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EFFECTS OF MOISTURE UPON SPIRAL
FLOW IN THERMOSET MOLDING COMPOUNDS

PDO 6984548, Topical Report

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Project Team:
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**Kansas City
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EFFECTS OF MOISTURE UPON SPIRAL FLOW IN THERMOSET MOLDING COMPOUNDS

BDX-613-930 (Rev.), UNCLASSIFIED Topical Report, Published August 1973

Prepared by J. M. Conway, D/814, under PDO 6984548

The effects of moisture on spiral flow in precured thermoset molding compounds were evaluated. Two mineral-filled compounds were investigated: a cellulose-filled phenolic and a long-glass-fiber-reinforced diallyl phthalate. Results indicate that the flow properties, and therefore the molding properties and characteristics of these compounds are extremely sensitive to moisture in the uncured state.

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THE BENDIX CORPORATION

KANSAS CITY DIVISION

KANSAS CITY, MISSOURI

A prime contractor for the
Atomic Energy Commission

Contract Number AT(29-1)-613 USAEC

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SUMMARY

An evaluation was made of the effects of moisture on the flow properties of four thermoset molding compounds: Fiberite E-9405, a mineral-filled epoxy; Fiberite E-3824C, a mineral- and glass-filled epoxy; Cosmic D-69, a long-glass-fiber-filled diallyl phthalate; and Fiberite FM-1132, a cellulose-filled phenolic. The spiral flow of each compound was determined from preforms having moisture content in parts by weight (pbw) ranging from zero percent to saturation when the preforms were conditioned in a 90-percent relative humidity environment.

The moisture content of the epoxy compounds ranged from 0 to about 1 percent. The moisture content of the diallyl phthalate (DAP) compound was between 0 and 0.5 percent. The spiral flow of FM-1132 was determined for moisture contents up to 8 percent because the hygroscopic cellulose filler in the compound absorbed much more moisture than did the fillers in the other compounds.

The test data relating spiral flow to moisture content in the precured thermoset compounds supports several conclusions. The spiral flow lengths of the compounds increase as the moisture content increases, and increases in the spiral flow length of such compounds continue until a threshold moisture content is reached--and then a decline occurs. The threshold moisture content varies with the compound but is usually near the saturation point of each compound at 90 percent relative humidity. The flow properties of FM-1132 are affected the most because of the large amounts of moisture absorbed by this compound. The increase in spiral flow of the compound in picking up 9 percent pbw moisture was about 1100 percent. Increases for the other compounds ranged from 50 to 100 percent. And, moisture has more effect upon the flow properties of thermoset molding compounds than other volatiles. This is especially true for FM-1132.

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DISCUSSION

SCOPE AND PURPOSE

Variations caused by moisture in the flow properties in thermoset molding compounds are responsible for many inconsistencies in vendor test data and lot acceptance test results. Discrepancies in shelf life extension testing are also common. Recent examples of such problems were encountered with two lots of epoxy molding compounds. Lot W-3579 of Fiberite E-9405 which, during lot acceptance testing, had a spiral flow length under the 44 inch (1.12 m) material specification limit measured 80 inches (2.03 m) when tested later. Lot W-5527 of Fiberite E-3824C, which during lot acceptance testing passed the material specification spiral flow requirement of 16 to 21 inches (0.406 to 0.534 m), yielded a spiral flow of 27 inches (0.685 m) when tested for shelf life extension.

The frequency at which lots of E-3824C increased out of spiral flow tolerances during in-house storage resulted in a specification change which increased the spiral flow limit to 30 inches (0.762 m). Variations between vendor flow data and data obtained at Bendix during lot acceptance testing occur frequently. Four lots of epoxy molding compounds in which vendor certifications indicated that the spiral flows were within specification limits and Bendix test data indicated that spiral flows were significantly above the specification high limit, are cases in point.

Inconsistent flow properties of thermoset molding compounds have caused defective parts and necessitated many processing changes. Materials with spiral flows that are too short usually result in parts with knit lines or incomplete fills. Such problems were encountered with parts made from a long-glass-fiber-filled DAP. Both parts experienced incomplete fills because the DAP spiral flow was too short to fill the molds before curing.

Too much spiral flow also results in defective parts. Voids frequently appeared in some parts because the E-3824C had excessive spiral flow. The problems were solved by deliberately B-staging (partially curing) the E-3824C until the spiral flow had decreased to the desired length. The same problems were experienced with wet lots of E-9405 used in making another part. Voids often appear in parts molded from thermosets having excessive spiral flow because the viscosity of the molten thermoset is so low that insufficient back pressure is built up in the mold.

