

APPENDIX 5A. ENGINEERING DATA

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APPENDIX 5A ENGINEERING DATA

5A.1 INTRODUCTION

This appendix presents baseline specifications and detailed cost-efficiency results for each of the electric motor equipment classes analyzed in the engineering analysis (chapter 5).

5A.2 BASELINE AND MAXIMUM TECHNOLOGY DESIGN SUMMARIES

Table 2.1 and Table 2.2 show the baseline and maximum technology designs for each equipment class analyzed, respectively. In the engineering analysis, all changes to cost and efficiency are measured relative the levels in Table 2.1. The representative motors chosen from each equipment class are all 4-pole, totally enclosed, fan-cooled, continuous duty, 60 hertz, and operate on less than 600 volts.

Table 2.1 Baseline Design Data

Parameter (Units)	Unit	5 hp (Design B)	30 hp (Design B)	75 hp (Design B)	5 hp (Design C)	50 hp (Design C)
Efficiency	%	82.5	89.5	93.0	87.5	93.0
Power Factor	%	0.83	0.86	0.87	0.75	0.85
Cycles	Hz	60	60	60	60	60
Tested Voltage	V	460	460	460	460	460
Speed	RPM	1,745	1,755	1,775	1,750	1,770
Full Load Torque	Nm	20.3	121.6	300.5	20.3	201
Current	A	6.9	37	88	7.2	59.2
Core Steel	-	M56	M56	M56	M47	M47
Stack Length	in	2.8	7.88	8.15	4.75	8.67
Rotor Material	-	Aluminum	Aluminum	Aluminum	Aluminum	Aluminum
Main Wire	AWG	19	18	17	18	17
Insulation Class	-	F	F	F	F	F
Temperature Rise	°C	76.1	74.5	53.5	63.5	64.2
Breakdown Torque	% of Full Load	300	250	205	355	257
Locked-Rotor Torque	% of Full Load	240	200	170	326	211
Locked-Rotor Current	A	46	212	506	45	344
Pull-Up Torque	% of Full Load	187	142	165	248	159

Table 2.2 Maximum Technology Design Data of Software Modeled Motors

Parameter (Units)	Unit	5 hp (Design B)	30 hp (Design B)	75 hp (Design B)	5 hp (Design C)	50 hp (Design C)
Efficiency	%	91.7	94.5	96.5	91.0	95.0
Power Factor	%	0.84	0.79	0.79	0.79	0.80
Hertz	Hz	60	60	60	60	60
Tested Voltage	V	460	460	460	460	460
Speed	RPM	1,776	1,784	1,789	1,776	1,782
Torque	Nm	20.1	119.6	298.5	19.9	199.7
Current	A	6.0	37.3	91.9	6.5	61.3
Core Steel	-	M36	M36	M36	M36	M36
Stack Height	in	5.32	7.0	13.0	5.32	9.55
Rotor Material	-	Copper	Copper	Copper	Copper	Copper
Main Wire	AWG	20	18	14	18	17
Temperature Rise	°C	70	70	70	70	70
Breakdown Torque	% of Full Load	305	202	202	260.8	233.5
Locked-Rotor Torque	% of Full Load	214	164	163.7	260.8	202.9
Locked-Rotor Current	A	43.9	208	541.3	41.7	359.6
Pull-Up Torque	% of Full Load	214	139	139.3	260.8	202.9

5A.3 DESIGN SPECIFICATIONS AND LOAD PERFORMANCE OF BASELINE MOTORS

Nameplate data and results of the IEEE Standard 112 (Test Method B) (IEEE 112B) testing for the baseline representative motors are displayed in sections 5A.3.1 through 5A.3.5.

5A.3.1 5-Horsepower, NEMA Design B, Baseline Data and IEEE 112B Test Results

Table 3.1 5-Horsepower, NEMA Design B, Nameplate Data

Parameter	Value
Phases	3
Voltage	230/460
Rated Horsepower	5.0
Rated Current	13.7/6.9
Frame	184TP
NEMA Nameplate Nominal Efficiency	82.5%
Hertz	60
RPM	1745
Enclosure	TEFC
Insulation Class	F
Service Factor	1.15
Code Letter (for locked-rotor kVA)	J

Table 3.2 5-Horsepower, NEMA Design B, IEEE 112B Test Results (460 Volts)

Load	Efficiency	Power Factor	Current
%	%	%	Amperes
25	73.9	47.8	3.3
50	82.5	67.9	4.2
75	84.4	77.6	5.4
100	82.5	82.7	6.9
115	82.9	84.4	7.7

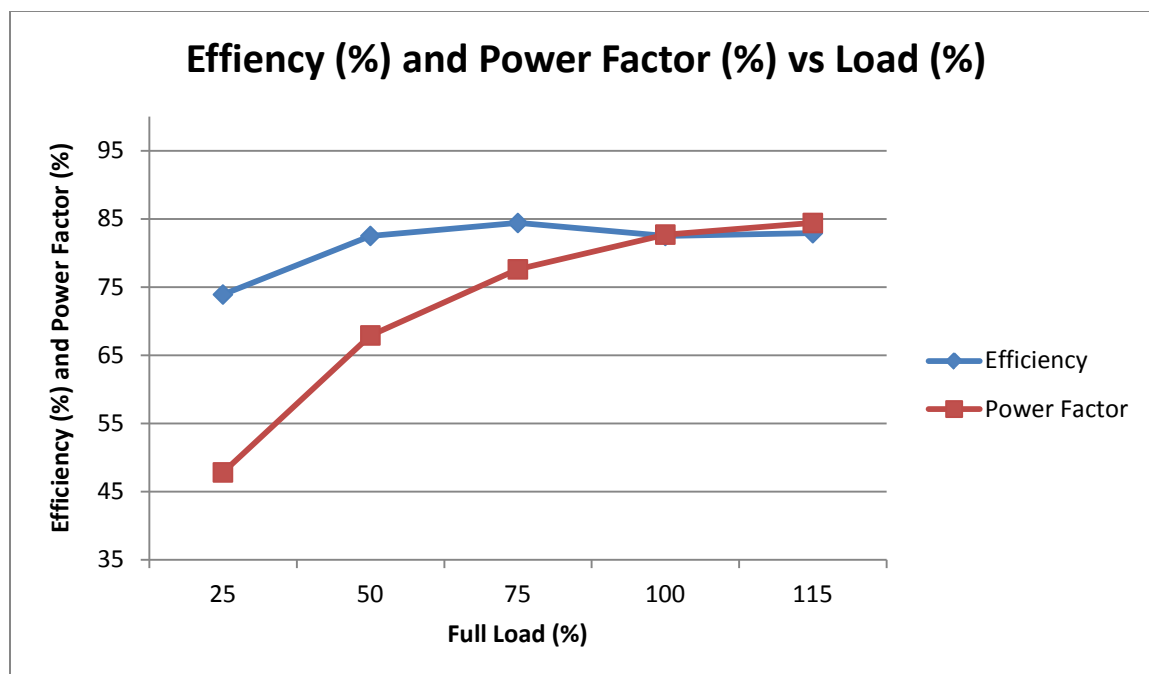


Figure 3.1 5-Horsepower, NEMA Design B, Efficiency and Power Factor versus Load

5A.3.2 30-Horsepower, NEMA Design B, Baseline Data and IEEE 112B Test Results

Table 3.3 30-Horsepower, NEMA Design B, Nameplate Data

Parameter	Value
Phases	3
Voltage	230/460
Rated Horsepower	30.0
Rated Current	74/37
Frame	286TPA
NEMA Nameplate Nominal Efficiency	89.5%
Hertz	60
RPM	1755
Enclosure	TEFC
Insulation Class	F
Service Factor	1.15
Code Letter (for locked-rotor kVA)	G

Table 3.4 30-Horsepower, NEMA Design B, IEEE 112B Test Results (460 Volts)

Load	Efficiency	Power Factor	Current
%	%	%	Amperes
25	86.7	58.6	13.8
50	90.7	77.2	20.1
75	90.8	83.9	27.6
100	88.5	86.2	37
115	87.4	86.6	43

