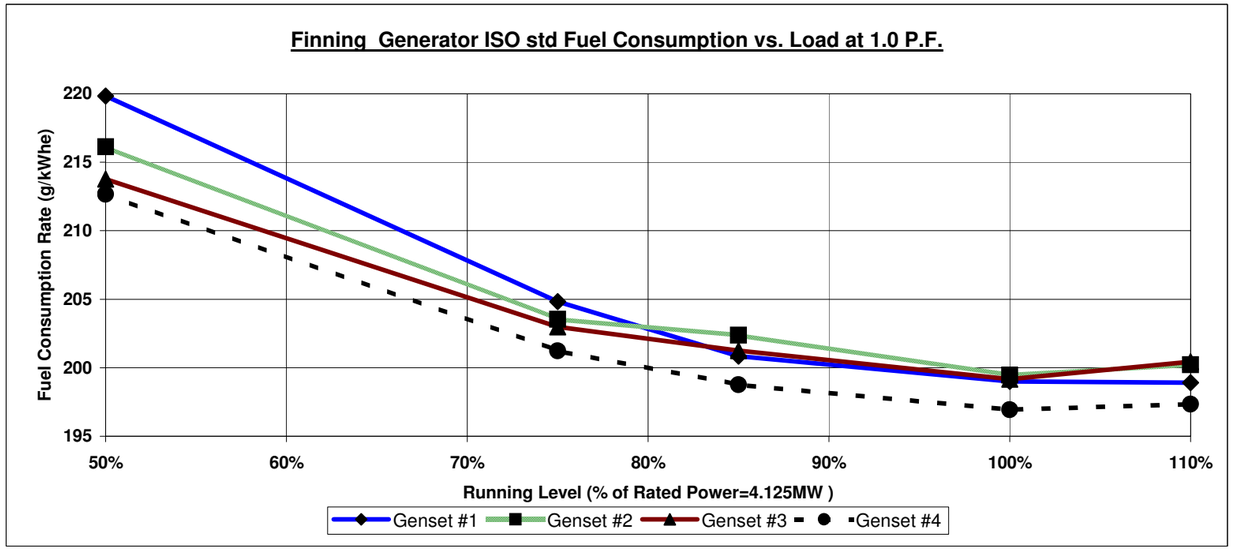
Summary of CAT 3616 Diesel Generator Fuel Consumption Rates Corrected to ISO Fuel Standard

Results based on Finning Lab Fuel Analysis

	Engine Load	50%	75%	85%	100%	110%
Unit #1	Consumption Rate (g/kWhe)	219.84	204.83	200.85	199.00	198.91
Unit #2	Consumption Rate (g/kWhe)	216.14	203.53	202.37	199.47	200.22
Unit #3	Consumption Rate (g/kWhe)	213.78	202.97	201.24	199.16	200.43
Unit #4	Consumption Rate (g/kWhe)	212.66	201.23	198.76	196.93	197.35

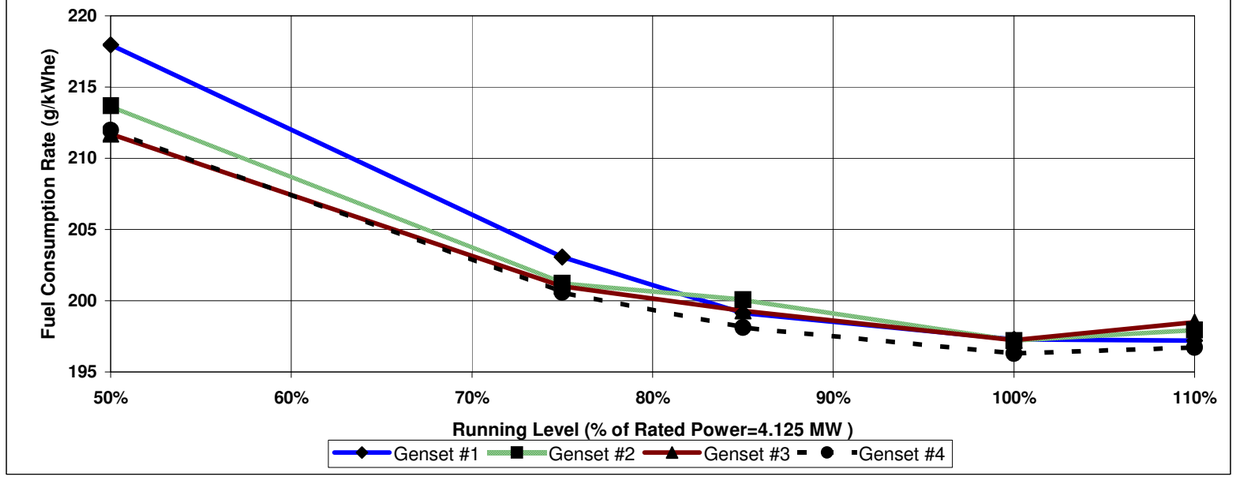
Finning 85% Fuel Consumption Rate Average **200.8** +/- 2.6



