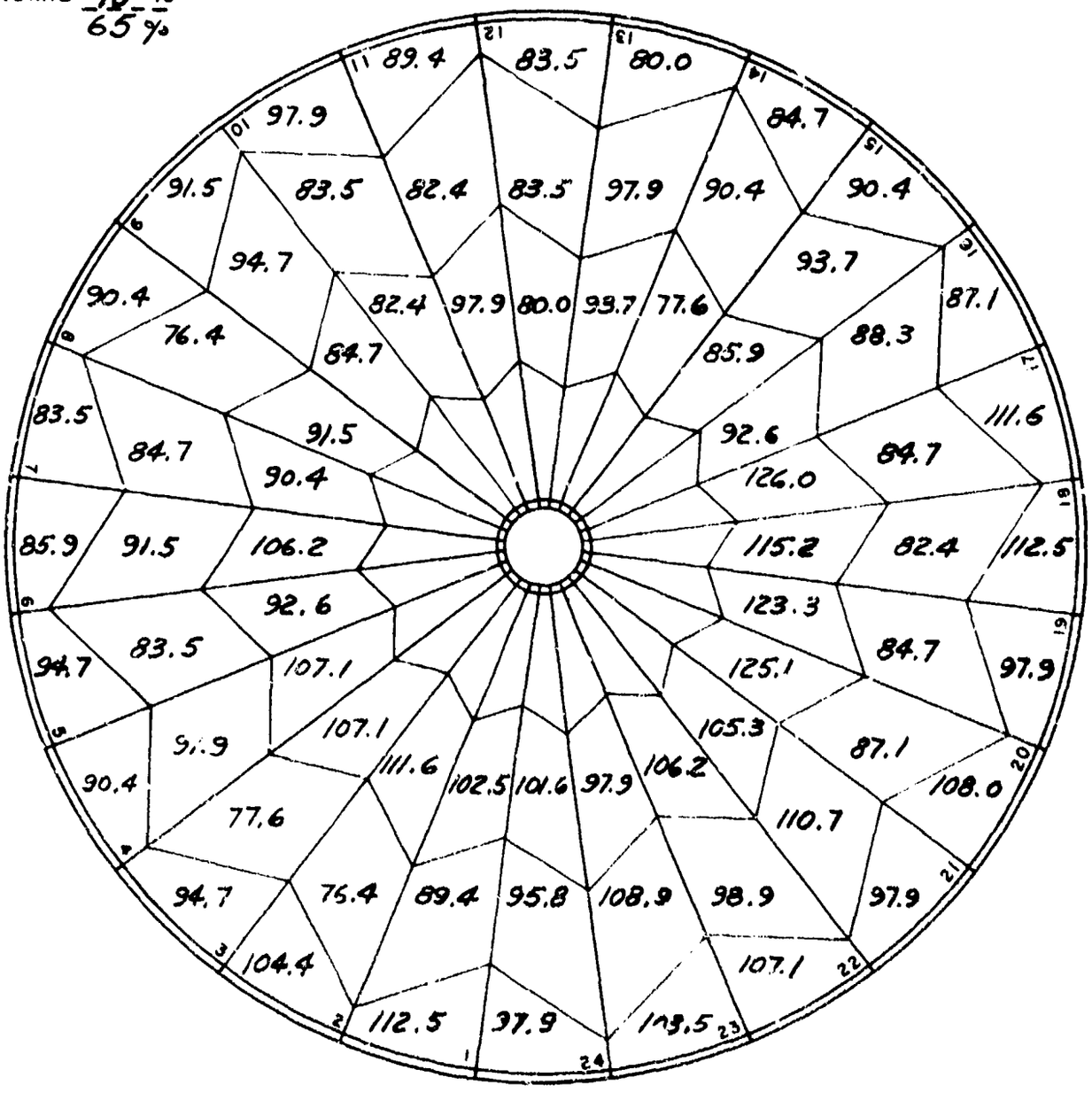
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 950227

TEMP. 80 °F

HUMID 70 %
65 %



AVERAGE POROSITY: 95.1

DATE 7/25/50

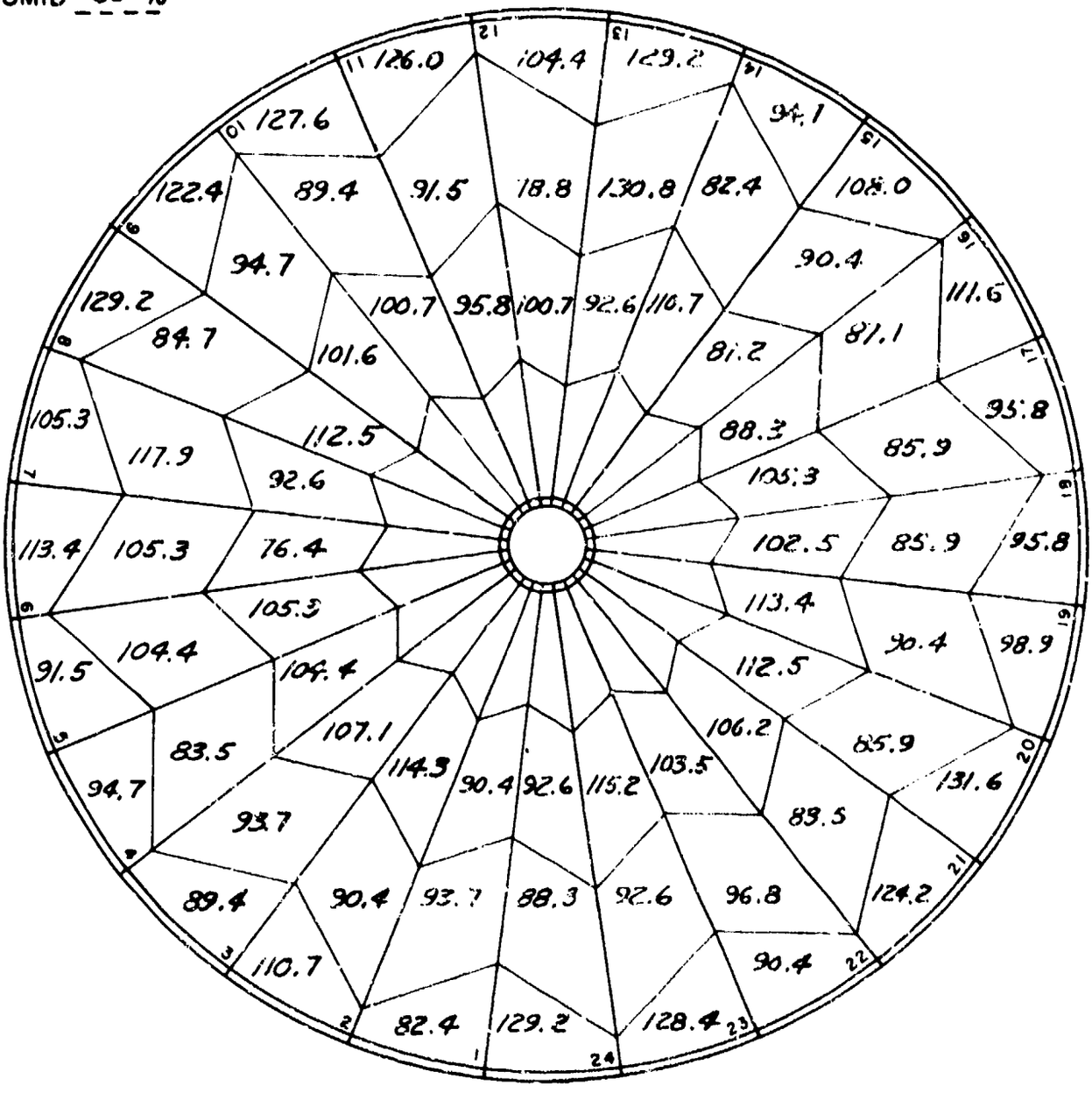
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350228

TEMP. 78 °F

HUMID 65 %



AVERAGE POROSITY: 101.2

DATE 7/26/50

BY L.D.

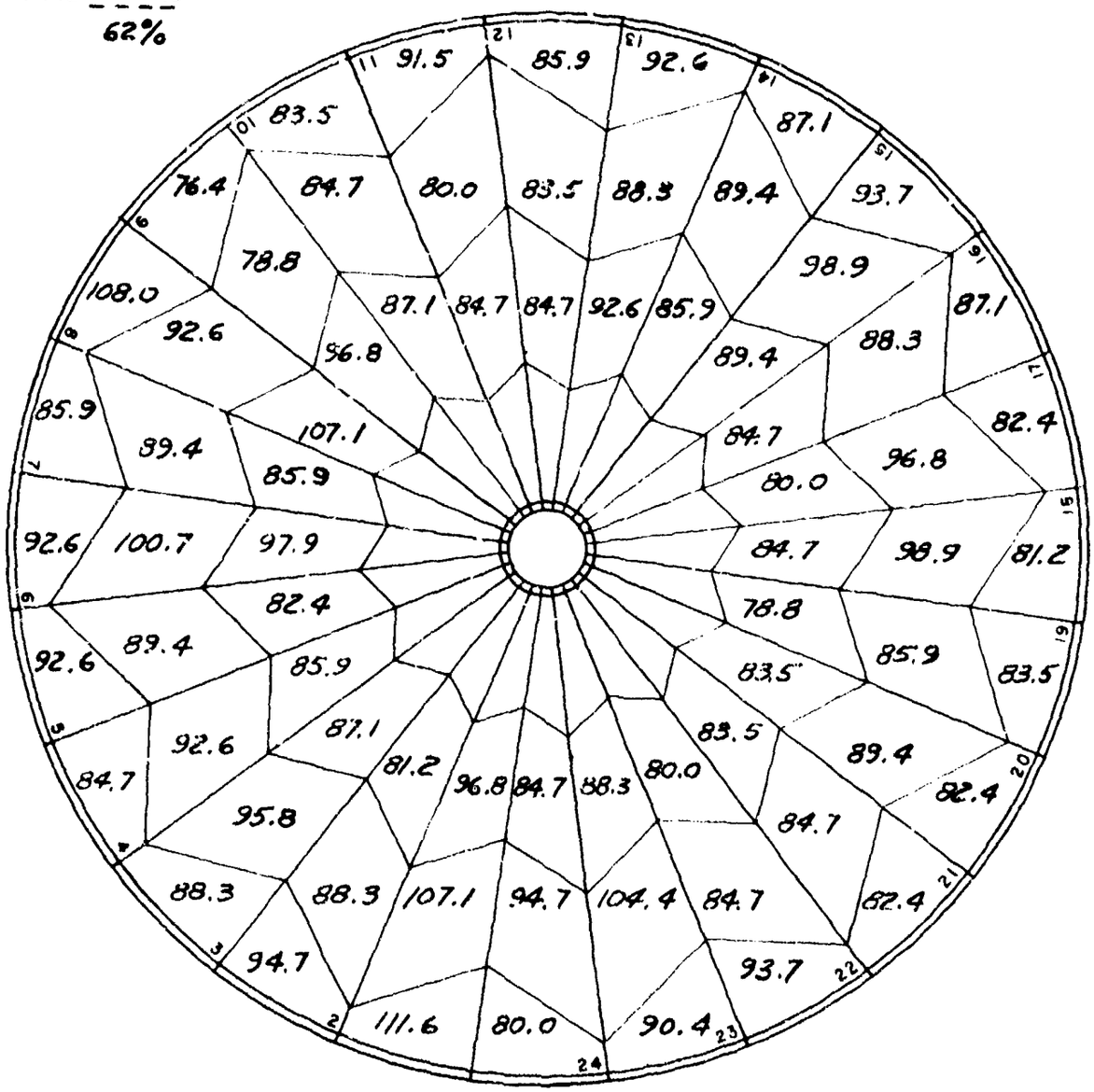
POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. 350229

TEMP. 78 °F

HUMID 65 %

62%



AVERAGE POROSITY: 89.1

DATE 7/26/50

BY L.D.

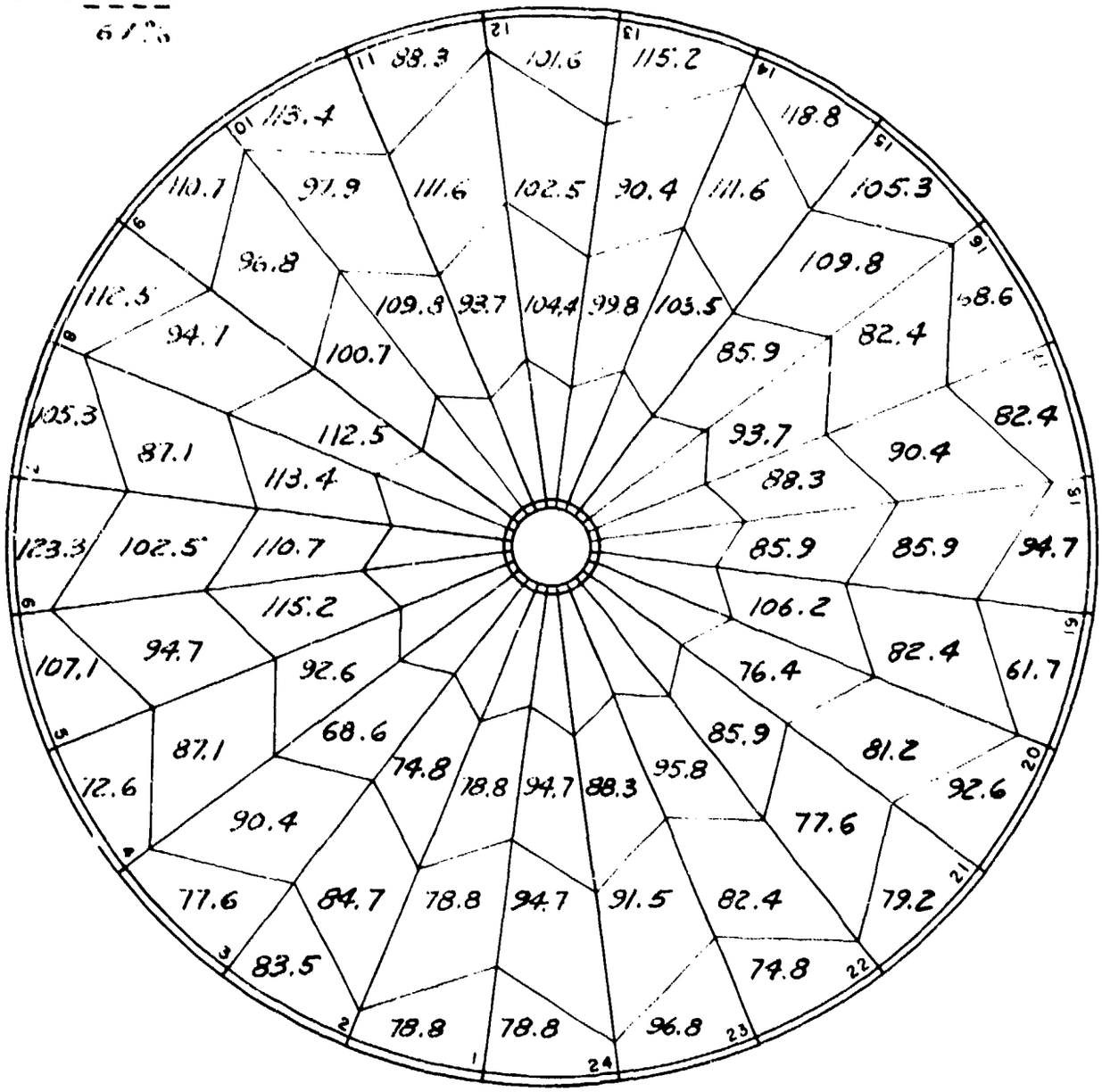
POROSITY MEASUREMENTS 24 GORE CANOPY BEFORE TOWER TESTS

SERIAL NO. [illegible]

TEMP. 80 °F

HUMID 62 %

64 %



AVERAGE POROSITY: 93.5

DATE 7/26/50

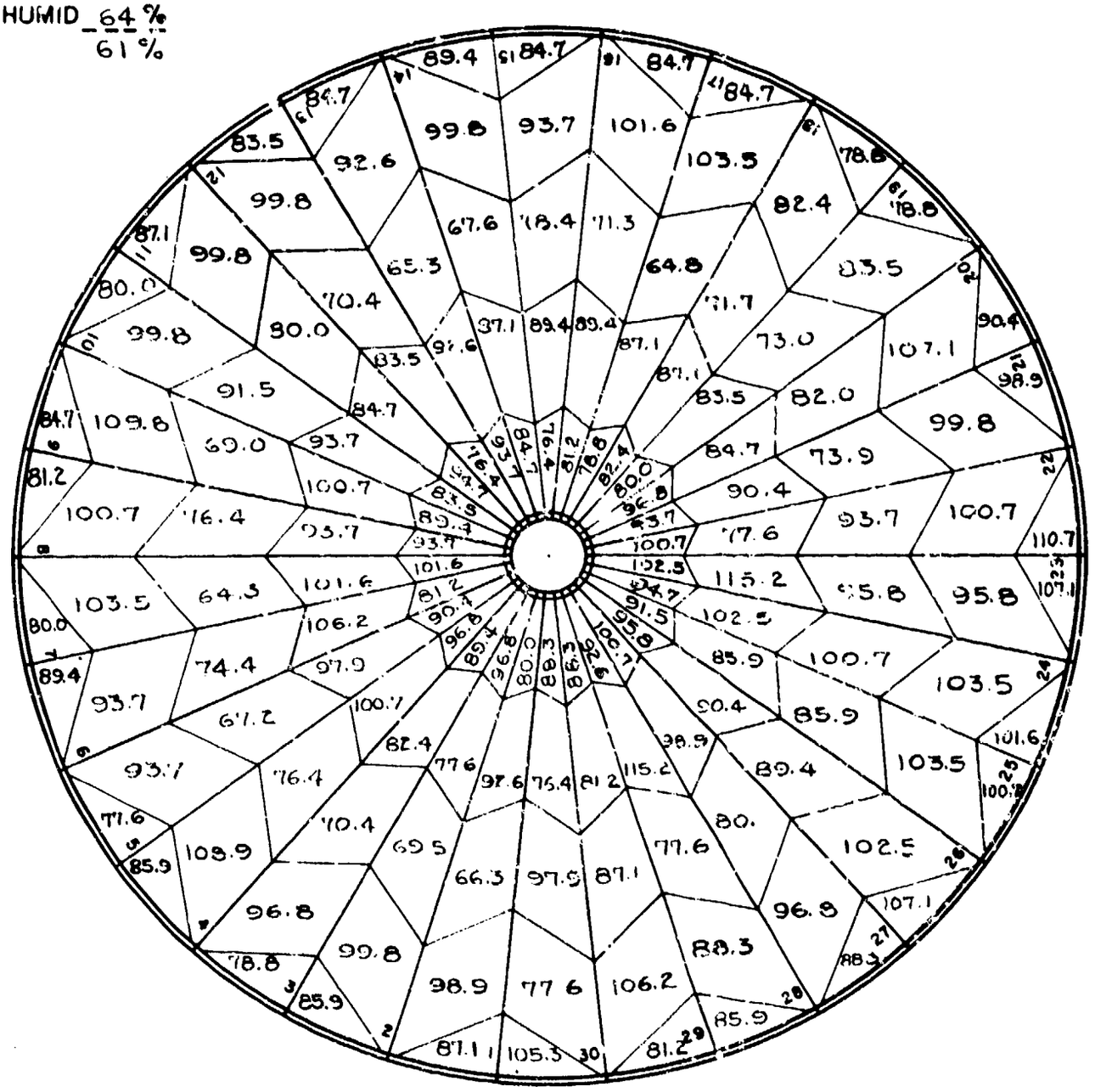
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY **BEFORE 100 M.P.H. TEST**

SERIAL NO. 350231

TEMP. 76 °F

HUMID 64 %
61 %



AVERAGE POROSITY 89.2

DATE 8-8-50

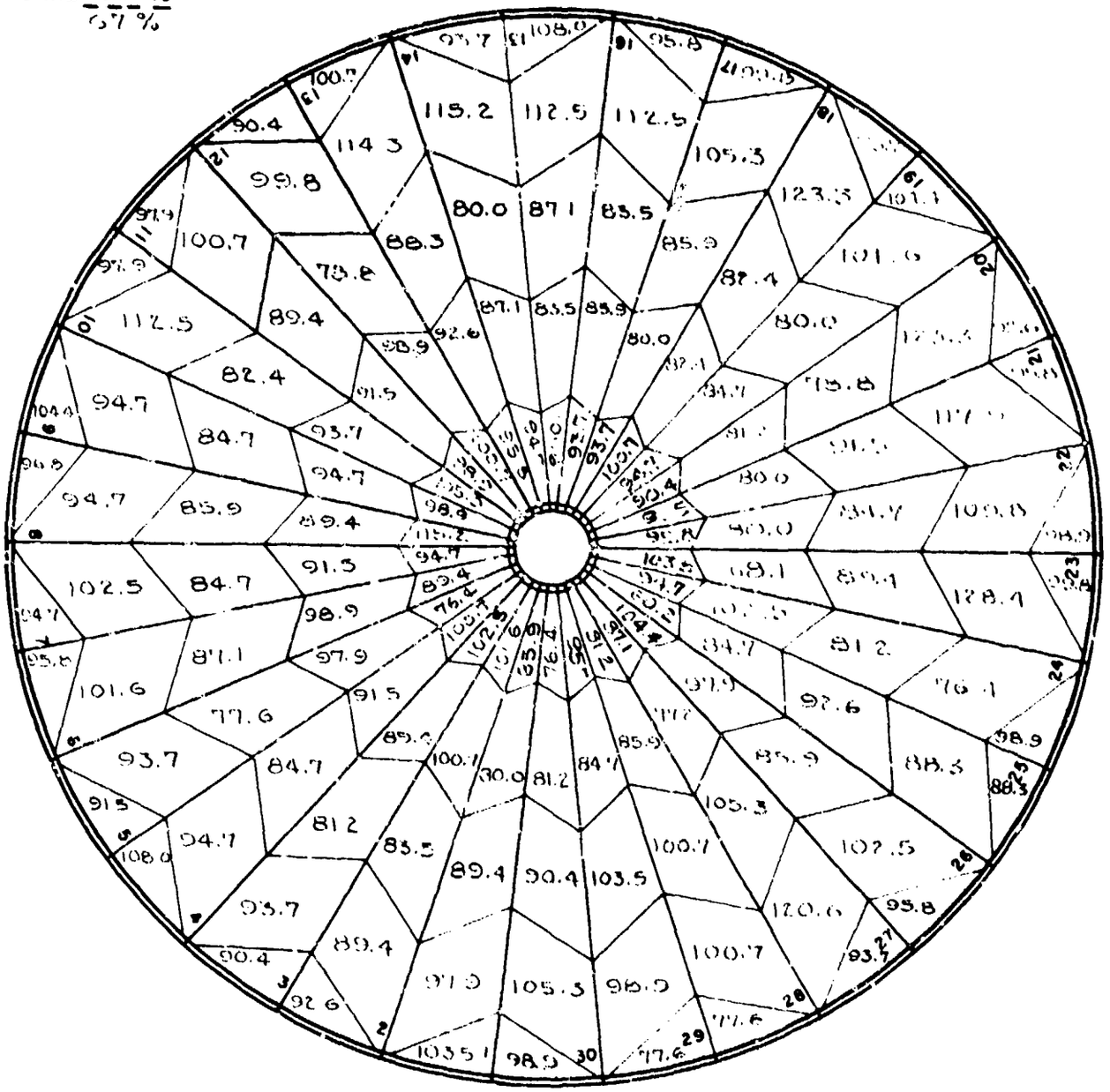
BY L.O

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. [illegible]

TEMP. 81 °F

HUMID [illegible] %
67 %



AVERAGE POROSITY 93.8

DATE 8 [illegible] 50

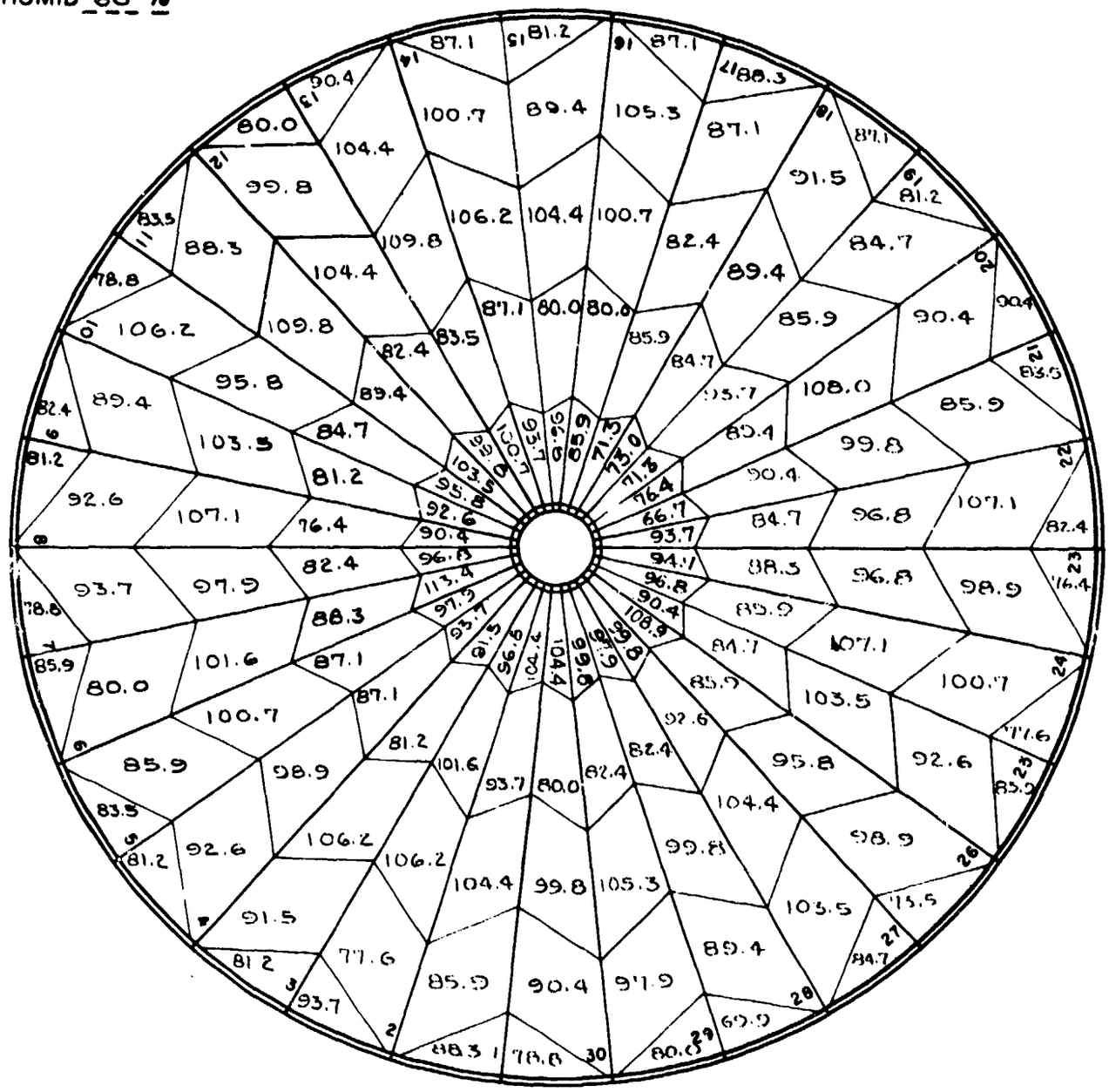
BY [illegible]

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350233

TEMP. 71 °F

HUMID 66 %



AVERAGE POROSITY 91.3

DATE 9 12 56

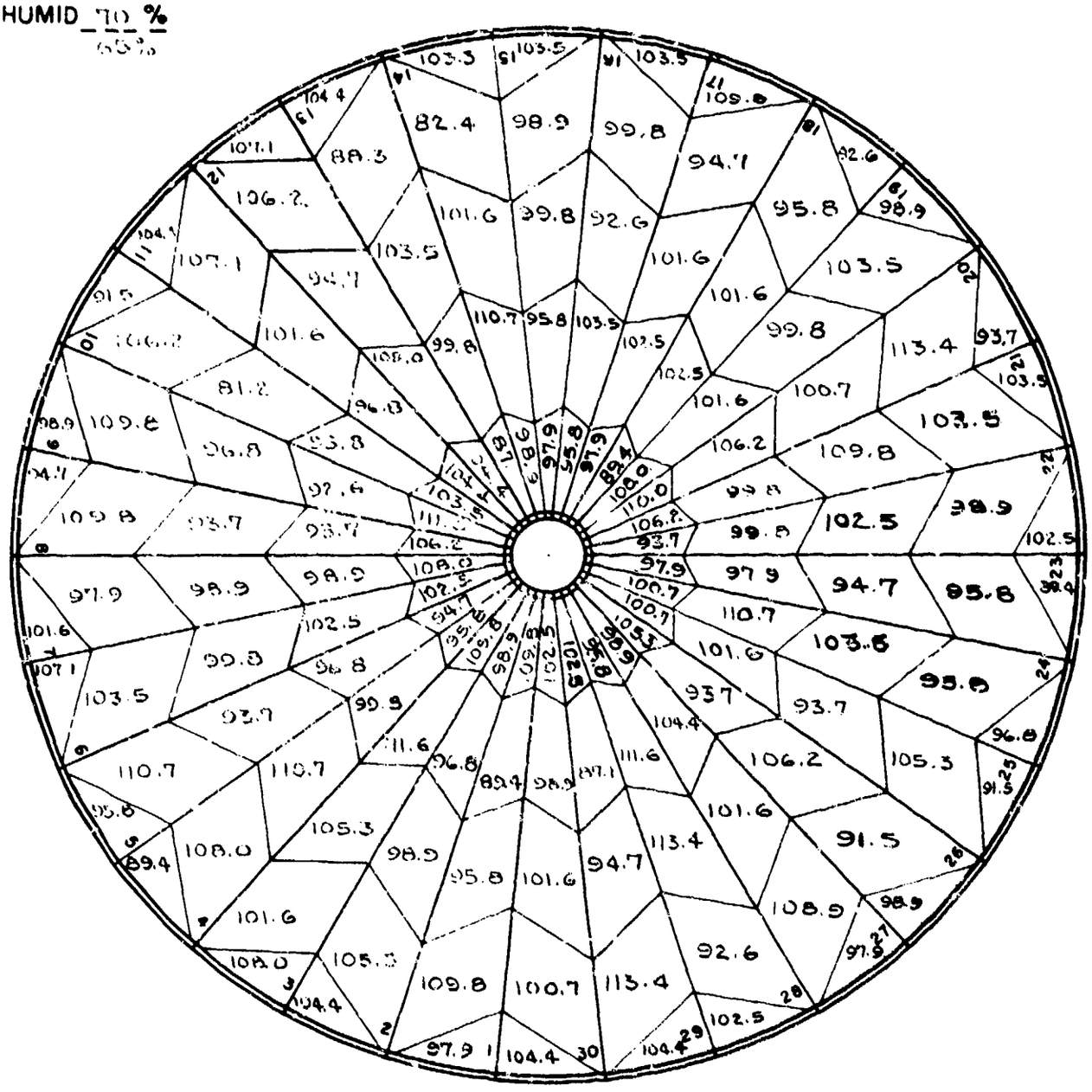
BY A.V.

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 550254

TEMP. 77 °F

HUMID 70 %
65%



AVERAGE POROSITY: 100.7

DATE 8-11-50

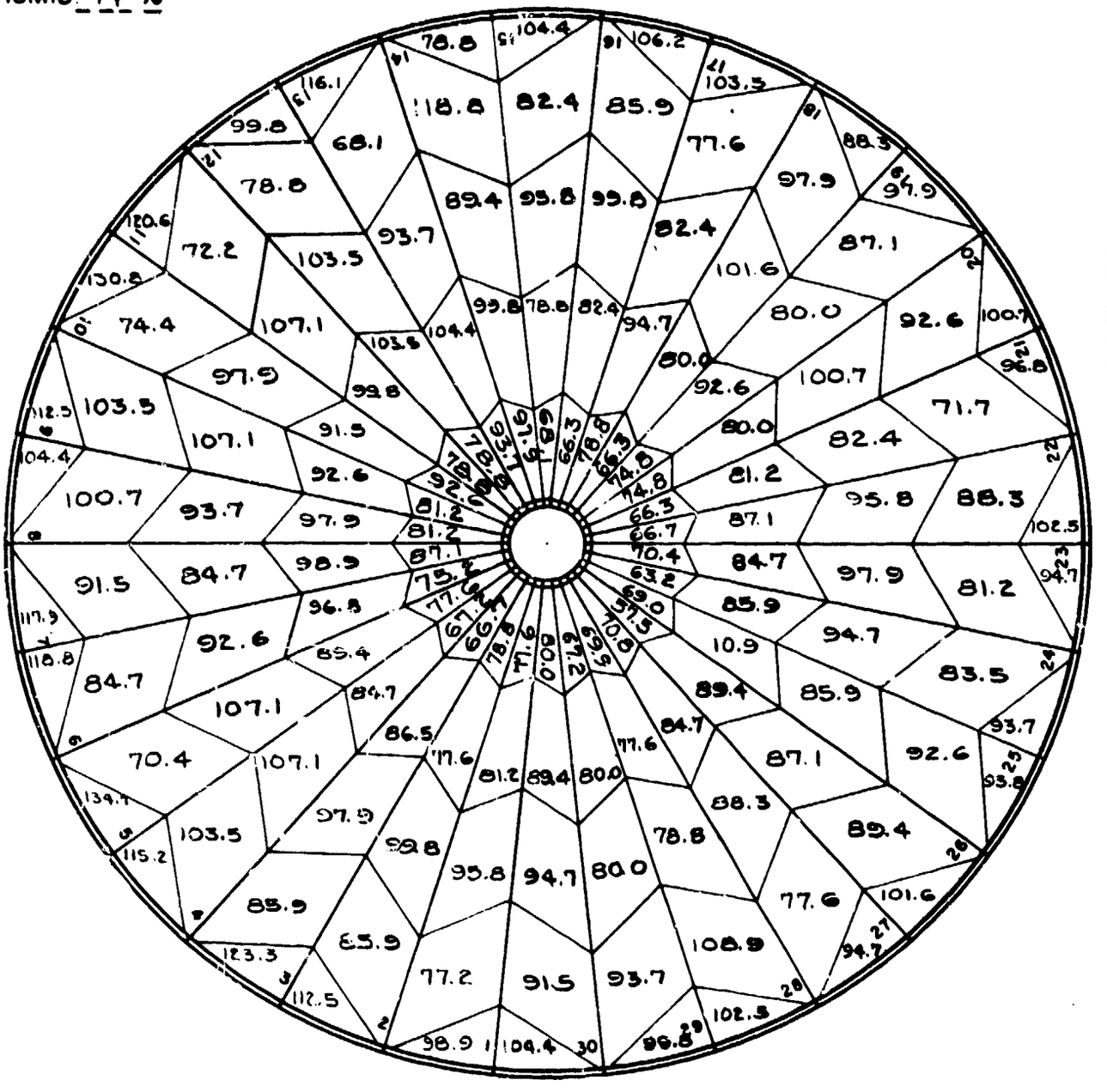
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350235

TEMP. 79 °F

HUMID. 74 %



AVERAGE POROSITY 89.6

DATE 9-8-50

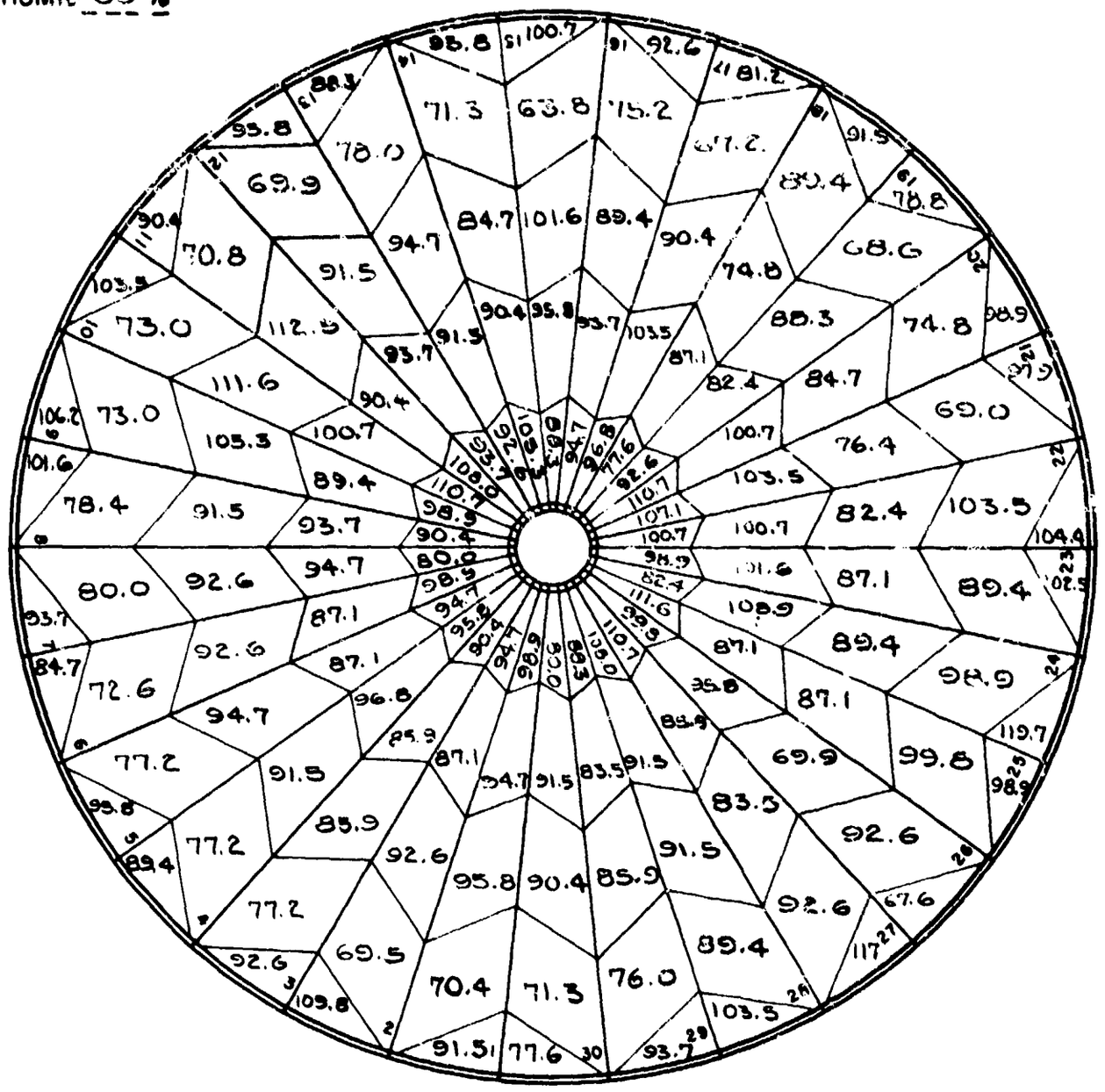
BY A.V.

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350236

TEMP. 70 °F

HUMID 65 %



AVERAGE POROSITY: 90.8

DATE 9-13-50

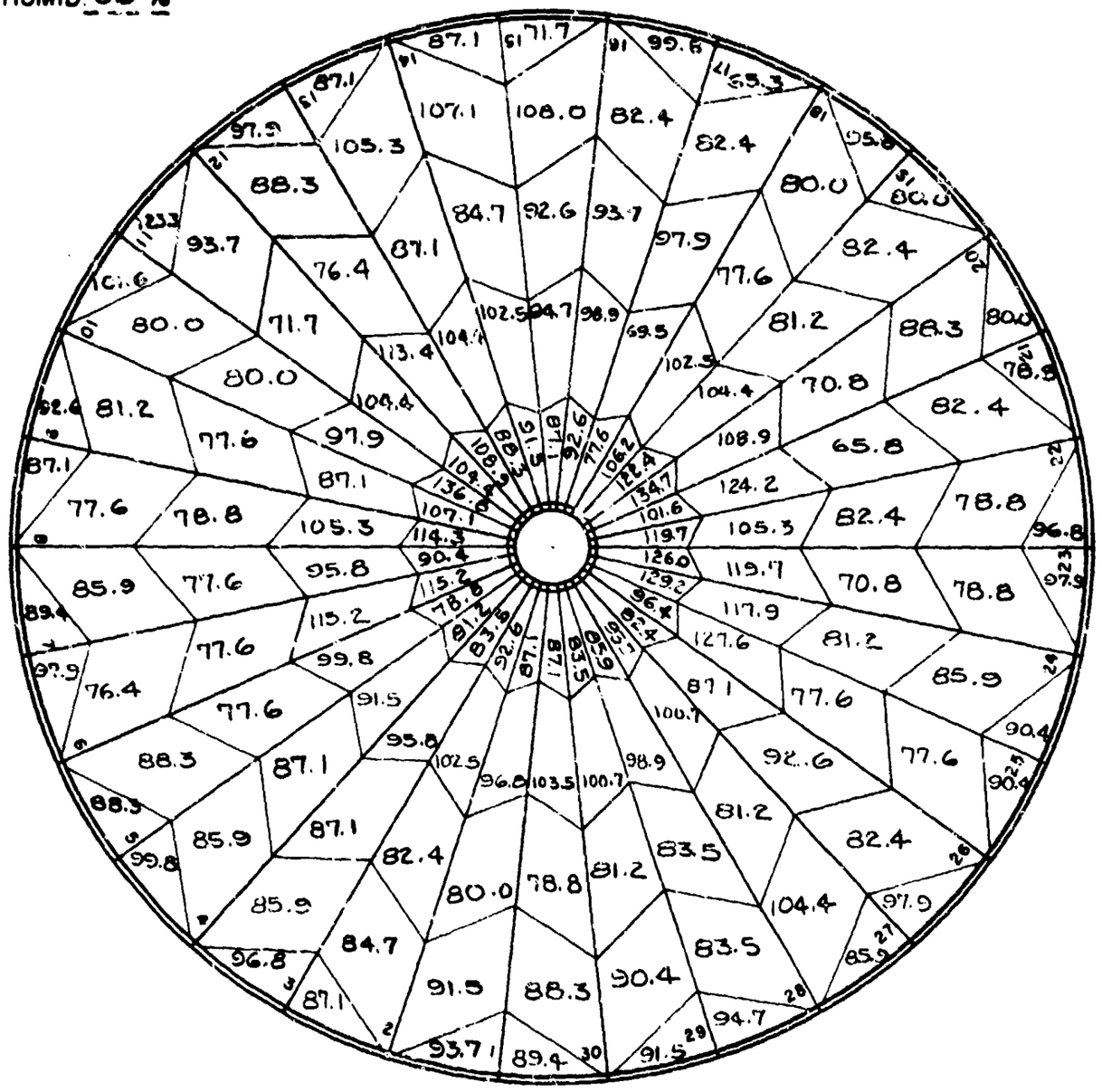
BY A.V.

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350237

TEMP. 72 °F

HUMID. 65 %



AVERAGE POROSITY: 92.3

DATE 9-14-50

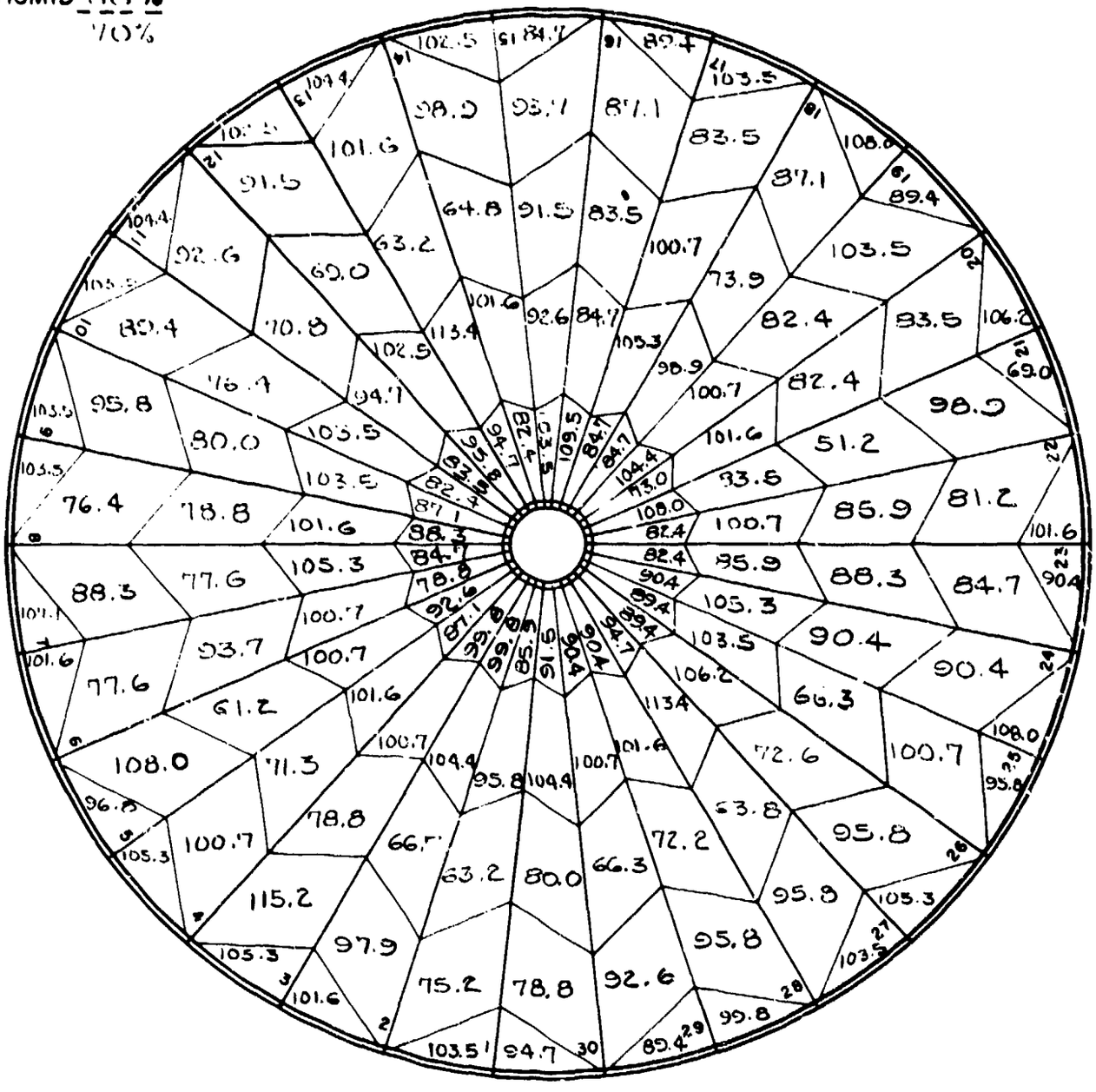
BY A.Y.

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H.

SERIAL NO. [illegible]

TEMP. 78 °F

HUMID 68 %
70%



AVERAGE POROSITY 91.6

DATE 8-23-56

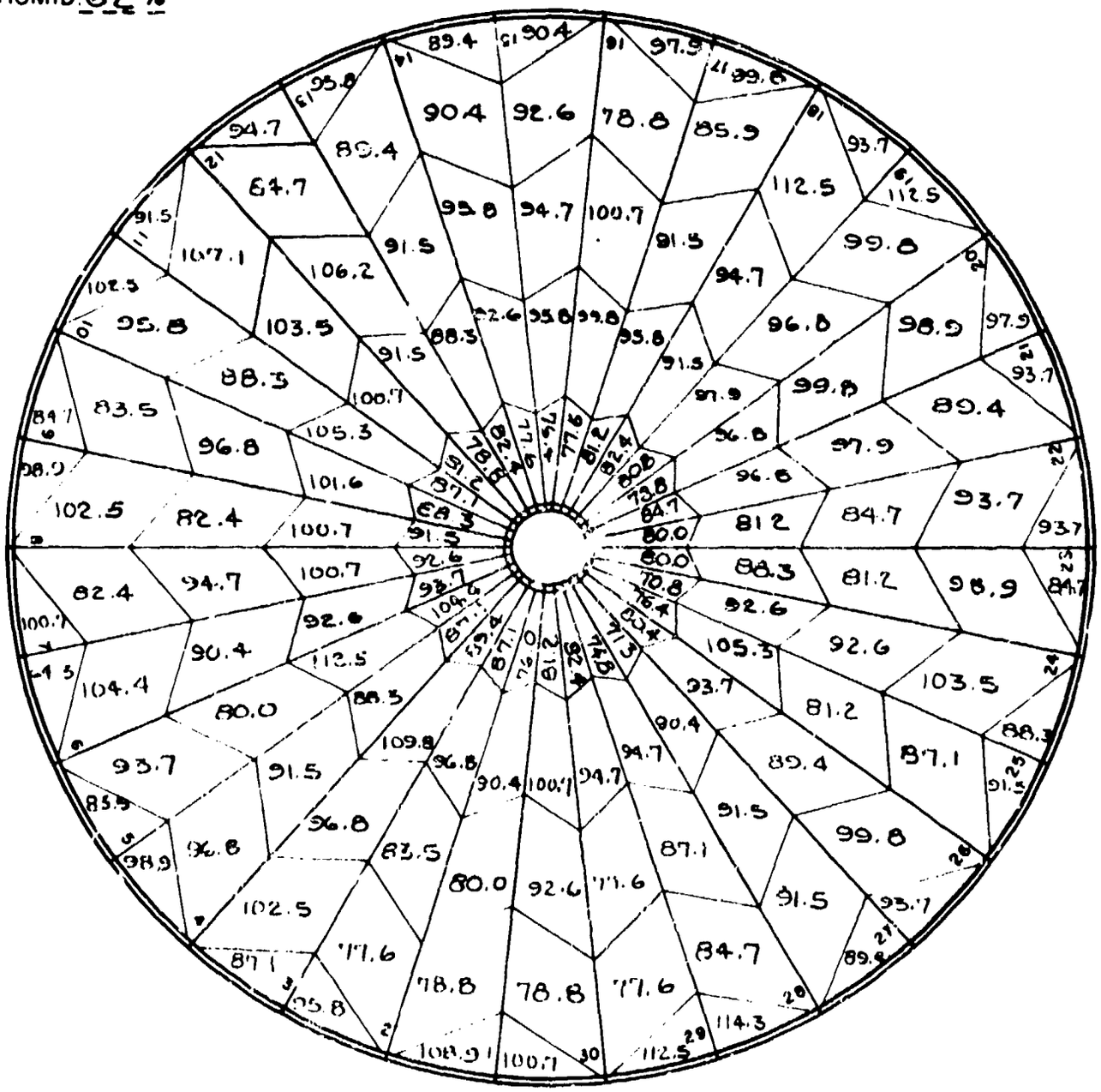
BY L. D.

POROSITY MEASUREMENTS 30 GORE CANOPY **BEFORE 100 M.P.H.**

SERIAL NO. 350239

TEMP. 72 °F

HUMID. 62 %



AVERAGE POROSITY 91.4

DATE 9-5-50

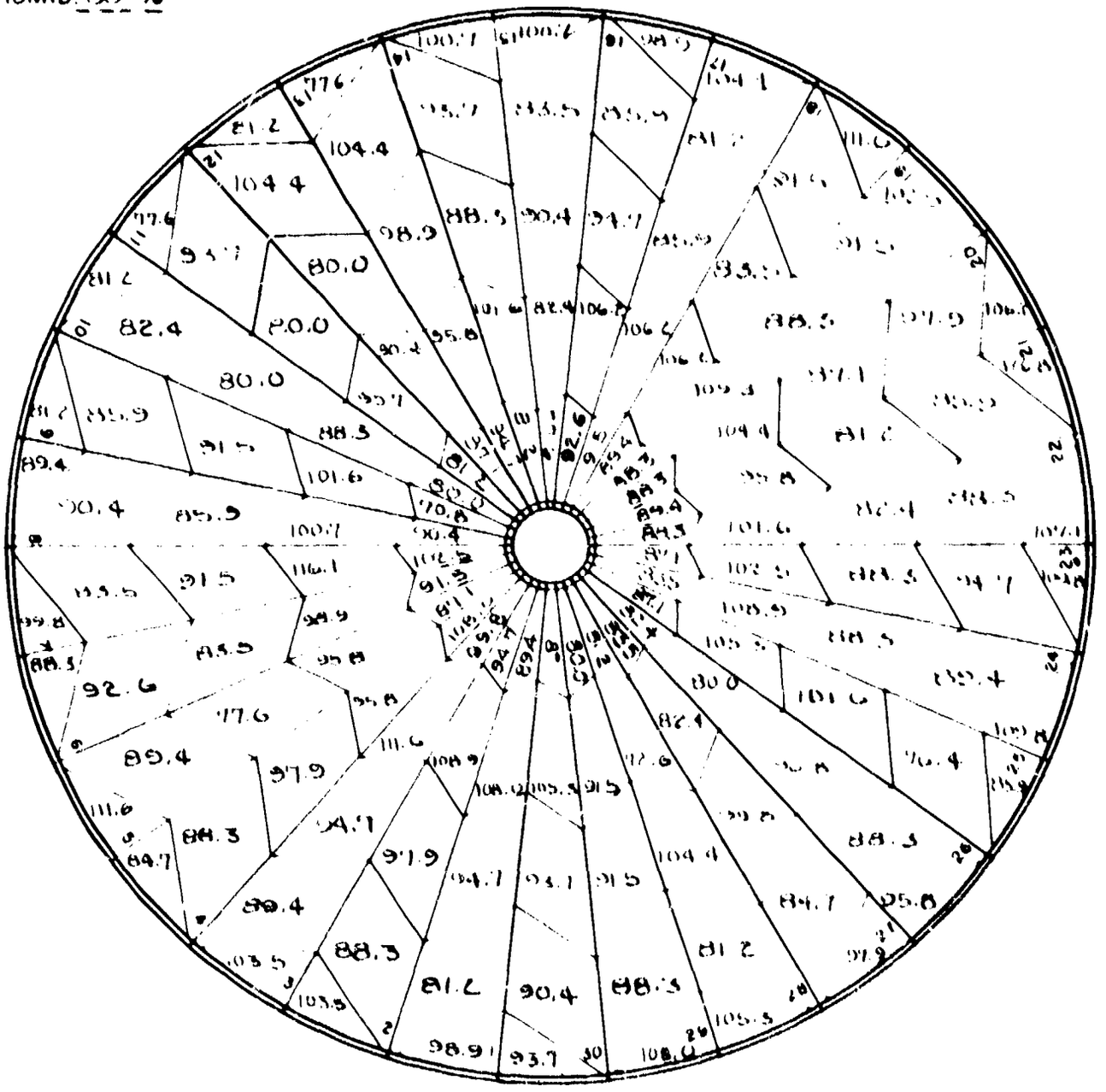
BY A.Y.

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350240

TEMP. 72 °F

HUMID. 65 %



AVERAGE POROSITY 92.8

DATE 9-18-5

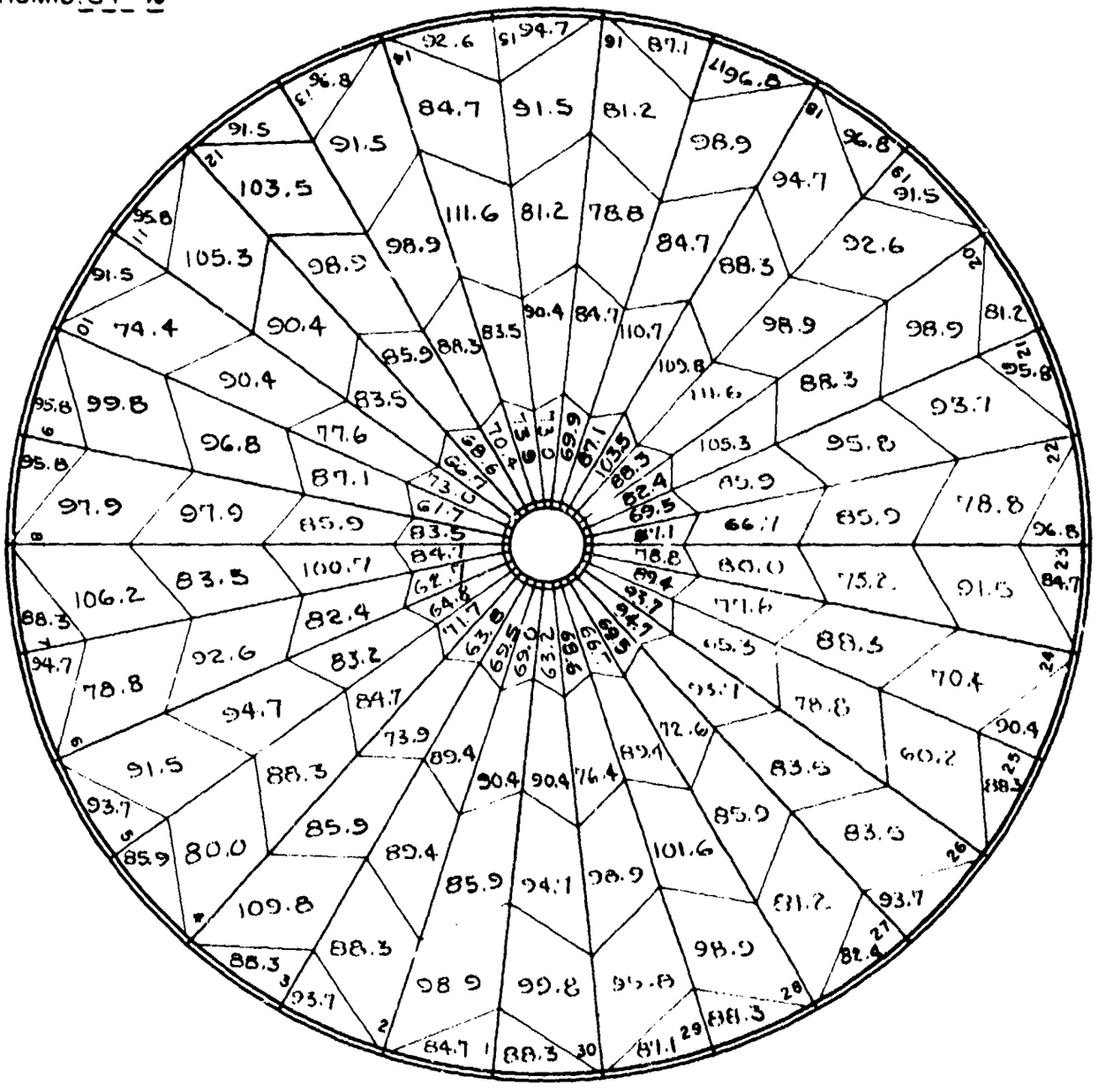
BY. [illegible]

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350241

TEMP. 70 °F

HUMID. 64 %



AVERAGE POROSITY 87.0

DATE 9 22 50

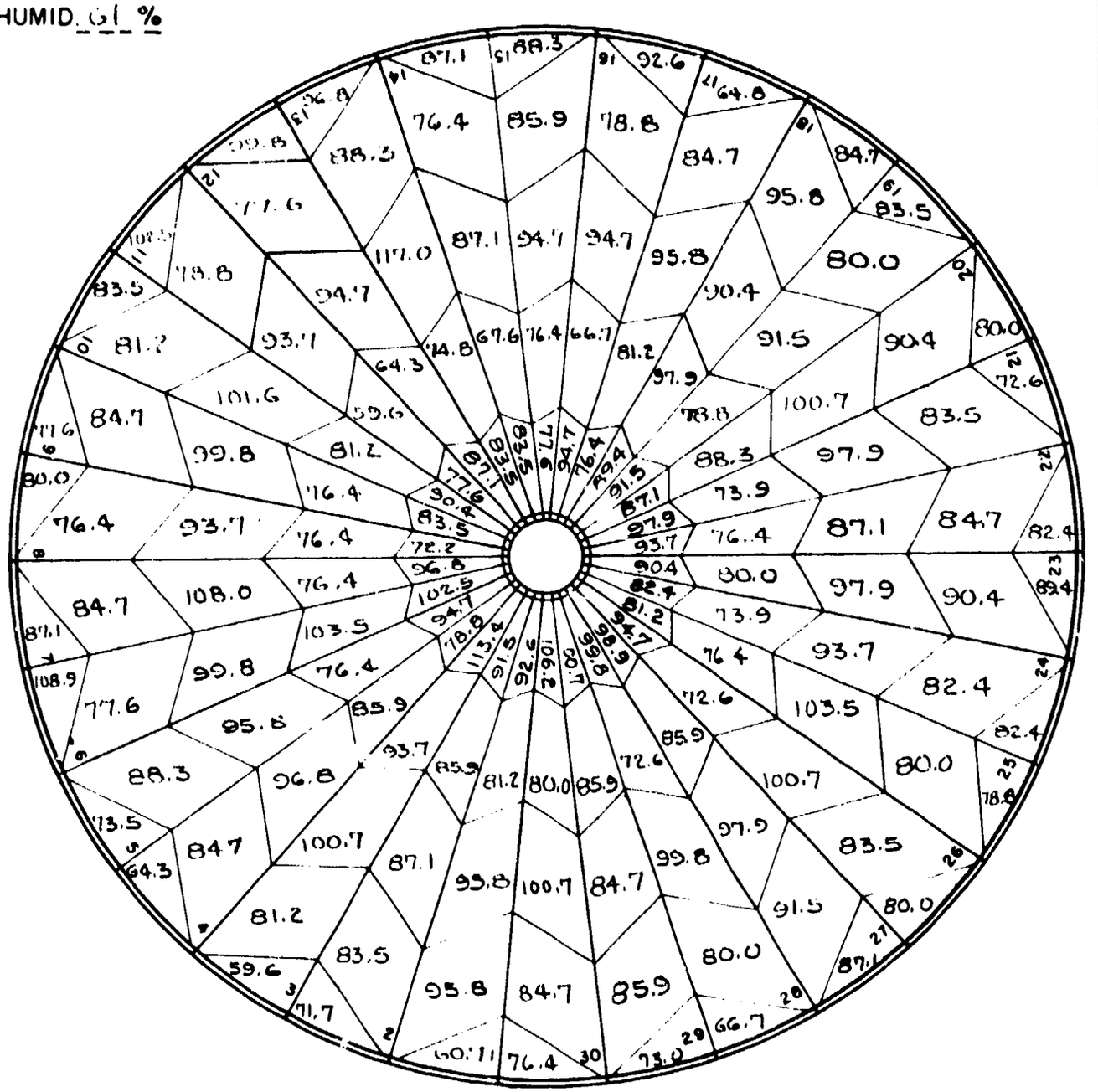
BY L.D

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350242

TEMP. 73 °F

HUMID. 61 %



AVERAGE POROSITY 86.3

DATE 8-21-50

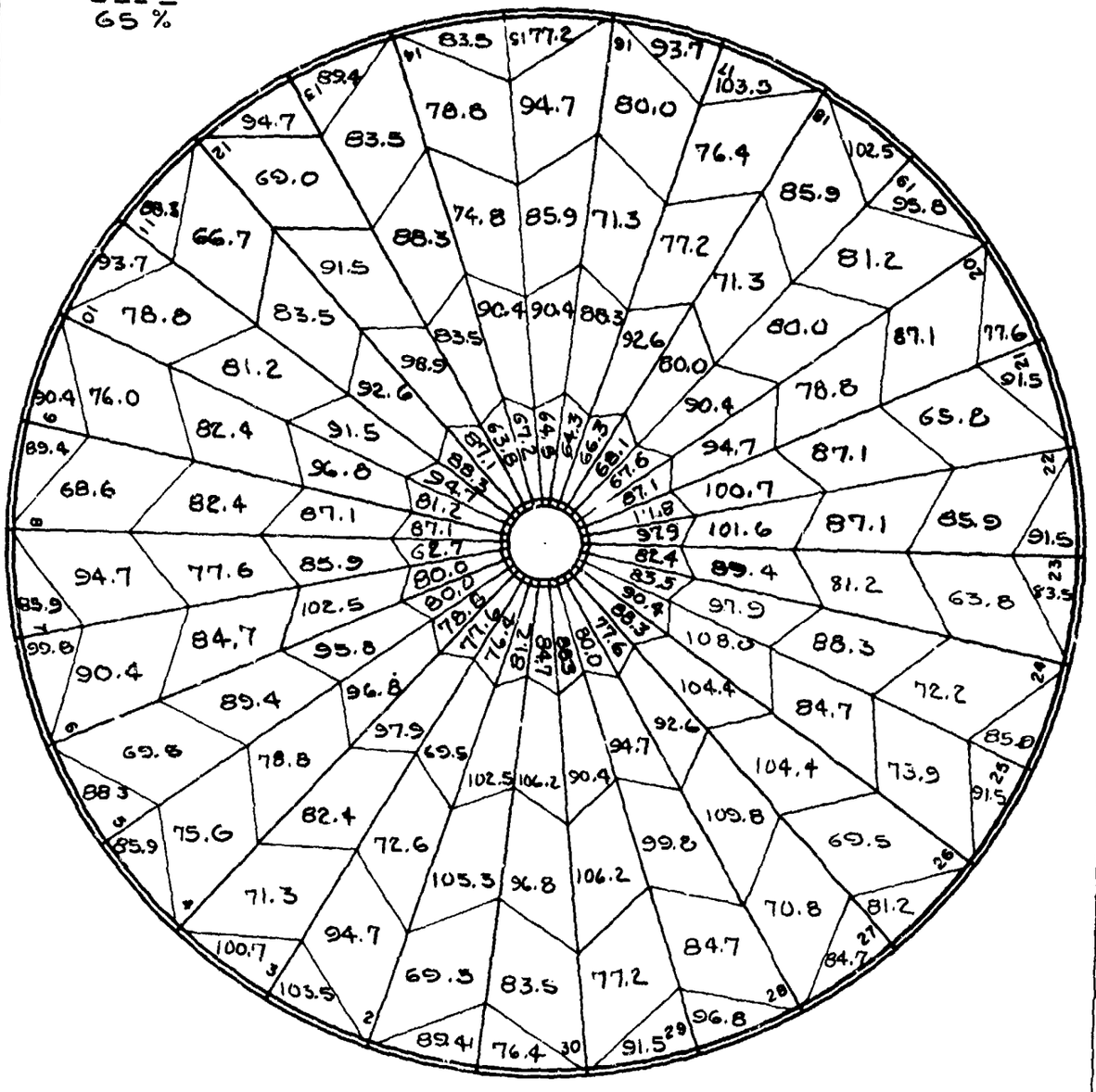
BY L.D

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350243

TEMP. 74 °F

HUMID. 57 %
65 %



AVERAGE POROSITY: 85.5

DATE 8-21-50

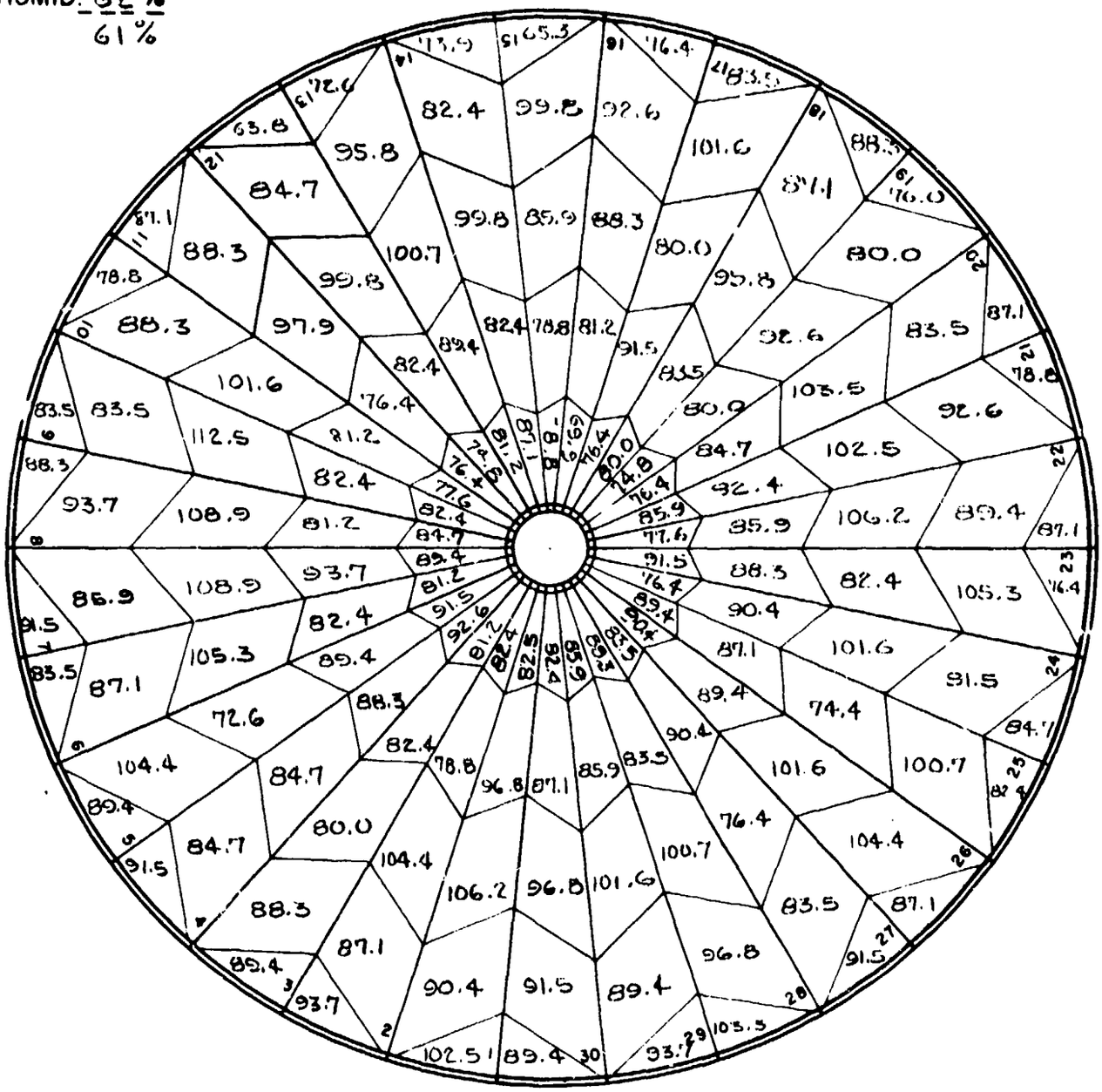
BY L.D

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350244

TEMP. 74 °F

HUMID. 62 %
61 %



AVERAGE POROSITY: 87.9

DATE 8-14-50

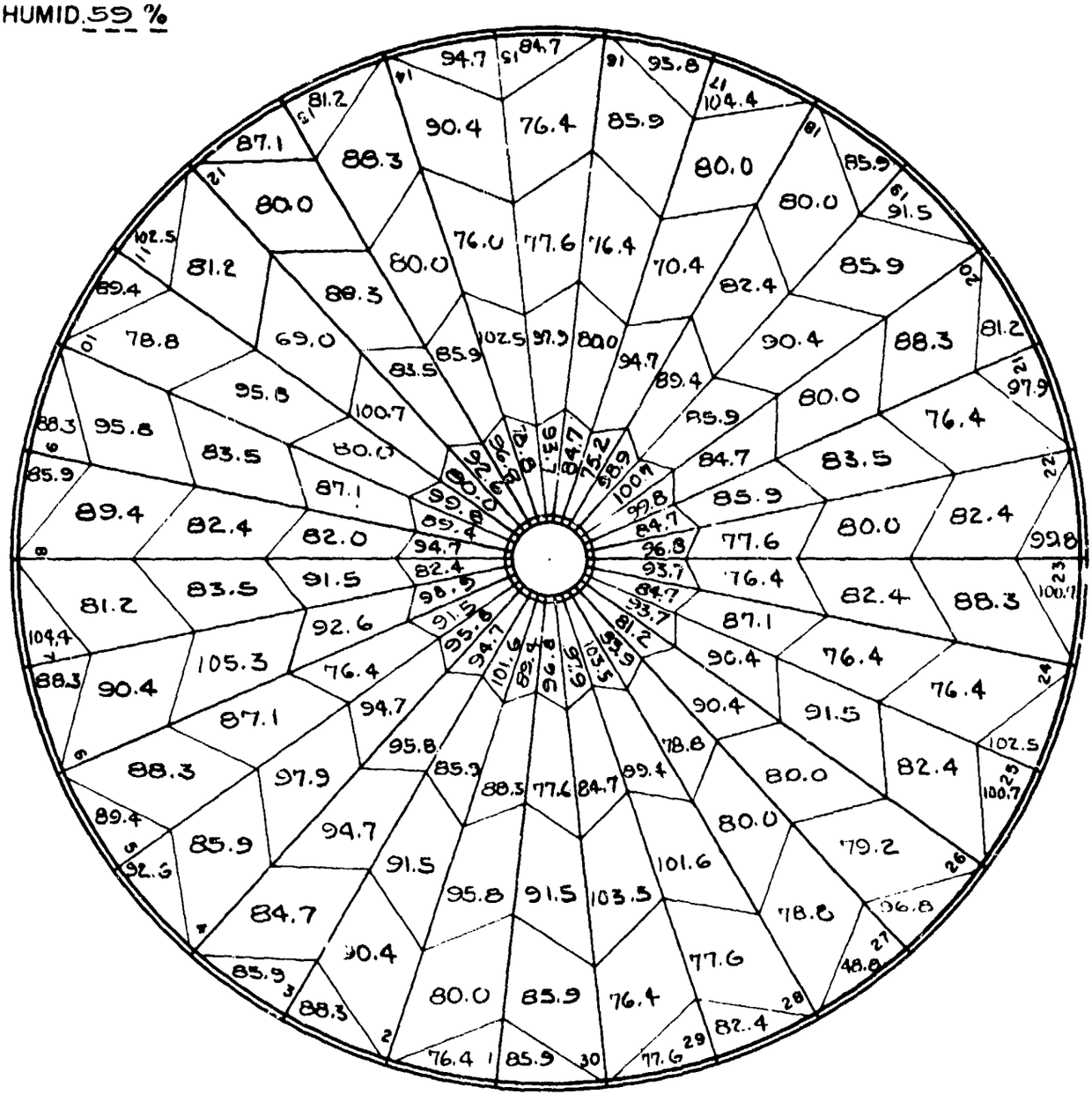
BY L.D

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350245

TEMP. 72 °F

HUMID. 59 %



AVERAGE POROSITY: 87.7

DATE 8-15-50

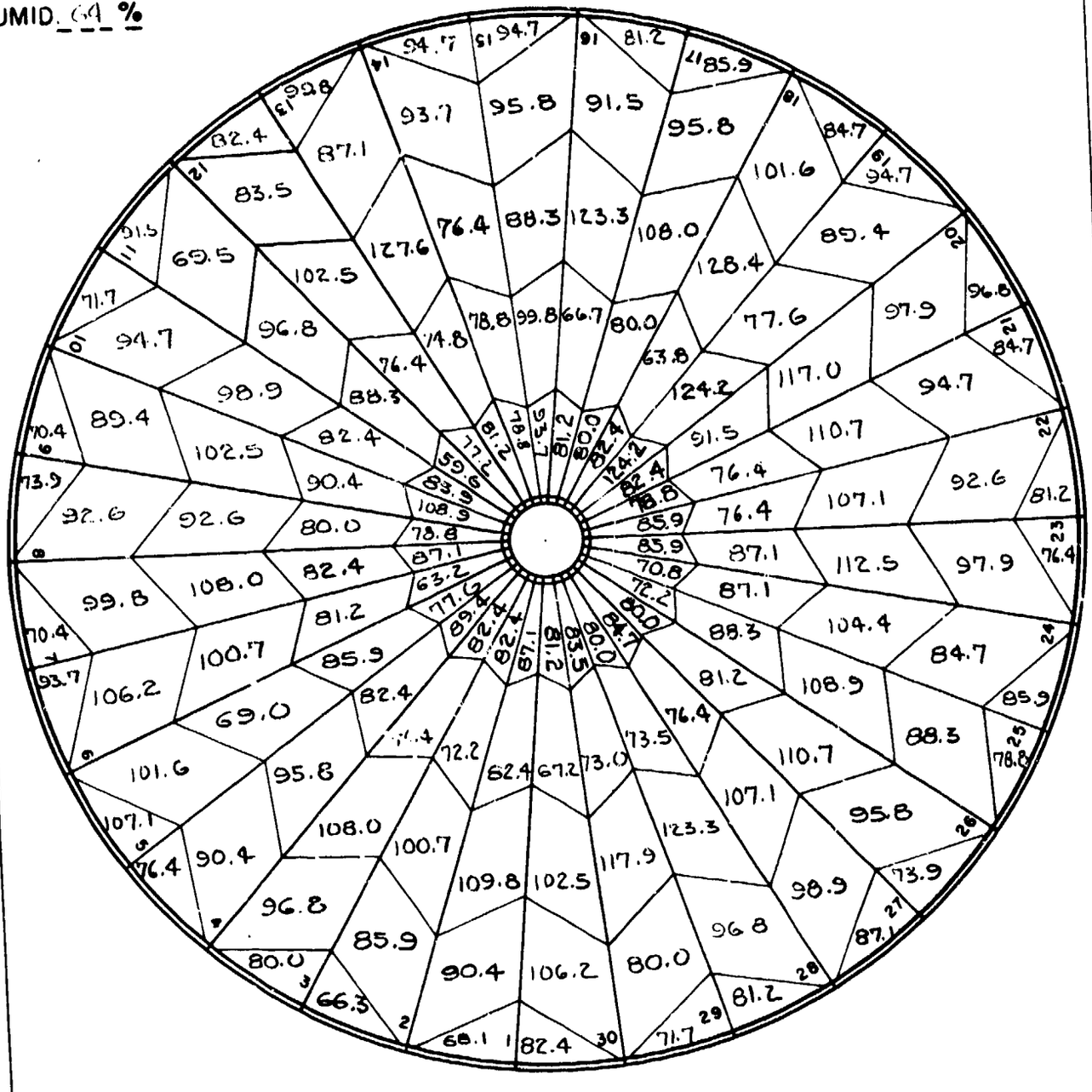
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350246

