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APPENDICES

Appendix A : Technical data of nonionic surfactants (Handbook of Industrial Surfactant).

Technical Data for CO-610

Igepal CO-610 [Rhone-Poulenc Surf] Nonoxynol-8 (7-8 EO); CAS 9016-45-9; nonionic; low foaming detergent, wetting agent, emulsifier, lubricant; for metal working; biodeg; FDA compliance; pale yel. Liq., aromatic odor, sol. in naphtha, xylene, butyl Cellusolve, perchloroethylene, ethanol, water, sp.gr. 1.05; visc. 230-290 cps; HLB 12.2; cloud pt. 72-82 F (1%) flash pt. > 200 F (PMCC); pour pt. 37 ± 2 F; surf. Tens. 30 dynes/cm (0.01 %); 100 %act.

Technical Data for CO-630

Igepal CO-630 [Rhone-Poulenc Surf] Nonoxynol-9 ; CAS 9016-45-9; nonionic; detergent, wetting agent and rewetting agent, corrosion inhibitor, penetrant, emulsifier, dispersant for textile, paper, leather, household/industrial cleaners, agric., paints, metal processing, emulsion cleaning ; biodeg; FDA, EPA compliance; almost colorless liq., aromatic odor, sol. in naphtha, xylene, butyl Cellusolve, perchloroethylene, ethanol, water, sp.gr. 1.06; visc. 225-300 cps; HLB 13.0; cloud pt. 126-133 F (1%) flash pt. > 200 F (PMCC); pour pt. 31 ± 2 F; surf. Tens. 31 dynes/cm (0.01 %); toxicology: severe eye irritant; LD50(oral, rat) 3 g/kg; 100 %act.

Technical Data for CO-660

Igepal CO-660 [Rhone-Poulenc Surf] Nonoxynol-10, CAS 9016-45-9; nonionic; detergent, wetting agent and rewetting agent, corrosion inhibitor, penetrant, emulsifier for textile, paper, leather, household/industrial cleaners, agric., paints, metal processing, emulsion cleaning ; biodeg; FDA, EPA compliance; pale yel. liq., aromatic odor, sol. in naphtha, xylene, butyl Cellusolve, perchloroethylene, ethanol, water, sp.gr. 1.06; visc. 225-275 cps; HLB 13.2 ; cloud pt. 140-149 F (1%); flash pt. > 200 F (PMCC) ; pour pt. 46±2 F; surf. Tens. 31 dynes/cm (0.01 %); 100 %act.

Appendix B : Ross-Miles Test Data

Table B-1 Foam height of $NP(EO)_8$ at different temperature

Temp (°C)	Foam height of $NP(EO)_8$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
10	12.1	11.5	13.1	10.9	12.6	11.2	0.71	0.46
15	13.0	10.0	12.5	10.8	12.8	10.4	0.35	0.53
18	13.2	10.0	13.0	10.2	13.1	10.1	0.18	0.18
20	12.9	10.4	13.2	11.0	13.1	10.7	0.21	0.39
22	12.5	10.0	12.5	9.5	12.5	9.8	0.00	0.35
24	12.3	9.8	12.4	9.9	12.3	9.8	0.07	0.07
26	11.8	9.3	11.8	9.3	11.8	9.3	0.00	0.00
28	11.0	9.0	11.3	8.3	11.1	8.6	0.18	0.53
30	10.0	7.5	10.3	7.8	10.1	7.6	0.18	0.18
40	7.7	6.5	7.2	5.0	7.5	5.7	0.35	1.06
50	7.3	4.0	7.3	3.5	7.3	3.8	0.00	0.35
60	7.4	3.9	6.9	3.6	7.1	3.7	0.35	0.18
70	6.4	2.6	5.9	2.6	6.1	2.6	0.35	0.00

