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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$\pm$2 F; surf. Tens. 31 dynes/cm (0.01 %); 100 % act.

Appendix B: Technical Data.

Table B-1 Technical data of each raw material.

Surfactants	Cloud point specification (°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 B-2 Comparison of concentrations of the surfactant solution in different units.

Surfactants	Molecular weight	Concentration	
		wt%	M
$NP(EO)_8$	572	0.5	0.0087
		1.0	0.0175
$NP(EO)_9$	616	0.5	0.0081
		1.0	0.0162
$NP(EO)_{10}$	660	0.5	0.0075
		1.0	0.0152

Appendix C: Cloud point test data.

Table C-1 Cloud point of 0.01 M $NP(EO)_8$/SDS and $NP(EO)_9$/SDS at different mole ratio.

X_{SDS}	Cloud point (^{O}C)	
	$NP(EO)_8$	$NP(EO)_9$
0.000	27	55
0.001	31	57
0.002	46	61
0.003	53	74
0.004	56	77
0.005	72	86

Table C-2 Cloud point of 0.01 M $NP(EO)_8$/SDS, $NP(EO)_9$/SDS, and $NP(EO)_{10}$ /SDS ratio 0.9/0.1 with NaCl.

$NP(EO)_8$/SDS	
C_{NaCl} (M)	CP (°C)
0.000	91.0
0.010	77.0
0.014	73.0
0.020	57.5
0.025	46.0
0.030	43.0
0.040	40.0
0.060	33.0
0.070	32.0
0.075	31.5
0.080	31.0
0.100	26.0

$NP(EO)_9$/SDS	
C_{NaCl} (M)	CP (°C)
0.020	84.0
0.060	66.0
0.080	63.0
0.100	61.0
0.120	59.0
0.140	58.0
0.160	57.0
0.200	55.0
0.240	52.0
0.300	50.0
0.400	47.0
0.500	44.0

$NP(EO)_{10}$/SDS	
C_{NaCl} (M)	CP (°C)
0.050	74.0
0.100	69.0
0.200	63.0
0.250	60.5
0.300	59.0
0.400	55.5
0.450	54.5
0.500	53.0
0.600	50.0
0.700	48.0
0.800	46.0
1.000	42.0

Table C-3 Cloud point of 0.01 M $NP(EO)_8/SDS$ with NaCl at varying mole ratio.

$NP(EO)_8/SDS$ + NaCl									
1.0/0.0		0.9/0.1		0.8/0.2		0.7/0.3		0.6/0.4	
C_{NaCl} (M)	CP (°C)	C_{NaCl} (M)	CP (°C)	C_{NaCl} (M)	CP (°C)	C_{NaCl} (M)	CP (°C)	C_{NaCl} (M)	CP (°C)
0.000	27.0	0.000	91.0	0.050	82.0	0.100	93.0	0.200	98.0
0.100	26.0	0.010	77.0	0.080	60.5	0.120	84.0	0.250	85.0
0.200	24.5	0.014	73.0	0.100	51.0	0.150	69.0	0.300	61.0
0.300	23.0	0.020	57.5	0.110	47.0	0.160	67.0	0.320	50.0
0.400	22.0	0.025	46.0	0.120	43.0	0.180	60.0	0.340	39.0
0.500	21.0	0.030	43.0	0.140	38.0	0.200	51.0	0.350	35.0
		0.040	40.0	0.150	35.0	0.220	45.0	0.360	30.5
		0.060	33.0	0.160	33.5	0.240	38.0	0.370	26.0
		0.070	32.0	0.180	30.0	0.250	34.0	0.380	21.0
		0.075	31.5	0.200	27.0	0.260	33.0		
		0.080	31.0			0.280	28.0		
		0.100	26.0			0.300	23.0		

Appendix D: Ross-Miles test data.

Table D-1 Foam height of SDS at different SDS concentration, temperature = 30°C.