TEMP. 111 °F

HUMID. 64 %



AVERAGE POROSITY: 89.0

DATE 8-15-50

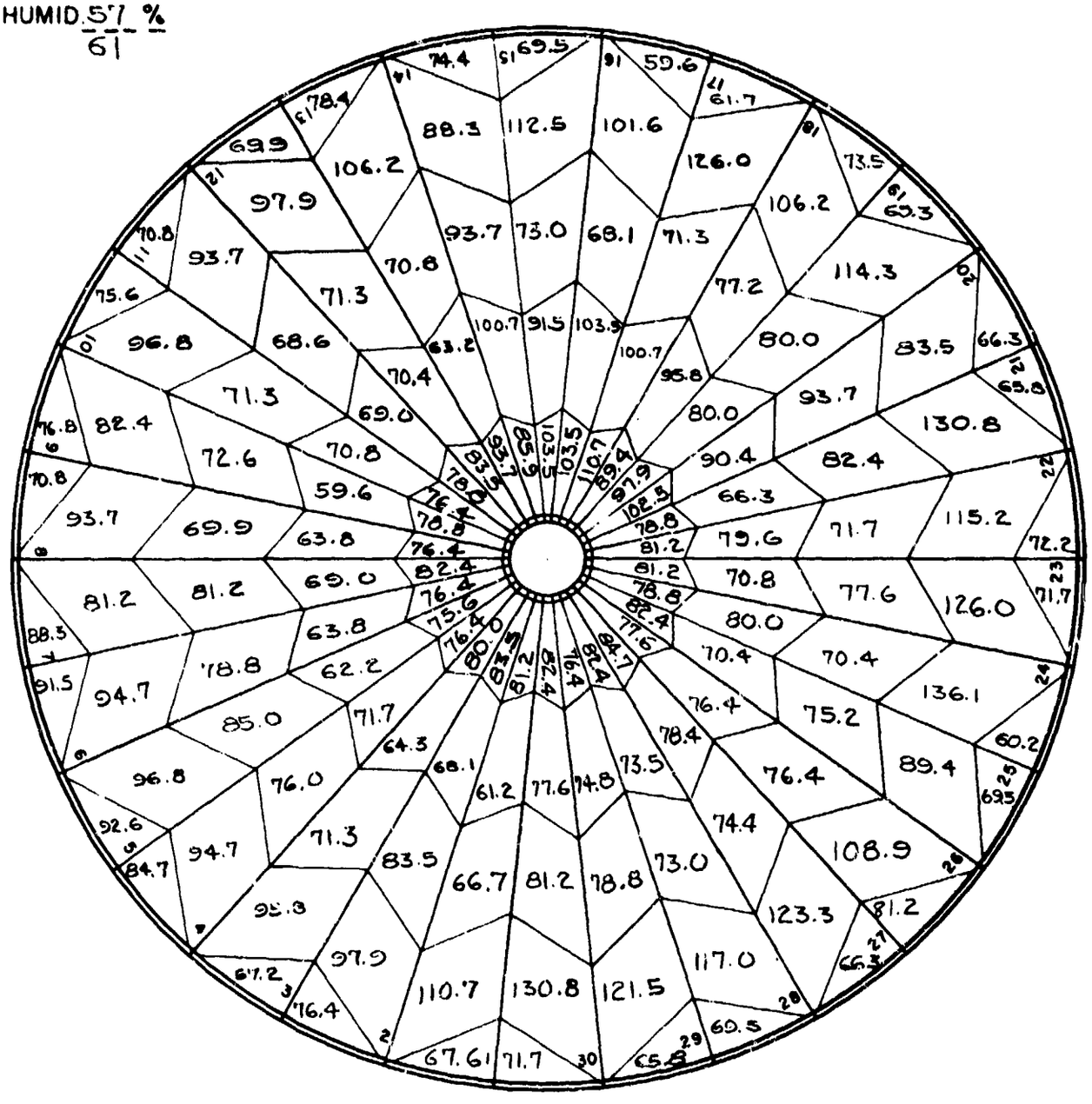
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350247

TEMP. 80 °F

HUMID. 57 %
61



AVERAGE POROSITY: 83.0

DATE 8-15-50

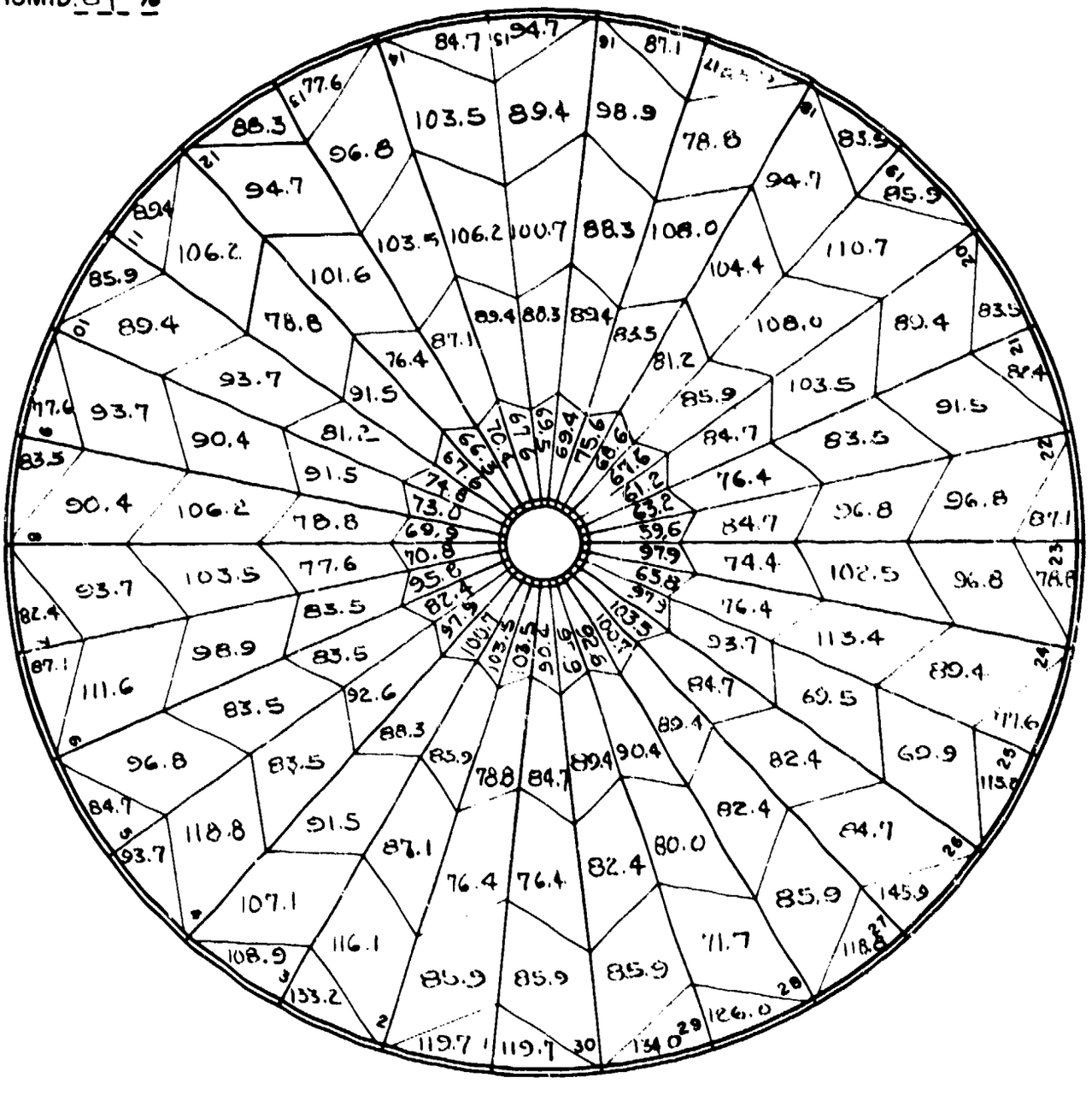
BY L.D

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H. TEST

SERIAL NO. 350248

TEMP. 71 °F

HUMID. 64 %



AVERAGE POROSITY 89.9

DATE 9-6-50

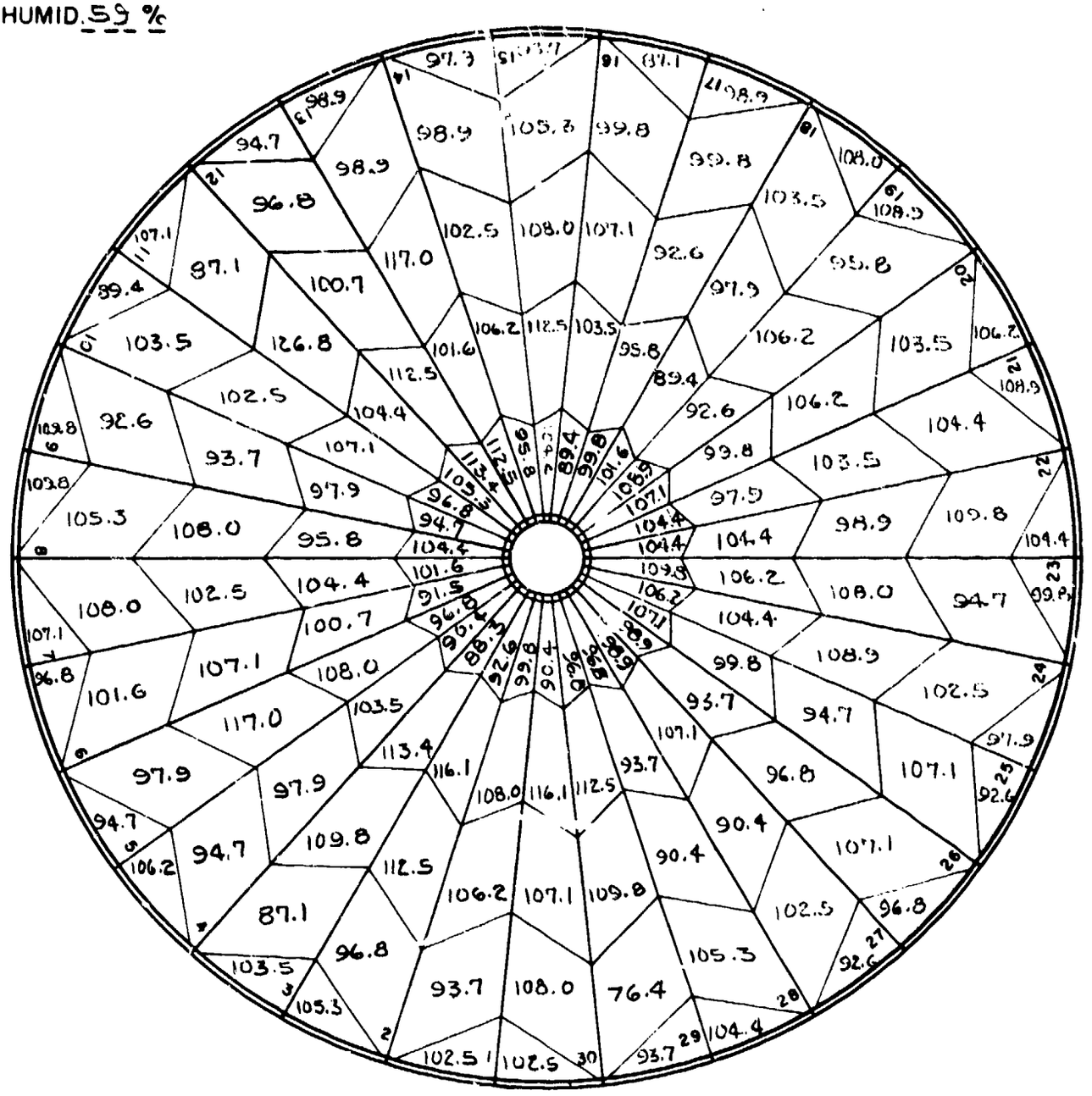
BY A.V.

POROSITY MEASUREMENTS 30 GORE CANOPY BEFORE 100 M.P.H.

SERIAL NO. 350249

TEMP. 80 °F

HUMID. 59 %



AVERAGE POROSITY: 101.7

DATE 9-7-50

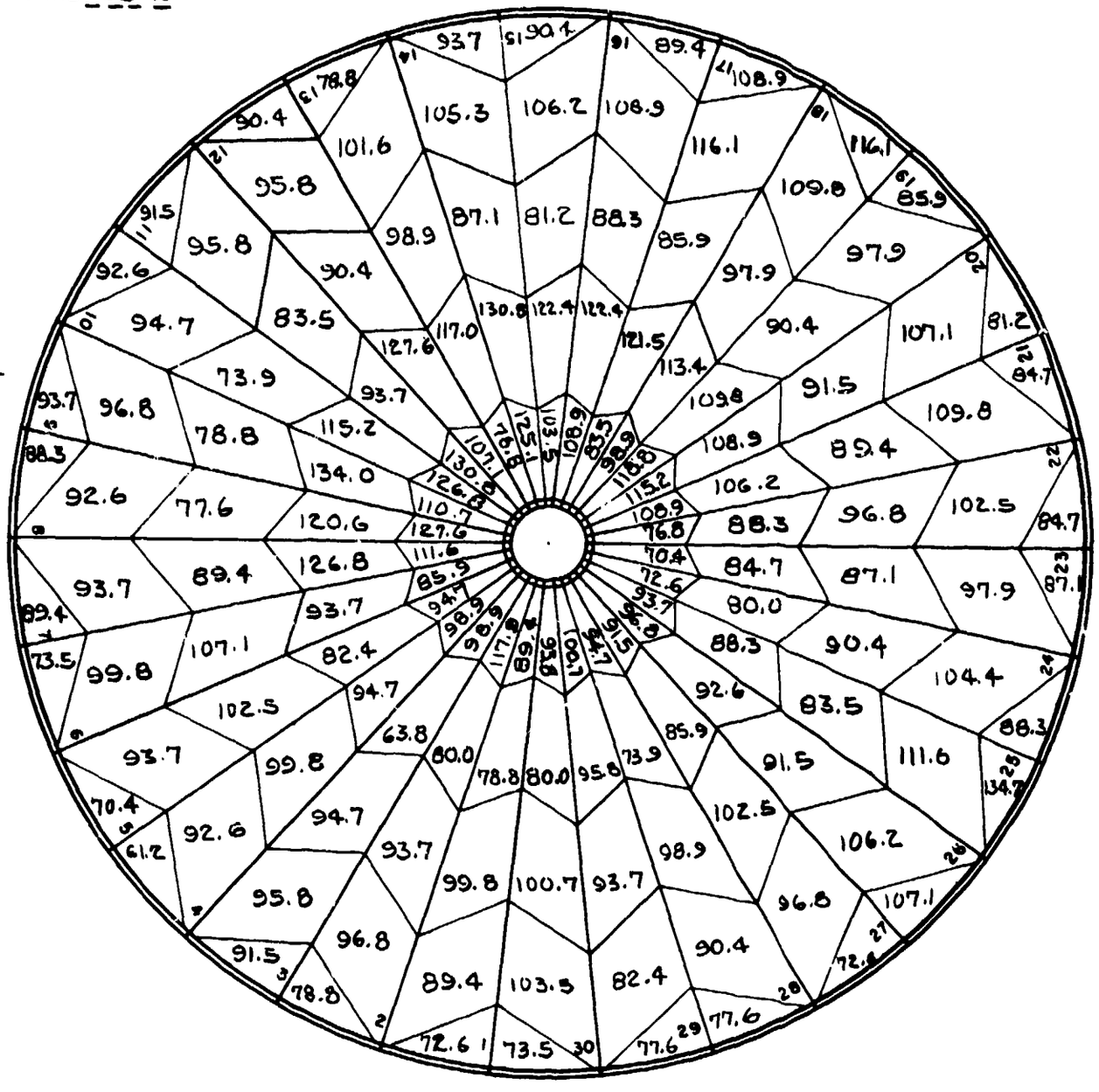
BY A.V

POROSITY MEASUREMENTS 30 GORE CANOPY **BEFORE 100 M.P.H. TEST**

SERIAL NO. 350250

TEMP. 71 °F

HUMID. 65 %



AVERAGE POROSITY: 96.3

DATE 9-7-50

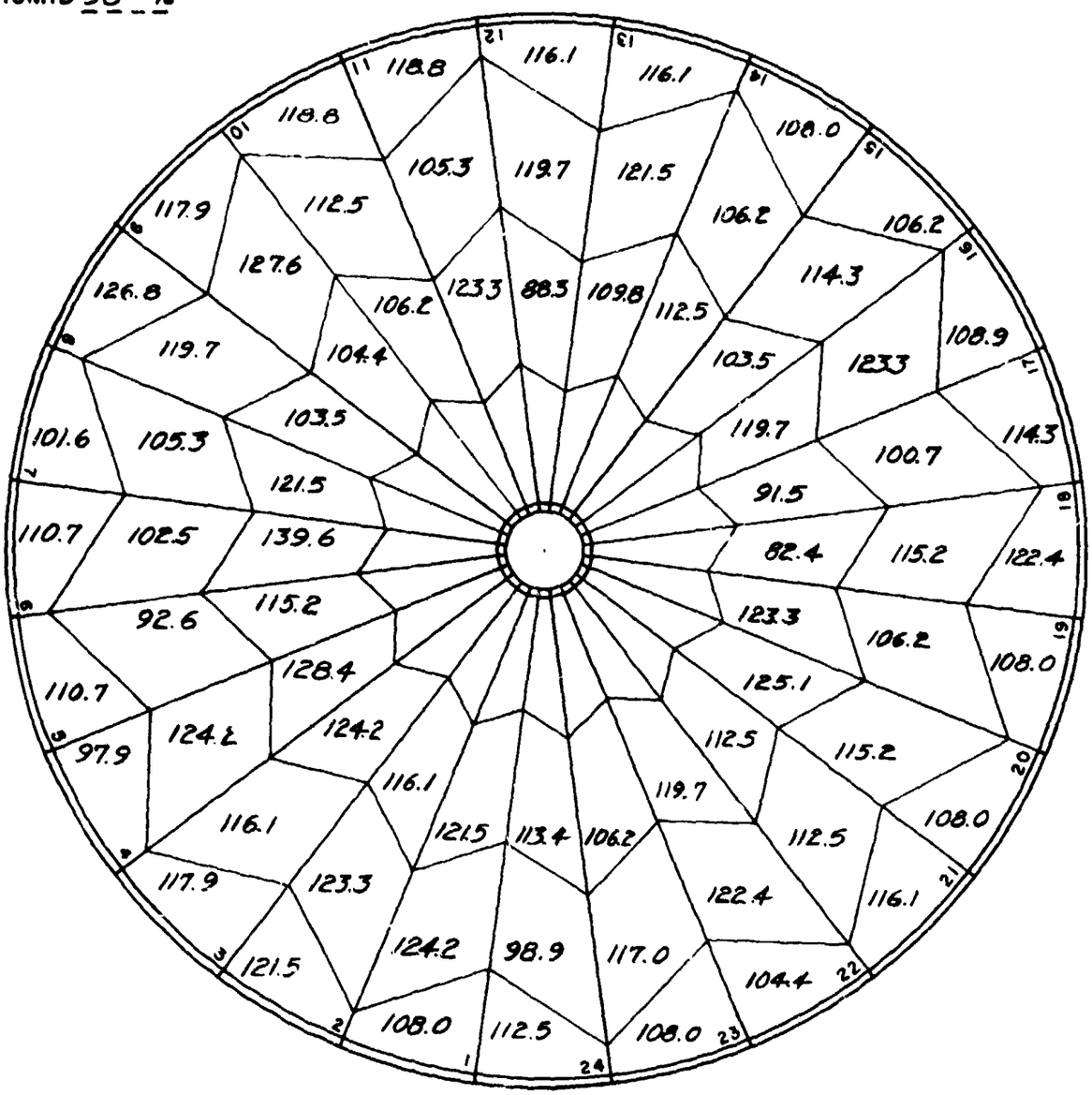
BY A.Y.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350201

TEMP. 71 °F

HUMID 38 %



AVERAGE POROSITY: 113.0

DATE 11-7-50

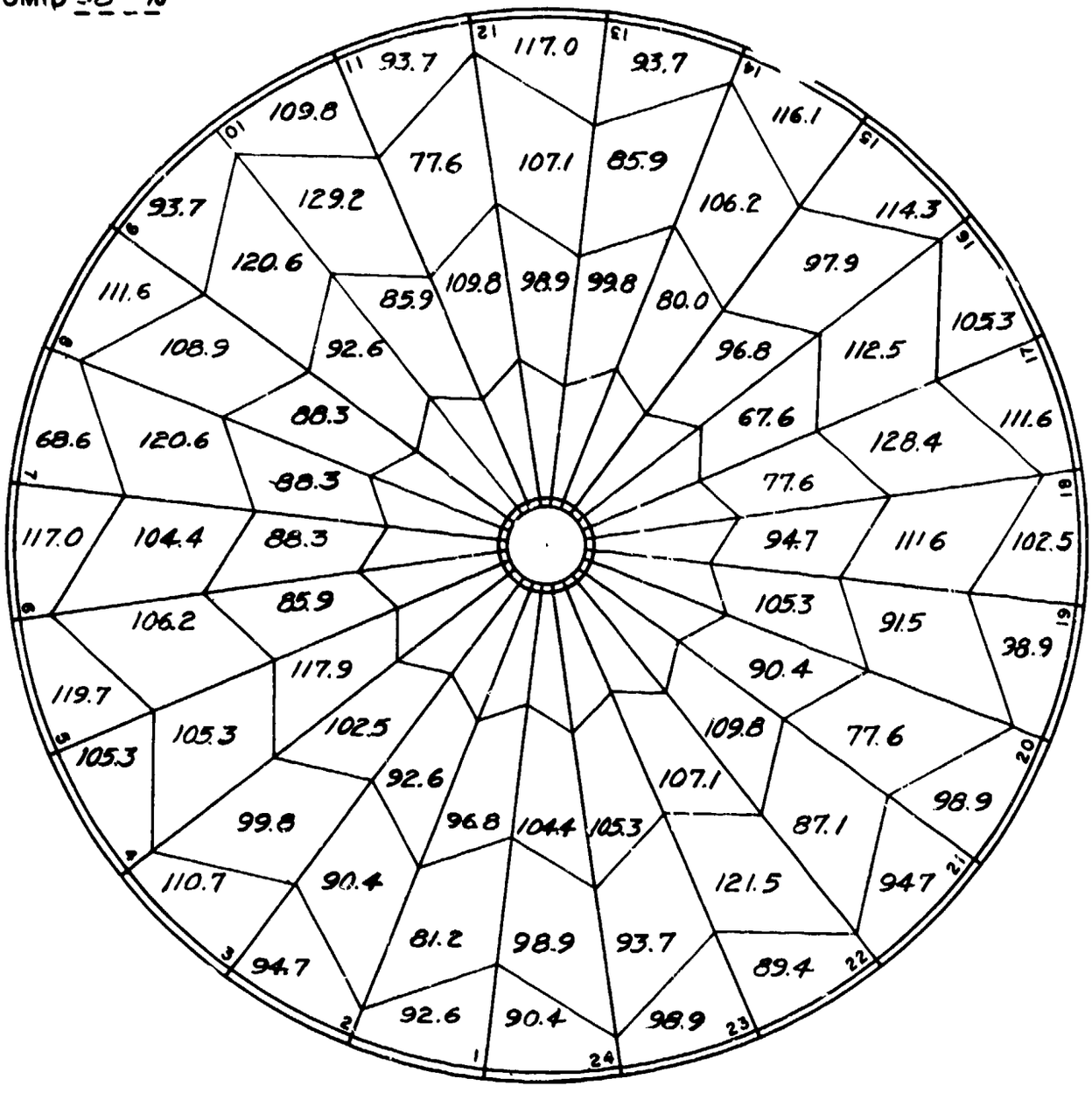
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350202

TEMP. 70 °F

HUMID 38 %



AVERAGE POROSITY: 100.0

DATE 11-8-50

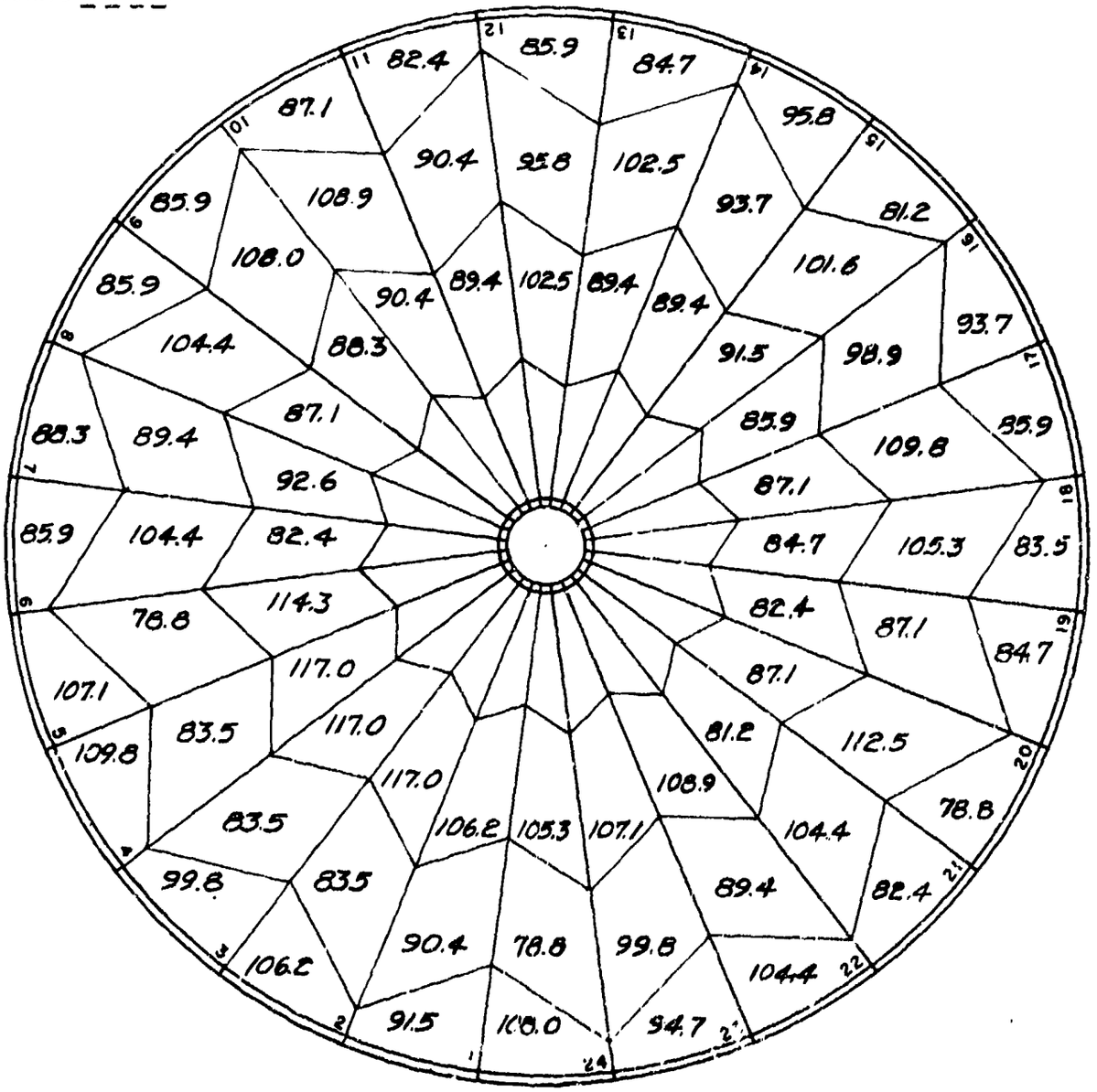
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350203

TEMP. 72 °F

HUMID 42 %



AVERAGE POROSITY: 94.4

DATE 11-2-50

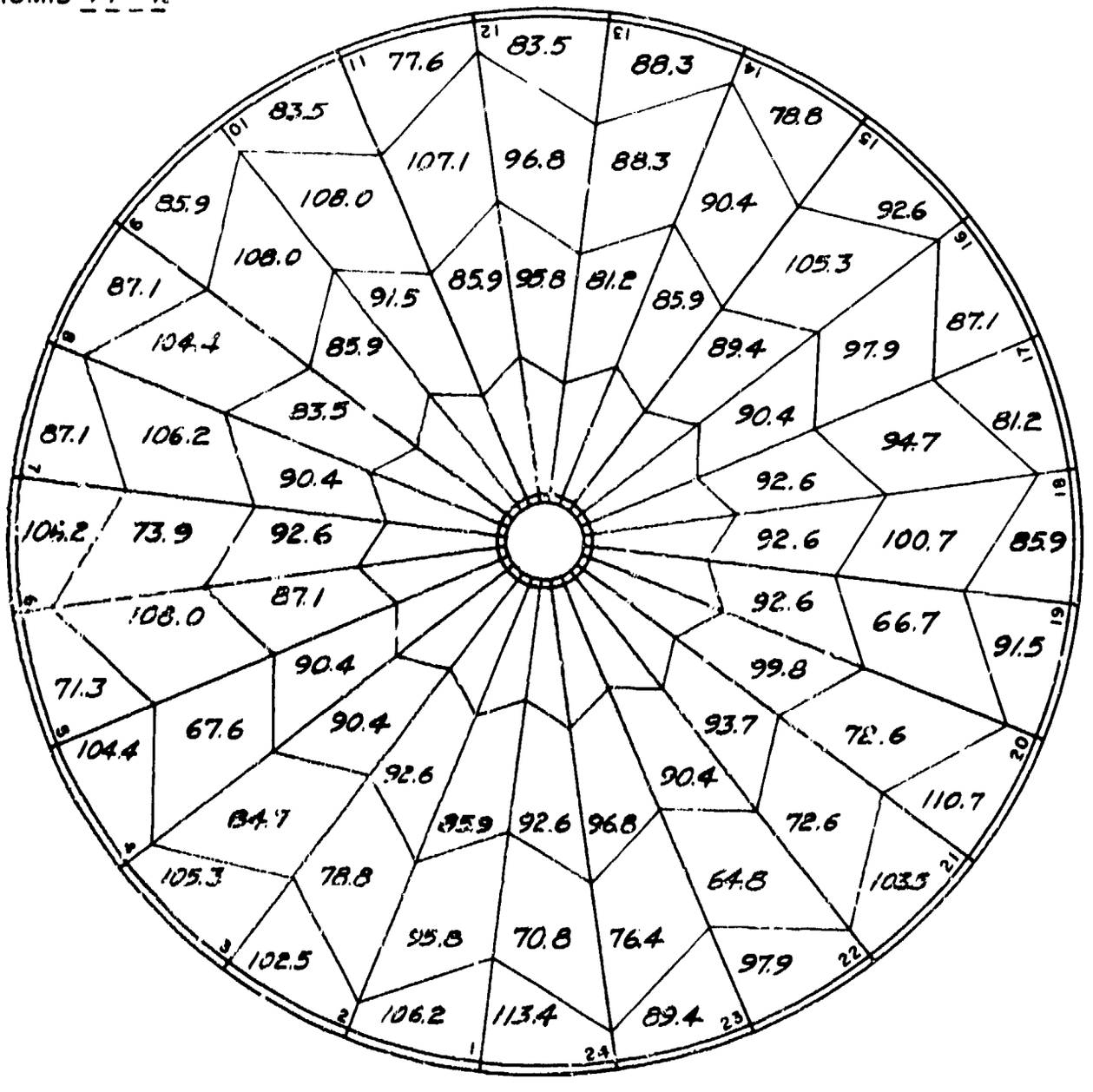
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350204

TEMP. 74 °F

HUMID 47 %



AVERAGE POROSITY: 90.7

DATE 11-1-50

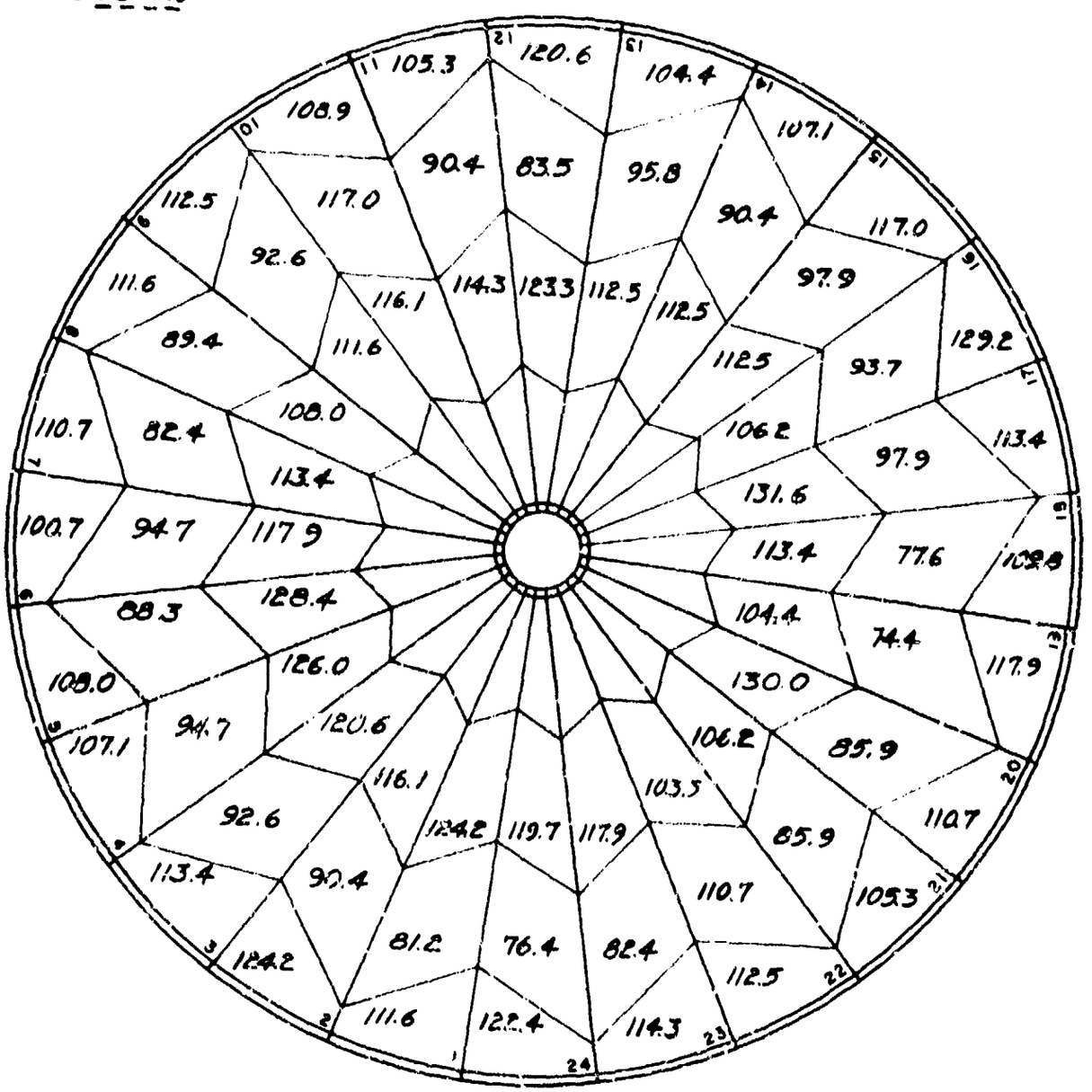
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350205

TEMP. 70 °F

HUMID 32 %



AVERAGE POROSITY: 106.3

DATE 11-13-50

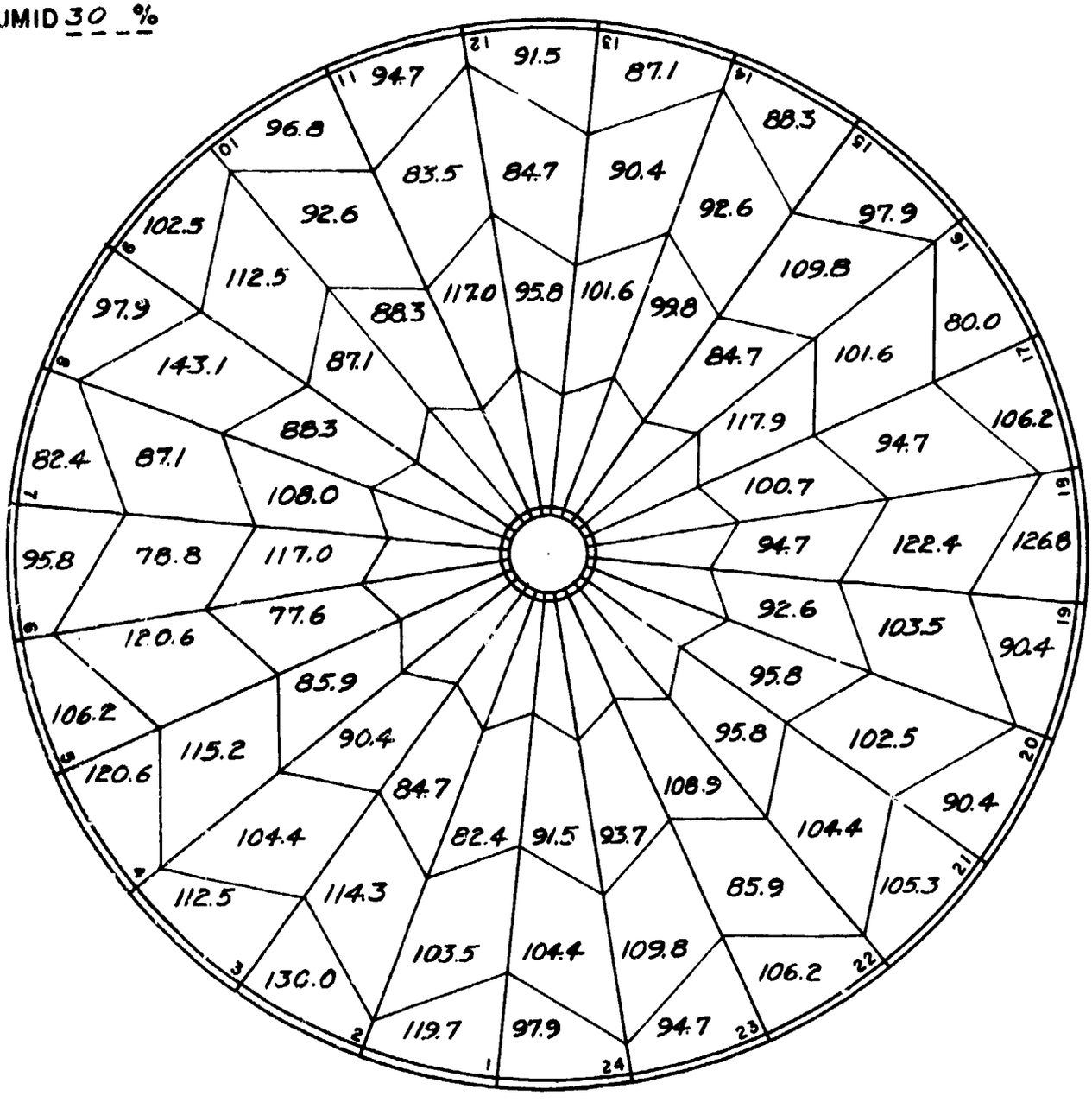
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350206

TEMP. 70 °F

HUMID 30 %



AVERAGE POROSITY: 99.8

DATE 11-14-50

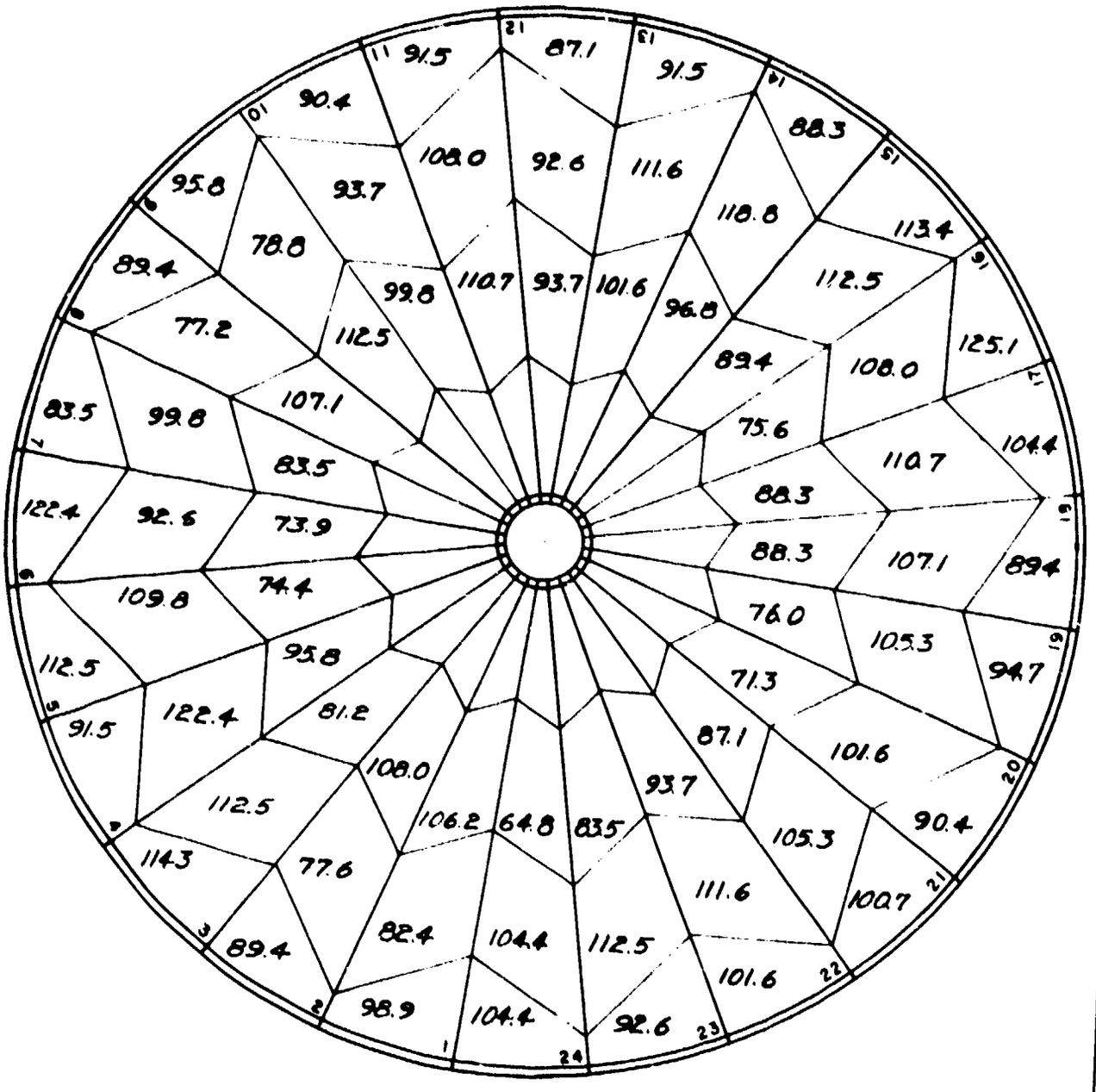
BY A.V

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350207

TEMP. 71 °F

HUMID 38 %



AVERAGE POROSITY: 97.0

DATE 11-7-57

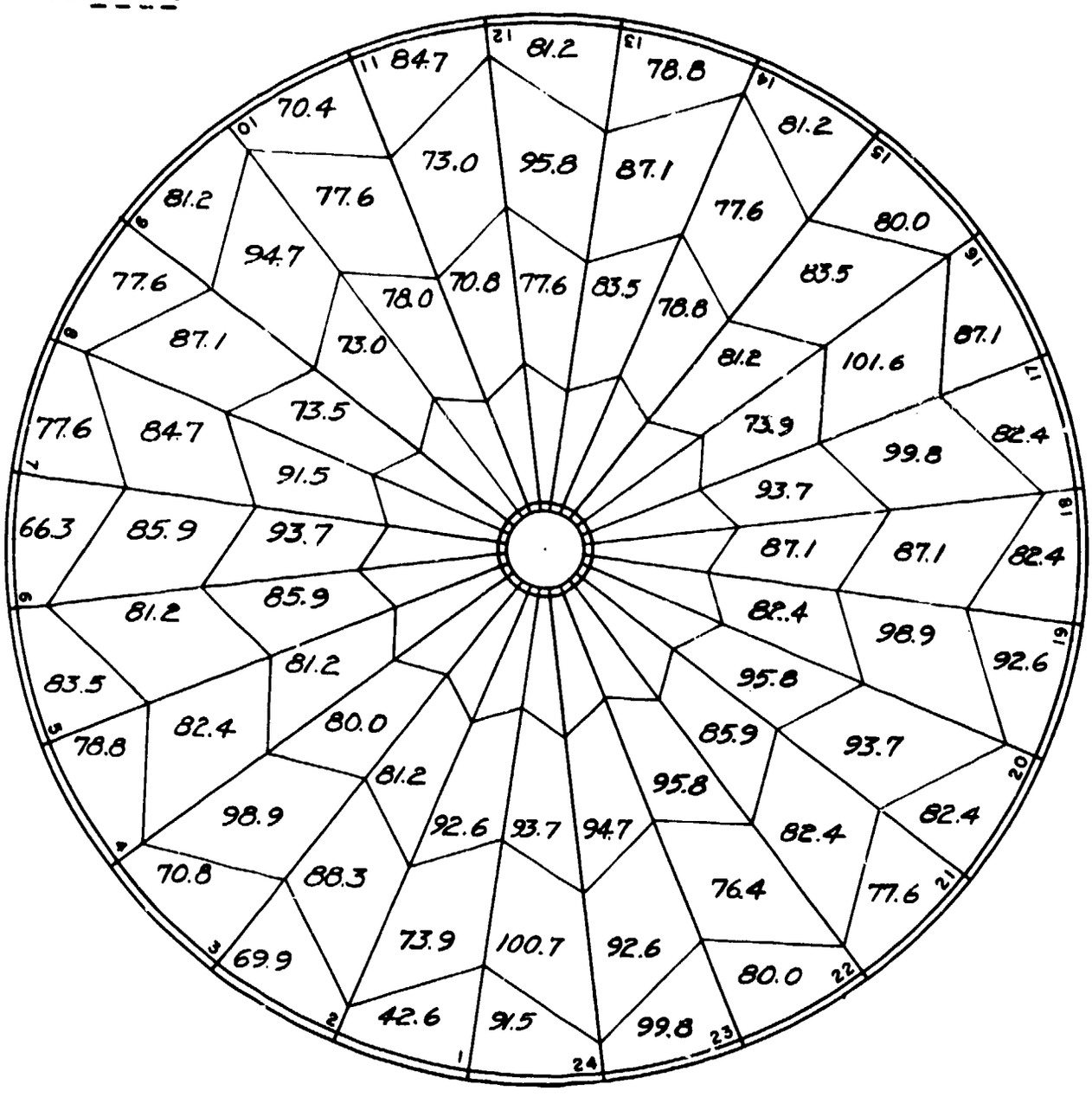
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350208

TEMP. 72 °F

HUMID 35 %



AVERAGE POROSITY 83.8

DATE 11-9-50

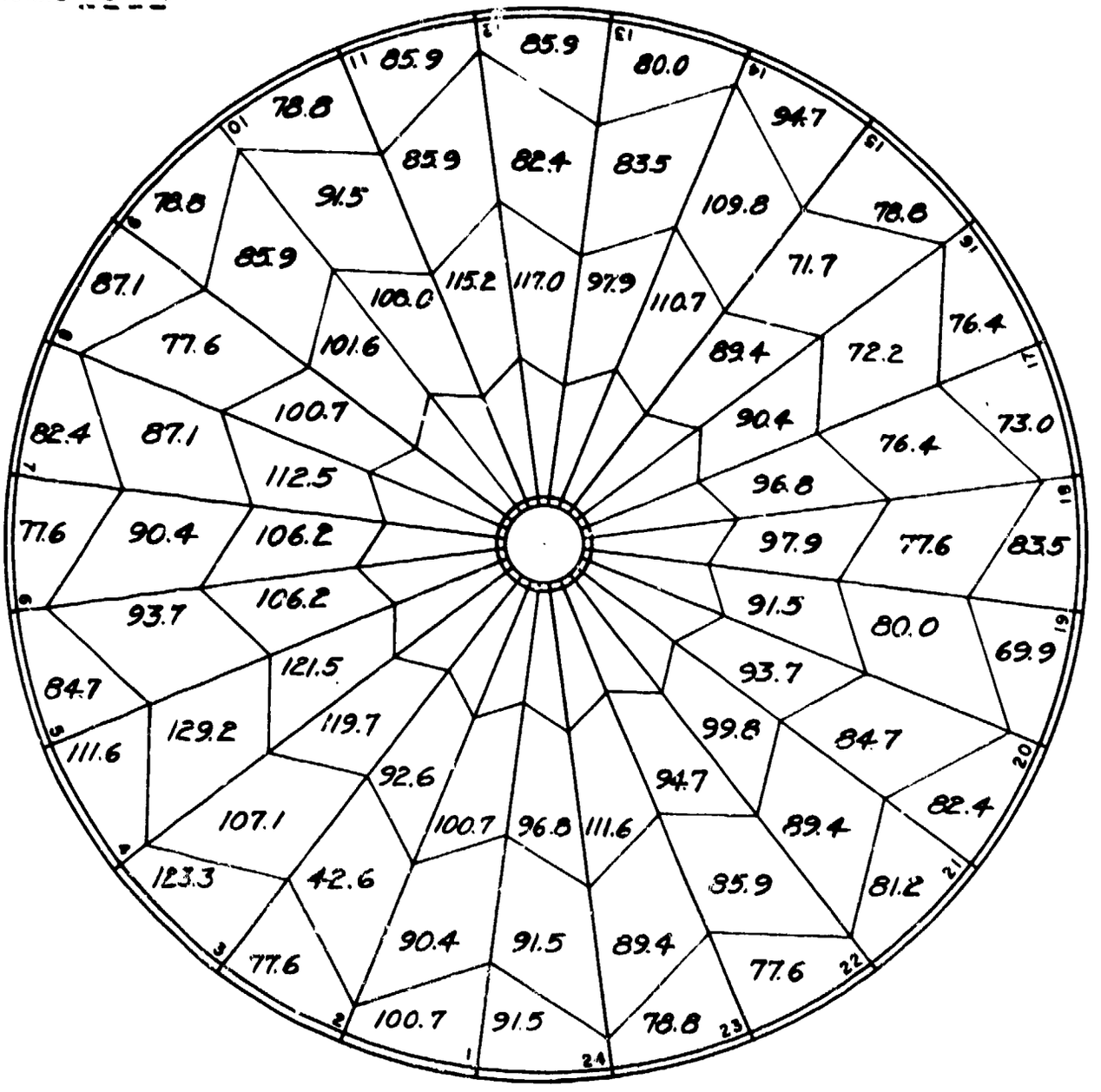
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350209

TEMP. 74 °F

HUMID 35 %



AVERAGE POROSITY: 91.5

DATE 11-10-50

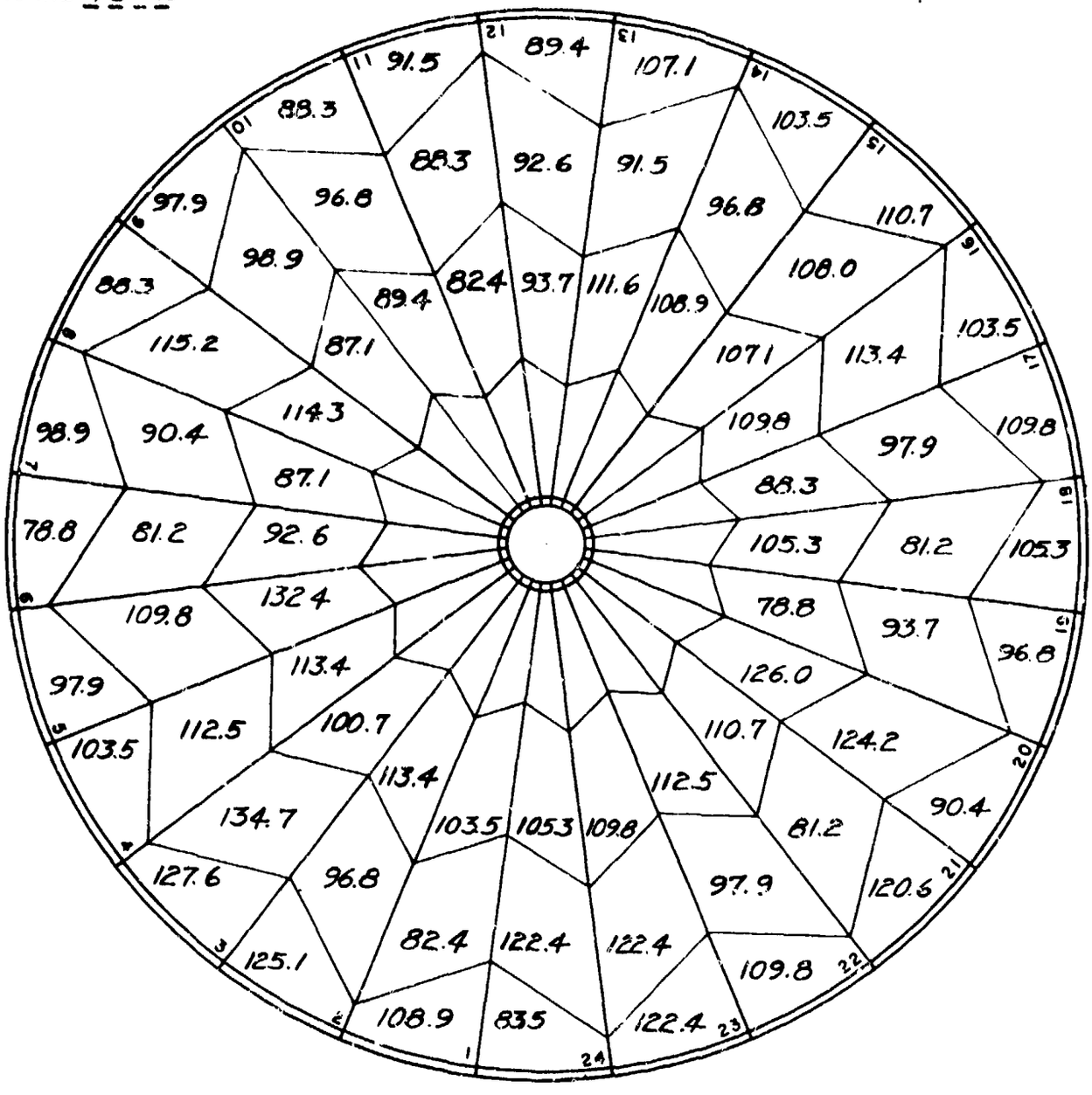
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350210

TEMP. 72 °F

HUMID 40 %



AVERAGE POROSITY: 102.4

DATE 11-3-50

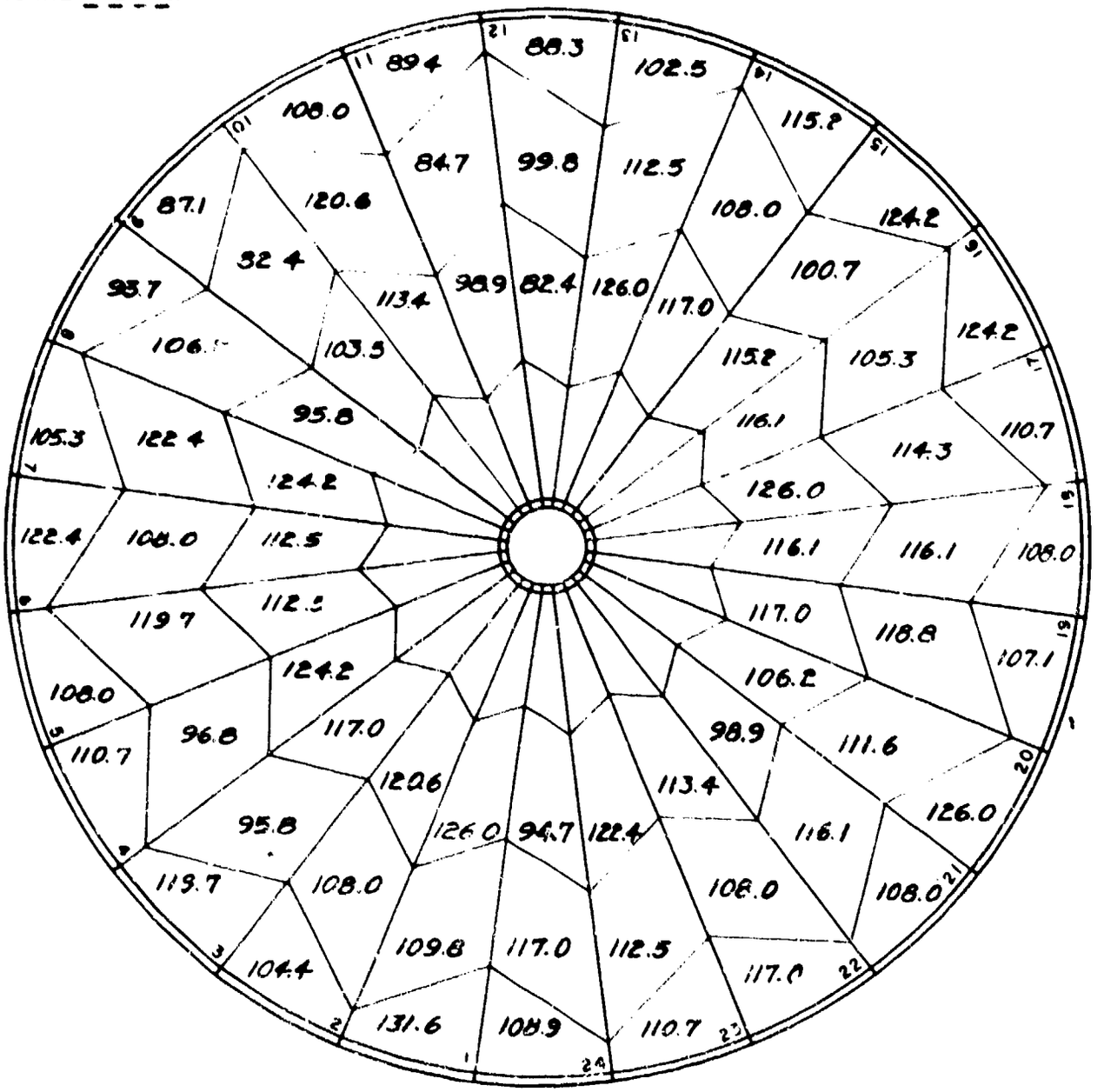
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350211

TEMP 72 °F

HUMID 40 %



AVERAGE POROSITY: 110.1

DATE 11-3-50

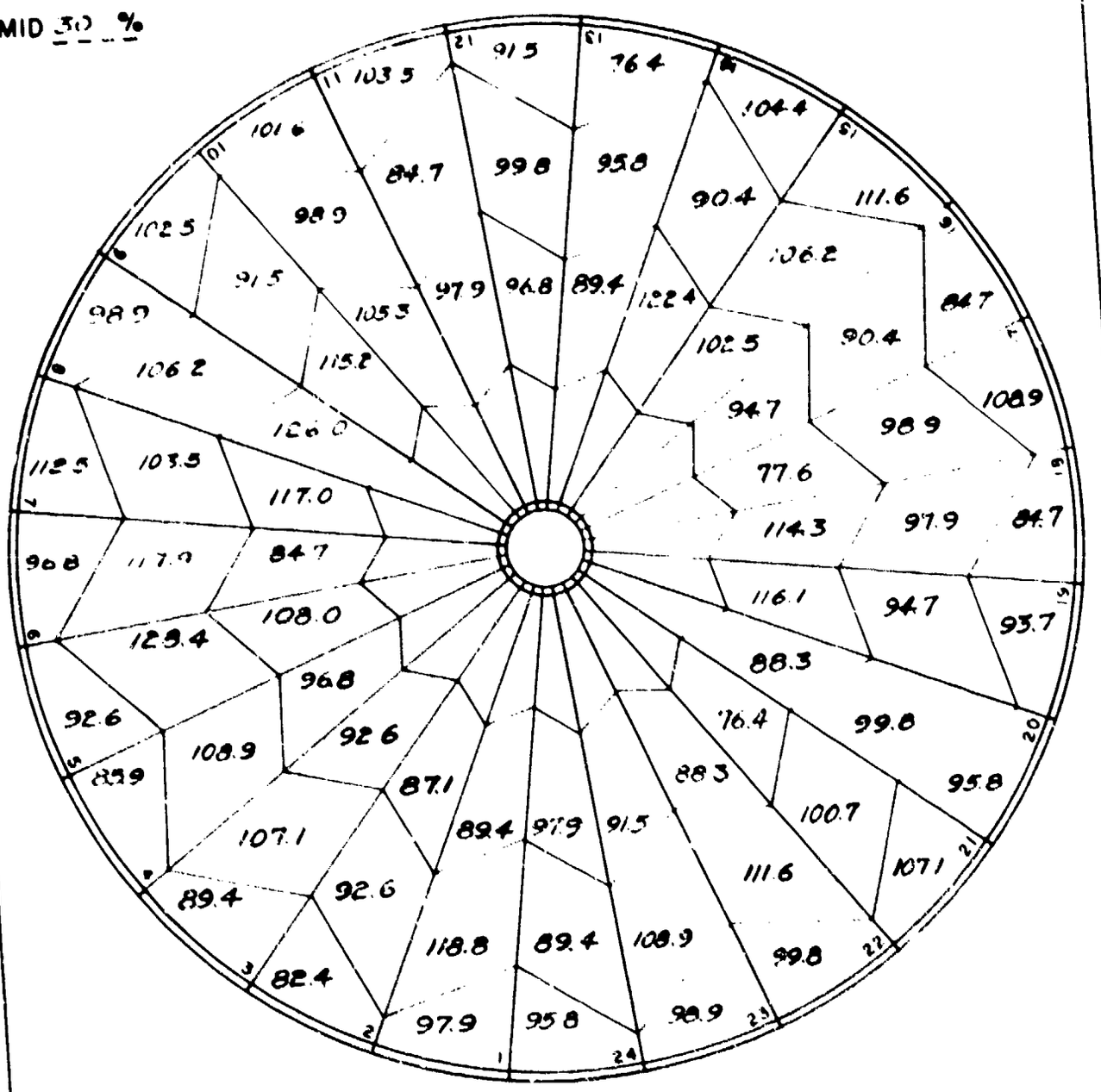
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. [illegible]

TEMP 70 °F

HUMID 30 %



DATE 11-14-50

BY A.V.

