NASA TECHNICAL MEMORANDUM

REPORT NO. 53886

88

REACTION OF ENCAPSULATING FOAMS TO SPECIFIC ENVIRONMENTAL CONDITIONS

By H. M. Walker
Manufacturing Engineering Laboratory

September 12, 1969

NASA

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

N70-37527 (ACCESSION NUMBER) (THRU)
16 (PAGES) 1 (CODE)
TMX-53886 (NASA CR OR TMX OR AD NUMBER) 18 (CATEGORY)
FACILITY FORM 602

MSFC - Form 3190 (September 1968)

R ME-IN-67-9

Changed to TM X-53886, September 1969

REACTION OF ENCAPSULATING FOAMS TO SPECIFIC ENVIRONMENTAL CONDITIONS

By

H. M. Walker

George C. Marshall Space Flight Center
Hunstville, Alabama

ABSTRACT

This Engineering Project was carried out in the form of an investigation, conducted to establish the relative degrees of dimensional stability exhibited by two separate foam systems when exposed to simultaneous thermal cycling. The foam systems under study were mixed and cast into aluminum boxes and compared by one physical characteristic - the vertical, unidirectional expansion of the foam when exposed to incrementally increased temperatures.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER

REACTION OF ENCAPSULATING FOAMS TO SPECIFIC ENVIRONMENTAL CONDITIONS

By

H. M. Walker

MANUFACTURING ENGINEERING LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

REACTION OF ENCAPSULATING FOAMS TO SPECIFIC ENVIRONMENTAL CONDITIONS

SUMMARY

Polyurethane foam is used to encapsulate wire bundles and terminals in closed electrical distributor boxes on Saturn V stages. An undesirable characteristic of one of the approved foam materials has been a marked swelling at some interval after installation which could have an adverse effect on the installed circuitry. Parallel environmental exposure tests were performed using specimens of the suspect material and another more stable candidate. Data was accumulated concerning the effects of temperature, vacuum and relative humidity (as well as various combinations of the three conditions) on dimension stability. The less stable of the two materials showed considerable growth due to temperature increase. Relative humidity and vacuum had significantly less effect on dimensional stability; however, it should be required that some determination be made regarding the reaction of these or any candidate substitute to these environmental conditions.

PURPOSE

It becomes necessary to determine the amount of dimensional distortion which could be expected to occur in electrical encapsulating foams as a result of exposure to various thermal environments. Certain electrical distribution boxes have been examined, after being subjected to varied environmental conditions, and the observation made that the encapsulating foam, initially poured and foamed in place, had expanded considerably, in some instances to the extent that the reinforced plastic cover plates were pushed out. Since it is highly probable that that solder joints in the encapsulated wiring are thus subjected to potentially damaging stresses, which could result in discontinuities and possible flight schedule impact, it was urgent that a series of tests be conducted to determine the rate of deformation of the two foam systems used in this particular application, when specimens are subjected to certain environmental conditions.

TEST SPECIMEN PREPARATION

Twenty aluminum boxes, measuring 16.5 by 6.4 by 7.62 centimeters (6.5 by 2.5 by 3 inches), open on one 16.5 by 7.63 centimeters (6.5 by 3 inches) side, were obtained to be foam-filled for environmental testing. Ten boxes were foamed with each of the two foam formulations, as follows:

Nopco Foam B-610 R/T. - Foam components were mixed in the following required proportions:

B-610-R 54 parts by wt
B-610-T 46 parts by wt

The foam was cast into each box in two mixes, with the final portion volumetrically restrained by a ported plate over the open surface. A second variable was introduced to determine effect on component behavior, by inclusion of insulated copper wire bundles, taped to the bottoms of six of the ten boxes. These bundles were considered representative of wire bundles in related distributor boxes. The remaining four boxes were filled with foam only.