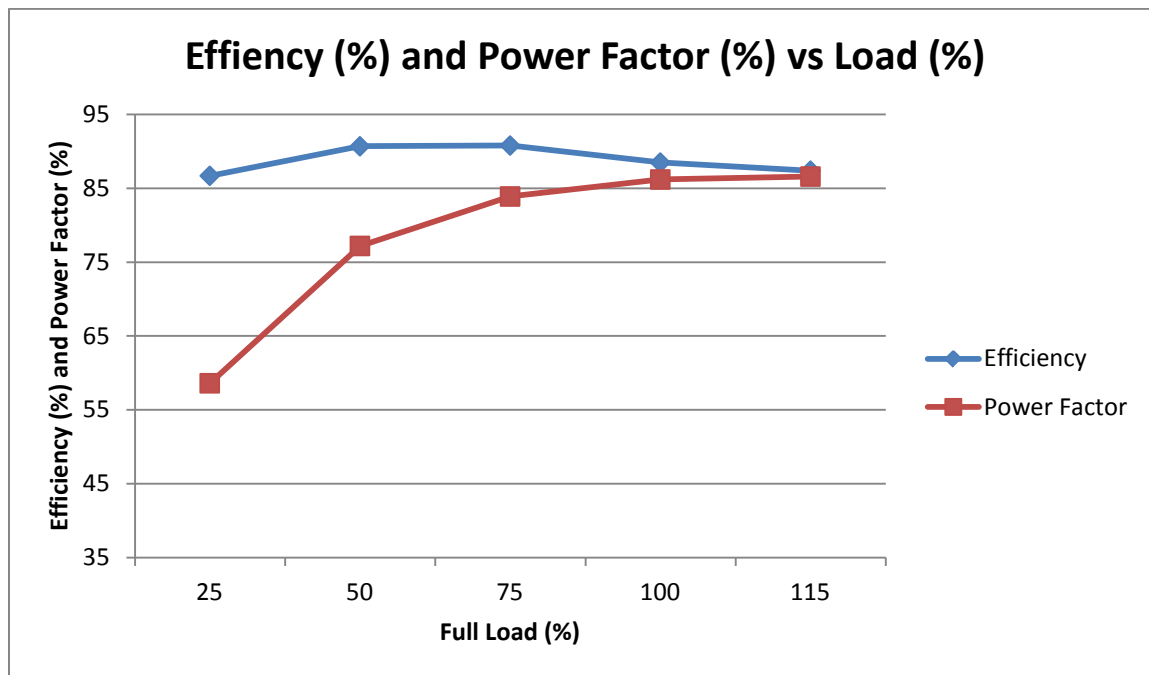


Figure 3.2 30-Horsepower, NEMA Design B, Efficiency and Power Factor versus Load

5A.3.3 75-Horsepower, NEMA Design B, Baseline Data and IEEE 112B Test Results

Table 3.5 75-Horsepower, NEMA Design B, Nameplate Data

Parameter	Value
Phases	3
Voltage	460
Rated Horsepower	75.0
Rated Current	88.0
Frame	365TP
NEMA Nameplate Nominal Efficiency	93.0%
Hertz	60
RPM	1775
Enclosure	TEFC
Insulation Class	F
Service Factor	1.15
Code Letter (for locked-rotor kVA)	F

Table 3.6 75-Horsepower, NEMA Design B, IEEE 112B Test Results (460 Volts)

Load	Efficiency	Power Factor	Current
%	%	%	Amperes
25	88.1	64.7	31
50	92.3	81.0	47
75	93.0	85.7	66
100	92.4	86.8	88
115	91.7	86.6	102

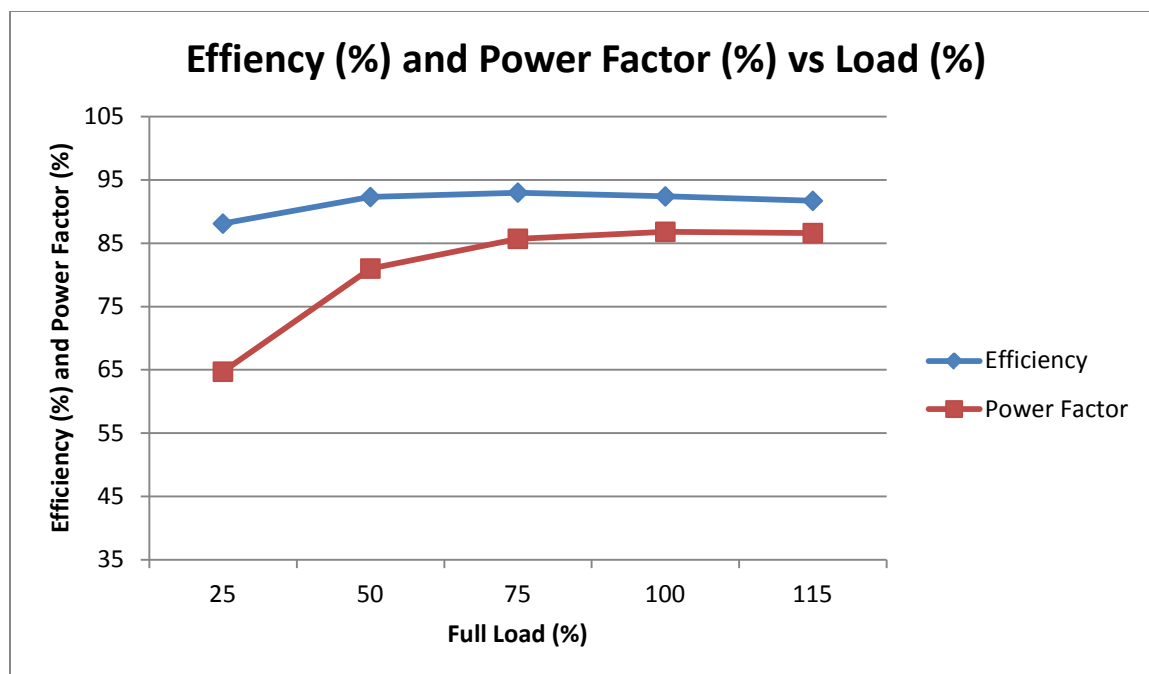


Figure 3.3 75-Horsepower NEMA Design B Efficiency and Power Factor versus Load

5A.3.4 5 Horsepower, NEMA Design C, Baseline Data and IEEE 112B Test Results

Table 3.7 5 Horsepower NEMA Design C Nameplate Data

Parameter	Value
Phases	3
Voltage	208-230/460
Rated Horsepower	5.0
Rated Current	15.3-14.16/7.08
Frame	184T
NEMA Nameplate Nominal Efficiency	87.5%
Hertz	60
RPM	1750
Enclosure	TEFC
Insulation Class	F
Service Factor	1.15
Code Letter (for locked-rotor kVA)	J

Table 3.8 5-Horsepower, NEMA Design C, IEEE 112B Test Results

Load	Power	Efficiency	Power Factor	Current
%	HP	%	%	Amperes
25.8	1.29	79.42	37	4.1
51.1	2.55	86.22	57	4.9
76.1	3.81	87.66	68	5.9
100.9	5.04	87.47	75	7.2
116	5.79	86.99	77	8.1
125.7	6.29	86.49	79	8.7

