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APPENDICES

APPENDIX A

Rheological Behavior Determination

The Brookfield RVT Viscometer measures fluid parameter of viscosity at given shear rates. We determined the viscosity of the thickeners using RVT with SC4-14 Spindle at 2.5, 5, 10, 20, and 50 RPM, at 25 ± 2°C. The viscosities were determined by reading values multiplied with factor and 10^{-3}, in Pa s (factor for RPM of 2.5, 5, 10, 20 and 50 are 5,000, 2,500, 1,250, 625, and 250). The shear rate and shear stress were calculated as follows:

$$\text{Shear rate } (\text{sec}^{-1}) = 0.4 \times \text{RPM} \qquad \text{(A-1)}$$

$$\text{Shear stress } (\text{N m}^{-2}) = \text{TK} \times \text{SMC} \times \text{SRC} \times \text{Torque} \times 10^{-1} \qquad \text{(A-2)}$$

where:

TK = Model spring constant: 1

SMC = Current spindle multiplier constant: 125

SRC = Current spindle shear rate constant: 0.4

Torque = Current viscometer torque in percent expressed as a number between 0 and 100: reading values from the viscometer

Tables A-1 to A-5 show data of rheological behavior of thickener solution with various crosslinking agent concentrations.

Table A-1 Rheological Behavior of Thickener Solution with 0.5 Wt% Crosslinking Agent Concentration

Thickener Solution (wt%)	RPM	Reading (TK)			Average	Factor	Viscosity (Pa s)	Shear rate (sec^{-1})	Shear stress ($N\ m^{-2}$)
6	2.5	1	1	1	1.0	5,000	5.0	1	5.0
	5	1.5	1.5	1.5	1.5	2,500	3.8	2	7.5
	10	1.5	1.5	2	1.7	1,250	2.1	4	8.3
	20	2.5	2.5	2.5	2.5	625	1.6	8	12.5
	50	4	4	3.5	3.8	250	1.0	20	19.2
8	2.5	1.5	2	2	1.8	5,000	9.2	1	9.2
	5	2.5	2.5	2.5	2.5	2,500	6.3	2	12.5
	10	3	3	3	3.0	1,250	3.8	4	15.0
	20	4	4	4	4.0	625	2.5	8	20.0
	50	6.5	6.5	6	6.3	250	1.6	20	31.7
10	2.5	4	4	4	4.0	5,000	20.0	1	20.0
	5	5	5	5.5	5.2	2,500	12.9	2	25.8
	10	6.5	6.5	6.5	6.5	1,250	8.1	4	32.5
	20	8	8	8	8.0	625	5.0	8	40.0
	50	12.5	12.5	12.5	12.5	250	3.1	20	62.5
12	2.5	5	5	5	5.0	5,000	25.0	1	25.0
	5	6.5	6.5	6.5	6.5	2,500	16.3	2	32.5
	10	8.5	8	8	8.2	1,250	10.2	4	40.8
	20	11	11	10.5	10.8	625	6.8	8	54.2
	50	17.5	17.5	17	17.3	250	4.3	20	86.7

Table A-1 Rheological Behavior of Thickener Solution with 0.5 Wt% Crosslinking Agent Concentration (continued)

Thickener Solution (wt%)	RPM	Reading (TK)			Average	Factor	Viscosity (Pa s)	Shear rate (sec^{-1})	Shear stress (N m^{-2})
15	2.5	6.5	6.5	6.5	6.5	5,000	32.5	1	32.5
	5	7.5	7.5	7.5	7.5	2,500	18.8	2	37.5
	10	10	10	10	10.0	1,250	12.5	4	50.0
	20	13	13	13	13.0	625	8.1	8	65.0
	50	20	20	19.5	19.8	250	5.0	20	99.2

Table A-2 Rheological Behavior of Thickener Solution with 1.0 Wt% Crosslinking Agent Concentration