Stafoam (per BMS-8-38D). - Foam components were mixed in the following proportions:

Part T - 100 parts by wt
Part R - 82 parts by wt

This material was cast and cured in the same manner as the Nopco components above, with the vented plate being used to restrain the final pour. Included in this lot also were six units with embedded wire bundles taped in place.

COMPONENT CURE

While the rise time of both the two foam systems is measured in a very few minutes, the material continues to cure, changing mechanical properties in the process, for several hours; as a consequence, the completed foam-box assemblies were allowed to post-cure at ambient temperature for 24 hours.

IDENTIFICATION

The 10 Napco samples were identified as follows:

a. Imbedded Wire Specimens

1 N - W
2 N - W
3 N - W
4 N - W
5 N - W
6 N - W

b. Plain Specimens

7 N
8 N
9 N
10 N

The spray foam specimens were identified as follows:

a. Imbedded Wire Specimens

1 S - W
2 S - W
3 S - W
4 S - W
5 S - W
6 S - W

b. Plain Specimens

7 S
8 S
9 S
10 S

TESTING

From the selection of test specimens were chosen four groups, four specimens to the group, representing each of the combinations of distinguishing characteristics (two foam types, with and without wire bundles). These groups, with units identifiable by symbol (N or S for Nopco or Stayfoam, W for Wire Bundle inclusion) were as follows:

1. Group I (1N-W, 1S-W, 7N, 7S) Subjected to incrementally increased temperatures, from ambient to 394K (250°F) being exposed to each temperature for two hours.

2. Group II (2N-W, 2S-W, 8N, and 8S) Subjected to incrementally increased temperatures while under 98 000 N/m^2 (29 in.) Hg vacuum.

3. Group III (4N-W, 4S-W, 10N, and 10S) Exposed randomly variable temperatures to 324.79K (125°F) and 100 percent R. H.

4. Group IV (3N-W, 3S-W, 9N, and 9S) held at room temperature.

TEST RESULTS

Group I. - In Group I testing, considered the most important area of this investigation, the specimens were removed briefly for measurement at the end of each exposure period. Total depth of the foam was measured and recorded (see Table I) and percentage growth calculated at 353K (175°F); a set of curves, are shown in Figure 1, showing more graphically the relative rates of growth of the four samples.

Group II. - This group of samples obviously could not be assumed closely, without breaking vacuum. However, calibrated scales were affixed to each specimen, visible through the vacuum oven view-port, and provided a measure of accuracy in estimating growth at each temperature increment. The specimens were placed in a vacuum oven and, with no heat being applied initially, a vacuum of 29 inches Hg was developed in the chamber. A moderate amount of growth was measured in the stayfoam specimens at this point, as is seen in Table II. Percent growth, measured at 353K (175°F), was 12.5 percent in both the stayfoam specimens while the Nopco specimens showed no obvious change throughout the cycle. Figure 2 illustrates more dramatically the difference in growth rates between stayfoam and Nopco samples.