Results based on Independent Lab Fuel Analysis

	Engine Load	50%	75%	85%	100%	110%
Unit #1	Consumption Rate (g/kWhe)	217.95	203.07	199.12	197.29	197.20
Unit #2	Consumption Rate (g/kWhe)	213.68	201.22	200.07	197.20	197.95
Unit #3	Consumption Rate (g/kWhe)	211.71	201.01	199.30	197.23	198.50
Unit #4	Consumption Rate (g/kWhe)	211.98	200.58	198.12	196.29	196.71

Independent 85% Fuel Consumption Rate Average **199.1508** +/- 2.6



85% rated Load Fuel Consumption Rate g/netkWe **200.0** +/- 3.4 (Average of both Finning and Independent Lab Results)

Accuracy of kWh measurement = 0.2% of Current Transformer + 0.1% of Potential Transformer + 0.4% of Power meter Range=+/- 0.3% of reading +/- (SQRT(3)*100* 35* 600VA*0.004=14.6kW)

At 85% ISO rated power =3512kW error can be+/-(0.003 x 3512kWh) +/-14.6kWh = +/- (14kWh +14.6kW +/-28.6kWh this corresponds to relative error of 0.8%

Accuracy of fuel flow meter = +/- 0.5% at 1000 liter/hr. It is assumed relative error is constant over the flow range of the tests

Net Resultant Accuracy of the fuel consumption measurement is calculated to be 0.8% of kwh measurement + 0.5% of flow measurement for net relative error of +/-1.3%

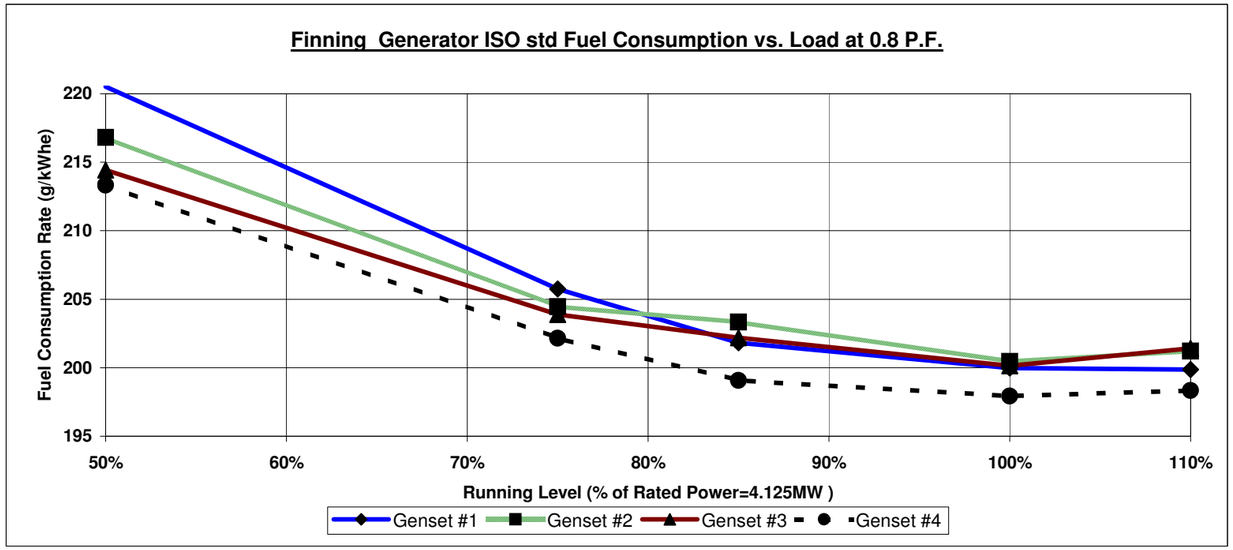
Accuracy of Independent Fuel Calorific Content = 0.78% of Value