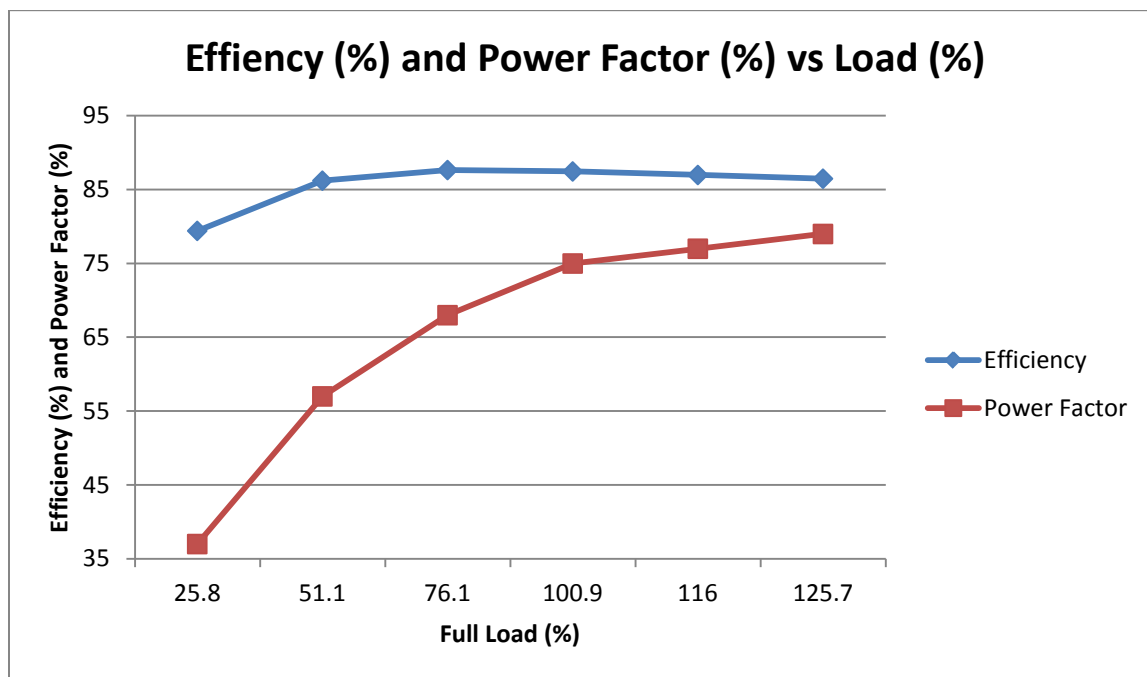


Figure 3.4 5-Horsepower, NEMA Design C, Efficiency and Power Factor versus Load

5A.3.5 50-Horsepower, NEMA Design C, Baseline Data and IEEE 112B Test Results

Table 3.9 50-Horsepower, NEMA Design C, Nameplate Data

Parameter	Value
Phases	3
Voltage	208-230/460
Rated Horsepower	50.0
Rated Current	130-118/59
Frame	236T
NEMA Nameplate Nominal Efficiency	93.0%
Hertz	60
RPM	1770
Enclosure	TEFC
Insulation Class	F
Service Factor	1.15
Code Letter (for locked-rotor kVA)	F

Table 3.10 50-Horsepower, NEMA Design C, IEEE 112B Test Results

Load	Power	Efficiency	Power Factor	Current
%	HP	%	%	Amperes
25.1	12.55	88.04	55	24.5
50.1	25.05	92.25	75	34
75.2	37.57	93.16	82	45.9
100.2	50.07	93.08	85	59.2
115.2	57.56	92.81	86	67.8
125.2	62.59	92.54	86	73.8

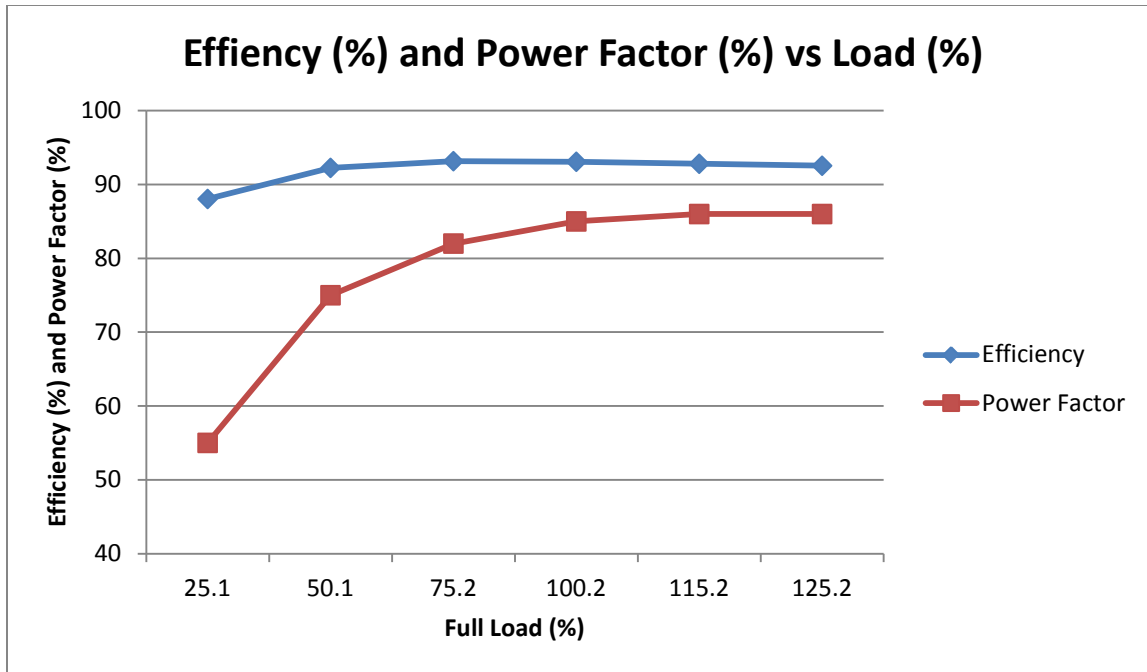


Figure 3.5 50-Horsepower, NEMA Design C, Efficiency and Power Factor versus Load

5A.4 DESIGN SPECIFICATIONS AND LOAD PERFORMANCE OF MAXIMUM TECHNOLOGY MOTORS

Performance data and speed versus torque curves for the maximum-technology, computer-modeled motors are displayed in sections 5A.4.1 through 5A.4.5.

5A.4.1 5-Horsepower, NEMA Design B, Maximum Technology Data and Modeling Results

Table 4.1 5-Horsepower, NEMA Design B, Computer Modeling Data

Load	Power	Efficiency	Power Factor	Current
%	HP	%	%	Amperes
0	0	0	6.9	2.35
25	1.25	86.4	49.5	2.74
50	2.50	91.1	71.3	3.60
75	3.75	92.1	80.5	4.73
100	5.00	92.1	84.4	6.02
115	5.75	91.8	85.4	6.86
125	6.25	91.6	85.7	7.45
150	7.50	90.7	85.7	9.04

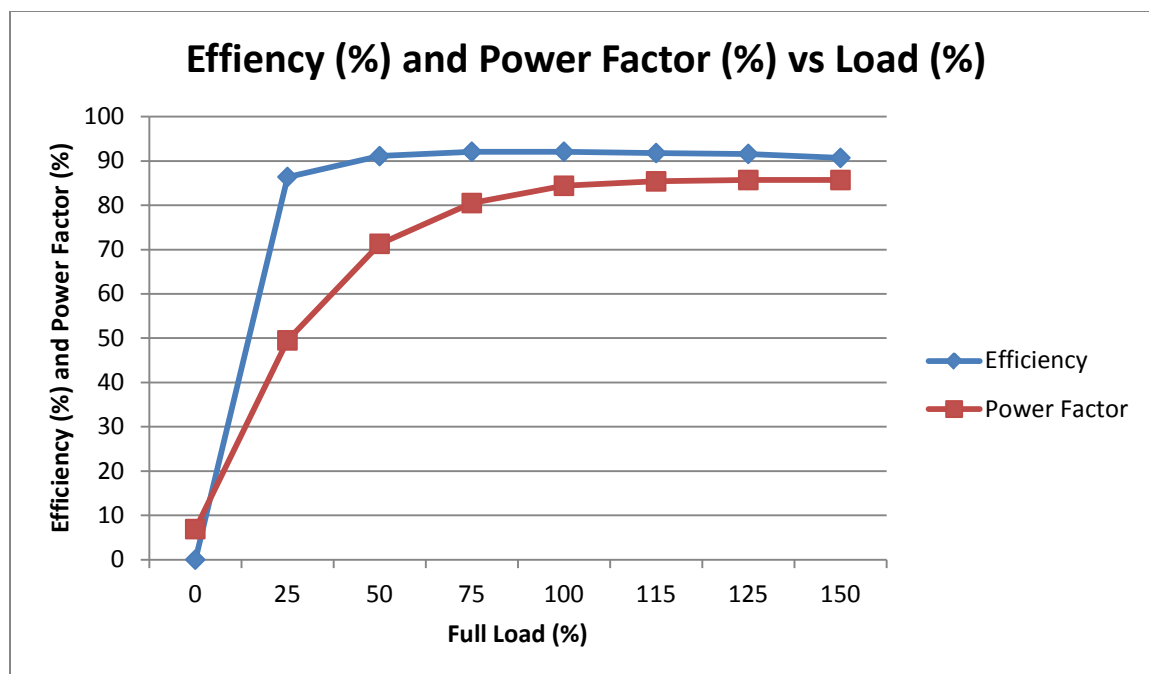


Figure 4.1 5-Horsepower, NEMA Design B, Efficiency and Power Factor versus Load

5A.4.2 30-Horsepower, NEMA Design B, Maximum Technology Data and Modeling Results