Time (min)	Foam height (cm)					
	0.002 M	0.004 M	0.006 M	0.008 M	0.010 M	0.020 M
0	17.0	19.1	19.6	21.7	22.0	22.6
5	13.3	17.2	17.9	19.7	20.2	20.5
10	10.0	15.7	16.4	19.5	20.2	20.1
15	8.00	14.6	15.8	19.3	19.8	19.6
20	5.50	13.3	14.9	19.1	19.6	19.6

Table D-2 Foam height and stability index of 0.01 M SDS at different temperature.

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
20.0	22.0	20.2	19.5	0.918	0.886
30.0	22.0	20.2	19.6	0.918	0.891
40.0	21.4	19.7	18.8	0.921	0.878
50.0	21.3	18.7	13.0	0.878	0.610
60.0	19.9	15.7	8.10	0.789	0.407
70.0	18.6	9.00	0.70	0.484	0.038

Table D-3 Foam height of 0.01 M $NP(EO)_8$, $NP(EO)_9$, and $NP(EO)_{10}$ at different temperature, cloud point = 27, 55, and 64°C respectively.

Temperature (°C)	$NP(EO)_8$	Temperature (°C)	$NP(EO)_9$	Temperature (°C)	$NP(EO)_{10}$
20.0	12.4	20.0	19.1	20.0	20.8
25.0	12.9	30.0	19.8	30.0	20.4
27.0	12.8	40.0	20.8	40.0	23.0
30.0	8.70	50.0	20.9	50.0	22.0
35.0	4.90	55.0	21.1	60.0	21.7
40.0	4.60	60.0	11.1	64.0	22.3
45.0	3.20	70.0	4.50	70.0	8.10
50.0	2.80			80.0	4.70

Table D-4 Foam height and stability index of 0.01 M $NP(EO)_8$ at different temperature, cloud point = 27°C.

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
20.0	12.4	10.4	7.10	0.838	0.572
25.0	12.9	9.90	5.50	0.767	0.425
27.0	12.8	9.60	5.30	0.750	0.414
30.0	8.70	6.50	3.70	0.747	0.425
35.0	4.90	3.50	2.00	0.714	0.408
40.0	4.60	3.20	1.80	0.695	0.391
45.0	3.20	2.10	1.30	0.656	0.406
50.0	2.80	1.80	1.10	0.643	0.393

Table D-5 Foam height and stability index of 0.01 M $NP(EO)_9$ at different temperature, cloud point = 55°C.

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
20.0	19.1	16.6	8.60	0.842	0.436
30.0	19.8	15.3	8.30	0.772	0.419
40.0	20.8	15.1	2.40	0.725	0.115
50.0	20.9	4.10	1.00	0.196	0.048
55.0	21.1	2.50	0.00	0.118	0.000
60.0	11.1	1.30	0.00	0.117	0.000
70.0	4.50	1.00	0.00	0.222	0.000

Table D-6 Foam height and stability index of 0.01 M $NP(EO)_{10}$ at different temperature, cloud point = 64°C.

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
20.0	20.8	18.2	14.1	0.875	0.678
30.0	20.4	18.0	12.5	0.882	0.613
40.0	23.0	19.6	4.40	0.852	0.191
50.0	22.0	10.1	2.30	0.459	0.104
60.0	21.7	3.90	1.10	0.179	0.050
64.0	22.3	3.00	0.00	0.134	0.000
70.0	8.10	0.90	0.00	0.111	0.000
80.0	4.70	0.90	0.00	0.183	0.000

Table D-7 Foam height and stability index of 0.01 M $NP(EO)_8/SDS$, $NP(EO)_9$ /SDS, and $NP(EO)_{10}/SDS$ at different mole ratio, temperature = 30°C.