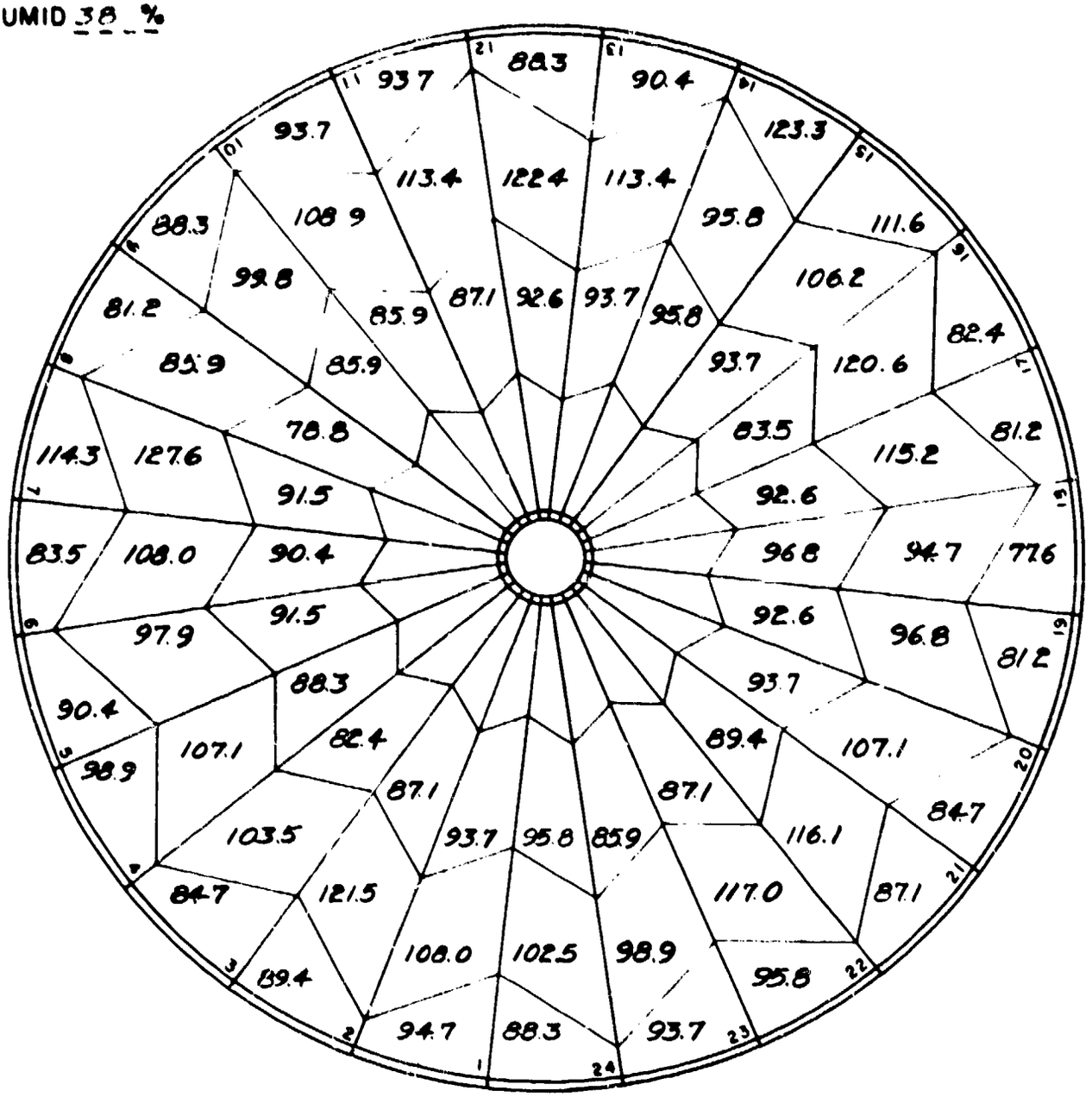
AVERAGE POROSITY: 99.1

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350213

TEMP 71 °F

HUMID 38 %



AVERAGE POROSITY: 96.4

DATE 11-7-50

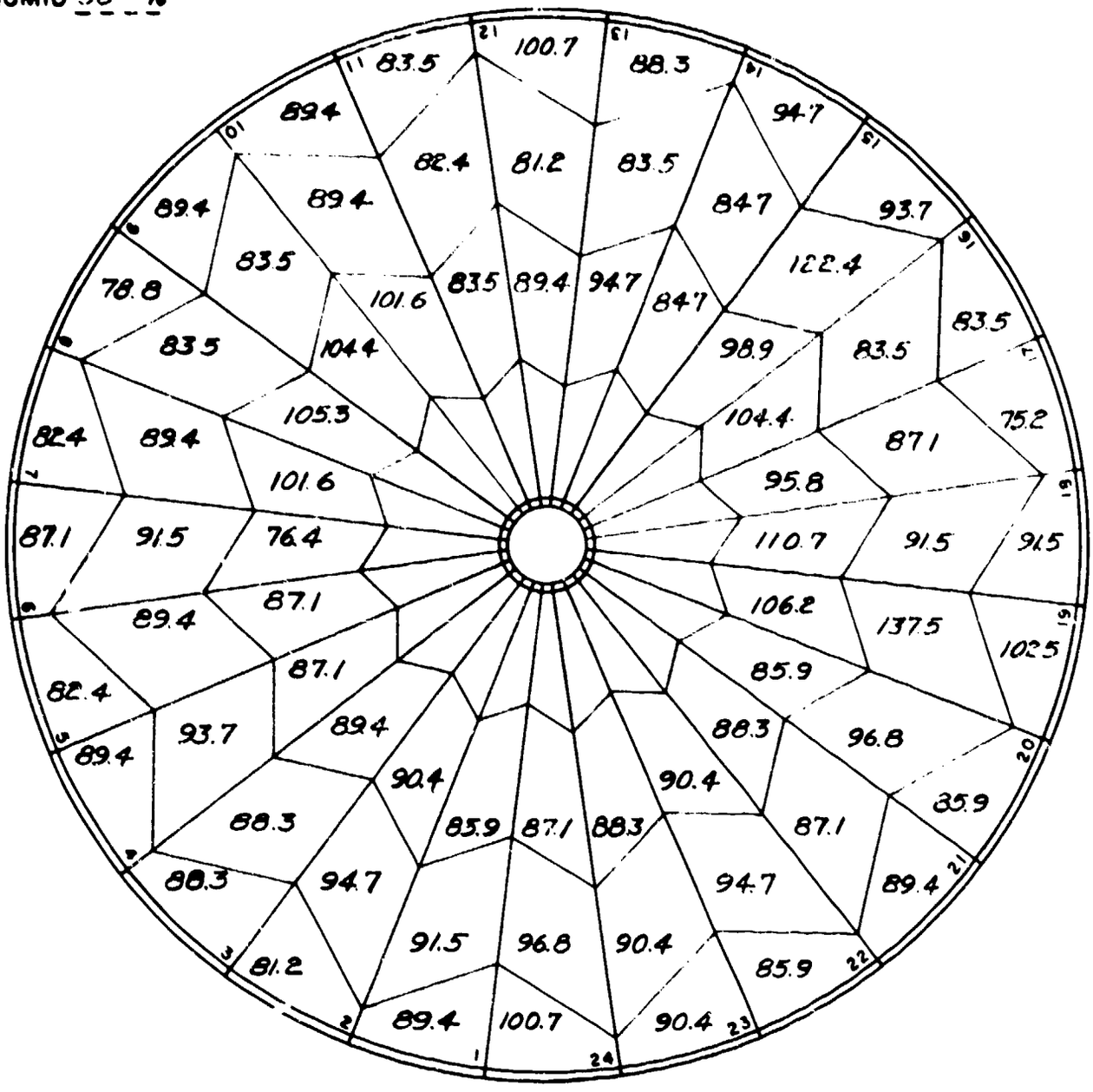
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350214

TEMP 70 °F

HUMID 38 %



AVERAGE POROSITY: 91.3

DATE 11-8-50

BY A.V

POROSITY MEASUREMENTS 4 GORE CANOPY **AFTER 100 M.P.H.**

SERIAL NO 350215

TEMP 74 °F

HUMID 35 %

105.3 106.2 122.4

117.0 108.0

98.9 85.9 90.4

85.9 87.1 95.8 98.9

102.5 87.1

108.0 116.1 112.5 120.6 114.3 116.1 108.0

80.0 76.4 98.9 84.7

126.0 107.1 107.1

120.6 96.8 90.4

115.2 110.7

108.0 80.0 107.1 106.2 81.2 114.3

94.7 107.1 108.9 84.7

96.8 103.5 103.5

106.2

105.3 108.9 100.7 89.4

114.3

106.2 106.2

97.9 94.7 92.6 99.8 90.4 108.0

101.6 91.5 85.9 120.6

105.3 78.8 108.0

108.9 103.5

103.5 90.4 96.8

101.6

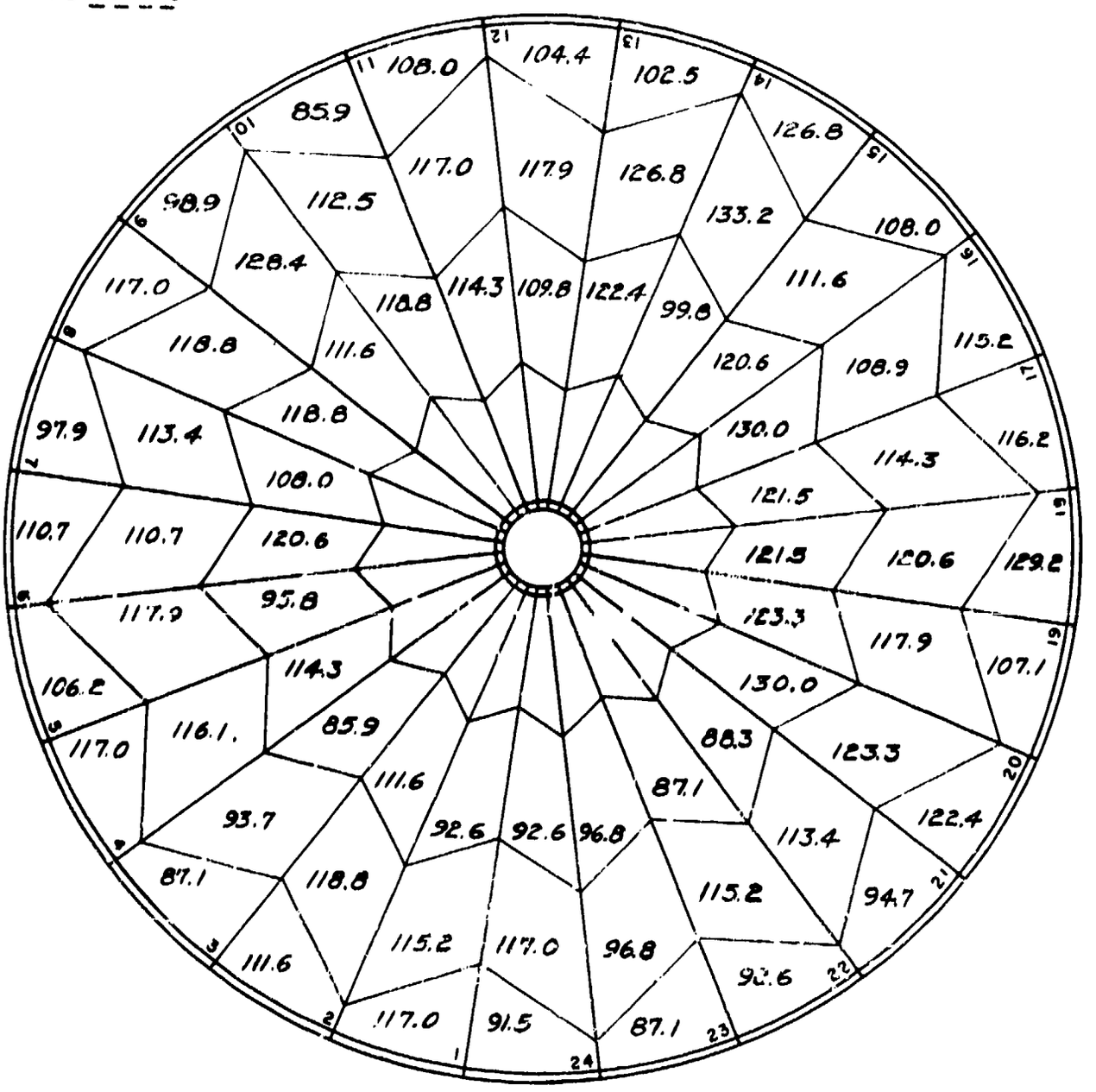
11-10-50
A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350216

TEMP. 72 °F

HUMID 42 %



AVERAGE POROSITY: 114 %

DATE 11-2-50

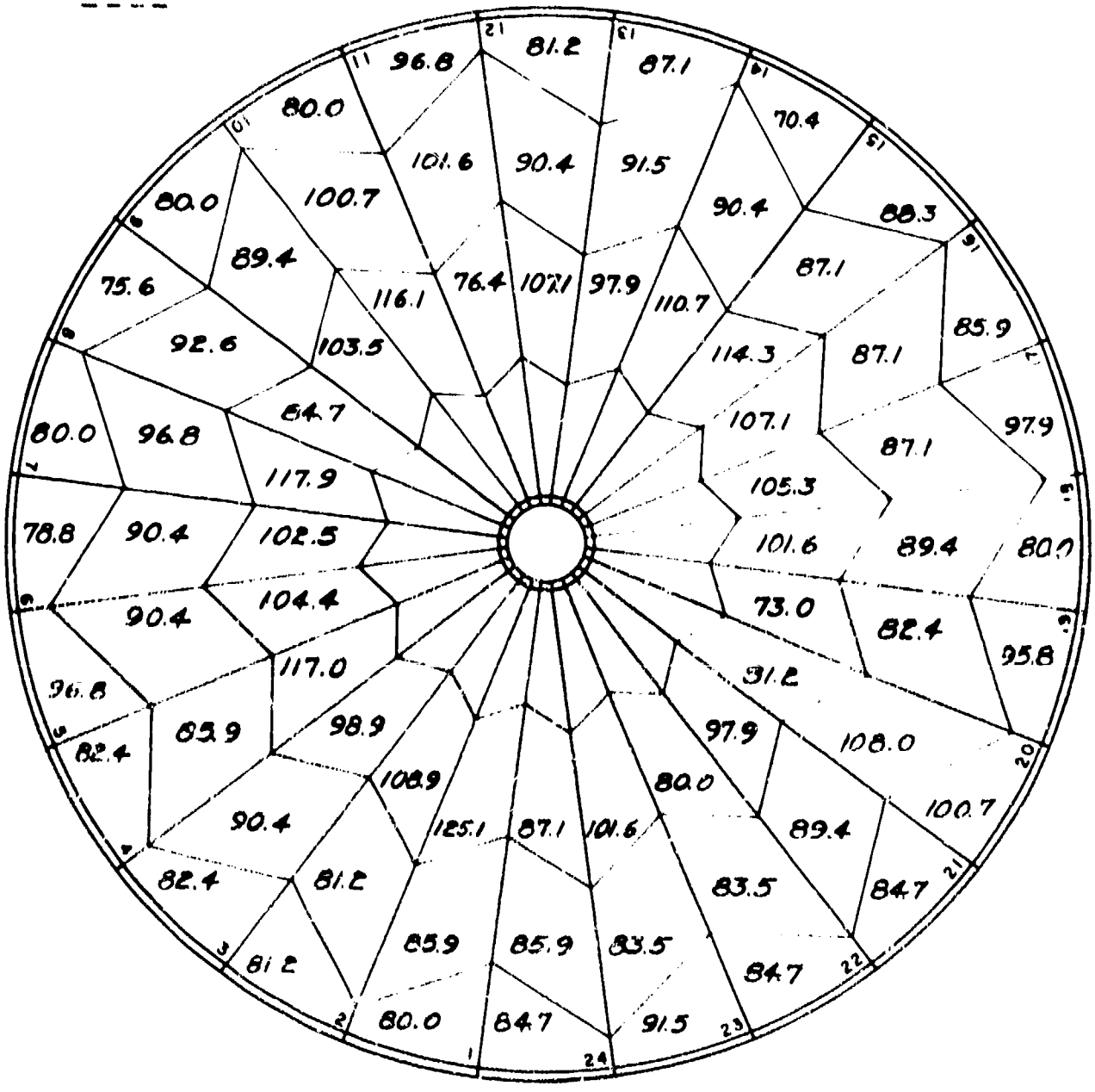
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350217

TEMP. 72 °F.

HUMID 40 %



AVERAGE POROSITY 98.1

DATE 11-3-50

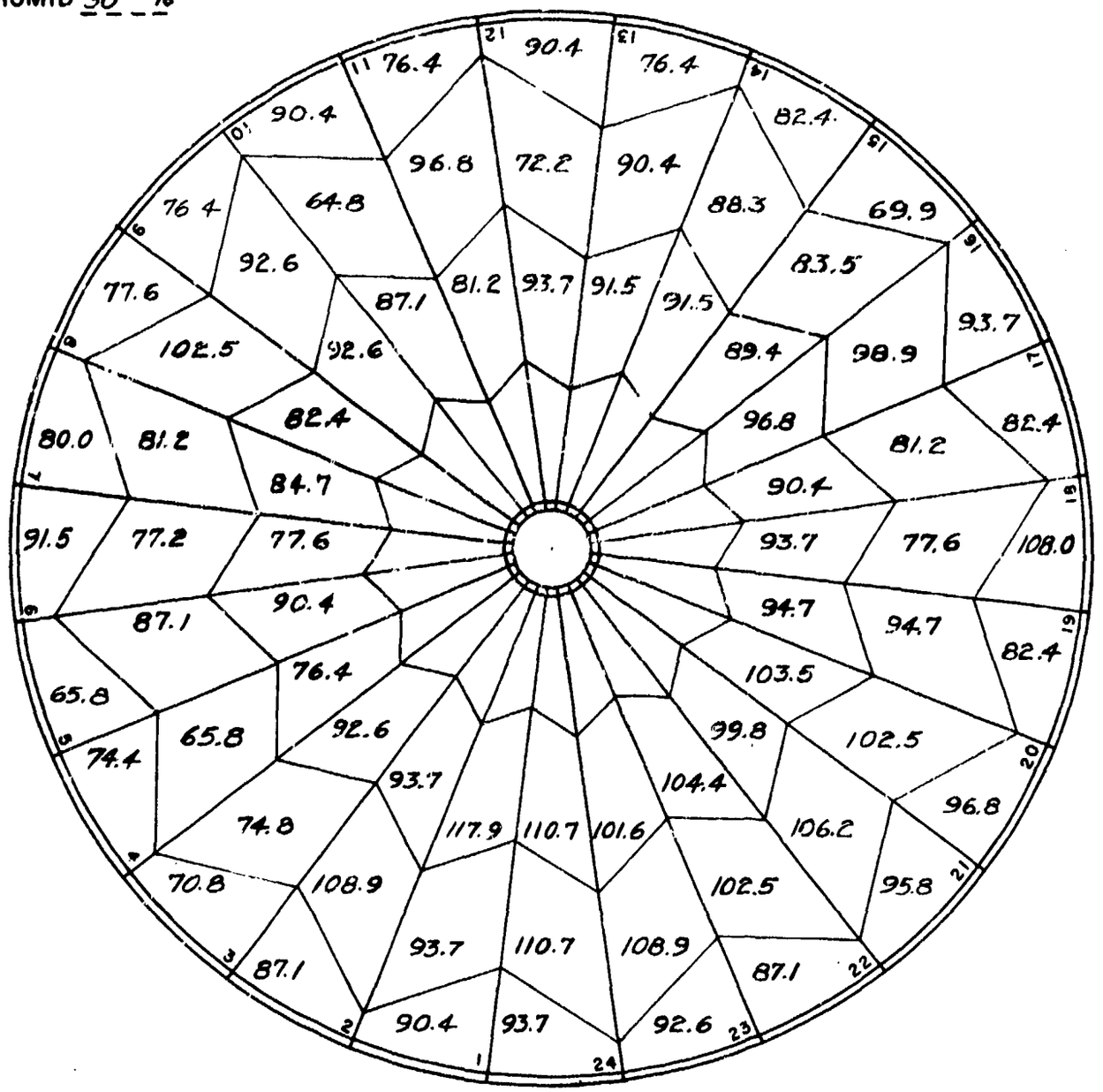
BY A.Y.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350218

TEMP. 70 °F

HUMID 30 %



AVERAGE POROSITY: 89.4

DATE 11-14-50

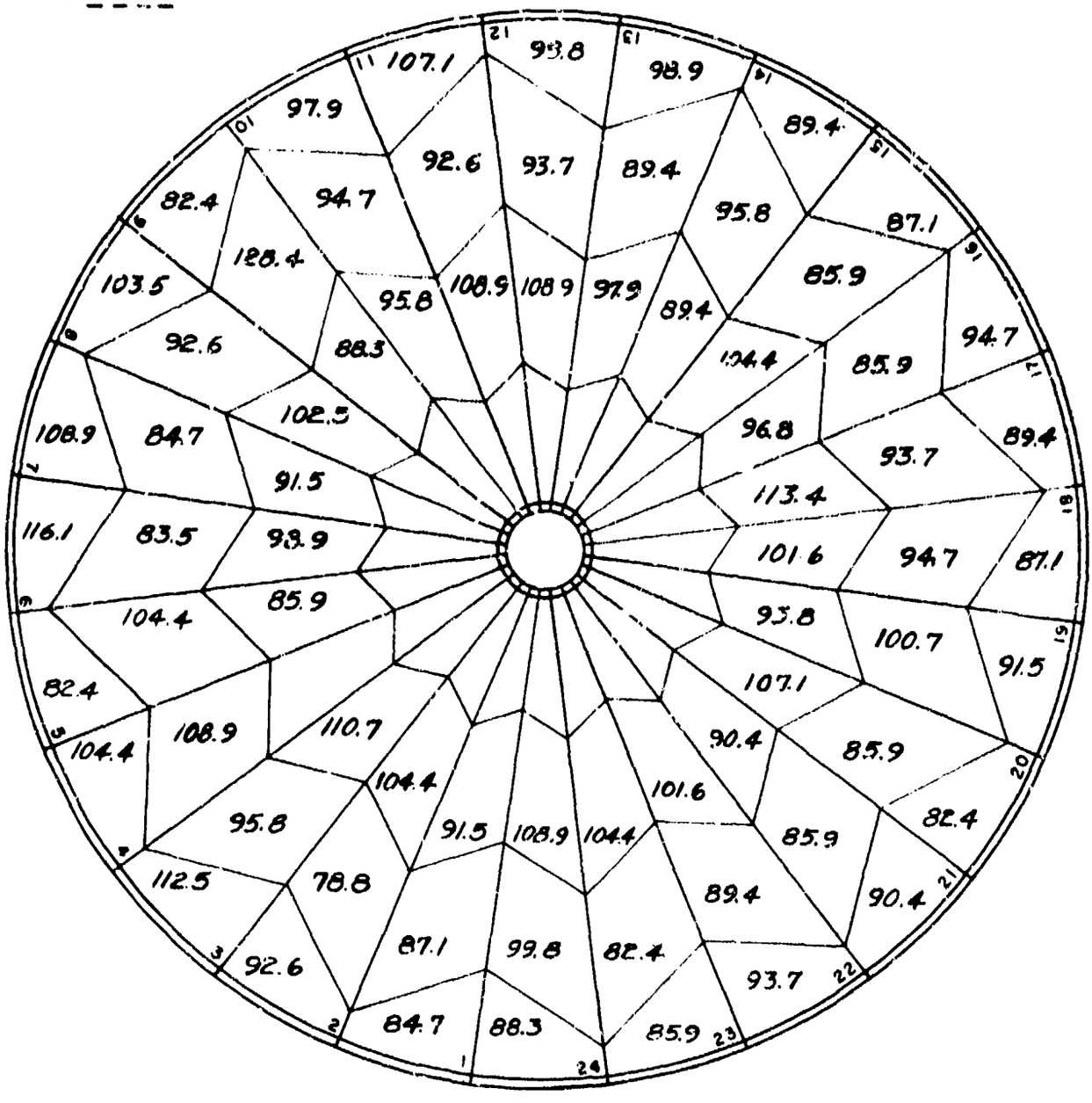
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350219

TEMP. 70 °F

HUMID 38 %



AVERAGE POROSITY: 96.0

DATE 11-8-50

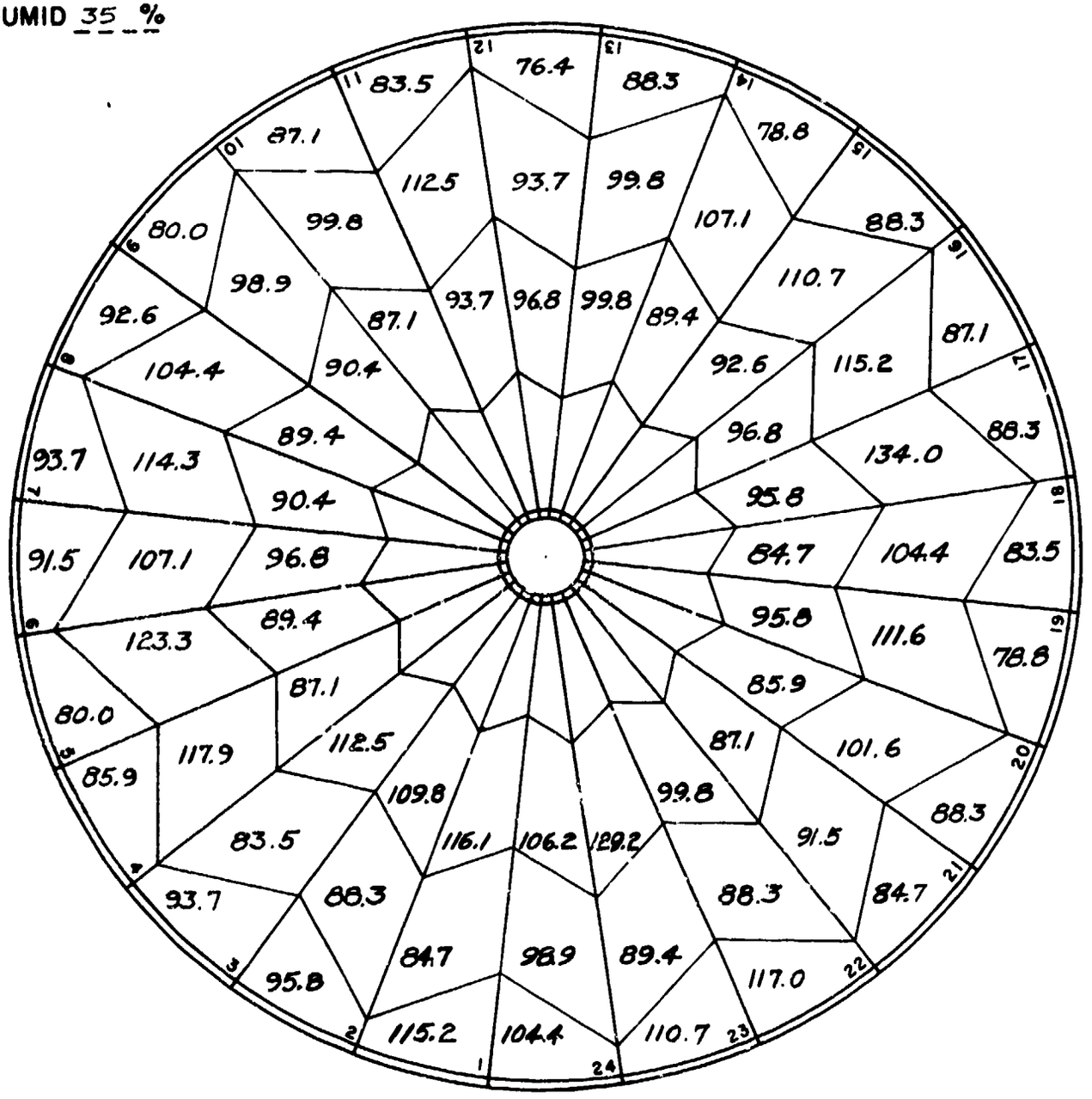
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350220

TEMP. 72 °F

HUMID 35 %



AVERAGE POROSITY: 96.9

DATE 11-9-50

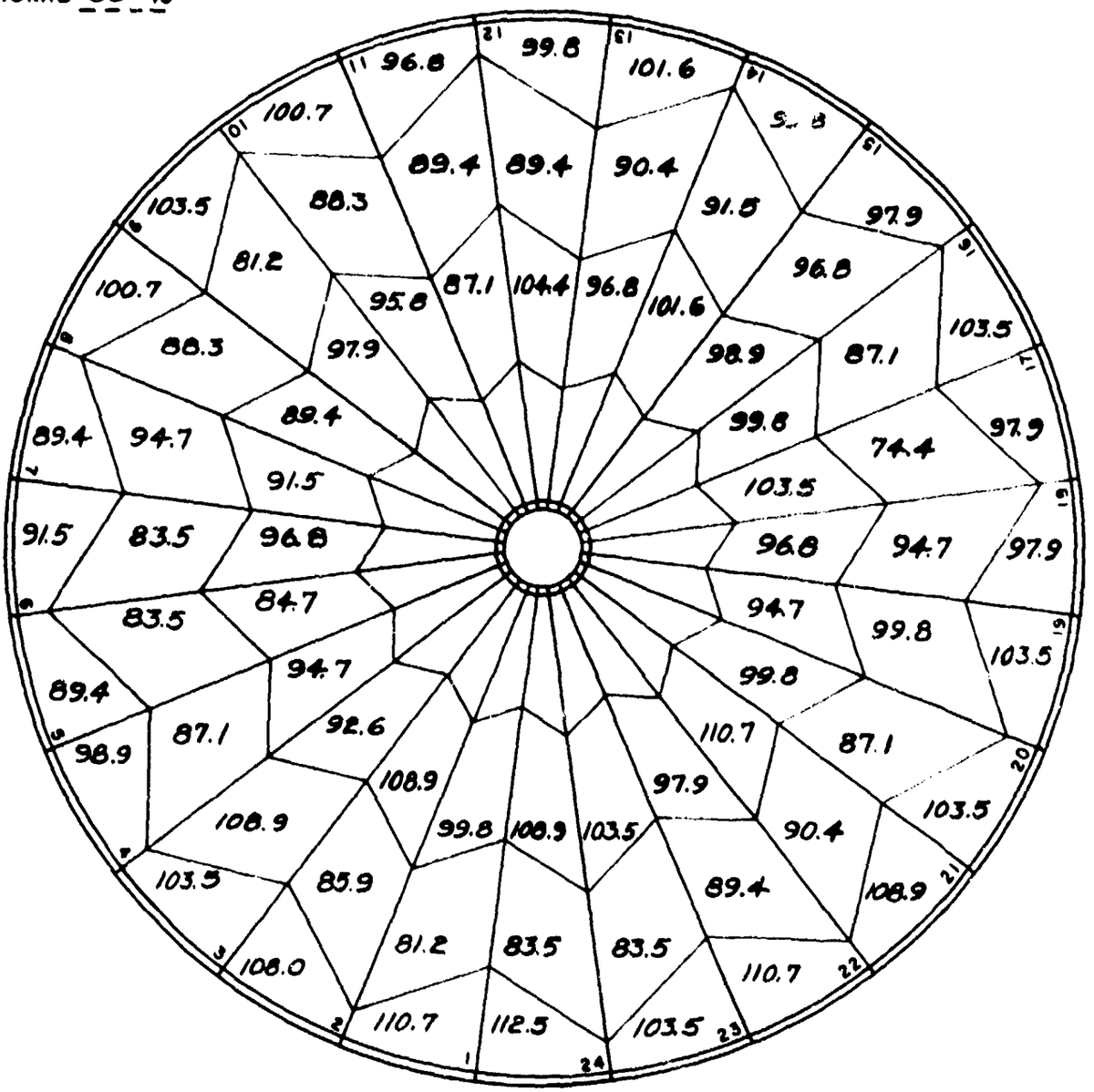
BY A.V

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350221

TEMP. 74 °F

HUMID 35 %



AVERAGE POROSITY: 91.6

DATE 11-10-50

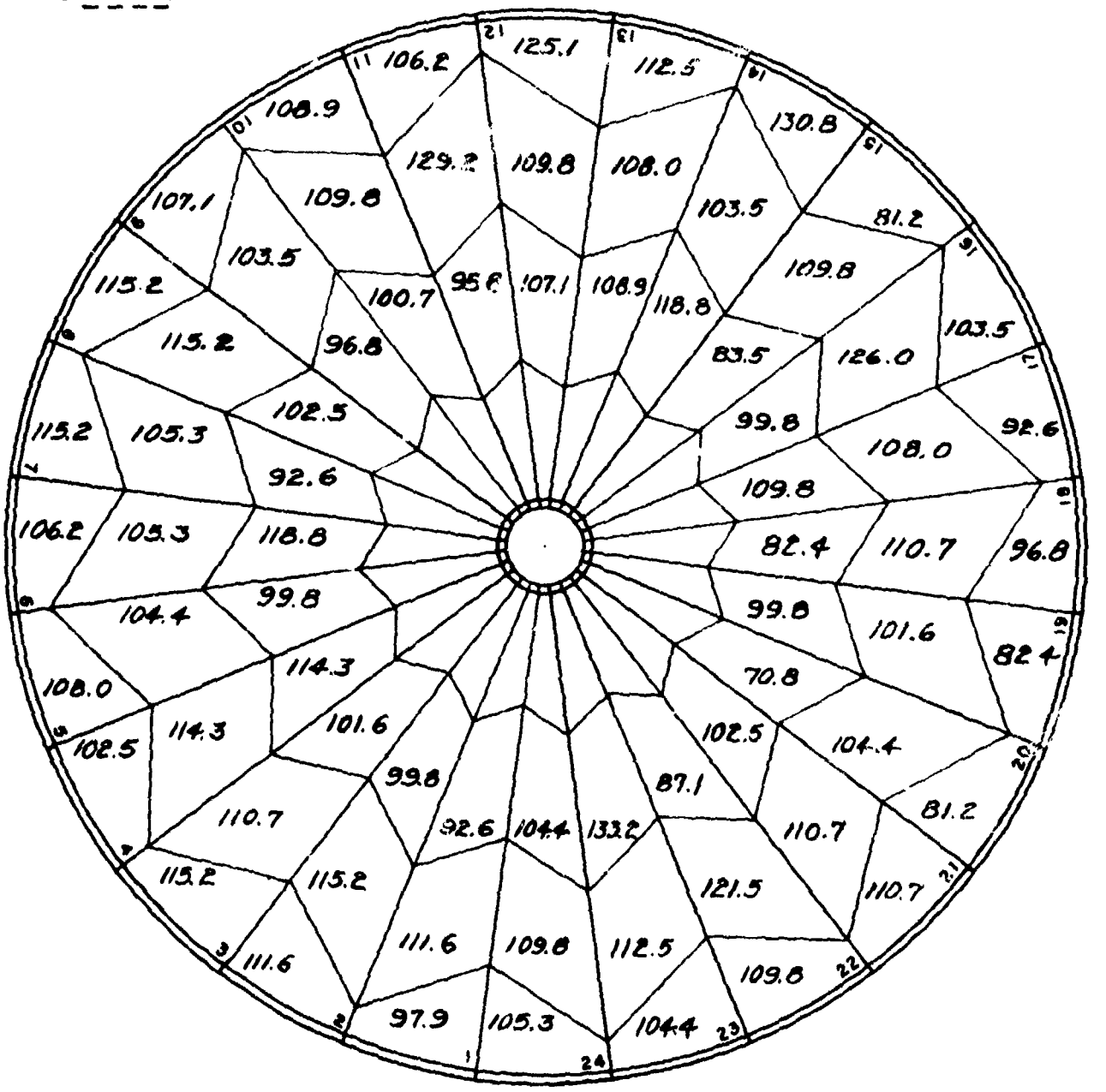
BY A.V

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350222

TEMP. 75 °F

HUMID 50 %



AVERAGE POROSITY 105.8

DATE 10-31-50

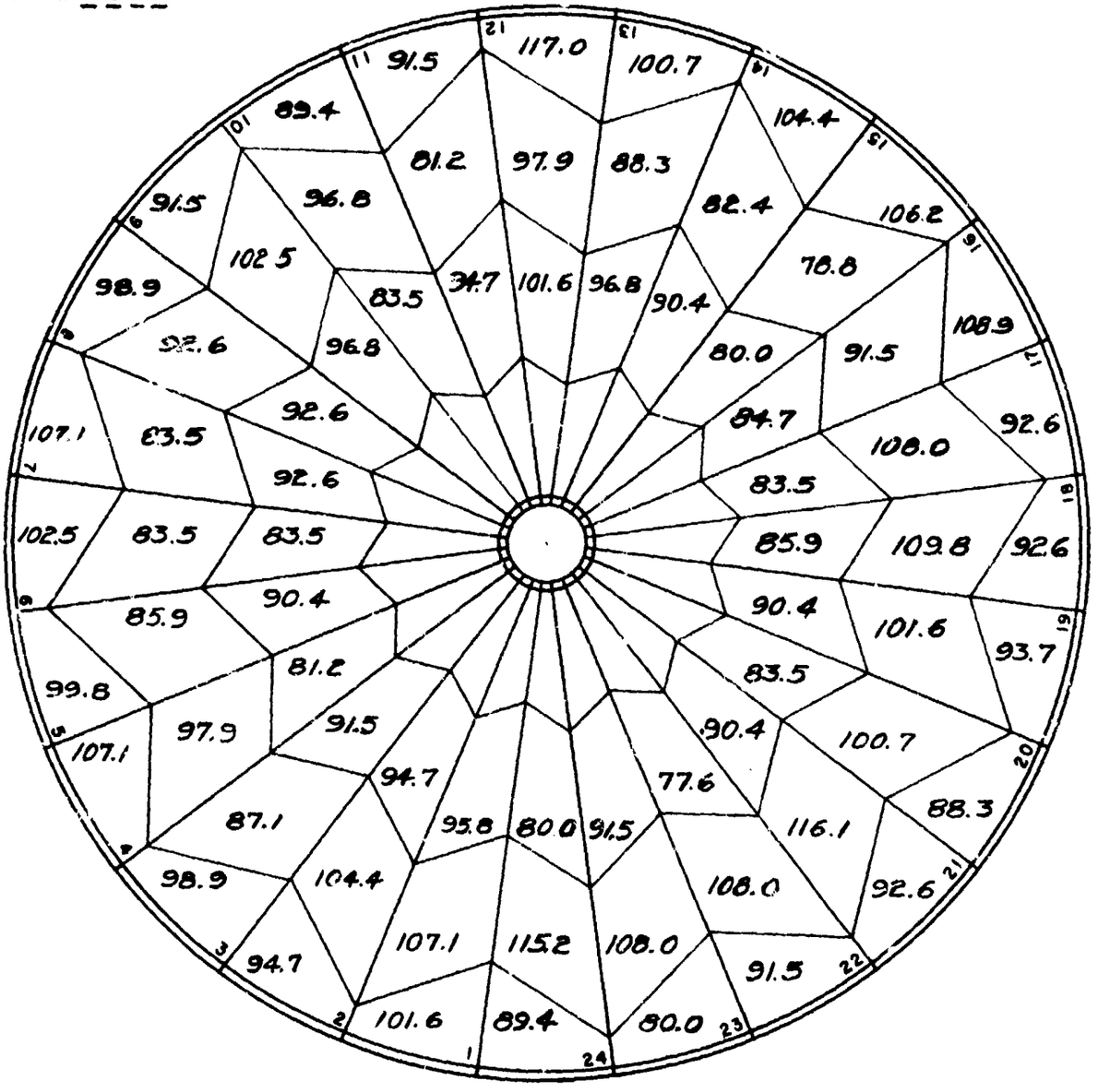
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350223

TEMP. 70 °F

HUMID 32 %



AVERAGE POROSITY: 94.5

DATE 11-13-50

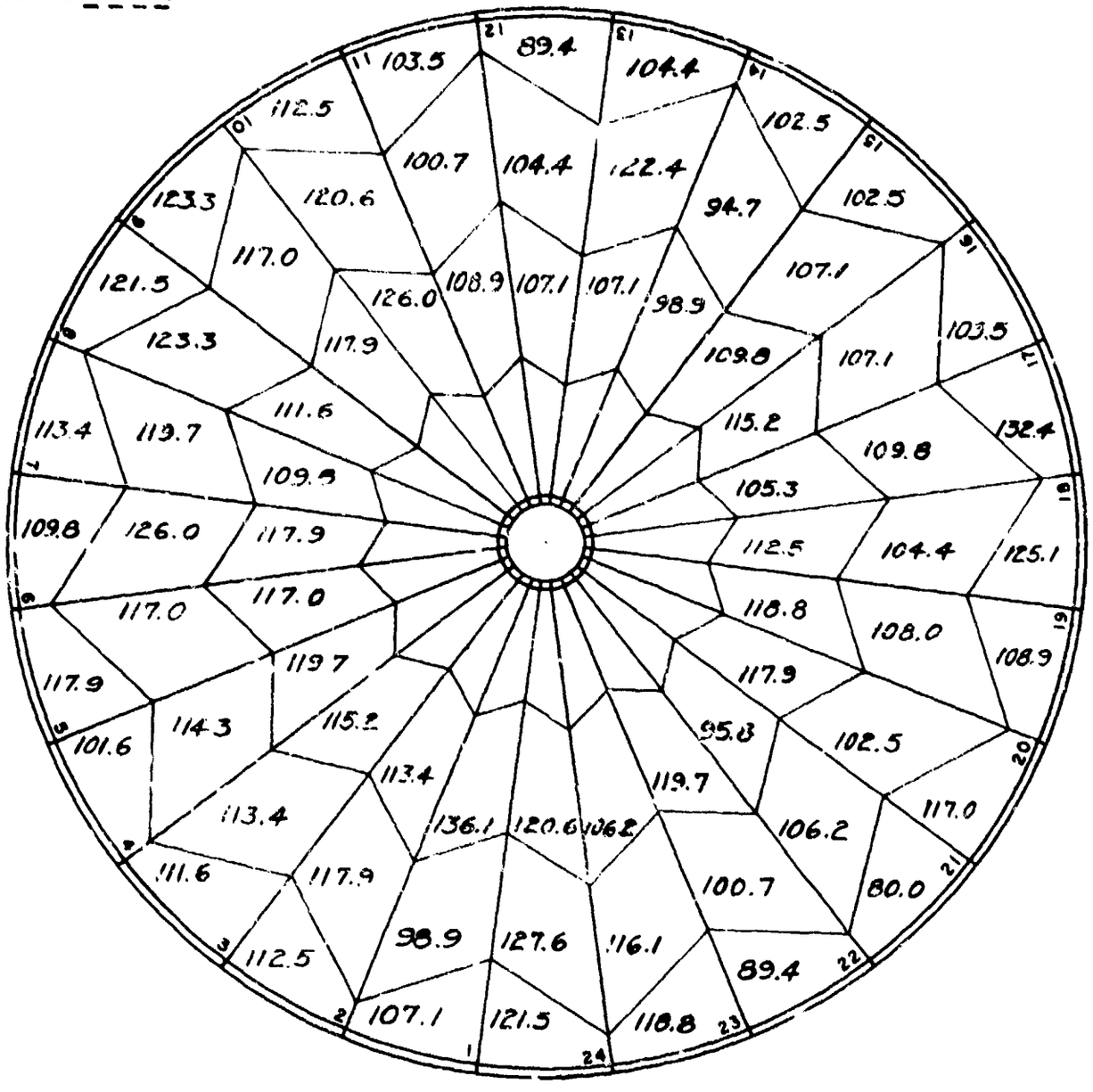
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350224

TEMP. 70 °F

HUMID 24 %



AVERAGE POROSITY: 111.6

DATE 11-15-50

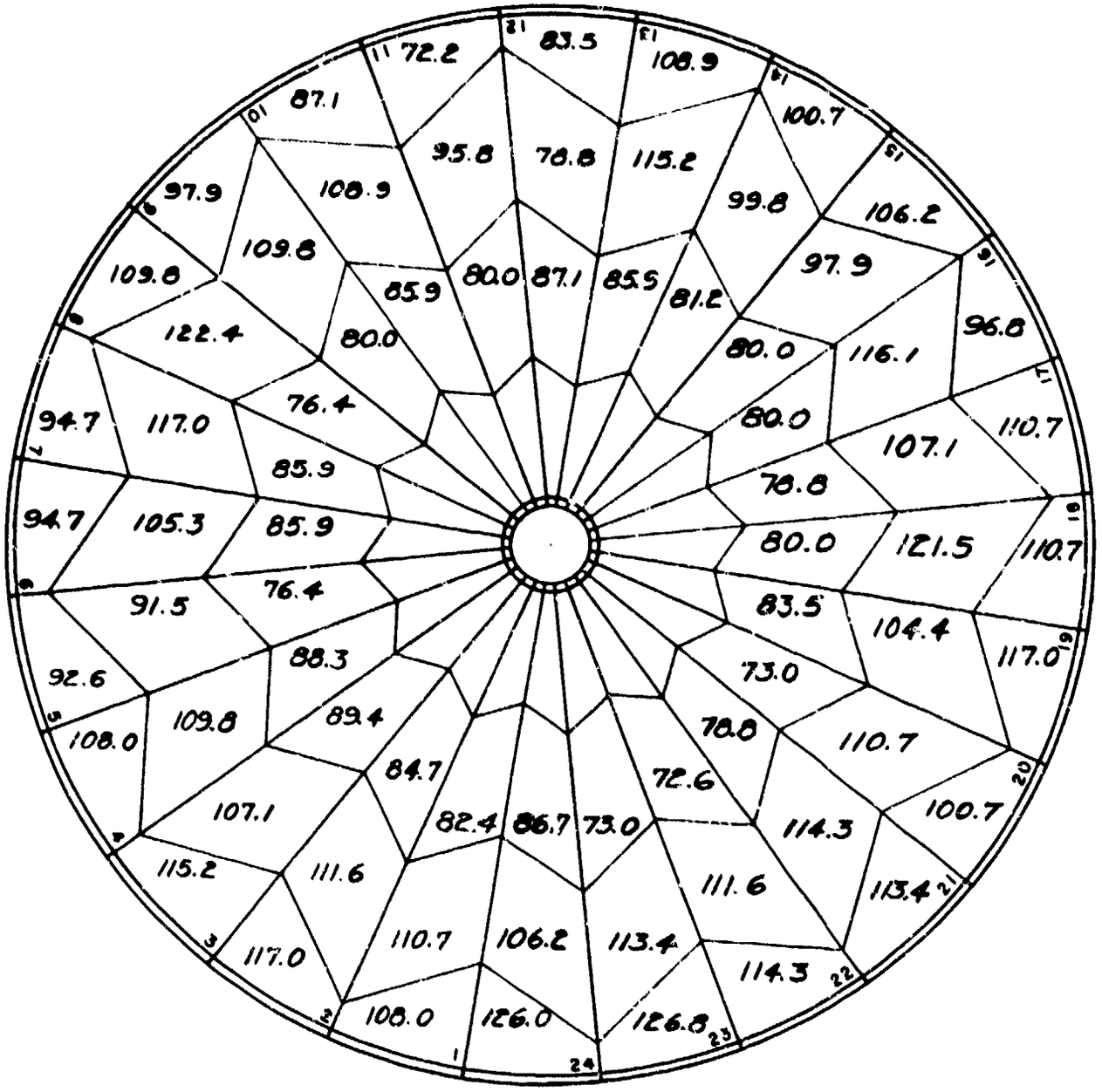
BY A.V

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350223

TEMP. 74 °F

HUMID 47 %



AVERAGE POROSITY: 98.0

DATE 11-1-50

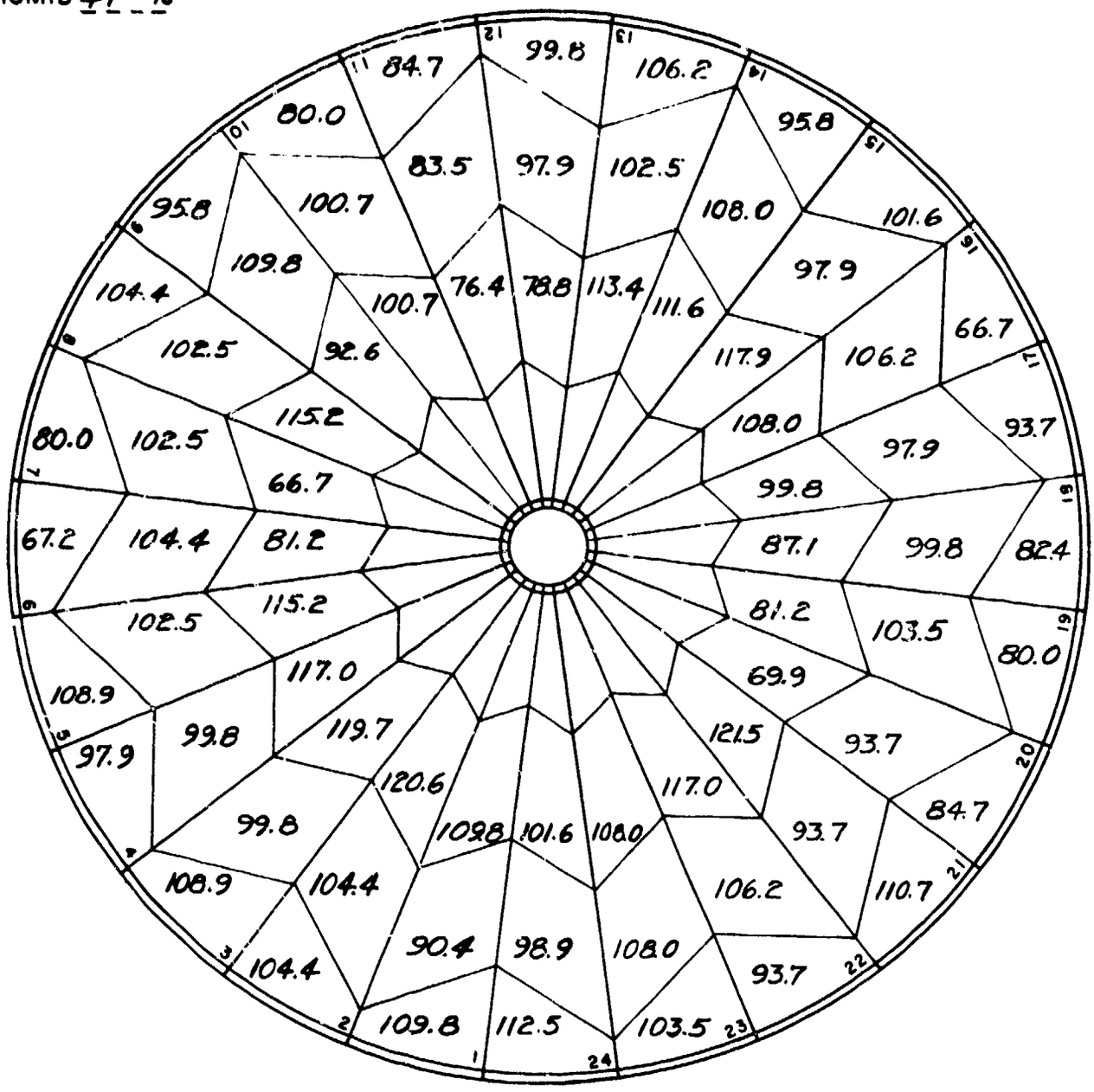
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350226

TEMP. 74 °F

HUMID 47 %



AVERAGE POROSITY: 98.9

DATE 11-1-50

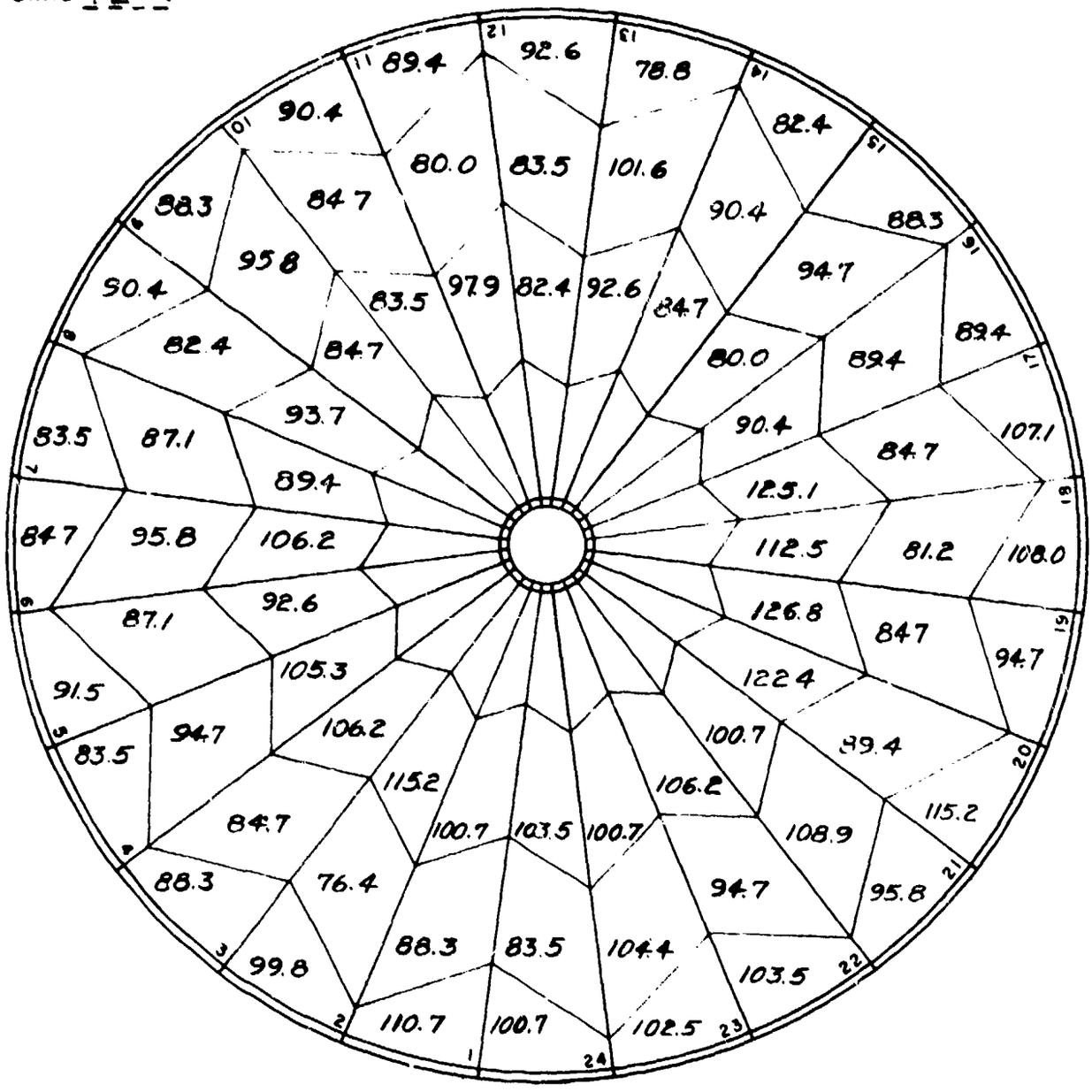
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350227

TEMP 72 °F

HUMID 42 %



AVERAGE POROSITY: 94.6

DATE 11-2-50

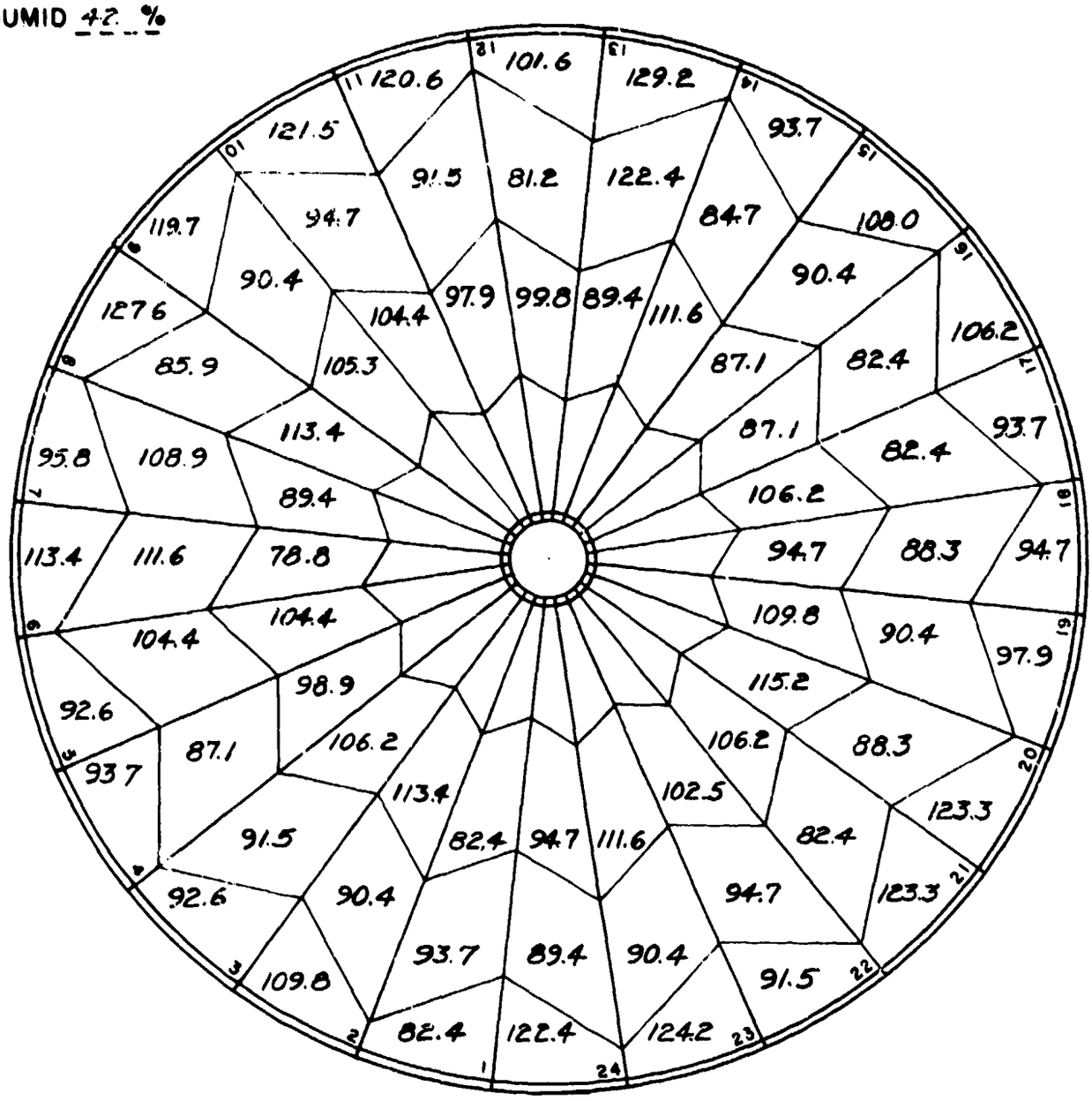
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350228

TEMP 72 °F

HUMID 42 %



AVERAGE POROSITY: 100.1

DATE 11-2-50

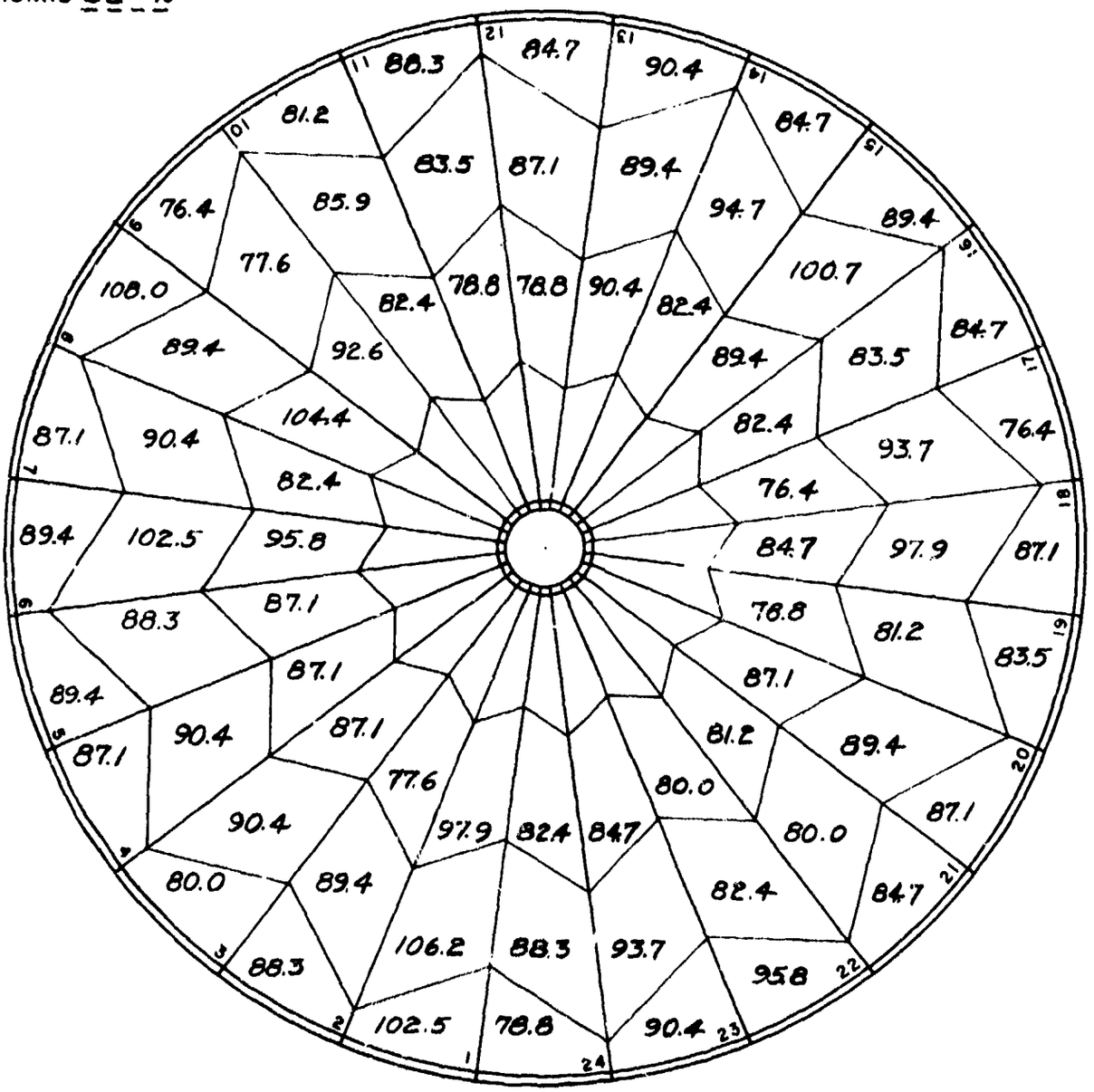
BY A.V

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350229

TEMP. 70 °F

HUMID 32 %



AVERAGE POROSITY: 87.5

DATE 11-13-50

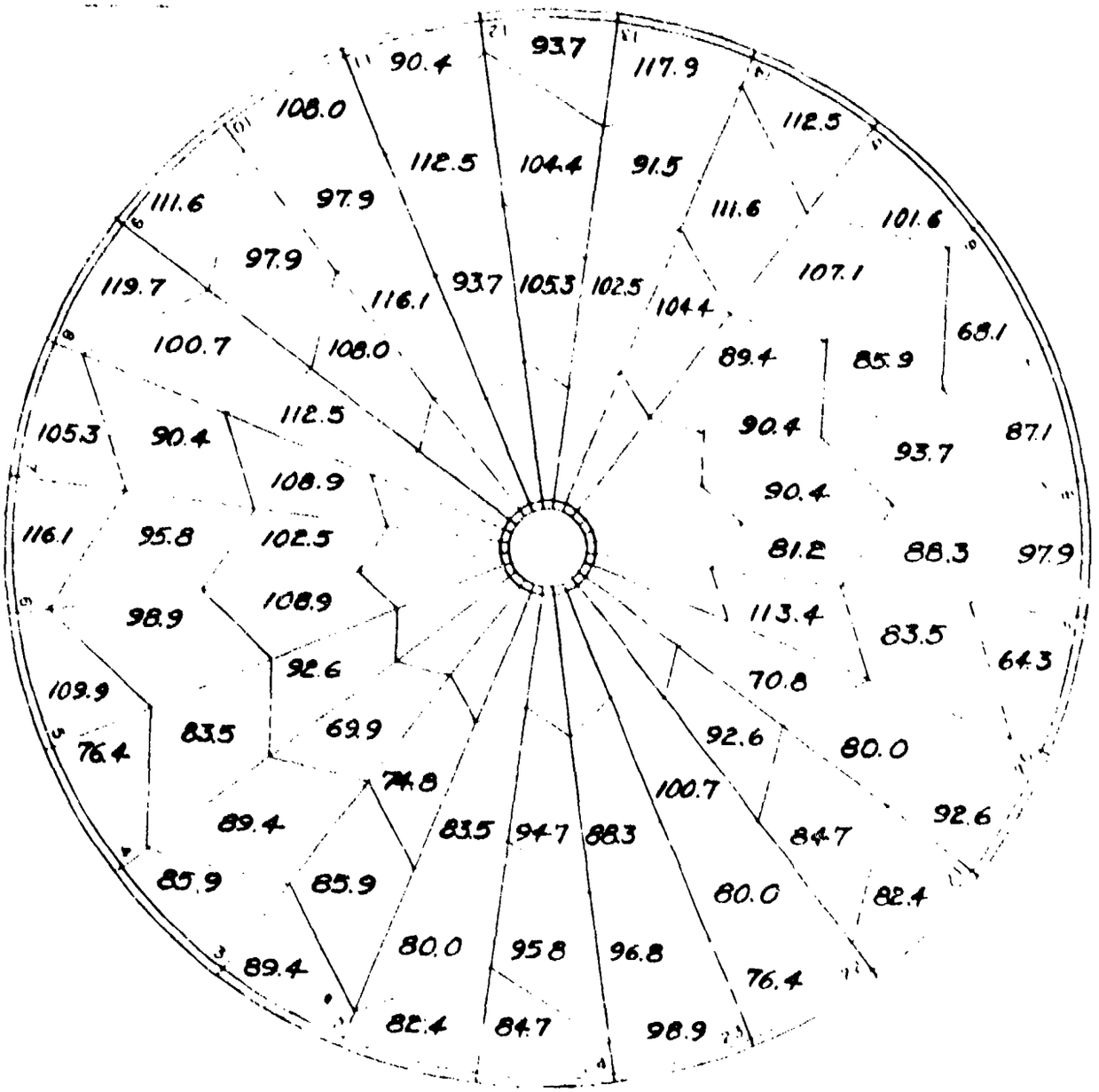
BY A.V.