Summary of CAT 3616 Diesel Generator Fuel Consumption Rates Corrected to ISO Fuel Standard

Results based on Finning Lab Fuel Analysis

	Engine Load	50%	75%	85%	100%	110%
Unit #1	Consumption Rate (g/kWhe)	220.52	205.76	201.82	199.98	199.87
Unit #2	Consumption Rate (g/kWhe)	216.81	204.45	203.34	200.46	201.21
Unit #3	Consumption Rate (g/kWhe)	214.44	203.89	202.20	200.15	201.42
Unit #4	Consumption Rate (g/kWhe)	213.32	202.15	199.08	197.92	198.33

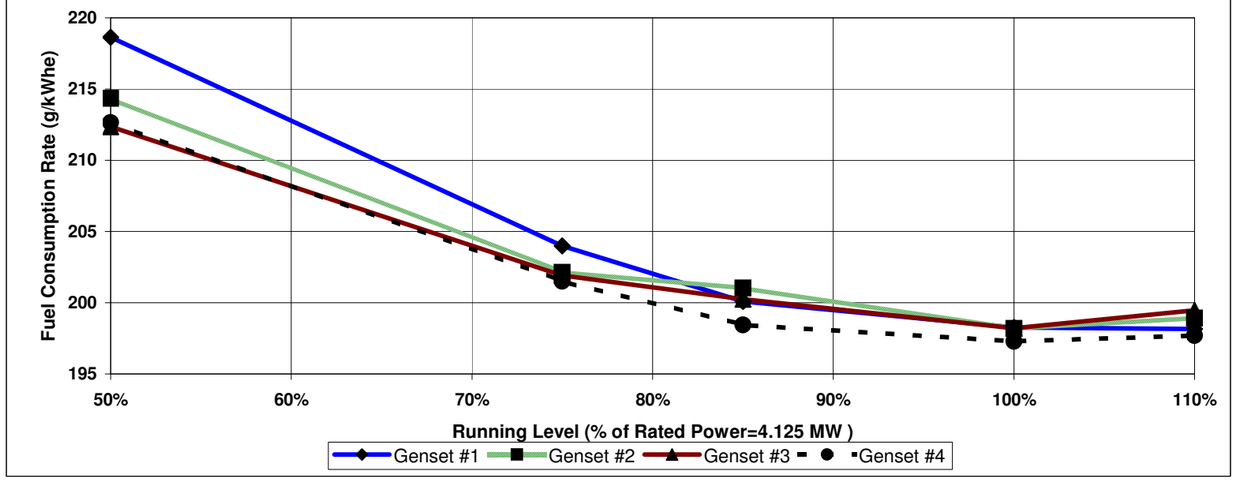
Finning 85% Fuel Consumption Rate Average **201.6** +/- 2.6



Results based on Independent Lab Fuel Analysis

	Engine Load	50%	75%	85%	100%	110%
Unit #1	Consumption Rate (g/kWhe)	218.63	203.99	200.09	198.27	198.16
Unit #2	Consumption Rate (g/kWhe)	214.34	202.13	201.03	198.18	198.92
Unit #3	Consumption Rate (g/kWhe)	212.37	201.92	200.24	198.21	199.47
Unit #4	Consumption Rate (g/kWhe)	212.64	201.50	198.44	197.29	197.70