$NP(EO)_8/SDS$

X_{SDS}	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
0.0	8.70	6.50	3.70	0.747	0.425
0.2	19.0	16.5	15.5	0.868	0.815
0.5	20.1	17.6	16.8	0.875	0.836
0.8	20.7	19.1	17.1	0.922	0.826
1.0	22.0	20.2	19.6	0.918	0.891

$NP(EO)_9/SDS$

X_{SDS}	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
0.0	19.8	15.3	8.30	0.772	0.419
0.2	20.5	18.5	17.3	0.902	0.844
0.5	20.7	19.2	17.5	0.928	0.845
0.8	20.9	19.5	18.5	0.933	0.885
1.0	22.0	20.2	19.6	0.918	0.891

$NP(EO)_{10}/SDS$

X_{SDS}	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
0.0	20.4	18.0	12.5	0.882	0.613
0.2	20.1	18.4	16.5	0.915	0.821
0.5	20.4	18.7	15.7	0.916	0.770
0.8	20.8	18.9	18.0	0.908	0.865
1.0	22.0	20.2	19.6	0.918	0.891

Table D-8 Foam height and stability index of 0.01 M $NP(EO)_8/SDS$ at different mole ratio and temperature.

$NP(EO)_8/SDS$ 1.0/0.0, cloud point = 27°C

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
20.0	12.4	10.4	7.10	0.838	0.572
25.0	12.9	9.90	5.50	0.767	0.425
27.0	12.8	9.60	5.30	0.750	0.414
30.0	8.70	6.50	3.70	0.747	0.425
35.0	4.90	3.50	2.00	0.714	0.408
40.0	4.60	3.20	1.80	0.695	0.391
45.0	3.20	2.10	1.30	0.656	0.406
50.0	2.80	1.80	1.10	0.643	0.393

$NP(EO)_8/SDS$ 0.999/0.001, cloud point = 31°C

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
20.0	12.7	11.3	10.0	0.889	0.787
25.0	12.6	11.2	10.0	0.888	0.793
30.0	12.5	11.0	6.60	0.880	0.528
31.0	12.0	7.60	6.00	0.633	0.500
35.0	8.50	6.00	4.80	0.706	0.565
40.0	5.70	5.50	4.50	0.965	0.789
45.0	5.00	4.70	3.80	0.940	0.760

$NP(EO)_8/SDS$ 0.998/0.002, cloud point = 46°C

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
20.0	11.9	10.7	10.0	0.899	0.840
30.0	11.8	10.5	9.80	0.889	0.831
35.0	11.7	10.5	8.70	0.897	0.744
40.0	11.3	10.0	8.50	0.885	0.752
46.0	11.0	9.40	7.80	0.854	0.709
50.0	6.00	5.80	5.60	0.966	0.933
55.0	5.60	5.50	5.30	0.982	0.946

Table D-9 Foam height and stability index of 0.01 M $NP(EO)_9/SDS$ at different mole ratio and temperature.

$NP(EO)_9/SDS$ 1.0/0.0, cloud point = 55°C

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
20.0	19.1	16.6	8.60	0.842	0.436
30.0	19.8	15.3	8.30	0.772	0.419
40.0	20.8	15.1	2.40	0.725	0.115
50.0	20.9	4.10	1.00	0.196	0.048
55.0	21.1	2.50	0.00	0.118	0.000
60.0	11.1	1.30	0.00	0.117	0.000
70.0	4.50	1.00	0.00	0.222	0.000

$NP(EO)_9/SDS$ 0.999/0.001, cloud point = 57°C

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
20.0	19.2	16.6	12.0	0.865	0.625
30.0	20.0	17.0	6.70	0.850	0.335
40.0	20.9	15.7	5.10	0.751	0.244
50.0	20.2	10.8	4.30	0.535	0.213
57.0	19.4	8.60	3.60	0.443	0.186
60.0	14.0	8.20	3.90	0.586	0.278
65.0	6.90	5.50	2.40	0.797	0.348
70.0	3.90	3.60	1.50	0.923	0.385

$NP(EO)_9/SDS$ 0.998/0.002, cloud point = 61°C

Temperature (°C)	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
30.0	19.6	16.9	11.5	0.862	0.587
40.0	20.4	16.8	11.1	0.823	0.544
50.0	19.9	15.5	6.60	0.779	0.332
55.0	20.2	11.6	5.40	0.574	0.267
61.0	19.6	10.2	4.30	0.520	0.219
65.0	11.3	8.40	3.90	0.743	0.345
70.0	4.30	3.70	1.10	0.860	0.256

Table D-10 Foam height of 0.01 M $NP(EO)_8/SDS$ 0.9/0.1 with or without NaCl at different temperature.