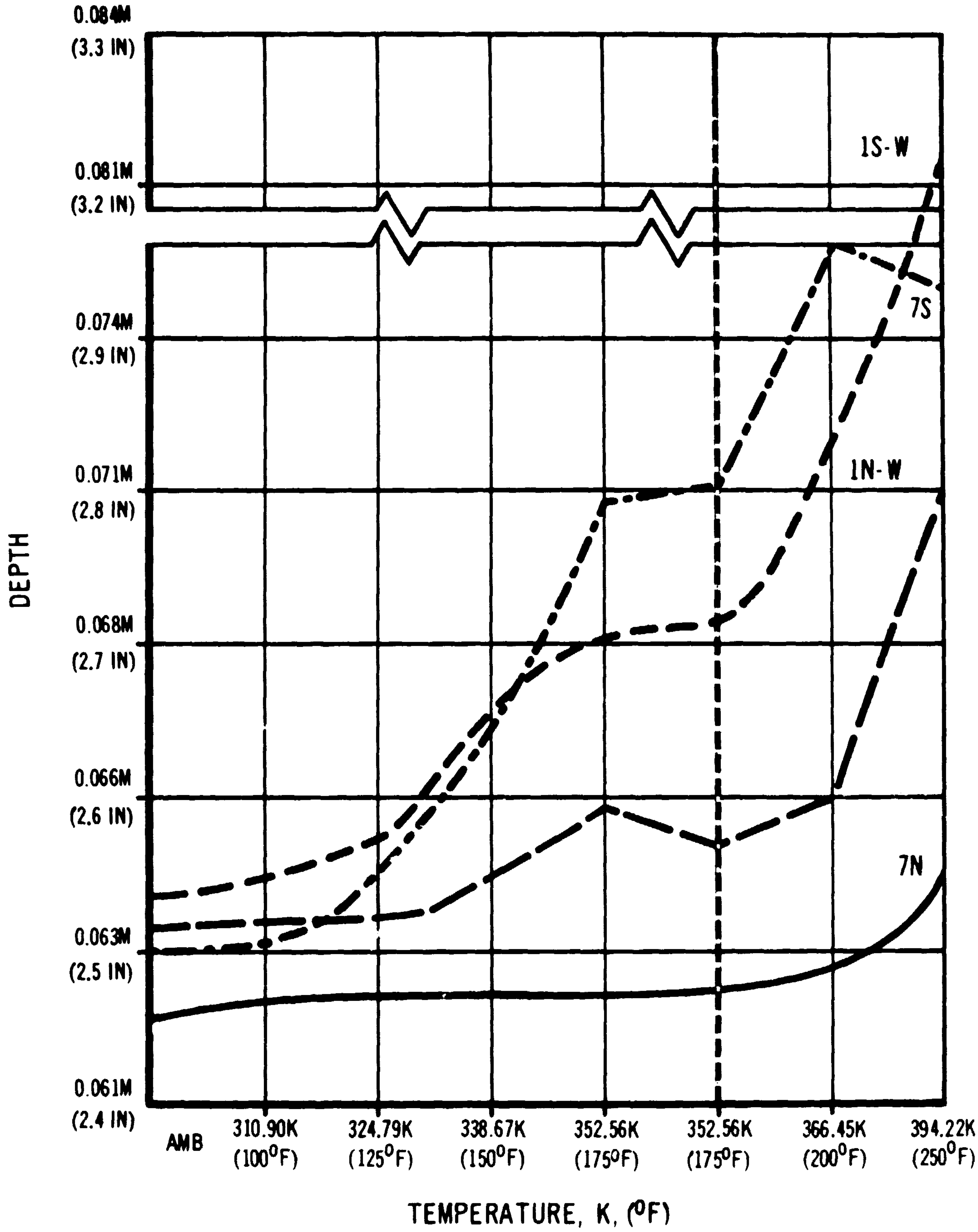

FIGURE 1. GROUP I SAMPLES-TOTAL DEPTH VS TEMPERATURE, °F (°C)

TABLE I. TABULATED MEASUREMENTS IN INCHES (AND CENTIMETERS) AT VARIOUS TEMPERATURE LEVELS, AFTER TWO HOURS EXPOSURE, AND PERCENT GROWTH AT CRITICAL TEMPERATURES

Specimen	Initial	311K (100°F)	325K (125°F)	339K (150°F)	353K (175°F)	353K* (175°F)	366K (200°F)	394K (250°F)	* Percent at 353K (175°F)
7S	2.50 (6.35)	2.50 (6.35)	2.56 (6.56)	2.64 (6.70)	2.79 (7.08)	2.80 (7.12)	2.96 (7.52)	2.94 (7.46)	12%
7N	2.46 (6.25)	2.47 (6.28)	2.47 (6.28)	2.47 (6.28)	2.49 (6.32)	2.47 (6.28)	2.48 (6.30)	2.54 (6.45)	0.5%
1S-W	2.54 (6.45)	2.55 (6.47)	2.57 (6.52)	2.66 (6.75)	2.70 (6.86)	2.71 (6.88)	2.84 (7.22)	3.21 (8.15)	8%
1N-W	2.52 (6.40)	2.52 (6.40)	2.52 (6.40)	2.55 (6.47)	2.59 (6.58)	2.56 (6.50)	2.60 (6.60)	2.80 (7.11)	1.6%