Thickener Solution (wt%)	RPM	Reading (TK)			Average	Factor	Viscosity (Pa s)	Shear rate (sec^{-1})	Shear stress ($N\ m^{-2}$)
6	2.5	1.5	1.5	1.5	1.5	5,000	7.5	1	7.5
	5	2	2	2	2.0	2,500	5.0	2	10.0
	10	2.5	2.5	2.5	2.5	1,250	3.1	4	12.5
	20	3.5	4	3.5	3.7	625	2.3	8	18.3
	50	7	6.5	6.5	6.7	250	1.7	20	33.3
8	2.5	2.5	2.5	2.5	2.5	5,000	12.5	1	12.5
	5	3.5	3.5	3.5	3.5	2,500	8.8	2	17.5
	10	4.5	4.5	4	4.3	1,250	5.4	4	21.7
	20	6.5	6	6.5	6.3	625	4.0	8	31.7
	50	10.5	10.5	9.5	10.2	250	2.5	20	50.8
10	2.5	4.5	4.5	4.5	4.5	5,000	22.5	1	22.5
	5	6	6	6.5	6.2	2,500	15.4	2	30.8
	10	8	8	8	8.0	1,250	10.0	4	40.0
	20	11	11.5	11.5	11.3	625	7.1	8	56.7
	50	17.5	17.5	17.5	17.5	250	4.4	20	87.5
12	2.5	7	7.5	7.5	7.3	5,000	36.7	1	36.7
	5	9.5	10	10	9.8	2,500	24.6	2	49.2
	10	12.5	12	12.5	12.3	1,250	15.4	4	61.7
	20	16.5	16.5	17	16.7	625	10.4	8	83.3
	50	27	27	27	27.0	250	6.8	20	135.0

Table A-3 Rheological Behavior of Thickener Solution with 1.5 Wt% Crosslinking Agent Concentration

Thickener Solution (wt%)	RPM	Reading (TK)			Average	Factor	Viscosity (Pa s)	Shear rate (sec^{-1})	Shear stress ($N\ m^{-2}$)
6	2.5	1.5	2	1.5	1.7	5,000	8.3	1	8.3
	5	2	2	2.5	2.2	2,500	5.4	2	10.8
	10	3	3	2.5	2.8	1,250	3.5	4	14.2
	20	3.5	4	3.5	3.7	625	2.3	8	18.3
	50	6.5	6.5	6.5	6.5	250	1.6	20	32.5
8	2.5	6	5.5	5.5	5.7	5,000	28.3	1	28.3
	5	6.5	6.5	6	6.3	2,500	15.8	2	31.7
	10	8	7.5	8	7.8	1,250	9.8	4	39.2
	20	9.5	9	8.5	9.0	625	5.6	8	45.0
	50	14	13	14	13.7	250	3.4	20	68.3
10	2.5	7.5	7.5	7.5	7.5	5,000	37.5	1	37.5
	5	8.5	9	8.5	8.7	2,500	21.7	2	43.3
	10	11	11	11	11.0	1,250	13.8	4	55.0
	20	14	14.5	14.5	14.3	625	9.0	8	71.7
	50	19.5	19.5	19.5	19.5	250	4.9	20	97.5
12	2.5	12	12.5	12.5	12.3	5,000	61.7	1	61.7
	5	14.5	15	15	14.8	2,500	37.1	2	74.2
	10	18	18	18	18.0	1,250	22.5	4	90.0
	20	22	22.5	22	22.2	625	13.9	8	110.8
	50	32.5	33	31.5	32.3	250	8.1	20	161.7

Table A-4 Rheological Behavior of Thickener Solution with 2.0 Wt% Crosslinking Agent Concentration

Thickener Solution (wt%)	RPM	Reading (TK)			Average	Factor	Viscosity (Pa s)	Shear rate (sec^{-1})	Shear stress ($N\ m^{-2}$)
6	2.5	3	3	3	3.0	5,000	15.0	1	15.0
	5	4	4	3.5	3.8	2,500	9.6	2	19.2
	10	4.5	5	5	4.8	1,250	6.0	4	24.2
	20	6.5	6	6	6.2	625	3.9	8	30.8
	50	9.5	9	9	9.2	250	2.3	20	45.8
8	2.5	5.5	5.5	6	5.7	5,000	28.3	1	28.3
	5	8	8	8	8.0	2,500	20.0	2	40.0
	10	9.5	8.5	8.5	8.8	1,250	11.0	4	44.2
	20	12	12.5	12	12.2	625	7.6	8	60.8
	50	18	18.5	18	18.2	250	4.5	20	90.8
10	2.5	8	8.5	8.5	8.3	5,000	41.7	1	41.7
	5	10.5	10.5	10.5	10.5	2,500	26.3	2	52.5
	10	13.5	13.5	13.5	13.5	1,250	16.9	4	67.5
	20	18	17.5	17.5	17.7	625	11.0	8	88.3
	50	28	28	28	28.0	250	7.0	20	140.0
12	2.5	11.5	11.5	12	11.7	5,000	58.3	1	58.3
	5	15	15	14.5	14.8	2,500	37.1	2	74.2
	10	19	18.5	18	18.5	1,250	23.1	4	92.5
	20	23.5	24	24	23.8	625	14.9	8	119.2
	50	39.5	41	41	40.5	250	10.1	20	202.5

