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APPENDICES

Appendix A

NCO Index and NCO Conversion Calculations

NCO Index Calculation

Example

Calculation the parts by weight (pbw) of pure PMDI (MR-200), Molar mass = 366.99, functionality = 2.7 at an isocyanate index 100, 130, 150 and 180 required to react with the following formulation:

Table A1 Formulations of RPUR foams

Formulation (pbw)	Part by weight
Raypol ® 4221 (OHV = 438.93 mgKOH/g, functionality = 4.3)	100.0
Catalysts	0.5
Sufactant	2.5
Blowing agent (distilled water, Mw = 18 g/mole, functionality = 2)	2.0
PMDI (MR-200), NCO indexes of 100, 130, 150 and 180	?

$$\text{Equivalent weight of Raypol 4221} = \frac{56.1}{438.93} \times 1000 = 127.81$$

$$\text{Equivalent weight of water} = \frac{18}{2} = 18$$

Surfactants and catalysts are neglected in stoichiometric calculations because they do not react with NCO groups.

$$\text{Number of equivalent in formulation} = \frac{\text{parts by weight (pbw)}}{\text{equivalent weight}}$$

Equivalent in the above formulation:

$$\text{Polyol (Rapol 4221)} = \frac{100}{127.81} = 0.782$$

$$\text{Water (blowing agent)} = \frac{2.0}{9.0} = 0.222$$

$$\text{Total eqoivalent weight} = 1.014$$

For stoichiometric equivalence, PMDI pbw is total equivalent × equivalent weight because PMDI reacts with polyol and water.

Thus:

$$\text{PMDI (pbw)} = 1.004 \times \frac{\text{PMDI molar mass}}{\text{functionality}} = 1.004 \times \frac{366.99}{2.7}$$

$$= 136.47$$

Notes: 136.47 defines the isocyanate quantity at 100 index

Where:

$$\text{Isocyanate index} = \frac{\text{actual amount of isocyanate}}{\text{theoretical amount of isocyanate}} \times 100$$

Thus:

Isocyanate index 100

$$\text{Isocyanate actual} = \frac{136.37}{100} \times 100 = 136.37$$

Isocyanate index 130

$$\text{Isocyanate actual} = \frac{136.37}{100} \times 130 = 177.71$$

Isocyanate index 150

$$\text{Isocyanate actual} = \frac{136.37}{100} \times 150 = 204.56$$

Isocyanate index 180

$$\text{Isocyanate actual} = \frac{136.37}{100} \times 180 = 245.47$$

NCO Conversion Calculation

The NCO conversion can be calculated by FTIR method, defined as the ratio between isocyanate peak area at time t and isocynate peak at time 0, following equation:

$$\text{Isocyanate conversion (\%)} = \left[1 - \frac{NCO^t}{NCO^1} \right] \times 100$$

Where:

NCO^t is the area of isocyanate absorbance peak area at time t

NCO^1 is the area of isocyanate absorbance peak area at time 0 = 98.1

Quantity of free NCO in RPUR foams were normalized by aromatic ring absorption band at 1595 cm^{-1}.

Example

Calculate the conversion of isocyanate (α) and PIR/PUR of RPUR foams catalyzed by Cu(tetraen):Zn(tetraen) at NCO Index 100

Conversion of Isocyanate

Absorbance peak area of initial NCO^1 = 98.1

Absorbance peak area of final NCO^1 = 0.33

Thus:

$$\text{conversion of isocyanate (\%)} = \left[1 - \frac{NCO^{f}}{NCO^{i}} \right] \times 100$$

$$= \left[1 - \frac{0.33}{98.1} \right] \times 100$$

% NCO conversion = 99.6

PIR/PUR

Absorbance peak area of PIR (polyisocyanate) = 0.771

Absorbance peak area of PUR (polyurethane) = 3.773

Thus:

$$\text{PIR/PUR} = \frac{0.771}{3.773} = 0.204$$

Table A2 NCO conversion of RPUR foam catalyzed by DMCHA at different NCO indexes

NCO indexes	Peak area					NCO conversion (%)	PIR/PUR
	NCO 2277 cm^{-1}	Ar-H 1595 cm^{-1}	PIR 1415 cm^{-1}	PUR 1220 cm^{-1}	NCO^{f} (Ar-H=1.0)		
100	0.429	1.835	0.968	5.054	0.234	99.761	0.191
130	1.215	2.388	1.288	6.145	0.508	99.481	0.210
150	1.291	2.193	1.215	4.532	0.589	99.400	0.268
180	1.888	2.406	1.348	4.337	0.784	99.010	0.311

Table A3 NCO conversion of RPUR foam catalyzed by Cu(tetraen) at different NCO indexes

NCO indexes	Peak area					NCO conversion (%)	PIR/PUR
	NCO 2277 cm^{-1}	Ar-H 1595 cm^{-1}	PIR 1415 cm^{-1}	PUR 1220 cm^{-1}	NCO' (Ar-H=1.0)		
100	0.439	1.485	0.708	3.394	0.295	99.698	0.189
130	0.793	2.275	1.218	4.433	0.349	99.644	0.209
150	1.234	2.015	1.232	5.143	0.532	99.320	0.220
180	1.570	2.091	1.173	4.190	0.751	98.923	0.280

Table A4 NCO conversion of RPUR foam catalyzed by Zn(tetraen) at different NCO indexes

NCO indexes	Peak area					NCO conversion (%)	PIR/PUR
	NCO 2277 cm^{-1}	Ar-H 1595 cm^{-1}	PIR 1415 cm^{-1}	PUR 1220 cm^{-1}	NCO' (Ar-H=1.0)		
100	0.377	1.540	0.731	3.610	0.245	99.750	0.193
130	0.785	2.065	1.121	5.794	0.380	99.612	0.203
150	1.445	2.457	1.347	6.515	0.588	99.400	0.207
180	1.754	2.272	1.173	4.649	0.772	98.900	0.283

Table A5 NCO conversion of RPUR foams catalyzed by Cu(tetraen):Zn(tetraen) at different NCO indexes

NCO indexes	Peak area					NCO conversion (%)	PIR/PUR
	NCO 2277 cm^{-1}	Ar-H 1595 cm^{-1}	PIR 1415 cm^{-1}	PUR 1220 cm^{-1}	NCO' (Ar-H=1.0)		
100	0.542	1.639	0.771	3.773	0.330	99.662	0.192
130	0.721	2.156	1.150	5.998	0.335	99.559	0.204
150	1.175	2.111	1.135	5.261	0.557	99.222	0.216
180	1.717	2.369	1.320	4.575	0.724	98.830	0.289

Table A6 NCO conversion of RPUR foams catalyzed by Cu(tetraen)-W at different NCO indexes

NCO indexes	Peak area					NCO conversion (%)	PIR/PUR
	NCO 2277 cm^{-1}	Ar-H 1595 cm^{-1}	PIR 1415 cm^{-1}	PUR 1220 cm^{-1}	NCO[f] (Ar-H=1.0)		
100	0.590	1.915	0.978	5.703	0.330	99.663	0.173
130	0.632	1.727	0.915	4.794	0.342	99.651	0.190
150	0.626	2.137	1.159	5.351	0.293	99.301	0.217
180	1.306	2.063	1.126	4.044	0.633	99.020	0.278

Table A7 NCO conversion of RPUR foams catalyzed by Zn(tetraen)-W at different NCO indexes

NCO indexes	Peak area					NCO conversion (%)	PIR/PUR
	NCO 2277 cm^{-1}	Ar-H 1595 cm^{-1}	PIR 1415 cm^{-1}	PUR 1220 cm^{-1}	NCO[f] (Ar-H=1.0)		
100	0.572	1.955	1.014	6.001	0.270	99.752	0.160
130	0.752	1.986	1.047	5.365	0.379	99.514	0.200
150	0.587	2.014	1.086	4.944	0.292	99.302	0.220
180	0.765	1.821	1.000	3.656	0.420	98.930	0.274

