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APPENDICES

Appendix A Adsorption Isotherms Data

Table A1 Adsorption isotherm of 1:0 molar ratio of Arquad® T-50:Teric® X-10 at pH 5

No.	Initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	50	37.87	34.59	36.23	0.49	0.62	0.55
2	100	50.93	55.44	53.19	1.96	1.78	1.87
3	200	88.26	86.70	87.48	4.47	4.53	4.50
4	400	164.37	167.13	165.75	9.43	9.31	9.37
5	600	244.85	242.37	243.61	14.21	14.31	14.26
6	800	323.29	317.51	320.40	19.07	19.30	19.18
7	1000	402.55	403.33	402.94	23.90	23.87	23.88
8	1000	399.17	424.57	411.87	24.03	23.02	23.53
9	2000	682.05	724.78	703.41	52.72	51.01	51.86
10	3000	1079.71	1091.36	1085.53	76.81	76.35	76.58
11	4000	1458.43	1516.69	1487.56	101.66	99.33	100.50
12	5000	1865.31	1861.91	1863.61	125.39	125.52	125.46
13	7000	2468.84	2500.88	2484.86	181.25	179.96	180.61
14	8000	2851.44	2807.26	2829.35	205.94	207.71	206.83
15	9000	3169.96	3206.86	3188.41	233.20	231.73	232.46
16	10000	3525.86	3648.21	3587.03	258.97	254.07	256.52
17	11000	4016.25	4016.25	4016.25	279.35	279.35	279.35
18	12000	4520.24	4439.64	4479.94	299.19	302.41	300.80
19	13000	4876.63	4829.53	4853.08	324.93	326.82	325.88
20	14000	5333.04	5439.86	5386.45	346.68	342.41	344.54
21	16000	6129.32	6095.33	6112.33	394.83	396.19	395.51
22	17000	6804.22	6833.35	6818.79	407.83	406.67	407.25
23	18000	7318.89	7585.94	7452.42	427.24	416.56	421.90
24	22000	10374.07	10733.77	10553.92	465.04	450.65	457.84
25	23000	11311.72	12257.45	11784.59	467.53	429.70	448.62
26	25000	14330.79	12124.08	13227.44	426.77	515.04	470.90
27	27000	14625.83	13926.63	14276.23	494.97	522.93	508.95
28	28000	15207.82	14852.16	15029.99	511.69	525.91	518.80
29	29000	16060.60	16792.13	16426.36	517.58	488.31	502.95
30	30000	16884.88	17681.83	17283.35	524.60	492.73	508.67
31	40000	26420.95	26443.72	26432.34	543.16	542.25	542.71

*Amount of surfactant adsorbed

= (initial concentration-equilibrium concentration)×(volume of surfactant solution)/(silica weight)

Table A2 Adsorption isotherm of 3:1 molar ratio of Arquad® T-50:Teric® X-i0 at pH 5

No.	Initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	80	42.48	37.76	40.12	1.50	1.69	1.60
2	160	61.81	72.17	66.99	3.93	3.51	3.72
3	320	135.64	136.14	135.89	7.37	7.35	7.36
4	480	192.77	194.72	193.74	11.49	11.41	11.45
5	1000	298.54	218.81	298.54	28.06	31.25	28.06
6	2000	453.41	449.39	451.40	61.86	62.02	61.94
7	3000	685.80	691.83	688.82	92.57	92.33	92.45
8	4000	958.80	953.58	956.19	121.65	121.86	121.75
9	5000	1221.35	1222.96	1222.15	151.15	151.08	151.11
10	6000	1705.43	1539.38	1622.40	171.78	178.42	175.10
11	7000	1768.95	1775.39	1772.17	209.24	208.98	209.11
12	8000	1930.58	1921.33	1925.96	242.78	243.15	242.96
13	9000	2189.51	2254.64	2222.07	272.42	269.81	271.12
14	10000	2464.52	2525.63	2495.07	301.42	298.97	300.20
15	12000	3029.41	2922.06	2975.74	358.82	363.12	360.97
16	14000	4637.25	4190.96	4414.11	374.51	392.36	383.44
17	16000	6380.65	7519.66	6950.16	384.77	339.21	361.99
18	18000	9638.34	10216.69	9927.52	334.47	311.33	322.90
19	20000	12025.54	12134.71	12080.12	318.98	314.61	316.80

*Amount of surfactant adsorbed

= (Initial concentration-Equilibrium concentration)*(volume of surfactant solution)/(silica weight)

Table A3 Adsorption isotherm of 1:1 molar ratio of Arquad® T-50:Teric® X-10 at pH 5

No.	Initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	50	39.34	35.44	37.39	0.43	0.58	0.50
2	200	72.13	75.04	73.58	5.11	5.00	5.06
3	400	115.29	114.89	115.09	11.39	11.40	11.40
4	600	148.78	149.74	149.26	18.05	18.01	18.03
5	800	183.04	180.86	181.95	24.68	24.77	24.72
6	1000	211.87	218.99	215.43	31.53	31.24	31.38
7	2000	379.28	382.05	380.67	64.83	64.72	64.77
8	3000	502.50	513.04	507.77	99.90	99.48	99.69
9	4000	651.80	645.14	648.47	133.93	134.19	134.06
10	5000	791.12	793.34	792.23	168.36	168.27	168.31
11	6000	876.87	890.75	883.81	204.93	204.37	204.65
12	7000	1051.15	1043.11	1047.13	237.95	238.28	238.11
13	8000	1189.36	1191.58	1190.47	272.43	272.34	272.38
14	9000	1353.37	1350.60	1351.99	305.87	305.98	305.92
15	10000	1502.12	1527.38	1514.75	339.92	338.90	339.41
16	11000	1572.89	1688.62	1630.75	377.08	372.46	374.77
17	12000	2116.00	1945.05	2030.52	395.36	402.20	398.78
18	13000	2672.98	2562.81	2617.89	413.08	417.49	415.28
19	14000	3792.77	3445.87	3619.32	408.29	422.17	415.23
20	15000	4123.02	4242.36	4182.69	435.08	430.31	432.69
21	16000	4988.89	4997.21	4993.05	440.44	440.11	440.28
22	17000	5802.02	7120.24	6461.13	447.92	395.19	421.55
23	18000	7977.78	7814.04	7895.91	400.89	407.44	404.16
24	19000	9060.10	8979.62	9019.86	397.60	400.82	399.21
25	20000	10117.46	10192.39	10154.92	395.30	392.30	393.80