Independent 85% Fuel Consumption Rate Average **200.0** +/- 2.6



85% rated Load Fuel Consumption Rate g/netkWe **200.8** +/- **3.4** (Average of both Finning and Independent Lab Results)

Accuracy of kWh measurement = 0.2% of Current Transformer + 0.1% of Potential Transformer + 0.4% of Power meter Range=+/- 0.3% of reading +/- (SQRT(3)*100* 35* 600VA*0.004=14.6kW)

At 85% ISO rated power =3512kW error can be+/-(0.003 x 3512kWh) +/-14.6kWh = +/- (14kWh +14.6kW +/-28.6kWh this corresponds to relative error of 0.8%

Accuracy of fuel flow meter = +/- 0.5% at 1000 liter/hr. It is assumed relative error is constant over the flow range of the tests

Net Resultant Accuracy of the fuel consumption measurement is calculated to be 0.8% of kwh measurement + 0.5% of flow measurement for net relative error of +/-1.3%

Accuracy of Independent Fuel Calorific Content = 0.78% of Value

Unit #1 CAT 3616 Load Test

Unit #1 - Finning Lab Test

	50%	75%	85%	100%	110%
Test Start Time	8:30	9:00	15:00	9:30	16:10
Test End Time	8:50	9:20	16:00	13:30	17:10
Duration (hrs)	0.33	0.33	1.00	4	1.000
Totalizer Start (kg)	78.4531	295.8447	4988.414	601.1582	5809.207
Totalizer End (kg)	223.3525	499.6025	5669.75	3774.0605	6682.686
Fuel Used (kg)	144.90	203.76	681.3359	3172.9023	873.479
Kwh Start	383	1431	25736	2988	29987
Kwh End	1072	2463	29249	19467	34521
Kwh Generated	689	1032	3513	16479	4534
Test Generator Current	287	430	487	574	632
Generator Current for 0.8pf at test kW load	358.59	537.10	609.44	714.71	786.57
Generator loss kW at 0.8pf load current	82.64	104.11	114.21	129.22	139.16
Generator loss kW at test current	76.37	90.41	97.46	109.21	117.43
Subtract Generator Operating Parasitic Load kWh (46.3kWxDuration(h))	15.43	15.43	46.30	185.20	46.30
Net kWhe for other loads at 1.0 PF	673.57	1016.57	3466.70	16293.80	4487.70
Subtract increase in Gen loss kWh for 0.8 PF load ((Generator kW loss @ 0.8 PF-kW loss@ 1.0 PF) x Duration(h))	2.09	4.57	16.75	80.05	21.73
Net kWhe for other loads operating at 0.8 PF	671.48	1012.00	3449.95	16213.75	4465.97
1.0 PFTest Fuel Consumption Rate (g/netkWhe)	215.12	200.44	196.54	194.73	194.64
0.8 PF.Test Fuel Consumption Rate (g/netkWhe)	**215.79**	**201.34**	**197.49**	**195.69**	**195.59**
Finning Net ISO SFC correction ratio	1.0219	1.0219	1.0219	1.0219	1.0219
1.0 PF ISO std Fuel Consumption Rate (g/kWhe)	219.84	204.83	200.85	199.00	198.91
0.8 PF ISO std Fuel Consumption Rate (g/kWhe)	**220.5245**	**205.7576**	**201.8229**	**199.98383**	**199.8749**

Specific Gravity	0.8383
Degrees API (Finning Lab Test)	37
Net Heat of Comb. (BTU/lb) (LHV, from table 1)	18430
Conversion Factor (from table 1)	2.326
Actual Test Fuel LHV (kJ/kg) (from Finning table)	42868.18
ISO Fuel LHV (kJ/kg) (Standard)	42000
Actual Test / ISO Fuel Ratio	1.021
Beta SFC adjustment factor	
for test conditions to ISO std	0.998767
Net ISO correction ratio	
(Fuel Ratio/Beta)	**1.021931**