POROSITY MEASUREMENTS 124 GORE CANOPY **AFTER 100 M.P.H.**

SERIAL NO. 350230

TEMP 70 °F

HUMID 24 %



AVERAGE POROSITY 94.5

DATE 11-15-50

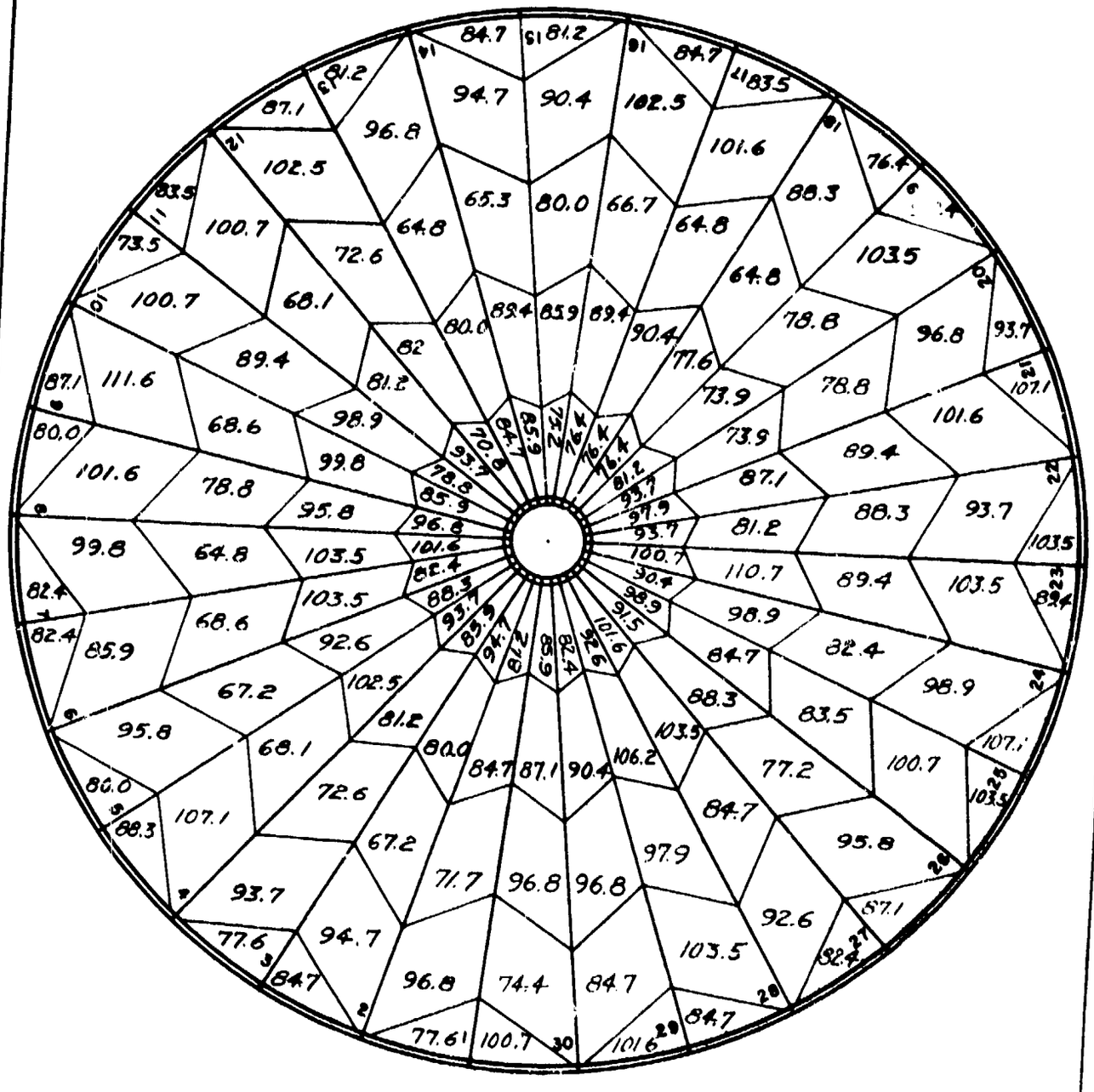
BY A.V.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350231

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 88.9

DATE 2-20-51

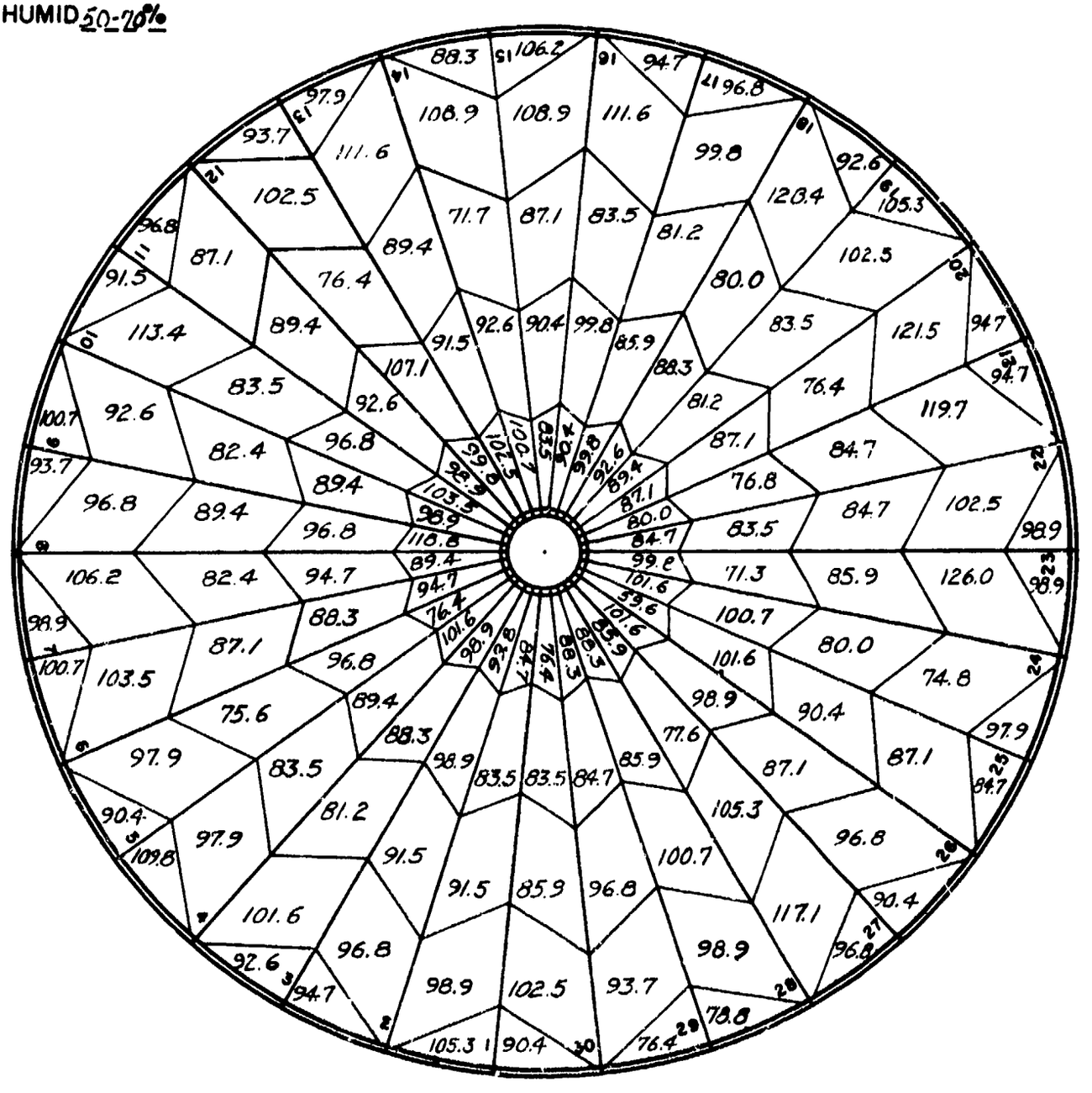
BY L.D & C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350232

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 93.4

DATE 2-20-51

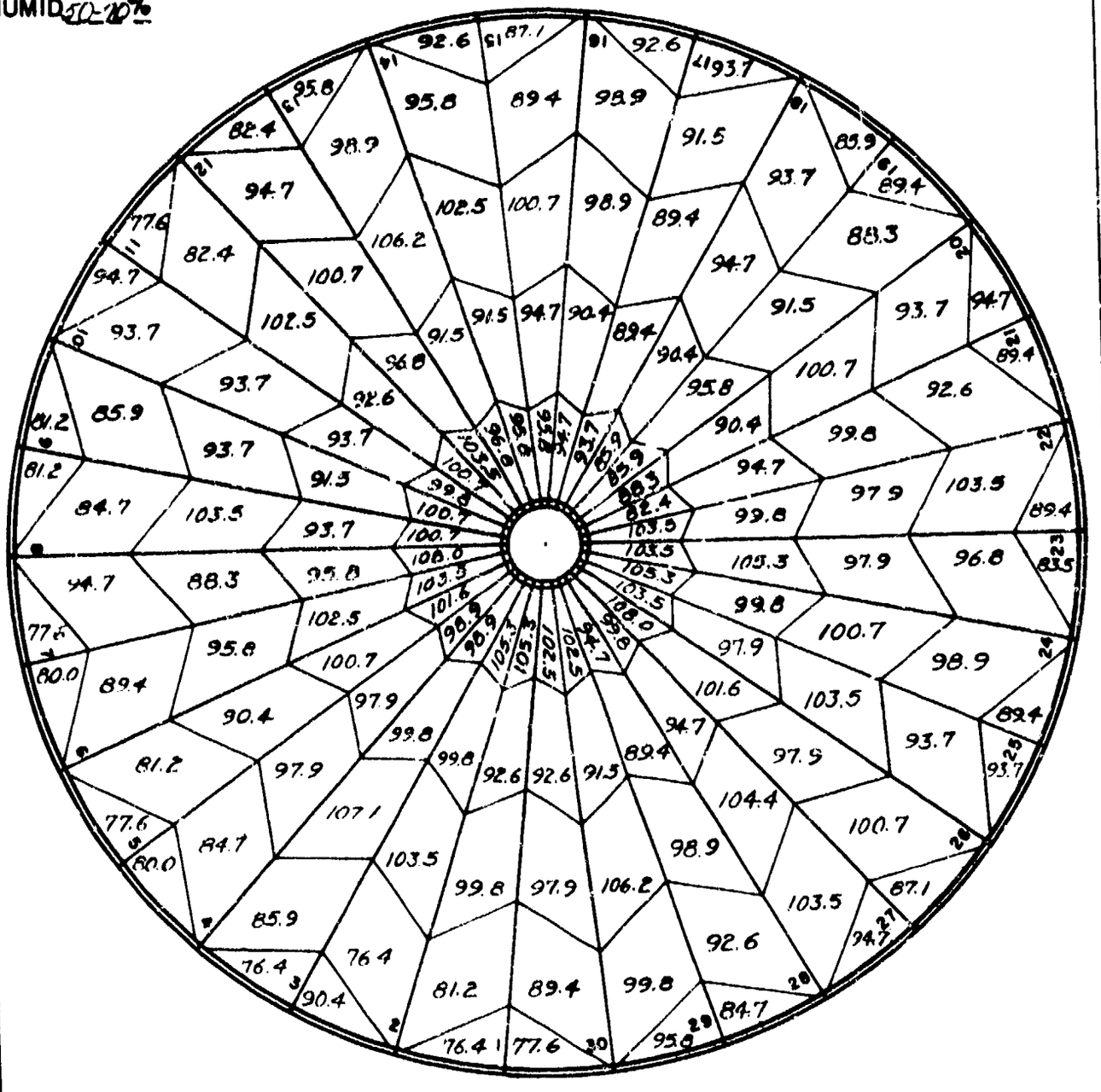
BY L.D. & C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350233

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY · 94.3

DATE 2-22-51

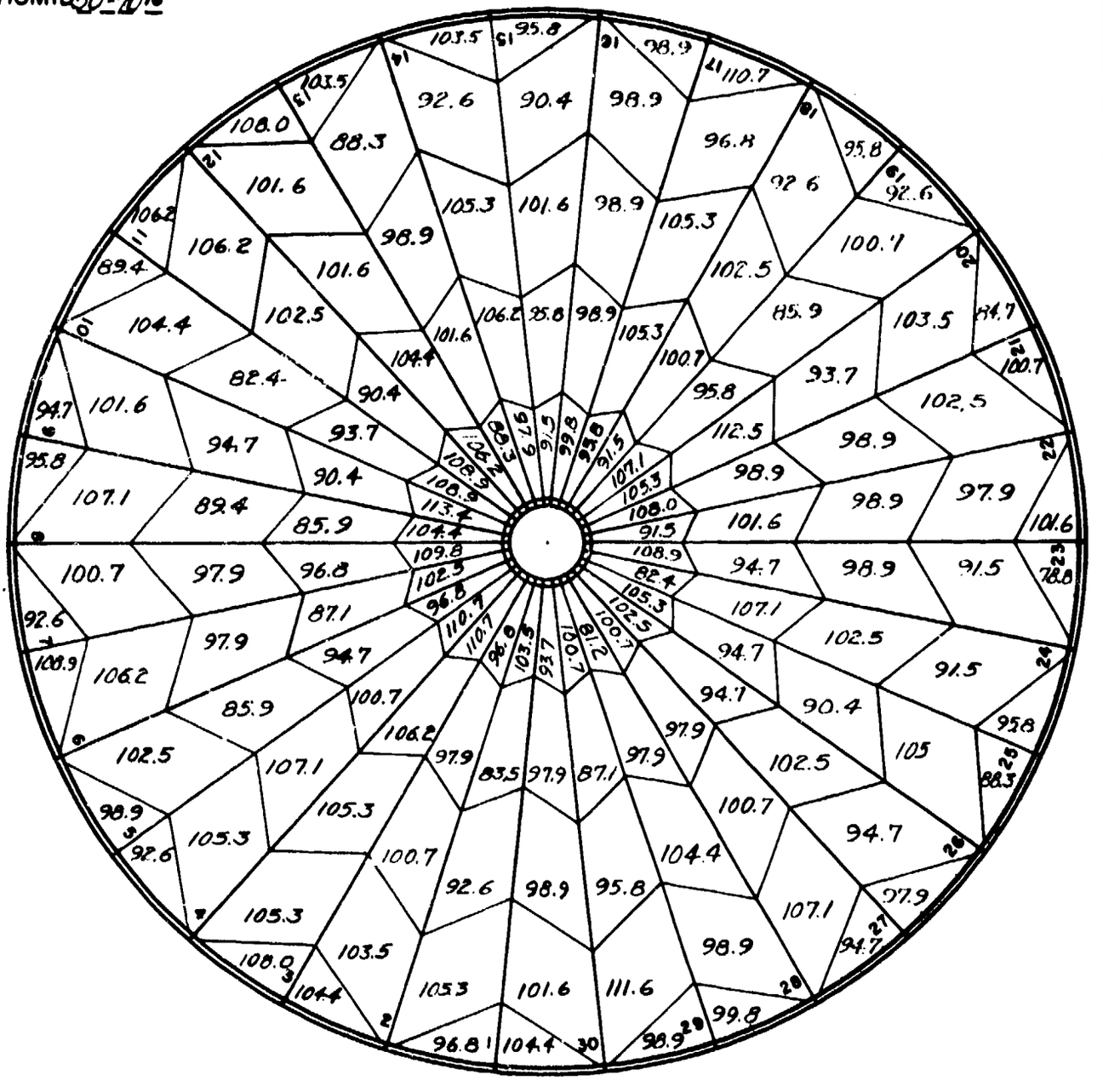
BY L.D&CM

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350234

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 99.0

DATE 2-20-51

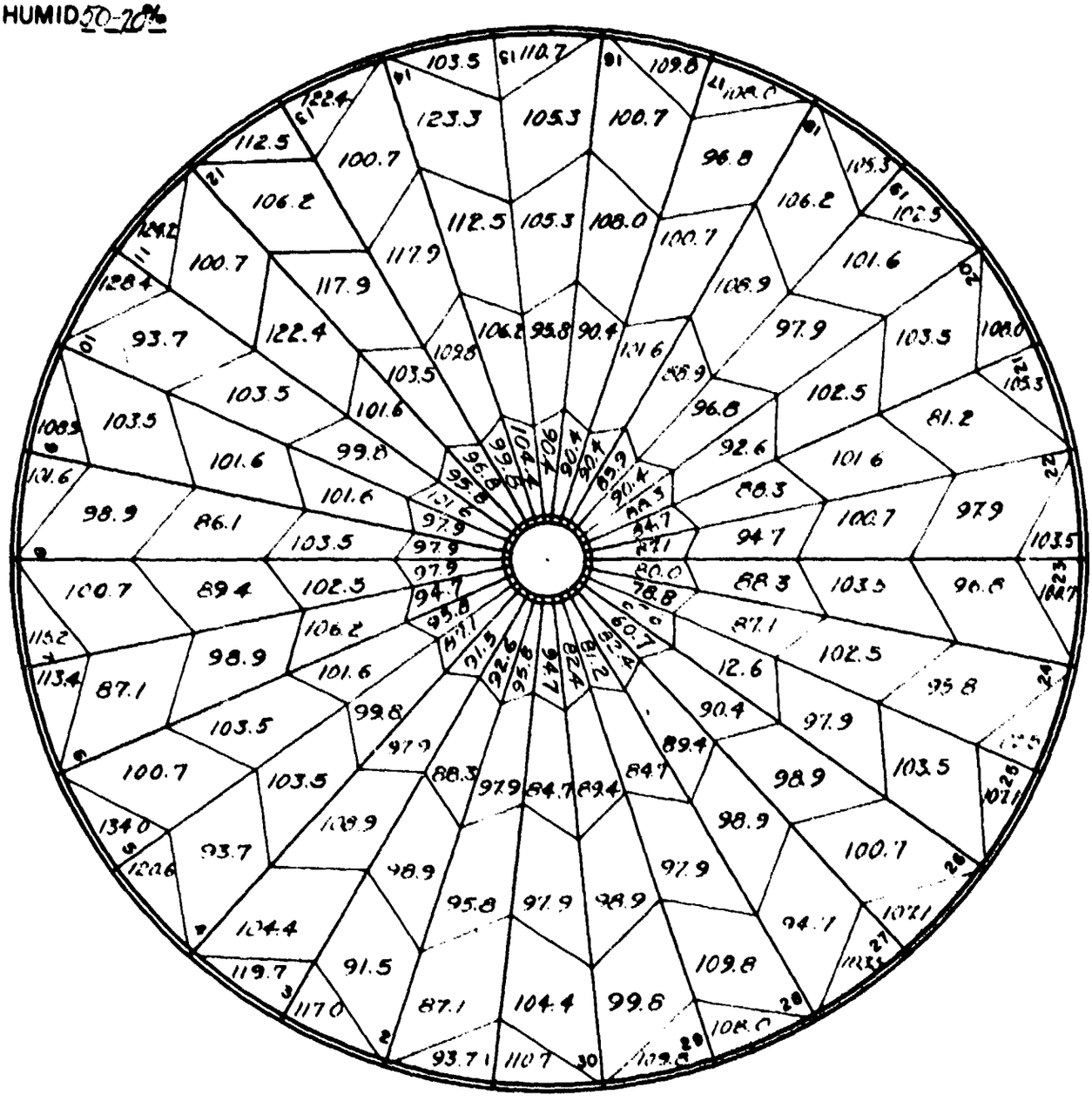
BY L.D & C.M

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350235

TEMP 75-80 °F

HUMID 50-70%



AVERAGE POROSITY 99.1

DATE 8-23-51

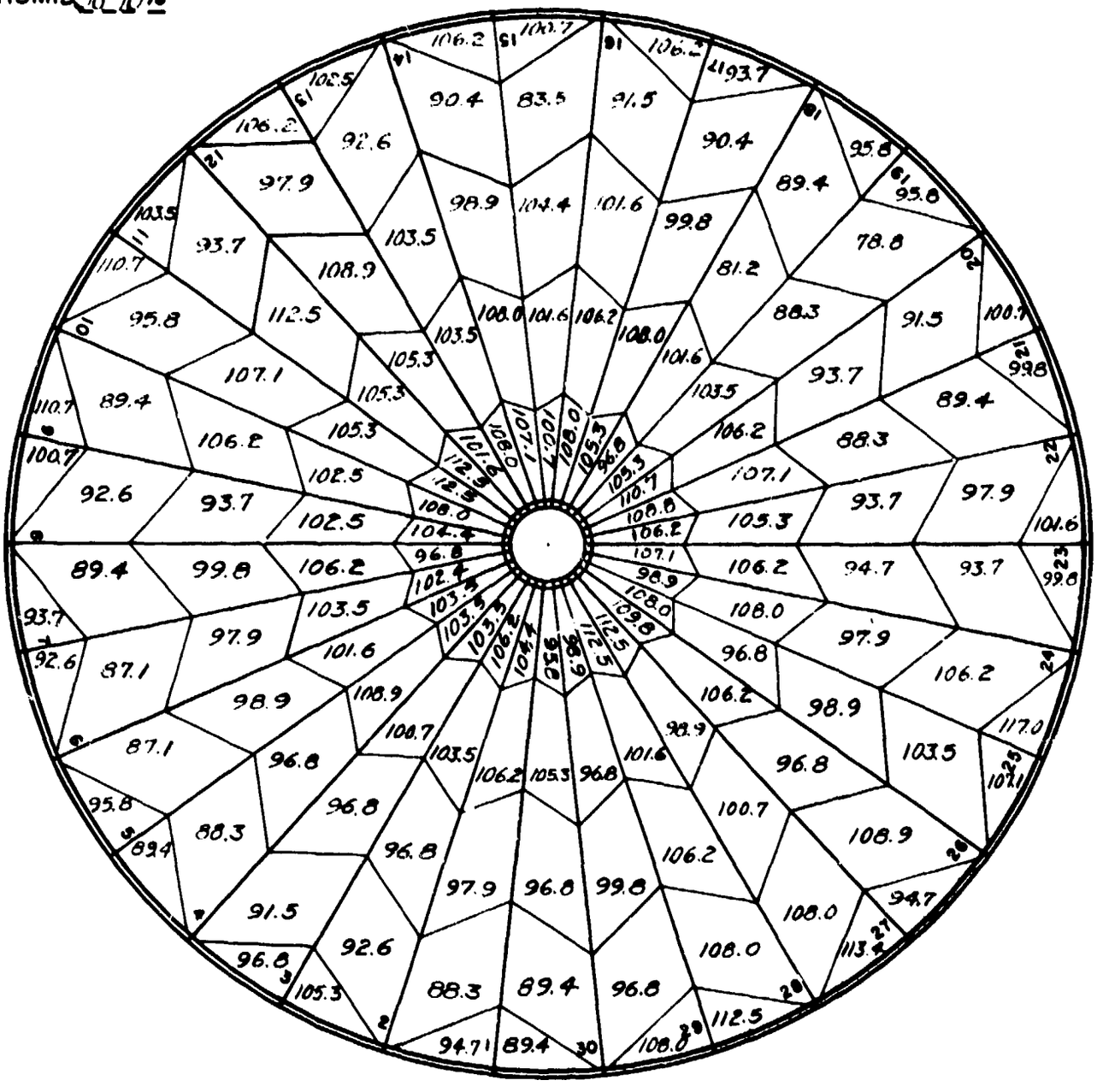
BY [illegible]

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350236

TEMP. 70-80°F

HUMID. 50-70%



AVERAGE POROSITY 100.5

DATE 2-24-51

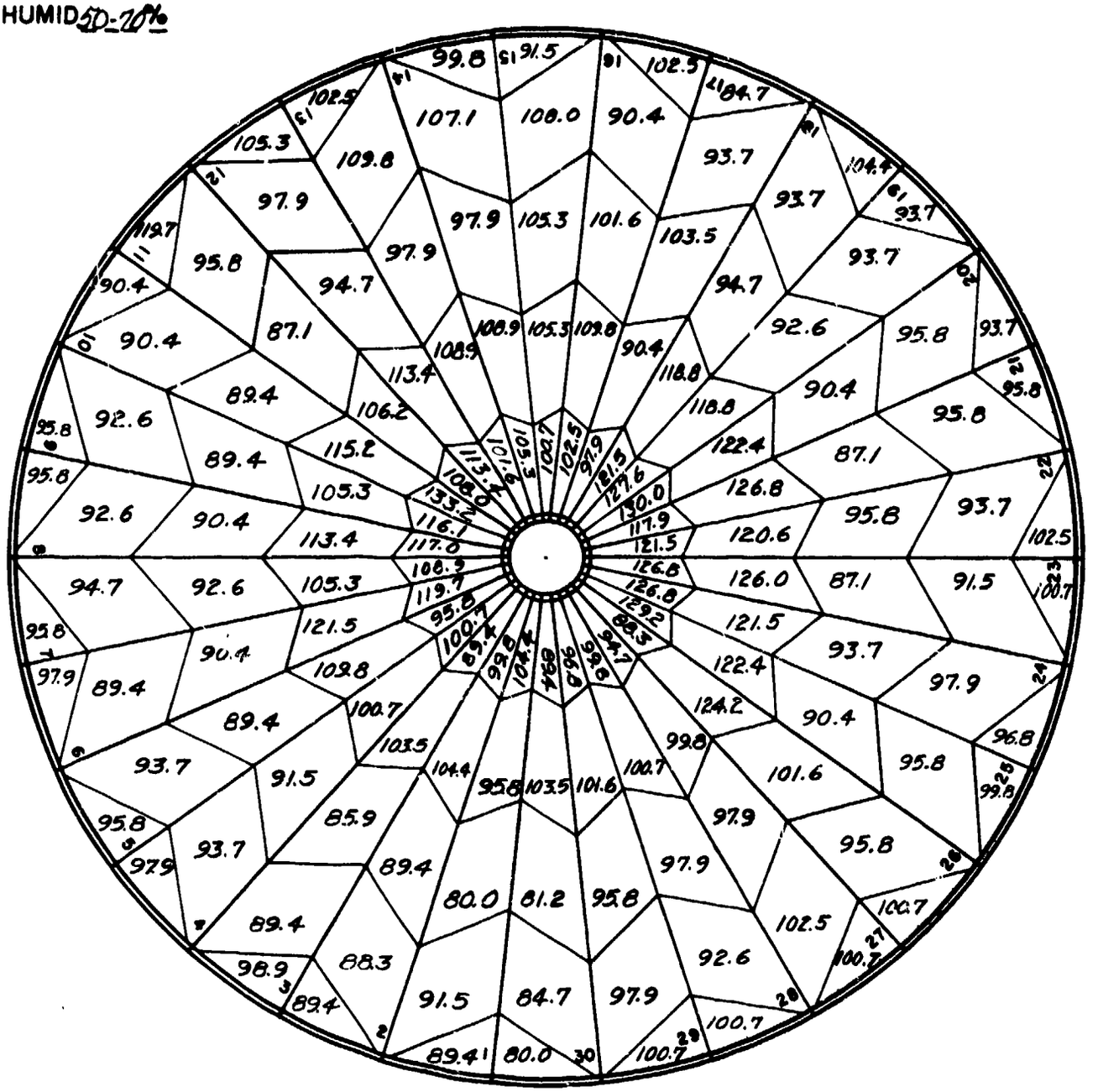
BY C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350237

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 101.1

DATE 2-22-51

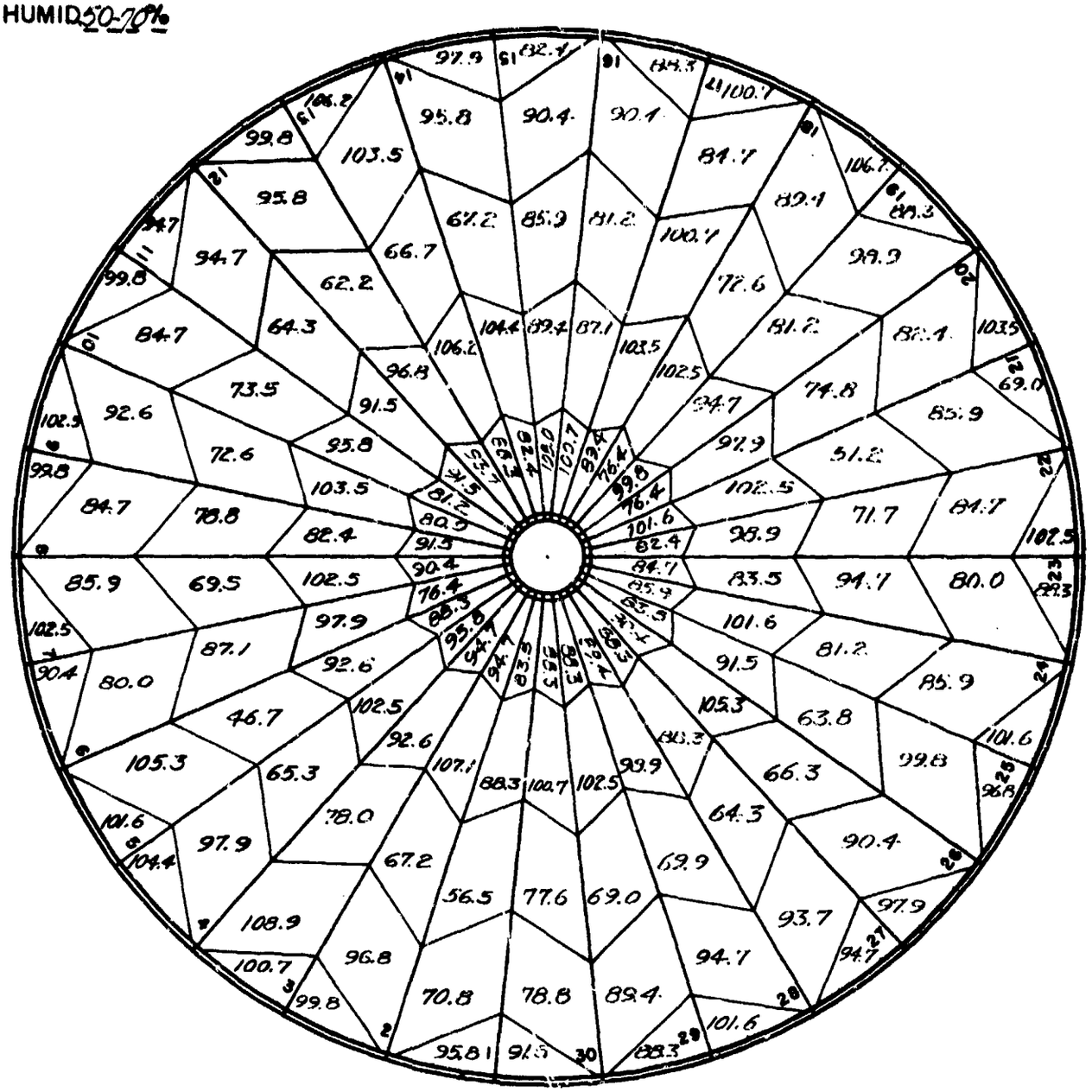
BY CM

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 550238

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 89.0

DATE 2-19-51

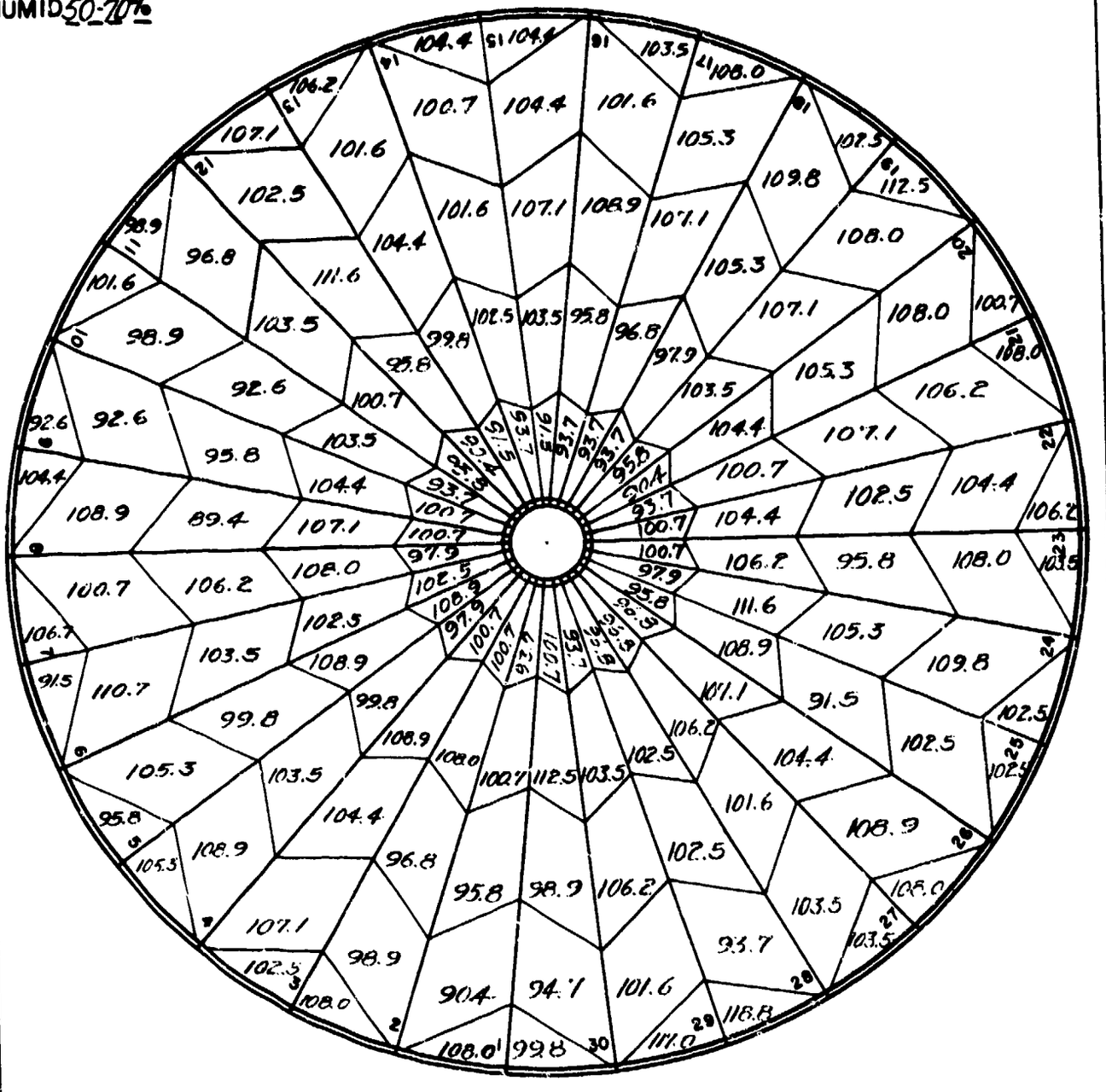
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350239

TEMP 75-80°F

HUMID 50-70%



AVERAGE POROSITY 102.1

DATE 2-24-57

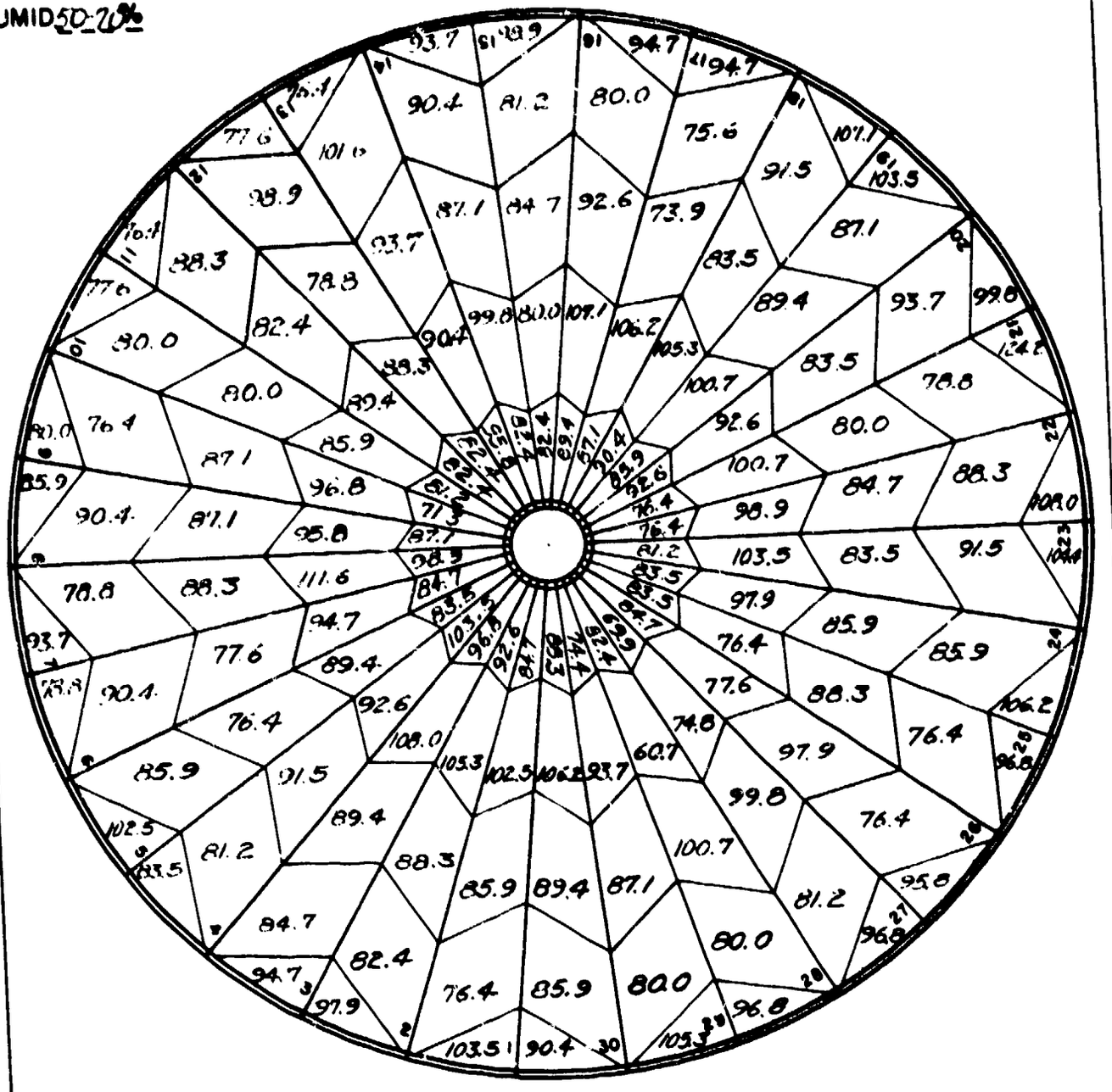
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 35022-10

TEMP 75-80°F

HUMID 50-70%



AVERAGE POROSITY 89.1

DATE 2-27-51

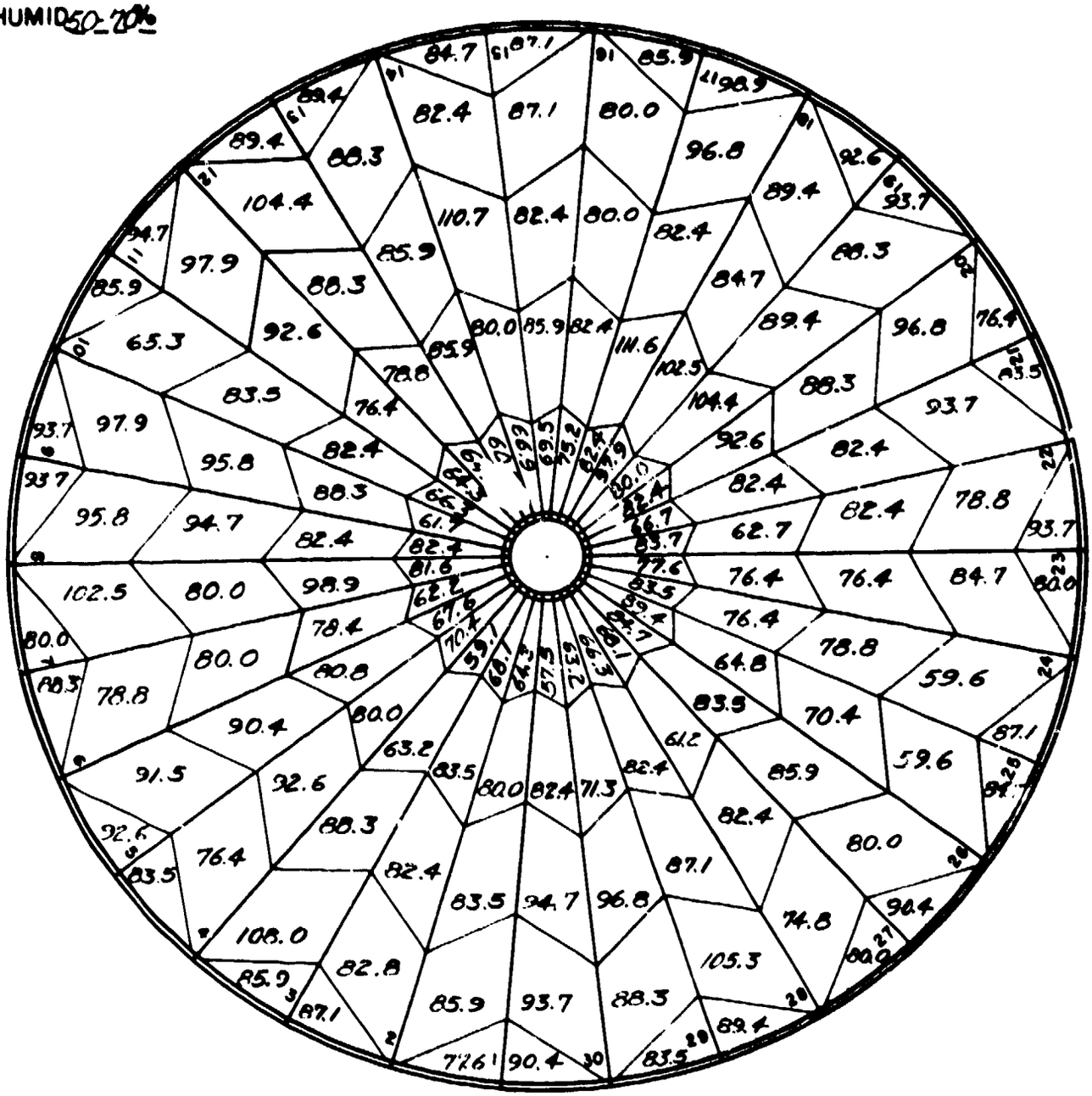
BY L.D.S. C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350241

TEMP 75-80°F

HUMID 50-70%



AVERAGE POROSITY 83.1

DATE 2-26-51

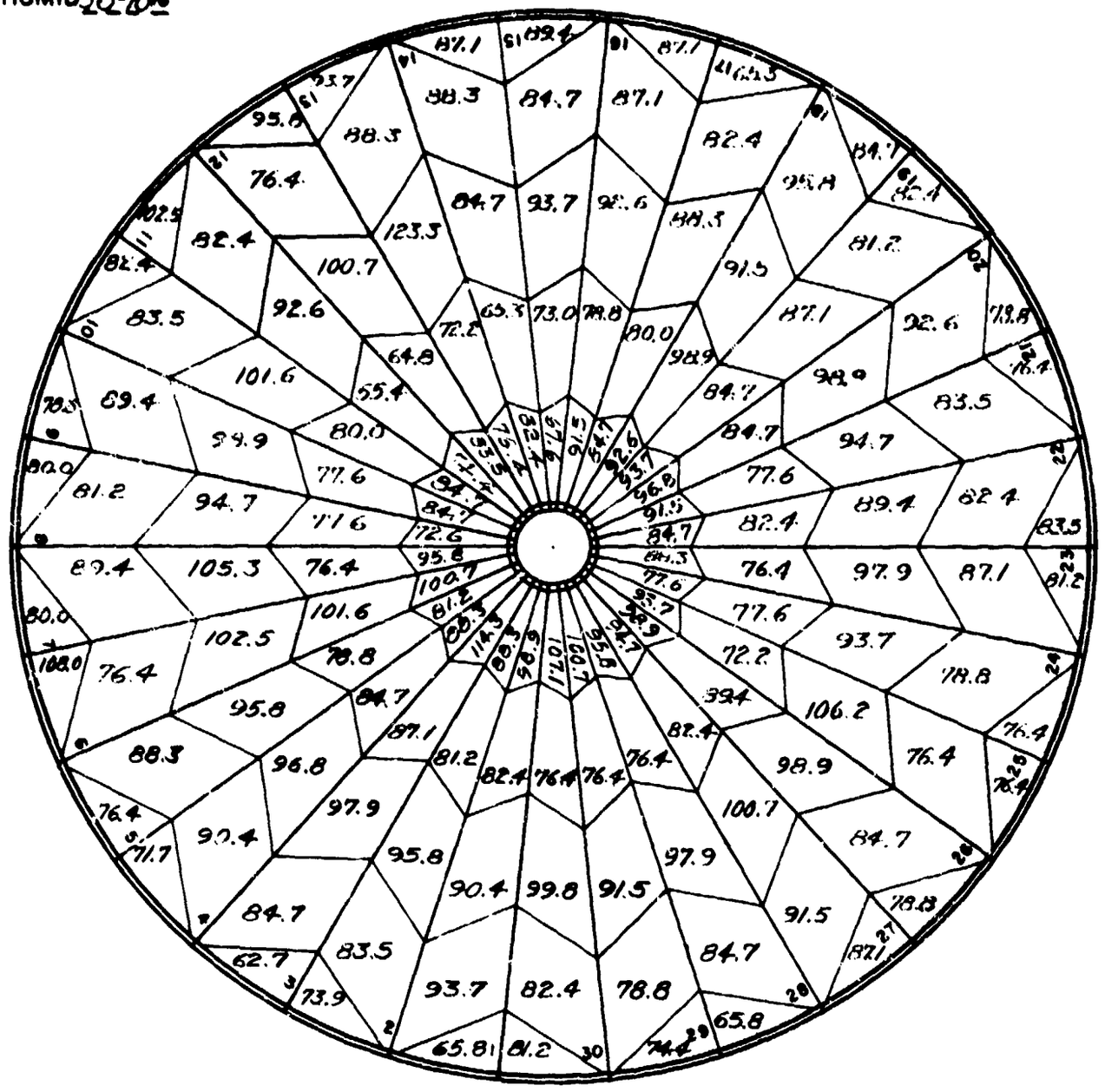
BY L.D

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 550242

TEMP 75-80°F

HUMID 50-70%



AVERAGE POROSITY 86.3

DATE 2-19-51

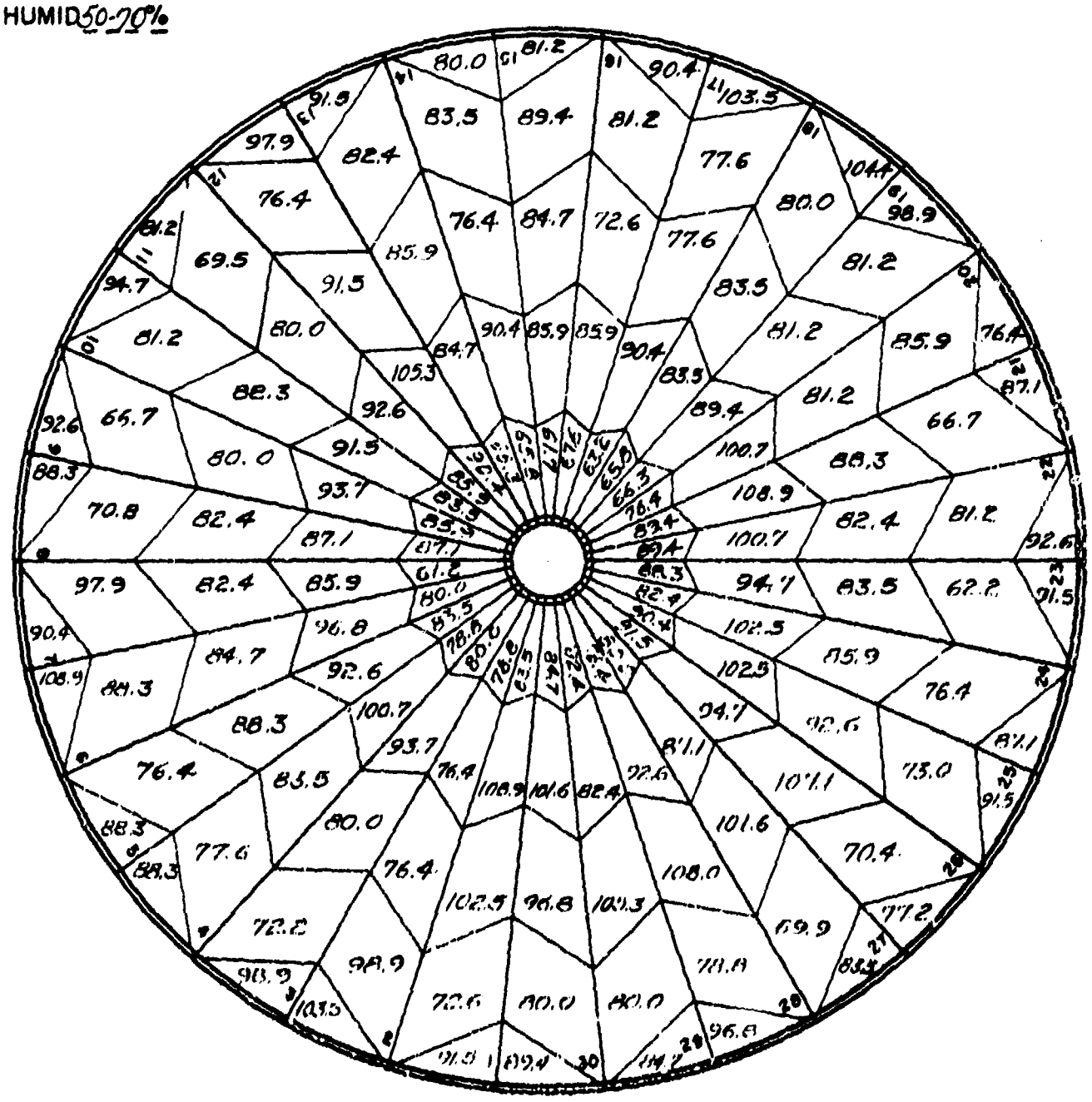
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350243

TEMP 75-80°F

HUMID 50-70%



AVERAGE POROSITY 88.8

DATE 8-19-57

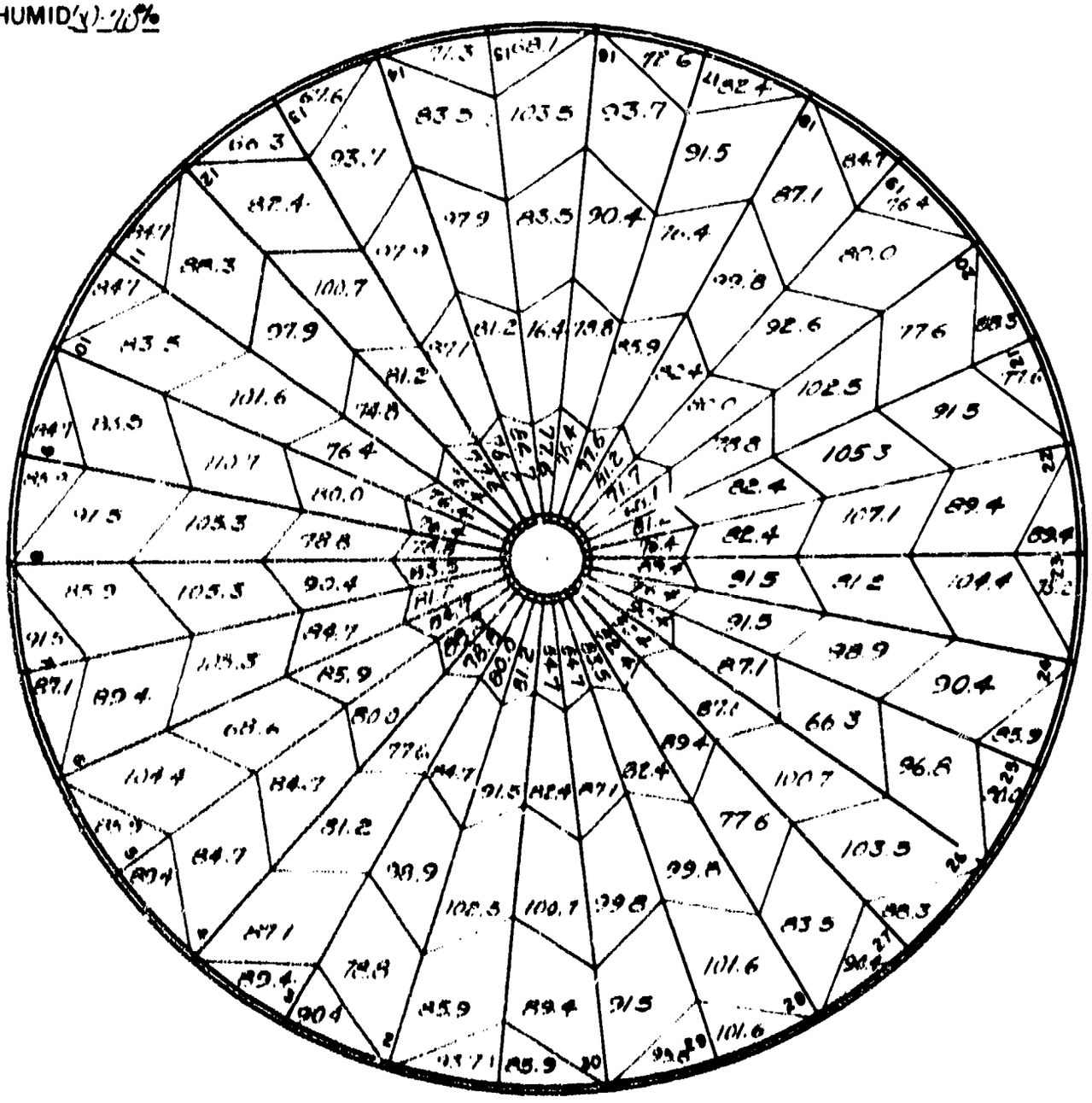
BY J.D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. [illegible]

TEMP [illegible] °F

HUMID [illegible] %



AVERAGE POROSITY 86.5

DATE 2-26-51

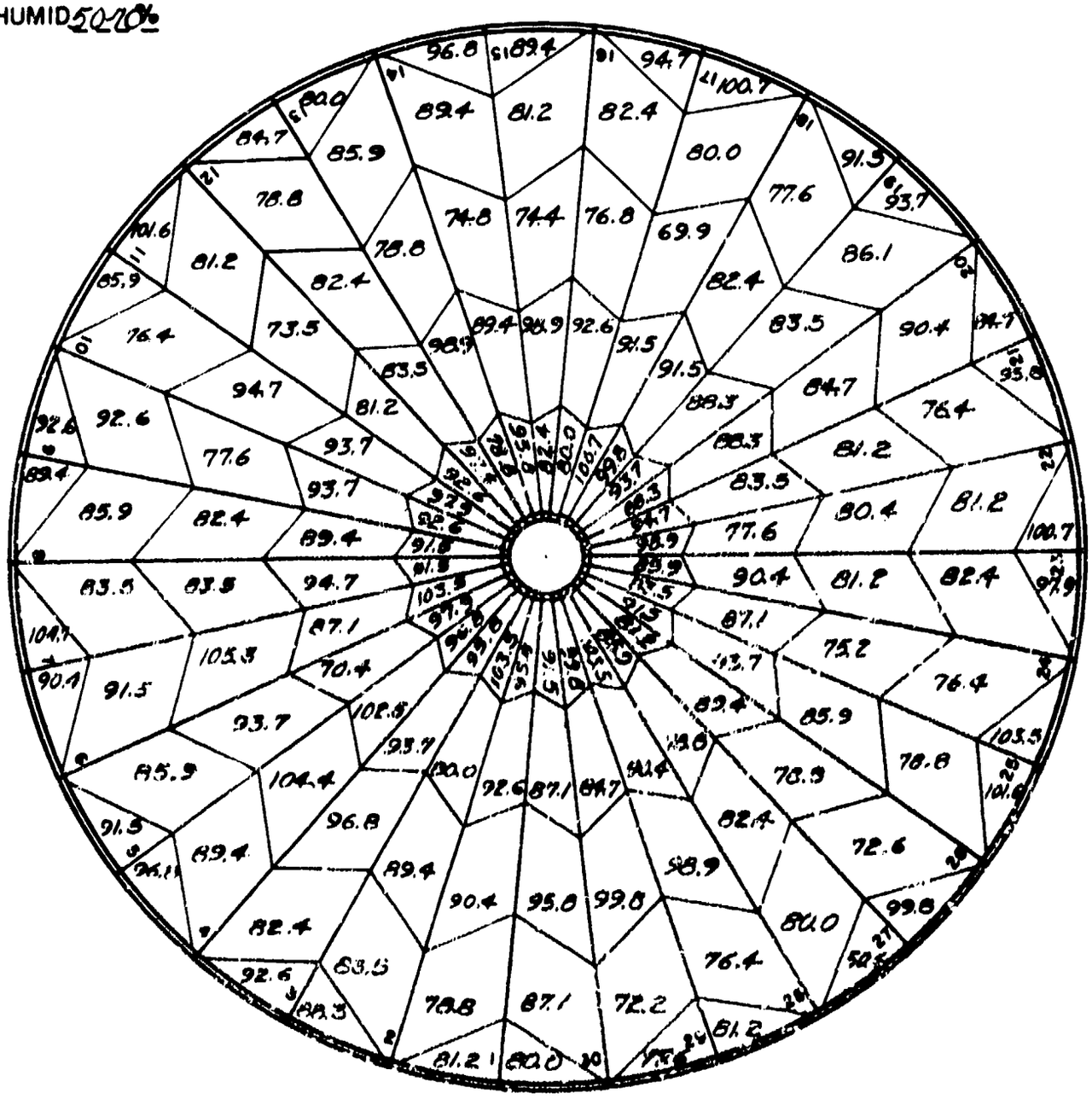
BY L.B.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350245

TEMP 75-80°F

HUMID 50-70%



AVERAGE POROSITY 88.0

DATE 2-27-57

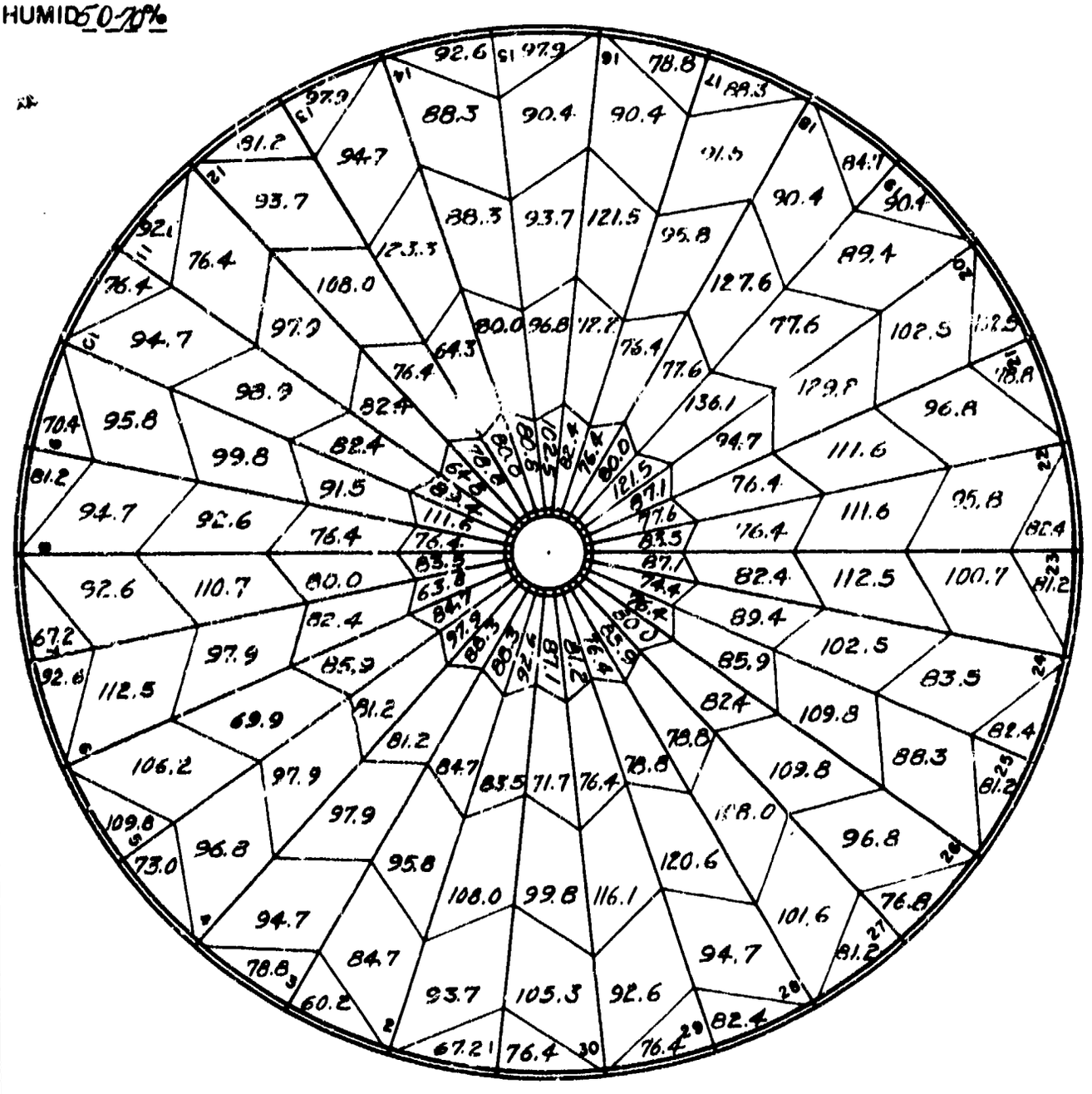
BY L.D

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350246

TEMP 75-80°F

HUMID 50-70%



AVERAGE POROSITY 89.8

DATE 2-16-51

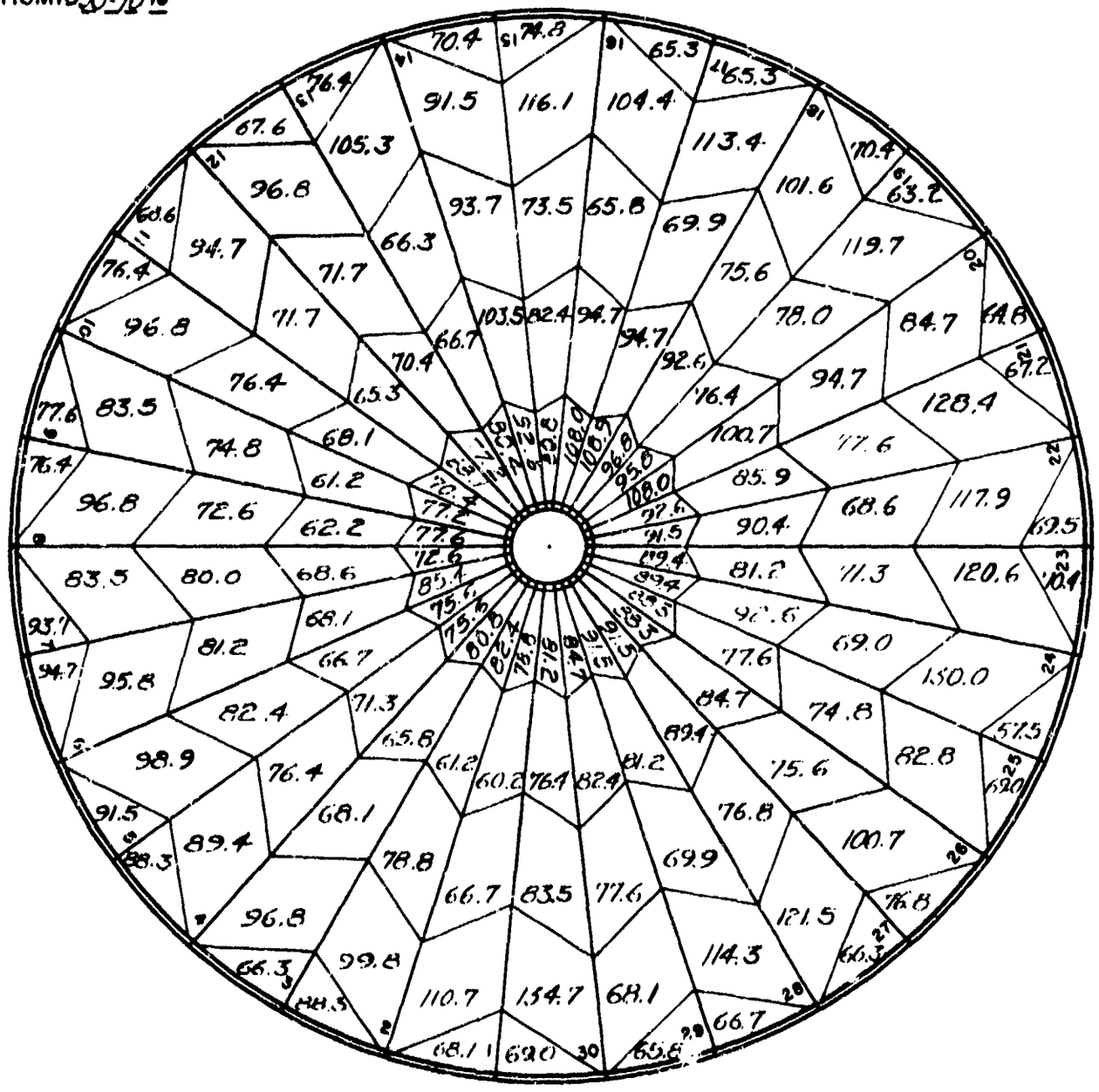
BY L.D. & C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350247

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 83.2

DATE 2-17-61

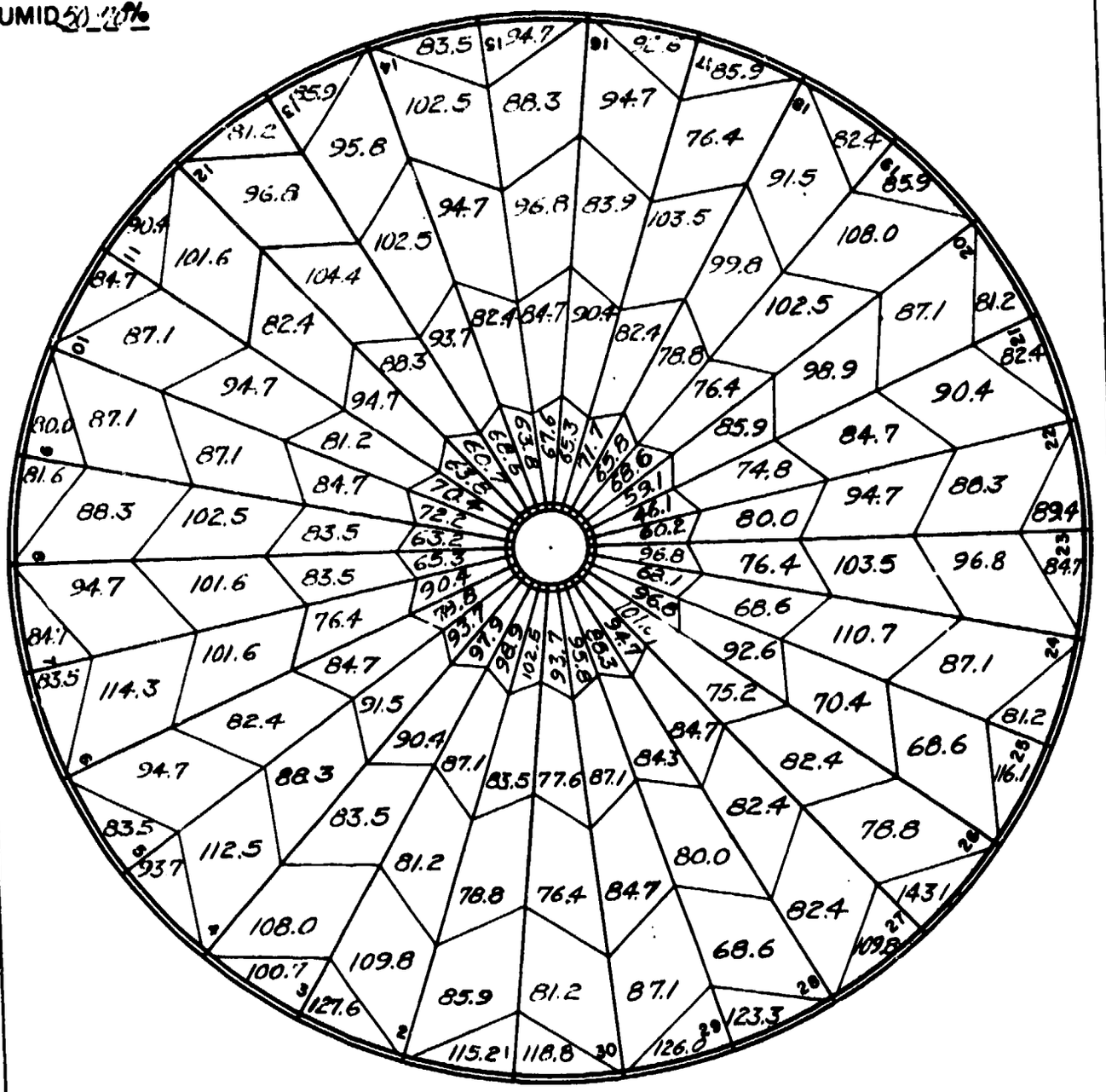
BY L.D.S. C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 3502-18

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY 88.1

DATE 2-21-51

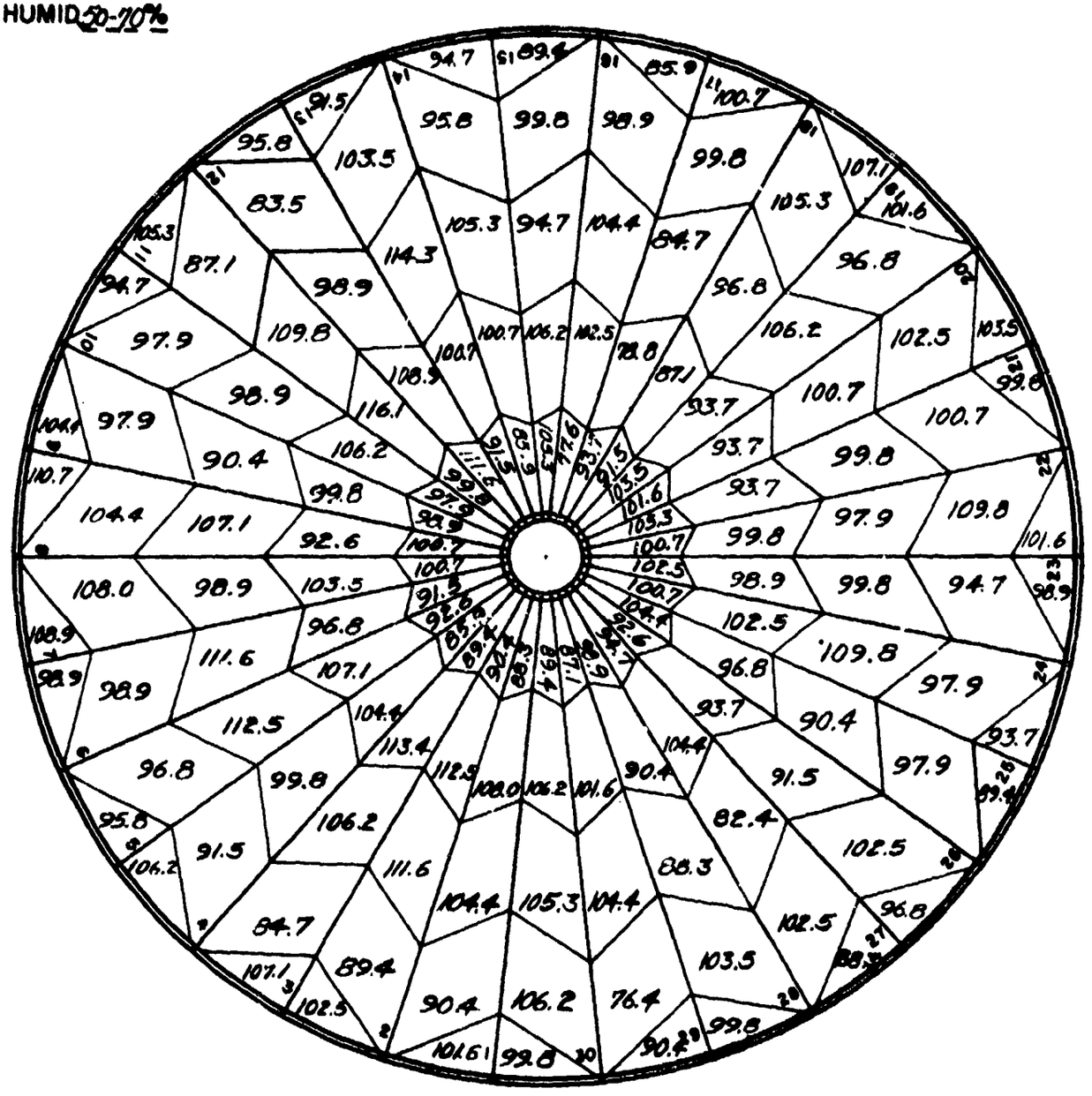
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350249

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY 98.7

DATE 2-28-51

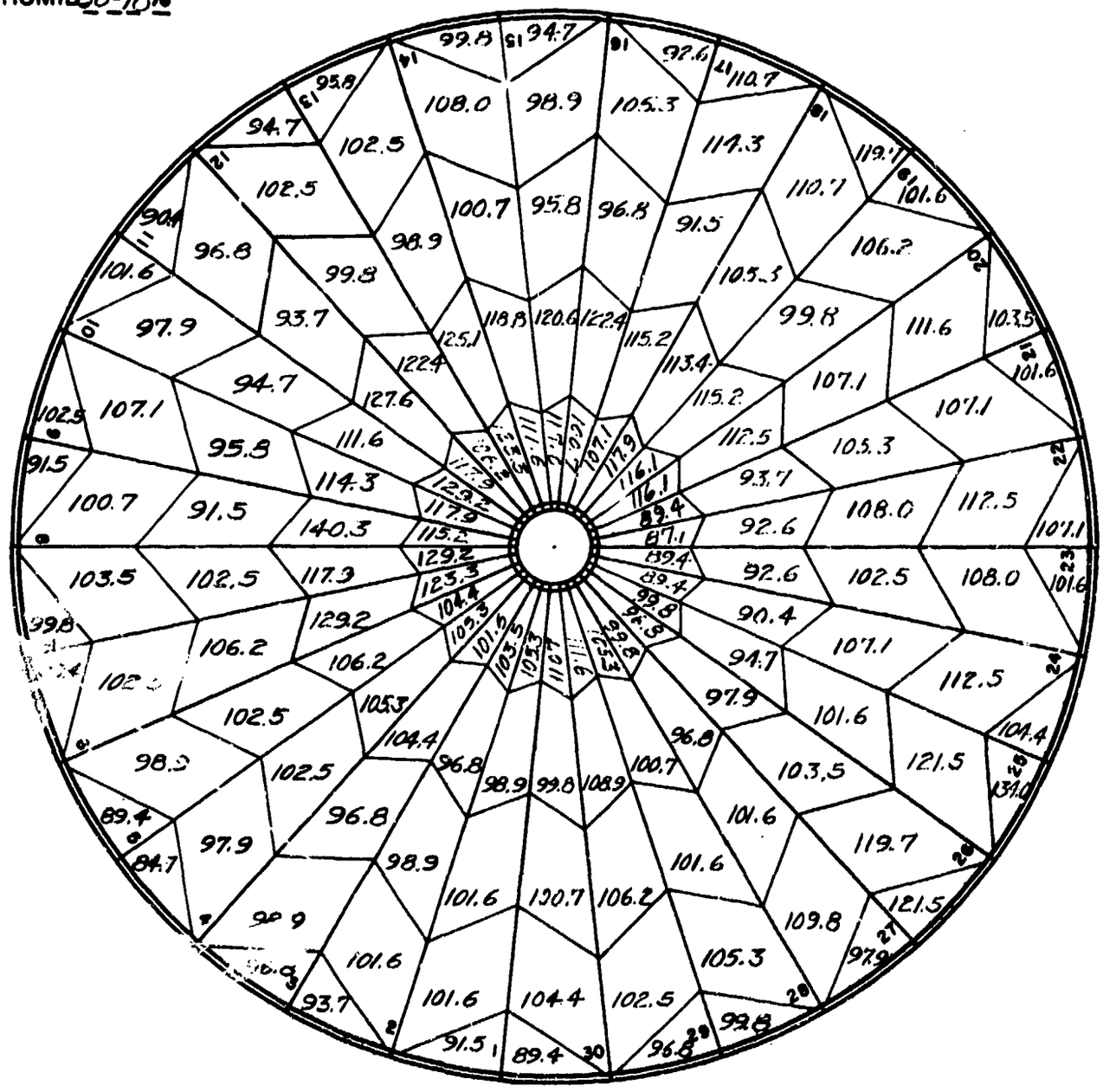
BY L.D. & C.M

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 100 M.P.H.