Table A8 NCO conversion of RPUR foams catalyzed by Cu(tetraen):Zn(tetraen)-W at different NCO indexes

NCO indexes	Peak area					NCO conversion (%)	PIR/PUR
	NCO 2277 cm^{-1}	Ar-H 1595 cm^{-1}	PIR 1415 cm^{-1}	PUR 1220 cm^{-1}	NCO[f] (Ar-H=1.0)		
100	0.538	2.173	1.108	6.412	0.279	99.667	0.713
130	0.706	1.925	1.025	4.984	0.323	99.554	0.205
150	0.798	1.826	1.008	5.016	0.437	99.323	0.219
180	1.074	1.994	1.087	4.268	0.549	98.543	0.254

Appendix B

Reaction Times, Standard Deviation and Physical Properties

Table B1 Formulations of RPUR foams prepared at the NCO indexes of 100-180

Chemicals	NCO indexes			
	100	**130**	**150**	**180**
Polyol	100	100	100	100
Catalyst	0.5	0.5	0.5	0.5
Surfactant	2.5	2.5	2.5	2.5
Blowing agent	2.0	2.0	2.0	2.0
PMDI	136.4	177.7	204.6	245.6

Table B2 Formulations of RPUR foams prepared with variation of blowing agent 1-4 pbw

Chemicals	Blowing agent content (pbw)			
	1	**2**	**3**	**4**
NCO Index	100	100	100	100
Polyol	100	100	100	100
Catalyst	0.5	0.5	0.5	0.5
Surfactant	2.5	2.5	2.5	2.5
PMDI	121.7	136.7	151.8	166.9

Table B3 Standard deviation (S.D.) of RPUR foams prepared at the NCO index of 100 by variation of metal (II) acetate:amine ratios

Catalysts	$M(OAc)_2$:tetraen	Standard deviation (S.D.)					
		Cream time (s)	Gel time (s)	Rise time (s)	Tack free time (s)	Density (kg/m^3)	Volume (V/8)
Cu(tetraen)	1:2	0.5	0.7	1.2	0.5	0.2	0.0
Zn(tetraen)	1:2	0.3	0.5	1.1	0.7	0.4	0.0
Ni(tetraen)	1:2	0.7	0.5	1.5	0.8	0.2	0.0
Co(tetraen)	1:2	0.3	0.6	1.1	0.6	0.3	0.0
Mn(tetraen)	1:2	0.6	0.6	2.1	1.2	0.9	0.0
Cu(tetraen): Zn(tetraen)	1:2	0.6	0.3	1.8	1.1	0.7	0.0
Cu(tetraen): Ni(tetraen)	1:2	0.6	0.7	2.2	1.8	0.4	0.0
Cu(tetraen):Co(tetraen)	1:2	0.3	0.8	2.5	1.2	0.6	0.0
Cu(tetraen):Mn(tetraen)	1:2	0.4	0.6	1.1	1.3	0.4	0.0
Cu(tetraen)-W	1:2	0.3	0.5	0.8	1.1	0.6	0.0
Zn(tetraen)-W	1:2	0.5	0.6	0.6	0.9	0.2	0.0
Cu(tetraen): Zn(tetraen)-W	1:2	0.3	0.6	0.4	1.3	0.4	0.0
Cu(tetraen)	1:1	0.4	0.5	0.8	0.4	0.2	0.0
Zn(tetraen)	1:1	0.3	0.6	0.9	0.7	0.3	0.0
Cu(tetraen): Zn(tetraen)	1:1	0.2	0.4	0.5	0.3	0.6	0.0
Cu(tetraen)-W	1:1	0.4	0.6	0.5	0.7	0.5	0.0
Zn(tetraen)-W	1:1	0.6	0.3	0.7	0.2	0.6	0.0
Cu(tetraen): Zn(tetraen)-W	1:1	0.2	0.5	0.6	0.7	0.3	0.0
Cu(tetraen)	1:0.5	0.8	1.2	0.8	1.5	0.8	0.2
Cu(tetraen): Zn(tetraen)	1:0.5	0.7	0.8	1.1	1.5	0.7	0.1
Cu(tetraen)-W	1:0.5	0.6	0.9	0.9	0.8	0.7	0.0
Cu(tetraen): Zn(tetraen)-W	1:0.5	0.5	0.6	0.8	0.6	0.5	0.0