$NP(EO)_8/SDS$ 0.9/0.1 (CP = 93°C)		$NP(EO)_8/SDS$ 0.9/0.1 + 0.035 M NaCl (CP = 46°C)		$NP(EO)_8/SDS$ 0.9/0.1 + 0.075 M NaCl (CP = 31°C)	
Temperature (°C)	Foam height (cm)	Temperature (°C)	Foam height (cm)	Temperature (°C)	Foam height (cm)
20.0	16.5	20.0	14.8	20.0	14.3
25.0	16.1	25.0	14.9	25.0	14.1
30.0	15.8	30.0	15.0	30.0	13.9
35.0	16.2	35.0	15.1	31.0	14.1
40.0	15.6	40.0	15.5	35.0	12.2
45.0	15.5	46.0	16.1	40.0	7.2
50.0	15.5	50.0	12.1	45.0	4.9
		55.0	11.6		

Table D-11 Foam height of 0.01 M $NP(EO)_9/SDS$ 0.9/0.1 with or without NaCl at different temperature.

$NP(EO)_9/SDS$ 0.9/0.1 (CP > 100°C)		$NP(EO)_9/SDS$ 0.9/0.1 + 0.100 M NaCl (CP = 61°C)		$NP(EO)_9/SDS$ 0.9/0.1 + 0.016 M NaCl (CP = 57°C)	
Temperature (°C)	Foam height (cm)	Temperature (°C)	Foam height (cm)	Temperature (°C)	Foam height (cm)
20.0	20.8	30.0	20.4	20.0	19.8
30.0	22.1	40.0	21.3	30.0	20.9
40.0	22.3	50.0	21.6	40.0	21.2
50.0	21.4	55.0	21.4	50.0	20.0
55.0	20.9	61.0	20.3	57.0	19.3
60.0	21.0	65.0	15.8	60.0	14.2
65.0	20.4	70.0	8.50	65.0	7.30
70.0	20.3				

Table D-12 Foam height of 0.01 M $NP(EO)_{10}/SDS$ 0.9/0.1 with or without NaCl at different temperature.

$NP(EO)_{10}/SDS$ 0.9/0.1 (CP > 100°C)		$NP(EO)_{10}/SDS$ 0.9/0.1 + 0.200 M NaCl (CP = 63°C)		$NP(EO)_8/SDS$ 0.9/0.1 + 0.500 M NaCl (CP = 53°C)	
Temperature (°C)	Foam height (cm)	Temperature (°C)	Foam height (cm)	Temperature (°C)	Foam height (cm)
20.0	22.1	30.0	21.8	20.0	20.4
30.0	23.1	40.0	22.1	30.0	20.7
40.0	22.5	50.0	22.5	40.0	21.0
50.0	22.4	55.0	22.3	50.0	21.2
55.0	22.6	60.0	22.5	53.0	20.8
60.0	22.3	63.0	21.9	60.0	5.00
65.0	22.1	70.0	11.5	65.0	3.70
70.0	21.7				

Table D-13 Foam height of 0.01 M $NP(EO)_8/SDS$ with or without NaCl at different mole ratio and temperature.

$NP(EO)_8/SDS$

Temperature (°C)	Cloud point = 31°C		Temperature (°C)	Cloud point = 46°C	
	0.001 X_{SDS}	0.1 X_{SDS} + 0.075 M NaCl		0.002 X_{SDS}	0.1 X_{SDS} + 0.035 M NaCl
20.0	12.7	14.3	20.0	11.9	14.8
25.0	12.6	14.1	30.0	11.8	15.0
30.0	12.5	13.9	35.0	11.7	15.1
31.0	12.0	14.1	40.0	11.3	15.5
35.0	8.50	12.2	46.0	11.0	16.1
40.0	5.70	7.20	50.0	6.00	12.1
45.0	5.00	4.90	55.0	5.60	11.6

Table D-14 Foam height of 0.01 M $NP(EO)_9/SDS$ with or without NaCl at different mole ratio and temperature.