Table B-2 Foam height of $NP(EO)_9$ at different temperature

Temp (°C)	Foam height of $NP(EO)_9$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
10	16.7	14.7	16.9	14.6	16.8	14.7	0.11	0.07
20	18.2	15.5	17.0	13.5	17.6	14.5	0.85	1.41
30	17.8	14.6	17.3	14.3	17.6	14.4	0.35	0.18
40	16.9	11.4	18.2	10.7	17.5	11.0	0.88	0.53
45	17.0	6.5	16.9	7.6	16.9	7.0	0.07	0.81
50	16.4	4.1	16.1	4.4	16.2	4.2	0.18	0.18
52	16.1	3.4	17.0	4.5	16.6	3.9	0.64	0.81
54	19.5	3.3	19.8	2.3	19.6	2.8	0.18	0.71
56	17.0	1.3	17.0	2.5	17.0	1.9	0.00	0.85
58	13.4	1.6	14.0	2.2	13.7	1.9	0.42	0.42
60	9.3	0.9	9.6	1.6	9.4	1.2	0.18	0.46
65	5.3	0.8	4.9	0.8	5.1	0.8	0.28	0.00
70	4.1	0.7	4.1	0.5	4.1	0.6	0.00	0.14
80	4.1	0.6	4.1	0.6	4.1	0.6	0.00	0.00

Table B-3 Foam height of $NP(EO)_{10}$ at different temperature

Temp (°C)	Foam height of $NP(EO)_{10}$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
10	17.4	16.6	17.4	16.6	17.4	16.6	0.00	0.00
20	18.1	16.1	17.7	15.7	17.9	15.9	0.28	0.28
30	18.7	16.2	18.0	16.2	18.3	16.2	0.53	0.00
40	17.9	13.4	17.9	13.6	17.9	13.5	0.00	0.18
50	17.4	12.6	17.9	11.1	17.6	11.9	0.35	1.06
55	17.6	10.6	17.1	10.6	17.4	10.6	0.35	0.00
60	17.4	9.9	16.4	7.2	16.9	8.5	0.71	1.94
62	17.3	6.1	15.3	5.1	16.3	5.6	1.41	0.71
64	16.2	4.7	15.7	5.5	16.0	5.1	0.35	0.53
66	21.1	4.1	21.2	4.7	21.2	4.4	0.07	0.42
68	20.2	2.7	19.6	3.4	19.9	3.0	0.42	0.46
70	15.7	2.4	15.3	1.8	15.5	2.1	0.28	0.42
75	7.2	1.7	8.2	2.2	7.7	2.0	0.71	0.35
80	5.2	1.2	5.2	1.2	5.2	1.2	0.00	0.00

Table B-4 Stability Index of $NP(EO)_8$ at different temperature

Temp (°C)	Stability Index of $NP(EO)_8$		
	First run	Second run	Average
10	0.95	0.83	0.89
15	0.77	0.86	0.81
18	0.75	0.79	0.77
20	0.81	0.83	0.82
22	0.80	0.76	0.78
24	0.80	0.80	0.80
26	0.79	0.79	0.79
28	0.82	0.73	0.78
30	0.75	0.76	0.75
40	0.84	0.69	0.76
50	0.55	0.48	0.52
60	0.52	0.53	0.52
70	0.41	0.44	0.43

Table B-5 Stability Index of $NP(EO)_9$ at different temperature

Temp (°C)	Stability Index of $NP(EO)_9$		
	First run	Second run	Average
10	0.88	0.87	0.87
20	0.85	0.79	0.82
30	0.82	0.83	0.82
40	0.67	0.59	0.63
45	0.38	0.45	0.42
50	0.25	0.27	0.26
52	0.21	0.26	0.24
54	0.17	0.11	0.14
56	0.08	0.15	0.11
58	0.12	0.16	0.14
60	0.10	0.16	0.13
65	0.15	0.16	0.16
70	0.17	0.12	0.15
80	0.15	0.15	0.15

Table B-6 Stability Index of $NP(EO)_{10}$ at different temperature

Temp (°C)	Stability Index of $NP(EO)_{10}$		
	First run	Second run	Average
10	0.96	0.96	0.96
20	0.89	0.89	0.89
30	0.87	0.90	0.88
40	0.75	0.76	0.75
50	0.73	0.62	0.67
55	0.60	0.62	0.61
60	0.57	0.44	0.50
62	0.35	0.33	0.34
64	0.29	0.35	0.32
66	0.19	0.22	0.21
68	0.13	0.17	0.15
70	0.15	0.12	0.14
75	0.24	0.27	0.25
80	0.23	0.23	0.23