The objective of this study was to determine the exact increases that occur in the spiral flow of certain thermoset molding compounds when predetermined amounts of moisture are absorbed in these compounds. This knowledge helps determine why discrepancies occur between vendor flow data and data obtained during Bendix lot acceptance testing. Vendor and Bendix data must correlate if batch-to-batch uniformity is to be achieved. In addition, the flow properties of thermoset molding compounds change during in-house storage. Such changes sometimes cause parts to be defective, and this necessitates process changes. Knowing how flow properties change as moisture is absorbed permits materials to be conditioned to certain moisture contents to achieve desirable flow characteristics.

PRIOR WORK

A study was conducted evaluating the effects of relative humidity upon the flow properties of transfer molding compounds. In this study four compounds E-9405, E-3824C, 9-BMG, and DAP 52-20-30 were evaluated for spiral flow after conditioning at 1 percent, 90 percent, and as-received relative humidities. The spiral flow length of the compounds was found to increase with exposure to higher relative humidities.

ACTIVITY

Approximately 50 pounds each of the four compounds E-9405, E-3824C, FM-1132, and DAP D-69 (Lots W-7653, W-6404, C-3081, and 327, respectively) were procured to evaluate spiral flow versus moisture content. Fresh lots were used so results could be obtained from high quality material and not material that had aged or had long exposure to high humidity. Most of the work centered around five areas of activity: fabrication of preforms from the raw compounds, drying of preforms, conditioning preforms to achieve desired moisture contents, CEC moisture analysis of preforms, and spiral flow versus moisture content testing.

Fabricating Preforms

It was necessary to make preforms in two sizes. The harder flowing compounds (FM-1132 and DAP D-69) were pressed at room temperature into preforms 1.13 inches (29 mm) in diameter and 1.0 inch (25 mm) thick. The softer flowing E-9405 and E-3824C were pressed at room temperature into preforms 2.1 inches (52 mm) in diameter and 0.4 inches (10 mm) thick. It was necessary to make preforms of different sizes because the press used to make preforms out of the soft materials could not develop enough pressure to pack the FM-1132 and DAP D-69; conversely, the press used to pack the hard compounds could not be adjusted to a low enough pressure to make preforms out of E-3824C and E-9405. In all, about 50 to 75 preforms from each molding compound were fabricated, depending upon the number of moisture intervals evaluated.

Drying Preforms

The preforms of a given compound were placed in a chamber equipped with a dry nitrogen flow setup which produced a relative humidity of less than 1 percent. The weights of selected preforms were monitored periodically until there was no further weight loss. The weights of selected dry preforms, called representative samples, were recorded and all preforms were then sealed in large vapor barrier bags containing activated molded desiccant.

Conditioning Preforms

The spiral flow length of each compound was determined for a wide range of moisture contents. From previous studies, the saturation levels of each compound at 90 percent relative humidity were known, and it was decided that spiral flow should be determined for preforms having moisture contents ranging from zero percent to saturation. Such a distribution would encompass a wide range of moisture contents that would be encountered under production conditions. The target moisture contents for each compound are listed in Table 1. These are termed target moisture contents because a number of problems were envisioned in achieving the predetermined moisture contents shown.

The experimental objective was to establish an average spiral flow length for a compound at each of the moisture contents listed in Table 1. It was predetermined that the average spiral flow should be computed from a sample of five preforms and that moisture contents should be verified by two methods: weight analysis and CEC moisture analysis. This required that at least six preforms of a compound (five for spiral flow and one for CEC testing) be conditioned to each moisture content. It was not necessary

to condition more than six because moisture content testing by weight is a nondestructive test and any or all of the six preforms could be weight tested before the spiral flow or CEC tests were performed.

Table 1. Target Moisture Contents in Percent Parts by Weight

E-9405	E-3824C	FM-1132	DAP D-69
0	0	0	0
0.10	0.10	0.50	0.10
0.20	0.20	1.00	0.15
0.30	0.30	1.50	0.20
0.40	0.40	2.00	0.30
0.50	0.50	3.00	0.40
0.60	0.60	4.00	0.50
0.70	0.70	5.00	Saturated
0.80	0.80	6.00	
0.90	0.90	7.00	
1.00	1.00	Saturated	
Saturated*	Saturated		
*The equilibrium moisture content of the compounds when stabilized at 90 percent relative humidity.			