Table B4 Standard deviation (S.D.) of RPUR foams prepared at the NCO index of 100 by variation of catalyst content

Catalysts	Catalyst Content (pbw)	Standard deviation (S.D.)					
		Cream time (s)	Gel time (s)	Rise time (s)	Tack free time (s)	Density (kg/m^3)	Volume (V/8)
DMCHA	0.25	0.3	0.3	2.0	2.5	0.5	0.0
Cu(tetraen)	0.25	0.2	1.0	1.1	0.6	0.2	0.0
Zn(tetraen)	0.25	0.5	1.3	1.0	0.7	0.6	0.0
Cu(tetraen): Zn(tetraen)	0.25	0.4	1.2	1.1	0.8	0.5	0.0
Cu(tetraen)-W	0.25	0.2	1.1	1.2	0.5	0.8	0.0
Zn(tetraen)-W	0.25	0.2	0.7	0.9	1.0	0.6	0.0
Cu(tetraen): Zn(tetraen)-W	0.25	0.4	0.8	1.1	1.0	0.9	0.0
DMCHA	0.50	0.7	0.7	2.0	1.2	1.3	0.0
Cu(tetraen)	0.50	0.6	0.6	2.1	2.0	1.4	0.0
Zn(tetraen)	0.50	0.6	1.2	1.5	1.5	0.3	0.0
Cu(tetraen): Zn(tetraen)	0.50	0.6	1.2	1.2	1.8	0.3	0.0
Cu(tetraen)-W	0.50	0.7	0.5	1.2	0.7	0.3	0.0
Zn(tetraen)-W	0.50	1.2	0.7	1.5	0.6	0.5	0.0
Cu(tetraen): Zn(tetraen)-W	0.50	0.6	0.5	1.2	0.7	0.1	0.0
DMCHA	1.00	0.6	0.5	1.1	1.5	0.7	0.0
Cu(tetraen)	1.00	0.3	0.6	1.2	1.1	0.9	0.0
Zn(tetraen)	1.00	0.4	0.9	1.2	1.5	0.7	0.0
Cu(tetraen): Zn(tetraen)	1.00	0.7	0.8	1.0	0.9	0.8	0.0
Cu(tetraen)-W	1.00	0.3	0.7	0.9	0.9	0.5	0.0
Zn(tetraen)-W	1.00	0.4	0.6	1.1	1.2	0.7	0.0
Cu(tetraen): Zn(tetraen)-W	1.00	0.2	0.5	1.0	0.8	0.8	0.0

Table B5 Standard deviation (S.D.) of RPUR foams prepared at the NCO index of 100 by variation of $M_1(OAc)_2$:$M_2(OAc)_2$ ratios

Catalysts	$M_1(OAc)_2$: $M_2(OAc)_2$: tetraen	Standard deviation (S.D.)					
		Cream time (s)	Gel time(s)	Rise time (s)	Tack free (s)	Density (kg/m^3)	Volume (V/8)
Cu(tetraen):Zn(tetraen)	0.7:0.3:1	0.7	1.1	1.5	1.2	0.5	0.0
Cu(tetraen):Zn(tetraen)	0.5:0.5:1	0.6	1.2	1.2	1.8	0.3	0.0
Cu(tetraen):Zn(tetraen)	0.3:0.7:1	0.3	1.2	1.2	2.1	0.3	0.0
Cu(tetraen):Zn(tetraen)-W	0.7:0.3:1	0.8	1.0	1.5	0.9	0.7	0.0
Cu(tetraen):Zn(tetraen)-W	0.5:0.5:1	0.6	0.5	1.2	0.7	0.5	0.0
Cu(tetraen):Zn(tetraen)-W	0.3:0.7:1	0.8	1.0	1.1	2.1	0.8	0.0