Table B-7 Foam height of $NP(EO)_9$ at 30 °C and 60 °C at different concentrations

Concentration (M)	Foam height of $NP(EO)_9$				
	At 30 °C		At 60 °C		Appearance of solution at 60 °C
	0 min	5 min	0 min	5 min	
0.0005	10.1	8.1	7.2	2.6	Clear
0.001	11.3	8.8	9.4	1.6	Clear
0.003	14.6	12.4	12.6	4.7	Clear
0.005	16.5	11.7	8.2	1.9	Cloudy
0.01	17.2	13.4	8.7	1.9	Cloudy
0.02	17.7	14.1	13.2	5.5	Cloudy

Table B-8 Foam height of dilute phase of $NP(EO)_8$ at phase separation temperature of 25 °C

Temp (°C)	Foam height of dilute phase at phase separation temperature of 25 °C of $NP(EO)_8$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
10	11.0	10.4	11.0	10.3	11.00	10.35	0.00	0.07
20	11.4	8.9	11.40	9.1	11.40	9.0	0.00	0.07
25	11.9	8.7	11.8	8.5	11.83	8.58	0.11	0.11
35	5.9	5.4	5.9	5.2	5.85	5.23	0.00	0.09
45	4.8	3.3	4.3	4.3	4.50	2.88	0.35	0.71
55	4.3	33	4.2	3.0	4.20	3.13	0.07	0.18

Table B-9 Foam height of dilute phase of $NP(EO)_8$ at phase separation temperature of 35 °C

Temp (°C)	Foam height of dilute phase at phase separation temperature of 35 °C of $NP(EO)_8$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
10	10.2	7.5	9.8	7.5	10.00	7.50	0.28	0.00
20	10.5	8.0	10.5	7.8	10.50	7.90	0.00	0.14
25	11.3	8.0	10.8	7.0	11.00	7.50	0.35	0.71
30	11.1	8.0	10.9	8.6	11.00	8.30	0.14	0.42
35	11.5	8.0	10.6	7.8	11.05	7.80	0.64	0.14
40	11.4	7.4	11.4	7.4	11.40	7.40	0.00	0.00
45	3.3	2.5	4.0	4.0	3.63	2.65	0.53	1.06
55	4.3	3.3	4.2	3.0	4.25	3.13	0.07	0.18

Table B-10 Foam height of dilute phase of $NP(EO)_8$ at phase separation temperature of 45 °C

Temp (°C)	Foam height of dilute phase at phase separation temperature of 45 °C of $NP(EO)_8$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
10	7.5	7.3	7.5	7.5	7.50	7.40	0.00	0.14
20	7.5	6.8	7.5	7.2	7.50	7.00	0.00	0.28
25	8.2	7.5	7.5	6.8	7.85	7.10	0.49	0.49
30	8.2	6.8	7.6	7.0	7.80	6.90	0.42	0.14
35	8.0	6.8	7.0	6.5	7.50	6.50	0.71	0.18
40	7.7	6.2	7.7	5.8	7.70	6.00	0.00	0.28
45	7.6	6.1	7.8	7.8	7.68	5.55	0.11	1.17
50	8.3	5.2	7.7	4.6	8.00	4.90	0.42	0.42
55	4.3	3.3	4.2	3.0	4.20	3.13	0.07	0.18

Table B-11 Foam height of dilute phase of $NP(EO)_9$ at phase separation temperature of 55 °C

Temp (°C)	Foam height of dilute phase at phase separation temperature of 55 °C of $NP(EO)_9$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
25	16.0	13.9	16.0	14.0	16.00	13.95	0.00	0.07
35	16.9	10.7	16.8	11.0	16.85	10.85	0.07	0.21
45	17.1	7.9	17.0	7.0	17.05	7.80	0.07	0.60
50	16.0	5.3	16.0	5.7	16.00	5.50	0.00	0.28
55	15.6	4.6	15.5	4.5	15.55	4.55	0.07	0.07
60	14.7	2.4	15.3	2.5	15.00	2.60	0.42	0.07
65	14.7	2.5	14.9	2.5	14.80	2.50	0.14	0.00
70	3.9	1.4	4.0	1.4	3.85	1.40	0.07	0.00