The most efficient way to condition preforms was to use a representative sample method. It was assumed that when a number of preforms were simultaneously exposed to the conditioning environment the moisture content of any group of preforms at any time could be accurately approximated by calculating the average moisture content of representative preforms exposed to the same conditions for the same time. In this study, four preforms in each conditioning lot were used as representative preforms.

It was also assumed that the average moisture content of the representative preforms at any time could be calculated by dividing the weight gain of all the representative preforms by the dry weight of all the representative preforms (all times 100 percent) rather than averaging the individual moisture contents of the four representative preforms. By using this procedure

the average moisture content of the representative preforms, and therefore any group of preforms in a conditioning lot could be calculated with only one weighing operation.

The advantages of using representative samples can be seen in the conditioning procedure for E-9405. Seventy-six preforms were required to evaluate the effects of the 12 different predetermined moisture contents upon the spiral flow length of E-9405. Four of the 76 were the representative preforms which verified moisture content by weight gain. The remaining 72 were used for spiral flow and CEC tests and were pulled in groups of six for each of the twelve moisture contents. By using this method only the total weight of the four representative preforms was required after drying. From the dry weight of the representative preforms, 12 target weights were calculated to achieve each of the 12 desired moisture contents. For example, the total dry weight of the four representative preforms of E-9405 was 145.634 g. The target weights to obtain the first three moisture contents of 0, 0.10, and 0.20 percent are 145.634 g for 0 percent (145.634×1.000), 145.779 g for 0.10 percent (145.634×1.001), and 145.925 g for 0.20 percent (145.634×1.002).

The first target weight was identical to the dry weight of the representative samples; consequently, six preforms out of the 72 test preforms were sealed in vapor barrier bags immediately after removal from the drying chamber. The remaining 66 test preforms and the representative preforms were then placed into a 90 percent relative humidity chamber at $83 \pm 3^\circ\text{F}$ ($28 \pm 2^\circ\text{C}$). The weight of the representative samples was periodically monitored until it approached the second target weight of 145.779 g. When the representative samples reached this weight, six more preforms out of the test group were individually sealed into vapor barrier bags to represent the 0.10 percent moisture content condition. During this time the representative samples remained in the 90 percent relative humidity environment with the remaining 60 test preforms. After the 0.10 percent moisture preforms were bagged the weight of the representative samples was again monitored until the third target weight of 145.925 g was reached and then the bagging operation was repeated. This procedure was repeated until all 12 moisture contents of the E-9405 had been reached. This process was then repeated for the other compounds.

CEC Testing Preforms

One preform at each moisture content for each compound was tested on a CEC moisture analyzer, an instrument accurate to about 0.001 percent. The instrument is equipped with an electrical circuit in which a segment of wire is coated with a compound having high affinity for moisture. A dry inert gas, usually nitrogen, is passed over a small sample carrying the

moisture across the coated wire. As the moisture is absorbed by the coating the current in the circuit changes and is measured and converted to percent moisture content. This method of testing was used as a backup to check the accuracy of moisture contents determined by the weight analysis method.

Spiral Flow Versus Moisture Content Testing

Two spiral flow tests were used in this study depending upon the compounds tested. The standard Epoxy Molding Materials Institute (EMMI) method (149°C, 6.89 MPa, and 3.25 ±0.25 mm cull thickness) was used to determine spiral flow for the soft flowing E-9405 and E-3824C. The spiral flow of FM-1132 and DAP D-69 was determined using the Archimedes Spiral Flow Test of Allied Chemical Corporation (Mesa) method. EMMI spiral flow testing was conducted on a 50-ton Hull transfer press. The spiral flow testing of FM-1132 and DAP D-69 was done on a 40-ton Watson-Stillman transfer press equipped with a Mesa spiral flow mold.

A number of precautions were taken before testing to ensure that reliable and consistent spiral flow data could be obtained. First, the platens and molds were heated up approximately 2 hours to ensure that the temperatures had stabilized. The press motors were turned on 1 hour prior to testing so transient pressure variations would be avoided. During this time about four or five preforms of the material to be tested were run to break in the mold. After temperatures and pressures had stabilized spiral flow testing was begun.