Table B6 Standard deviation (S.D.) of RPUR foams prepared at the NCO index of 100 by mixed amines [ethylenediamine (en) and triethylenetetramine (trien)] in metal complexes

Catalysts	Standard deviation (S.D.)					
	Cream time (s)	Gel time (s)	Rise time (s)	Tack free time (s)	Density (kg/m^3)	Volume (V/8)
Cu(tetraen)	0.6	0.6	2.1	2.0	1.4	0.0
Zn(tetraen)	0.6	1.2	1.5	1.5	0.3	0.0
Cu(tetraen):Zn(tetraen)	0.6	1.2	1.2	1.8	0.3	0.0
Cu(tetraen)(en)	0.4	1.1	0.8	1.2	0.7	0.0
Zn(tetraen)(en)	0.2	1.3	1.5	1.3	0.9	0.0
Cu(tetraen)(en):Zn(tetraen)(en)	0.6	0.9	1.3	0.9	0.9	0.0
Cu(tetraen)(trien)	0.3	1.1	1.2	0.8	0.7	0.0
Zn(tetraen)(trien)	0.3	1.2	1.1	0.9	0.8	0.0
Cu(tetraen)(trien):Zn(tetraen)(trien)	0.2	1.1	1.5	1.2	0.9	0.0

Table B7 Reaction times and standard deviation (S.D.) of RPUR foams prepared by variation blowing agent content at the NCO index of 100 and catalyzed by DMCHA

	0 pbw		1 pbw		2 pbw		3 pbw		4 pbw	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:33	0.5	0:29	0.7	0:28	0.7	0:27	0.6	0:27	0.5
Gel time	0:44	0.3	0:40	0.6	0:41	0.7	0:44	0.4	0:45	0.8
Rise time	4:20	1.2	2:42	1.5	3:10	2.1	3:45	1.2	4:00	1.7
Tack free time	4:00	1.1	3:50	1.3	4:28	1.2	5:06	1.1	5:42	2.5
Density (kg/m^3)	60.2	1.2	43.4	0.8	37.0	1.3	33.0	0.4	30.1	2.1
Volume	5.50	0.0	6.00	0.0	7.00	0.0	8.0	0.0	>8.00	0.0

Table B8 Reaction times and standard deviation (S.D.) of RPUR foams prepared by variation blowing agent content at the NCO index of 100 and catalyzed by Cu(tetraen)

	0 pbw		1 pbw		2 pbw		3 pbw		4 pbw	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:45	0.3	0:37	0.2	0:35	0.6	0:34	0.3	0:33	0.8
Gel time	1:09	0.5	1:06	0.7	1:09	0.6	1:14	0.8	1:15	0.7
Rise time	2:40	1.2	3:15	1.2	3:52	2.1	4:30	2.5	4:38	2.2
Tack free time	2:28	0.8	3:00	2.1	3:40	2.0	4:22	1.9	5:08	2.5
Density (kg/m^3)	66.7	0.9	50.1	1.5	43.0	1.4	37.2	1.1	34.1	2.5
Volume	4.50	0.0	4.75	0.0	6.25	0.0	7.00	0.0	7.25	0.0

Table B9 Reaction times and standard deviation (S.D.) of RPUR foams prepared by variation blowing agent content at the NCO index of 100 and catalyzed by Zn(tetraen)