Table B-12 Foam height of dilute phase of $NP(EO)_9$ at phase separation temperature of 70 °C

Temp (°C)	Foam height of dilute phase at phase separation temperature of 70 °C of $NP(EO)_9$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
25	10.1	9.0	10.0	9.0	10.05	9.00	0.07	0.00
35	10.5	9.2	10.5	8.8	10.05	9.00	0.00	0.28
45	11.5	7.0	11.5	7.9	11.50	7.45	0.00	0.64
50	12.4	3.8	12.5	4.0	12.45	3.90	0.07	0.14
55	12.4	6.9	11.8	6.8	12.00	6.85	0.42	0.07
60	12.4	2.8	12.5	3.0	12.40	2.90	0.07	0.014
65	12.3	1.5	12.7	1.9	12.50	1.70	0.28	0.28
70	11.6	1.6	11.7	1.6	11.65	1.60	0.07	0.00

Table B-13 Foam height of dilute phase of $NP(EO)_{10}$ at phase separation temperature of 70 °C

Temp (°C)	Foam height of dilute phase at phase separation temperature of 70 °C of $NP(EO)_{10}$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
25	10.8	9.0	10.7	8.8	10.75	8.88	0.05	0.18
35	10.3	9.0	10.7	9.0	10.50	9.00	0.28	0.00
45	11.5	7.0	11.5	7.1	11.50	7.05	0.00	0.07
55	12.4	6.9	12.3	6.8	12.35	6.85	0.07	0.07
70	12.0	1.6	12.2	1.6	12.10	1.60	0.14	0.00
75	12.0	1.0	12.0	1.4	12.00	1.20	0.00	0.28
80	11.9	0.5	12.1	0.7	12.00	0.60	0.14	0.14

Table B-14 Foam height of coacervate phase of $NP(EO)_8$ at phase separation temperature of 25 °C

Temp (°C)	Foam height of coacervate phase at phase separation temperature of 25 °C of $NP(EO)_8$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
25	1.5	1.2	1.5	1.2	1.50	1.20	0.00	0.00
35	5.8	4.1	5.1	3.1	5.45	3.58	0.49	0.67
45	6.7	3.5	7.2	2.7	6.95	3.08	0.35	0.53
55	12.7	3.2	13.3	3.3	13.00	3.25	0.42	0.07

Table B-15 Foam height of coacervate phase of $NP(EO)_8$ at phase separation temperature of 35 °C

Temp (°C)	Foam height of coacervate phase at phase separation temperature of 35 °C of $NP(EO)_8$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
25	1.1	0.7	1.4	0.8	1.23	0.75	0.18	0.07
35	3.8	3.1	3.5	3.2	3.63	3.13	0.25	0.11
45	5.3	4.5	5.0	4.3	5.13	4.38	0.18	0.18
55	13.3	11.8	12.5	11.0	12.88	11.38	0.53	0.53

Table B-16 Foam height of coacervate phase of $NP(EO)_8$ at phase separation temperature of 45 °C

Temp (°C)	Foam height of coacervate phase at phase separation temperature of 45 °C of $NP(EO)_8$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
25	0.5	0.2	0.5	0.3	0.50	0.25	0.00	0.07
35	1.4	1.0	1.6	1.0	1.50	1.00	0.14	0.00
45	4.7	2.0	4.3	1.9	4.45	1.95	0.21	0.07
55	8.2	0.8	8.8	1.5	8.50	1.15	0.42	0.49

Table B-17 Foam height of coacervate phase of $NP(EO)_9$ at phase separation temperature of 55 °C

Temp (°C)	Foam height of coacervate phase at phase separation temperature of 55 °C of $NP(EO)_9$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
25	14.4	12.7	14.2	12.7	14.28	12.65	0.18	0.00
35	13.4	10.4	13.2	10.7	13.30	10.55	0.14	0.21
45	13.5	12.0	13.5	11.9	13.45	11.95	0.00	0.07
55	12.2	5.5	12.6	6.1	12.40	5.80	0.28	0.42
70	7.7	1.1	7.7	1.3	7.70	1.20	0.00	0.14