*Amount of surfactant adsorbed

= (Initial concentration-Equilibrium concentration)*(volume of surfactant solution)/(silica weight)

Table A4 Adsorption isotherm of 1:3 molar ratio of Arquad® T-50:Teric® X-10 at pH 5

No.	Initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	200	124.44	121.24	122.84	3.02	3.15	3.09
2	400	151.13	151.72	151.42	9.95	9.93	9.94
3	600	171.97	172.63	172.30	17.12	17.09	17.11
4	800	194.18	192.69	193.43	24.23	24.29	24.26
5	1000	213.70	213.93	213.82	31.45	31.44	31.45
6	2000	288.31	288.54	288.42	68.47	68.46	68.46
7	3000	358.46	355.64	357.05	105.66	105.77	105.72
8	4000	422.99	424.40	423.69	143.08	143.02	143.05
9	5000	491.99	491.99	491.99	180.32	180.32	180.32
10	6000	560.99	567.59	564.29	217.56	217.30	217.43
11	7000	646.48	651.89	649.19	254.14	253.92	254.03
12	8000	743.03	740.44	741.74	290.28	290.38	290.33
13	9000	825.69	818.63	822.16	326.97	327.25	327.11
14	10000	906.47	906.47	906.47	363.74	363.74	363.74
15	12000	1840.70	1882.38	1861.54	406.37	404.70	405.54
16	14000	3808.07	3947.01	3877.54	407.68	402.12	404.90
17	16000	5779.20	5779.20	5779.20	408.83	408.83	408.83
18	18000	7919.90	7795.08	7857.49	403.20	408.20	405.70
19	20000	10027.62	10058.24	10042.93	398.90	397.67	398.28

*Amount of surfactant adsorbed

= (Initial concentration-Equilibrium concentration)*(volume of surfactant solution)/(silica weight)

Table A5 Adsorption isotherm of 0:1 molar ratio of Arquad® T-50:Teric® X-10 at pH 5

No.	initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	200	118.35	89.23	103.79	3.27	4.43	3.85
2	400	113.90	127.68	120.79	11.44	10.89	11.17
3	600	137.83	137.41	137.62	18.49	18.50	18.50
4	800	141.21	140.75	140.98	26.35	26.37	26.36
5	1000	155.16	157.08	156.12	33.79	33.72	33.76
6	2000	195.07	197.36	196.22	72.20	72.11	72.15
7	3000	233.28	233.28	233.28	110.67	110.67	110.67
8	4000	254.24	248.56	251.40	149.83	150.06	149.94
9	5000	295.06	300.74	297.90	188.20	187.97	188.08
10	6000	328.03	315.37	321.70	226.88	227.39	227.13
11	7000	371.91	374.31	373.11	265.12	265.03	265.08
12	8000	418.85	424.96	421.91	303.25	303.00	303.12
13	9000	743.71	774.49	759.10	330.25	329.02	329.64
14	10000	1446.48	1353.48	1399.98	342.14	345.86	344.00
15	12000	3275.13	3179.07	3227.10	348.99	352.84	350.92
16	14000	5268.39	5226.91	5247.65	349.26	350.92	350.09
17	16000	7541.10	7453.77	7497.44	338.36	341.85	340.10
18	18000	9595.49	9652.26	9623.88	336.18	333.91	335.05
19	20000	11927.15	11835.46	11881.30	322.91	326.58	324.75
20	25000	15485.77	15564.36	15525.06	380.57	377.43	379.00

*Amount of surfactant adsorbed

= (Initial concentration-Equilibrium concentration)*(volume of surfactant solution)/(silica weight)

Table A6 Adsorption isotherm of 1:0 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	200	106.76	100.86	103.81	3.73	3.97	3.85
2	400	153.18	152.21	152.70	9.87	9.91	9.89
3	600	242.21	242.21	242.21	14.31	14.31	14.31
4	800	309.81	310.92	310.36	19.61	19.56	19.59
5	1000	395.54	393.41	394.48	24.18	24.26	24.22
6	2000	734.08	743.75	738.92	50.64	50.25	50.44
7	3000	1141.72	1142.69	1142.21	74.33	74.29	74.31
8	4000	1513.10	1527.60	1520.35	99.48	98.90	99.19
9	5000	1944.92	1909.13	1927.02	122.20	123.63	122.92
10	6000	2341.44	2346.27	2343.85	146.34	146.15	146.25
11	7000	2853.04	2825.48	2839.26	165.88	166.98	166.43
12	8000	3165.42	3120.45	3142.94	193.38	195.18	194.28
13	9000	3578.38	3523.74	3551.06	216.86	219.05	217.96
14	10000	3835.15	3925.09	3880.12	246.59	243.00	244.80
15	12000	4614.65	4531.96	4573.31	295.41	298.72	297.07
16	14000	5393.67	5031.00	5212.33	344.25	358.76	351.51
17	16000	6128.68	5848.21	5988.45	394.85	406.07	400.46
18	20000	9755.38	8222.49	8988.94	409.78	471.10	440.44
19	40000	28952.71	28991.39	28972.05	441.89	440.34	441.12

*Amount of surfactant adsorbed

= (Initial concentration-Equilibrium concentration)*(volume of surfactant solution)/(silica weight)

Table A7 Adsorption isotherm of 3:1 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	200	3.83	3.52	3.67	7.85	7.86	7.85
2	400	6.53	6.55	6.54	15.74	15.74	15.74
3	600	9.35	9.50	9.43	23.63	23.62	23.62
4	800	12.45	12.58	12.52	31.50	31.50	31.50
5	1000	15.36	15.36	15.36	39.39	39.39	39.39
6	2000	29.30	29.58	29.44	78.83	78.82	78.82
7	3000	44.00	43.98	43.99	118.24	118.24	118.24
8	4000	58.80	60.05	59.43	157.65	157.60	157.62
9	5000	76.68	76.10	76.39	196.93	196.96	196.94
10	6000	91.76	92.57	92.17	236.33	236.30	236.31
11	7000	105.62	104.18	104.90	275.78	275.83	275.80
12	8000	122.13	126.95	124.54	315.11	314.92	315.02
13	9000	146.30	145.21	145.75	354.15	354.19	354.17
14	10000	159.45	158.49	158.97	393.62	393.66	393.64
15	12000	194.84	187.71	191.28	472.21	472.49	472.35
16	14000	235.14	236.00	235.57	550.59	550.56	550.58
17	15000	257.15	273.15	265.15	589.71	589.07	589.39
18	16000	320.12	330.78	325.45	627.20	626.77	626.98
19	18000	466.11	469.16	467.63	701.36	701.23	701.29
20	20000	599.92	620.48	610.20	776.00	775.18	775.59
21	20000	560.82	516.89	538.85	777.57	779.32	778.45
22	25000	824.11	822.08	823.09	967.04	967.12	967.08
23	30000	1139.20	1146.31	1142.75	1154.43	1154.15	1154.29
24	35000	1442.86	1442.10	1442.48	1342.29	1342.32	1342.30
25	40000	1771.92	1779.79	1775.85	1529.12	1528.81	1528.97