Table 4.2 30-Horsepower, NEMA Design B, Computer Modeling Data

Load	Power	Efficiency	Power Factor	Current
%	HP	%	%	Amperes
0	0	0	5.4	12.44
25	7.50	90.3	51.5	15.10
50	14.98	93.8	71.6	20.87
75	22.49	94.7	78.6	28.28
100	29.98	94.8	80.3	36.88
115	34.49	94.7	79.8	42.76
125	37.48	94.5	78.9	47.08
150	44.95	93.5	73.8	60.97

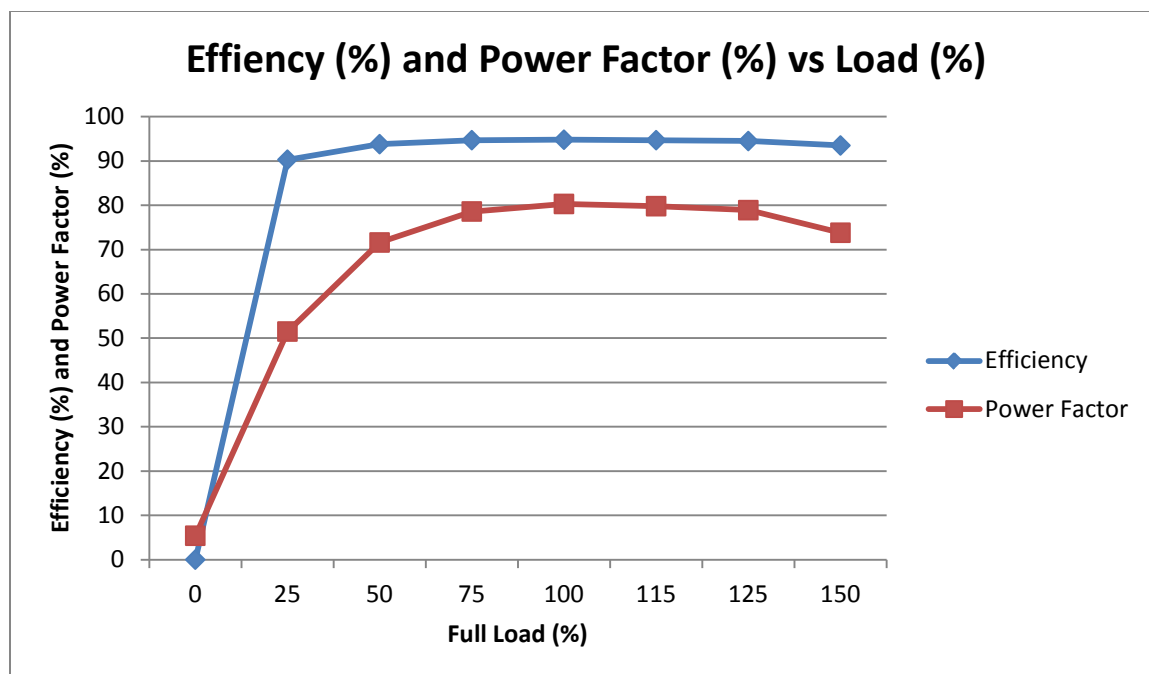


Figure 4.2 30-Horsepower, NEMA Design B, Efficiency and Power Factor versus Load

5A.4.3 75-Horsepower, NEMA Design B, Maximum Technology Data and Modeling Results

Table 4.3 75-Horsepower, NEMA Design B, Computer Modeling Data

Load	Power	Efficiency	Power Factor	Current
%	HP	%	%	Amperes
0	0	0.00	3.10	28.96
25	18.74	94.20	52.30	35.63
50	37.43	96.10	72.30	50.47
75	56.20	96.50	78.50	69.47
100	74.98	96.40	79.30	91.88
115	86.22	96.20	78.00	107.56
125	93.71	96.00	76.40	119.64
150	110.58	94.60	65.60	166.98

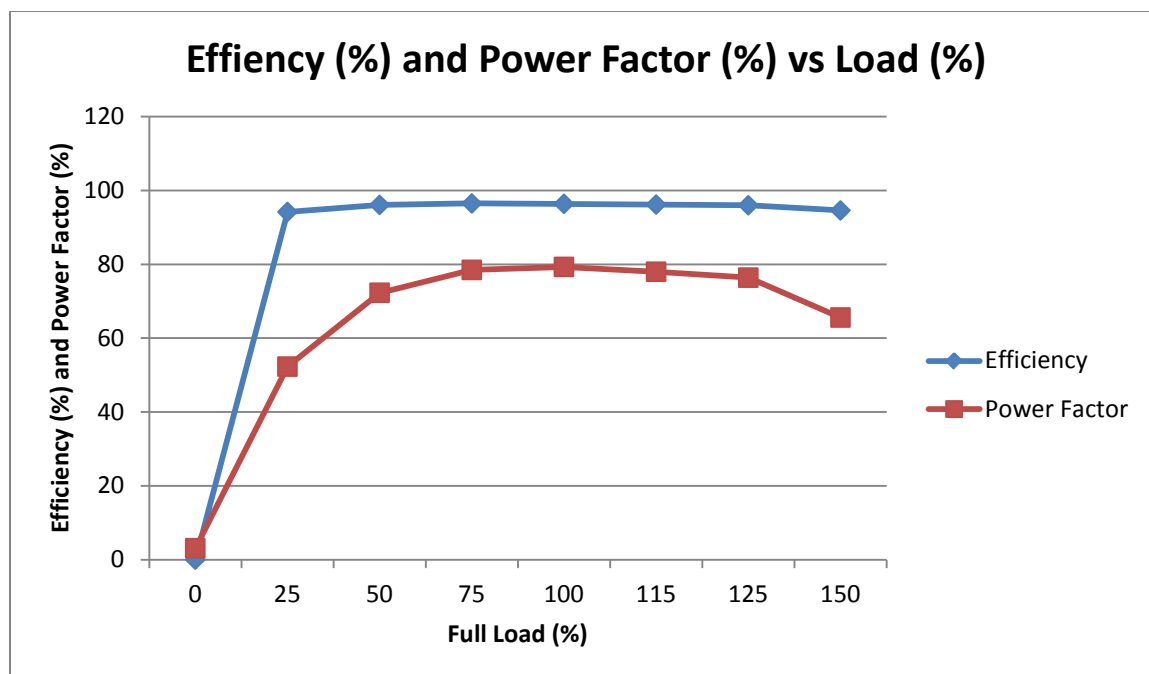


Figure 4.3 75-Horsepower, NEMA Design B, Efficiency and Power Factor versus Load

5A.4.4 5-Horsepower, NEMA Design C, Maximum Technology Data and Modeling Results

Table 4.4 5-Horsepower, NEMA Design C, Computer Modeling Data

Load	Power	Efficiency	Power Factor	Current
%	HP	%	%	Amperes
0	0.00	0.0	7.7	2.94
25	1.25	82.6	43.0	3.29
50	2.48	88.9	64.1	4.10
75	3.75	90.7	74.5	5.20
100	5.00	91.0	79.3	6.49
115	5.75	90.9	80.6	7.35
125	6.25	90.7	81.1	7.96
150	7.50	89.9	81.0	9.64