Table B-18 Foam height of coacervate phase of $NP(EO)_9$ at phase separation temperature of 70 °C

Temp (°C)	Foam height of coacervate phase at phase separation temperature of 70 °C of $NP(EO)_9$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
25	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00
35	0.7	0.7	0.5	0.5	0.60	0.60	0.14	0.14
45	1.3	0.9	1.0	0.6	1.15	0.75	0.21	0.21
55	6.3	4.3	5.9	3.9	6.10	4.10	0.28	0.28
70	10.7	1.7	10.5	1.5	10.60	1.60	0.14	0.14

Table B-19 Foam height of coacervate phase of $NP(EO)_{10}$ at phase separation temperature of 70 °C

Temp (°C)	Foam height of coacervate phase at phase separation temperature of 70 °C of $NP(EO)_{10}$ (cm)							
	First run		Second run		Average		Standard Deviation	
	0 min	5 min	0 min	5 min	0 min	5 min	0 min	5 min
25	11.1	9.1	11.2	9.2	11.15	9.15	0.07	0.07
35	11.1	8.9	11.3	9.0	11.20	8.95	0.14	0.07
45	11.3	7.8	11.3	8.2	11.25	8.00	0.28	0.00
55	10.8	2.8	10.7	2.7	10.75	2.75	0.07	0.07
70	10.9	1.1	11.0	1.2	10.95	1.15	0.07	0.07

Appendix C : Surfactant concentration in liquid foam data

Table C-1 Surfactant concentration in liquid foam of $NP(EO)_8$

Temp (^oC)	Surfactant concentration in liquid foam of $NP(EO)_8$ (M)
20	0.0237
22	0.0219
23	0.0226
24	0.0219
26	0.0216
30	0.0131

Table C-2 Surfactant concentration in liquid foam of $NP(EO)_9$

Temp (^oC)	Surfactant concentration in liquid foam of $NP(EO)_9$ (M)
48	0.0247
50	0.0243
52	0.0231
53	0.0227
54	0.0252
55	0.0249
56	0.0190
58	0.0159
60	0.0130

Table C-3 Surfactant concentration in liquid foam of $NP(EO)_{10}$

Temp (^oC)	Surfactant concentration in liquid foam of $NP(EO)_{10}$ (M)
60	0.0205
62	0.0208
64	0.0208
65	0.0208
66	0.0233
67	0.0225
68	0.0211
70	0.0210
72	0.0117

Appendix D : Surface tension data

Table D-1 Surface tension of $NP(EO)_8$

Temp (°C)	Surface tension of $NP(EO)_8$ (mN/m)
20	31.00
22	30.83
23	30.70
24	30.72
26	30.67
28	30.65
30	30.55

Table D-2 Surface tension of $NP(EO)_9$

Temp (°C)	Surface tension of $NP(EO)_9$ (mN/m)
48	30.84
50	30.62
52	30.31
53	30.20
54	29.81
55	30.09
56	30.29
58	30.38
60	29.86

Table D-3 Surface tension of $NP(EO)_{10}$

Temp (°C)	Surface tension of $NP(EO)_{10}$ (mN/m)
60	30.58
62	30.33
64	30.20
65	30.05
66	29.95
67	30.08
68	30.18
70	30.15
72	30.05

Appendix E : Technical Data

Table E-1 Technical data of each raw material

Surfactants	Cloud point specification (^{o}C)	Molecular weight	Density (g/cm^3)	CMC* (mole/l)
$NP(EO)_8$	22 – 28	572	1.05	$4.4*10^{-5}$
$NP(EO)_9$	52 – 56	616	1.05	$6.7*10^{-5}$
$NP(EO)_{10}$	60 - 65	660	1.06	$6.8*10^{-5}$

* From Handbook of surfactants

Table E-2 Comparison of concentrations of the surfactant solution in different units

Surfactants	Molecular weight	Concentration	
		wt%	M
$NP(EO)_8$	572	1	0.0175
$NP(EO)_9$	616	1	0.0162
$NP(EO)_{10}$	660	1	0.0152

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