During testing, one primary concern was keeping the mold, the platens, and the punch at the desired temperature (149°C). In the past, there had been some difficulty in obtaining consistent flow test results. The problems were later found to be associated with the unloading operation. After a spiral flow specimen had cured, the transfer punch was raised and the mold was removed from the bottom mold plate and placed on a table to permit removal of the spiral flow specimens. The mold and punch would cool off while parts were being unloaded, and when the next shot was run, neither the punch nor the mold would have recovered to the required temperature. This caused variations in test conditions. It was not uncommon to get spiral flow length variations of 20 percent for identical preforms of the soft flow compounds and variations of 30 percent for the hard flow compounds. By leaving the spiral flow mold on the mold plate during unloading and employing the above precautions of initially stabilizing molding temperatures and pressures, variations in the spiral flow of the soft and hard flow compounds were reduced to 2 and 10 percent respectively.

Spiral Flow Versus Moisture Content of E-9405

The data in Table 2 indicate that the flow properties of E-9405 are very sensitive to moisture content. For Lot W-7653 the spiral flow length of E-9405 ranges from a minimum of 37.8 inches (960 mm) when dry to a maximum of 59 inches (1499 mm) at a moisture content of 1.00 percent pbw. This represents an increase in spiral flow of 56 percent based on the flow length of the dry compound. From the standard deviations in the spiral flow lengths of E-9405 it can be seen that the test results were consistent. This was because E-9405 contains practically no volatiles as evidenced by the excellent agreement between the CEC and weight analyses data.

One interesting point is the decrease in spiral flow that occurs in the compounds when a threshold moisture content is reached. For E-9405 this value is approximately 1.10 percent pbw. The cause of this decrease is not known but it is suspected that excessive moisture in the material causes it to B-stage at a faster rate in the transfer pot. The decrease in the spiral flow that occurred between the moisture contents of 1.00 and 1.19 percent pbw was 14.6 inches (371 mm), an amount comparable to the increase in spiral flow for E-9405 in going from 0 percent moisture up to 1.00 percent pbw. Such occurrences illustrate why processing changes are often necessary to control flow properties of wet lots of materials.

The changes in the flow properties of E-9405 with the increasing moisture contents are illustrated in Figure 1. The numbers below the spiral flow specimens correspond to the group numbers in Table 2. The specimen above each number was the specimen out of the five that had a spiral flow length closest to the average spiral flow length of that group.

Spiral Flow Versus Moisture Content of E 3824C

The spiral flow data for E-3824C (Lot E-6404 in Table 3) indicate that this material is somewhat more sensitive to moisture than E-9405. In picking up 1.00 percent pbw moisture the spiral flow of E-3824C increased 90 percent. The behavior of the spiral flow of E-3824C paralleled that of E-9405 at the lower moisture contents, but the deviations increased at elevated moisture contents. The spiral flow of E-9405 increased on the average 2 to 3 inches (50 to 75 mm) for each additional 0.10 percent pbw moisture picked up while the E-3824C generally increased 3 to 4 inches (75 to 100 mm) for the same moisture pickup.

Another difference is that the decline in spiral flow length after E-3824C had reached the threshold moisture content was not so great as the decline in E-9405. The difference in saturation moisture contents between the two compounds is probably the reason for the discrepancy. Illustrations of the

Table 2. Spiral Flow Versus Moisture Content for E-9405

Group*	Exposure (Hours)	Target Moisture Contents (Percent pbw)	Actual Moisture Content by Weight Analysis (Percent pbw)	Actual Moisture Content by CEC Analysis (Percent pbw)	Spiral Flow** (Inches)(mm)
1	0	0	0	0.06	37.8 $\pm$ 0.2*** (960 $\pm$ 5)
2	0.13	0.10	0.10	0.13	40.4 $\pm$ 0.3 (1026 $\pm$ 8)
3	0.42	0.20	0.20	0.29	44.1 $\pm$ 0.3 (1120 $\pm$ 8)
4	0.66	0.30	0.32	0.33	47.8 $\pm$ 0.6 (1214 $\pm$ 15)
5	1.08	0.40	0.44	0.42	50.5 $\pm$ 0.4 (1283 $\pm$ 10)
6	1.33	0.50	0.50	0.49	52.2 $\pm$ 0.4 (1326 $\pm$ 10)
7	2.00	0.60	0.60	0.54	54.8 $\pm$ 0.3 (1392 $\pm$ 8)
8	2.66	0.70	0.70	0.62	56.6 $\pm$ 0.4 (1438 $\pm$ 10)
9	3.50	0.80	0.80	0.73	58.0 $\pm$ 0.4 (1473 $\pm$ 10)
10	4.75	0.90	0.90	0.83	58.6 $\pm$ 0.1 (1488 $\pm$ 2)
11	6.16	1.00	1.00	0.86	59.0 $\pm$ 0.2 (1500 $\pm$ 5)
12	28.00	Saturated	1.19	1.04	44.4 $\pm$ 0.5 (1128 $\pm$ 12)
*Five samples in each group **Average of five samples ***Tolerances represent standard deviations from the listed averages.