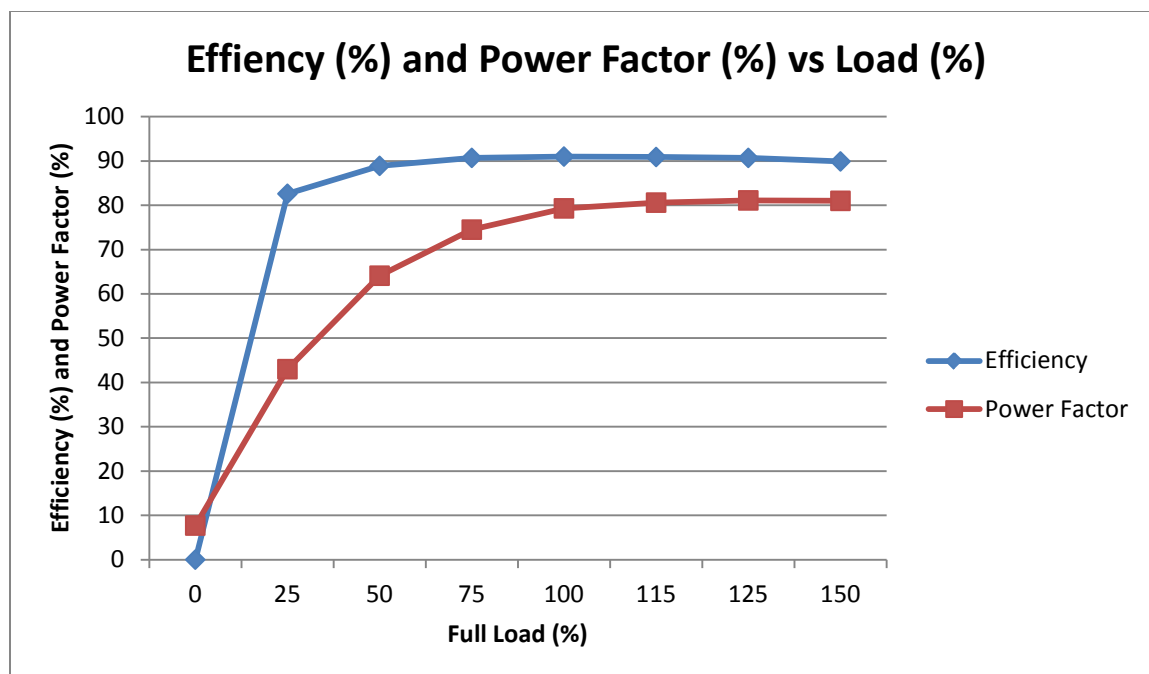


Figure 4.4 5-Horsepower, NEMA Design C, Efficiency and Power Factor versus Load

5A.4.5 50-Horsepower, NEMA Design C, Maximum Technology Data and Modeling Results

Table 4.5 50-Horsepower, NEMA Design C, Computer Modeling Data

Load	Power	Efficiency	Power Factor	Current
%	HP	%	%	Amperes
0	0.00	0.00	4.50	20.08
25	12.49	91.70	52.00	24.51
50	24.96	94.50	72.20	34.25
75	37.47	95.10	78.90	46.75
100	49.96	95.00	80.30	61.35
115	57.47	94.70	79.60	71.42
125	62.47	94.40	78.50	78.96
150	74.77	93.00	72.10	104.42

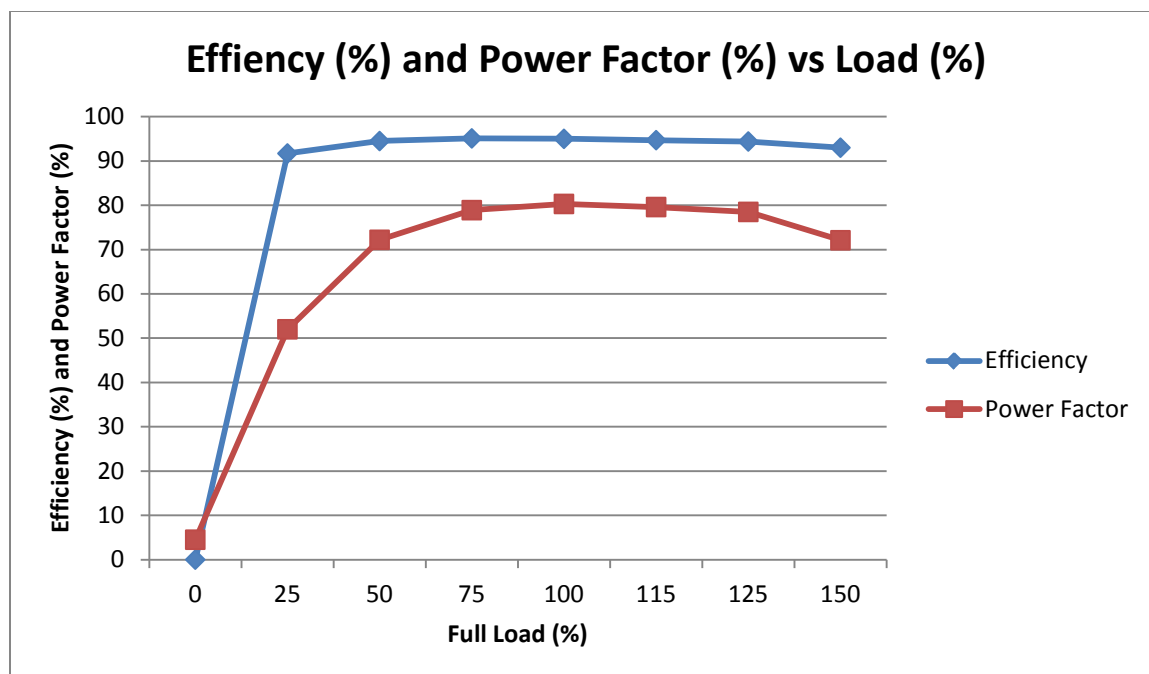


Figure 4.5 50-Horsepower, NEMA Design C, Efficiency and Power Factor versus Load

5A.5 CANDIDATE STANDARD LEVELS OF EFFICIENCY

As part of the scaling process, DOE developed candidate standard levels (CSLs) of efficiency for each equipment class group using NEMA efficiency tables and incremental improvements of motor losses. Table 5.1–Table 5.10 show the CSLs that were developed for the various NEMA design letters, pole configurations, and enclosure types.

Table 5.1 NEMA Design A & B Electric Motors at CSL 0

Horsepower	Nominal Full Load Efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	75.5	75.5	75.5	77.0	74.5	80.0	66.0	72.0
1.5	74.0	80.0	77.0	80.0	75.5	75.5	72.0	75.5
2	77.0	82.5	80.0	79.0	78.5	80.0	78.0	80.0
3	80.0	84.0	78.5	80.0	81.5	82.5	80.0	78.5
5	80.0	81.5	82.5	82.5	84.0	85.5	84.5	82.5
7.5	81.5	84.0	84.0	84.0	82.5	81.5	85.5	84.0
10	82.5	85.5	86.5	87.5	84.0	87.5	84.0	85.5
15	85.5	86.5	86.5	87.5	88.5	85.5	88.5	86.5
20	88.5	88.5	87.5	88.5	87.5	87.5	89.5	86.5
25	91.0	89.5	89.5	85.5	91.7	87.5	88.5	87.5
30	89.5	88.5	89.5	87.5	89.5	87.5	91.0	89.5
40	91.0	88.5	91.0	89.5	89.5	88.5	91.0	89.5
50	92.4	88.5	91.0	89.5	90.2	90.2	91.0	91.0
60	92.4	89.5	91.7	90.2	92.4	89.5	91.0	92.4
75	93.0	89.5	93.0	91.0	92.4	89.5	92.0	93.6
100	93.6	91.0	92.4	92.4	93.0	93.0	92.0	93.6
125	94.5	93.6	92.4	93.0	93.6	93.6	92.5	93.6
150	93.6	92.4	93.6	92.4	95.0	93.0	93.6	93.6
200	95.0	93.6	94.5	93.0	94.2	94.1	93.5	93.6
250	94.5	93.6	94.6	93.6	94.0	94.5	94.0	94.5
300	95.4	95.0	94.1	94.5	94.5	95.4	94.5	94.5
350	95.4	95.0	95.0	94.5	94.9	95.0	94.5	94.5
400	95.4	95.4	95.3	95.4	94.9	95.4	94.5	94.5
450	95.4	95.8	95.4	95.4	95.0	95.4	94.5	94.5
500	95.4	95.8	95.4	95.8	95.0	95.4	94.5	94.5