Unit #1 - PowerTech Lab Test

Accuracy of Measurement:
(+/-0.78% = 0.3MJ/kg)

1.0 PFTest Fuel Consumption Rate (g/netkWhe)	215.12	200.44	196.54	194.73	194.64
0.8 PF Test Fuel Consumption Rate (g/netkWhe)	215.79	201.34	197.49	195.69	195.59
Power Tech Net ISO SFC correction ratio	1.0132	1.0132	1.0132	1.0132	1.0132
1.0 PF ISO std Fuel Consumption Rate (g/kWhe)	217.95	203.07	199.12	197.29	197.20
0.8 PF ISO std Fuel Consumption Rate (g/kWhe)	**218.63**	**203.99**	**200.09**	**198.27**	**198.16**

Specific Gravity	0.8344
Calculated API (@60 deg F)	38
Actual Test Fuel LHV (kJ/kg) (from PowerTech lab Test)	42500
ISO Fuel LHV (kJ/kg) (Standard)	42000
Actual Test / ISO Fuel Ratio	**1.012**
Beta SFC adjustment factor	
for test conditions to ISO std	0.998767
Net ISO correction ratio	
(Fuel Ratio/Beta)	**1.013154**

Interpolation Formula of Generator Losses based on Generator stator current

GeneratorTotal Losses=NL + A*I+B*I^2+C*I^3	NL	A	B	C
Losses in W and Current in A	74000	-72.49	0.329522	-0.000168
Losses in kW and Current in Per Unit rated	74	-55.33333	192	-74.66667

Kato Engineering Generator Ratings for 0.8 power factor Per Unit Load	kV	kW	kVA	A	Total loss kW
1	4.1600	4400	5500	763.32	136
0.75	4.1600	3300.00	4125	572.49	109
0.5	4.1600	2200.00	2750	381.66	85
0.25	4.1600	1100.00	1375	190.83	71

Unit #2 CAT 3616 Load Test

Unit #2 - Finning Lab Test

	50%	75%	85%	100%	110%
Test Start Time	8:10	8:40	14:20	9:10	13:10
Test End Time	8:30	9:00	15:20	13:00	14:00
Duration (hrs)	0.33	0.33	1.000	3.833	0.833
Totalizer Start (kg)	88.3870	304.8071	4771.682	610.5861	3785.34
Totalizer End (kg)	229.7092	506.4812	5455.086	3651.9014	4516.24
Fuel Used (kg)	141.32	201.67	683.4039	3041.3153	730.8994
Kwh Start	417	1479	24661	3058	19566
Kwh End	1104	2511	28171	18869	23347
Kwh Generated	687	1032	3510	15811	3781
Test Generator Current	286.33	430	488	574	631
Generator Current for 0.8pf at test kW load	357.55	537.10	608.92	715.61	787.13
Generator loss kW at 0.8pf load current	82.53	104.11	114.14	129.35	139.23
Generator loss kW at test current	76.32	90.41	97.59	109.21	117.28
Subtract Generator Operating Parasitic Load kWh (53kWxDuration(h))	17.67	17.67	53.00	203.15	44.17
Net kWhe for other loads at 1.0 PF	669.33	1014.33	3457.00	15607.85	3736.83
Subtract increase in Gen loss kWh for 0.8 PF load ((Generator kW loss @ 0.8 PF-kW loss@ 1.0 PF) x Duration(h))	2.07	4.57	16.55	77.20	18.29
Net kWhe for other loads operating at 0.8 PF	667.26	1009.77	3440.45	15530.65	3718.54
1.0 PFTest Fuel Consumption Rate (g/netkWhe)	211.14	198.82	197.69	194.86	195.59
0.8 PF Test Fuel Consumption Rate (g/netkWhe)	**211.79**	**199.72**	**198.64**	**195.83**	**196.56**
Finning Net ISO SFC correction ratio	1.0237	1.0237	1.0237	1.0237	1.0237
1.0 PF ISO std Fuel Consumption Rate (g/kWhe)	216.14	203.53	202.37	199.47	200.22
0.8 PF ISO std Fuel Consumption Rate (g/kWhe)	**216.81**	**204.45**	**203.34**	**200.46**	**201.21**