Figure 1. Change in Spiral Flow Length of E-9405 Because of Moisture Absorption

Table 3. Spiral Flow Versus Moisture Content for E-3824C

Group*	Exposure (Hours)	Target Moisture Contents (Percent pbw)	Actual Moisture Content by Weight Analysis (Percent pbw)	Actual Moisture Content by CEC Analysis (Percent pbw)	Spiral Flow** (Inches) (mm)
1	0	0	0	0.05	38.4 $\pm$ 0.3*** (975 $\pm$ 8)
2	0.25	0.10	0.10	0.12	42.2 $\pm$ 0.8 (1072 $\pm$ 20)
3	0.61	0.20	0.20	0.18	46.1 $\pm$ 1.2 (1171 $\pm$ 30)
4	1.08	0.30	0.30	0.27	48.8 $\pm$ 1.0 (1240 $\pm$ 25)
5	1.58	0.40	0.40	0.39	53.6 $\pm$ 0.7 (1360 $\pm$ 18)
6	3.07	0.50	0.50	0.54	55.7 $\pm$ 1.7 (1415 $\pm$ 43)
7	4.58	0.60	0.60	0.55	50.8 $\pm$ 0.6 (1544 $\pm$ 15)
8	8.08	0.70	0.68	0.61	52.6 $\pm$ 1.1 (1590 $\pm$ 30)
9	24.00	0.80	0.80	0.70	58.6 $\pm$ 2.7 (1742 $\pm$ 69)
10	27.83	1.00	1.04	0.88	72.1 $\pm$ 1.0 (1830 $\pm$ 25)
11	53.00	Saturated	1.48	1.34	57.4 $\pm$ 0.6 (1712 $\pm$ 15)
<p>*Five samples in each group **Average of five samples ***Tolerances represent the standard deviations from the listed averages</p>					

E-3824C spiral flow test specimens, with to group numbers, are shown in Figure 2. Note the distortion that occurs in specimens of the higher moisture contents. This also occurred in E-9405 specimens.

Spiral Flow Versus Moisture Content of FM-1132

Of the compounds investigated, FM-1132 experienced the greatest percent change in spiral flow length because of moisture absorption. Based on a spiral flow length of 0.5 inches (12 mm) for the dry compound, change was approximately 1100 percent; however, it should be noted that total difference between the maximum and minimum values amounted to about 6 inches (152 mm). While the percentage change in the spiral flow length of FM-1132 was very high the amount of moisture absorbed by this compound was many times greater than the other compounds.

A number of problems were experienced in the testing of FM-1132 as can be seen by referring to the data in Table 4. One problem was the inability to obtain the desired moisture contents in the FM-1132 preforms because while moisture was being absorbed, varying amounts of volatiles were being released from the preforms. This caused irregular weight fluctuations. Consequently, the best moisture content measure for FM-1132 is the CEC results. While the loss of volatiles during moisture absorption caused irregularities in the moisture content data, volatile loss probably had little effect on spiral flow. This is evidenced by the significant increases in spiral flow with increasing CEC moisture contents despite the widening differences between CEC data and weight data. The loss of volatiles for high moisture contents was so pronounced that there was an odor of volatiles when the preforms neared saturation. The spiral flow specimens are shown in Figure 3.

Spiral Flow Versus Moisture Content of DAP D-69

Spiral flow testing of DAP, especially long-glass-fiber-filled D-69, has always resulted in inconsistent data. Regardless of how well temperatures and pressures are controlled during spiral flow testing, the deviations in identical specimens are often larger than those caused by the parameter being evaluated. Such was the case in this study. The tolerance for a particular average moisture content is often greater than the difference between average moisture contents of a group above or below a particular average moisture content. For example, the average moisture content of Group 5 (Table 5) is 10.7 inches (272 mm) and the tolerance (standard deviation) in the spiral flow lengths of the five specimens is ± 1.4 inches (36 mm). The tolerance of ± 1.4 inches, however, is greater than the difference between the 10.7 inch average and the 10.4 inch average (264 mm) of Group 4 or the difference between the 10.7 inch average and the 10.3 inch (261 mm) average of Group 6.

Text continued on page 25.