SERIAL NO. 350250

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 104.8

DATE 2-23-51

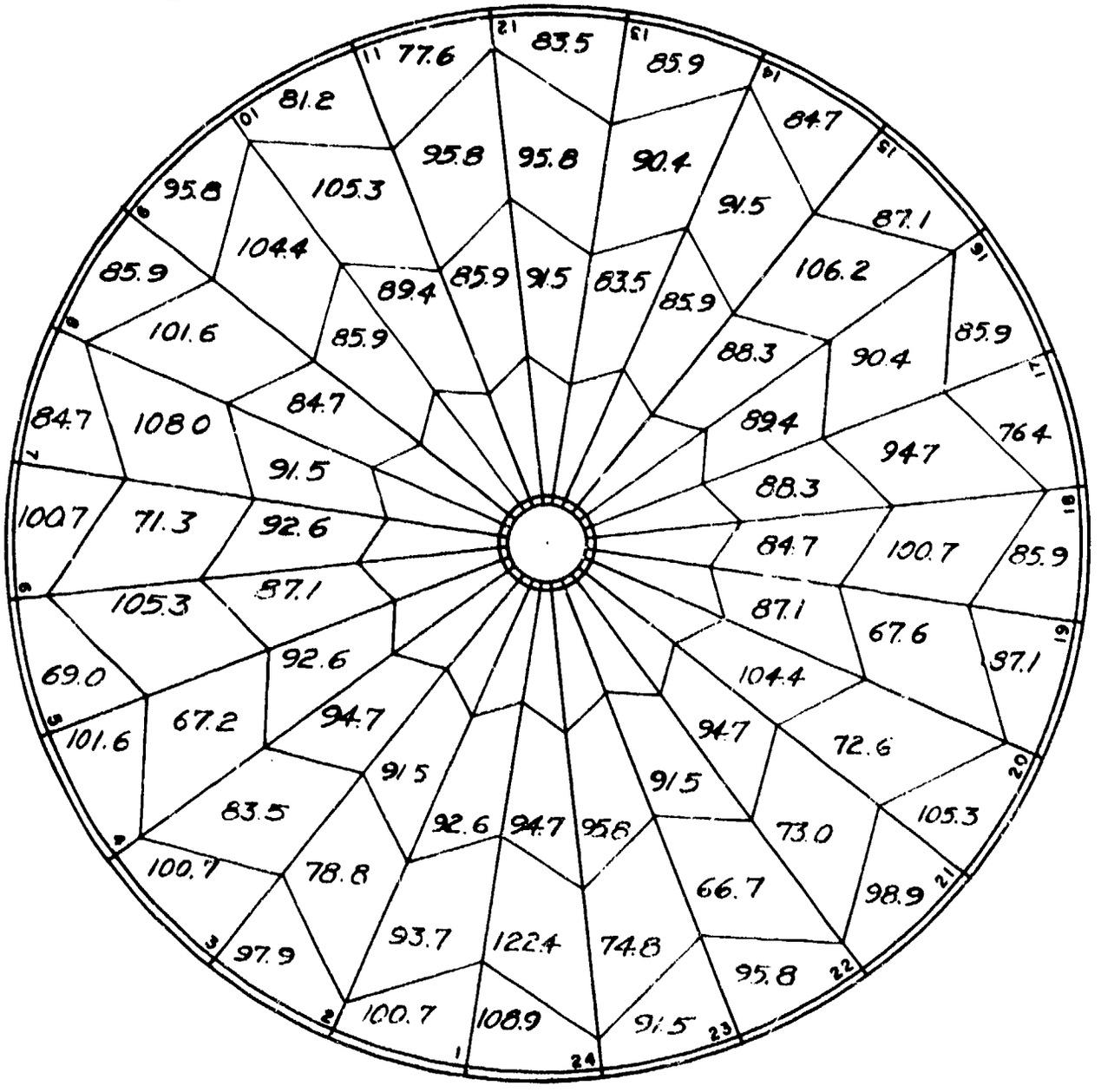
BY C.M

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350204

TEMP. 68 °F

HUMID 16 %



AVERAGE POROSITY: 101.8

DATE 2-2-51

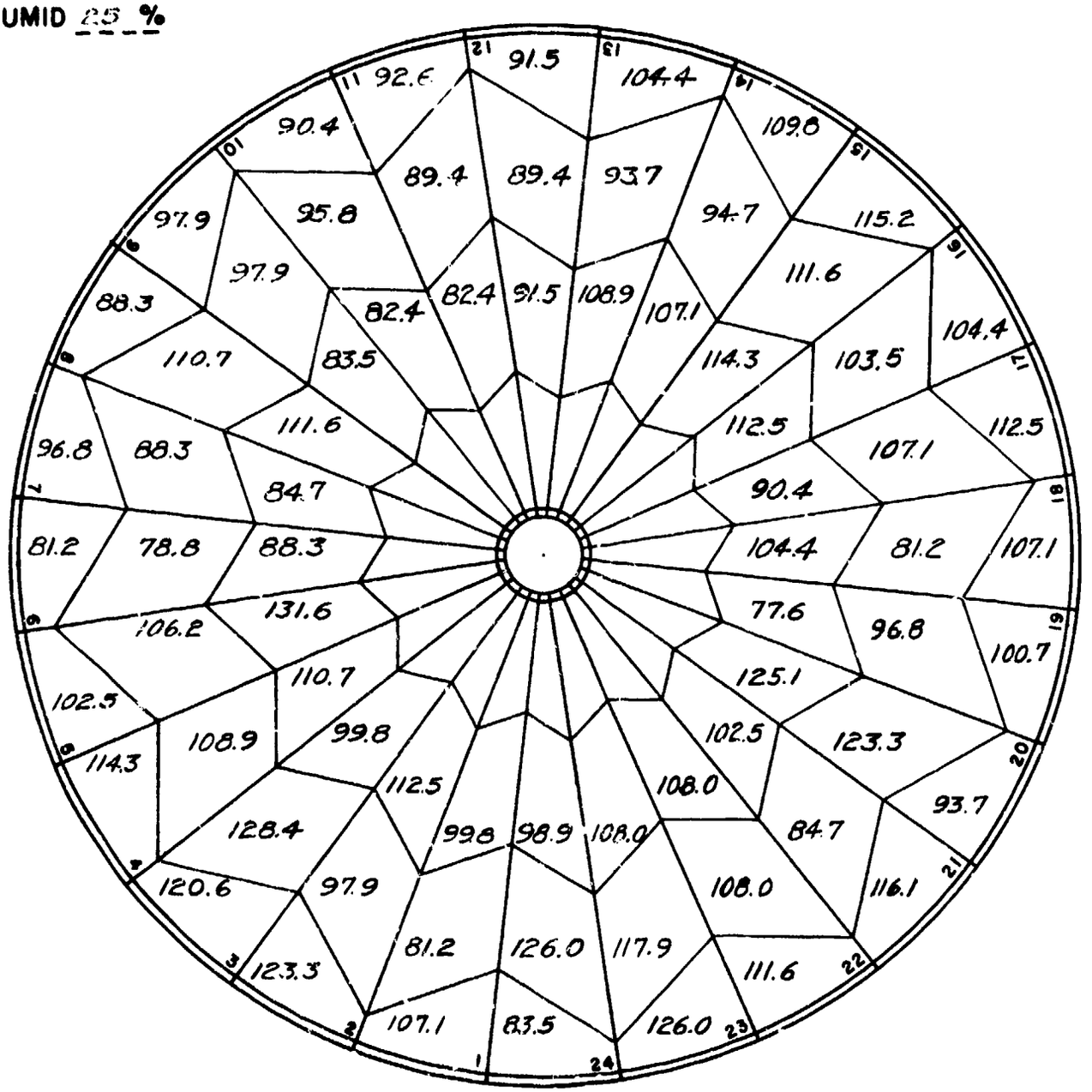
BY L.D

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350210

TEMP. 70 °F

HUMID 25 %



AVERAGE POROSITY: 102.1

DATE 12-5-50

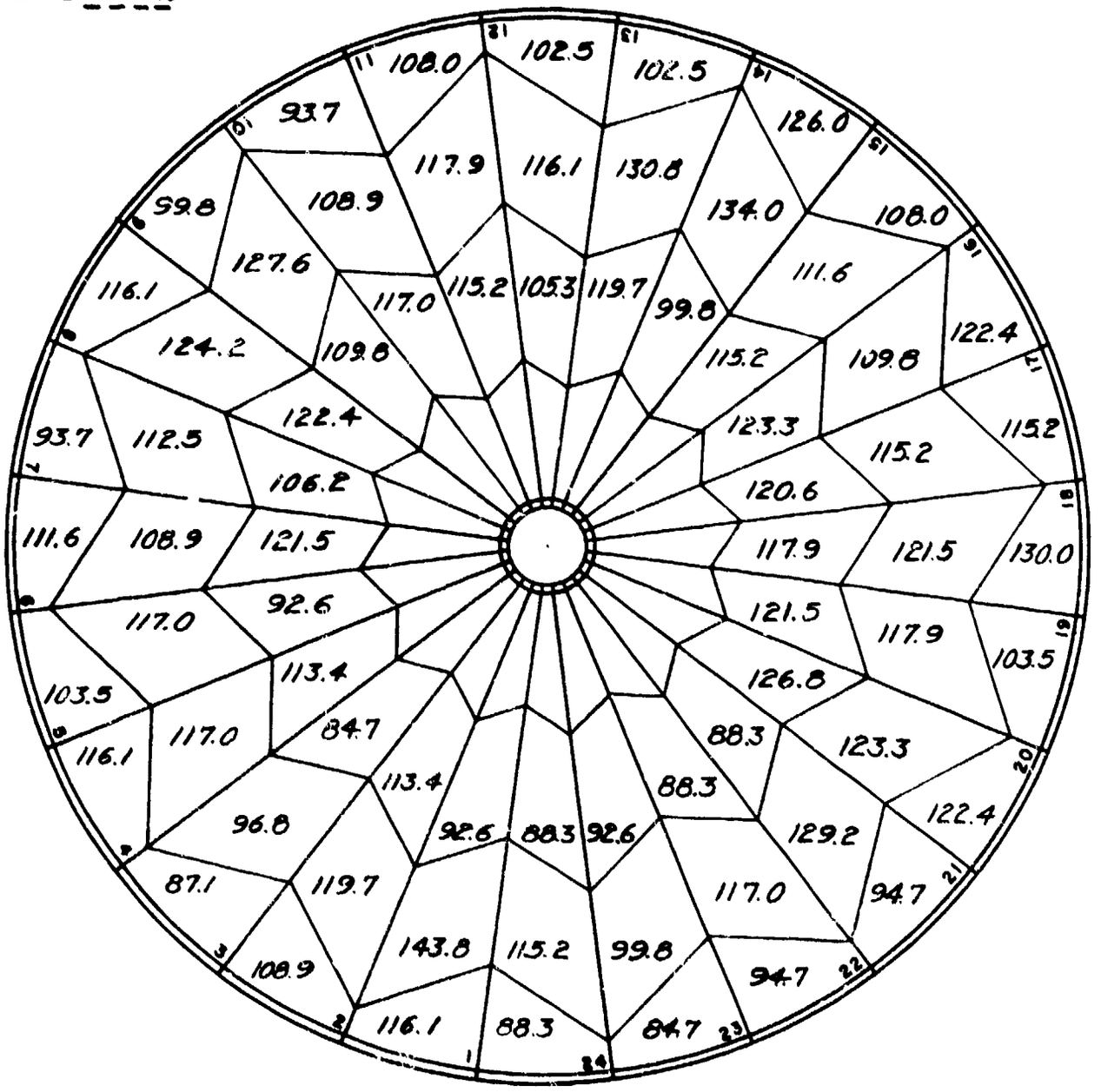
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350216

TEMP. 68 °F

HUMID 25 %



AVERAGE POROSITY: 110.9

DATE 12-5-50

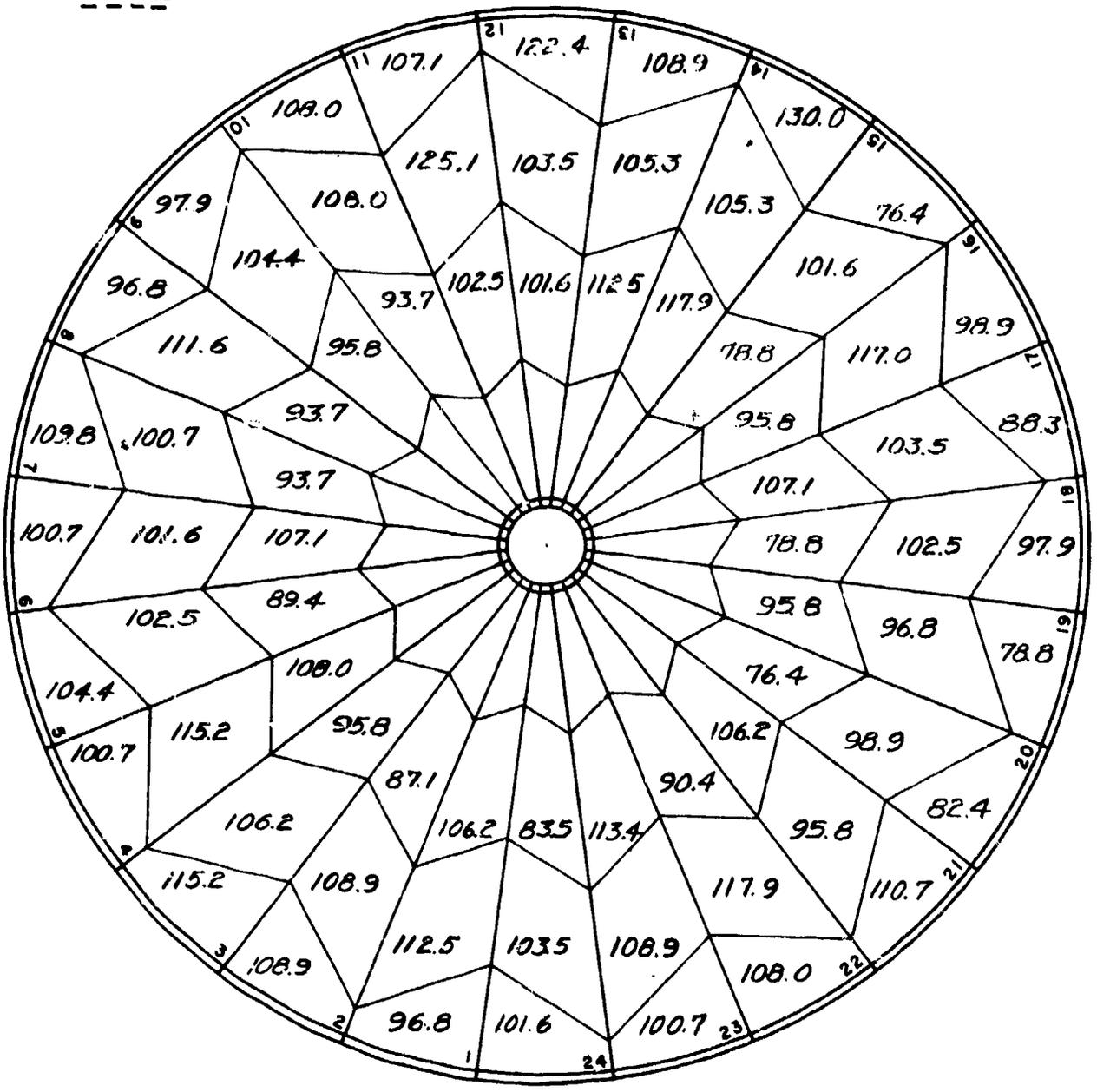
BY A.V.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350228

TEMP. 78 °F

HUMID 29 %



AVERAGE POROSITY: 101.8

DATE 12-8-50

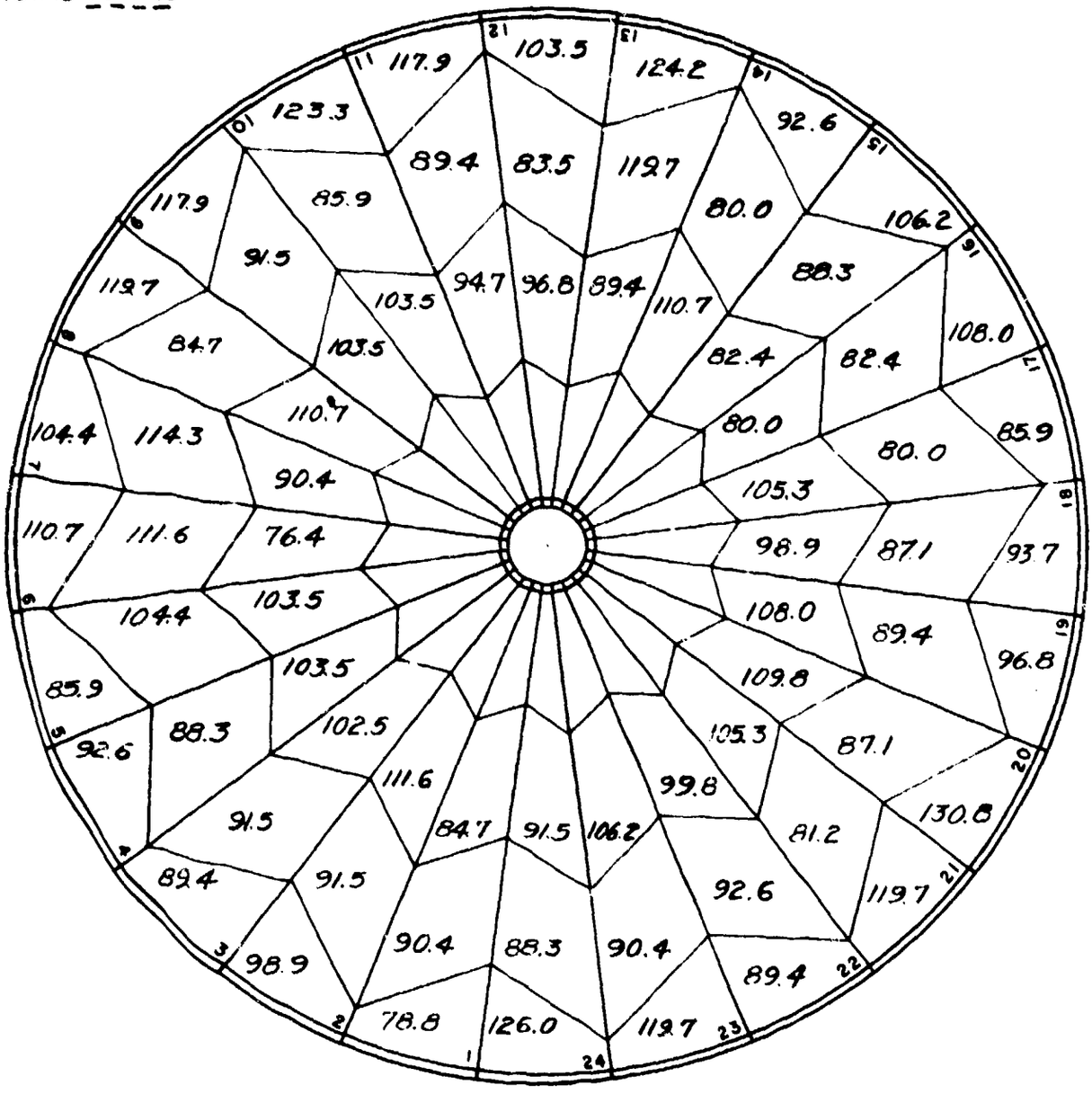
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350228

TEMP. 72 °F

HUMID 10 %



AVERAGE POROSITY: 98.6

DATE 12-8-50

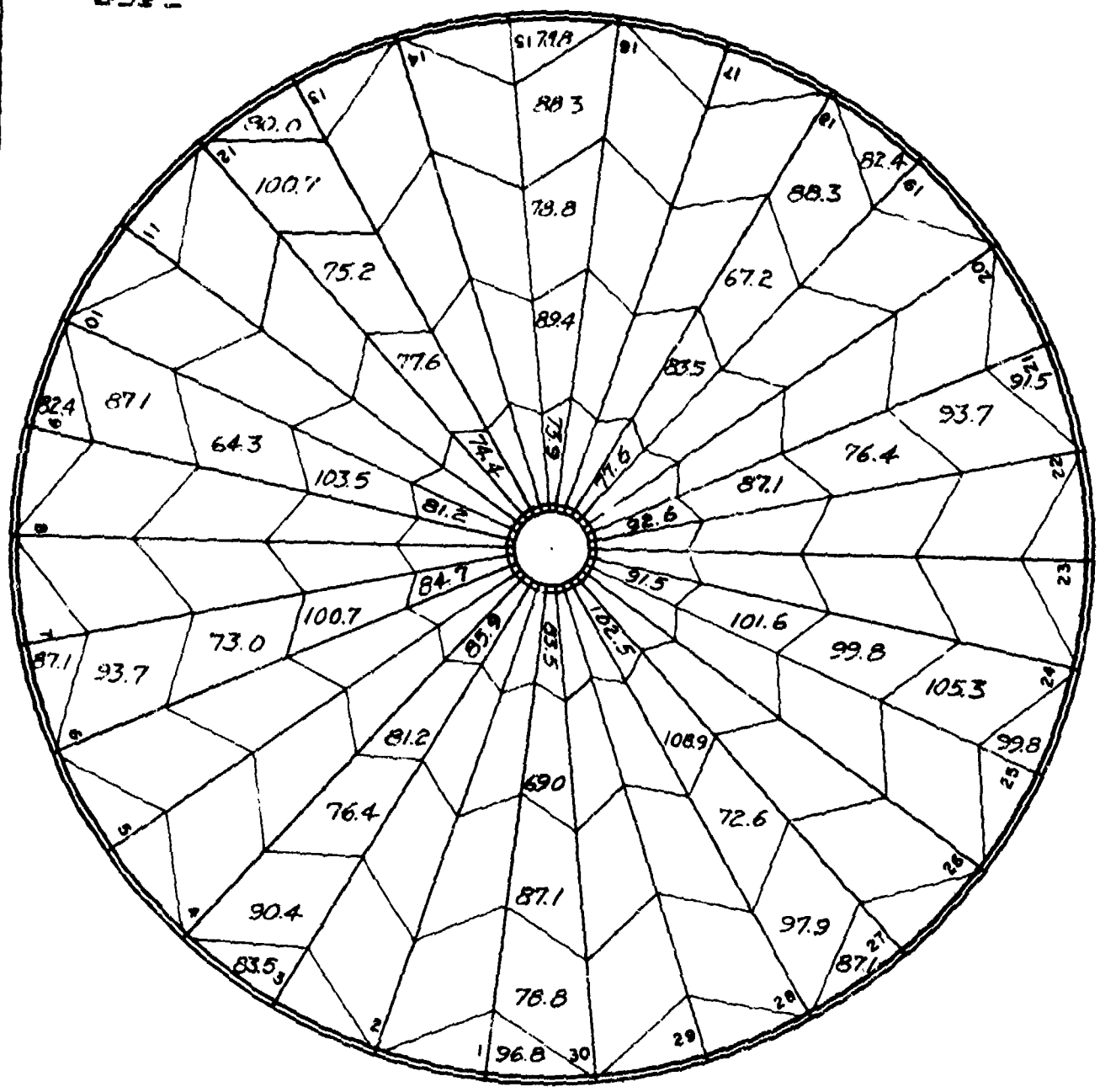
BY A.V.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350231

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY 86.3

DATE 3-3-51

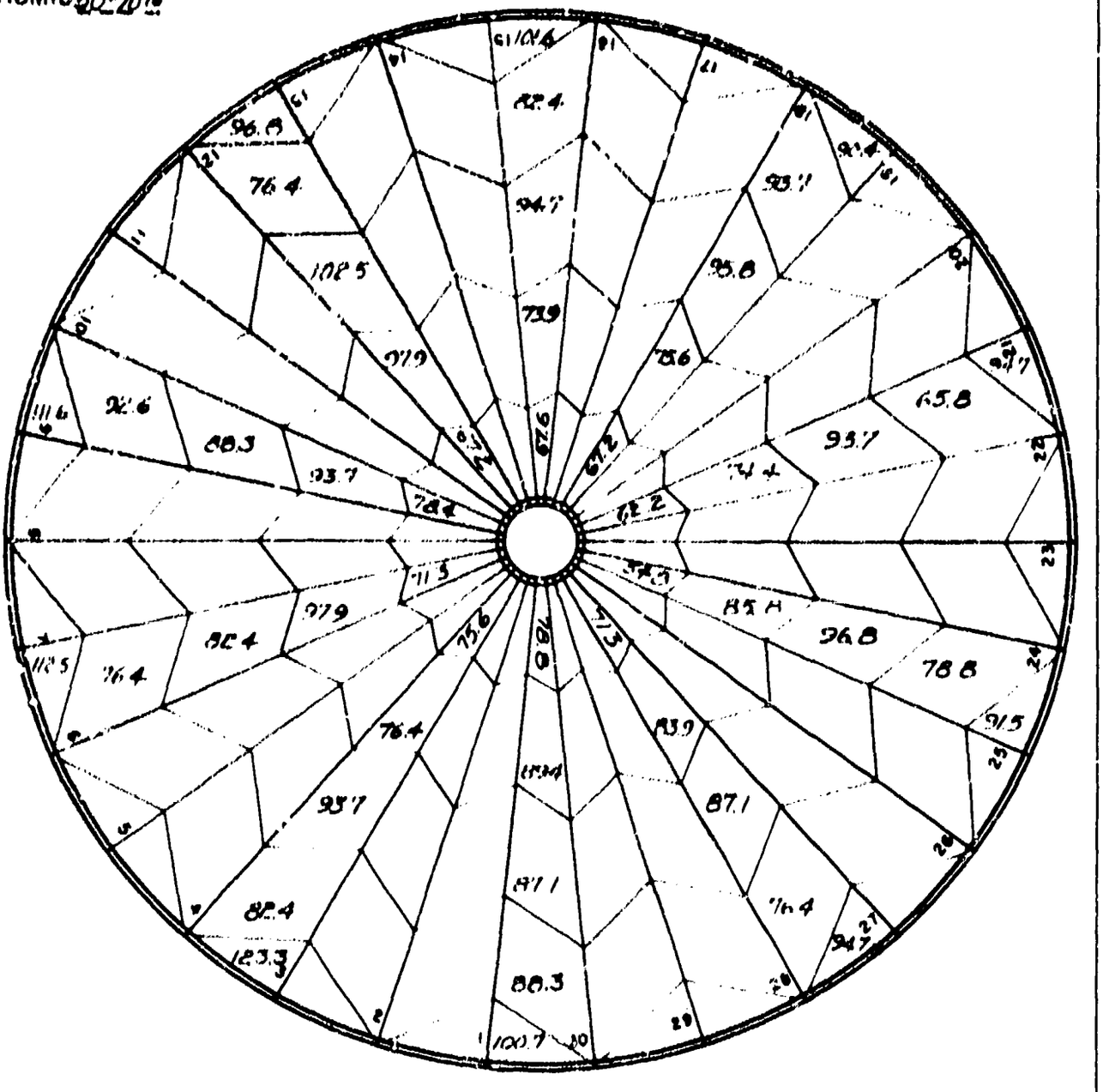
BY L.D. & C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 N.P.H.

SERIAL NO. 350235

TEMP. 75-80°F

HUMIC 50-20%



AVERAGE POROSITY 80.9

DATE 3-2-57

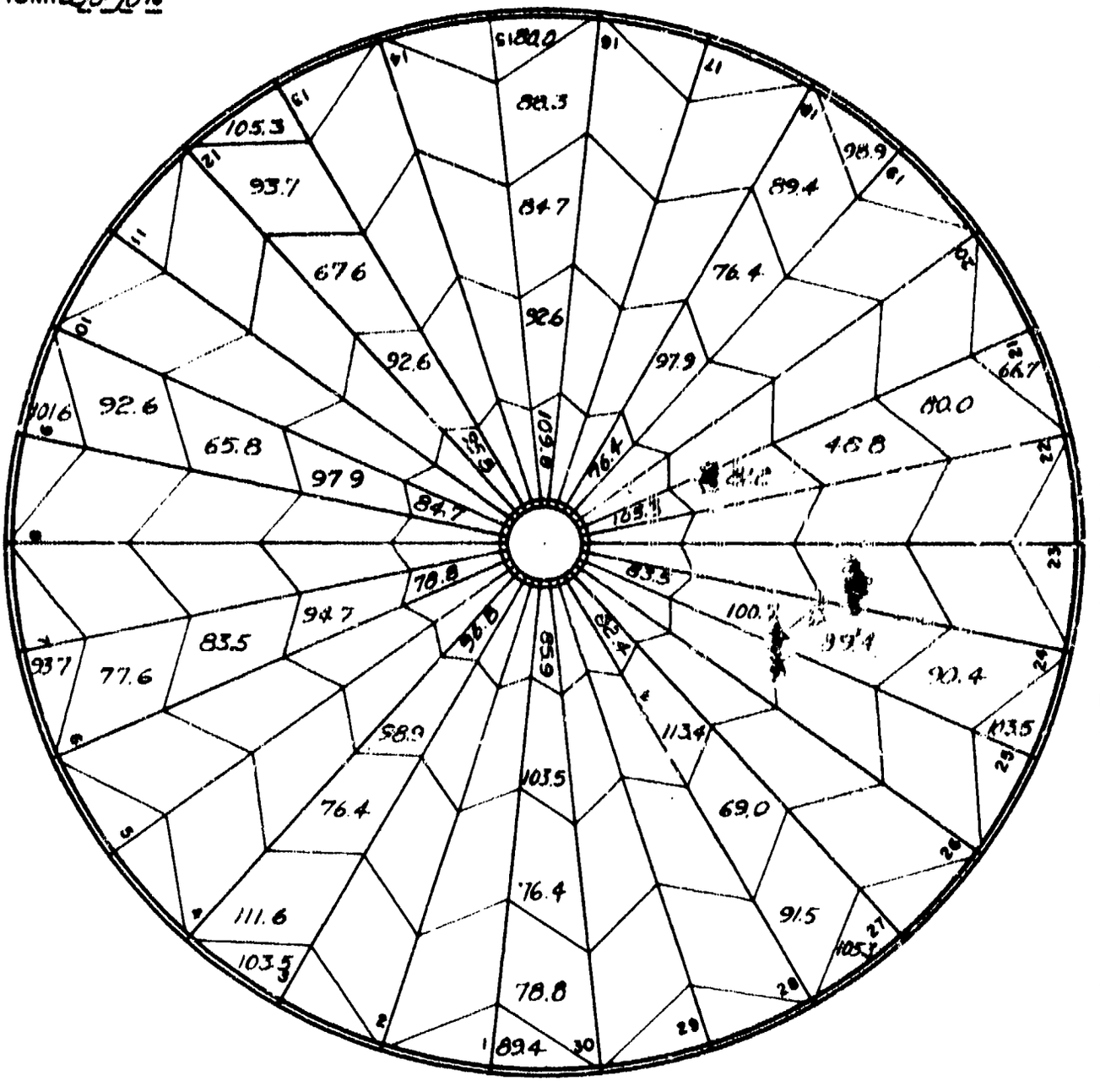
BY L. D. [illegible]

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350238

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY 89.1

DATE 3-3-51

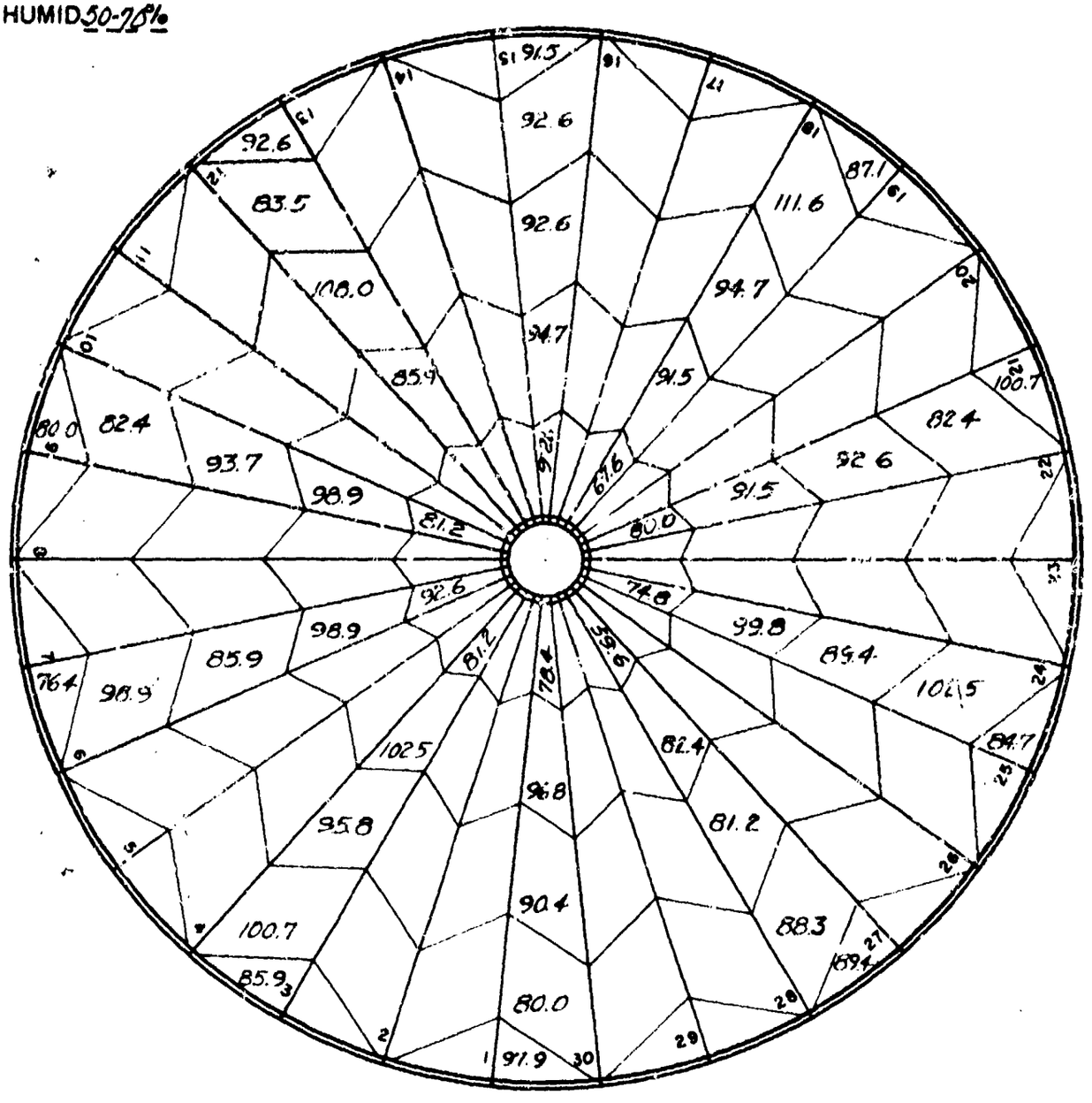
BY L.D. & C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350239

TEMP. 75-80°F

HUMID. 50-78%



AVERAGE POROSITY 88.8

DATE 3-2-51

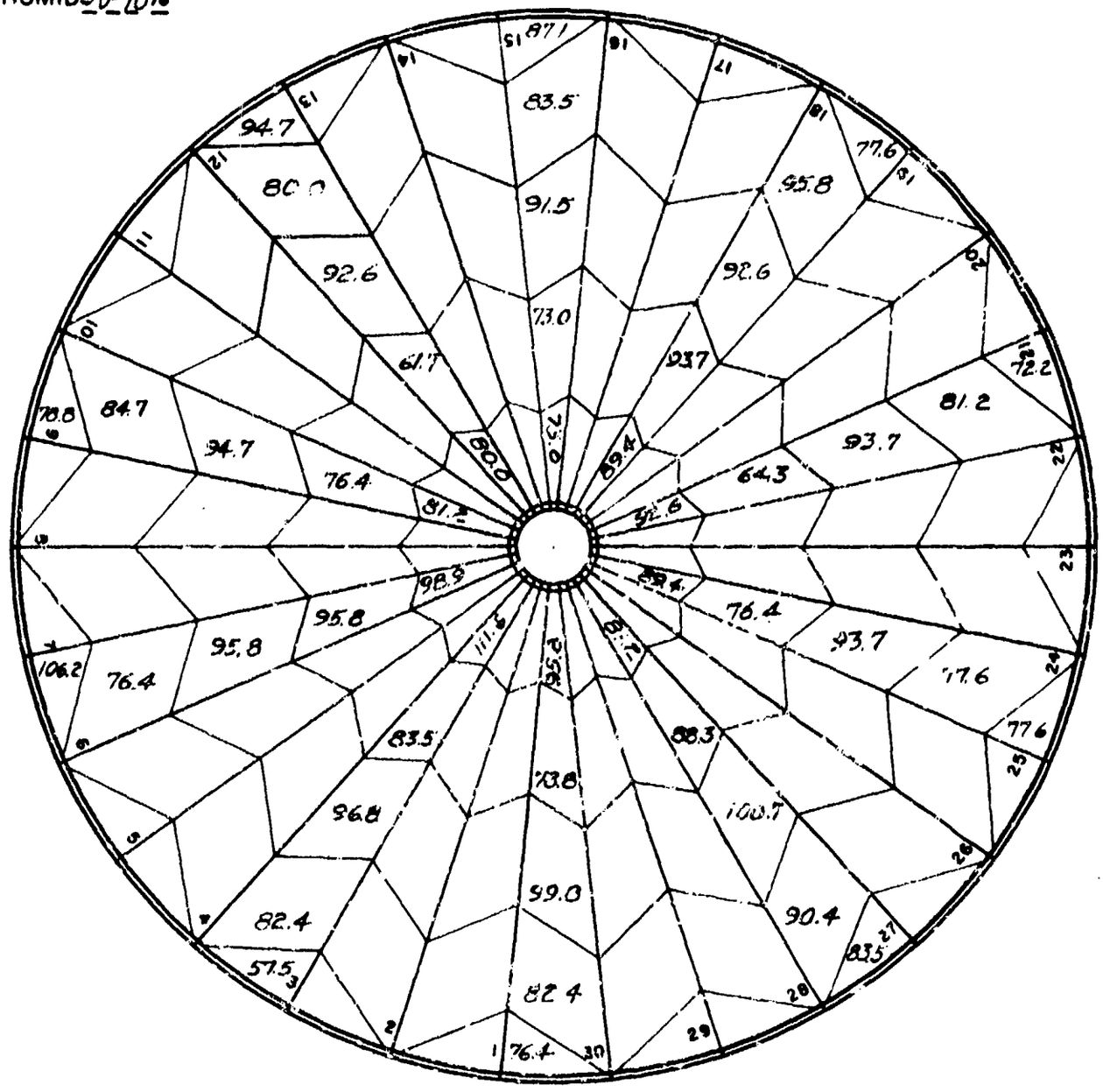
BY L.D. & C.H.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350242

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY 85.7

DATE 3-3-51

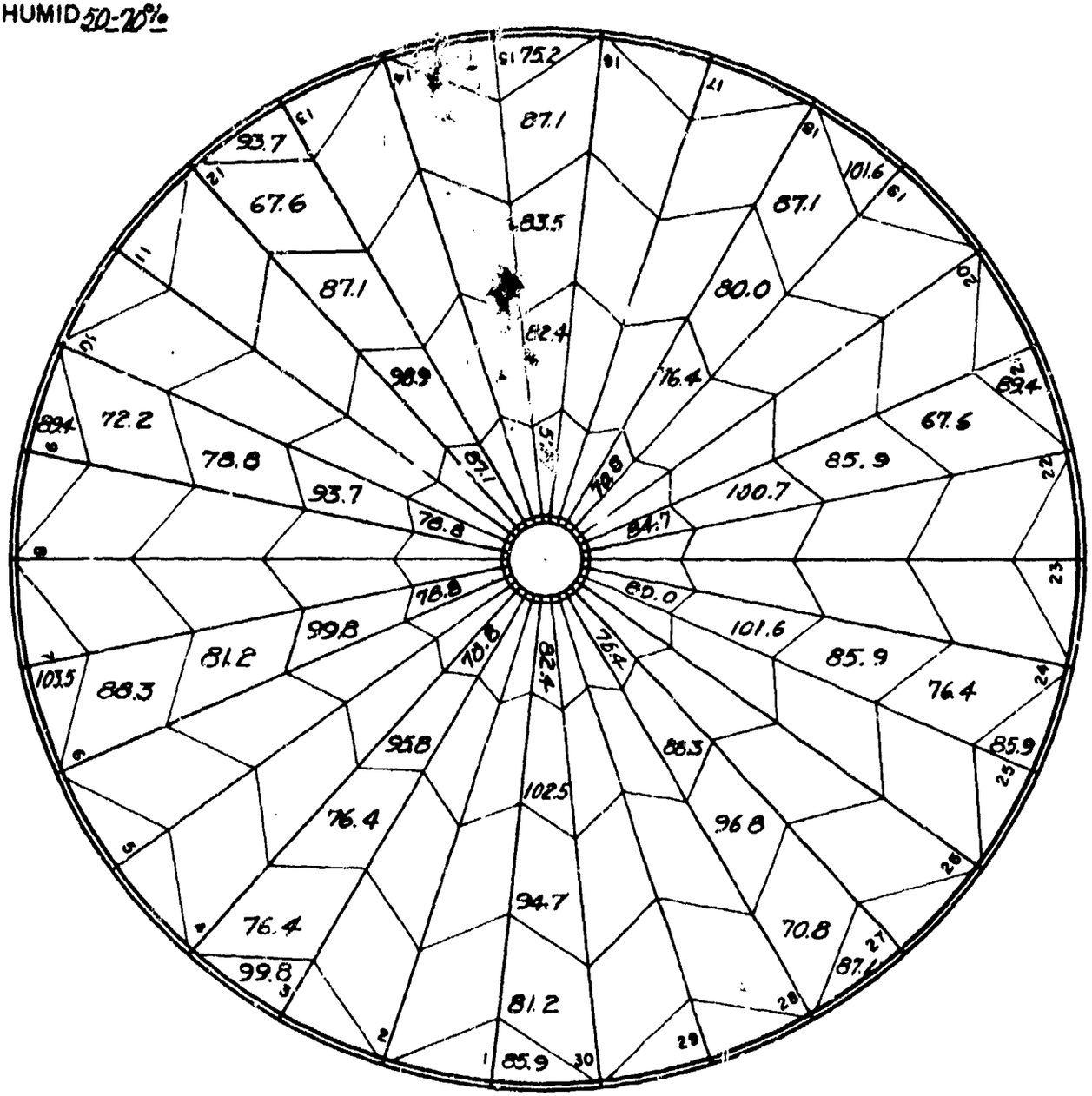
BY L.D.S. C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350243

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY 85.0

DATE 3-2-51

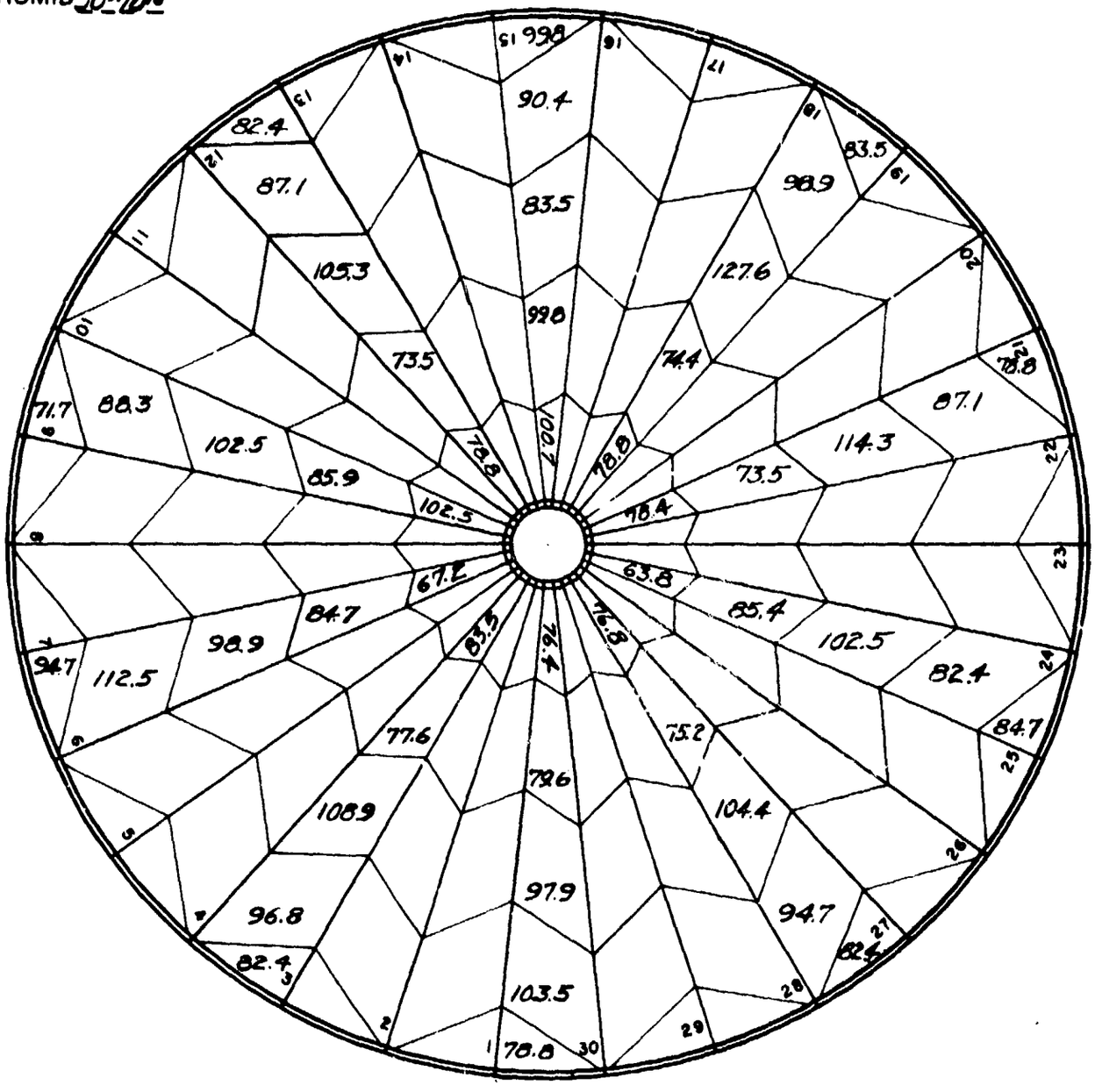
BY L.D. & C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350246

TEMP. 75-80F

HUMID. 50-70%



AVERAGE POROSITY 88.9

DATE 3-3-51

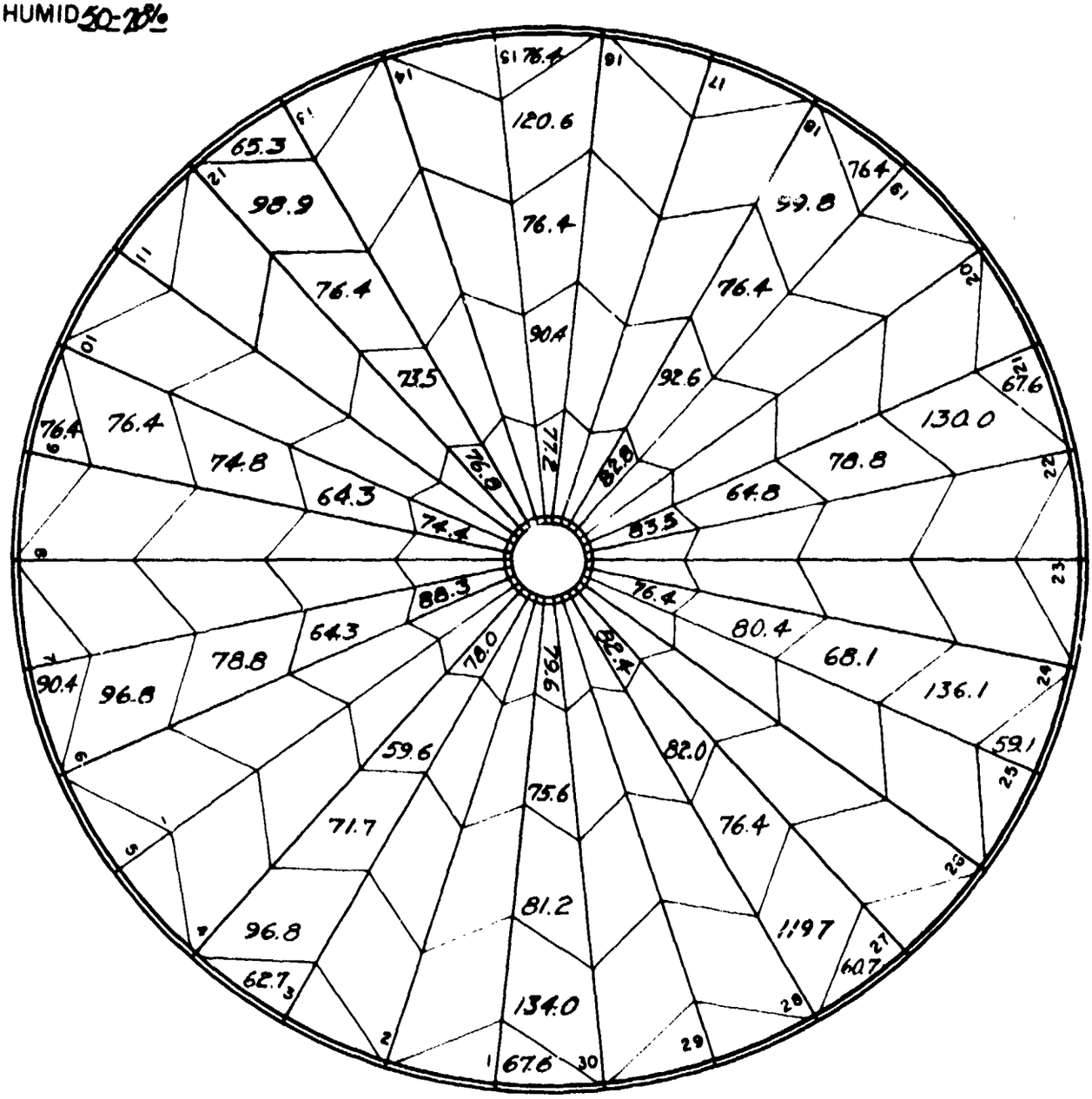
BY L.D. & C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350247

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY 82.4

DATE 3-2-51

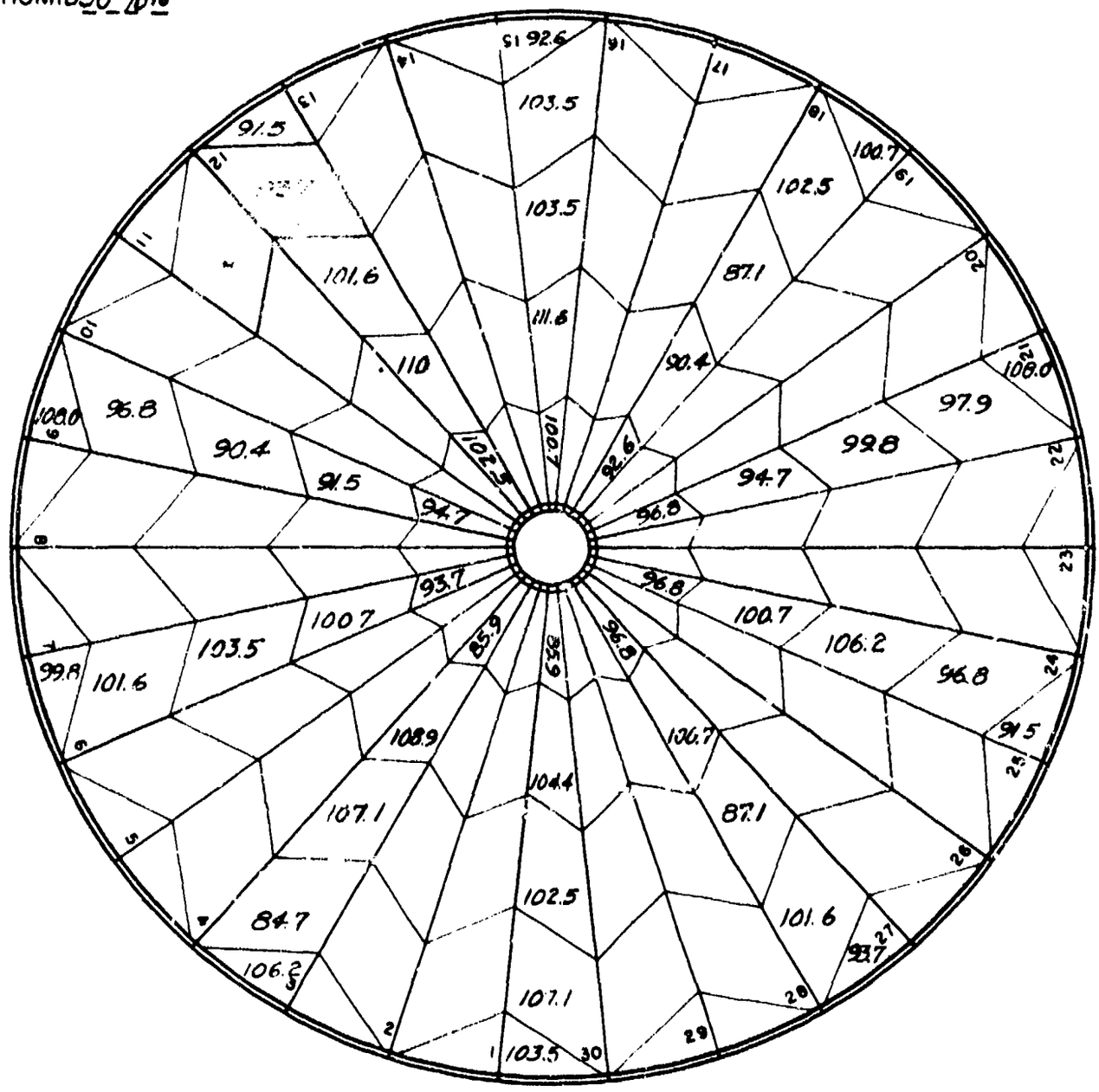
BY L.U.&C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 3502412

TEMP 75-80°F

HUMID 50-70%



AVERAGE POROSITY 98.6

DATE 3-12-51

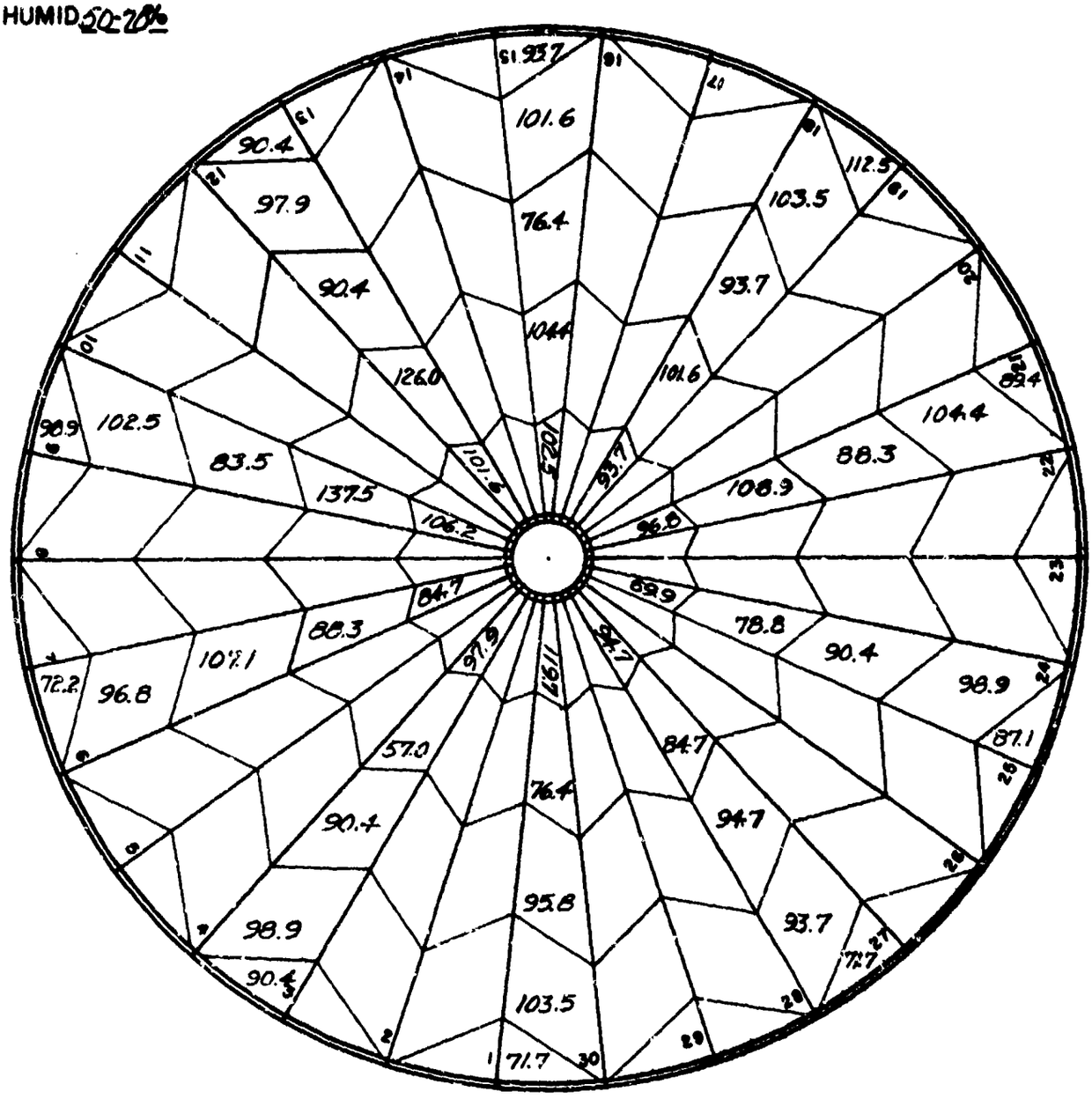
BY L.D. & C.M.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 150 M.P.H.