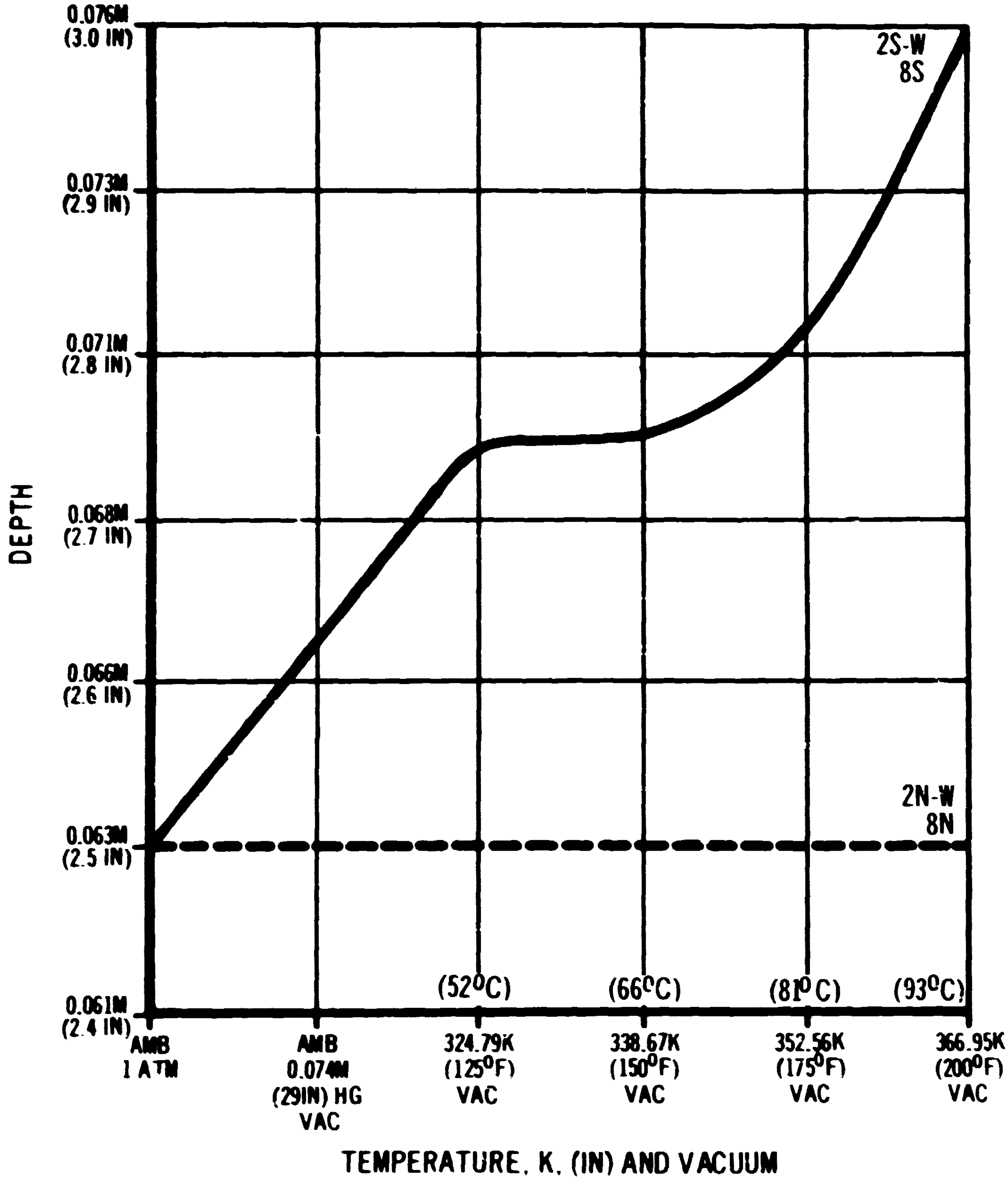

FIGURE 2. GROUP II SAMPLES-TOTAL DEPTH VS TEMPERATURE AND VACUUM

TABLE II. TABULATION OF MEASUREMENTS IN INCHES (AND CENTIMETERS) UNDER 29 INCHES Hg VACUUM (98 000 N/m^2) AND AT VARIOUS TEMPERATURES

Specimen	Initial	AMB (VAC)	125°F (325K) (VAC)	150°F (339K) (VAC)	175°F (353K) (VAC)	200°F (366K) (VAC)	Percent at 175°F (353K)
8S	2.50 (6.35)	2.62 (6.65)	2.75 (6.98)	2.75 (6.98)	2.813 (7.15)	3.00 (7.62)	12.5%
SN	2.50 (6.35)	2.50 (6.35)	2.50 (6.35)	2.50 (6.35)	2.50 (6.35)	2.50 (6.35)	0
2S-W	2.50 (6.35)	2.62 (6.65)	2.75 (6.98)	2.75 (6.98)	2.813 (7.15)	3.00 (7.62)	12.5%
2N-W	2.50 (6.35)	2.50 (6.35)	2.50 (6.35)	2.50 (6.35)	2.50 (6.35)	2.50 (6.35)	0

Group III. - These specimens were subjected to a constant 100 percent relative humidity environment, with random variation in temperature from room-temperature ambient to 325K (125°F) over a period of 15 days. Response was slower here, but the results after 15 days exposure were roughly comparable to those obtained in the previous tests. The stayfoam specimen, without the encapsulated wire, grew 8 percent. The embedded-wire stayfoam