*Amount of surfactant adsorbed

= (Initial concentration-Equilibrium concentration)*(volume of surfactant solution)/(silica weight)

Table A8 Adsorption isotherm of 1:1 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	200	5.25	5.22	5.24	7.79	7.79	7.79
2	400	8.75	8.75	8.75	15.65	15.65	15.65
3	600	12.75	12.75	12.75	23.49	23.49	23.49
4	800	14.17	14.24	14.21	31.43	31.43	31.43
5	1000	18.39	16.27	17.33	39.26	39.35	39.31
6	2000	28.94	29.13	29.04	78.84	78.83	78.84
7	3000	42.40	42.18	42.29	118.30	118.31	118.31
8	4000	54.98	55.07	55.02	157.80	157.80	157.80
9	5000	69.45	69.26	69.36	197.22	197.23	197.23
10	6000	82.68	82.62	82.65	236.69	236.70	236.69
11	7000	96.53	97.25	96.89	276.14	276.11	276.12
12	8000	112.06	112.59	112.33	315.52	315.50	315.51
13	9000	129.02	127.28	128.15	354.84	354.91	354.87
14	10000	142.56	140.17	141.37	394.30	394.39	394.35
15	12000	212.95	309.73	261.34	471.48	467.61	469.55
16	14000	399.80	398.56	399.18	544.01	544.06	544.03
17	15000	453.85	487.70	470.78	581.85	580.49	581.17
18	16000	585.23	593.93	589.58	616.59	616.24	616.42
19	18000	802.96	800.48	801.72	687.88	687.98	687.93
20	20000	984.66	1010.75	997.71	760.61	759.57	760.09
22	25000	1502.74	1509.58	1506.16	939.89	939.62	939.75
23	40000	14903.58	15571.37	15237.48	1003.86	977.15	990.50

*Amount of surfactant adsorbed

= (Initial concentration-Equilibrium concentration)*(volume of surfactant solution)/(silica weight)

Table A9 Adsorption isotherm of 1:3 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	200	8.52	8.52	8.52	7.66	7.66	7.66
2	400	8.18	9.20	8.69	15.67	15.63	15.65
3	600	12.05	11.09	11.57	23.52	23.56	23.54
4	800	14.73	15.19	14.96	31.41	31.39	31.40
5	1000	14.68	16.81	16.81	39.41	39.33	39.33
6	2000	26.71	27.67	27.19	78.93	78.89	78.91
7	3000	34.97	37.66	36.32	118.60	118.49	118.55
8	4000	48.25	45.68	46.96	158.07	158.17	158.12
9	5000	57.91	58.95	58.43	197.68	197.64	197.66
10	6000	69.32	69.95	69.64	237.23	237.20	237.21
11	7000	79.42	80.51	79.96	276.82	276.78	276.80
12	8000	88.82	91.88	90.35	316.45	316.32	316.39
13	9000	105.23	105.04	105 14	355.79	355.80	355.79
14	10000	118.58	120.52	119.55	395.26	395.18	395.22
15	12000	299.81	409.78	354.79	468.01	463.61	465.81
16	13000	379.20	376.96	378.08	504.83	504.92	504.88
17	15000	627.92	636.13	632.02	574.88	574.55	574.72
18	16000	700.64	711.08	705.86	611.97	611.56	611.77
19	17000	934.82	929.23	932.02	642.61	642 83	642.72
20	18000	1256.63	1176.46	1216.54	669.73	672.94	671.34
21	20000	1419.17	1450.54	1435.33	743.23	741.98	742.59
22	25000	2062.98	2110.57	2086.02	917.48	915.58	916.56
23	30000	2850.19	2872.41	2859.11	1085.99	1085.10	1085.64
24	35000	3236.18	3210.92	3223.55	1270.55	1271.56	1271.06
25	40000	3884.08	3921.23	3902.65	1444.64	1443.15	1443.89

*Amount of surfactant adsorbed

= (Initial concentration-Equilibrium concentration)*(volume of surfactant solution)/(silica weight)

Table A10 Adsorption isotherm of 0:1 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Equilibrium concentration (μM)			Amount of surfactant adsorbed* (μmol/g of silica)		
		1st	2nd	Average	1st	2nd	Average
1	200	118.35	89.23	103.79	3.27	4.43	3.85
2	400	113.90	127.68	120.79	11.44	10.89	11.17
3	600	137.83	137.41	137.62	18.49	18.50	18.50
4	800	141.21	140.75	140.98	26.35	26.37	26.36
5	1000	155.16	157.08	156.12	33.79	33.72	33.76
6	2000	195.07	197.36	196.22	72.20	72.11	72.15
7	3000	233.28	233.28	233.28	110.67	110.67	110.67
8	4000	254.24	248.56	251.40	149.83	150.06	149.94
9	5000	295.06	300.74	297.90	188.20	187.97	188.08
10	6000	328.03	315.37	321.70	226.88	227.39	227.13
11	7000	371.91	374.31	373.11	265.12	265.03	265.08
12	8000	418.85	424.96	421.91	303.25	303.00	303.12
13	9000	743.71	774.49	759.10	330.25	329.02	329.64
14	10000	1446.48	1353.48	1399.98	342.14	345.86	344.00
15	12000	3275.13	3179.07	3227.10	348.99	352.84	350.92
16	14000	5268.39	5226.91	5247.65	349.26	350.92	350.09
17	16000	7541.10	7453.77	7497.44	338.36	341.85	340.10
18	18000	9595.49	9652.26	9623.88	336.18	333.91	335.05
19	20000	11927.15	11835.46	11881.30	322.91	326.58	324.75
20	25000	15485.77	15564.36	15525.06	380.57	377.43	379.00