SERIAL NO. 350250

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 94.4

DATE 3-3-51

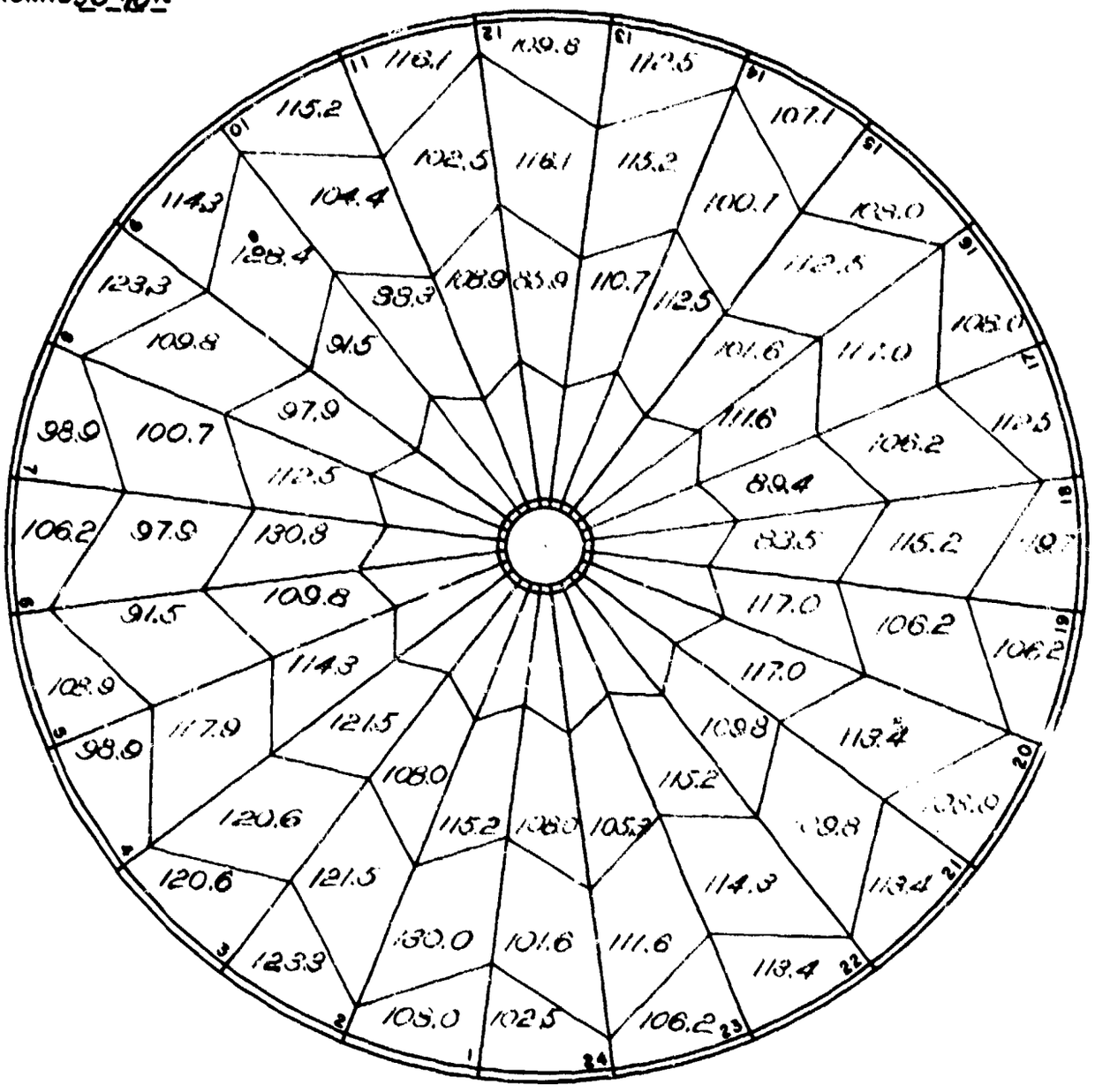
BY L.D & CM

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350201

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 109.6

DATE MAY 51

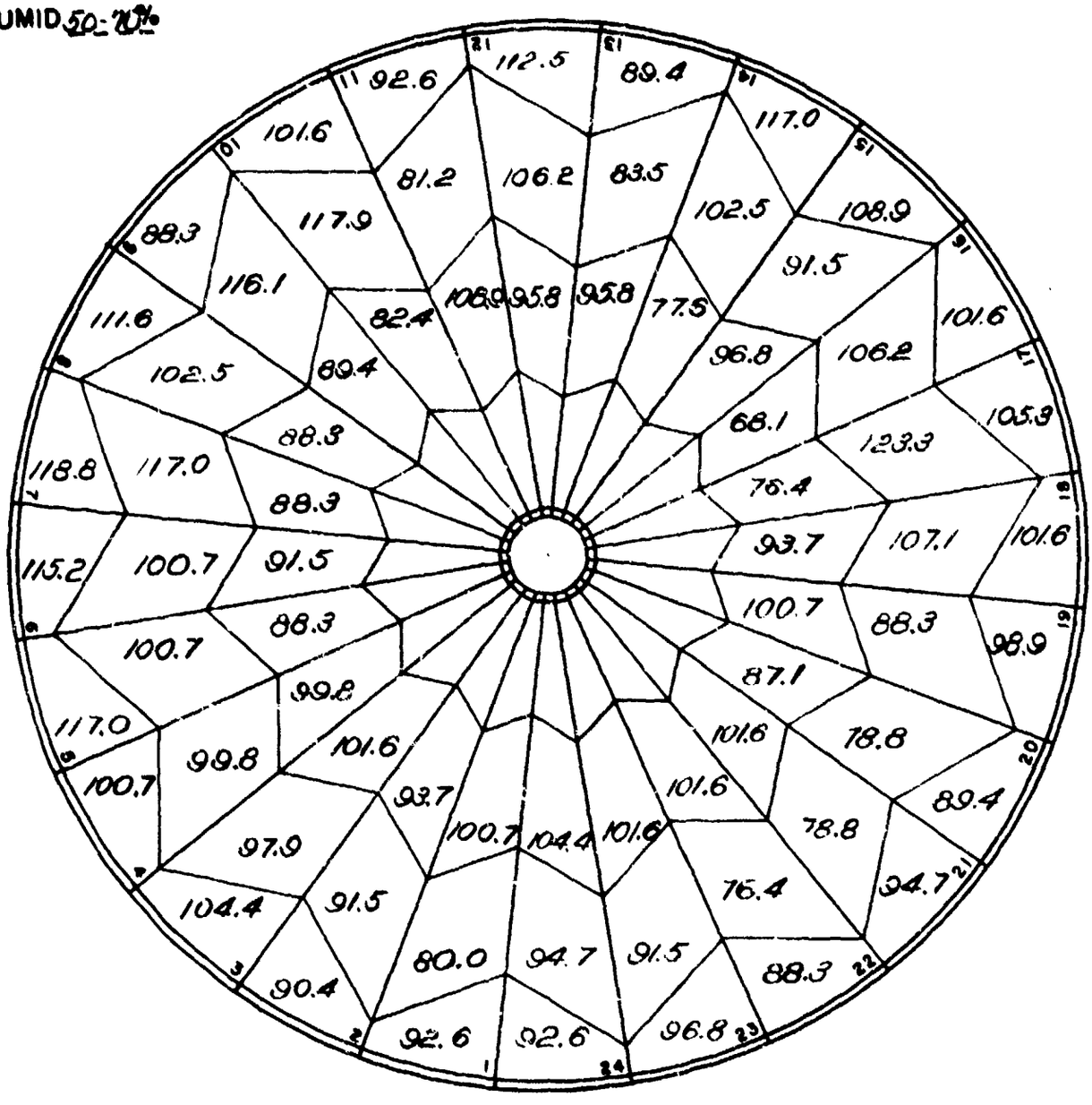
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350202 - - -

TEMP. 75-80 °F

HUMID. 50-70%



AVERAGE POROSITY: 97.2

DATE 2 MAY 51

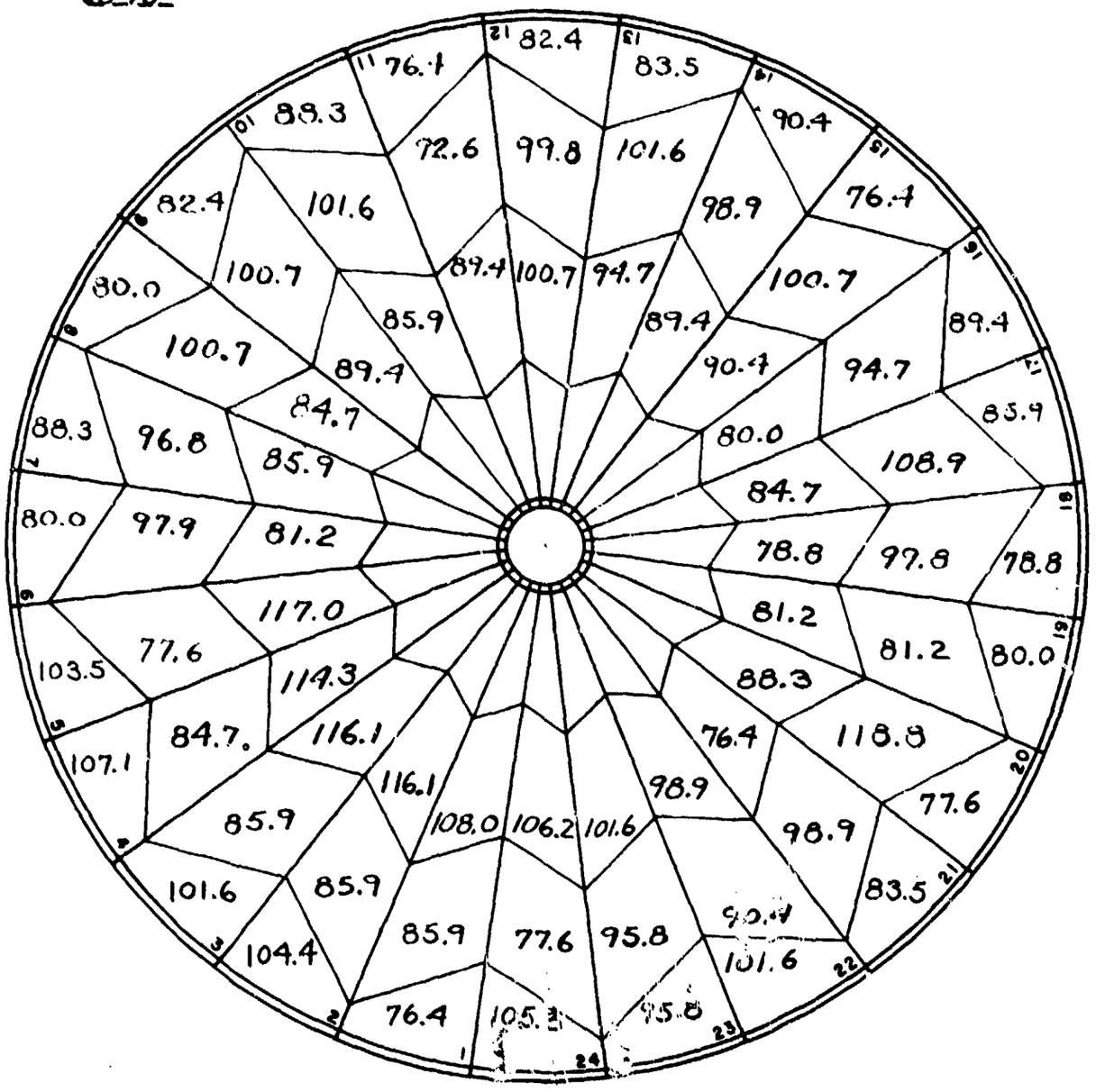
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350203

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 92.4

DATE 7 MAY 1951

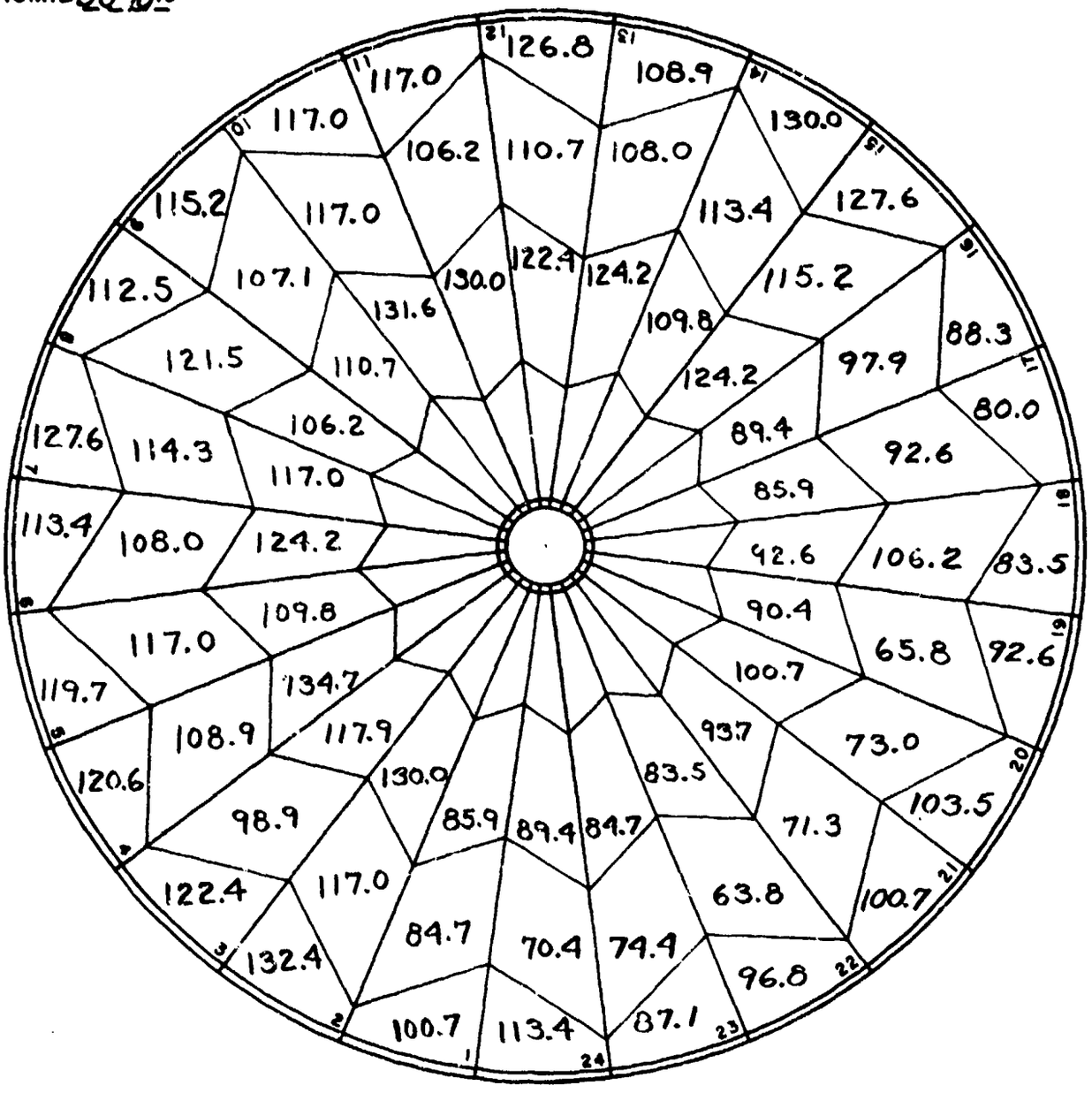
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350204

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 105.4

DATE 8 MAY 1951

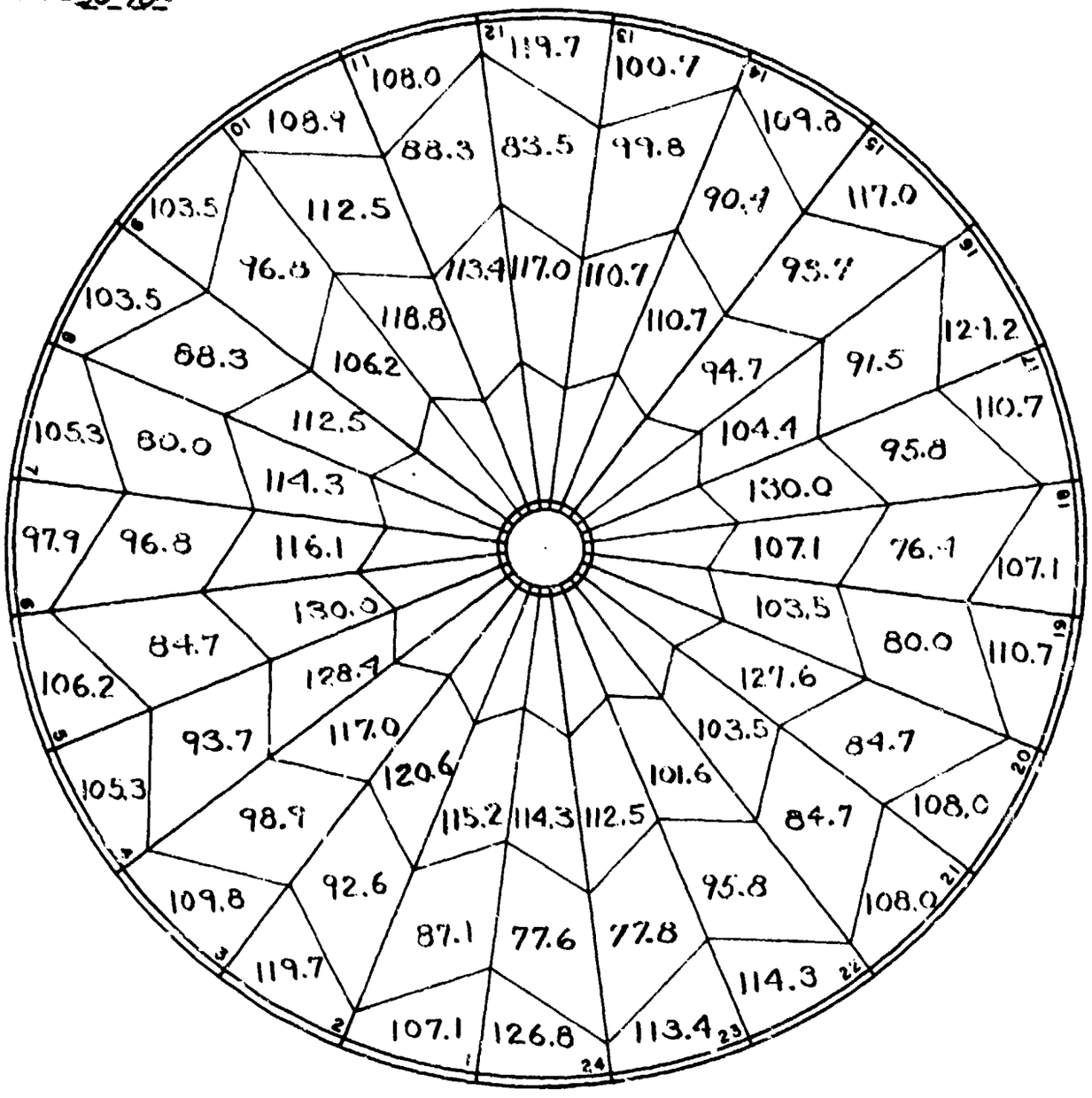
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350205

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 104.6

DATE 4 MAY 1951

BY L. D.

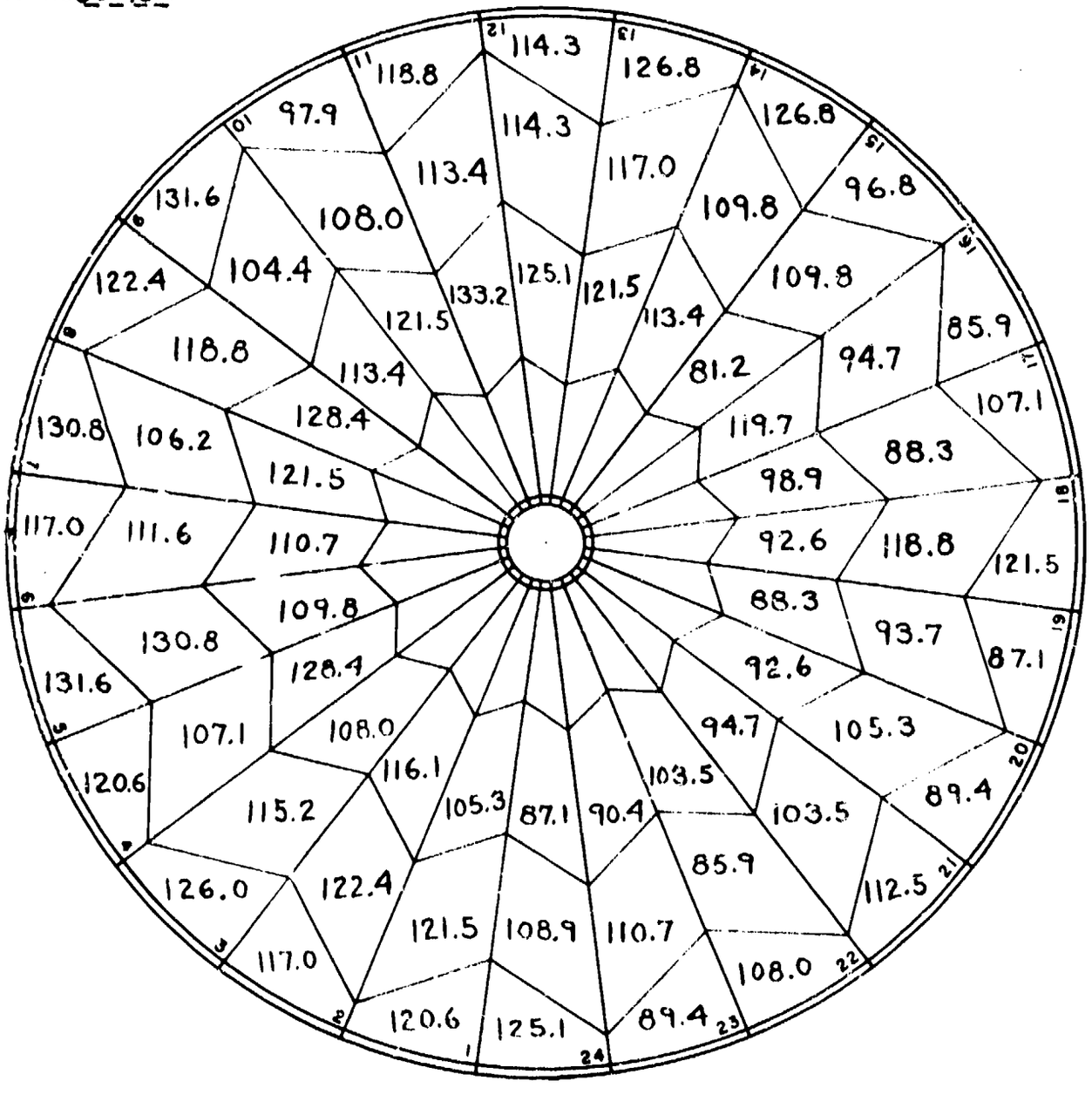
P

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350206

TEMP. 75-80F

HUMID. 50-70%



AVERAGE POROSITY: 110.5

DATE 4 MAY 1951

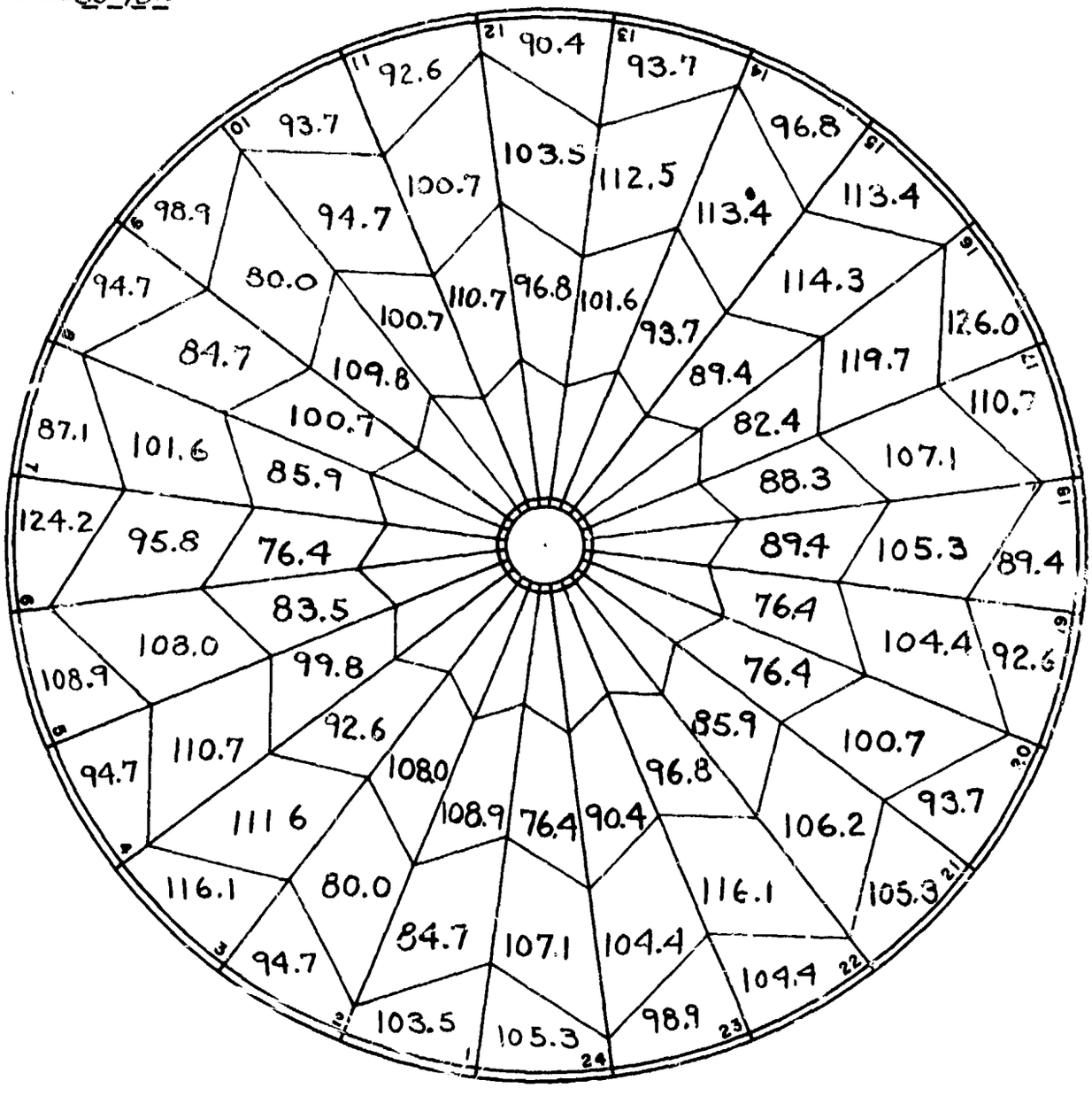
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350207

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 98.9

DATE 1 MAY 1951

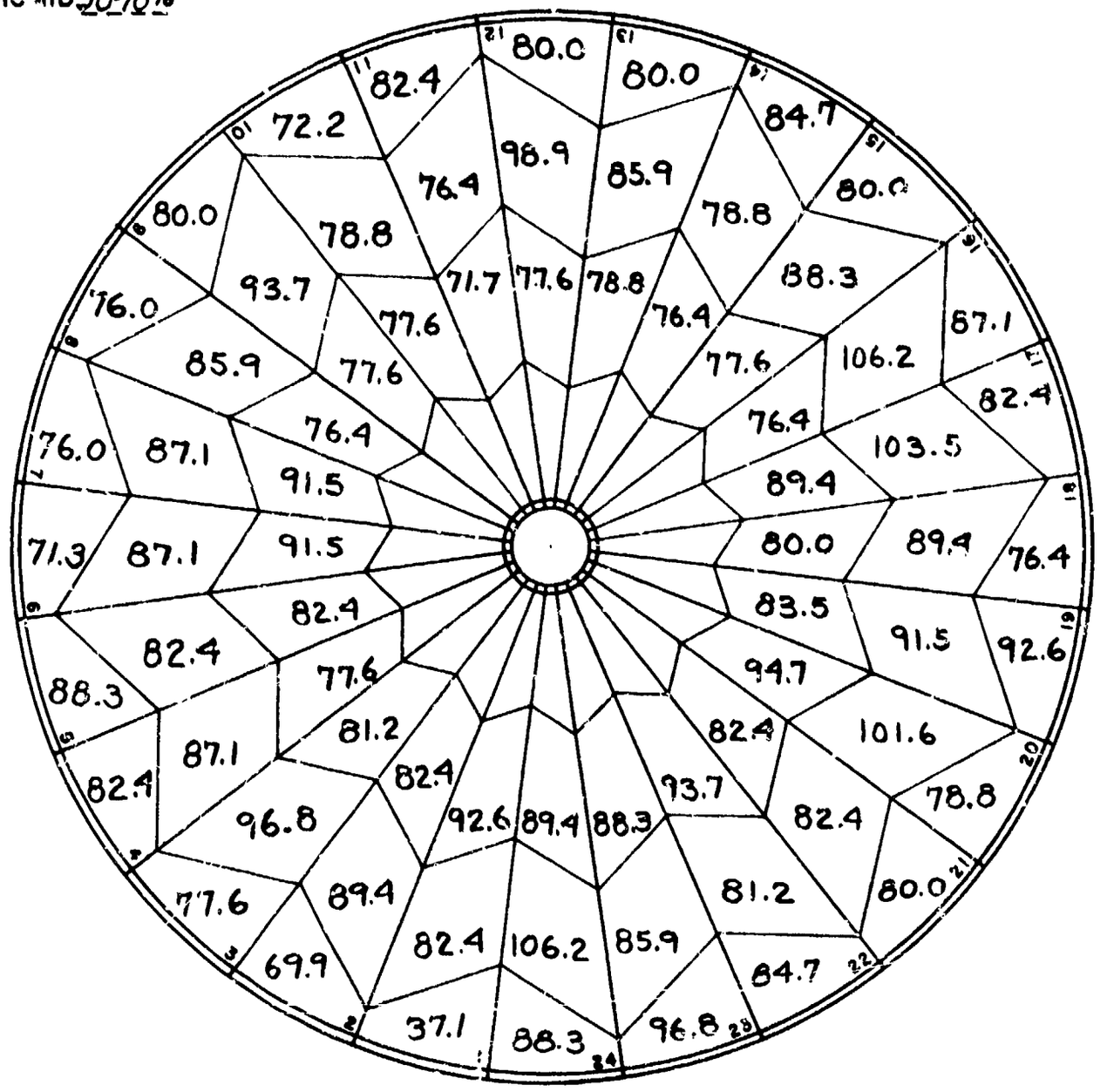
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350208

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 83.9

DATE 2 MAY 1951

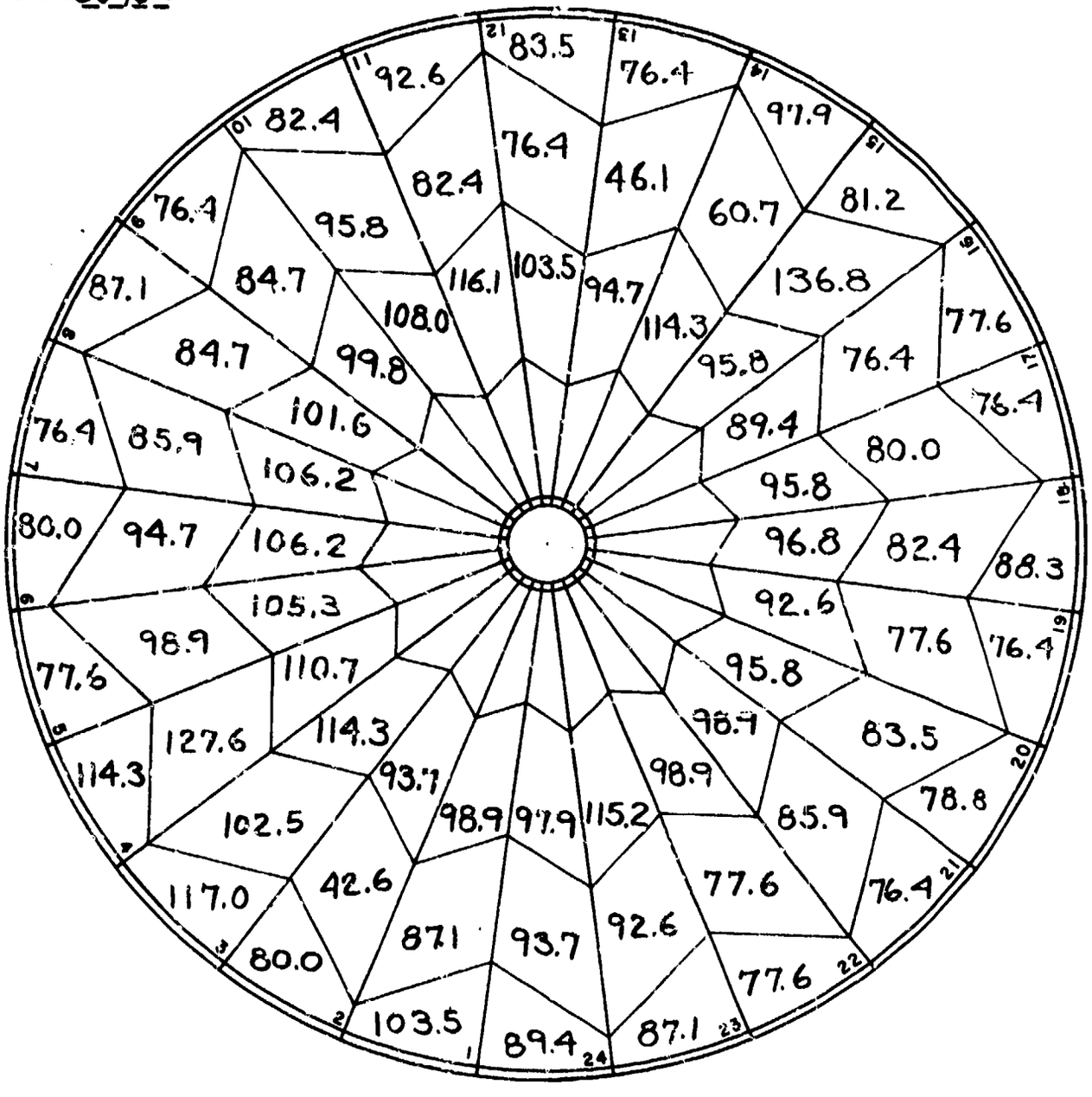
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350209

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 91.1

DATE 1 MAY 1951

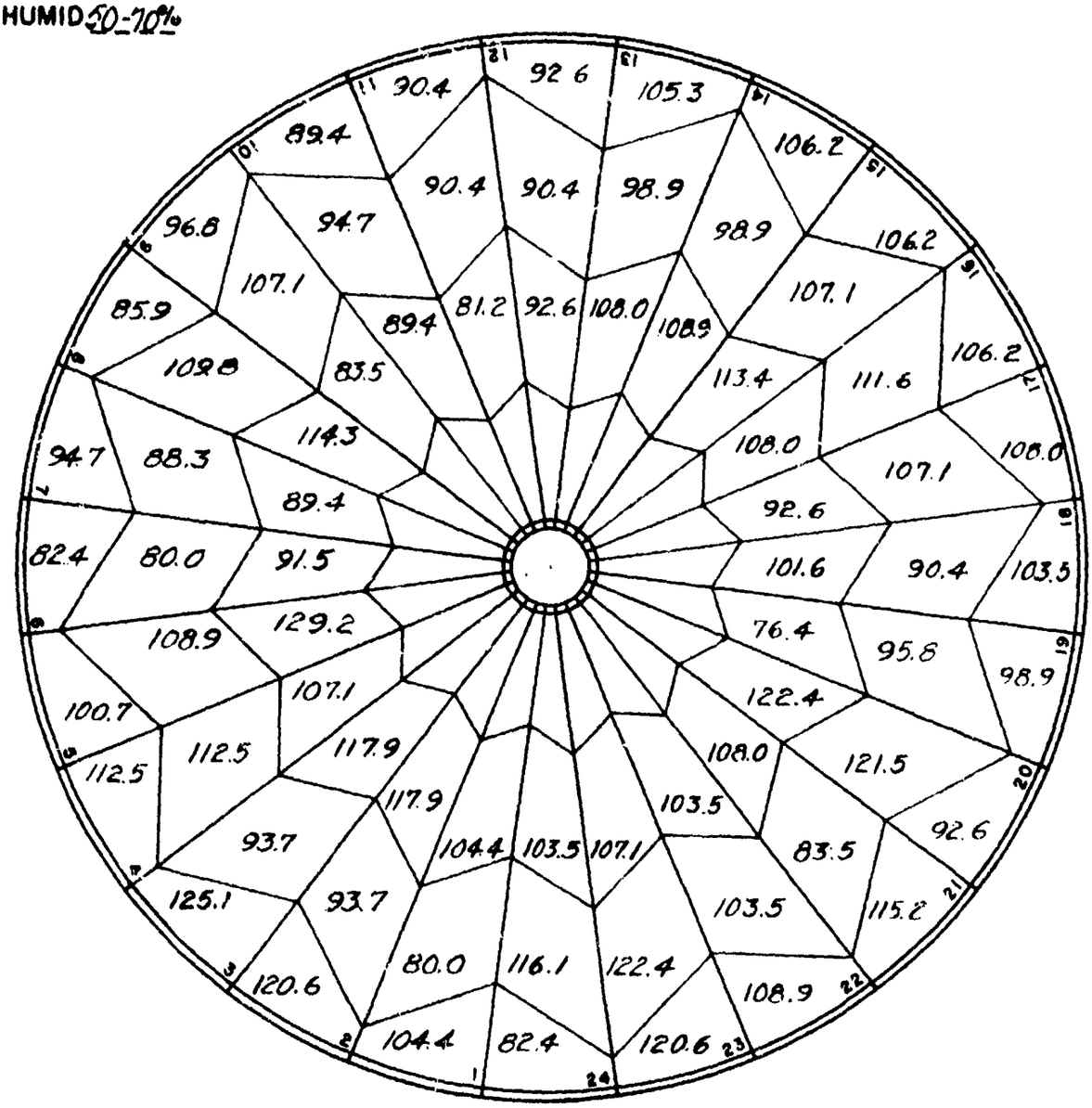
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350210

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 101.8

DATE 7-2-51

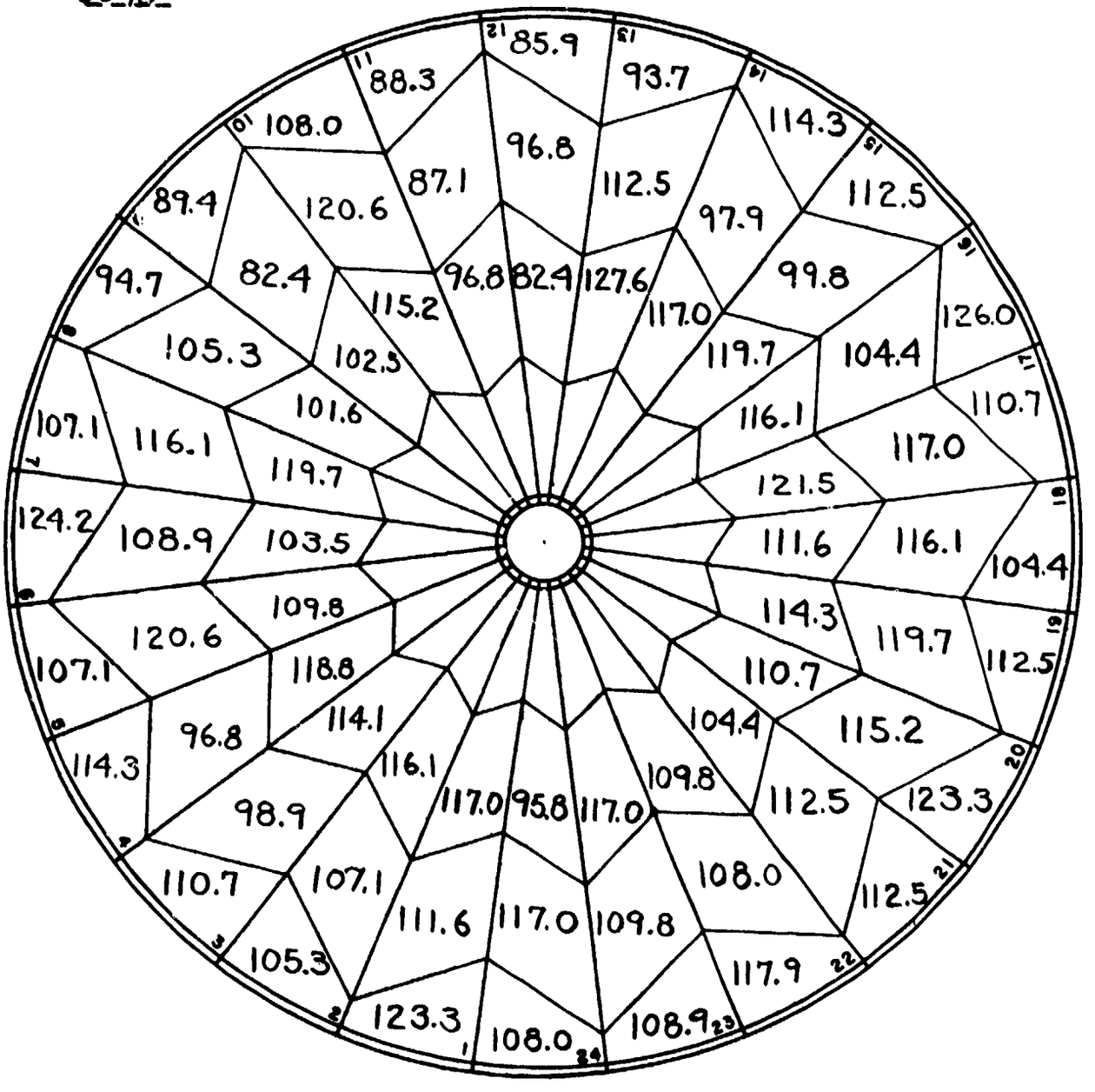
BY L.D

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350211

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 108.8

DATE 1 MAY 1951

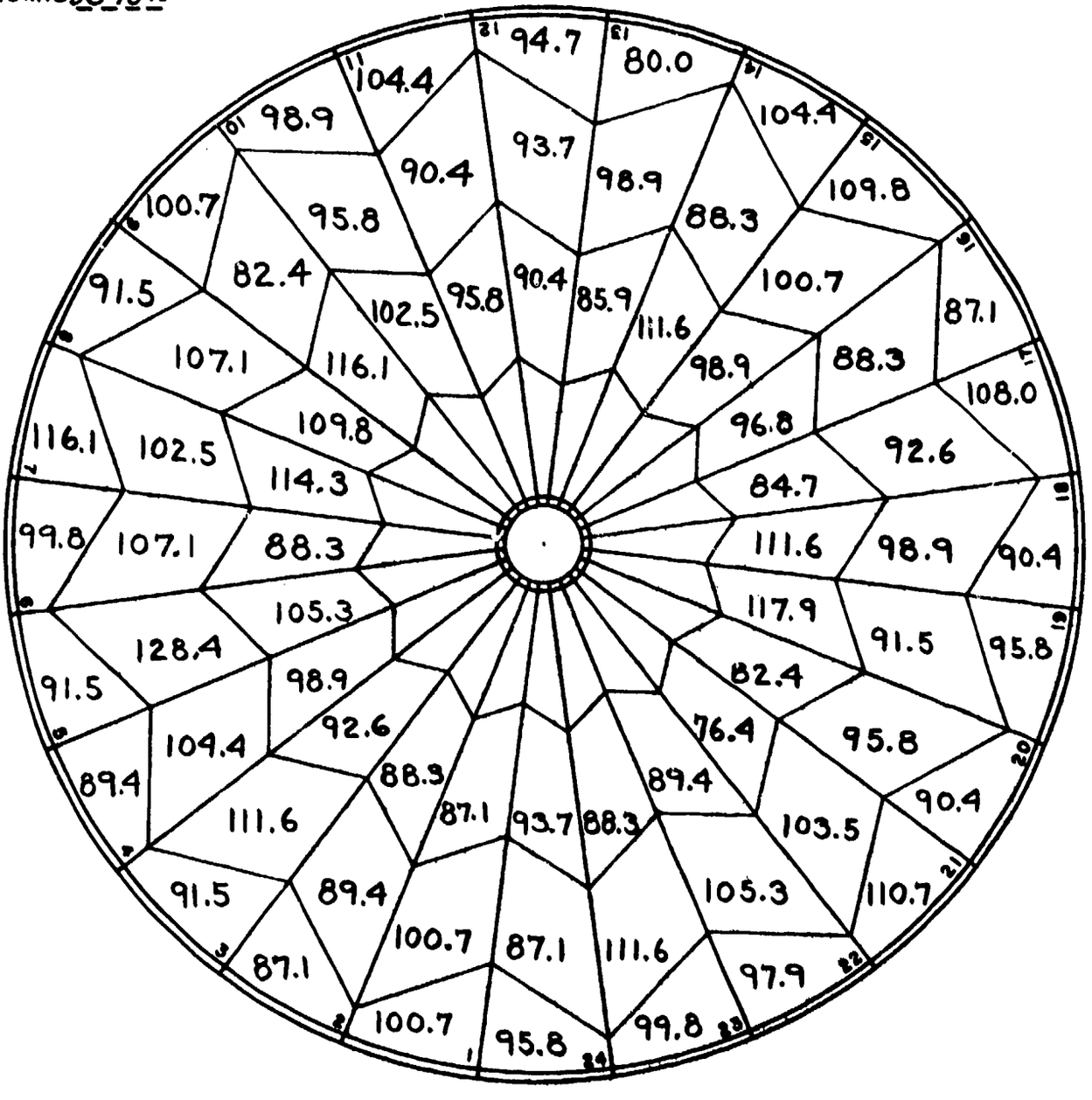
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350212---

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 97.8

DATE 2 MAY 1951

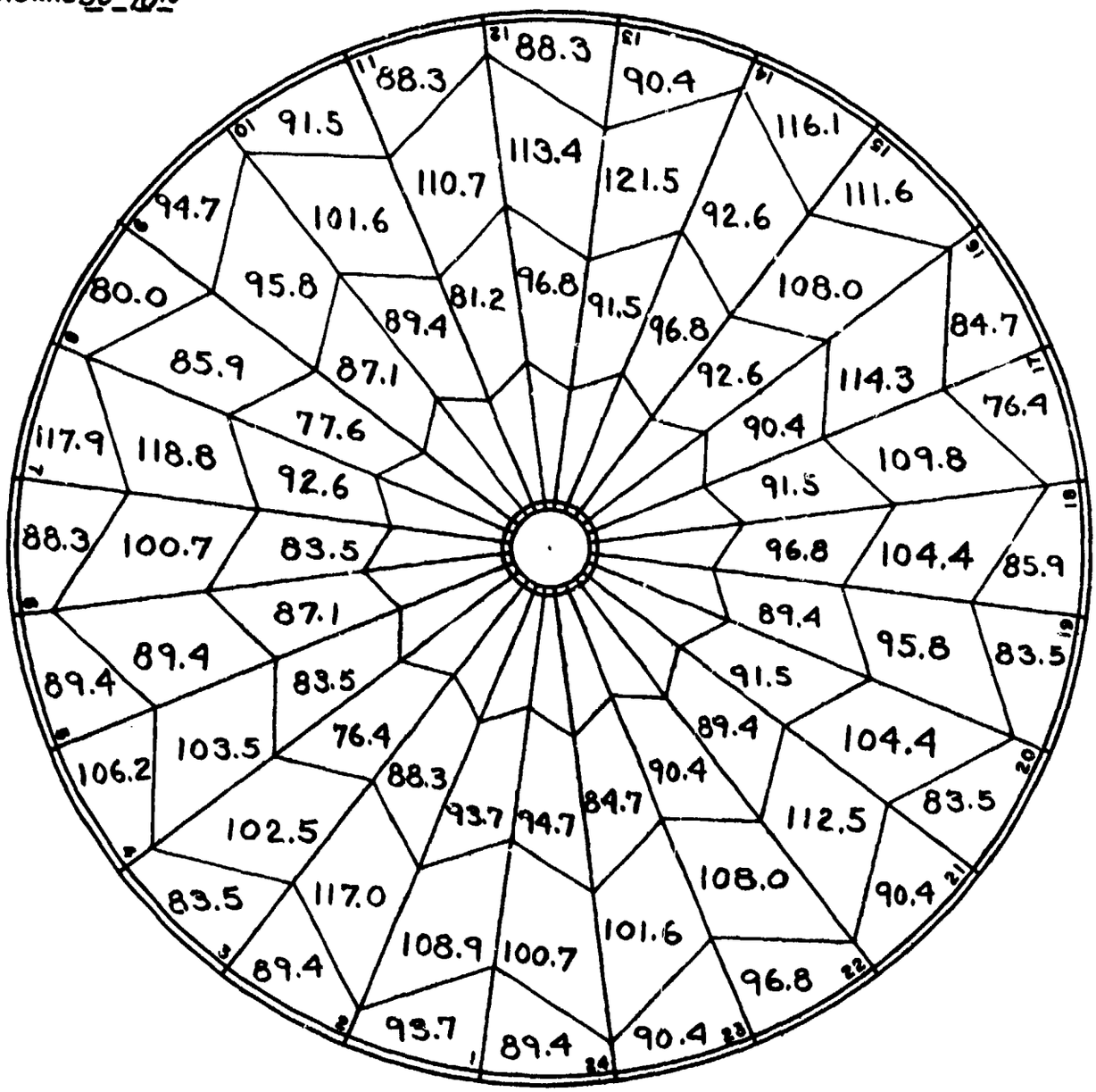
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350213

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 95.4

DATE 1 MAY 1951

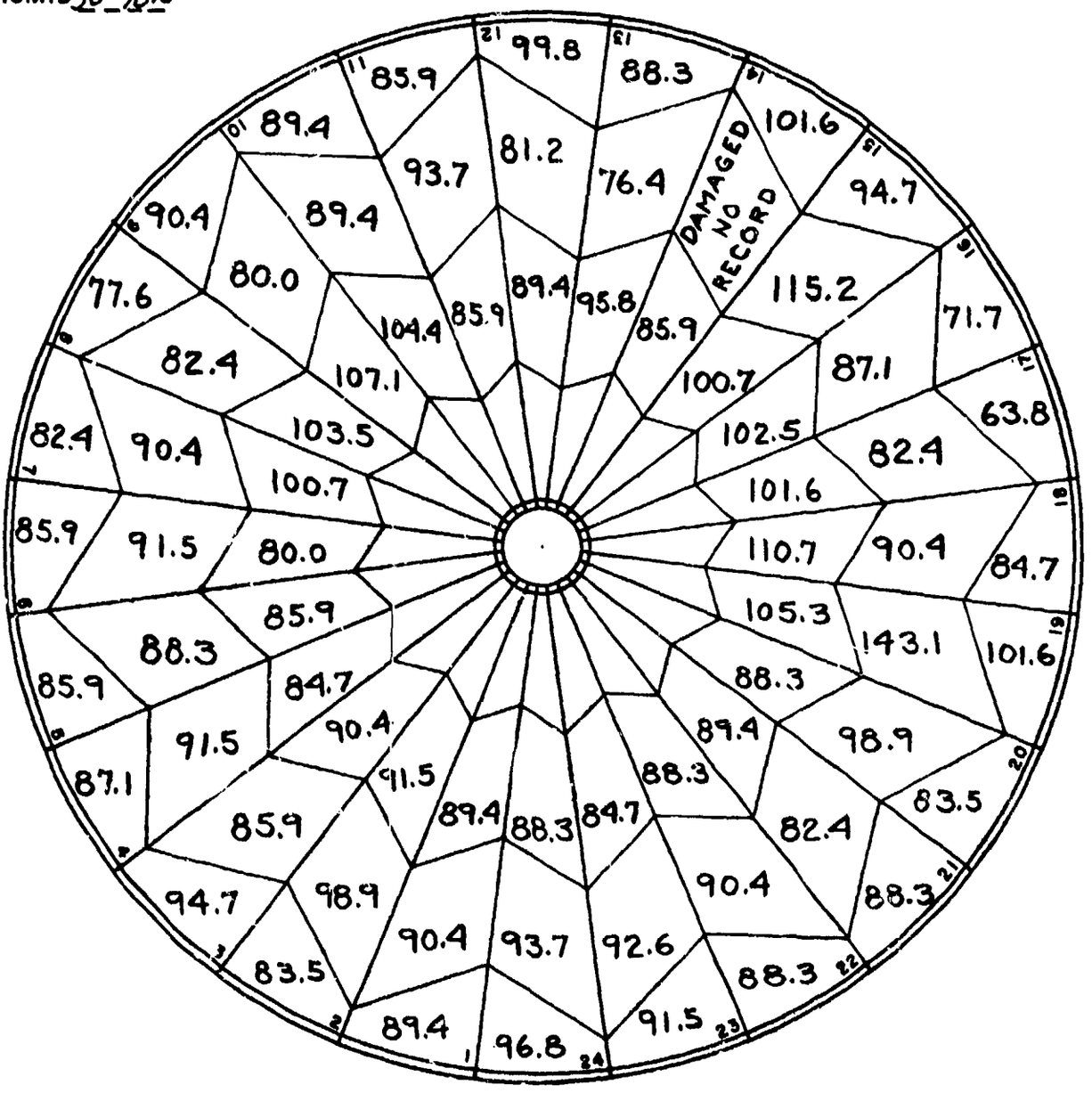
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350214

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 91.2

DATE 2 MAY 1951

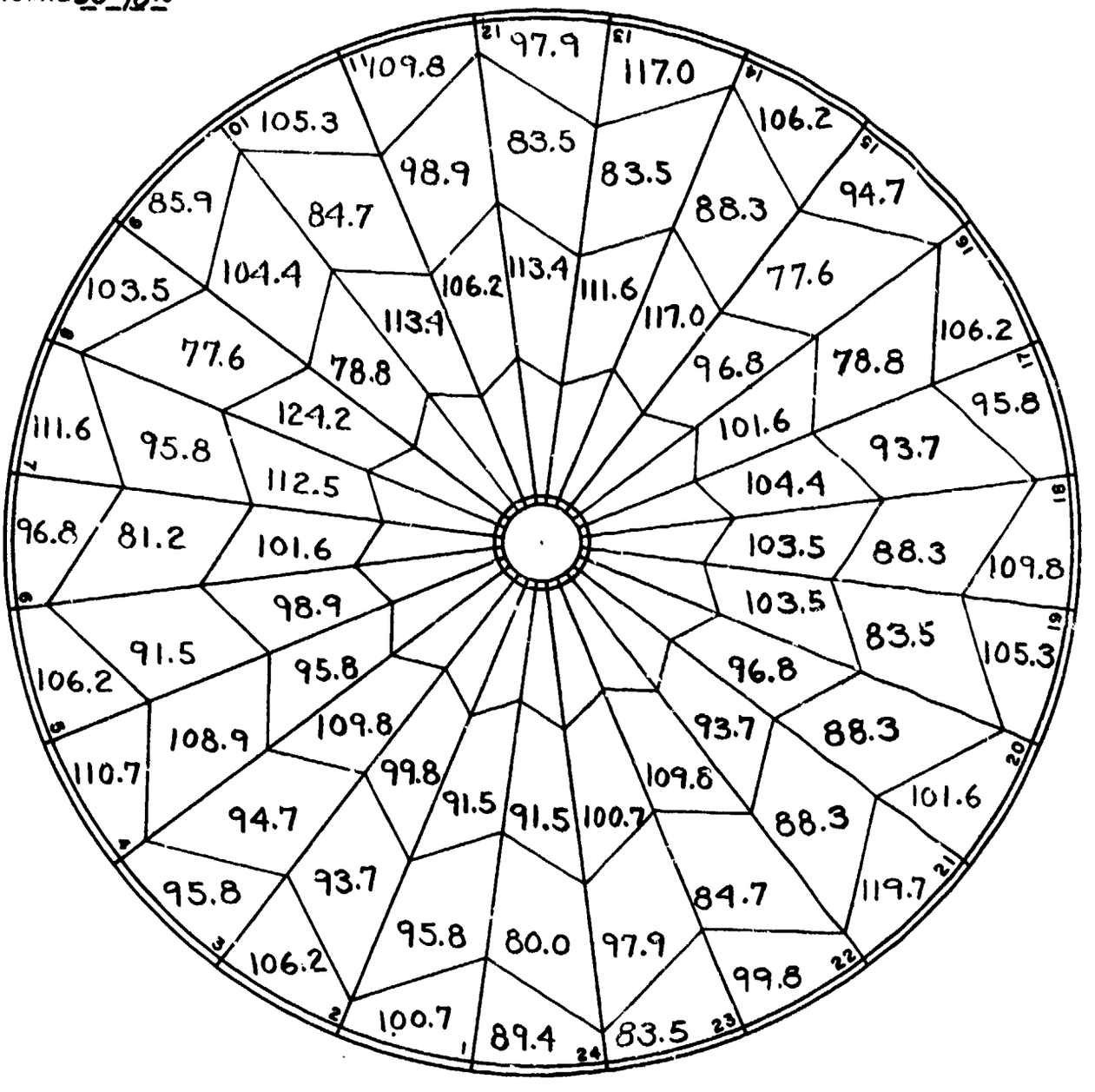
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350215

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 98.3

DATE 2 MAY 1951

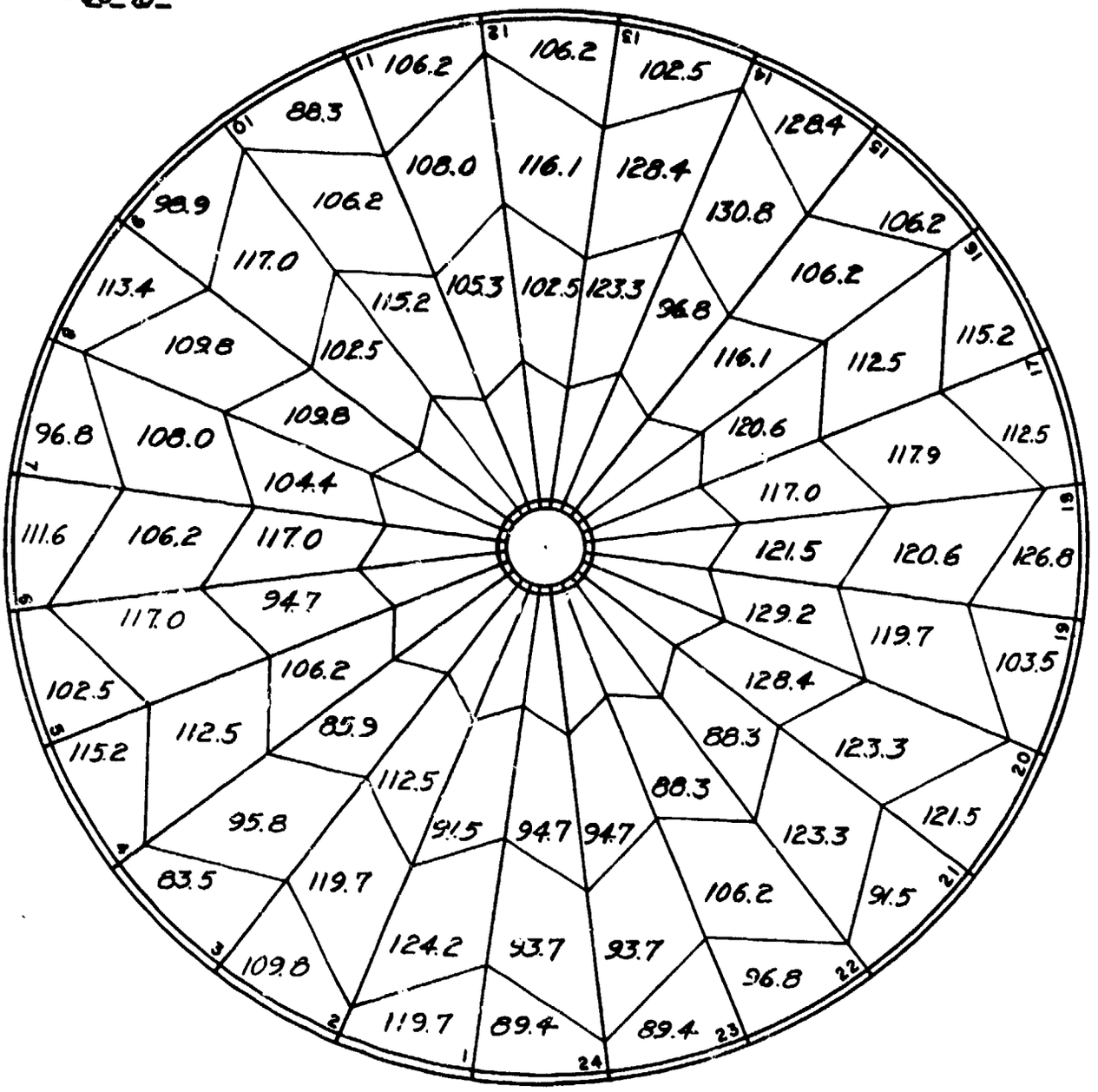
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350216

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 108.8

DATE 2-2-51

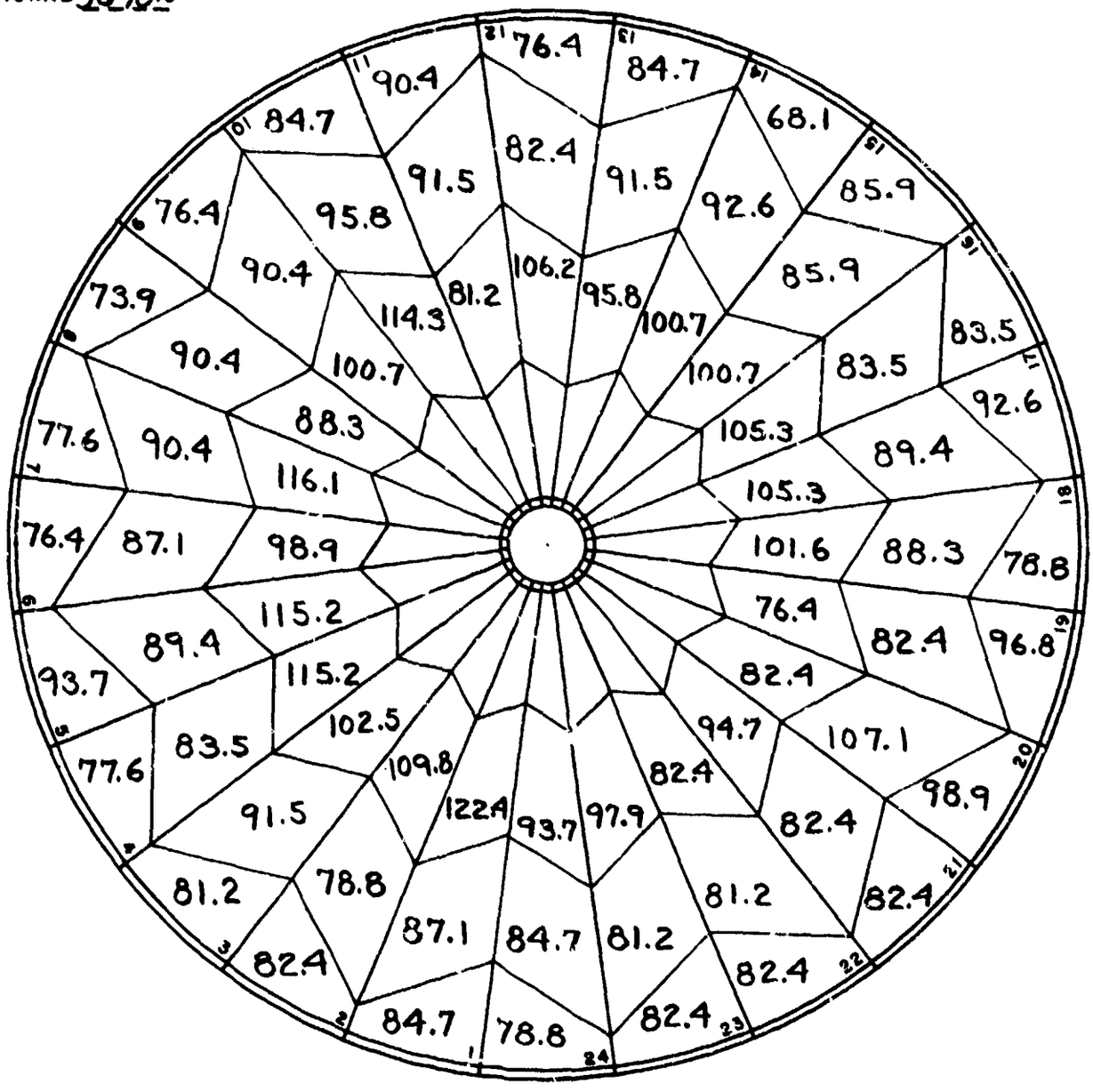
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350217

TEMP. 75-80F

HUMID 50-70%



AVERAGE POROSITY: 90.5

DATE 2 MAY 1951

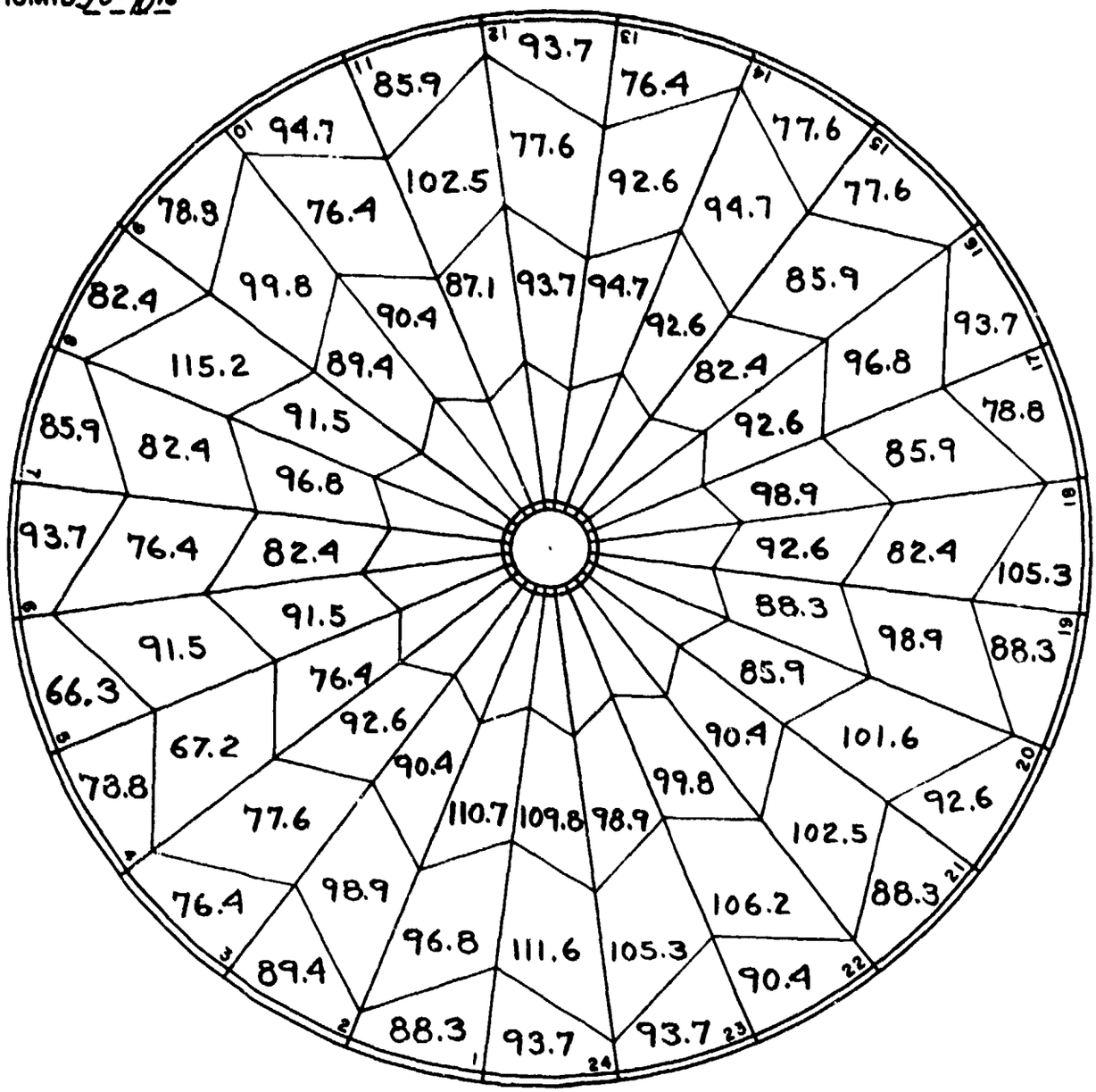
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350218

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 90.5

DATE 1 MAY 1951

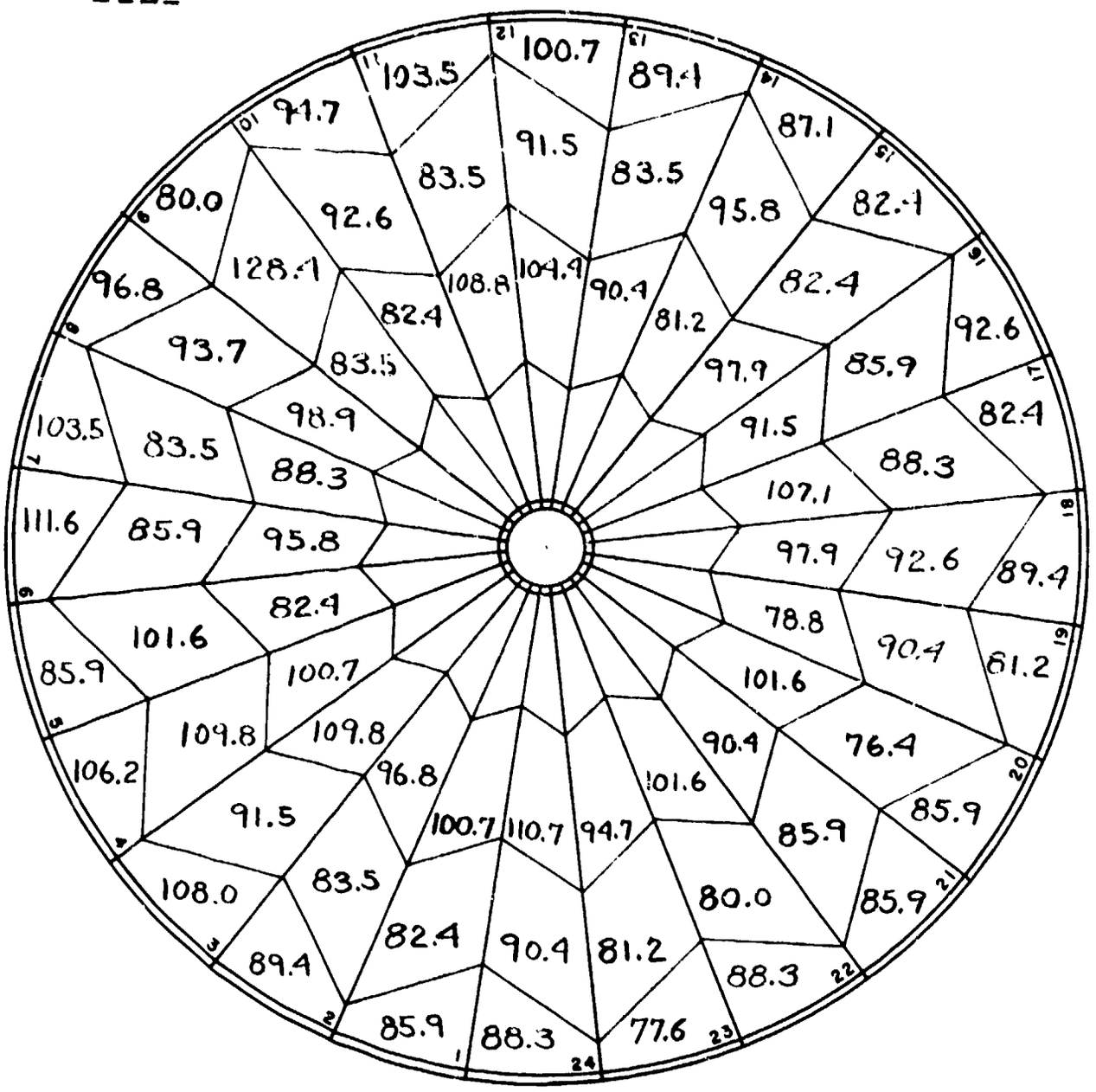
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350219

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 92.4

DATE 7 MAY 1951

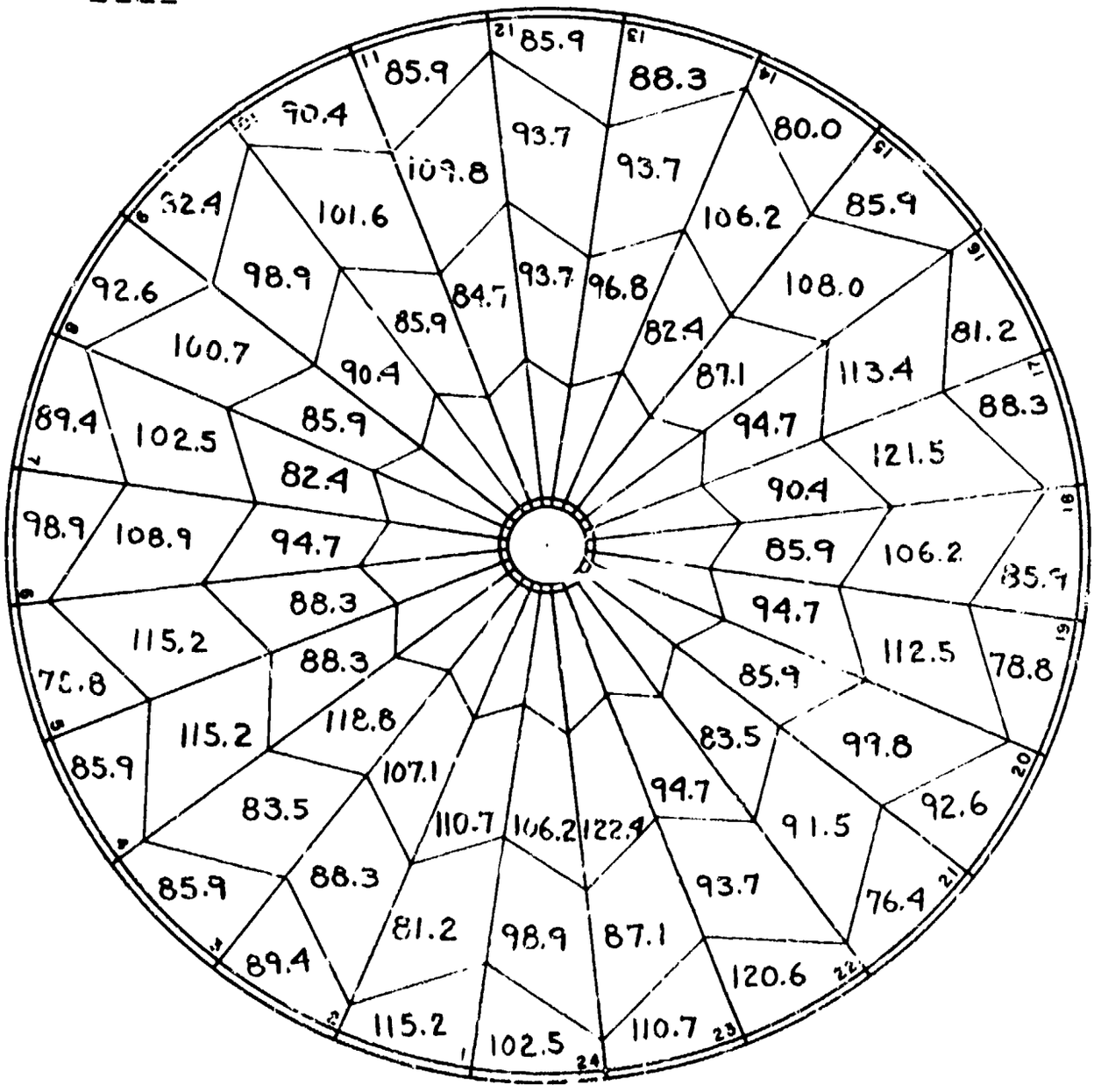
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350220

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 95.3

DATE 3 MAY 1951

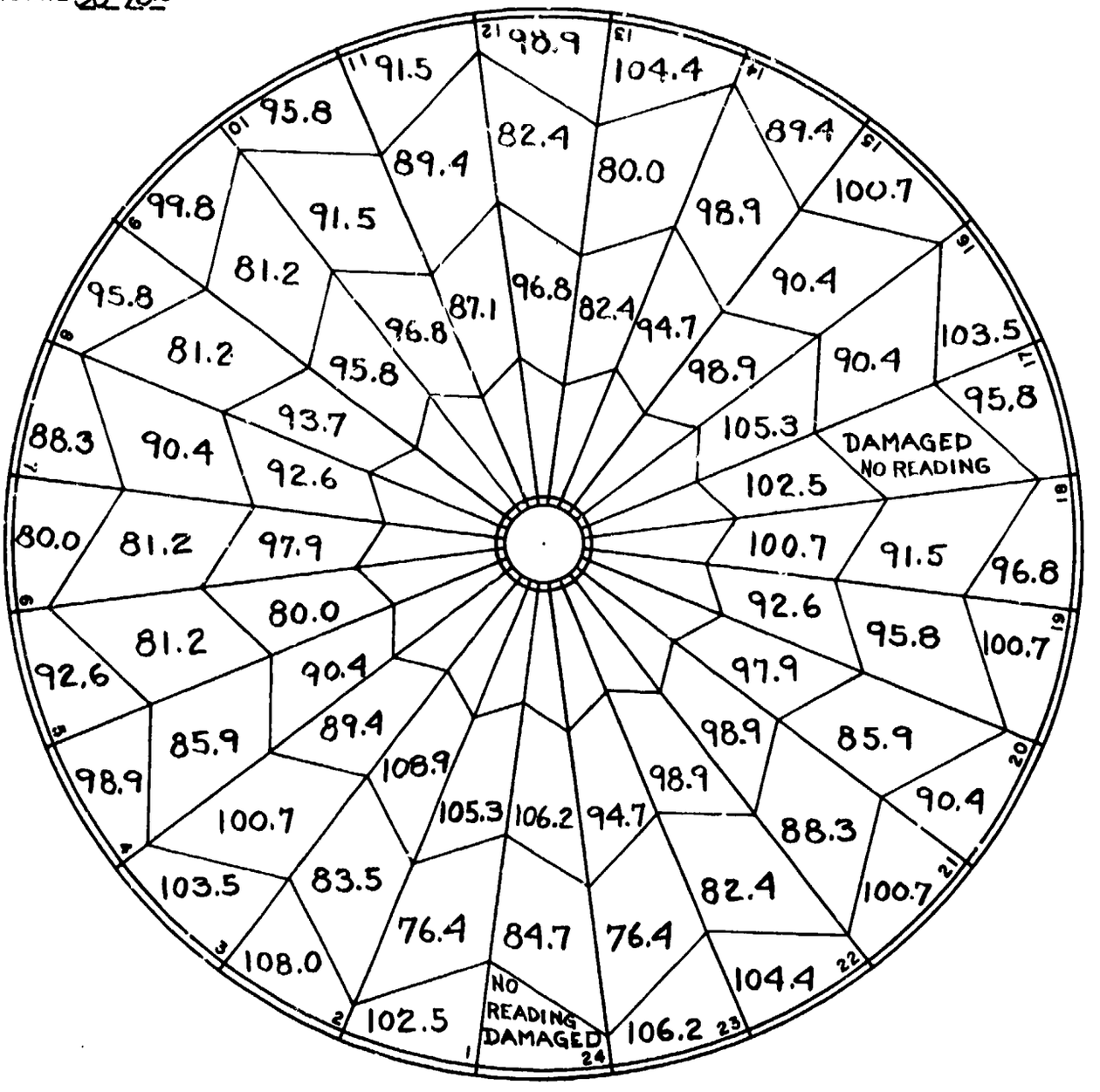
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350221