specimen grew less than 2 percent, which is rather contradictory in view of Groups I and II results. Tabulated depth measurements are shown in Table III, along with total percentage growth; Figure 3 is a graphic comparison of specimen growth with time.

TABLE III. TABULATION IN INCHES (AND CENTIMETERS) OF FOAM DEPTH MEASUREMENTS WITH TIME, AND FINAL GROWTH PERCENTAGE

Specimen	Initial	7 DA	10 DA	15 DA	%
9S-	2.510 (6.37)		2.554 (6.47)	2.710 (6.88)	8.00
9N-	2.482 (6.30)		2.508 (6.37)	2.518 (6.40)	1.45
3S-W	2.506 (6.37)		2.505 (6.36)	2.549 (6.47)	1.73
3N-W	2.516 (6.38)	2.519 (6.40)	2.523 (6.41)	2.528 (6.43)	0.44

Group IV. - These specimens were originally intended for exposure at room temperature 100 percent R. H. for a prolonged period of time. However, the Humidity Chamber in which the specimens were to be tested was inoperable at the time; consequently, the specimens were simply stored at room temperature. Only one of the specimens showed any measurable growth - the stayfoam samples without embedded wires grew to a depth of 6.9 centimeters (2.70 inches) or 8 percent. The remaining three specimens were unaffected.

