*From Kentucky
Give to Reg*

BDX-613-870

EFFECT OF AMINE CATALYST ON
COMPRESSIVE PROPERTIES OF URETHANE FOAM

Technological Spinoff Report

March 1973

Bendix Corporation
Kansas City, Missouri

THIS DOCUMENT CONFIRMED AS
UNCLASSIFIED
DIVISION OF CLASSIFICATION
BY L. L. Cucchiara /wer
DATE 5/2/73

MASTER

R9936

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

This report has been reproduced directly from the best available copy.

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22151.

Price: Paper Copy \$4.00

Microfiche \$0.95

EFFECT OF AMINE CATALYST ON
COMPRESSIVE PROPERTIES OF
URETHANE FOAM

March 1973

Project Leaders:

S. L. DeGisi

T. E. Neet

Department 814

Technological Spinoff Report

Contract Number AT(29-1)-613 USAEC

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Technical Communications

**Kansas City
Division**

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

pey

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

EFFECT OF AMINE CATALYST ON COMPRESSIVE PROPERTIES OF URETHANE FOAM

Prepared by S. L. DeGisi and T. E. Neet

Experiments were performed to determine if compressive properties of a rigid urethane foam system were independent of an amine catalyst used in the material formulations. Compression testing confirmed that neither type or concentration of amine catalyst significantly affected the physical properties of equivalent density foams provided they were adequately cured.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONTENTS

Section	Page
SUMMARY	9
DISCUSSION	11
SCOPE AND PURPOSE	11
PRIOR WORK	11
ACTIVITY	11
ACCOMPLISHMENTS	24
REFERENCES	25

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ILLUSTRATIONS

Figure		Page
1	Compressive Strength of Core Samples at 6 Percent Strain	13
2	Compressive Strength of Core Samples at 10 Percent Strain	13
3	Effect of Block Density on Core Density of Catalyzed and Uncatalyzed Blocks Made From CPR 1040-10 Material	17
4	Density Variation in 6- By 6- By 1-Inch Test Blocks (152.4 By 152.4 By 25.4 mm)	19
5	Effect of Catalysts and Preheat Temperatures on the Rise-Rate and Gel Time Characteristics of CPR 1040-10 Foam	23

TABLES

Number		Page
1	Foam System Formulations	12
2	Compressive Strengths and Exotherm Temperatures of 4- By 6- By 12-Inch Billets (101.6 By 152.4 By 304.8 mm)	14
3	Rise Rate and Gel Time Data for CPR 1040-10 Material . . .	15
4	Effect of Variables on the Compressive Strength of Samples From 6- By 6- By 1-Inch Blocks (152.4 By 152.4 By 25.4 mm)	16

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

SUMMARY

Previous experiments¹ have shown that the compressive properties of a rigid urethane foam system are independent of the type and concentration of amine catalyst used in the material formulation. However, these experiments were performed on test samples taken from the cores of large billets which had been cured for 4 hours at 300°F (149°C).

There was a possibility that the effect of the catalyst was masked by the action of the cure cycle and that specimens from molded-to-size blocks might display different compressive properties. To extend the previous experiments an uncatalyzed toluene diisocyanate prepolymer-polyester polyol based foam system, CPR 1040-10 from the CPR Division of the Upjohn Company², was evaluated. This material was used as received from the vendor and with the addition of three different amine catalysts. Two concentrations of each catalyst were used. Samples were also made using the as-received material preheated from 77°F (25°C) to 130°F (54°C). From these various formulations, 4- by 6- by 12-inch billets (101.6 by 152.4 by 304.8 mm) were made and allowed to cure at room temperature. Thin, molded-to-size, 6- by 6- by 1-inch test blocks (152.4 by 152.4 by 25.4 mm) were made and cured at either room temperature or 165°F (74°C) for 4 hours. The exotherm profiles of both types of billets were obtained. Rise-rate and gel time tests were conducted on all material formulations at the appropriate preheat conditions.