TEMP. 75-80°F

HUMID 50-20%



AVERAGE POROSITY: 93.5

DATE 8 MAY 1951

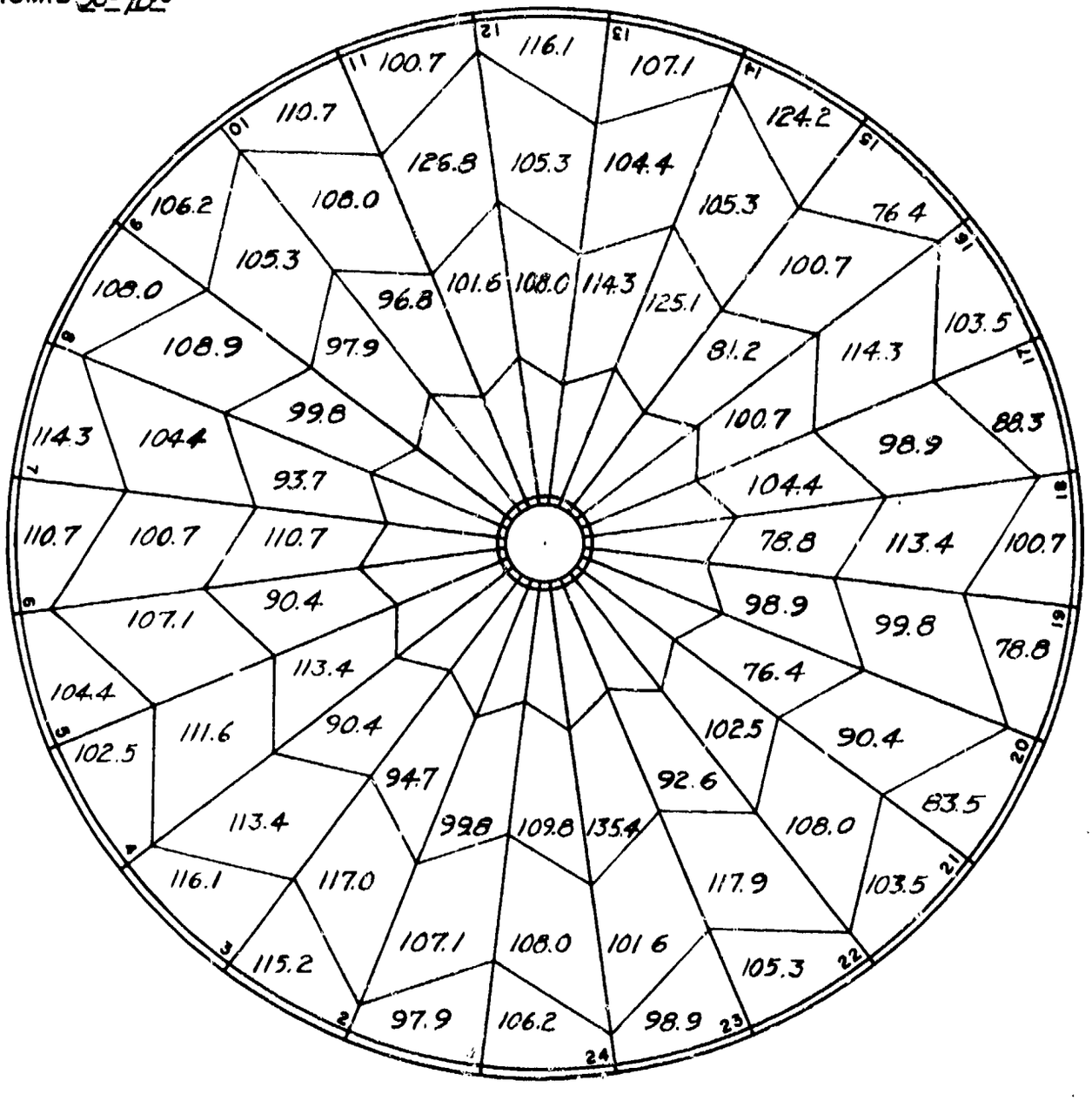
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350222

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 103.4

DATE 2-2-57

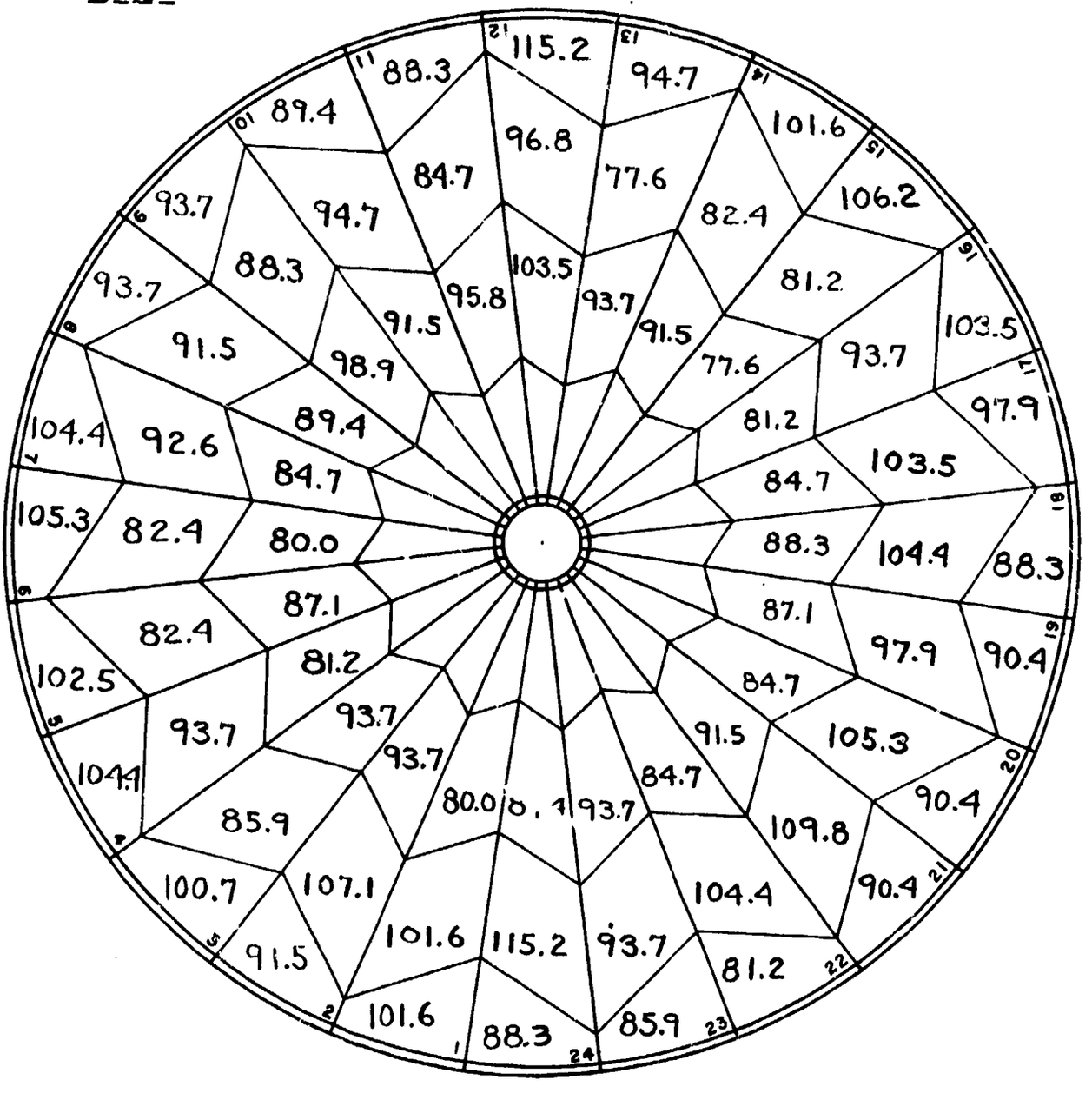
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350223

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 93.2

DATE 8 MAY 1951

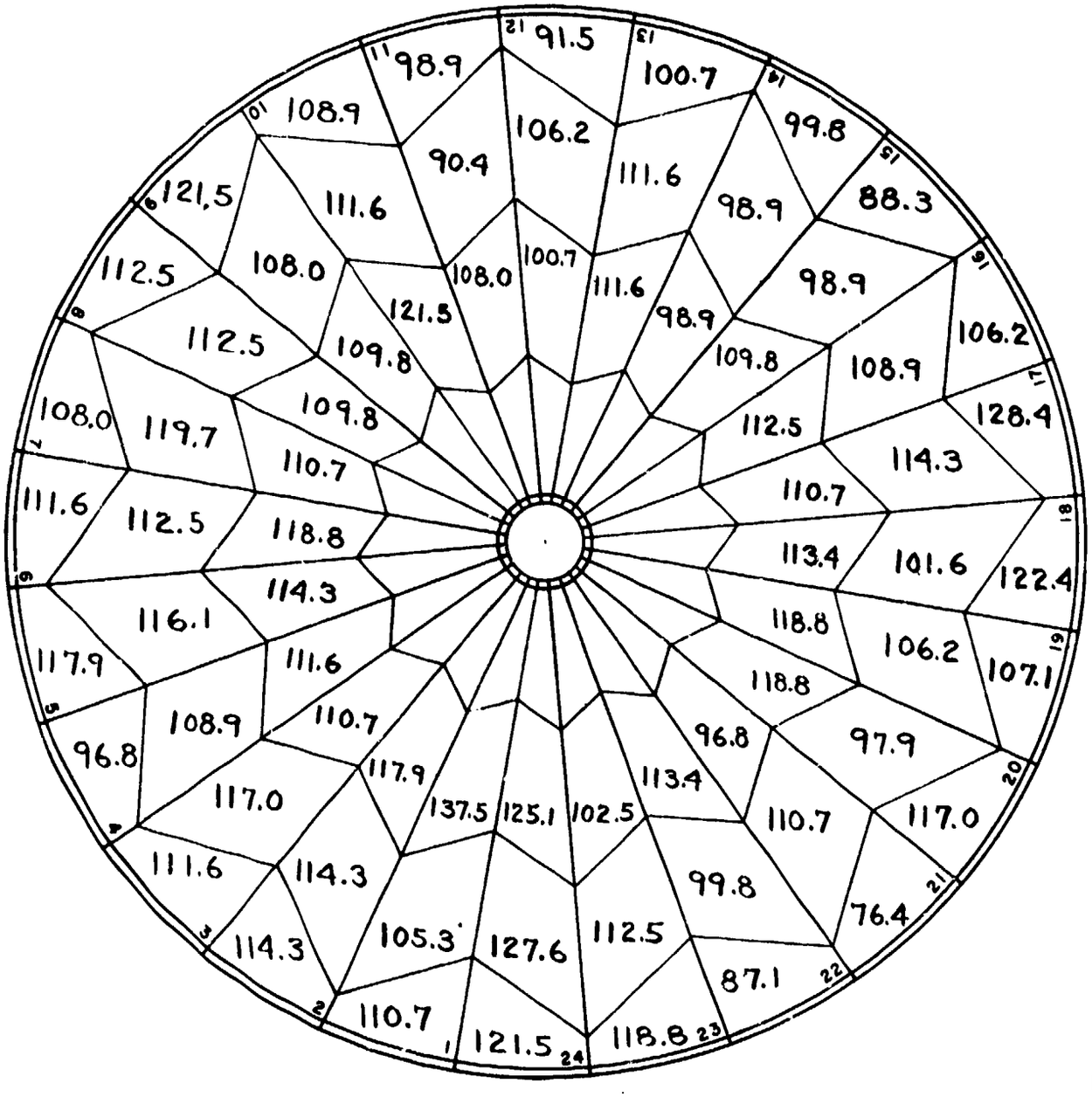
BY L.D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350224

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 109.6

DATE 8 MAY 1951

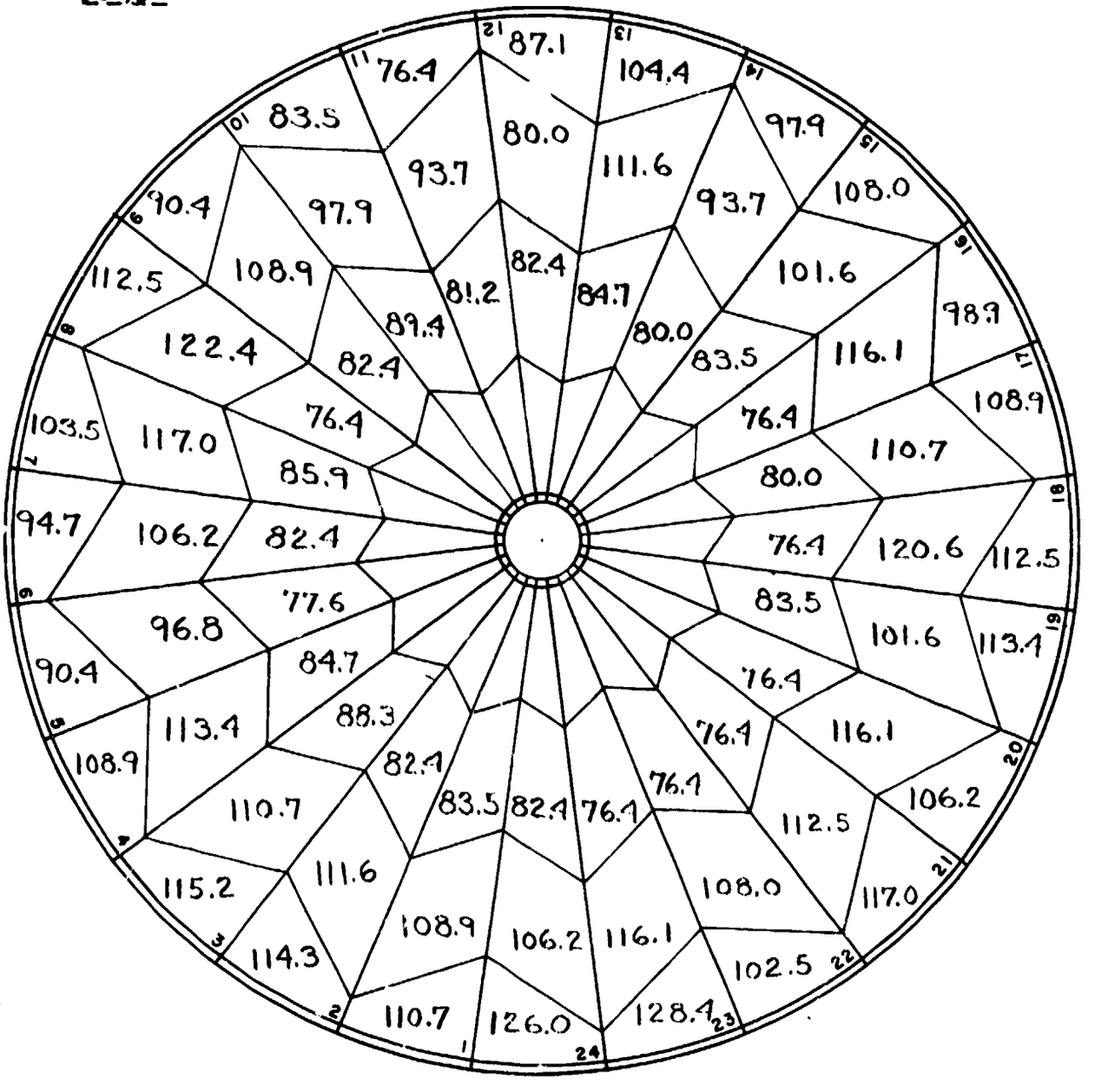
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350225

TEMP. 75-80F

HUMID 50-70%



AVERAGE POROSITY: 97.8

DATE 4 MAY 1951

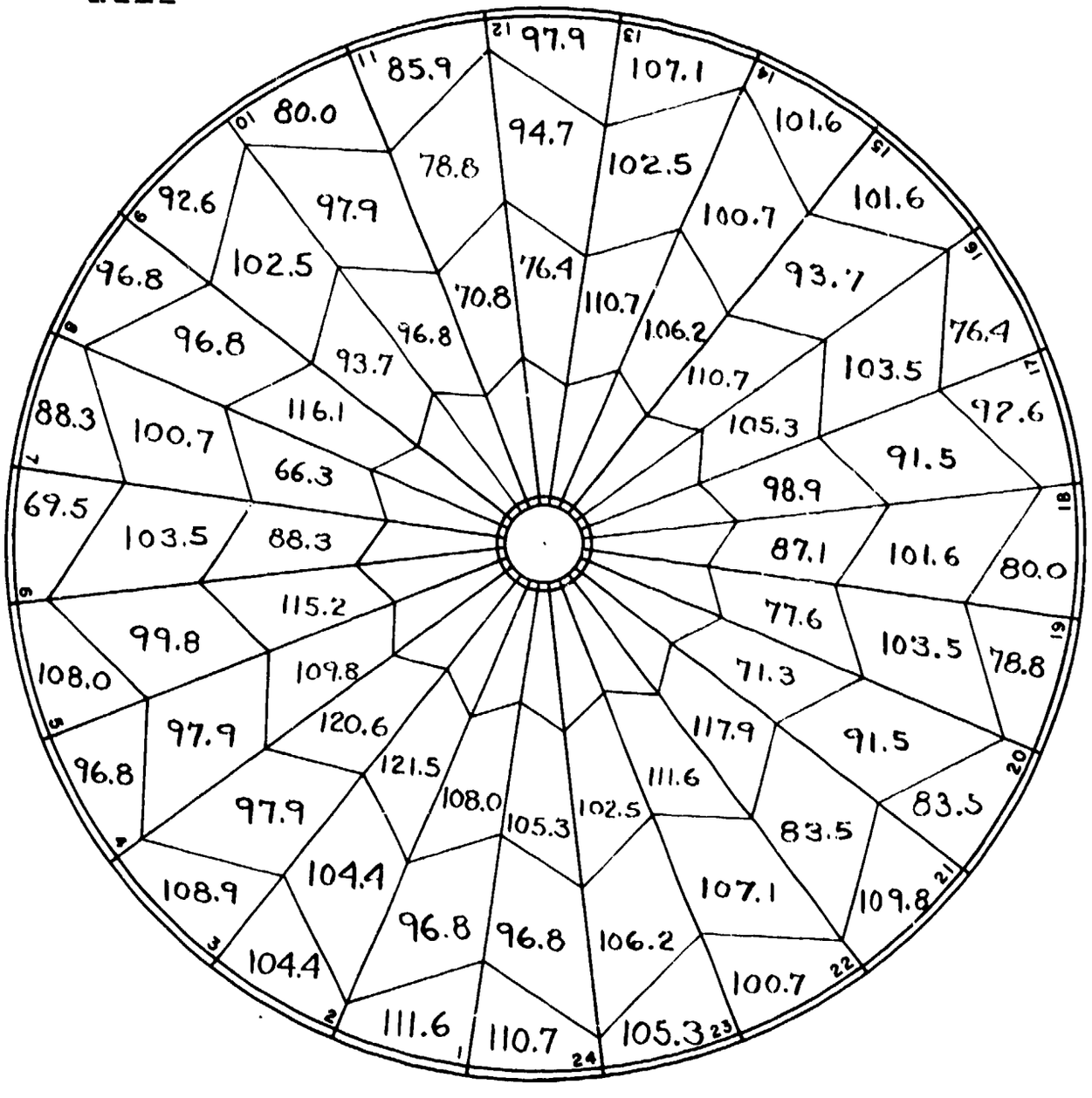
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350226

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 97.7

DATE 7 MAY 1951

BY L. D.

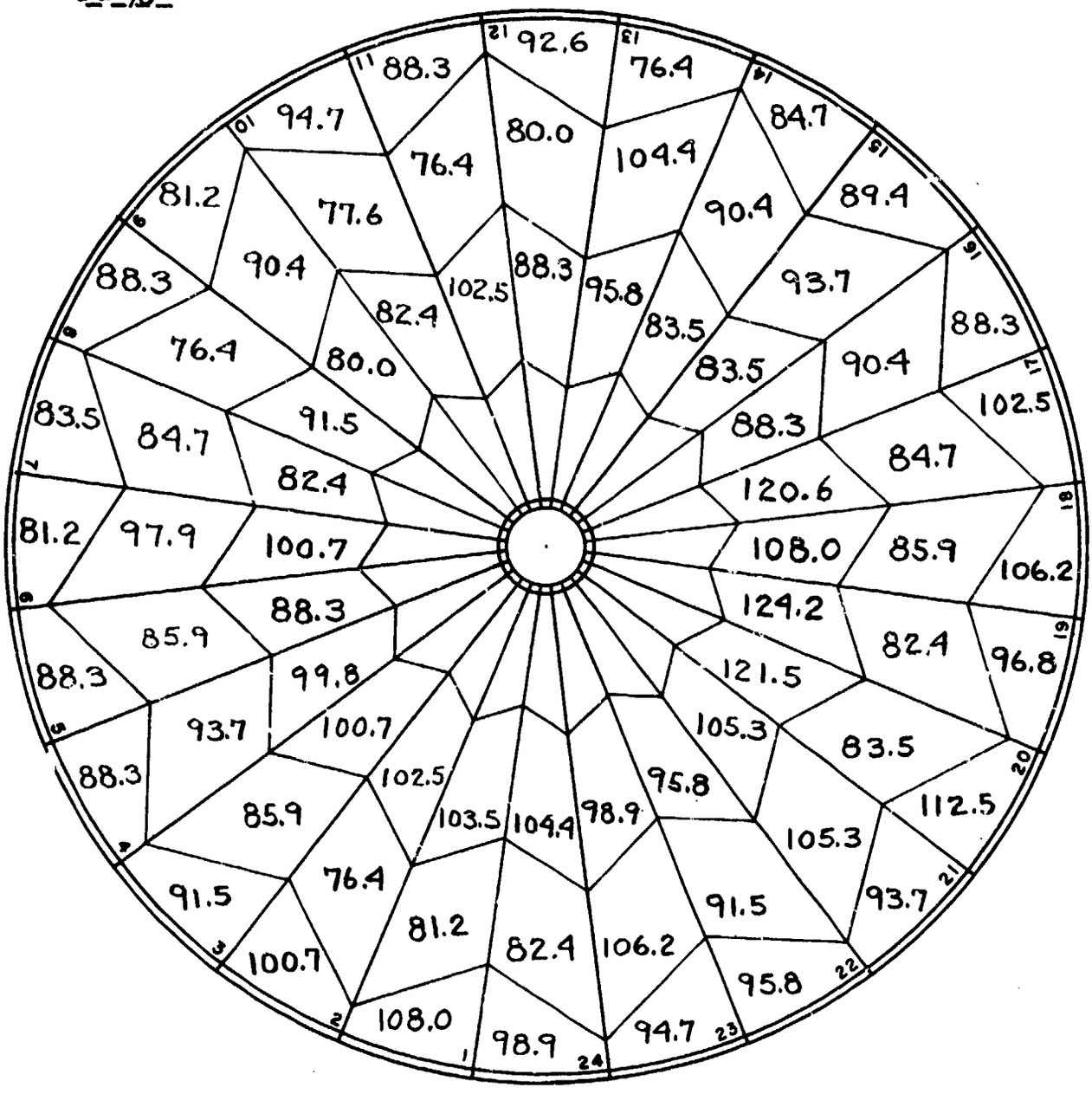
	PIONEER PARACHUTE CO., INC. MANCHESTER, CONN.	Appendix "C" Page 175

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350227

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 92.9

DATE 3 MAY 1951

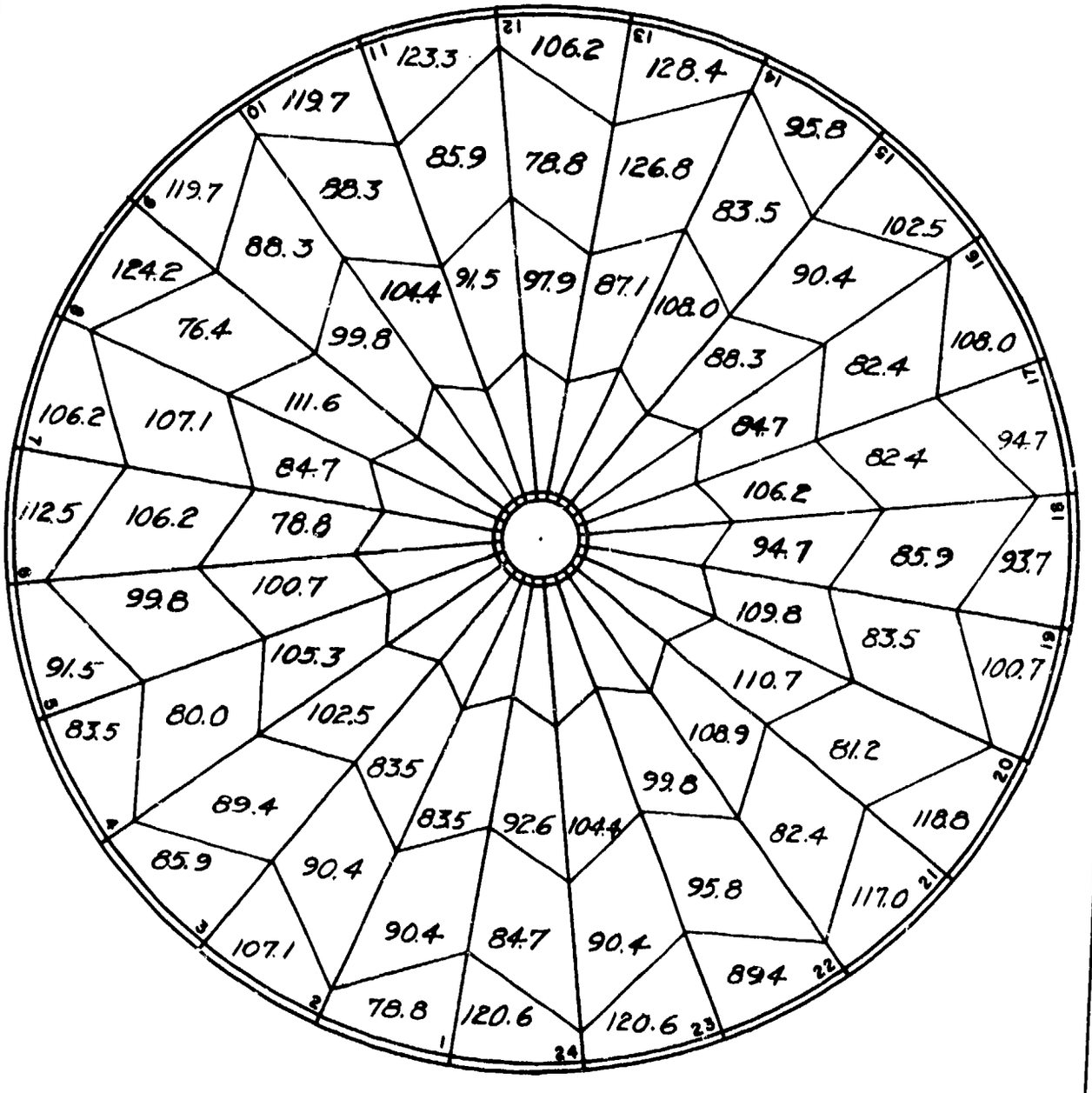
BY L. D.

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350228

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 98.2

DATE 2-2-51

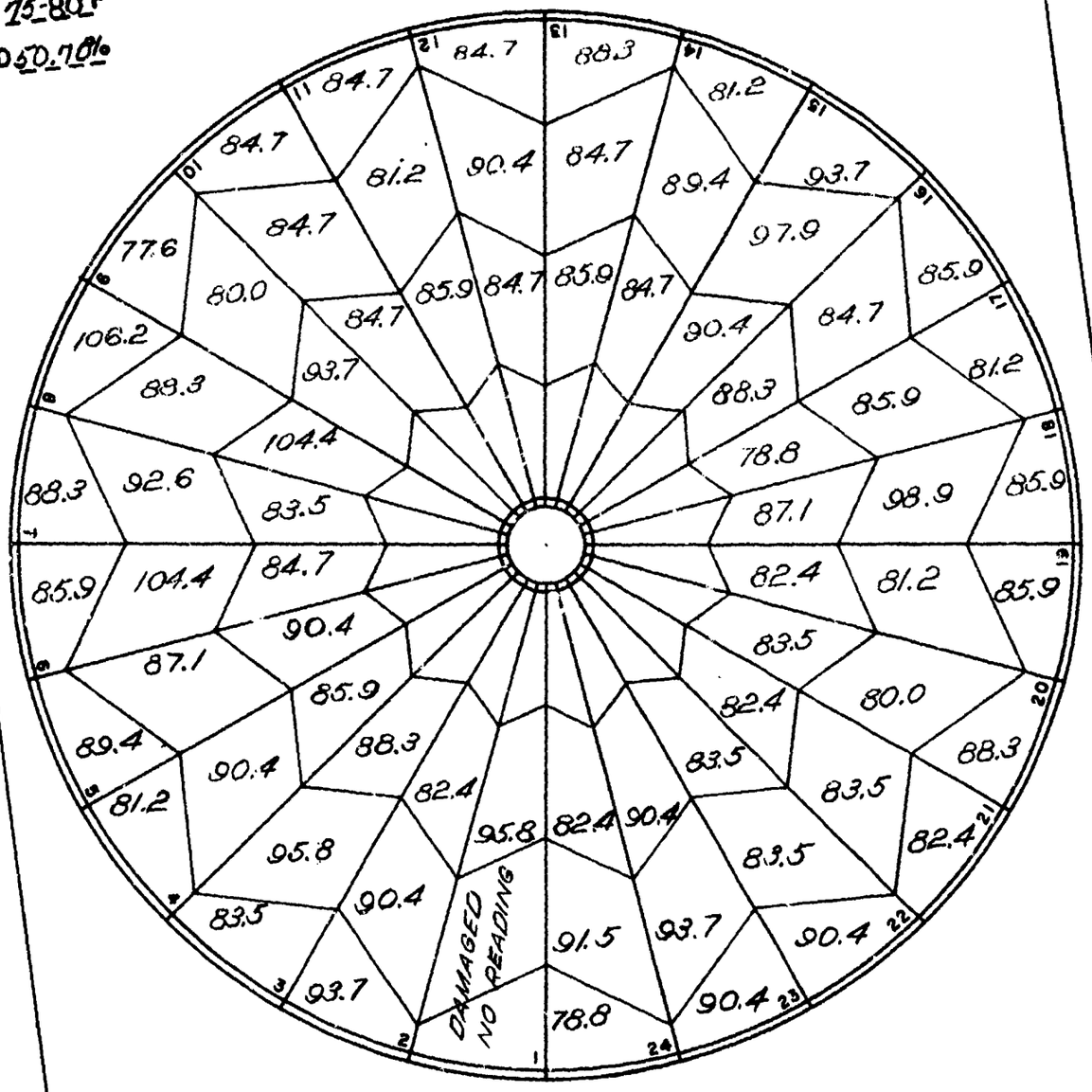
BY L.D

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350229

TEMP. 75-80°F

HUMID 50-70%



DATE 9 MAY 51

BY L.D.

AVERAGE POROSITY: 87.4

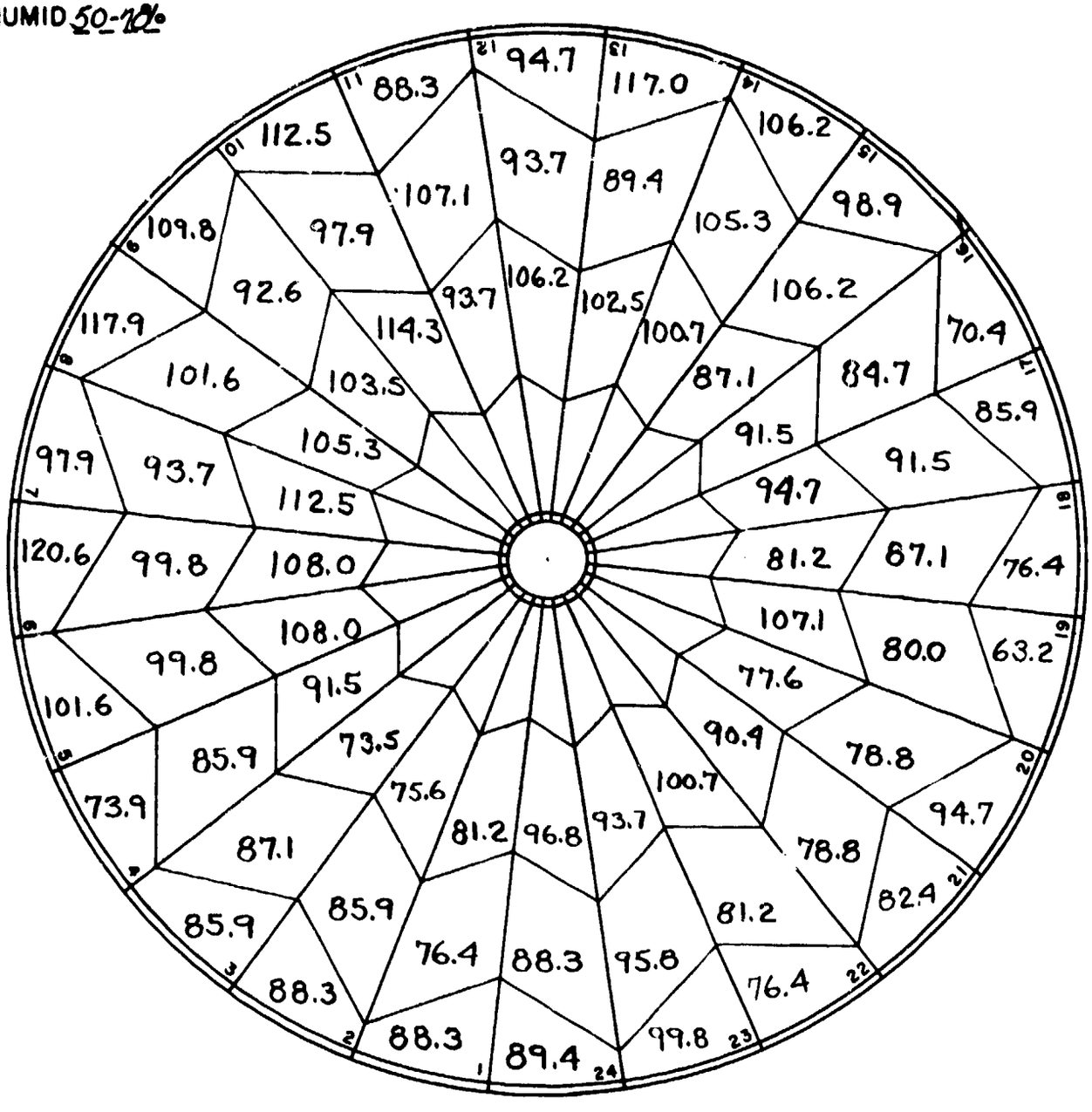
WADC 52-57

POROSITY MEASUREMENTS 24 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350230

TEMP. 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 93.4

DATE 3 MAY 1951

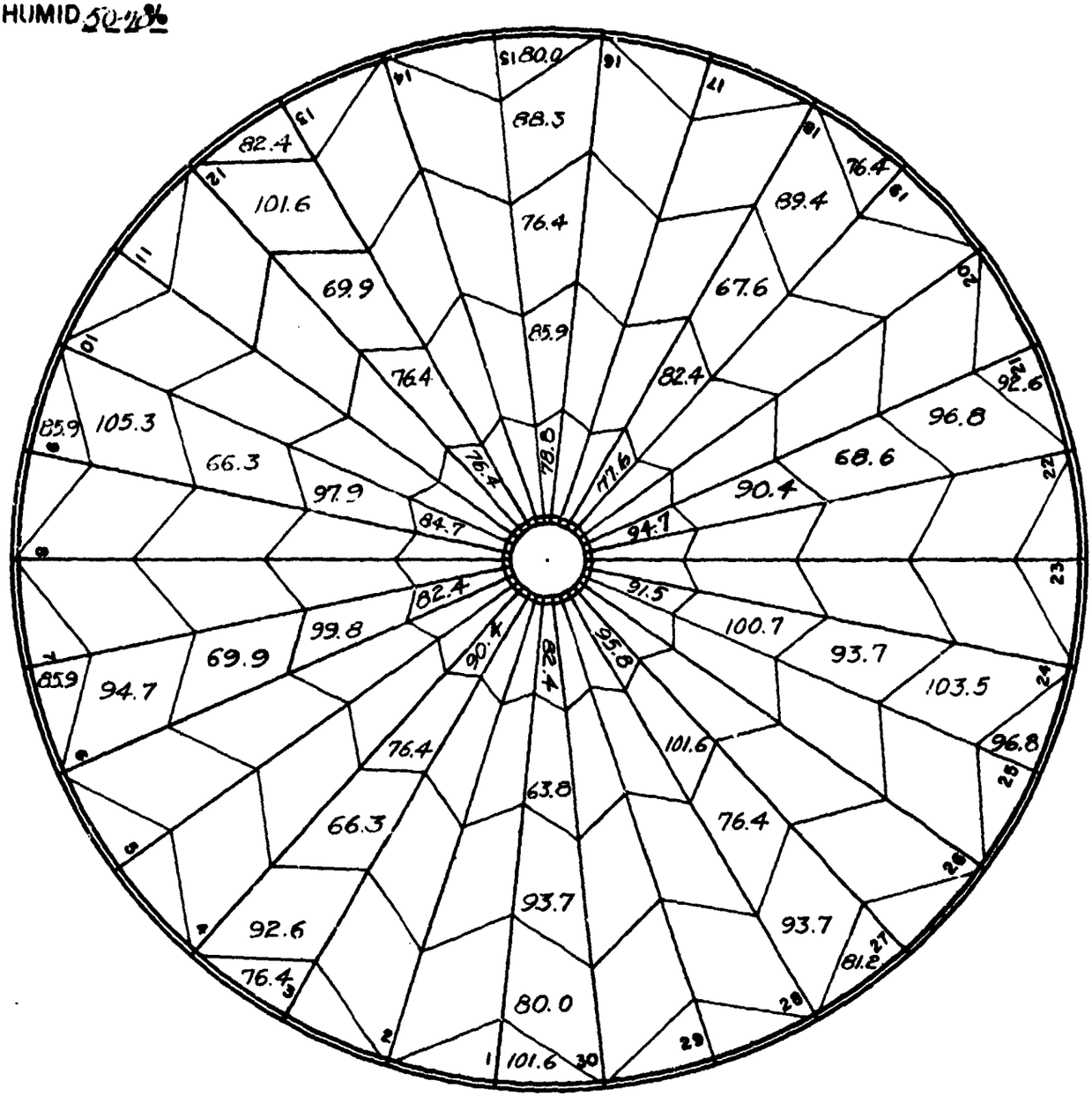
BY L. D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350231

TEMP. 75-80°F

HUMID. 50-60%



AVERAGE POROSITY: 85.7

DATE 3-13-51

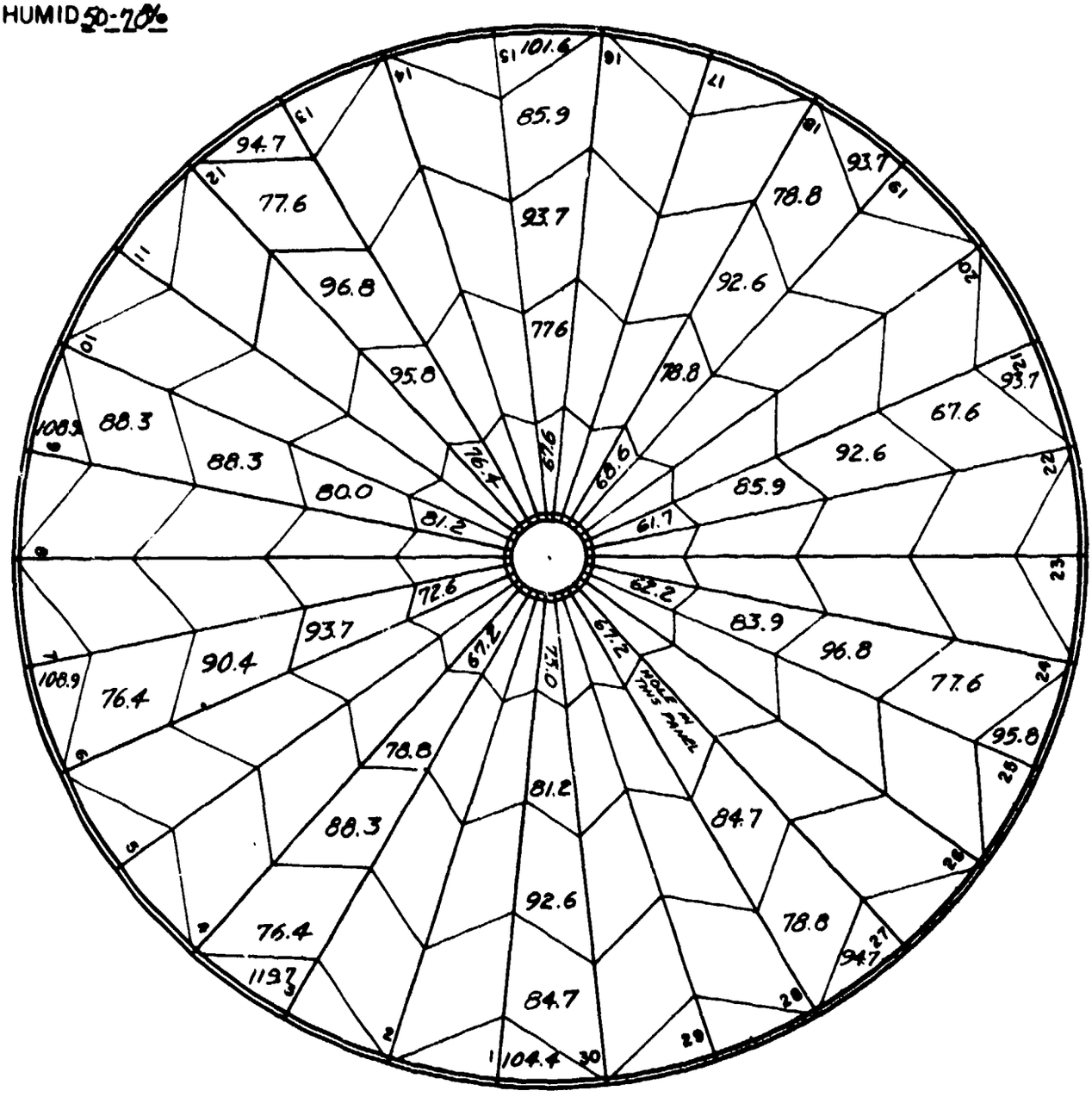
BY L.Q.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350235

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 85.5

DATE 3-14-51

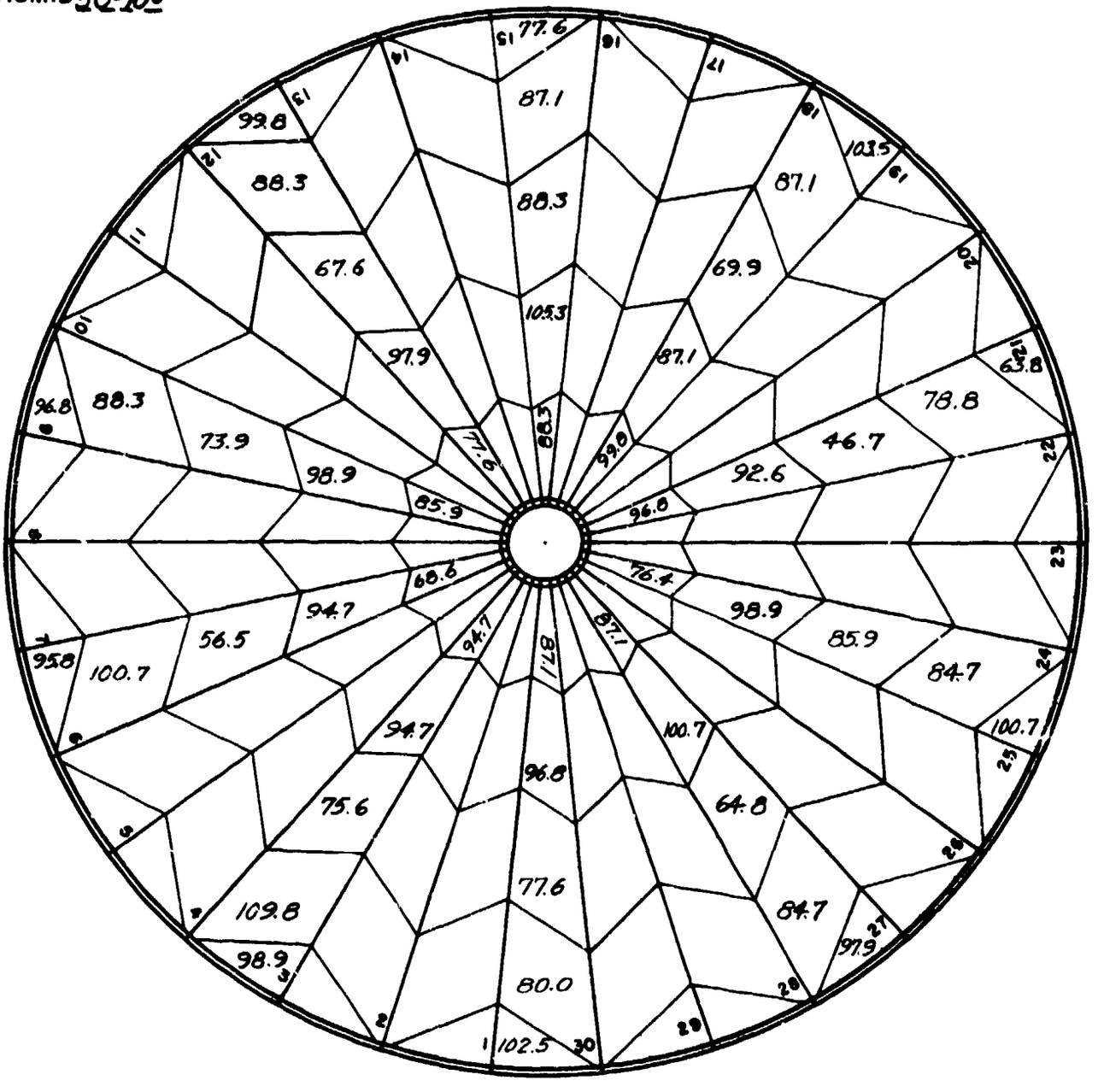
BY L.D

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350238

TEMP. 25-80°F

HUMID 50-70%



AVERAGE POROSITY: 87.3

DATE 4-2-51

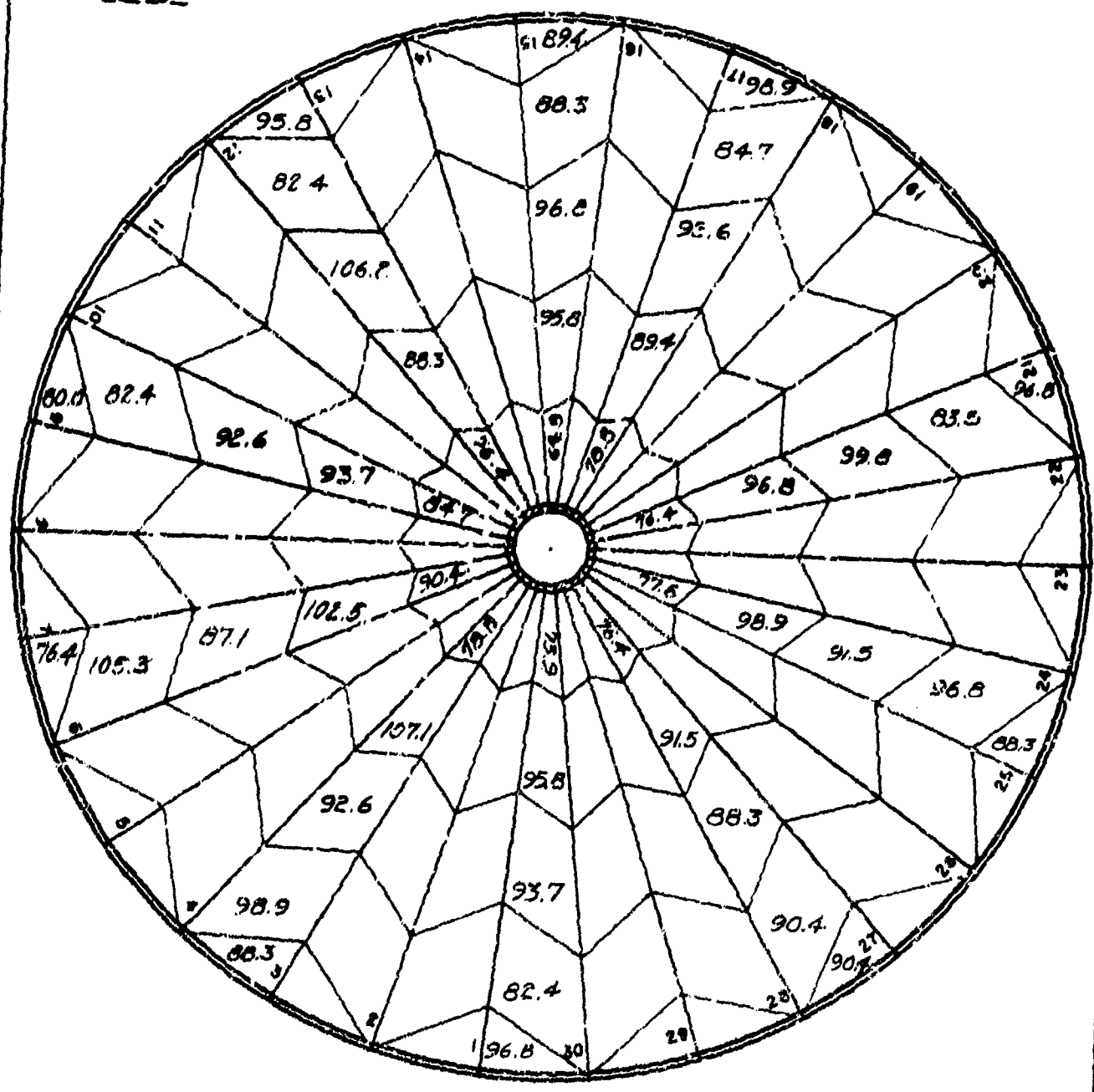
BY A.V.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350239

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY: 89.5

DATE 3-14-51

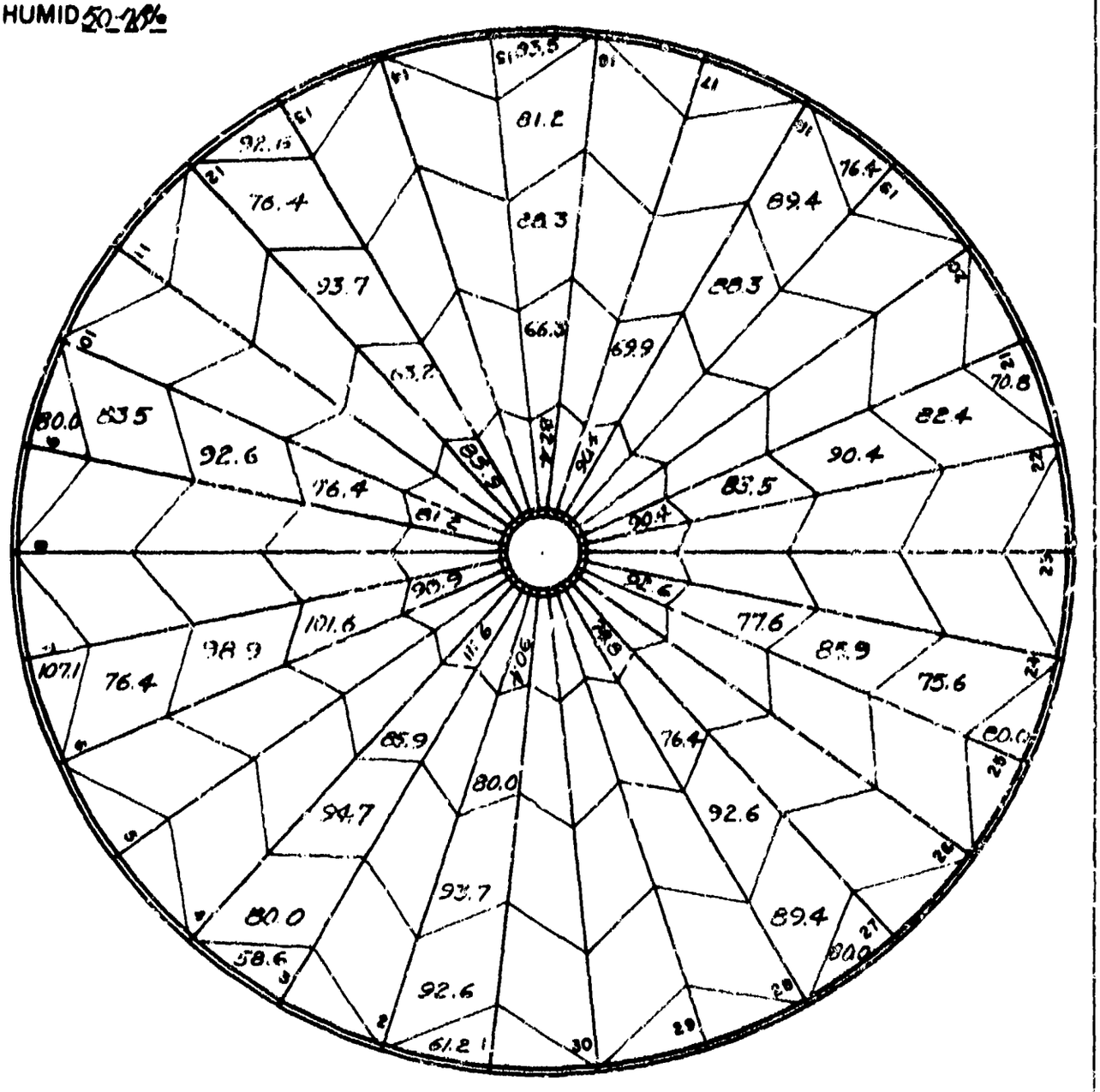
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 290 M.P.H.

SERIAL NO. 350240

TEMP. 75-80°F

HUMID 50-28%



AVERAGE POROSITY 84.4

DATE 3-30-51

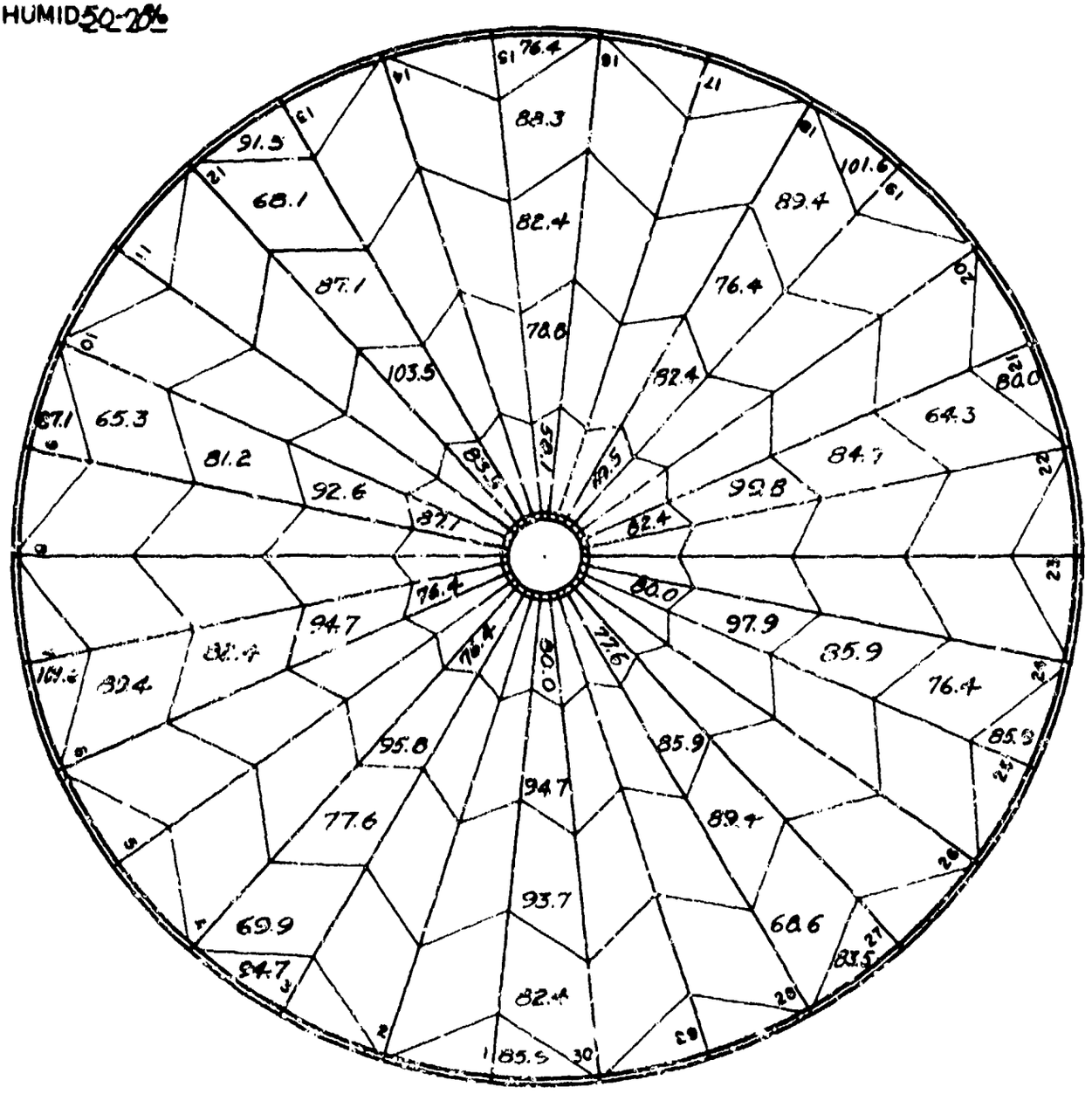
BY A.V.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350243

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY 83.8

DATE 3-13-57

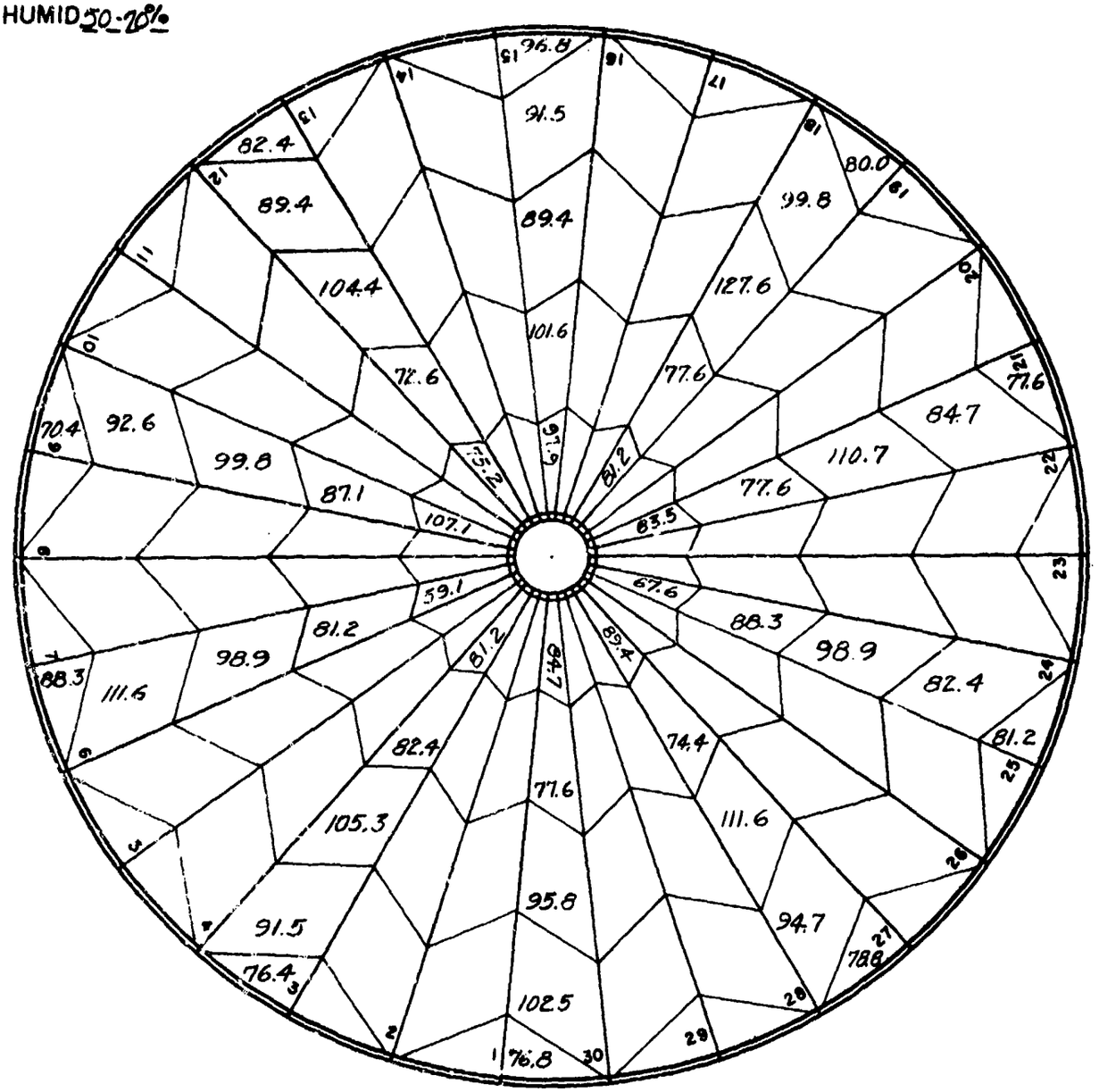
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350246

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY 88.8

DATE 3-31-51

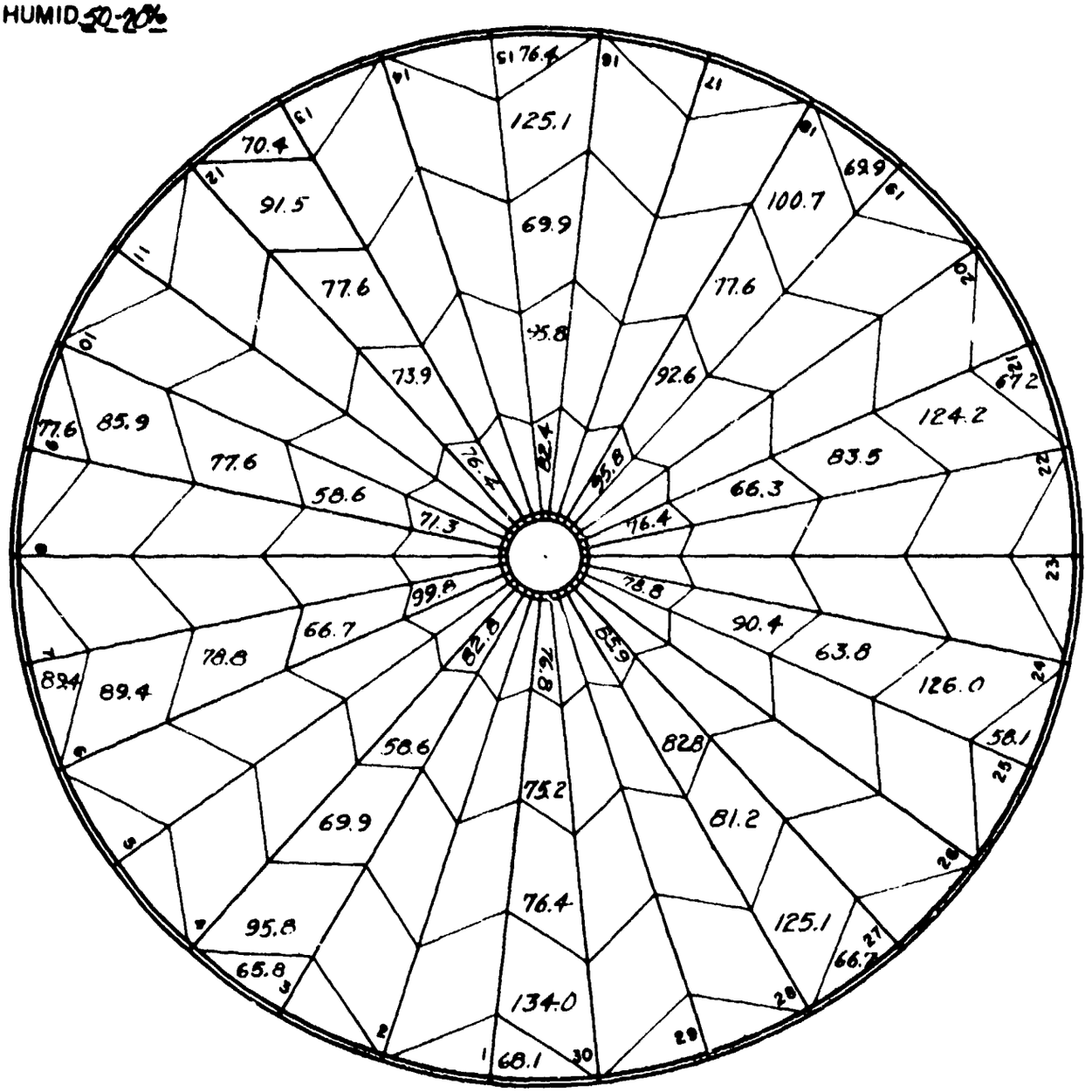
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350247

TEMP. 75-80°F

HUMID. 50-70%



AVERAGE POROSITY 83.0

DATE 3-14-51

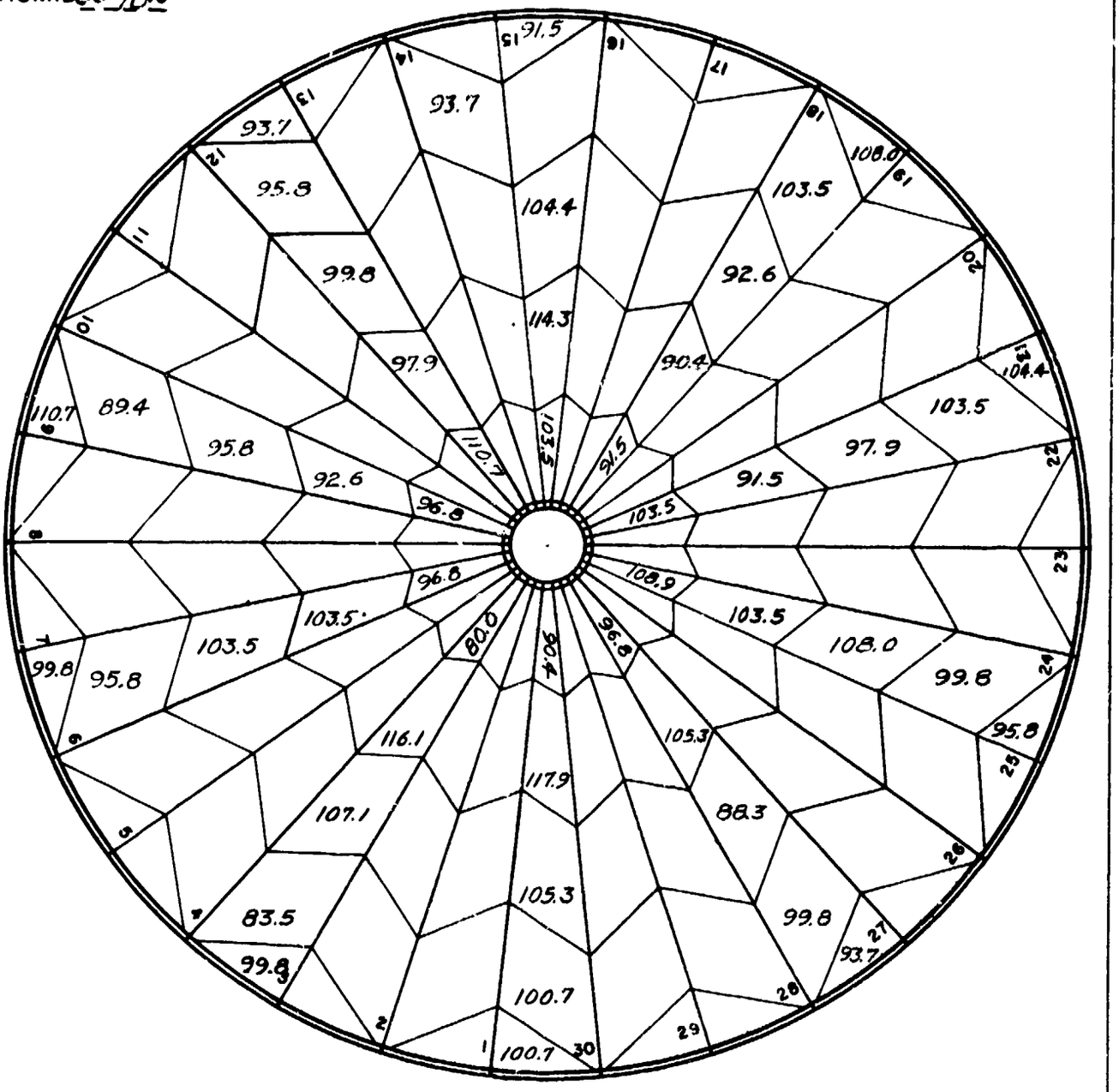
BY D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350249

TEMP 75-80°F

HUMID 50-70%



AVERAGE POROSITY: 99.6

DATE 3-20-51

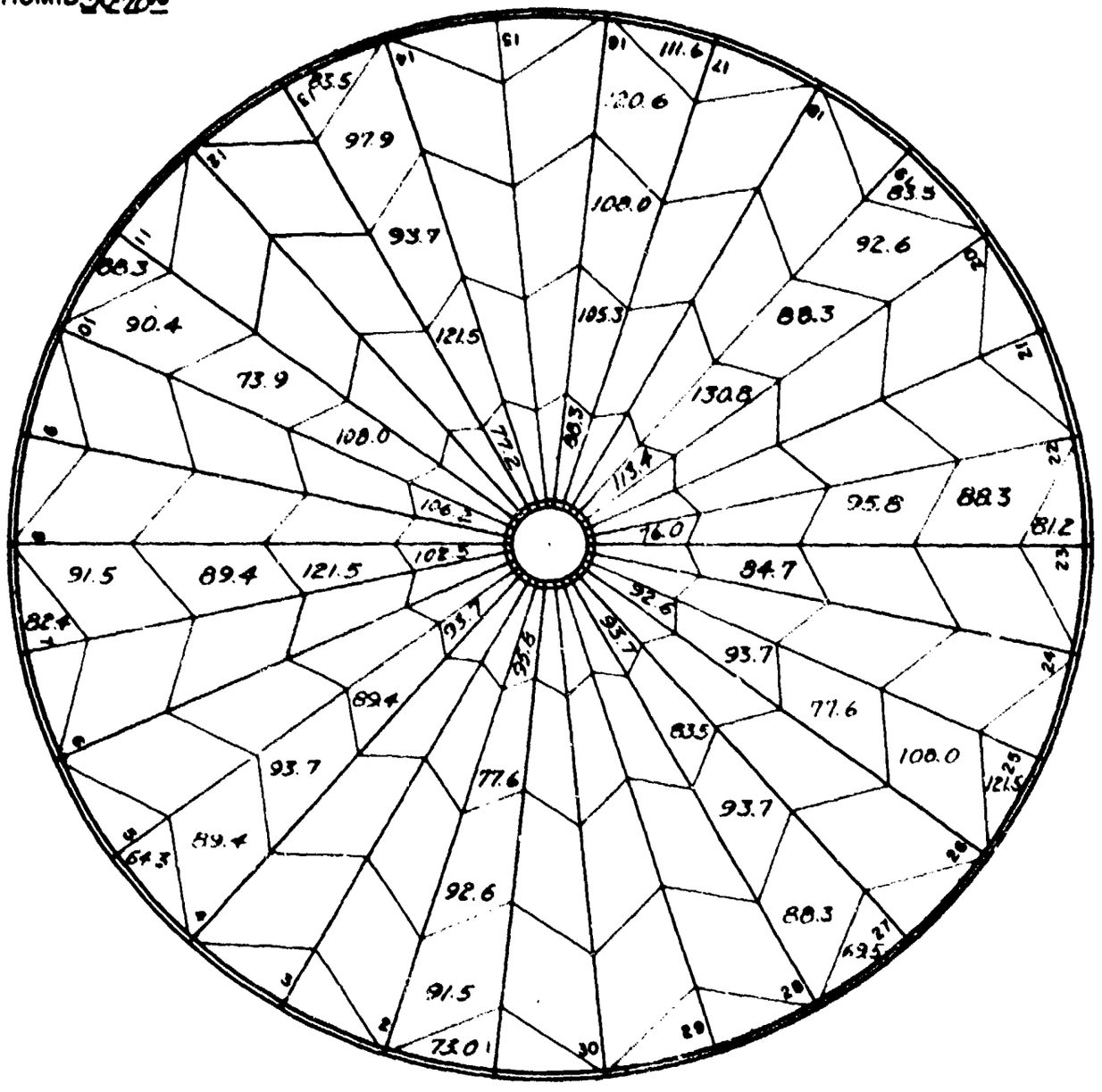
BY L.D.