*Amount of surfactant adsorbed

= (Initial concentration-Equilibrium concentration)*(volume of surfactant solution)/(silica weight)

Table A11 Molar ratios of Arquad® T-50:Teric® X-10 adsorbed onto the silica surface at initial molar ratio 3:1 and pH 8

No.	Initial concentration (μM)	Total amount of surfactants adsorbed (μmol/g of silica)	Nonionic surfactant adsorbed (μmol/g of silica)	Cationic surfactant adsorbed (μmol/g of silica	Ratio Cationic : Nonionic adsorbed
1	600	23.62	4.29	19.34	4.51
2	1000	39.39	8.33	31.06	3.73
3	2000	78.82	18.29	60.53	3.31
4	4000	157.62	38.19	119.43	3.13
5	6000	236.31	57.83	178.48	3.09
6	8000	315.02	77.33	237.69	3.07
7	10000	393.64	96.98	296.66	3.06
8	14000	550.58	124.26	426.32	3.43
9	16000	626.98	129.49	497.49	3.84
10	20000	775.59	135.46	640.13	4.73

Table A12 Molar ratios of Arquad® T-50:Teric® X-10 adsorbed onto the silica surface at initial molar ratio 1:1 and pH 8

No.	Initial concentration (μM)	Total amount of surfactants adsorbed (μmol/g of silica)	Nonionic surfactant adsorbed (μmol/g of silica)	Cationic surfactant adsorbed (μmol/g of silica	Ratio Cationic : Nonionic adsorbed
1	600	23.49	9.26	14.23	1.54
2	1000	39.31	17.12	22.19	1.30
3	2000	78.84	36.87	41.97	1.14
4	4000	157.80	76.44	81.36	1.06
5	6000	236.69	113.84	122.86	1.08
6	8000	315.51	153.92	161.59	1.05
7	10000	394.35	188.52	205.82	1.09
8	14000	544.03	258.90	285.13	1.10
9	16000	616.42	205.99	410.43	1.99
10	20000	760.09	220.21	539.88	2.45

Table A13 Molar ratios of Arquad® T-50:Teric® X-10 adsorbed onto the silica surface at initial molar ratio 1:3 and pH 8

No.	Initial concentration (μM)	Total amount of surfactants adsorbed (μmol/g of silica)	Nonionic surfactant adsorbed (μmol/g of silica)	Cationic surfactant adsorbed (μmol/g of silica	Ratio Cationic : Nonionic adsorbed
1	600	23.54	14.38	9.15	0.64
2	1000	39.33	25.51	13.82	0.54
3	2000	78.91	55.26	23.66	0.43
4	4000	158.12	113.46	44.66	0.39
5	6000	237.21	172.62	64.59	0.37
6	8000	316.39	230.13	86.25	0.37
7	10000	395.22	270.27	124.95	0.46
8	16000	611.77	294.96	316.81	1.07
9	20000	742.63	333.35	409.27	1.23

Table A14 Zeta potential of 1:0 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Total amount of surfactants adsorbed (μmol/g of silica)
1	200	-53.36
2	1000	-58.65
3	2000	-49.81
4	3000	-22.19
5	7000	19.15
6	11000	34.35
7	18000	35.41

Table A15 Zeta potential of 3:1 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Total amount of surfactants adsorbed (μmol/g of silica)
1	200	-59.58
2	600	-57.21
3	1000	-48.91
4	2000	-39.50
5	3000	-35.71
6	4000	-21.48
7	5000	0.00
8	6000	7.34
9	8000	19.73
10	10000	27.86
11	12000	37.68
12	16000	40.46

Table A16 Zeta potential of 1:1 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Total amount of surfactants adsorbed (μmol/g of silica)
1	200	-69.27
2	600	-67.35
3	1000	-62.52
4	2000	-56.37
5	3000	-55.58
6	4000	-38.78
7	5000	-17.50
8	6000	10.76
9	8000	26.04
10	10000	38.02
11	12000	40.50
12	14000	44.26
13	16000	44.30

Table A17 Zeta potential of 1:3 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Total amount of surfactants adsorbed (μmol/g of silica)
1	200	-69.72
2	600	-65.18
3	1000	-64.73
4	2000	-58.69
5	3000	-53.49
6	4000	-52.72
7	5000	-46.31
8	6000	-42.20
9	8000	-29.54
10	10000	0.00
11	12000	27.65
12	16000	35.35

Table A17 Zeta potential of 0:1 molar ratio of Arquad® T-50:Teric® X-10 at pH 8

No.	Initial concentration (μM)	Total amount of surfactants adsorbed (μmol/g of silica)
1	200	-60.74
2	400	-63.61
3	600	-60.97
4	800	-54.86
5	1000	-49.00
6	2000	-40.91
7	3000	-38.98
8	4000	-37.65
9	6000	-36.99
10	8000	-29.06

Appendix B Continuous Stirred Tank Reactor

Co-monomer Loading Calculation

Table B1 Calculation of the amount of co-monomer loading for the surface modification

Monomer	Styrene	Isoprene
Mole ratio	1	3
Molecular weight	104.15	68.12
Density	0.906	0.681

Mole factor	Weight (g)		Total weight	Volume (ml)	
	Styrene	Isoprene		Styrene	Isoprene
0.01621	1.688	3.3120	5	1.863	4.863

Pump Flow Rate Determination

Table B2 Calculation of pump flow rate for 15 and 30 min retention times of the surface modification

Reactor size	1	liter (V)
Total run volume	12.5	liters

(τ)	($v = V / \tau$)		($t = \tau / v$)		
Mean resident time (min)	Flow rate		Total run time		
	ml / sec	ml / min	min	h	h : min
15	1.111	66.67	188	3.13	3:08
30	0.556	33.33	375	6.25	6:15

Calculation is based on a ratio of 80 grams silica per liter of surfactants solution, and for one-kilogram silica modification per a run.