Table A-5 Rheological Behavior of Thickener Solution with 2.5 Wt% Crosslinking Agent Concentration

Thickener Solution (wt%)	RPM	Reading (TK)			Average	Factor	Viscosity (Pa s)	Shear rate (sec^{-1})	Shear stress ($N\ m^{-2}$)
6	2.5	4.5	4.5	4.5	4.5	5,000	22.5	1	22.5
	5	5.5	5	5	5.2	2,500	12.9	2	25.8
	10	6.5	6	6.5	6.3	1,250	7.9	4	31.7
	20	8	7.5	8	7.8	625	4.9	8	39.2
	50	12.5	13	12	12.5	250	3.1	20	62.5
8	2.5	9	9.5	10	9.5	5,000	47.5	1	47.5
	5	11	11.5	11.5	11.3	2,500	28.3	2	56.7
	10	14.5	14	14	14.2	1,250	17.7	4	70.8
	20	18.5	18.5	18.5	18.5	625	11.6	8	92.5
	50	25	24.5	24.5	24.7	250	6.2	20	123.3
10	2.5	9.5	10	10	9.8	5,000	49.2	1	49.2
	5	12.5	12	12	12.2	2,500	30.4	2	60.8
	10	15	15.5	15	15.2	1,250	19.0	4	75.8
	20	19.5	19	19	19.2	625	12.0	8	95.8
	50	31	30	29.5	30.2	250	7.5	20	150.8
12	2.5	15	15	15	15.0	5,000	75.0	1	75.0
	5	18	18	18.5	18.2	2,500	45.4	2	90.8
	10	23.5	23	23	23.2	1,250	29.0	4	115.8
	20	30	29	29	29.3	625	18.3	8	146.7
	50	40.5	41	40.5	40.7	250	10.2	20	203.3

APPENDIX B

Data of Surface Tension of Water-Based Inks

Table B-1 Surface Tension of Various Concentrations of the Ink I Measured by Tensiometer (Kruss K8) at 25°C

Concentration (wt%)	Ink I					
	Reading Values (mN m^{-1})			Mean (mN m^{-1})	STDEV	Surface tension[a] (mN m^{-1})
	1	2	3			
0.1	38.9	40.3	40.8	40.0	0.73	42.8
0.5	39.7	39.6	40.2	39.8	0.24	42.6
1	37.0	37.0	37.2	37.1	0.09	39.7
10	32.5	32.6	32.5	32.5	0.04	34.8
15	32.7	32.5	32.5	32.6	0.09	34.8
20	32.2	32.1	32.1	32.1	0.04	34.4
25	31.5	31.8	31.7	31.7	0.11	33.9
Water (25°C)	**66.8**	**67.5**	**67.8**	**67.4**	**0.38**	**72.1**
Factor				**1.07**		

[a]Surface Tension = Mean x Factor

Table B-2 Surface Tension of Various Concentrations of the Ink II Measured by Tensiometer (Kruss K8) at 25°C

Concentration (wt%)	Ink II					
	Reading value (mN m^{-1})			Mean (mN m^{-1})	STDEV	Surface tension[a] (mN m^{-1})
	1	2	3			
0.1	42.2	42.3	42.3	42.3	0.04	45.2
0.5	36.5	36.9	36.7	36.7	0.13	39.3
1	34.2	34.5	34.4	34.4	0.11	36.8
10	28.8	28.7	28.8	28.8	0.04	30.8
15	28.8	28.5	28.5	28.6	0.13	30.6
20	30.2	29.8	29.7	29.9	0.20	32.0
25	29.8	30.5	30.4	30.2	0.29	32.3
Water (25°C)	**66.8**	**67.5**	**67.8**	**67.4**	**0.38**	**72.1**
Factor				**1.07**		

[a]Surface Tension = Mean x Factor

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