$NP(EO)_9/SDS$

Temperature (°C)	Cloud point = 57°C		Temperature (°C)	Cloud point = 61°C	
	0.001 X_{SDS}	0.1 X_{SDS} + 0.160 M NaCl		0.002 X_{SDS}	0.1 X_{SDS} + 0.100 M NaCl
20.0	19.2	19.8	30.0	19.6	20.4
30.0	20.0	20.9	40.0	20.4	21.3
40.0	20.9	21.2	50.0	19.9	21.6
50.0	20.2	20.0	55.0	20.2	21.4
57.0	19.4	19.3	61.0	19.6	20.3
60.0	14.0	14.2	65.0	11.3	15.8
65.0	6.90	7.30	70.0	4.30	8.50

Table D-15 Foam height of 0.01 M $NP(EO)_8/SDS$ with or without NaCl at different mole ratio and temperature, cloud point = 27°C.

Temperature (°C)	Foam height (cm)		
	X_{SDS} = 0	0.2 X_{SDS} + 0.200 M NaCl	0.4 X_{SDS} + 0.370 M NaCl
20.0	12.4	15.2	19.5
25.0	12.9	14.7	19.6
27.0	12.8	16.3	19.4
30.0	8.70	14.7	19.0
35.0	4.90	10.8	18.0
40.0	4.60	5.80	16.4
45.0	3.20	5.80	16.3

Appendix E: Shake test data.

Table E-1 Foam height of SDS at different SDS concentration, temperature = 30°C.

Time (min)	Foam height (cm)					
	0.002 M	0.004 M	0.006 M	0.008 M	0.010 M	0.020 M
0	8.75	8.85	9.25	9.80	10.1	10.2
5	8.50	8.72	9.00	9.75	10.0	10.1
10	8.10	8.23	8.75	9.72	9.80	9.91
15	7.10	8.02	8.44	9.70	9.73	9.85
20	5.80	7.65	8.35	9.60	9.50	9.50

Table E-2 Foam height of 0.01 M $NP(EO)_8$, $NP(EO)_9$, and $NP(EO)_{10}$ at different temperature, cloud point = 27, 55, and 64°C respectively.

Temperature (°C)	$NP(EO)_8$	Temperature (°C)	$NP(EO)_9$	Temperature (°C)	$NP(EO)_{10}$
20.0	4.46	20.0	5.95	20.0	7.00
25.0	4.30	30.0	5.73	30.0	6.40
27.0	4.10	40.0	5.70	40.0	6.00
30.0	3.68	50.0	5.64	50.0	5.80
40.0	2.81	55.0	5.81	60.0	6.00
50.0	2.50	60.0	4.73	64.0	5.90
				70.0	5.00

Table E-3 Foam height and stability index of 0.01 M $NP(EO)_8/SDS$, $NP(EO)_9$ /SDS, and $NP(EO)_{10}/SDS$ at different mole ratio, temperature = 30°C.

$NP(EO)_8/SDS$

X_{SDS}	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
0.0	3.68	3.02	1.87	0.821	0.508
0.2	6.35	5.28	3.20	0.831	0.636
0.5	7.34	5.95	4.20	0.908	0.641
0.8	8.78	6.55	5.36	0.894	0.759
1.0	10.1	10.0	9.50	0.992	0.941

$NP(EO)_9/SDS$

X_{SDS}	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
0.0	5.73	5.00	3.45	0.873	0.602
0.2	6.78	5.88	4.26	0.867	0.628
0.5	7.50	6.37	4.97	0.849	0.663
0.8	8.74	7.35	6.18	0.841	0.707
1.0	10.1	10.0	9.50	0.992	0.941

$NP(EO)_{10}/SDS$

X_{SDS}	Foam height (cm)			Stability index	
	0 min	5 min	20 min	5 min	20 min
0.0	6.40	4.35	3.89	0.679	0.608
0.2	6.92	5.31	4.75	0.767	0.686
0.5	7.85	6.11	4.37	0.778	0.731
0.8	9.23	7.20	6.81	0.780	0.738
1.0	10.1	10.0	9.50	0.992	0.941

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