Appendix C Rubber Compound Physical Properties Results

Table C1 Rubber compound physical properties filled with different modified silicas and unmodified silica (Hi-Sil® 255)

Property	Hi-Sil® 255	1:0		3:1		1:1		1:3		0:1	
		S	L	S	L	S	L	S	L	S	L
Cure Time (min)	7.07	5.89	4.25	5.27	5.41	4.15	4.77	4.25	5.06	7.68	3.95
100%Modulus @before aging (MPa)	1.34	1.55	1.54	1.39	1.49	1.52	1.43	1.23	1.33	1.54	1.60
100%Modulus @after aging (MPa)	1.89	2.30	1.81	2.18	2.41	1.83	2.16	1.85	2.06	2.12	1.84
200%Modulus @before aging (MPa)	2.25	2.72	2.59	2.38	2.69	2.52	2.41	2.04	2.21	2.61	2.62
200%Modulus @after aging (MPa)	3.37	4.00	3.11	3.75	4.18	3.18	3.67	3.14	3.40	3.64	3.20
300%Modulus @before aging (MPa)	3.71	4.49	4.10	3.84	4.75	3.88	3.91	3.18	3.57	4.37	4.13
300%Modulus @after aging (MPa)	5.36	6.34	4.83	5.68	6.67	4.85	5.76	4.80	5.16	5.58	4.96
Tensile Strength @before aging (MPa)	25.06	24.76	25.32	24.41	25.64	25.68	24.98	24.17	24.84	24.94	25.47
Tensile Strength @after aging (MPa)	24.79	22.38	24.07	21.03	22.53	23.00	21.65	21.90	21.68	22.94	23.99
Tear Strength @before aging (MPa)	83.70	81.05	66.85	82.43	81.59	59.83	81.74	64.31	81.83	79.96	69.31
Tear Strength @after aging (MPa)	62.44	59.07	54.67	54.60	56.15	57.57	54.34	50.73	49.25	64.16	60.67
Abrasion (ml/kcycle)	0.34	0.43	0.39	0.34	0.31	0.39	0.36	0.34	0.34	0.37	0.39
Resilience (%)	63.98	64.90	71.73	65.23	63.40	66.13	65.64	71.11	70.73	59.80	63.63
Compression set (%)	42.04	47.45	44.87	46.56	44.92	47.78	52.54	62.37	48.94	41.24	44.31
Hardness @before aging (shore A)	56.70	56.60	57.55	55.50	56.80	54.85	56.30	53.00	55.30	59.10	58.60
Hardness @after aging (shore A)	65.80	65.30	63.10	64.15	64.70	59.90	63.30	57.95	62.10	66.65	64.00

1:0, 3:1, 1:1, 1:3, 0:1 : ratio of surfactants, Arquad® T-50 to Teric® X-10 molar ratio

S, L : the retention times of polymerization, 15 and 30 min, respectively

Table C2 Rubber compound physical properties using different modified silicas obtained from the present study compared to the modified silicas of the previous studies using CTAB surfactant (Nontasorn, 2002 and Kiatdamneon-ngam, 2003)

Property	Silica 1*	Silica 2**	1:0		3:1		1:1		1:3		0:1	
			S	L	S	L	S	L	S	L	S	L
Cure Time (min)	4.86	5.07	5.89	4.25	5.27	5.41	4.15	4.77	4.25	5.06	7.68	3.95
100%Modulus @before aging (MPa)	1.92	1.77	1.55	1.54	1.39	1.49	1.52	1.43	1.23	1.33	1.54	1.60
100%Modulus @after aging (MPa)	2.36	2.28	2.30	1.81	2.18	2.41	1.83	2.16	1.85	2.06	2.12	1.84
200%Modulus @before aging (MPa)	3.29	3.02	2.72	2.59	2.38	2.69	2.52	2.41	2.04	2.21	2.61	2.62
200%Modulus @after aging (MPa)	4.26	4.22	4.00	3.11	3.75	4.18	3.18	3.67	3.14	3.40	3.64	3.20
300%Modulus @before aging (MPa)	5.55	5.01	4.49	4.10	3.84	4.75	3.88	3.91	3.18	3.57	4.37	4.13
300%Modulus @after aging (MPa)	7.02	7.20	6.34	4.83	5.68	6.67	4.85	5.76	4.80	5.16	5.58	4.96
Tensile Strength @before aging (MPa)	27.54	28.33	24.7	25.3	24.4	25.64	25.6	24.9	24.1	24.84	24.9	25.4
Tensile Strength @after aging (MPa)	25.68	27.37	22.3	24.0	21.0	22.53	23.0	21.6	21.9	21.68	22.9	23.9
Tear Strength @before aging (MPa)	58.94	54.12	81.0	66.8	82.4	81.59	59.8	81.7	64.3	81.83	79.9	69.3
Tear Strength @after aging (MPa)	54.49	54.43	59.0	54.6	54.6	56.15	57.5	54.3	50.7	49.25	64.1	60.6
Abrasion (ml/kcycle)	0.48	0.45	0.43	0.39	0.34	0.31	0.39	0.36	0.34	0.34	0.37	0.39
Resilience (%)	74.20	70.80	64.9	71.7	65.2	63.40	66.1	65.6	71.1	70.73	59.8	63.6
Compression set (%)	69.06	57.46	47.4	44.8	46.5	44.92	47.7	52.5	62.3	48.94	41.2	44.3
Hardness @before aging (shore A)	57.67	55.10	56.6	57.5	55.5	56.80	54.8	56.3	53.0	55.30	59.1	58.6
Hardness @after aging (shore A)	59.77	58.57	65.3	63.1	64.1	64.70	59.9	63.3	57.9	62.10	66.6	64.0

Silica 1 and 2 : modified silica with 200 g CTAB, 5 g of styrene-isoprene loading and 1.65 g AIBN per kg silica at 30 min retention time

* results from Nontasorn (2002), ** results from Kaitdamneon-ngam (2003)

Table C3 Rubber compound physical properties using different modified silicas obtained from the present study compared to the modified silicas of the previous study at similar surfactant molar ratios (Imsawatgul, 2004)