Specific Gravity	0.8348
Degrees API (Finning Lab Test)	38
Net Heat of Comb. (BTU/lb) (LHV, from table 1)	18460
Conversion Factor (from table 1)	2.326
Actual Test Fuel LHV (kJ/kg) (from Finning table)	42937.96
ISO Fuel LHV (kJ/kg) (Standard)	42000
Actual Test / ISO Fuel Ratio	1.022
Beta SFC adjustment factor for test conditions to ISO std	0.998696
Net ISO correction ratio (Fuel Ratio/Beta)	**1.023667**

Unit #2 - PowerTech Lab Test

Accuracy of Measurement: (+/-0.78% = 0.3MJ/kg)

1.0 PFTest Fuel Consumption Rate (g/netkWhe)	211.14	198.82	197.69	194.86	195.59
0.8 PF Test Fuel Consumption Rate (g/netkWhe)	211.79	199.72	198.64	195.83	196.56
Power Tech Net ISO SFC correction ratio	1.012	1.012	1.012	1.012	1.012
1.0 PF ISO std Fuel Consumption Rate (g/kWhe)	213.680	201.217	200.066	197.203	197.947
0.8 PF ISO std Fuel Consumption Rate (g/kWhe)	**214.34**	**202.13**	**201.03**	**198.18**	**198.92**

Specific Gravity	0.827
Calculated API (@60 deg F)	40
Actual Test Fuel LHV (kJ/kg) (from PowerTech lab Test)	42450
ISO Fuel LHV (kJ/kg) (Standard)	42000
Actual Test / ISO Fuel Ratio	1.011
Beta SFC adjustment factor for test conditions to ISO std	0.998696
Net ISO correction ratio (Fuel Ratio/Beta)	**1.012034**

Interpolation Formula of Generator Losses based on Generator stator current

GeneratorTotal Losses=NL + A*I+B*I^2+C*I^3	NL	A	B	C
Losses in W and Current in A	74000	-72.49	0.329522	-0.000168
Losses in kW and Current in Per Unit rated	74	-55.33333	192	-74.66667

Kato Engineering Generator Ratings for 0.8 power factor Per Unit Load	kV	kW	kVA	A	Total loss kW
1	4.1600	4400	5500	763.32	136
0.75	4.1600	3300.00	4125	572.49	109
0.5	4.1600	2200.00	2750	381.66	85
0.25	4.1600	1100.00	1375	190.83	71

Unit #3 CAT 3616 Load Test

Unit #3 - Finning Lab Test

	50%	75%	85%	100%	110%
Test Start Time	9:50	10:20	16:01	10:50	14:50
Test End Time	10:10	10:40	17:01	14:40	15:30
Duration (hrs)	0.33	0.33	1.000	3.833	0.667
Totalizer Start (kg)	40.7226	254.9218	4760.385	559.6191	3731.908
Totalizer End (kg)	180.4882	456.0937	5439.621	3598.2871	4317.354
Fuel Used (kg)	139.77	201.17	679.2361	3038.668	585.4453
Kwh Start	202	1266	24649	2841	19346
Kwh End	888	2297	28153	18645	22368
Kwh Generated	686	1031	3504	15804	3022
Test Generator Current	286	430	488.6	574	631
Generator Current for 0.8pf at test kW load	357.03	536.58	607.88	715.23	786.40
Generator loss kW at 0.8pf load current	82.48	104.04	113.99	129.30	139.13
Generator loss kW at test current	76.29	90.41	97.67	109.21	117.28
Subtract Generator Operating Parasitic Load kWh (52kWxDuration(h))	17.33	17.33	52.00	199.33	34.67
Net kWhe for other loads at 1.0 PF	668.67	1013.67	3452.00	15604.67	2987.33
Subtract increase in Gen loss kWh for 0.8 PF load ((Generator kW loss @ 0.8 PF-kW loss@ 1.0 PF) x Duration(h))	2.06	4.54	16.32	77.00	14.57
Net kWhe for other loads operating at 0.8 PF	666.60	1009.12	3435.68	15527.67	2972.77
1.0 PFTest Fuel Consumption Rate (g/netkWhe)	209.02	198.46	196.77	194.73	195.98
0.8 PF.Test Fuel Consumption Rate (g/netkWhe)	**209.67**	**199.35**	**197.70**	**195.69**	**196.94**
Finning Net ISO SFC correction ratio	1.0228	1.0228	1.0228	1.0228	1.0228
1.0 PF ISO std Fuel Consumption Rate (g/kWhe)	213.78	202.97	201.24	199.16	200.43
0.8 PF ISO std Fuel Consumption Rate (g/kWhe)	**214.44**	**203.89**	**202.20**	**200.15**	**201.42**