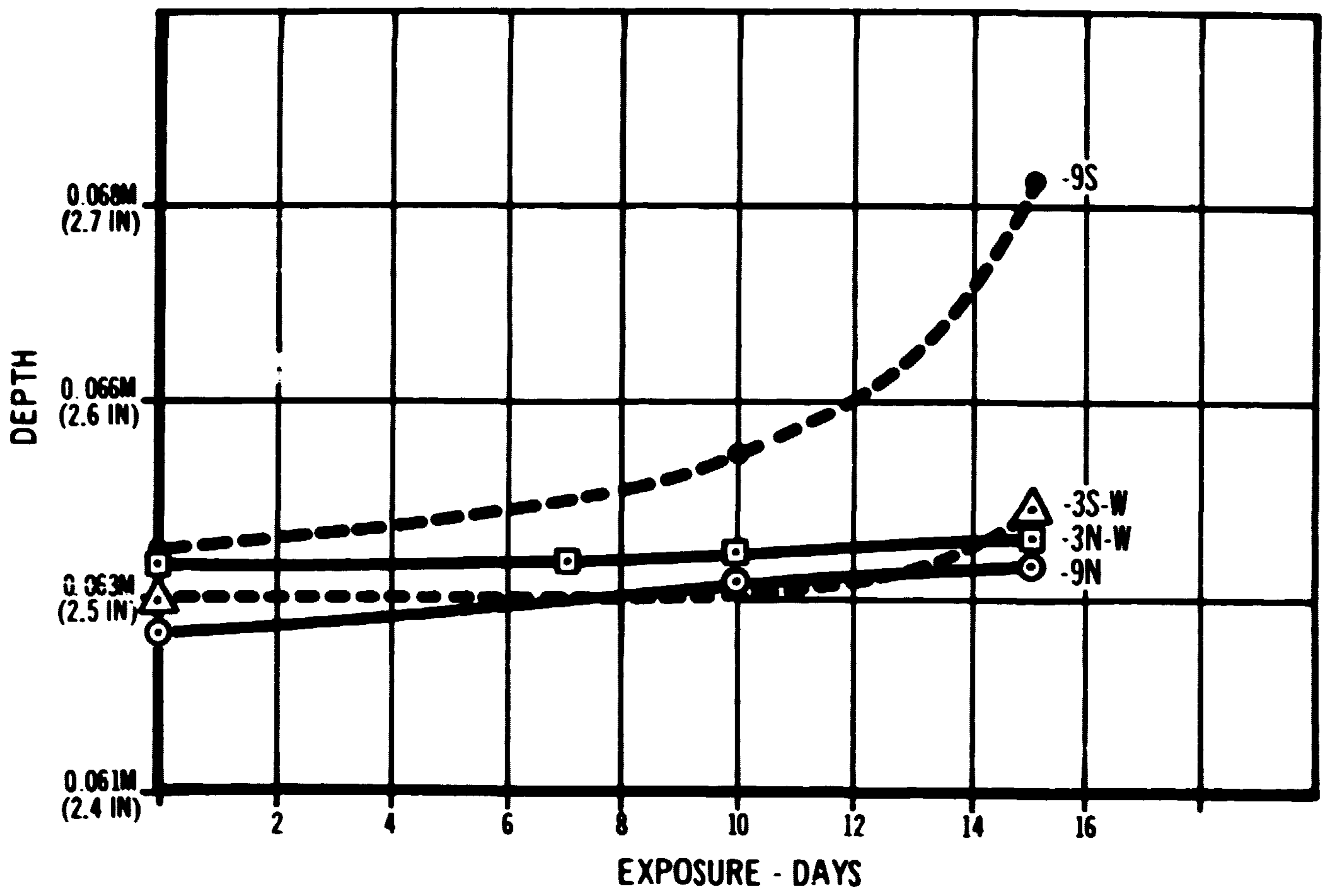

FIGURE 3. GROUP III SAMPLES-TOTAL FOAM DEPTH VS EXPOSURE TIME (DAYS)

CONCLUSIONS

It is apparent that the stayfoam material is markedly less stable dimensionally as an electrical potting compound than the Nopco counterpart, when cast with no externally applied curing aid. This, however, should not be construed to reflect an endorsement of the Nopco product. Rather, it will be recommended that all electrical encapsulating foams, which have applications similar to the distributor boxes in question, be screened and qualified as providing the dimensional stability necessary for the time and environment to which the parent structure may be exposed.