Property	CTAB:Triton X-100 molar ratio*				Arquad® T-50 : Teric® X-10 molar ratio			
	1:0	3:1	1:1	1:3	1:0	3:1	1:1	1:3
Cure Time (min)	4.82	5.58	5.49	5.28	4.25	5.41	4.77	5.06
100%Modulus @before aging (MPa)	1.22	1.54	1.15	1.57	1.54	1.49	1.43	1.33
100%Modulus @after aging (MPa)	1.91	2.12	1.92	2.15	1.81	2.41	2.16	2.06
200%Modulus @before aging (MPa)	2.10	2.62	2.02	2.72	2.59	2.69	2.41	2.21
200%Modulus @after aging (MPa)	3.48	3.85	3.35	3.96	3.11	4.18	3.67	3.40
300%Modulus @before aging (MPa)	3.40	4.13	3.22	4.27	4.10	4.75	3.91	3.57
300%Modulus @after aging (MPa)	5.45	6.07	5.63	6.27	4.83	6.67	5.76	5.16
Tensile Strength @before aging (MPa)	30.69	29.35	29.91	29.88	25.32	25.64	24.98	24.84
Tensile Strength @after aging (MPa)	25.60	26.20	26.90	28.00	24.07	22.53	21.65	21.68
Tear Strength @before aging (MPa)	65.60	75.38	64.74	69.82	66.85	81.59	81.74	81.83
Tear Strength @after aging (MPa)	55.26	54.98	54.61	57.60	54.67	56.15	54.34	49.25
Abrasion (ml/kcycle)	0.46	0.42	0.44	0.44	0.39	0.31	0.36	0.34
Resilience (%)	69.20	63.43	67.03	65.37	71.73	63.40	65.64	70.73
Compression set (%)	57.59	53.98	58.80	54.48	44.87	44.92	52.54	48.94
Hardness @before aging (shore A)	51.73	53.37	50.50	53.73	57.55	56.80	56.30	55.30
Hardness @after aging (shore A)	57.90	59.87	57.93	59.57	63.10	64.70	63.30	62.10

1:0, 3:1, 1:1, 1:3 : ratio of surfactants, Arquad® T-50 to Teric® X-10 molar ratio or CTAB to Triton X-100 molar ratio

* modified silica with CTAB and Triton X-100 in monolayer structure at 30 min polymerization time from Imsawatgul.(2004)

Table C4 Qualitative summary of surface-modified silica rubber physical properties as compared to the unmodified silica (Hi-Sil® 255)

Property	1:0		3:1		1:1		1:3		0:1	
	S	L	S	L	S	L	S	L	S	L
Cure Time (min)	+1	+1	+1	+1	+1	+1	+1	+1	0	+1
100%Modulus @before aging (MPa)	+1	+1	0	+1	+1	0	0	0	+1	+1
100%Modulus @after aging (MPa)	+1	0	+1	+1	0	+1	0	0	+1	0
200%Modulus @before aging (MPa)	+1	+1	0	+1	+1	0	0	0	+1	+1
200%Modulus @after aging (MPa)	+1	0	+1	+1	0	0	0	0	0	0
300%Modulus @before aging (MPa)	+1	+1	0	+1	0	0	-1	0	+1	+1
300%Modulus @after aging (MPa)	+1	0	0	+1	0	0	-1	0	0	0
Tensile Strength @before aging (MPa)	0	0	0	0	0	0	0	0	0	0
Tensile Strength @after aging (MPa)	0	0	-1	-1	0	-1	-1	-1	0	0
Tear Strength @before aging (MPa)	0	-1	0	0	-1	0	-1	0	0	-1
Tear Strength @after aging (MPa)	0	-1	-1	0	0	-1	-1	-1	0	0
Abrasion (ml/kcycle)	-1	-1	0	0	-1	0	0	0	0	-1
Resilience (%)	0	+1	0	0	0	0	+1	+1	0	0
Compression set (%)	-1	0	-1	0	-1	-1	-1	-1	0	0
Hardness @before aging (shore A)	0	0	0	0	0	0	0	0	0	0
Hardness @after aging (shore A)	0	0	0	0	0	0	-1	0	0	0
Comparative Score	**+5**	**+2**	**0**	**+6**	**0**	**-1**	**-5**	**-1**	**+4**	**+2**

Table C5 Qualitative summary of surface-modified silica rubber physical properties as compared to the modified silica of the previous study using CTAB surfactant (Nontasorn, 2002)

Property	1:0		3:1		1:1		1:3		0:1	
	S	L	S	L	S	L	S	L	S	L
Cure Time (min)	-1	+1	0	-1	+1	0	+1	0	-1	+1
100%Modulus @before aging (MPa)	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
100%Modulus @after aging (MPa)	0	-1	0	0	-1	0	-1	-1	-1	-1
200%Modulus @before aging (MPa)	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
200%Modulus @after aging (MPa)	0	-1	-1	0	-1	-1	-1	-1	-1	-1
300%Modulus @before aging (MPa)	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
300%Modulus @after aging (MPa)	0	-1	-1	0	-1	-1	-1	-1	-1	-1
Tensile Strength @before aging (MPa)	-1	0	-1	0	0	0	-1	0	0	0
Tensile Strength @after aging (MPa)	-1	0	-1	-1	-1	-1	-1	-1	-1	0
Tear Strength @before aging (MPa)	+1	+1	+1	+1	0	+1	0	+1	+1	+1
Tear Strength @after aging (MPa)	0	0	0	0	0	0	0	0	+1	+1
Abrasion (ml/kcycle)	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
Resilience (%)	-1	0	-1	-1	-1	-1	0	0	-1	-1
Compression set (%)	0	+1	+1	+1	+1	+1	0	+1	+1	+1
Hardness @before aging (shore A)	0	0	0	0	0	0	0	0	0	0
Hardness @after aging (shore A)	0	0	0	0	0	0	0	0	+1	0
Comparative Score	**-5**	**-2**	**-5**	**-3**	**-5**	**-4**	**-6**	**-4**	**-4**	**-2**

Table C6 Qualitative summary of surface-modified silica rubber physical properties as compared to the modified silica of the previous study using CTAB surfactant (Kaitdamneon-ngam, 2003)

Property	1:0		3:1		1:1		1:3		0:1	
	S	L	S	L	S	L	S	L	S	L
Cure Time (min)	-1	+1	0	0	+1	0	+1	0	-1	+1
100%Modulus @before aging (MPa)	-1	-1	-1	0	-1	-1	-1	-1	-1	0
100%Modulus @after aging (MPa)	0	-1	0	0	-1	0	-1	0	0	-1
200%Modulus @before aging (MPa)	0	-1	-1	-1	-1	-1	-1	-1	-1	-1
200%Modulus @after aging (MPa)	0	-1	-1	-1	-1	-1	-1	-1	-1	-1
300%Modulus @before aging (MPa)	-1	-1	-1	0	-1	-1	-1	-1	-1	-1
300%Modulus @after aging (MPa)	-1	-1	-1	0	-1	-1	-1	-1	-1	-1
Tensile Strength @before aging (MPa)	-1	-1	-1	0	0	-1	-1	-1	-1	-1
Tensile Strength @after aging (MPa)	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Tear Strength @before aging (MPa)	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
Tear Strength @after aging (MPa)	0	0	0	0	0	0	0	0	+1	+1
Abrasion (ml/kcycle)	0	+1	+1	+1	+1	+1	+1	+1	+1	+1
Resilience (%)	0	0	0	-1	0	0	0	0	-1	-1
Compression set (%)	+1	+1	+1	+1	+1	0	0	+1	+1	+1
Hardness @before aging (shore A)	0	0	0	0	0	0	0	0	0	0
Hardness @after aging (shore A)	+1	0	0	+1	0	0	0	0	+1	0
Comparative Score	**-3**	**-4**	**-4**	**0**	**-3**	**-5**	**-5**	**-4**	**-4**	**-3**