	0 pbw		1 pbw		2 pbw		3 pbw		4 pbw	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:30	0.3	0:33	0.2	0:33	0.6	0:32	0.8	0:30	0.4
Gel time	1:40	0.8	1:30	0.7	1:32	1.2	1:34	1.1	1:34	0.8
Rise time	4:20	1.2	5:05	1.1	5:44	1.5	6:25	1.3	7:00	1.2
Tack free time	4:48	2.2	5:18	1.2	6:00	1.5	6:38	1.5	7:36	1.1
Density (kg/m^3)	62.7	0.5	47.0	0.9	40.5	0.3	34.3	0.5	32.2	1.2
Volume	4.50	0.0	5.00	0.0	6.50	0.0	7.25	0.0	8.00	0.0

Table B10 Reaction times and standard deviation (S.D.) of RPUR foams prepared by variation blowing agent content at the NCO index of 100 and catalyzed by Cu(tetraen):Zn(tetraen)

	0 pbw		1 pbw		2 pbw		3 pbw		4 pbw	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:42	0.4	0:36	0.5	0:35	0.6	0:34	0.5	0:32	0.8
Gel time	1:20	0.9	1:13	0.7	1:16	1.2	1:18	0.8	1:20	0.8
Rise time	3:45	1.1	4:15	1.5	4:40	1.2	5:27	1.5	5:45	1.5
Tack free time	3:23	0.8	3:50	2.2	4:26	1.8	5:10	2.1	6:00	1.8
Density (kg/m^3)	64.4	0.8	48.5	0.9	41.5	0.3	36.0	0.7	33.0	1.6
Volume	4.50	0.0	5.00	0.0	6.50	0.0	7.25	0.0	8.00	0.0

Table B11 Reaction times and standard deviation (S.D.) of RPUR foams prepared by variation blowing agent content at the NCO index of 100 and catalyzed by Cu(tetraen)-W

	0 pbw		1 pbw		2 pbw		3 pbw		4 pbw	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:40	0.5	0:32	0.4	0:33	0.7	0:30	0.7	0:28	0.7
Gel time	1:12	0.8	1:04	0.5	1:05	0.5	1:09	0.8	1:10	0.8
Rise time	2:30	1.2	2:50	1.1	3:36	1.2	4:17	1.1	4:10	1.2
Tack free time	2:18	2.2	2:42	1.2	3:20	0.7	3:57	1.5	4:38	2.2
Density (kg/m^3)	66.7	1.5	49.4	0.7	42.7	0.3	37.0	0.8	33.8	0.5
Volume	4.50	0.0	4.75	0.0	6.25	0.0	7.00	0.0	7.25	0.0

Table B12 Reaction times and standard deviation (S.D.) of RPUR foams prepared by variation blowing agent content at the NCO index of 100 and catalyzed by Zn(tetraen)-W

	1 pbw		2 pbw		3 pbw		4 pbw	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:34	1.5	0:30	1.2	0:29	1.1	0:28	0.8
Gel time	1:30	0.9	1:30	0.7	1:32	1.2	1:32	1.3
Rise time	4:40	1.1	5:20	1.5	6:00	0.9	6:30	1.5
Tack free time	5:00	1.3	5:38	0.6	6:17	1.3	7:00	2.1
Density (kg/m^3)	47.0	0.9	40.1	0.5	35.0	0.9	32.1	1.2
Volume	5.00	0.0	6.50	0.0	7.25	0.0	8.00	0.0

Table B13 Reaction times and standard deviation (S.D.) of RPUR foams prepared by variation blowing agent content at the NCO index of 100 and catalyzed by Cu(tetraen):Zn(tetraen)-W

	1 pbw		2 pbw		3 pbw		4 pbw	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:34	0.7	0:33	0.6	0:31	1.1	0:31	0.4
Gel time	1:12	0.4	1:13	0.5	1:16	0.6	1:20	1.2
Rise time	3:32	1.0	4:21	1.2	4:50	1.5	5:00	2.1
Tack free time	3:24	1.2	4:00	0.7	4:38	1.2	5:22	1.8
Density (kg/m^3)	48.0	0.4	41.5	0.1	36.1	0.9	33.0	1.5
Volume	5.00	0.0	6.50	0.0	7.25	0.0	8.00	0.0