Specific Gravity	0.8358
Degrees API (Finning Lab Test)	38
Net Heat of Comb. (BTU/lb) (LHV, from table 1)	18450
Conversion Factor (from table 1)	2.326
Actual Test Fuel LHV (kJ/kg) (from Finning table)	42914.7
ISO Fuel LHV (kJ/kg) (Standard)	42000
Actual Test / ISO Fuel Ratio	1.022
Beta SFC adjustment factor	
for test conditions to ISO std	0.99905
Net ISO correction ratio	
(Fuel Ratio/Beta)	**1.02275**

Unit #3 - PowerTech Lab Test

Accuracy of Measurement:
(+/-0.78% = 0.3MJ/kg)

1.0 PFTest Fuel Consumption Rate (g/netkWhe)	209.0213	198.4596	196.7660	194.7282	195.9759
0.8 PF Test Fuel Consumption Rate (g/netkWhe)	209.67	199.35	197.70	195.69	196.94
Power Tech Net ISO SFC correction ratio	1.0129	1.0129	1.0129	1.0129	1.0129
1.0 PF ISO std Fuel Consumption Rate (g/kWhe)	211.71	201.01	199.30	197.23	198.50
0.8 PF ISO std Fuel Consumption Rate (g/kWhe)	**212.37**	**201.92**	**200.24**	**198.21**	**199.47**

Specific Gravity	0.8348
Calculated API (@60 deg F)	38
Actual Test Fuel LHV (kJ/kg) (from PowerTech lab Test)	42500
ISO Fuel LHV (kJ/kg) (Standard)	42000
Actual Test / ISO Fuel Ratio	**1.012**
Beta SFC adjustment factor	
for test conditions to ISO std	0.99905
Net ISO correction ratio	
(Fuel Ratio/Beta)	**1.012867**

Interpolation Formula of Generator Losses based on Generator stator current

GeneratorTotal Losses=NL + A*I+B*I^2+C*I^3	NL	A	B	C
Losses in W and Current in A	74000	-72.49	0.329522	-0.000168
Losses in kW and Current in Per Unit rated	74	-55.33333	192	-74.66667

Kato Engineering Generator Ratings for 0.8 power factor Per Unit Load	kV	kW	kVA	A	Total loss kW
1	4.1600	4400	5500	763.32	136
0.75	4.1600	3300.00	4125	572.49	109
0.5	4.1600	2200.00	2750	381.66	85
0.25	4.1600	1100.00	1375	190.83	71