Table C7 Qualitative summary and percent improvement of surface-modified silica rubber physical properties obtained from the present study compared to the modified silicas of the previous study at similar surfactant molar ratios (Imsawatgul, 2004)

Property	Qualitative Summary				Percent Improvement			
	1:0	**3:1**	**1:1**	**1:3**	**1:0**	**3:1**	**1:1**	**1:3**
Cure Time (min)	+1	-1	0	0	11.8	-12.2	1.0	-5.0
100%Modulus @before aging (MPa)	+1	+1	+1	0	25.9	22.3	17.3	9.3
100%Modulus @after aging (MPa)	0	+1	+1	0	-5.4	26.0	13.1	7.8
200%Modulus @before aging (MPa)	+1	+1	+1	0	23.1	28.0	14.9	5.1
200%Modulus @after aging (MPa)	-1	+1	0	0	-10.5	20.0	5.4	-2.3
300%Modulus @before aging (MPa)	0	+1	+1	0	20.6	39.6	14.9	5.1
300%Modulus @after aging (MPa)	-1	+1	0	0	-11.3	22.4	5.7	-5.4
Tensile Strength @before aging (MPa)	-1	-1	-1	-1	-17.5	-16.5	-18.6	-19.1
Tensile Strength @after aging (MPa)	0	-1	-1	-1	-6.0	-12.0	-15.4	-15.3
Tear Strength @before aging (MPa)	0	+1	+1	+1	1.9	24.4	24.6	24.7
Tear Strength @after aging (MPa)	0	0	0	-1	-1.1	1.6	-1.7	-10.9
Abrasion (ml/kcycle)	+1	+1	+1	+1	16.3	32.6	21.7	26.1
Resilience (%)	0	0	0	0	3.7	-8.4	-5.2	2.2
Compression set (%)	+1	+1	0	+1	22.1	22.0	8.8	15.0
Hardness @before aging (shore A)	+1	0	0	0	11.3	9.8	8.8	6.9
Hardness @after aging (shore A)	0	+1	0	0	9.0	11.7	9.3	7.3
Comparative Score	**+3**	**+7**	**+4**	**0**				

1:0, 3:1, 1:1, 1:3 : ratio of surfactants, Arquad® T-50 to Teric® X-10 molar ratio

Table C8 Percent improvement of surface-modified silica rubber physical properties as compared to the unmodified silica (Hi-Sil® 255)

Property	1:0		3:1		1:1		1:3		0:1	
	S	L	S	L	S	L	S	L	S	L
Cure Time (min)	16.6	39.8	25.4	23.4	41.3	32.5	39.8	28.4	-8.7	44.1
100%Modulus @before aging (MPa)	15.8	15.1	3.9	20.0	13.9	7.2	-7.9	-0.1	15.7	20.1
100%Modulus @after aging (MPa)	21.4	-4.6	15.1	18.3	-3.5	14.0	-2.1	8.7	12.0	-2.9
200%Modulus @before aging (MPa)	21.3	15.1	6.0	25.1	12.4	7.4	-9.2	-1.7	16.2	16.8
200%Modulus @after aging (MPa)	18.7	-7.5	11.3	17.4	-5.7	9.0	-6.8	1.0	8.1	-5.1
300%Modulus @before aging (MPa)	21.0	10.5	3.4	30.0	4.5	5.2	-14.4	-3.7	17.7	11.2
300%Modulus @after aging (MPa)	18.3	-9.8	6.1	15.6	-9.5	7.5	-10.5	-3.7	4.2	-7.4
Tensile Strength @before aging (MPa)	-1.2	1.0	-2.6	1.3	2.5	-0.3	-3.6	-0.9	-0.5	1.6
Tensile Strength @after aging (MPa)	-9.7	-2.9	-15.2	-12.2	-7.2	-12.7	-11.7	-12.5	-7.5	-3.2
Tear Strength @before aging (MPa)	-3.2	-20.1	-1.5	-3.6	-28.5	-2.3	-23.2	-2.2	-4.5	-17.2
Tear Strength @after aging (MPa)	-5.4	-12.4	-12.6	-8.6	-7.8	-13.0	-18.8	-21.1	2.7	-2.8
Abrasion (ml/kcycle)	-25.0	-13.2	0.0	4.4	-13.2	-5.9	0.0	0.0	-7.4	-14.7
Resilience (%)	1.4	12.1	2.0	0.9	3.4	2.6	11.1	10.6	-6.5	-0.5
Compression set (%)	-12.9	-6.7	-10.8	-3.8	-13.6	-25.0	-48.4	-16.4	1.9	-5.4
Hardness @before aging (shore A)	-0.2	1.5	-2.1	-1.1	-3.3	-0.7	-6.5	-2.5	4.2	3.4
Hardness @after aging (shore A)	-0.8	-4.1	-2.5	-1.7	-9.0	-3.8	-11.9	-5.6	1.3	-2.7

Table C9 Percent improvement of surface-modified silica rubber physical properties as compared to the modified silica of the previous study using CTAB surfactant (Nontasorn, 2002)