Table B14 Reaction times and standard deviation (S.D.) of RPUR foams prepared at the NCO indexes of 100-180 and catalyzed by DMCHA

	NCO index 100		NCO index 130		NCO index 150		NCO index 180	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:28	0.7	0:28	0.7	0:25	1.4	0:28	0.7
Gel time	0:41	0.7	0:42	0.0	0:55	0.0	0:57	0.0
Rise time	3:10	2.1	4:00	1.4	5:42	1.4	6:50	2.1
Tack free time	4:28	1.2	5:20	2.1	6:50	1.0	7:30	1.0
Density (kg/m^3)	37.0	1.3	40.9	1.5	45.8	0.8	50.5	1.5
Volume	7.00	0.0	7.25	0.0	7.50	0.0	7.75	0.0
Compressive strength (kPa)								
Parallel to rise	250.0	-	-	-	309.7	-	400.1	-
Perpendicular to rise	-	-	-	-	136.7	-	-	-

Table B15 Reaction times and standard deviation (S.D.) of RPUR foams prepared at the NCO indexes of 100-180 and catalyzed by Cu(tetraen)

	NCO index 100		NCO index 130		NCO index 150		NCO index 180	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:35	0.6	0:36	1.4	0:34	1.4	0:32	0.7
Gel time	1:09	0.6	1:27	0.7	1:39	2.1	1:42	1.4
Rise time	3:52	2.1	4:40	2.1	4:50	2.1	4:50	0.7
Tack free time	3:40	2.0	4:08	1.7	4:30	1.4	5:47	2.2
Density (kg/m^3)	43.0	1.4	47.1	1.4	51.1	0.5	57.5	0.8
Volume	6.25	0.0	6.75	0.0	7.00	0.0	7.00	0.0
Compressive strength (kPa)								
Parallel to rise	-	-	-	-	353.8	-	-	-

Table B16 Reaction times and standard deviation (S.D.) of RPUR foams prepared at the NCO indexes of 100-180 and catalyzed by Zn(tetraen)

	NCO index 100		NCO index 130		NCO index 150		NCO index 180	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:33	0.6	0:37	0.7	0:34	1.0	0:28	0.7
Gel time	1:32	1.2	1:53	0.7	2:08	1.2	2:15	2.4
Rise time	5:44	1.5	6:07	1.2	6:33	0.0	6:53	2.4
Tack free time	6:00	1.5	6:20	0.7	6:45	2.1	7:52	2.1
Density (kg/m^3)	40.5	0.3	43.8	0.5	48.5	0.4	56.0	1.5
Volume	6.50	0.0	7.00	0.0	7.25	0.0	7.25	0.0
Compressive Strength (kPa)								
Parallel to rise	-	-	-	-	336.8	-	-	-

Table B17 Reaction times and standard deviation (S.D.) of RPUR foams prepared at the NCO indexes of 100-180 and catalyzed by Cu(tetraen):Zn(tetraen)

	NCO index 100		NCO index 130		NCO index 150		NCO index 180	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:35	0.6	0:36	0.7	0:33	1.2	0:29	1.4
Gel time	1:16	1.2	1:36	1.2	1:50	2.1	1:58	2.1
Rise time	4:40	1.2	5:00	1.2	6:40	2.1	5:30	1.4
Tack free time	4:26	1.8	4:48	0.7	5:15	1.4	6:15	1.2
Density (kg/m^3)	41.8	0.3	45.2	0.5	49.8	1.1	56.5	1.3
Volume	6.50	0.0	7.00	0.0	7.25	0.0	7.25	0.0
Compressive Strength (kPa)				-	-	-	-	-
Parallel to rise	266.6	-	-	-	341.9	-	414.8	-
Perpendicular to rise	-	-	-	-	195.2	-	-	-