Compression testing confirmed that neither type or concentration of amine catalyst significantly affected the physical properties of equivalent density foams, provided they were adequately cured. The billets all reached and maintained the same exothermic temperature of 360°F (180°C) for more than 4 hours. This sufficiently cured the foam so that all formulations produced material of the same strength. The catalysts and component preheats altered the apparent strength of the foam in the thin, molded sections by affecting the maximum exotherm and density gradients. The more reactive material produced exothermic heat faster, thereby creating a higher temperature. This resulted in an increased cure in the blocks cured at room temperature. At equivalent densities, these blocks were stronger. Since this exotherm remained above 165°F (74°C) for less than 0.5 hours, curing these blocks at 165°F for 4 hours resulted in foams of equal compressive strength in all specimens. However, density gradients masked this equal strength conclusion since the more reactive materials created foams with greater density gradients. This made the samples appear to be weaker because lower density foam was being tested.

The rise-rate and gel time determinations produced perhaps significant but, as yet, unexplained results. Materials catalyzed by component temperature yielded different rise-rate versus gel time relationships than foam catalyzed with amine catalysts. Since the proper balance of the foam's blowing to gelling properties is required to produce parts of high visual quality, further work on the relationship between the rise-rate and gel time characteristics of foams is warranted.

DISCUSSION

SCOPE AND PURPOSE

Previous work conducted by the Kansas City Division showed that neither the type nor concentration of amine catalyst in a urethane foam formulation significantly affects the compressive strength of the rigid foam. However, these data were all collected using samples taken from the cores of large billets. Furthermore, all billets were subjected to a 4-hour cure at 300°F (149°C). Since that time it has been suggested that the effect of the catalyst was masked by the cure cycle and that specimens from molded-to-size blocks might display different results. The following investigation was conducted to test these contentions.

PRIOR WORK

In the previous study¹, several different concentrations of 6 amine catalysts were used in formulations of the Bendix Rigifoam 6003-6 foam system. Low density, 6.5 pounds per cubic foot (104.1 kg/m³) nominal density, and high density, 14.0 pound per cubic foot (224.3 kg/m³) nominal density, billets were made from the base formulation without catalyst and with each of the catalysts at several different concentrations. The low density billets were formed by allowing the foam to rise unrestricted in 1/2 gallon paper containers. The high density billets were formed by restricting the foam rise in a mold. All billets were cured for 4 hours at 300°F (149°C) before 1-inch cube (25.4 mm³) test specimens were machined from their cores.

ACTIVITY

CPR 1040-12, an uncatalyzed, rigid polyurethane foam system manufactured by the CPR Division, Upjohn Company, was selected for this study. The component materials consist of a toluene diisocyanate prepolymer and a polyester polyol resin. Three different amine catalysts at two different concentrations of each were used in addition to the uncatalyzed material (Table 1). Two sizes of evaluation billets, 4 by 6 by 12 inches (101.6 by 152.4 by 304.8 mm) and 6 by 6 by 1 inches (152.4 by 152.4 by 25.4 mm) were poured from these materials. Thermocouples were placed in the cores of these blocks to determine the magnitude and duration of the exothermic temperature rise. All molds were at 77°F (25°C) at the time of pour.

Table 1. Foam System Formulations

Formulation	Toluene Diisocyanate Prepolymer (pbw)	Polyester Resin (pbw)	Catalyst (pbw)
1 (Standard)	137	100	None 00
2	137	100	N-methylmorpholine (NMM) 0.25
3	137	100	N-methylmorpholine (NMM) 0.50
4	137	100	Tetramethylbutane diamine (TMBDA) 0.10
5	137	100	Tetramethylbutane diamine (TMBDA) 0.20
6	137	100	Triethylene diamine* 0.10
7	137	100	Triethylene diamine 0.20

*Dabco, 33LV, Houdry Chemical Company

One-inch-cube (25.4 mm^3) compression test specimens were cut from the cores of the 4- by 6- by 12-inch room temperature cured billets. No significant differences were found in the compressive strengths (Table 2) for any of the formulations at either 6 or 10 percent strain. This is shown by Figures 1 and 2 representing least squares, best fit lines through both the catalyst and no catalyst formulations. Both lines coincide. The peak exotherms of 360°F (180°C) and exotherm duration of greater than 4 hours were not affected by any of the various material formulations. The only significant effect of the catalysts on the 4- by 6- by 12-inch billets was observed in the density distribution. All billets poured with catalysts of any type or concentration produced essentially identical core densities at a given pour weight. The billets poured without catalyst required an increased pour weight to produce an equivalent core density (Figure 3). For information purposes, the rise-rate characteristics⁴ and gel time data⁵ on these formulations are included in Table 3. It might be significant that the gel-time-to-foaming-time ratio is greater for the uncatalyzed foam than for the catalyzed material.