Table 5.2 NEMA Design A & B Electric Motors at CSL 1

Horsepower	Nominal Full Load Efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	75.5	75.5	82.5	82.5	80.0	80.0	74.0	74.0
1.5	82.5	82.5	84.0	84.0	85.5	84.0	77.0	75.5
2	84.0	84.0	84.0	84.0	86.5	85.5	82.5	85.5
3	85.5	84.0	87.5	86.5	87.5	86.5	84.0	86.5
5	87.5	85.5	87.5	87.5	87.5	87.5	85.5	87.5
7.5	88.5	87.5	89.5	88.5	89.5	88.5	85.5	88.5
10	89.5	88.5	89.5	89.5	89.5	90.2	88.5	89.5
15	90.2	89.5	91.0	91.0	90.2	90.2	88.5	89.5
20	90.2	90.2	91.0	91.0	90.2	91.0	89.5	90.2
25	91.0	91.0	92.4	91.7	91.7	91.7	89.5	90.2
30	91.0	91.0	92.4	92.4	91.7	92.4	91.0	91.0
40	91.7	91.7	93.0	93.0	93.0	93.0	91.0	91.0
50	92.4	92.4	93.0	93.0	93.0	93.0	91.7	91.7
60	93.0	93.0	93.6	93.6	93.6	93.6	91.7	92.4
75	93.0	93.0	94.1	94.1	93.6	93.6	93.0	93.6
100	93.6	93.0	94.5	94.1	94.1	94.1	93.0	93.6
125	94.5	93.6	94.5	94.5	94.1	94.1	93.6	93.6
150	94.5	93.6	95.0	95.0	95.0	94.5	93.6	93.6
200	95.0	94.5	95.0	95.0	95.0	94.5	94.1	93.6
250	95.4	94.5	95.0	95.4	95.0	95.4	94.5	94.5
300	95.4	95.0	95.4	95.4	95.0	95.4	94.5	94.5
350	95.4	95.0	95.4	95.4	95.0	95.4	94.5	94.5
400	95.4	95.4	95.4	95.4	95.0	95.4	94.5	94.5
450	95.4	95.8	95.4	95.8	95.0	95.4	94.5	94.5
500	95.4	95.8	95.8	95.8	95.0	95.4	94.5	94.5

Table 5.3 NEMA Design A & B Electric Motors at CSL 2

Horsepower	Nominal Full Load Efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	77.0	77.0	85.5	85.5	82.5	82.5	75.5	75.5
1.5	84.0	84.0	86.5	86.5	87.5	86.5	78.5	77.0
2	85.5	85.5	86.5	86.5	88.5	87.5	84.0	86.5
3	86.5	85.5	89.5	89.5	89.5	88.5	85.5	87.5
5	88.5	86.5	89.5	89.5	89.5	89.5	86.5	88.5
7.5	89.5	88.5	91.7	91.0	91.0	90.2	86.5	89.5
10	90.2	89.5	91.7	91.7	91.0	91.7	89.5	90.2
15	91.0	90.2	92.4	93.0	91.7	91.7	89.5	90.2
20	91.0	91.0	93.0	93.0	91.7	92.4	90.2	91.0
25	91.7	91.7	93.6	93.6	93.0	93.0	90.2	91.0
30	91.7	91.7	93.6	94.1	93.0	93.6	91.7	91.7
40	92.4	92.4	94.1	94.1	94.1	94.1	91.7	91.7
50	93.0	93.0	94.5	94.5	94.1	94.1	92.4	92.4
60	93.6	93.6	95.0	95.0	94.5	94.5	92.4	93.0
75	93.6	93.6	95.4	95.0	94.5	94.5	93.6	94.1
100	94.1	93.6	95.4	95.4	95.0	95.0	93.6	94.1
125	95.0	94.1	95.4	95.4	95.0	95.0	94.1	94.1
150	95.0	94.1	95.8	95.8	95.8	95.4	94.1	94.1
200	95.4	95.0	96.2	95.8	95.8	95.4	94.5	94.1
250	95.8	95.0	96.2	95.8	95.8	95.8	95.0	95.0
300	95.8	95.4	96.2	95.8	95.8	95.8	95.0	95.0
350	95.8	95.4	96.2	95.8	95.8	95.8	95.0	95.0
400	95.8	95.8	96.2	95.8	95.8	95.8	95.0	95.0
450	95.8	96.2	96.2	96.2	95.8	96.2	95.0	95.0
500	95.8	96.2	96.2	96.2	95.8	96.2	95.0	95.0

Table 5.4 NEMA Design A & B Electric Motors at CSL 3

Horsepower	Nominal Full Load Efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	78.5	78.5	86.5	86.5	84.0	84.0	77.0	77.0
1.5	85.5	85.5	87.5	87.5	88.5	87.5	80.0	78.5
2	86.5	86.5	87.5	87.5	89.5	88.5	85.5	87.5
3	87.5	86.5	90.2	90.2	90.2	89.5	86.5	88.5
5	89.5	87.5	90.2	90.2	90.2	90.2	87.5	89.5
7.5	90.2	89.5	92.4	91.7	91.7	91.0	87.5	90.2
10	91.0	90.2	92.4	92.4	91.7	92.4	90.2	91.0
15	91.7	91.0	93.0	93.6	92.4	92.4	90.2	91.0
20	91.7	91.7	93.6	93.6	92.4	93.0	91.0	91.7
25	92.4	92.4	94.1	94.1	93.6	93.6	91.0	91.7
30	92.4	92.4	94.1	94.5	93.6	94.1	92.4	92.4
40	93.0	93.0	94.5	94.5	94.5	94.5	92.4	92.4
50	93.6	93.6	95.0	95.0	94.5	94.5	93.0	93.0
60	94.1	94.1	95.4	95.4	95.0	95.0	93.0	93.6
75	94.1	94.1	95.8	95.4	95.0	95.0	94.1	94.5
100	94.5	94.1	95.8	95.8	95.4	95.4	94.1	94.5
125	95.4	94.5	95.8	95.8	95.4	95.4	94.5	94.5
150	95.4	94.5	96.2	96.2	96.2	95.8	94.5	94.5
200	95.8	95.4	96.5	96.2	96.2	95.8	95.0	94.5
250	96.2	95.4	96.5	96.2	96.2	96.2	95.4	95.4
300	96.2	95.8	96.5	96.2	96.2	96.2	95.4	95.4
350	96.2	95.8	96.5	96.2	96.2	96.2	95.4	95.4
400	96.2	96.2	96.5	96.2	96.2	96.2	95.4	95.4
450	96.2	96.5	96.5	96.5	96.2	96.5	95.4	95.4
500	96.2	96.5	96.5	96.5	96.2	96.5	95.4	95.4