Unit #4 CAT 3616 Load Test

Unit #4 - Finning Lab Test

	50%	75%	85%	100%	110%
Test Start Time	8:50	9:20	15:00	9:50	13:50
Test End Time	9:10	9:40	16:00	13:40	14:40
Duration (hrs)	0.33	0.33	1.167	3.833	0.833
Totalizer Start (kg)	85.6328	297.0488	4706.336	597.2656	3731.533
Totalizer End (kg)	225.0097	496.1191	5375.512	3599.5664	4451.58
Fuel Used (kg)	139.38	199.07	669.18	3002.30	720.05
Kwh Start	388	1438	24609	2999	19506
Kwh End	1076	2468	28116	18807	23285
Kwh Generated	688	1030	3507	15808	3779
Test Generator Current	286	427	485	571	628
Generator Current for 0.8pf at test kW load	358.0682	536.06	521.49	715.41	786.71
Generator loss kW at 0.8pf load current	82.59	103.97	102.00	129.32	139.17
Generator loss kW at test current	76.29	90.06	97.20	108.79	116.85
Subtract Generator Operating Parasitic Load kWh (50kWxDuration(h))	16.67	16.67	58.33	191.67	41.67
Net kWhe for other loads at 1.0 PF	671.33	1013.33	3448.67	15616.33	3737.33
Subtract increase in Gen loss kWh for 0.8 PF load ((Generator kW loss @ 0.8 PF-kW loss@ 1.0 PF) x Duration(h))	2.10	4.64	5.60	78.70	18.60
Net kWhe for other loads operating at 0.8 PF	669.24	1008.70	3443.07	15537.63	3718.73
1.0 PFTest Fuel Consumption Rate (g/netkWhe)	207.61	196.45	194.04	192.25	192.66
0.8 PF.Test Fuel Consumption Rate (g/netkWhe)	**208.26**	**197.35**	**194.35**	**193.23**	**193.63**
Finning Net ISO SFC correction ratio	1.0243	1.0243	1.0243	1.0243	1.0243
1.0 PF ISO std Fuel Consumption Rate (g/kWhe)	212.66	201.23	198.76	196.93	197.35
0.8 PF ISO std Fuel Consumption Rate (g/kWhe)	**213.32**	**202.15**	**199.08**	**197.92**	**198.33**

Specific Gravity	0.8353
Degrees API (Finning Lab Test)	38
Net Heat of Comb. (BTU/lb) (LHV, from table 1)	18460
Conversion Factor (from table 1)	2.326
Actual Test Fuel LHV (kJ/kg) (from Finning table)	42937.96
ISO Fuel LHV (kJ/kg) (Standard)	42000
Actual Test / ISO Fuel Ratio	1.022
Beta SFC adjustment factor for test conditions to ISO std	0.998072
Net ISO correction ratio (Fuel Ratio/Beta)	**1.024307**

Unit #4 - PowerTech Lab Test

Accuracy of Measurement:
(+/-0.78% = 0.3MJ/kg)

1.0 PFTest Fuel Consumption Rate (g/netkWhe)	207.6121	196.4510	194.0390	192.2539	192.6633
0.8 PF Test Fuel Consumption Rate (g/netkWhe)	208.26	197.35	194.35	193.23	193.63
Power Tech Net ISO SFC correction ratio	1.021	1.021	1.021	1.021	1.021
1.0 PF ISO std Fuel Consumption Rate (g/kWhe)	211.9753	200.5796	198.117	196.29434	196.7123
0.8 PF ISO std Fuel Consumption Rate (g/kWhe)	**212.64**	**201.50**	**198.44**	**197.29**	**197.70**

Specific Gravity	0.8304
Calculated API (@60 deg F)	39
Actual Test Fuel LHV (kJ/kg) (from PowerTech lab Test)	42800
ISO Fuel LHV (kJ/kg) (Standard)	42000
Actual Test / ISO Fuel Ratio	1.019
Beta SFC adjustment factor for test conditions to ISO std	0.998072
Net ISO correction ratio (Fuel Ratio/Beta)	**1.0210**

Interpolation Formula of Generator Total Losses based on Generator stator current

GeneratorTotal Losses=NL + A*I+B*I^2+C*I^3	NL	A	B	C
Losses in W and Current in A	74000	-72.49	0.329522	-0.000168
Losses in kW and Current in Per Unit rated	74	-55.33333	192	-74.66667

Kato Engineering Generator Ratings for 0.8 power factor Per Unit Load	kV	kW	kVA	A	Total loss kW
1	4.1600	4400	5500	763.32	136
0.75	4.1600	3300.00	4125	572.49	109
0.5	4.1600	2200.00	2750	381.66	85
0.25	4.1600	1100.00	1375	190.83	71