Figure 1. Compressive Strength of Core Samples at 6 Percent Strain

Figure 2. Compressive Strength of Core Samples at 10 Percent Strain

Table 2. Compressive Strengths and Exotherm Temperatures of
4- By 6- By 12-Inch Billets (101.6 By 152.4 By 304.8 mm)

Formulation	Maximum Exotherm		Compressive Strength *			
			6 Percent Deflection		10 Percent Deflection	
	(°F)	(°C)	(psi)	(MPa)	(psi)	(MPa)
Standard	363	183.9	495	3.4	496	3.4
0.25 NMM	373	189.4	471	3.2	479	3.3
0.50 NMM	365	184.4	474	3.3	483	3.3
0.05 TMBDA	373	189.4	481	3.3	487	3.4
0.10 TMBDA	366	185.5	484	3.3	503	3.5
0.10 DABCO	373	189.4	483	3.3	487	3.4
0.20 DABCO	375	190.6	477	3.3	494	3.4
*Compressive strength normalized to a sample density of 12 pounds per cubic foot (192.2 kg/m ³) from the equation ³ , compressive strength equals A density) ^B .						

The 6- by 6- by 1-inch test blocks (152.4 by 152.4 by 25.4 mm) were cured at either room temperature or 165°F (73.9°C) for 4 hours. In addition to material previously mentioned, blocks of the basic foam system without catalyst were made with the foam components heated from the normal temperature of 77°F (25.0°C) to 130°F (54.4°C) as shown in Table 4. One-inch-cube test specimens were cut from these blocks. Also 1- by 1- by 0.5-inch specimens (25.4 by 25.4 by 12.7 mm) were obtained from the cores of the blocks by removing the foam skins. This was done to reduce the density gradient across the sample. The compressive strength results are listed in Table 4. It is evident that the catalyst, or material reactivity, plays an important part in determining the compressive properties of material foamed in narrow cross-sections. However, this effect can be traced directly to the density gradient throughout the sample and the degree and duration of the exotherm.

Table 3. Rise-Rate and Gel Time Data for CPR 1040-10 Material

Formulation	Material Preheat		T_I (sec)	T_{VM} (sec)	T_R (sec)	V_m		H_m		C (Minutes ⁻¹)	T_G (seconds)
	(°F)	(°C)				(in/min)	(mm/min)	(Inches)	(mm)		
Standard	77	25.0	232	340	1062	0.50	12.7	4.15	105.4	0.120	734
Standard	93	33.9	158	227	749	0.89	22.6	5.90	149.9	0.151	600
Standard	103	39.5	108	166	597	1.20	30.5	5.65	143.5	0.212	396
Standard	116	46.7	88	130	458	1.48	37.6	5.70	144.8	0.260	349
Standard	130	54.4	65	78	358	2.06	52.3	5.60	142.2	0.368	245
+0.25 NMM	77	25.0	146	240	543	1.50	38.1	6.47	164.3	0.232	372
+0.50 NMM	77	25.0	119	185	405	2.65	67.3	6.52	165.6	0.406	248
+0.05 TMBDA	77	25.0	140	267	451	2.25	57.2	6.58	167.1	0.342	301
+0.10 TMBDA	77	25.0	100	166	267	4.69	119.1	7.13	181.1	0.658	187
+0.10 DABCO	77	25.0	174	352	570	1.55	39.4	6.00	152.4	0.258	385
+0.20 DABCO	77	25.0	144	233	434	2.87	72.9	6.45	163.8	0.445	261
T_I = Initiation time, time from start of mix until 2 percent of maximum foam expansion occurs. T_{VM} = Time to maximum velocity, time from start of mixing until maximum foaming velocity occurs. T_R = Rise Time, time from start of mixing until 95 percent of maximum foam expansion occurs. V_m = Maximum Velocity, maximum instantaneous foaming velocity. H_m = Maximum Height, final height of the foam. C = Rise-Rate Constant, V_m/H_m T_G = Gel Time, time from start of mixing until gelation begins.											