Property	1:0		3:1		1:1		1:3		0:1	
	S	L	S	L	S	L	S	L	S	L
Cure Time (min)	-21.2	12.6	-8.4	-11.3	14.6	1.9	12.6	-4.1	-58.0	18.7
100%Modulus @before aging (MPa)	-19.5	-20.0	-27.7	-22.3	-20.8	-25.5	-36.0	-30.6	-19.6	-16.5
100%Modulus @after aging (MPa)	-2.6	-23.5	-7.6	2.0	-22.6	-8.5	-21.4	-12.8	-10.1	-22.0
200%Modulus @before aging (MPa)	-17.2	-21.4	-27.7	-18.3	-23.3	-26.7	-38.0	-32.9	-20.7	-20.3
200%Modulus @after aging (MPa)	-6.2	-26.9	-12.0	-2.0	-25.4	-13.9	-26.4	-20.2	-14.6	-25.0
300%Modulus @before aging (MPa)	-19.1	-26.1	-30.8	-14.5	-30.1	-29.6	-42.7	-35.6	-21.3	-25.6
300%Modulus @after aging (MPa)	-9.7	-31.2	-19.0	-5.0	-31.0	-18.0	-31.7	-26.5	-20.5	-29.4
Tensile Strength @before aging (MPa)	-10.1	-8.1	-11.4	-6.9	-6.8	-9.3	-12.2	-9.8	-9.4	-7.5
Tensile Strength @after aging (MPa)	-12.9	-6.3	-18.1	-12.3	-10.5	-15.7	-14.7	-15.6	-10.7	-6.6
Tear Strength @before aging (MPa)	37.5	13.4	39.8	38.4	1.5	38.7	9.1	38.8	35.7	17.6
Tear Strength @after aging (MPa)	8.4	0.3	0.2	3.0	5.6	-0.3	-6.9	-9.6	17.7	11.3
Abrasion (ml/kcycle)	11.5	19.8	29.2	35.4	19.8	25.0	29.2	29.2	24.0	18.8
Resilience (%)	-12.5	-3.3	-12.1	-14.6	-10.9	-11.5	-4.2	-4.7	-19.4	-14.2
Compression set (%)	31.3	35.0	32.6	35.0	30.8	23.9	9.7	29.1	40.3	35.8
Hardness @before aging (shore A)	-1.9	-0.2	-3.8	-1.5	-4.9	-2.4	-8.1	-4.1	2.5	1.6
Hardness @after aging (shore A)	9.3	5.6	7.3	8.2	0.2	5.9	-3.0	3.9	11.5	7.1

Table C10 Percent improvement of surface-modified silica rubber physical properties as compared to the modified silica of the previous study using CTAB surfactant (Kaitdamneon-ngam, 2003)

Property	1:0		3:1		1:1		1:3		0:1	
	S	L	S	L	S	L	S	L	S	L
Cure Time (min)	-16.2	16.2	-3.9	-6.7	18.1	5.9	16.2	0.2	-51.5	22.1
100%Modulus @before aging (MPa)	-12.7	-13.2	-21.6	-15.7	-14.1	-19.2	-30.6	-24.7	-12.8	-9.4
100%Modulus @after aging (MPa)	0.9	-20.8	-4.4	5.6	-19.8	-5.3	-18.7	-9.7	-6.9	-19.3
200%Modulus @before aging (MPa)	-9.8	-14.4	-21.2	-11.0	-16.4	-20.1	-32.5	-26.9	-13.6	-13.1
200%Modulus @after aging (MPa)	-5.3	-26.2	-11.2	-1.0	-24.7	-13.1	-25.7	-19.4	-13.8	-24.3
300%Modulus @before aging (MPa)	-10.3	-18.1	-23.4	-5.2	-22.5	-22.1	-36.6	-28.7	-12.8	-17.6
300%Modulus @after aging (MPa)	-12.0	-32.9	-21.1	-7.4	-32.7	-20.0	-33.4	-28.4	-22.5	-31.2
Tensile Strength @before aging (MPa)	-12.6	-10.6	-13.8	-9.5	-9.4	-11.8	-14.7	-12.3	-12.0	-10.1
Tensile Strength @after aging (MPa)	-18.2	-12.1	-23.2	-17.7	-16.0	-20.9	-20.0	-20.8	-16.2	-12.3
Tear Strength @before aging (MPa)	49.8	23.5	52.3	50.8	10.6	51.0	18.8	51.2	47.7	28.1
Tear Strength @after aging (MPa)	8.5	0.4	0.3	3.2	5.8	-0.2	-6.8	-9.5	17.9	11.5
Abrasion (ml/kcycle)	5.6	14.4	24.4	31.1	14.4	20.0	24.4	24.4	18.9	13.3
Resilience (%)	-8.3	1.3	-7.9	-10.5	-6.6	-7.3	0.4	-0.1	-15.5	-10.1
Compression set (%)	17.4	21.9	19.0	21.8	16.9	8.6	-8.5	14.8	28.2	22.9
Hardness @before aging (shore A)	2.7	4.4	0.7	3.1	-0.5	2.2	-3.8	0.4	7.3	6.4
Hardness @after aging (shore A)	11.5	7.7	9.5	10.5	2.3	8.1	-1.1	6.0	13.8	9.3

Table C11 Qualitative summary of rubber physical properties using different modified silicas

Property	1:0		3:1		1:1		1:3		0:1	
	S	L	S	L	S	L	S	L	S	L
Cure Time (min)	2	7.5	4	3	9	6	7.5	5	1	10
100%Modulus @before aging (MPa)	9	7	3	5	6	4	1	2	8	10
100%Modulus @after aging (MPa)	9	1	8	10	2	7	4	5	6	3
200%Modulus @before aging (MPa)	10	6	3	9	5	4	1	2	7	8
200%Modulus @after aging (MPa)	9	1	8	10	3	7	2	5	6	4
300%Modulus @before aging (MPa)	9	6	3	10	4	5	1	2	8	7
300%Modulus @after aging (MPa)	9	2	7	10	3	8	1	5	6	4
Tensile Strength @before aging (MPa)	3	7	2	9	10	6	1	4	5	8
Tensile Strength @after aging (MPa)	5	10	1	6	8	2	4	3	7	9
Tear Strength @before aging (MPa)	6	3	10	7	1	8	2	9	5	4
Tear Strength @after aging (MPa)	8	5	4	6	7	3	2	1	10	9
Abrasion (ml/kcycle)	1	3.5	8	10	3.5	6	8	8	5	2
Resilience (%)	4	10	5	2	7	6	9	8	1	3
Compression set (%)	5	8	6	7	4	2	1	3	10	9
Hardness @before aging (shore A)	6	8	4	7	2	5	1	3	10	9
Hardness @after aging (shore A)	9	4	7	8	2	5	1	3	10	6
Total	**104**	**89**	**83**	**119**	**76.5**	**84**	**46.5**	**68**	**105**	**105**

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