Table 5.5 NEMA Design A & B Electric Motors at CSL 4

Horsepower	Nominal Full Load Efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	80.0	80.0	87.5	87.5	85.5	85.5	78.5	78.5
1.5	86.5	86.5	88.5	88.5	89.5	88.5	81.5	80.0
2	87.5	87.5	88.5	88.5	90.2	89.5	86.5	88.5
3	88.5	87.5	91.0	91.0	91.0	90.2	87.5	89.5
5	90.2	88.5	91.0	91.0	91.0	91.0	88.5	90.2
7.5	91.0	90.2	93.0	92.4	92.4	91.7	88.5	91.0
10	91.7	91.0	93.0	93.0	92.4	93.0	91.0	91.7
15	92.4	91.7	94.1	94.1	93.0	93.0	91.0	91.7
20	92.4	92.4	94.1	94.1	93.0	93.6	91.7	92.4
25	93.0	93.0	94.5	94.5	94.1	94.1	91.7	92.4
30	93.0	93.0	94.5	95.0	94.1	94.5	93.0	93.0
40	93.6	93.6	95.0	95.0	95.0	95.0	93.0	93.0
50	94.1	94.1	95.4	95.4	95.0	95.0	93.6	93.6
60	94.5	94.5	95.8	95.8	95.4	95.4	93.6	94.1
75	94.5	94.5	96.2	95.8	95.4	95.4	94.5	95.0
100	95.0	94.5	96.2	96.2	95.8	95.8	94.5	95.0
125	95.8	95.0	96.2	96.2	95.8	95.8	95.0	95.0
150	95.8	95.0	96.5	96.5	96.5	96.2	95.0	95.0
200	96.2	95.8	96.8	96.5	96.5	96.2	95.4	95.0
250	96.5	95.8	96.8	96.5	96.5	96.5	95.8	95.8
300	96.5	96.2	96.8	96.5	96.5	96.5	95.8	95.8
350	96.5	96.2	96.8	96.5	96.5	96.5	95.8	95.8
400	96.5	96.5	96.8	96.5	96.5	96.5	95.8	95.8
450	96.5	96.8	96.8	96.8	96.5	96.8	95.8	95.8
500	96.5	96.8	96.8	96.8	96.5	96.8	95.8	95.8

Table 5.6 NEMA Design A & B Electric Motors at CSL 5

Horsepower	Nominal Full Load Efficiency (%)							
	2 Pole		4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	81.5	81.5	88.5	88.5	86.5	86.5	80.0	80.0
1.5	87.5	87.5	89.5	89.5	90.2	89.5	82.5	81.5
2	88.5	88.5	89.5	89.5	91.0	90.2	87.5	89.5
3	89.5	88.5	91.7	91.7	91.7	91.0	88.5	90.2
5	91.0	89.5	91.7	91.7	91.7	91.7	89.5	91.0
7.5	91.7	91.0	93.6	93.0	93.0	92.4	89.5	91.7
10	92.4	91.7	93.6	93.6	93.0	93.6	91.7	92.4
15	92.4	91.7	94.1	94.1	93.0	93.0	91.0	91.7
20	92.4	92.4	94.1	94.1	93.0	93.6	91.7	92.4
25	93.0	93.0	94.5	94.5	94.1	94.1	91.7	92.4
30	93.0	93.0	94.5	95.0	94.1	94.5	93.0	93.0
40	93.6	93.6	95.0	95.0	95.0	95.0	93.0	93.0
50	94.1	94.1	95.4	95.4	95.0	95.0	93.6	93.6
60	95.0	95.0	96.2	96.2	95.8	95.8	94.1	94.5
75	95.0	95.0	96.5	96.2	95.8	95.8	95.0	95.4
100	95.4	95.0	96.5	96.5	96.2	96.2	95.0	95.4
125	96.2	95.4	96.5	96.5	96.2	96.2	95.4	95.4
150	96.2	95.4	96.8	96.8	96.8	96.5	95.4	95.4
200	96.5	96.2	97.1	96.8	96.8	96.5	95.8	95.4
250	96.8	96.2	97.1	96.8	96.8	96.8	96.2	96.2
300	96.8	96.5	97.1	96.8	96.8	96.8	96.2	96.2
350	96.8	96.5	97.1	96.8	96.8	96.8	96.2	96.2
400	96.8	96.8	97.1	96.8	96.8	96.8	96.2	96.2
450	96.8	97.1	97.1	97.1	96.8	97.1	96.2	96.2
500	96.8	97.1	97.1	97.1	96.8	97.1	96.2	96.2

Table 5.7 NEMA Design C Electric Motors at CSL 0

Horsepower	Nominal Full Load Efficiency (%)					
	4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	82.5	82.5	80.0	80.0	74.0	74.0
1.5	84.0	84.0	85.5	84.0	77.0	75.5
2	84.0	84.0	86.5	85.5	82.5	85.5
3	87.5	86.5	87.5	86.5	84.0	86.5
5	87.5	87.5	87.5	87.5	85.5	87.5
7.5	89.5	88.5	89.5	88.5	85.5	88.5
10	89.5	89.5	89.5	90.2	88.5	89.5
15	91.0	91.0	90.2	90.2	88.5	89.5
20	91.0	91.0	90.2	91.0	89.5	90.2
25	92.4	91.7	91.7	91.7	89.5	90.2
30	92.4	92.4	91.7	92.4	91.0	91.0
40	93.0	93.0	93.0	93.0	91.0	91.0
50	93.0	93.0	93.0	93.0	91.7	91.7
60	93.6	93.6	93.6	93.6	91.7	92.4
75	94.1	94.1	93.6	93.6	93.0	93.6
100	94.5	94.1	94.1	94.1	93.0	93.6
125	94.5	94.5	94.1	94.1	93.6	93.6
150	95.0	95.0	95.0	94.5	93.6	93.6
200	95.0	95.0	95.0	94.5	94.1	93.6
250	-	-	-	-	-	-
300	-	-	-	-	-	-
350	-	-	-	-	-	-
400	-	-	-	-	-	-
450	-	-	-	-	-	-
500	-	-	-	-	-	-

Table 5.8 NEMA Design C Electric Motors at CSL 1

Horsepower	Nominal Full Load Efficiency (%)					
	4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	85.5	85.5	82.5	82.5	77.0	77.0
1.5	86.5	86.5	87.5	86.5	80.0	78.5
2	86.5	86.5	88.5	87.5	85.5	87.5
3	89.5	88.5	89.5	88.5	86.5	88.5
5	89.5	89.5	89.5	89.5	87.5	89.5
7.5	91.0	90.2	91.0	90.2	87.5	90.2
10	91.0	91.0	91.0	91.7	90.2	91.0
15	92.4	92.4	91.7	91.7	90.2	91.0
20	92.4	92.4	91.7	92.4	91.0	91.7
25	93.6	93.0	93.0	93.0	91.0	91.7
30	93.6	93.6	93.0	93.6	92.4	92.4
40	94.1	94.1	94.1	94.1	92.4	92.4
50	94.1	94.1	94.1	94.1	93.0	93.0
60	94.5	94.5	94.5	94.5	93.0	93.6
75	95.0	95.0	94.5	94.5	94.1	94.5
100	95.4	95.0	95.0	95.0	94.1	94.5
125	95.4	95.4	95.0	95.0	94.5	94.5
150	95.8	95.8	95.8	95.4	94.5	94.5
200	95.8	95.8	95.8	95.4	95.0	94.5
250	-	-	-	-	-	-
300	-	-	-	-	-	-
350	-	-	-	-	-	-
400	-	-	-	-	-	-
450	-	-	-	-	-	-
500	-	-	-	-	-	-