Table 4. Effect of Variables on the Compressive Strength of Samples From 6- By 6- By 1-Inch Blocks (152.4 By 152.4 By 25.4 mm)

Formulation	Maximum Exotherm (°F) (°C)		Compressive Strength at 10 Percent Deflection*							
			1-Inch Thick (25.4 mm) Specimens				1/2-Inch Thick (12.7) Specimens			
			R. T. Cure		4 Hours at 165°F (73.9°C) Cure		R. T. Cure		4 Hours at 165°F (73.9°C) Cure	
	(°F)	(°C)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)	(psi)	(MPa)
Standard	162	72.2	579	4.0	750	5.2	717	4.9	872	6.0
+0.25 NMM	251	121.7	429	3.0	418	2.9	792	5.5	867	6.0
+0.50 NMM	268	131.0	457	3.2	---	---	846	5.8	---	---
+0.05 TMBDA	264	128.9	376	2.6	410	2.8	756	5.2	850	5.9
+0.10 TMBDA	306	152.2	378	2.6	---	---	860	5.9	---	---
+0.10 DABCO	295	145.0	334	2.3	371	2.6	829	5.7	865	6.0
+0.20 DABCO	328	164.4	425	2.9	---	---	856	5.9	---	---
+130°F (54.4°C) component preheat	---	---	---	---	531	3.7	---	---	576	4.0
+130°F (54.4°C) component preheat and cooled to room temperature	---	---	---	---	745	5.1	---	---	863	6.0
*Data normalized to a density of 17 pounds per cubic foot (272.3 kg/m ³) ³ .										

Without catalyst, a peak exotherm of 165°F (74°C) was obtained. Addition of any of the amine catalysts at any concentration resulted in an increase in the peak and duration of the exotherm. In all cases the exotherm remained above the 165°F level for less than 0.5 hours. Previous work on the CPR 1040-10 foam system showed that an increase in cure temperature at a constant cure time resulted in a significant increase in the compressive strength of the foam material. This effort also showed that, at a given cure temperature, the compressive strength increased to a maximum as the cure time increased. At a cure temperature of 165°F a cure time of 4 hours was required for maximum strength. By curing all of the blocks for 4 hours at 165°F, all blocks should be at the same maximum strength. Indeed, this is the case.

Figure 3. Effect of Block Density on Core Density of Catalyzed and Uncatalyzed Blocks Made From CPR 1040-10 Material

The compressive strength of the 1-inch thick (25.4 mm) samples shown in Table 4 decreased as the maximum exotherm (the effective cure temperature) increased. This anomaly occurs because of the increased density gradient in the higher reactivity blocks. Since the compressive strength of a foam is proportional to its density raised to a power, the recorded compressive strength of the sample would be dependent on, or proportional to, the lowest density portion of that sample. Examples in Figure 4 illustrate the density variations in the 6- by 6- by 1-inch blocks (152.4 by 152.4 by 25.4 mm). Figure 4, Example 1, shows the standard material has a minimum density gradient. The 1-inch high (25.4 mm) samples and the 0.5-inch high (12.7 mm) core specimens have approximately the same density. This is not the case for any of the catalyzed systems in Examples 2 through 7. These blocks all have lower density cores as shown by the 0.5-inch (12.7 mm) core samples. Therefore, at an equivalent 1-inch high specimen density, the catalyzed foam should appear to have a lower strength than the uncatalyzed materials. When the core specimens with minimum density gradients were tested both the catalyzed and uncatalyzed materials had the same strength at the same density, provided all blocks were sufficiently cured. The 0.5 inch (12.7 mm) results in Table 4 for blocks cured 4 hours at 165°F (74°C) confirm this conclusion.