Table B18 Reaction times and standard deviation (S.D.) of RPUR foams prepared at the NCO indexes of 100-180 and catalyzed by Cu(tetraen)-W

	NCO index 100		NCO index 130		NCO index 150		NCO index 180	
	Reaction times (min)	S.D. (s)	Reaction times (min)	S.D. (s)	Reaction times (min)	S.D. (s)	Reaction times (min)	S.D. (s)
Cream time	0:33	0.7	0:34	0.5	0:35	1.2	0:30	1.2
Gel time	1:05	0.5	1:23	0.3	1:35	0.7	1:40	1.5
Rise time	3:36	1.2	4:05	1.7	4:24	2.1	4:50	2.1
Tack free time	3:20	0.7	3:50	1.2	4:10	1.2	5:35	1.2
Density (kg/m^3)	42.7	0.3	46.6	0.5	50.4	0.7	57.0	0.6
Volume	6.25	0.0	6.75	0.0	7.00	0.0	7.00	0.0

Table B19 Reaction times and standard deviation (S.D.) of RPUR foams prepared at the NCO indexes of 100-180 and catalyzed by Zn(tetraen)-W

	NCO index 100		NCO index 130		NCO index 150		NCO index 180	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D.**
Cream time	0.30	1.2	0:36	0.8	0:36	1.2	0:30	1.2
Gel time	1:30	0.7	1:47	0.5	1:56	0.7	2:08	0.8
Rise time	5:20	1.5	5:45	1.2	6:00	1.5	6:40	1.2
Tack free time	5:38	0.6	6:00	0.7	6:18	1.2	7:33	1.2
Density (kg/m^3)	40.1	0.5	43.3	0.7	47.6	0.7	55.4	0.6
Volume	6.50	0.0	7.00	0.0	7.25	0.0	7.25	0.0

Table B20 Reaction times and standard deviation (S.D.) of RPUR foams prepared at the NCO indexes of 100-180 and catalyzed by Cu(tetraen):Zn(tetraen)-W

	NCO index 100		NCO index 130		NCO index 150		NCO index 180	
	Reaction times (min)	S.D. (s)	Reaction times (min)	S.D. (s)	Reaction times (min)	S.D. (s)	Reaction times (min)	S.D. (s)
Cream time	0:33	0.6	0:35	1.2	0:34	0.7	0:31	1.2
Gel time	1:13	0.5	1:32	0.6	1:45	0.6	1:55	0.8
Rise time	4:21	1.2	4:48	1.5	5:02	1.5	4:57	1.5
Tack free time	4:00	0.7	4:22	0.7	4:40	1.2	5:50	2.2
Density (kg/m^3)	41.5	0.1	45.0	0.7	48.7	1.0	56.1	0.6
Volume	6.50	0.0	7.00	0.0	7.25	0.0	7.25	0.0

Table B21 Reaction times and standard deviation (S.D.) of RPUR foams prepared by variation blowing agent content at the NCO index of 150 and catalyzed by Cu(tetraen):Zn(tetraen)

	1 pbw		2 pbw		3 pbw		4 pbw	
	Reaction times (min)	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**	**Reaction times (min)**	**S.D. (s)**
Cream time	0:33	0.8	0:33	1.2	0:34	1.1	0:34	1.2
Gel time	1:45	0.3	1:50	2.1	1:54	0.7	1:57	0.8
Rise time	5:45	1.2	6:40	2.1	7:03	1.5	7:30	1.8
Tack free time	4:47	0.7	5:15	1.4	5:46	1.2	6:05	2.1
Density (kg/m^3)	56.6	0.6	49.8	1.1	46.0	0.3	44.3	0.3
Volume	6.75	0.0	7.25	0.0	7.50	0.0	7.75	0.0
Compressive Strength (kPa)								
Parallel to rise	419.8	-	341.9	-	299.5	-	173.3	-
Perpendicular to rise	-	-	195.2	-	-	-	-	-

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