Table 5.9 NEMA Design C Electric Motors at CSL 2

Horsepower	Nominal Full Load Efficiency (%)					
	4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	86.5	86.5	84.0	84.0	78.5	78.5
1.5	87.5	87.5	88.5	87.5	81.5	80.0
2	87.5	87.5	89.5	88.5	86.5	88.5
3	90.2	89.5	90.2	89.5	87.5	89.5
5	90.2	90.2	90.2	90.2	88.5	90.2
7.5	91.7	91.0	91.7	91.0	88.5	91.0
10	91.7	91.7	91.7	92.4	91.0	91.7
15	93.0	93.0	92.4	92.4	91.0	91.7
20	93.0	93.0	92.4	93.0	91.7	92.4
25	94.1	93.6	93.6	93.6	91.7	92.4
30	94.1	94.1	93.6	94.1	93.0	93.0
40	94.5	94.5	94.5	94.5	93.0	93.0
50	94.5	94.5	94.5	94.5	93.6	93.6
60	95.0	95.0	95.0	95.0	93.6	94.1
75	95.4	95.4	95.0	95.0	94.5	95.0
100	95.8	95.4	95.4	95.4	94.5	95.0
125	95.8	95.8	95.4	95.4	95.0	95.0
150	96.2	96.2	96.2	95.8	95.0	95.0
200	96.2	96.2	96.2	95.8	95.4	95.0
250	-	-	-	-	-	-
300	-	-	-	-	-	-
350	-	-	-	-	-	-
400	-	-	-	-	-	-
450	-	-	-	-	-	-
500	-	-	-	-	-	-

Table 5.10 NEMA Design C Electric Motors at CSL 3

Horsepower	Nominal Full Load Efficiency (%)					
	4 Pole		6 Pole		8 Pole	
	Enclosed	Open	Enclosed	Open	Enclosed	Open
1	87.5	87.5	85.5	85.5	80.0	80.0
1.5	88.5	88.5	89.5	88.5	82.5	81.5
2	88.5	88.5	90.2	89.5	87.5	89.5
3	91.0	90.2	91.0	90.2	88.5	90.2
5	91.0	91.0	91.0	91.0	89.5	91.0
7.5	92.4	91.7	92.4	91.7	89.5	91.7
10	92.4	92.4	92.4	93.0	91.7	92.4
15	93.6	93.6	93.0	93.0	91.7	92.4
20	93.6	93.6	93.0	93.6	92.4	93.0
25	94.5	94.1	94.1	94.1	92.4	93.0
30	94.5	94.5	94.1	94.5	93.6	93.6
40	95.0	95.0	95.0	95.0	93.6	93.6
50	95.0	95.0	95.0	95.0	94.1	94.1
60	95.4	95.4	95.4	95.4	94.1	94.5
75	95.8	95.8	95.4	95.4	95.0	95.4
100	96.2	95.8	95.8	95.8	95.0	95.4
125	96.2	96.2	95.8	95.8	95.4	95.4
150	96.5	96.5	96.5	96.2	95.4	95.4
200	96.5	96.5	96.5	96.2	95.8	95.4
250	-	-	-	-	-	-
300	-	-	-	-	-	-
350	-	-	-	-	-	-
400	-	-	-	-	-	-
450	-	-	-	-	-	-
500	-	-	-	-	-	-

5A.6 MATERIAL PRICING ASSUMPTIONS

DOE gathered material pricing information from numerous sources, including subject matter experts (SMEs), manufacturers, internal material pricing databases developed from research on other rulemakings, the U.S. Census Bureau's Producer Price Index, the London Metal Exchange and the Commodity Exchange, Inc. DOE used a 2011 dollar pricing for a majority of the materials, but for copper wire and cast copper prices DOE used a five-year average dating from 2007-2011.

5A.6.1 Copper Wire Pricing

DOE used a five-year average price for copper due to the large price fluctuations in copper wire and copper used for casting. The five-year average copper pricings are displayed in Table 6.1. DOE used a constant price for all wire gauges due to the small pricing differences between the different wire gauges.

Table 6.1 Copper Material Pricing

Material Type	5 Year Average	Year				
		2011	2010	2009	2008	2007
Cu Wire (\$/lb)	2011-2007					
Cu Wire, Gauge 14 & 14.5	\$4.35	\$4.00	\$3.49	\$2.45	\$3.39	\$3.39
Cu Wire, Gauge 15 & 15.5	\$4.35	\$4.00	\$3.49	\$2.45	\$3.39	\$3.39
Cu Wire, Gauge 16 & 16.5	\$4.35	\$4.00	\$3.49	\$2.45	\$3.39	\$3.39
Cu Wire, Gauge 17 & 17.5	\$4.35	\$4.00	\$3.49	\$2.45	\$3.39	\$3.39
Cu Wire, Gauge 18 & 18.5	\$4.35	\$4.00	\$3.49	\$2.45	\$3.39	\$3.39
Cu Wire, Gauge 19 , 19.5, 20 & 20.5	\$4.35	\$4.00	\$3.49	\$2.45	\$3.39	\$3.39
Casting Materials (\$/lb)						
Casting Materials - Copper	\$3.35	\$4.00	\$3.49	\$2.45	\$3.39	\$3.39

5A.6.2 2011 Material Pricing

DOE used a constant 2011\$ pricing for the remaining materials which include electrical steels, aluminum for casting, cast iron, and hot rolled steel. These price assumptions are displayed in Table 6.2.

Table 6.2 Material Pricing in Constant 2011\$

Motor Frame/End Bell Material (\$/lb)	
Frame Material - Cast Iron 20k-30k psi	\$0.60
Frame Material - Steel Fabrication	\$0.47
Frame Material - Aluminum (extruded or cast)	\$1.30
Casting Materials (\$/lb)	
Casting Materials - Aluminum	\$1.30
Core Steels - ASTM #, Thickness, Processing (\$/lb)	
26M12, .0185", fully/semi-processed	\$1.10
26M15, .0185", fully/semi-processed	\$1.05
26M19, .0185", fully/semi-processed	\$1.02
26M22, .0185", fully/semi-processed	\$0.95
26M27, .0185", fully/semi-processed	\$0.89
26M36, .0185", fully/semi-processed	\$0.80
26M47, .0185", fully/semi-processed	\$0.78
26M56, .0185", fully/semi-processed	\$0.73
Other AISI Size or Thickness	
Rotor Shaft (\$/lb)	
Hot Rolled AISI #1040 Series	\$0.52
Bearings (\$/each)	
Front Bearing, 5-HP	\$10.11
Back Bearing, 5-HP	\$5.66
Front Bearing, 30-HP	\$31.30
Back Bearing, 30-HP	\$14.39
Front Bearing, 50-HP	\$49.35
Back Bearing, 50-HP	\$25.29
Front Bearing, 75-HP	\$67.41
Back Bearing, 75-HP	\$36.19

5A.7 LABOR TIME AND COST ASSUMPTIONS

DOE estimated labor hours for each CSL of each representative unit. DOE requested information from manufacturers concerning labor time associated with certain electric motor horsepower ratings. A summary of these labor time estimates is displayed in Table 7.1. Due to the limited manufacturer feedback, DOE relied primarily on SME input to derive the time requirements to build the representative units. For the purchased representative units (CSL 0-3 for the NEMA Design B motors and CSL 0 for the NEMA Design C motors) DOE relied on visual inspection by motor industry experts to determine if a motor was machine or hand wound. All motors above CSL 3 were considered hand wound, regardless of slot fill percentage. Approximate slot fill percentages are displayed in Table 7.2.

Table 7.1 Labor Hour Assumptions by Candidate Standard Level (CSL)

APPENDIX 5A.	Labor Hours					
HP Rating	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
5, Design B	1.25	1.31	1.38	1.45	3.50*	3.68*
30, Design B	2.00	2.10	2.21	2.32	6.00*	-
75, Design B	3.50	3.68	3.86	4.06	9.00*	9.45*
5, Design C	1.25	1.31	3.50*	3.68*	-	-
50, Design C	2.75	2.89	7.50*	7.88*	-	-

* Based on slot fill measurements, DOE assumed a hand-wound labor hour amount for these motors

Table 7.2 Slot Fill Percentages by Candidate Standard Level (CSL)

APPENDIX 5A.	Approximate Slot Fill					
HP Rating	CSL 0	CSL 1	CSL 2	CSL 3	CSL 4	CSL 5
5, Design B	43.5%	57.2%	70.0%	68.6%	82.4%	85.2%
30, Design B	48.4%	84.0%	70.0%	70.0%	83.2%	-
75, Design B	48.0%	44.5%	70.0%	70.0%	85.1%	83.4%
5, Design C	67.9%	79.9%	83.9%	82.9%	-	-
50, Design C	79.6%	74.8%	85.3%	81.3%	-	-