Figure 4, Example 8, depicts the density gradient of material preheated to 130°F (54.4°C) and cooled to room temperature before mixing. This procedure showed that the preheat did not change the composition of the foam because the blocks were similar to those of the standard material. Examples 9 and 10 show the effect of a 130°F (54.4°C) component temperature on the density gradient. Example 9 represents 1-inch cubes (25.4 mm³) with molded skins on two sides of the sample and 0.5-inch (12.7 mm) high specimens taken from the core of the block. Example 10 depicts 0.5 (12.7 mm)- and 0.7 (17.8 mm)-inch high samples with the molded skin intact on one surface. Except for the top to bottom density gradient, these blocks appear to have a fairly uniform density across the 1-inch dimension. However, this is not the case as shown by the compressive stress-strain curves. For example, a typical test coupon from the standard material block had a density of 18.66 pounds per cubic foot (298.9 kg/m³) and compressive strengths of 925 and 934 psi (6.38 and 6.44 MPa) at 6 percent and 10 percent deflections, respectively. A specimen with a density of 17.13 pounds per cubic foot (274.4 kg/m³) from the block made using the material preheated to 130°F (54.4°C) yielded compressive strengths of 500 and 730 psi (3.45 and 5.03 MPa) at 6 percent and 10 percent deflections, respectively. These data would tend to indicate that, while the standard block has a fairly uniform density, the block made from the preheated material contained a low density area approximately 0.008-inches

Text continued on page 22.

SPECIMEN THICKNESS IN INCHES (mm)			
1.000 (25.4)	0.500 (12.7)	1.000 (25.4)	0.500 (12.7)
18.40 (294.7)	18.38 (294.4)	18.31 (293.3)	18.33 (293.6)
18.45 (295.5)	18.38 (294.4)	18.51 (296.5)	18.49 (296.2)
18.66 (298.9)	18.43 (295.2)	18.81 (301.3)	18.65 (298.7)
18.83 (301.6)	18.43 (295.2)	18.89 (302.6)	18.71 (299.7)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

SPECIMEN THICKNESS IN INCHES (mm)			
1.000 (25.4)	0.500 (12.7)	1.000 (25.4)	0.500 (12.7)
14.61 (234.0)	10.46 (167.5)	14.62 (234.2)	10.58 (169.5)
16.32 (261.4)	11.33 (181.5)	16.27 (260.6)	11.25 (180.2)
17.43 (279.2)	11.76 (188.4)	17.28 (276.8)	11.79 (188.9)
18.55 (297.1)	12.64 (202.5)	17.24 (276.2)	12.35 (198.0)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

EXAMPLE 1, STANDARD MATERIAL

EXAMPLE 2, 0.25 NMN FORMULATION

SPECIMEN THICKNESS IN INCHES (mm)			
1.000 (25.4)	0.500 (12.7)	1.000 (25.4)	0.500 (12.7)
14.95 (239.5)	11.05 (177.0)	15.15 (242.7)	11.04 (176.8)
16.37 (262.2)	11.46 (183.6)	16.49 (264.1)	11.41 (182.8)
17.39 (278.6)	11.71 (187.6)	17.56 (281.3)	11.67 (186.9)
17.63 (282.4)	11.81 (189.2)	17.89 (286.6)	11.84 (189.7)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

SPECIMEN THICKNESS IN INCHES (mm)			
1.000 (25.4)	0.500 (12.7)	1.000 (25.4)	0.500 (12.7)
12.94 (207.3)	9.12 (146.1)	13.19 (211.3)	9.07 (145.3)
15.66 (250.8)	9.50 (152.2)	15.39 (246.5)	9.49 (152.0)
17.34 (277.8)	9.79 (156.8)	16.99 (272.1)	9.82 (157.3)
18.22 (291.8)	10.13 (162.3)	17.84 (285.8)	10.09 (161.6)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

EXAMPLE 3, 0.50 NMN FORMULATION

EXAMPLE 4, 0.05 TMBDA FORMULATION

Figure 4. Density Variation in 6-By 6-By 1-Inch Test Blocks
(152.4 By 152.4 By 25.4 mm)