POROSITY MEASUREMENTS 30 GORE CANOPY AFTER 200 M.P.H.

SERIAL NO. 350250

TEMP. 75-80°F

HUMID. 50-20%



AVERAGE POROSITY 93.6

DATE 3-30-51

BY A.V.

INDEX TO APPENDIX IV

WHIRLING TOWER TESTS

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WHIRLING TOWER TESTS

SECTION I - GENERAL

1. WHIRLING TOWER: This testing device is described in Memorandum Reports EXP-M-54-670-30A1 and ENG-M-54-670-44H titled "PARACHUTE TEST TOWER". In operation, it whirls a steel dummy fitted with a Lindquist-Ryan tensiometer around in a 200 ft. diameter circle. The parachute is mounted in a pack on the dummy from which it may be released at the operator's will. It is capable of accelerating a 250 lb. load to speeds above 200 MPH. The canopy risers are connected to a sliding member that is attached to one end of the tensiometer so that any force on the risers will be recorded on the film of the tensiometer. 4000 lb. and 10,000 lb. springs are used in the tensiometer. The tensiometer was recalibrated each time the springs were changed.

SECTION II - METHOD OF TESTING

1. SEQUENCE OF TEST OPERATIONS: The chutes were attached to the tower dummy (See Figure 4, Page 215.) and were then rotated until the designated launching speed was reached. The rip cord was pulled at a predetermined instant so that the chute opened at the proper position with respect to wind velocity and direction, speed of dummy and ideal point of observation. After the chute had opened and had brought the dummy to rest, the elongation of the lines was measured and recorded. Any broken lines, canopy damages or general malfunctions were recorded and the chute then folded and brought to the plant for complete inspection. The tensiometer film was then removed from the tensiometer and the film data recorded. Pertinent data, such as wind direction and velocity, barometric pressure, temperature and relative humidity were also recorded. The canopies and lines were carefully inspected after each test to determine the cause and extent of damage.

SECTION III - TEST RESULTS

1. DROP TEST DATA: The information gathered during the whirling tower tests is listed and summerized on the drop test reports, Pages 194 to 203. Such factors as wind velocity, direction, etc., of minor importance in the final analysis of the tests have been purposely omitted.

SECTION III - TEST RESULTS (CONT'D)

2. EVALUATION OF DATA: The principal considerations in studying the data were their affect on the performance of the line. The relation of these data to type of canopy and deployment were secondary but highly informative. The most important data from the project were the shock loads registered for each canopy opening.

These loads may be used directly to evaluate a line's ability to absorb impact forces. The static line test results were compared to the drop test results and a direct relationship was noted. In cases where a canopy suffered several line attachment failures, the recorded loads were counted and used in the final results. The lines, of course, were not counted as failures because strength of line exceeded strength of attachment. Other tests in which the lines did break, and thus limited the opening to a load less than average, were counted because they were typical of the maximum loads the lines would stand. Porosity effect is explained in Appendix "C".

3. PERMANENT SET MEASUREMENTS: The permanent set measurements made after each tower test were used to determine the recovery rate of the various lines. No exact period of time was set for these measurements. They were measured as soon as possible after the dummy was brought to rest after the canopy opening. These measurements were an indication of the stress placed on the lines. It was found that the lines recovered almost 100% by the time they were repacked for re-use. Graph, Page 211, shows % elongation remaining immediately after drop.

4. EVALUATION OF LINE BREAKS: This portion of the project required careful analysis because many of the lines were broken or badly damaged from causes other than direct stress or friction burning. In other instances, examination of lines that pulled away from the skirt of the canopy showed no signs of failure in the line itself. In order to evaluate the lines fairly, only those failures due to the following appear on Tables VIII and IX.

a. Lines broken due to high stress.
b. Lines broken from friction burns.
c. Lines broken due to combined friction burns and stress.

SECTION III - TEST RESULTS (CONT'D)

Lines broken at the link tie-on knot were presumed broken due to stress alone. Note that the knot reduces the strength of the line by 15% to 25%.

Lines broken at the skirt reinforcements were generally due to high stress. There is sometimes a slight weakening of the line at this point due to zig-zag sewing.

Lines broken between link and skirt were examined for burns to determine whether cause of failure was stress or friction.

SECTION IV - DISCUSSION OF TOWER TESTS

1. PURPOSE OF TESTING TWO SIZES OF CANOPIES: At the time this project was being planned, it was estimated that the loads from 200 MPH tests would not be high enough to stress the lines to their full strength, using 30 ft. extended skirt canopies. Therefore, the 24 ft. canopies that are known to produce high opening loads were selected for the larger portion of the tests. The 30 ft. canopies were used to study the performance of deployment bag openings and to collect information on the Type T-9 canopy.

2. TEST TOWER DUMMY: The tests called for a dummy weight of 240 lbs. but by the time the tensiometer and fittings were installed, it was 250 lbs. The outermost 10 ft. of the flying wires bring the total weight of the load to approximately 260 lbs. When this weight is launched at 200 MPH, it imposes a load on the 24 ft. canopies that is close to their ultimate strength. Soon after the first few tests, the weights on the dummy were shifted to the forward position of the dummy to gain better flying stability.

3. DEPLOYMENT BAG PERFORMANCE: The deployment bag is used on the Type T-9 parachute to hold the 30 ft. extended skirt canopy. Its purpose is to contain the canopy until all of the lines are paid out, thus preventing premature opening of the canopy. In operation, this system has some disadvantages. The bulk of the canopy is confined in a bag of relatively small dimensions. This bag can twist or tumble more than a canopy would, thus placing twists in the suspension lines.

The lines are withdrawn from the stowage loops very rapidly, oftimes tearing the loops. The loops were approximately 5 inches long, thus creating a source for burns due to friction. These faults are associated with the high speed launchings far more than with low speeds.

SECTION IV - DISCUSSION OF TOWER TESTS (CONT'D)

The twists in the lines may have contributed to slowing the openings of the canopies, thus aiding in the reduction of loads for this type of deployment.

4. REPEATED TESTS: In such cases where the tensiometer record was not clear, the loads were obviously out of line due to known causes, such as abnormally slow or fast openings, a test would be repeated. Precautions were taken to keep these repeat tests to a minimum. In the majority of the tests, one canopy with each type of line would be tested in its order so that atmospheric conditions would not vary too much between the different line groups. Unfortunately, the results of each day's testing had to be analysed before it was known whether a repeat test was needed. Approximately 41 repeat tests were made.

5. MISC. FACTORS INFLUENCING FINAL RESULTS: The average of four or six tests will usually give an indication of the performance of a canopy. To establish a more accurate rating of the performance, a minimum of ten or twelve tests should be made. One of the factors that must be considered is the effect of broken lines on the canopy loads. When lines are broken, air is spilled on the side of the canopy where these lines have failed to furnish support. The spilled air prevents the load from building up to normal.

The exact instant at which the line broke is very important. It is evident that if the break occurs due to high snatch force, the canopy will not register a high opening shock. The same reasoning applies if the line breaks while the opening shock peak is being approached.

Listed below are some causes for abnormal snatch force or opening shock loads:

a. Line-over the canopy openings.
b. Inverted canopy openings.
c. Slow pilot chute action.
d. Pilot chute area too small or too large for the size of the canopy.
e. Line attachment failure.
f. Torn canopy panel.

DROP TEST RECORD

SUSPENSION LINE GROUP NO. I — 24 FT. RIP-STOP FABRIC CANOPIES

SPEED 100 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS	OPENING TIME-SEC	DATE	TEMP.	RELATIVE HUMIDITY	BAR. PRESS.
350201	110.9	1650	1300	1.76	10/2/50	78	49	29.50
02	97.2	2475	1500	1.58	10/2/50	82	45	29.48
03	93.5	1200	1400	1.47	10/31/50	67	30	29.04
04	90.4	1800	1600	1.41	10/31/50	56	56	29.16
05	106.1	2525	1850	1.55	10/31/50	58	56	29.16
06	101.3	2165	2050	1.52	10/31/50	62	45	29.14
AVERAGE	99.9	1986	1617	1.55				

SPEED 150 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS	OPENING TIME-SEC	DATE	TEMP.	RELATIVE HUMIDITY	BAR. PRESS.
350201	110.9	4750	2725	1.08	12/18/50	25	18	29.12
02	100.0	3525	3000	1.06	12/18/50	30	30	29.00
03	94.4	5175	3250	1.10	12/18/50	32	31	28.98
04	90.7	3000	2260	1.40	5/4/51	50	30	28.96
05	106.3	4750	2725	1.18	12/18/50	30	35	28.96
06	99.8	3350	2625	0.83	2/5/51	38	15	29.32
AVERAGE	100.3	4092	2598	1.11				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS.	OPENING TIME-SEC	DATE	TEMP.	RELATIVE HUMIDITY	BAR. PRESS
350201		5000	4660	1.00	5/4/51	52	28	28.92
02		5000	4320	1.10	4/10/51	67	25	27.80
03		6320	4820	0.90	5/4/51	52	28	28.92
04	90.3	4660	4660	1.00	5/5/51	62	25	28.84
05		5160	2000	1.00	5/4/51	58	20	28.84
06		6000	4000	1.40	5/4/51	58	20	28.84
AVERAGE		5357	4077	1.06				

DROP TEST RECORD

SUSPENSION LINE GROUP NO II — 24 FT RIP-STOP FABRIC CANOPIES

SPEED 100 M P H

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350207	97.4	850	1250	1.48	10/2/50	78	49	29.50
08	80.6	2475	2365	1.38	10/2/50	82	45	29.48
09	91.0	1600	2145	1.43	10/2/50	83	44	29.44
10	102.4	2265	1400	1.80	10/31/50	56	56	29.16
11	109.0	2215	1800	1.62	10/31/50	58	56	29.16
12	98.6	2115	1730	1.56	10/31/50	62	45	29.14
AVERAGE	96.5	1920	1782	1.55				

SPEED 150 M P H

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350207	97.0	5300	2600	1.42	12/18/50	25	18	29.12
08	83.8	3100	2600	1.18	12/18/50	30	30	29.00
09	91.5	3250	2725	1.06	12/18/50	32	31	28.98
10	102.4	4625	3000	1.05	11/7/50	66	--	29.36
11	110.1	4320	2830	1.20	4/4/51	48	37	28.90
12	99.1	5325	3500	0.97	2/12/51	38	55	29.18
AVERAGE	97.3	4320	2876	1.15				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350207		7500	4660	0.80	4/27/51	58	28	29.52
08		4820	5500	0.90	4/10/51	67	25	27.80
09		4320	5000	1.10	4/27/51	59	26	29.50
10	102.1	5325	4250	0.62	1/26/51	29	48	28.94
11		6000	5000	1.00	4/27/51	59	26	29.50
12		6660	5320	1.10	4/27/51	60	25	29.50
AVERAGE		5771	4955	0.98				

DROP TEST RECORD

SUSPENSION LINE GROUP NO. III 24 FT. RIP-STOP FABRIC CANOPIES

SPEED 100 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK-LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350213	96.4	900	1630	1.59	10/2/50	79	48	29.50
14	92.0	1750	1450	1.67	10/2/50	82	44	29.46
15	101.6	2530	2215	1.47	10/2/50	82	44	29.44
16	111.0	2315	1550	1.56	10/31/50	56	56	29.16
17	92.6	1850	1600	1.55	10/31/50	60	55	29.16
18	89.0	950	1200	1.70	10/31/50	62	45	29.14
AVERAGE	97.1	1716	1608	1.59				

SPEED 150 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350213	96.4	3350	3200	0.94	2/12/51	42	52	29.16
14	91.3	2300	2600	1.10	12/18/50	30	30	29.00
15	101.6	4200	2725	1.11	12/18/50	30	32	28.98
16	110.7	1650	2625	0.94	2/12/51	38	55	29.18
17	92.1	1500	3200	0.90	2/12/51	39	52	29.18
18	89.4	2350	3650	0.85	2/12/51	42	52	29.16
AVERAGE	96.9	2558	3000	0.93				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS	OPENING TIME-SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350213		4160	4820	0.95	4/28/51	60	30	29.50
14		3130	2500	0.90	4/10/51	67	25	27.80
15		5320	3660	0.90	4/28/51	62	22	29.47
16	110.9	4100	4400	0.62	1/26/51	29	42	28.94
17		5160	5630	1.10	4/28/51	64	21	29.44
18		5000	5000	1.10	4/28/51	64	21	29.44
AVERAGE		4478	4335	0.93				

DROP TEST RECORD

SUSPENSION LINE GROUP NO IV — 24 FT. RIP-STOP FABRIC CANOPIES

SPEED 100 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350219	94.8	2425	1900	1.19	10/2/50	82	45	29.48
20	97.0	1400	2575	1.40	10/2/50	83	44	29.44
21	95.1	1050	1800	1.63	10/2/50	82	44	29.44
22	104.7	1950	1750	1.47	10/31/50	56	56	29.16
23	96.2	2115	1600	1.47	10/31/50	60	55	29.16
24	111.5	1300	1250	1.72	10/31/50	62	45	29.14
AVERAGE	99.9	1707	1813	1.48				

SPEED 150 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350219	96.0	2625	3350	1.0	1/26/51	29	42	28.94
20	96.9	3350	3250	1.0	12/2/50	42	52	29.16
21	96.1	3100	3675	1.08	12/18/50	30	32	28.98
22	105.8	3400	3800	1.0	11/7/50	66		29.36
23	94.5	2210	3200	0.84	2/12/51	42	52	29.16
24	111.6	2500	3200	1.02	2/12/51	44	49	29.18
AVERAGE	100.2	2864	3413	0.99				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350219		5000	4820	0.80	5/5/51	62	24	28.84
20		3260	4000	1.10	4/10/51	65	24	27.80
21		3390	4660	0.80	5/7/51	66	26	28.78
22	101.8	3950	3950	0.57	1/26/51	29	42	28.94
23		2390	4500	1.00	5/7/51	63	26	28.78
24		3500	5160	1.10	5/8/51	62	42	28.92
AVERAGE		3582	4515	0.88				

DROP TEST RECORD

SUSPENSION LINE GROUP NO V — 24 FT. RIP-STOP FABRIC CANOPIES

SPEED 100 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350225	98.6	1250	1350	1.63	10/31/50	67	30	29.04
26	97.3	1250	1750	1.39	10/31/50	67	30	29.04
27	95.1	1500	1800	1.43	10/31/50	68	26	29.04
28	101.2	900	1650	1.50	10/31/50	58	56	29.16
29	89.1	1200	1600	1.60	10/31/50	60	55	29.16
30	93.5	2365	1900	1.47	10/31/50	63	44	29.12
AVERAGE	95.8	1411	1675	1.50				

SPEED 150 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350225	98.0	3800	2150	1.14	12/18/50	26	25	29.08
26	98.9	2450	2300	1.10	12/18/50	32	31	28.98
27	94.6	4500	3000	1.10	12/18/50	32	30	28.98
28	100.1	4160	3000	1.30	5/5/51	62	25	28.84
29	87.5	2210	3050	0.72	2/12/51	44	49	29.18
30	94.5	3050	2775	0.99	2/12/51	44	49	29.20
AVERAGE	95.6	3362	2713	1.06				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350225		2665	3660	1.30	5/2/51	72	18	28.95
26		3390	3820	1.10	5/4/51	52	28	28.92
27		5500	5000	1.40	5/2/51	73	17	28.95
28	98.6	6500	4660	1.30	5/2/51	73	14	28.92
29		3820	1665	1.40	5/2/51	73	14	28.92
30		3260	4500	1.00	5/2/51	73	14	28.92
AVERAGE		4173	3884	1.25				

DROP TEST RECORD

SUSPENSION LINE GROUP NO. I — 30 FT. RIP-STOP FABRIC CANOPIES

SPEED 100 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS.	OPENING SHOCK-LBS.	OPENING TIME-SEC.	DATE	TEMP.	RELATIVE HUMIDITY	BAR. PRESS.
350231	89.2	550	700	2.8	2/13/51	53	51	29.29
32	93.8	700	650	3.0	2/13/51	55	46	29.28
33	91.3	450	600	3.2	2/13/51	53	48	29.28
34	100.7	275	500	3.5	2/13/51	54	47	29.28
AVERAGE	93.75	494	613	3.12				

SPEED 150 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK LBS.	OPENING TIME-SEC.	DATE	TEMP.	RELATIVE HUMIDITY	BAR PRESS
350231	88.9	1100	800	3.0	2/26/51	57	34	29.0
32	93.4	1000	900	2.5	2/27/51	55	26	28.84
33	94.3	1100	875	2.8	3/3/51	29	44	29.58
34	99.0	800	850	2.7	2/23/51	35	25	29.09
AVERAGE	93.90	1000	856	2.75				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS.	OPENING TIME-SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350231	86.3	1900	1500	3.6	3/6/51	32	52	29.54
32		1500	2250	1.6	3/28/51	56	31	29.37
33		2300	1850	2.0	3/16/51	45	50	28.8
34		1350	1350	2.0	3/28/51	63	23	29.31
AVERAGE		1763	1738	2.05				

DROP TEST RECORD

SUSPENSION LINE GROUP NO. II — 30 FT. RIP-STOP FABRIC CANOPIES

SPEED 100 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS	OPENING TIME-SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350235	89.6	225	500	3.1	2/20/51	35	71	29.3
36	90.8	275	650	3.1	2/13/51	55	46	29.28
37	92.3	375	500	3.8	2/13/51	53	48	29.28
38	91.6	300	700	3.0	2/13/51	54	47	29.28
AVERAGE	91.07	294	588	3.25				

SPEED 150 M P H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR. PRESS
350235	99.1	800	1000	2.4	2/26/51	57	34	29
36	100.5	900	1400	2.5	2/27/51	55	26	28.84
37	101.1	1100	950	3.2	3/3/51	29	44	29.58
38	89.0	700	800	3.1	2/23/51	32	31	29.06
AVERAGE	97.43	875	1038	2.8				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS	OPENING TIME-SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR. PRESS
350235	85.9	1400	1800	2.45	3/6/51	32	52	29.54
36		1750	1750	1.7	3/28/51	56	31	29.37
37		1200	1200	2.9	3/16/51	47	43	28.8
38	89.1	1550	1550	1.9	3/28/51	63	20	29.27
AVERAGE	87.5	1475	1575	2.24				

DROP TEST RECORD

SUSPENSION LINE GROUP NO. III — 30 FT. RIP-STOP FABRIC CANOPIES

SPEED 100 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350239	91.4	225	500	3.0	2/20/51	35	70	29.3
40	92.8	225	600	3.2	2/13/51	53	47	29.28
41	87.0	225	550	3.2	2/13/51	53	48	29.28
42	86.3	225	550	3.3	2/13/51	54	47	29.28
AVERAGE	89.37	225	550	3.17				

SPEED 150 M P H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350239	102.1	550	850	2.6	2/26/51	57	34	29
40	89.1	700	900	2.9	2/27/51	55	26	28.84
41	83.1	800	675	3.4	3/3/51	31	44	29.58
42	86.3	750	1650	2.5	2/23/51	32	31	29.06
AVERAGE	90.15	700	1019	2.85				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR. PRESS
350239	88.8	1500	1900	1.8	3/6/51	39	49	29.52
40		1950	1550	2.0	3/28/51	56	30	29.37
41		1100	1450	2.3	3/16/51	47	43	28.8
42	85.7	1900	1600	2.0	3/28/51	62	19	29.27
AVERAGE	87.25	1613	1625	2.02				

DROP TEST RECORD

SUSPENSION LINE GROUP NO. IV — 30 FT. RIP-STOP FABRIC CANOPIES

SPEED 100 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS	OPENING TIME-SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350243	85.5	300	550	3.0	2/13/51	53	51	29.29
44	87.9	275	550	2.9	2/20/51	35	70	29.32
45	87.7	550	450	3.3	2/13/51	54	47	29.28
46	89.0	375	650	2.9	2/13/51	54	45	29.30
AVERAGE	87.52	375	550	3.02				

SPEED 150 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS	OPENING TIME SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS.
350243	85.8	800	950	2.5	2/26/51	59	36	29
44	86.5	750	1075	2.68	2/27/51	55	26	28.84
45	88.0	800	980	3.0	3/3/51	31	44	29.58
46	89.8	700	850	2.9	2/23/51	32	31	29.06
AVERAGE	87.52	763	964	2.77				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS.	OPENING TIME-SEC.	DATE	TEMP.	RELATIVE HUMIDITY	BAR. PRESS
350243	85.0	1070	1570	2.5	3/6/51	57	21	29.4
44		1350	1550	.72	3/28/51	56	28	29.36
45		1250	1550	.58	3/16/51	47	43	28.8
46	88.9	1250	1650	2.8	3/28/51	62	19	29.27
AVERAGE	86.95	1230	1580	1.65				

DROP TEST RECORD

SUSPENSION LINE GROUP NO V — 30 FT. RIP-STOP FABRIC CANOPIES

SPEED 100 M.P.H

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK-LBS	OPENING TIME-SEC	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350247	83.0	175	500	3.1	2/13/51	55	46	29.28
48	89.9	175	500	3.5	2/13/51	53	48	29.28
49	101.7	175	700	3.0	2/13/51	54	47	29.28
50	96.3	175	375	3.1	2/20/51	36	72	29.32
AVERAGE	92.73	175	519	3.17				

SPEED 150 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE-LBS	OPENING SHOCK LBS	OPENING TIME SEC.	DATE	TEMP	RELATIVE HUMIDITY	BAR PRESS
350247	83.2	700	900	2.4	2/26/51	59	36	29
48	88.1	750	1100	2.1	4/2/51	53	54	28.95
49	98.7	600	940	3.2	3/3/51	36	38	29.5
50	104.8	395	1400	2.4	2/23/51	34	32	29.08
AVERAGE	93.70	611	1085	2.52				

SPEED 200 M.P.H.

PARACHUTE DATA		TENSIOMETER DATA			WEATHER DATA			
SERIAL NO.	CANOPY POROSITY	SNATCH FORCE LBS	OPENING SHOCK-LBS	OPENING TIME-SEC	DATE	TEMP.	RELATIVE HUMIDITY	BAR PRESS
350247	82.4	1200	1680	2.6	3/6/51	52	19	29.38
48		1250	1450	2.1	3/28/51	56	28	29.36
49	98.6	1200	1900	2.45	3/16/51	47	43	28.8
50	94.4	1350	1550	2.2	3/28/51	62	19	29.27
AVERAGE	91.8	1250	1645	2.34				

Best

Second Best

Worst

24 FT. CANOPIES

TABLE II TESTS AT 100 M.P.H.

LINE GROUP NO.	I	II	III	IV	V
Aver. Snatch Force	1986	1920	1716	1707	1411
Aver. Open. Shock	1617	1782	1608	1813	1675
Aver. Porosity	99.9	96.5	97.1	99.9	95.8
Aver. Open. Shock	1.55	1.55	1.59	1.48	1.50

TABLE III TESTS AT 150 M.P.H.

LINE GROUP NO.	I	II	III	IV	V
Aver. Snatch Force	4092	4320	2558	2864	3362
Aver. Open. Shock	2598	2676	3000	3413	2713
Aver. Porosity	100.3	97.3	96.9	100.2	95.6
Aver. Open. Time	1.11	1.15	0.93	0.99	1.06

TABLE IV TESTS AT 200 M.P.H.

LINE GROUP NO.	I	II	III	IV	V
Aver. Snatch Force	5357	5771	4478	3582	4173
Aver. Open. Shock	4077	4995	4335	4515	3884
Aver. Porosity	90.3	102.1	110.9	101.8	98.6
Aver. Open. Time	1.06	0.92	0.93	0.88	1.25

LINE EVALUATION TABLES BASED ON IMPACT LOADS

Best

Second Best

Worst

30 FT. CANOPIES

TABLE V TESTS AT 100 M.P.H.

LINE GROUP NO.	I	II	III	IV	V
Aver. Snatch Force	494	294	225	375	175
Aver. Open. Shock	613	588	550	550	519
Aver. Porosity	93.75	91.07	89.37	87.52	92.73
Aver. Open. Time	3.12	3.25	3.17	3.02	3.17

TABLE VI TESTS AT 150 M.P.H.

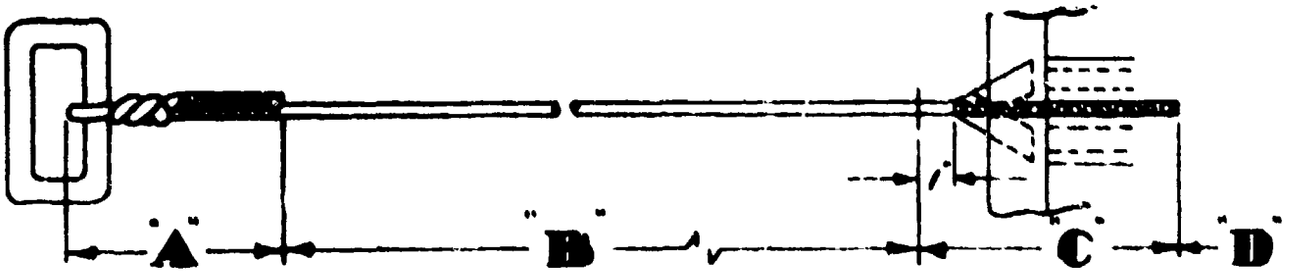
LINE GROUP NO.	I	II	III	IV	V
Aver. Snatch Force	1000	875	700	763	611
Aver. Open. Shock	856	1038	1019	964	1085
Aver. Porosity	93.90	97.43	90.15	87.52	93.70
Aver. Open. Time	2.75	2.80	2.85	2.77	2.52

TABLE VII TESTS AT 200 M.P.H.

LINE GROUP NO.	I	II	III	IV	V
Aver. Snatch Force	1763	1475	1613	1230	1250
Aver. Open. Shock	1738	1575	1625	1580	1645
Aver. Porosity	86.30	87.5	87.25	86.95	91.80
Aver. Open. Time	2.05	2.24	2.02	1.65	2.34

*See Appendix "C", Page 33

LINE EVALUATION TABLES BASED ON IMPACT LOADS



LINE BREAKAGE DUE TO OPENING FORCES AND DEPLOYMENT ACTION ONLY

"A" - Broken at Link Knot
"B" - Broken between Knot and Skirt
"C" - Broken at Skirt
"D" - Broken In Canopy

TABLE

Location of Line Breakage

24 ft. Canopies **All Speeds**

GROUP NO.	"A"	"B"	"C"	"D"	TOTAL
I	18	0	0	0	18
II	0	0	0	0	0
III	0	0	0	1	1
IV	17	6	1	0	24
V	0	0	0	0	0
TOTAL	35	6	1	1	43

TABLE

Location of Line Breakage

30 ft Canopies **All Speeds**

GROUP NO.	"A"	"B"	"C"	"D"	TOTAL
I	0	0	0	0	0
II	0	0	0	0	0
III	0	0	0	0	0
IV	0	25	3	0	28
V	0	0	1	0	1
TOTAL	0	25	4	0	29

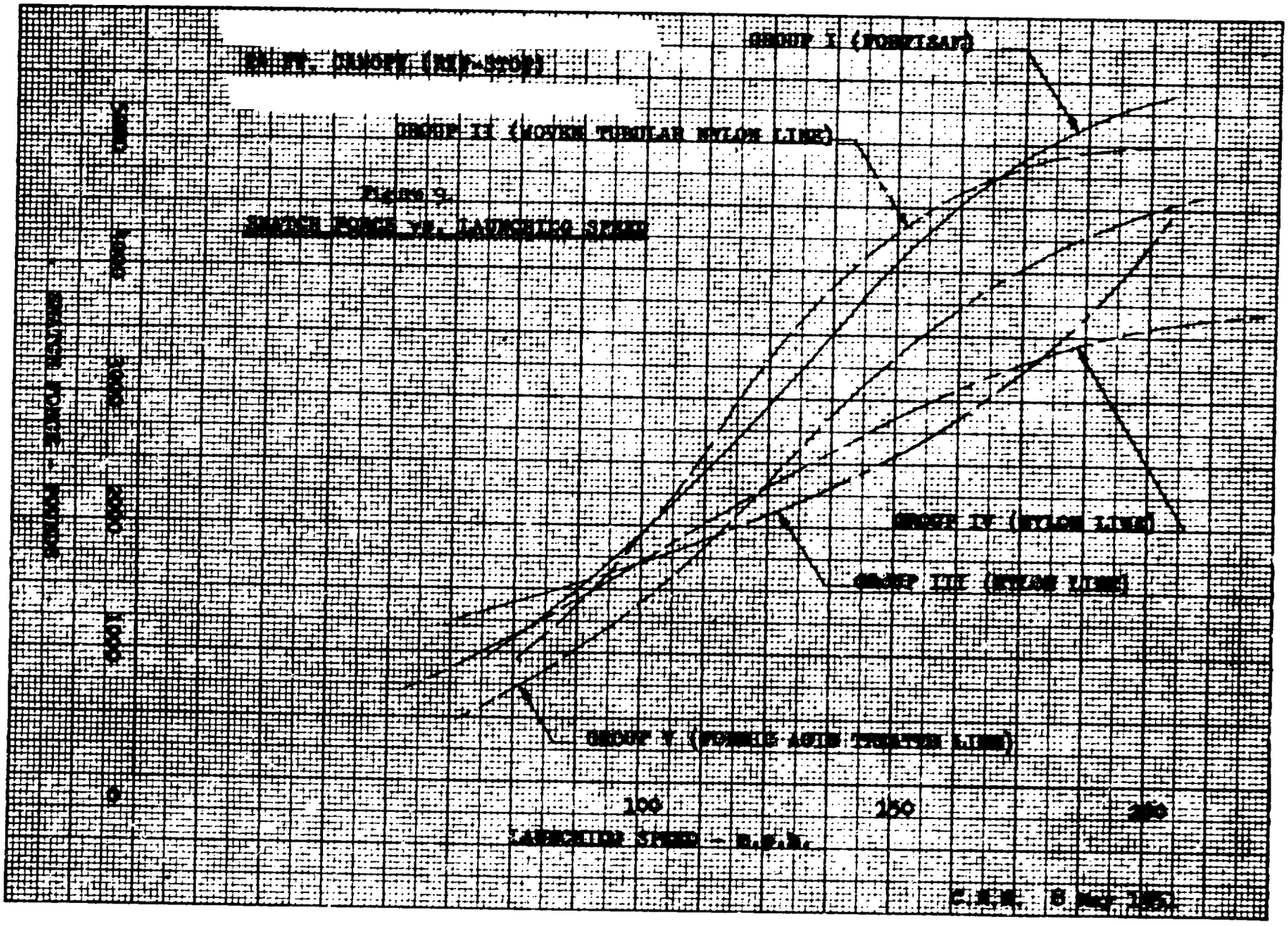


Figure 9.
MAXIMUM FORCE VS. LAUNCHING SPEED

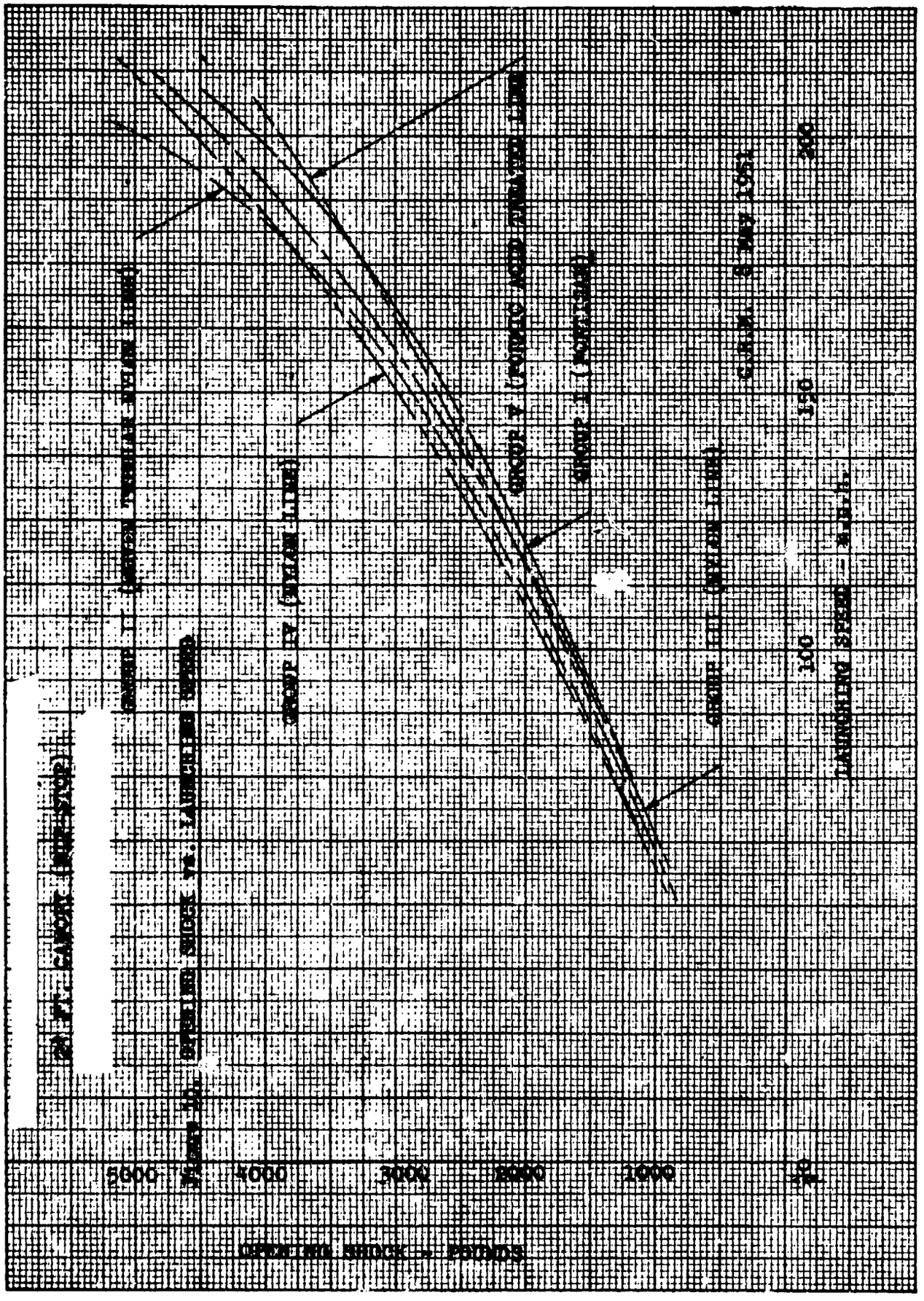


Figure 10. OPENING SHOCK vs. LAUNCHING SPEED

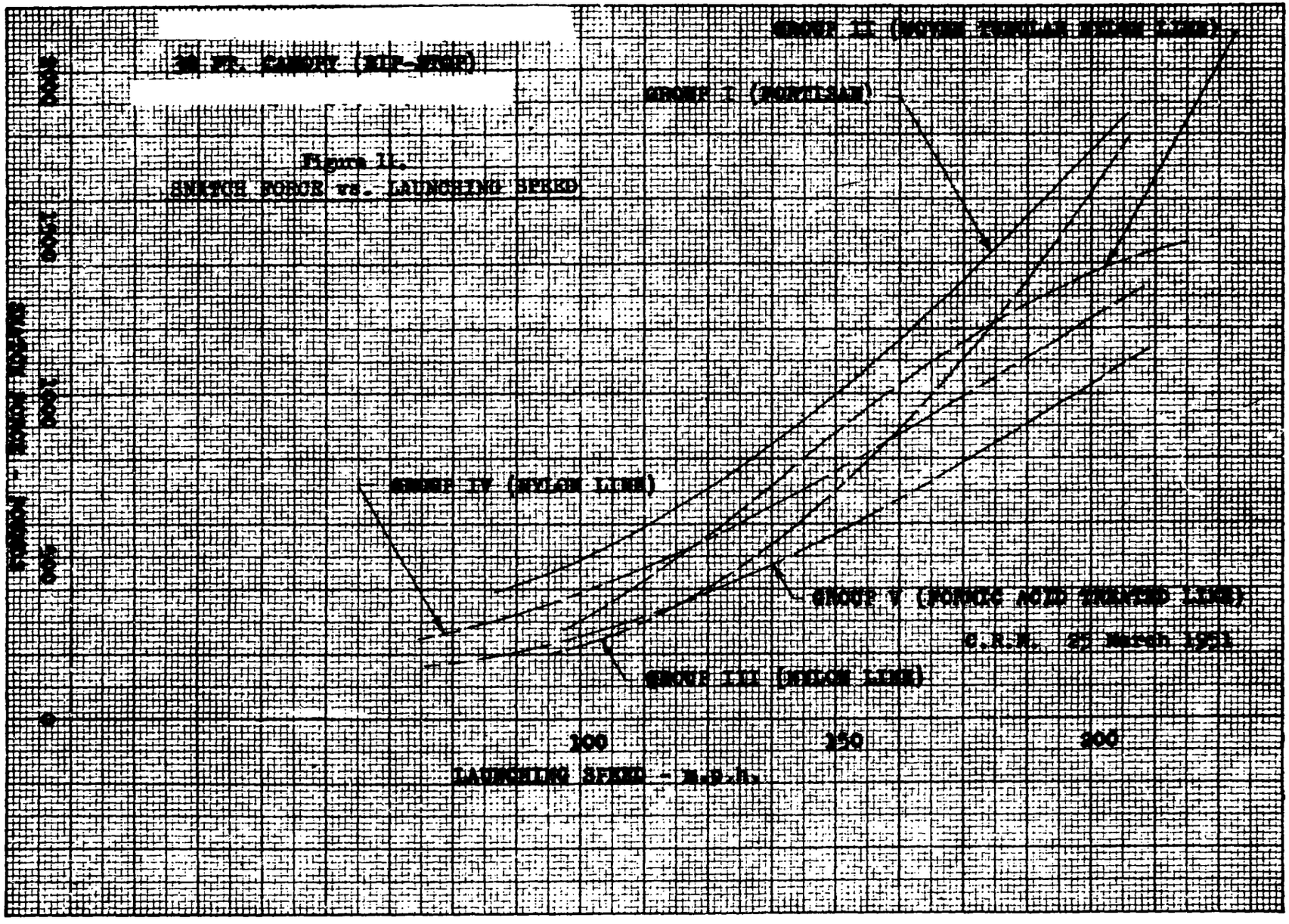
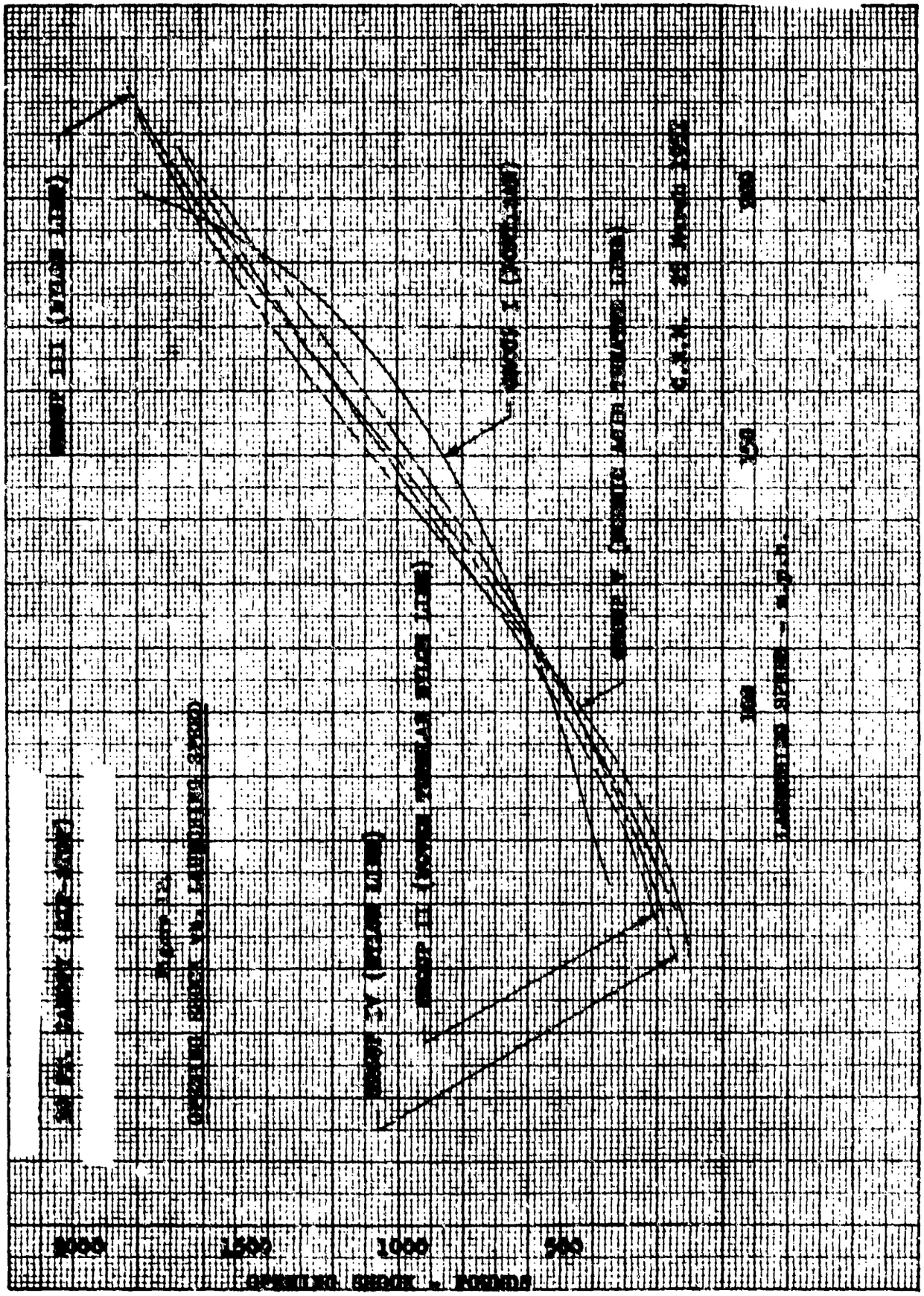


Figure 11.
SNATCH FORCE vs. LAUNCHING SPEED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1500
1000
500
150
100
50

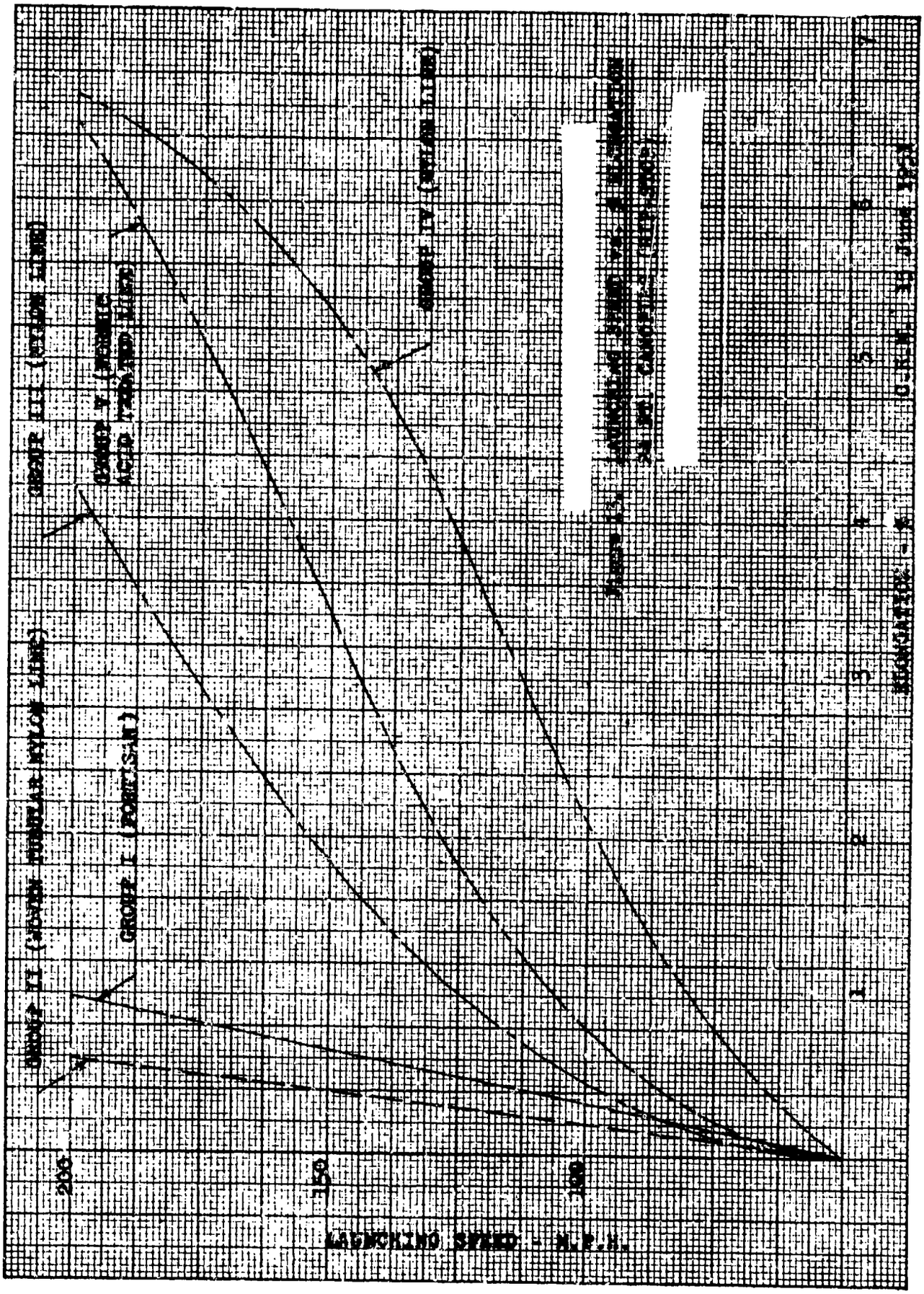

Figure 15. LAUNCHING SPEED vs. % ELONGATION
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APPENDIX V

LIST OF ILLUSTRATIONS

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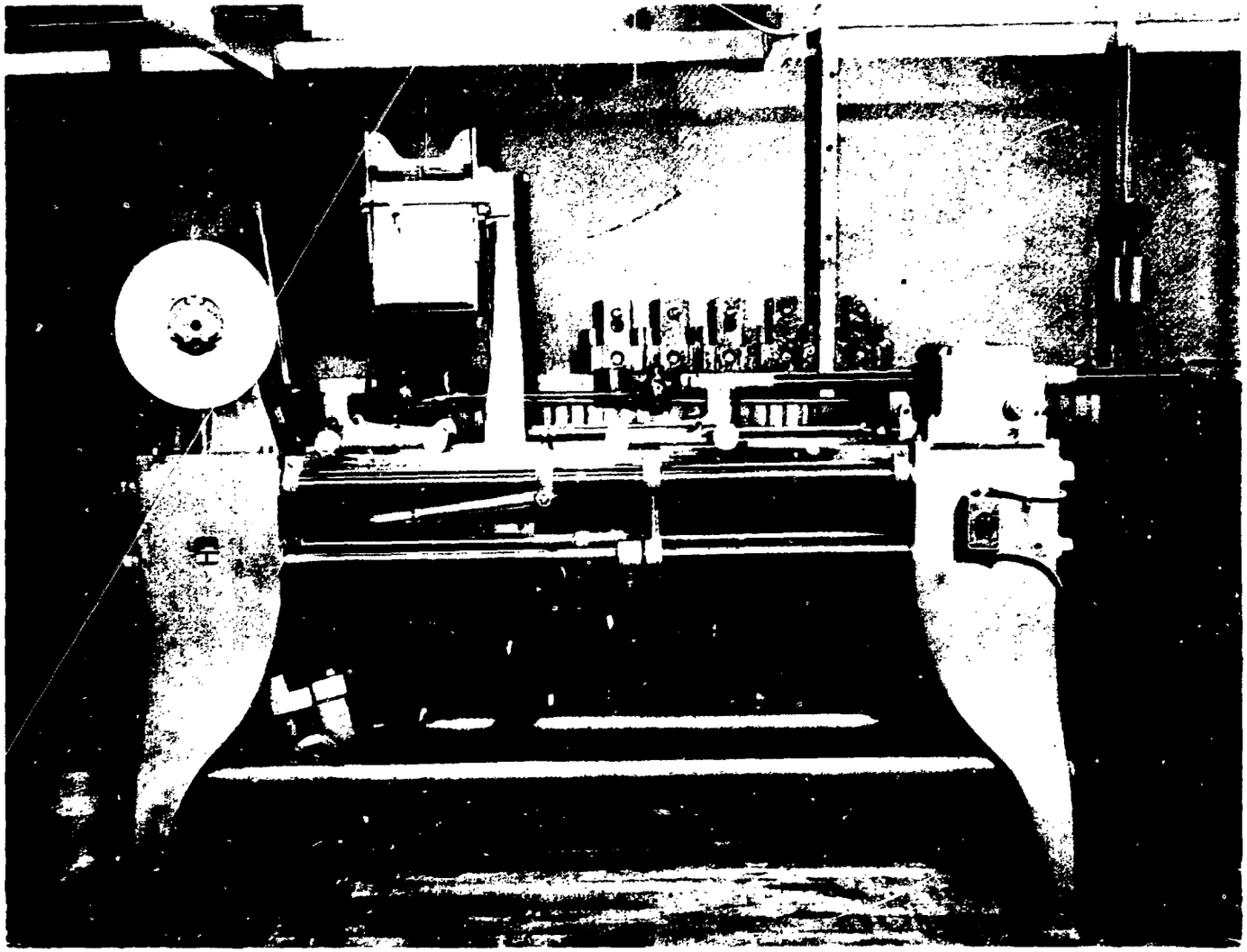

Figure 14. Scott Pendulum Type Tensile Tester with Cord Under Tension and Tensilgram record of elongation

Figure 15. Method of Clamping Cord in Jaws of Scott Tensile Tester

Figure 16. Frazier Air Porosity Tester in Use

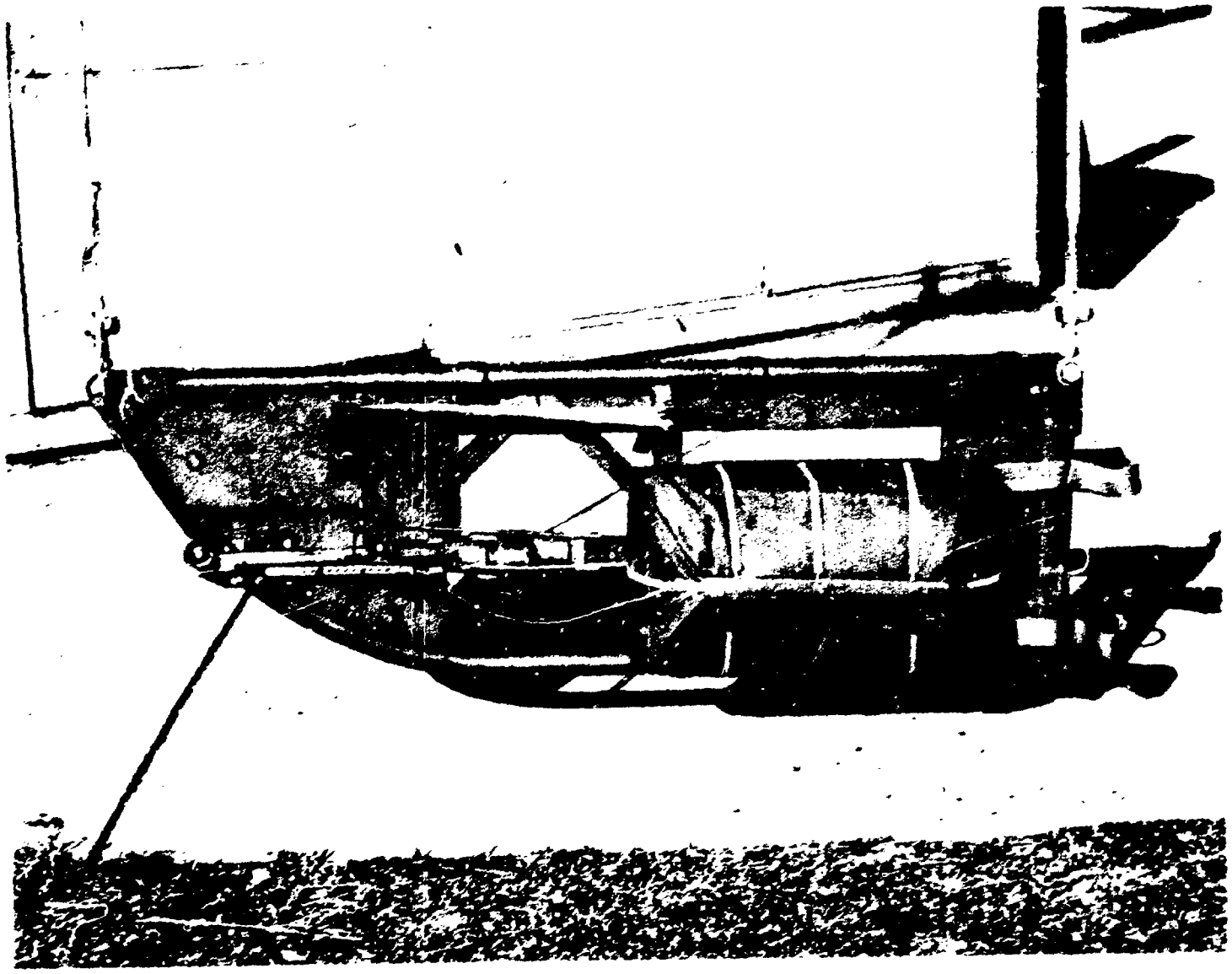

Figure 17. 30 ft. Extended Skirt Canopy in Deployment Bag and Mounted Inside of Drop Test Pack on Test Tower Dummy

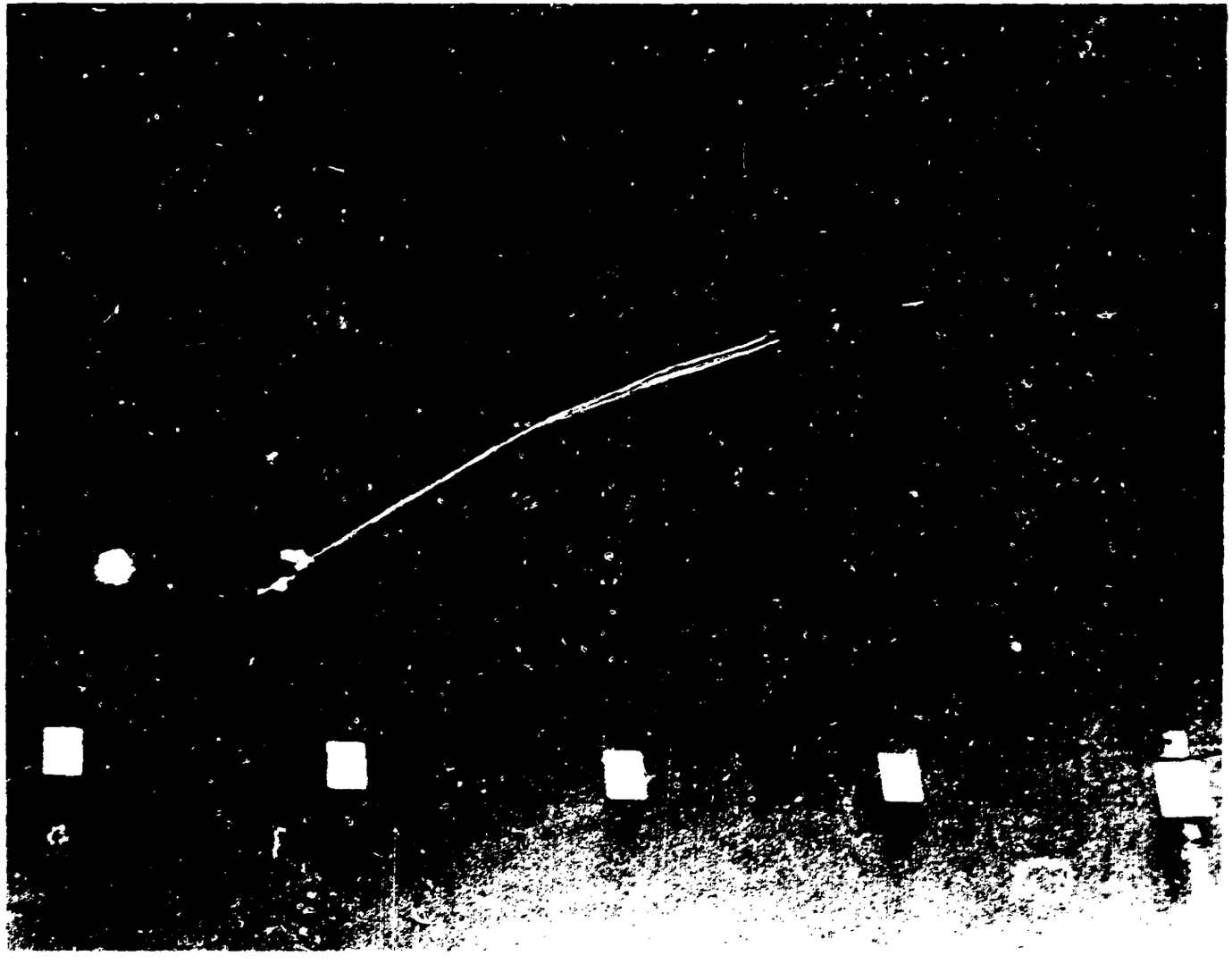

Figure 18. Deployment Bag Being Pulled From 30 ft. Canopy. Note outward motion due to centrifugal force

Figure 19. 30 ft. Extended Skirt Canopy After Snatch Force has Acted on Dummy. Opening Shock Peak is not yet Reached. Note Twist in Lines at End of Risers

Figure 20. Approximate Instant of Opening Shock Peak on the 30 ft. Canopy. Twists in lines caused Several Line Failures

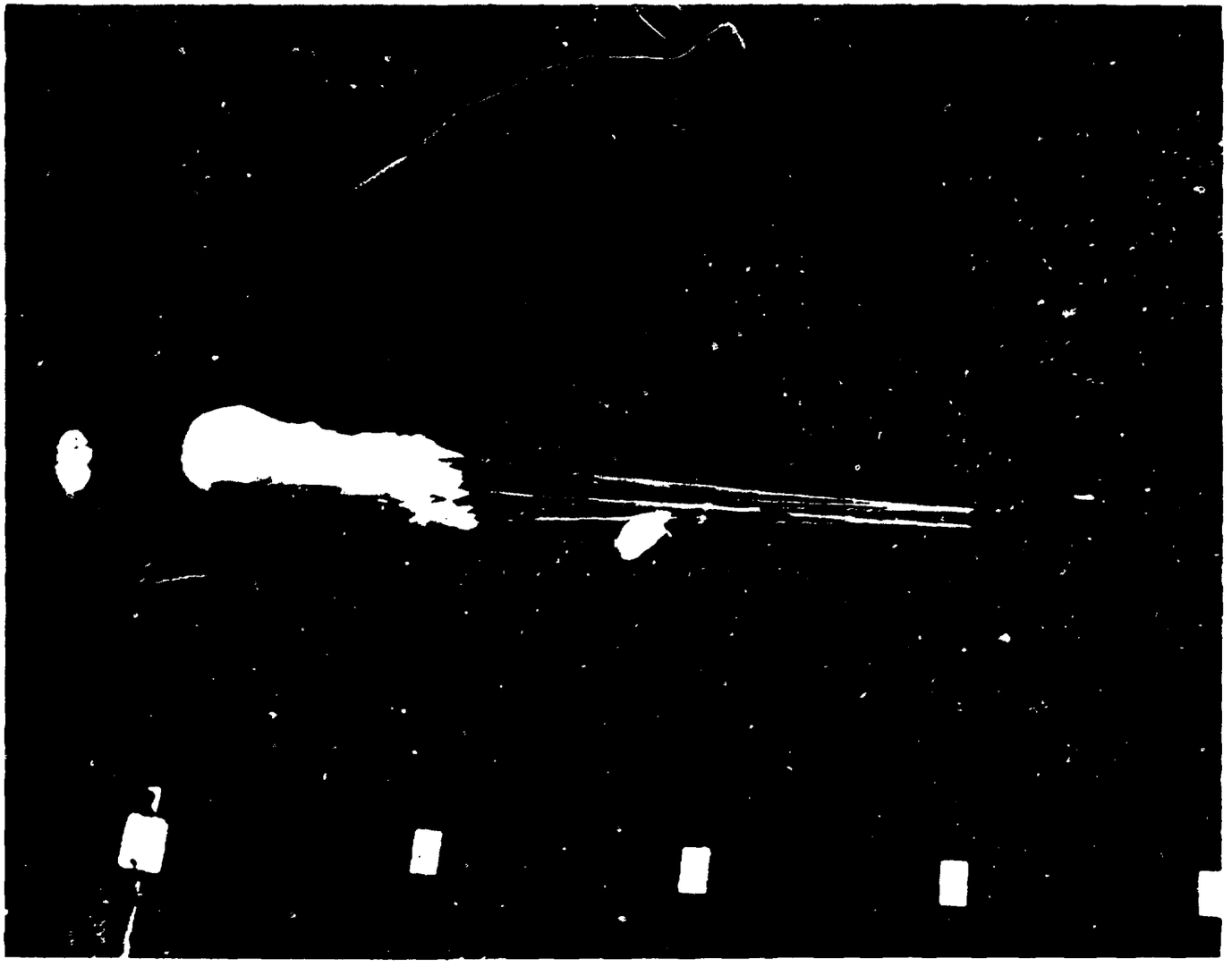

Figure 21. 24 ft. Canopy an Instant Before Snatch Force has pulled Lines Taut. The Canopy is Starting to Fill at the Vent Before Lines are Fully Stretched

Figure 22. 24 ft. Canopy During Opening. Opening Force is building up to a maximum

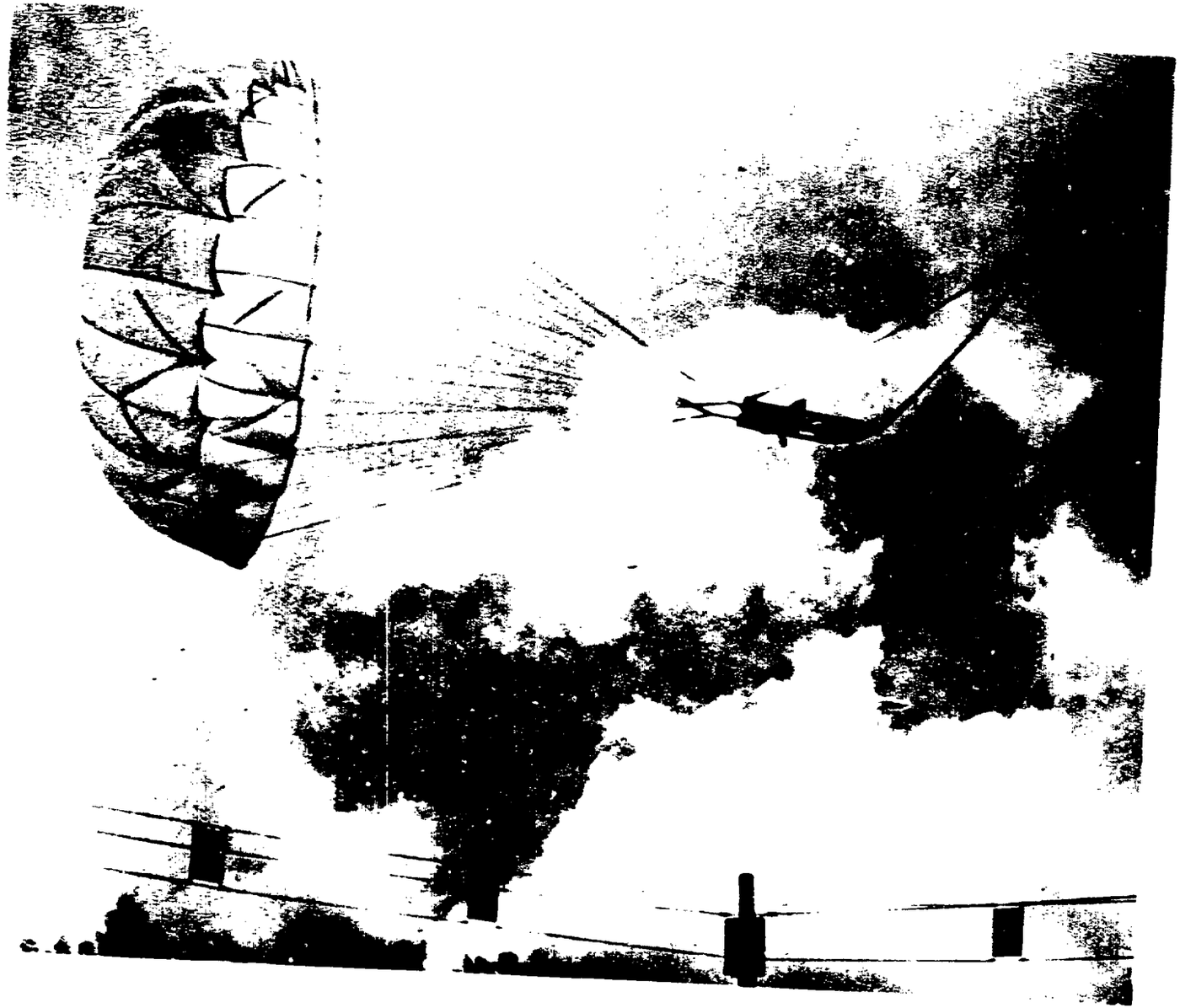

Figure 23. Typical 24 ft. Canopy Fully Opened. Dummy is Starting to Drift. Heavy Cross Seams Indicate Repaired Sections

DEFINITION OF TERMS

SNATCH FORCE:- The force imposed upon the subject load by the parachute to accelerate the mass of the parachute from its final velocity at line stretch (or snatch) to the velocity of the subject load.

OPENING SHOCK:- The force imposed on the subject load, a brief instant before the full opening of the canopy, due to the retarding effect of the mass of air entrapped in the canopy.

OPENING TIME:- The elapsed time from the instant the pilot chute emerges from the pack until the skirt of the canopy is fully open.

FRICTION BURNS:- The fusing of the fibers due to the heat generated when materials are brought into a quick forceful contact or when friction takes place.

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