Figure 2. Change in Spiral Flow Length of E-3824C Because of Moisture Absorption

Figure 3. Change in Spiral Flow Length of D-69 Because of Moisture Absorption

Table 4. Spiral Flow Versus Moisture Content for FM-1132

Group*	Exposure (Hours)	Target Moisture Contents (Percent pbw)	Actual Moisture Content by Weight Analysis (Percent pbw)	Actual Moisture Content by CEC Analysis (Percent pbw)	Spiral Flow** (Inches)(mm)
1	0	0	0	0.28	0.5 ±0.1 (13 ±2)***
2	0.56	0.5	0.50	0.30	0.8 ±0.2 (20 ±5)
3	1.70	1.0	1.00	0.64	1.1 ±0.4 (27 ±10)
4	3.33	1.5	1.53		1.4 ±0.4 (36 ±10)
5	5.33	2.0	2.00	1.58	1.3 ±0.2 (33 ±5)
6	24.00	3.0	3.56		4.8 ±0.3 (122 ±8)
7	32.00	4.0	3.83	4.33	5.7 ±0.3 (145 ±8)
8	48.00	5.0	4.18	5.51	6.0 ±0.8 (152 ±20)
9	96.00	6.0	4.52	6.76	6.2 ±0.7 (157 ±18)
10	168.00	7.0	4.97	8.10	6.0 ±0.6 (152 ±15)
11	360.00	Saturated	3.93	8.93	4.6 ±0.5 (117 ±12)

*Five samples in each group
 **Average of five samples
 ***Tolerances represent the standard deviation from the listed averages

Table 5. Spiral Flow Versus Moisture Content for D-69

Group*	Exposure (Hours)	Target Moisture Contents (Percent pbw)	Actual Moisture Content by Weight Analysis (Percent pbw)	Actual Moisture Content by CEC Analysis (Percent pbw)	Spiral Flow** (Inches)(mm)
1	0	0	0	0.05	7.4 ±1.4*** (180 ±30)
2	0.50	0.1	0.10	0.09	10.0 ±0.6 (254 ±15)
3	1.16	0.15	0.15	0.14	8.3 ±1.9 (210 ±48)
4	1.91	0.20	0.20	0.15	10.4 ±.8 (264 ±20)
5	4.83	0.30	0.30	0.21	10.7 ±1.4 (272 ±36)
6	7.75	0.40	0.34		10.3 ±1.3 (262 ±33)
7	24.00	0.50	0.51	0.39	13.6 ±1.5 (245 ±38)
8	48.00	0.60	0.63	0.49	14.4 ±1.7 (366 ±43)
9	288.00	Saturated	0.58	0.38	14.1 ±1.6 (358 ±41)

*Five samples in each group
 **Average of five samples
 ***Tolerances represent the standard deviations from the listed averages

Despite these inconsistencies, a number of conclusions can be drawn from the data. The relative agreement of the weight gain and CEC data indicates that very little volatiles are coming off the DAP D-69 preforms when the compound becomes wet. While there are inconsistencies between the spiral flow length of adjacent moisture content intervals, there is a definite trend toward increasing spiral flow with increasing moisture contents in DAP D-69.

This increase in spiral flow of DAP D-69 appears to be in three stages rather than being continuous. Dry DAP D-69 has a spiral flow length of approximately 7.4 inches (188 mm). DAP D-69 having intermediate moisture contents 0.1 to 0.3 percent pbw moisture will have a spiral flow in the 10-inch range while higher moisture contents up to saturations values will produce spiral flow lengths in the 13- to 14-inch (330 to 355 mm) range. The spiral flow test specimens for DAP D-69 are shown in Figure 4.

ACCOMPLISHMENTS

The change in spiral flow that occurs with increasing moisture content in each of four thermoset compounds was determined. Test results indicated that all compounds were significantly affected by even small changes in moisture content and showed the degree to which each compound was affected. Test results also indicated that the flow properties of Fiberite FM-1132 were most affected by moisture and established how much the spiral flow of this and other compounds changed for specific increases in moisture contents. By knowing this, it can be determined if discrepancies in the Vendor and Bendix flow data are the result of varying moisture contents or subtle differences in test methods. Such discrepancies must be eliminated in order to obtain uniform materials.

A knowledge of how the spiral flow of each compound changes for different moisture contents also will eliminate trial and error methods to achieve desirable flow characteristics in materials with deviated spiral flows. These materials could be conditioned to predetermine moisture contents to obtain the required flow properties. By conditioning material this way, processing changes could be avoided and the number of defective parts caused by flow problems would be reduced.

Figure 4. Change in Spiral Flow Length of FM-1132 Because of Moisture Absorption