SPECIMEN THICKNESS IN INCHES (mm)			
1.000 (25.4)	0.500 (12.7)	1.000 (25.4)	0.500 (12.7)
13.21 (211.6)	9.20 (147.4)	13.46 (215.6)	9.21 (147.5)
15.52 (248.6)	9.51 (152.3)	15.52 (248.6)	9.57 (153.3)
17.24 (276.2)	9.83 (157.5)	16.93 (271.2)	9.88 (158.3)
17.98 (288.0)	10.00 (160.2)	18.04 (289.0)	10.11 (161.9)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

SPECIMEN THICKNESS IN INCHES (mm)			
1.000 (25.4)	0.500 (12.7)	1.000 (25.4)	0.500 (12.7)
12.48 (199.9)	8.68 (139.0)	12.95 (207.4)	8.68 (139.0)
15.55 (249.1)	9.31 (149.1)	15.45 (247.5)	9.30 (149.0)
17.56 (281.3)	9.68 (155.1)	17.48 (280.0)	9.74 (156.0)
18.07 (302.3)	9.94 (159.2)	18.37 (294.3)	10.53 (168.7)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

EXAMPLE 5, 0.10 TMBDA FORMULATION

EXAMPLE 6, 0.10 DABCO FORMULATION

SPECIMEN THICKNESS IN INCHES (mm)			
1.000 (25.4)	0.500 (12.7)	1.000 (25.4)	0.500 (12.7)
13.45 (215.4)	10.90 (174.6)	13.74 (220.1)	10.85 (173.8)
15.76 (252.4)	11.35 (181.8)	16.03 (266.7)	11.15 (179.6)
18.36 (294.1)	11.72 (187.7)	18.60 (297.9)	11.49 (184.0)
19.06 (305.3)	11.66 (186.8)	19.22 (307.9)	11.51 (184.4)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

SPECIMEN THICKNESS IN INCHES (mm)			
1.000 (25.4)	0.500 (12.7)	1.000 (25.4)	0.500 (12.7)
18.36 (294.1)	18.32 (293.4)	18.28 (292.8)	18.35 (293.9)
18.65 (298.7)	18.33 (292.6)	18.60 (297.9)	18.34 (293.8)
18.79 (301.0)	18.41 (294.9)	18.78 (300.8)	18.42 (295.1)
18.92 (303.1)	18.55 (297.1)	18.88 (302.4)	18.49 (296.2)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

EXAMPLE 7, 0.20 DABCO FORMULATION

EXAMPLE 8, PREHEATED TO 130°F (54°C)
AND COOLED TO ROOM
TEMPERATURE

Figure 4 Continued. Density Variation in 6- By 6- By 1-inch Test Blocks
(152.4 By 152.4 By 25.4 mm)

SPECIMEN THICKNESS IN INCHES (mm)			
1.000 (25.4)	0.500 (12.7)	1.000 (25.4)	0.500 (12.7)
17.00 (272.3)	16.90 (270.7)	16.93 (271.2)	17.44 (279.4)
18.35 (293.9)	18.27 (292.6)	18.21 (291.7)	18.89 (302.6)
18.76 (300.5)	18.95 (303.5)	18.72 (299.9)	19.40 (310.7)
19.58 (313.6)	19.62 (314.3)	19.19 (307.4)	20.22 (323.9)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

EXAMPLE 9, PREHEATED TO 130°F

SPECIMEN THICKNESS IN INCHES (mm)			
0.500 (12.7 mm)	0.500 (12.7 mm)	0.700 (17.8 mm)	0.700 (17.8 mm)
17.13 (274.4)	17.01 (272.5)	15.72 (251.8)	16.62 (266.2)
18.79 (301.0)	18.48 (296.0)	18.11 (290.1)	18.52 (296.7)
19.07 (305.5)	19.00 (304.3)	18.89 (302.6)	19.66 (314.9)
19.54 (313.0)	19.33 (309.6)	19.05 (305.1)	19.78 (316.8)
DENSITY IN POUNDS PER CUBIC FOOT (kg/m ³)			

EXAMPLE 10, PREHEATED TO 130°F SAMPLES
WITH SKINS

Figure 4 Continued. Density Variation in 6- By 6- By 1-Inch Test Blocks
(152.4 By 152.4 By 25.4 mm)

thick (0.2 mm), thus accounting for the wide difference between the 6 and 10 percent compressive strengths.

The 1-inch high (25.4 mm) compression samples cured at either room temperature or 165°F (73.9°C) for 4 hours had radically different compressive strengths because of the density gradients created in the blocks. The compressive strengths of the 0.5-inch high (12.7 mm), room temperature cured blocks increased as the material exotherm increased. All but one of the blocks had the same strength when samples were taken from the cores of blocks cured at 165°F (73.9°C) for 4 hours to minimize the density gradients and provide complete specimen cure. The only exception was the block developed from the 130°F (54.4°C) preheated material. This preheat condition probably created a severe density gradient in the foam. In any case, the conclusion that the amine catalyst does not affect the physical compressive properties of the polymer is still valid. Completely cured foam has the same compressive strength at a given density regardless of the amine catalyst type or concentration. The catalyst type and concentration can alter the apparent compressive strength in cured, narrow, molded cross-sections due to the effect of the catalyst on the density distribution. The catalyst does have an actual effect on the compressive strength of uncured, narrow, molded cross-sections of foam. This is caused by the effect of the catalyst on the foam exotherm, and thus the foam cure, in these narrow sections.

Since it is not possible for the amine catalyst to alter the compressive properties of adequately cured foam, the only function of these catalysts is to aid in the processing of the material. The effect of the catalysts and component preheat temperature on the rise-rate and gel time characteristics of the material was shown earlier in Table 3. A better analysis of these variables can be obtained from Figure 5. Here the initiation time, time to maximum velocity, and rise time for each formulation on material preheat temperature have been plotted. The gel point for each formulation has been included on the proper curve.

The catalysts and preheat variables influenced the shape of the curves. While the curve for each preheat temperature is shifted slightly, all of these curves are strikingly similar and form a family of curves. This same conclusion might well apply for each of the catalyst formulations. Also, the gel points occur earlier in the foam rise for the material formulations containing catalysts. These gel points, independently, appear to fall almost on a vertical straight line. The significance of the gel points occurring early in the foam rise and falling on a straight line when plotted is not yet known. However, since the best molding foams gel toward the completion of the foam rise, studies of the effects indicated by Figure 5 might be significant in obtaining urethane foams with better moldability.

Figure 5. Effect of Catalysts and Preheat Temperatures on the Rise-Rate and Gel Time Characteristics of CPR 1040-10 Foam

ACCOMPLISHMENTS

This work provides further confirmation of the previous conclusion that neither the type nor concentration of the amine catalyst used in a urethane foam system have any direct effect on the compressive properties of the foamed polymer. In large billets where the effect of the catalyst on the exothermic temperature is minimal, the foams will have the same compressive strength at equivalent densities regardless of the type or concentration of amine catalyst used. In narrow cross-sections, the catalyst does play a role in determining the apparent physical properties of the foam through its effect on the maximum exothermic temperature and density gradient. Even in these thin sections, however, the strength of the foams at a given density will be the same if the material is adequately cured.

The blowing and gelling characteristics of the foam appear to be affected differently by catalysts and material preheat. The significance of these effects is not yet known. Further study of this is warranted since these relationships may be important in improving the moldability of urethane foam systems.

REFERENCES

- ¹S. L. DeGisi, and T. E. Neet, "Effect of Amine Catalysts On The Compressive Properties of a Rigid Urethane Foam," Journal of Cellular Plastics, July/August, 1971.
- ²Materials Specification 2170505-2170507: Polyurethane Foam, Rigid. The Bendix Corporation, Kansas City Division, September, 1966.
- ³Calvin James, Benning, Plastic Foams, Volume 1, Chemistry and Physics of Foam Formation, Interscience, New York, 1969, p 221.
- ⁴Process Specification 9952034. Testing, Rise-Rate, Rigid Urethane Foam. Bendix Corporation, Kansas City Division, July, 1969.
- ⁵Roger Jennings, "Instrumented Analysis of the Performance of Rigid Urethane Foaming Systems," Journal of Cellular Plastics, Vol. 5, No. 3 May through June 1969.