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 small electric motor product classes analyzed in the engineering analysis (chapter 5).

5A.2 BASELINE DESIGN OPTIONS

Table 2.1 shows the baseline design options for each product class analyzed. All changes to cost and efficiency are measured relative to this level in the engineering analysis. The representative motors chosen from each product class are: CSIR, ½ horsepower, four-pole; CSCR ¾ horsepower, four-pole; and polyphase, 1 horsepower, four-pole motors. Refer to chapter 5 of the TSD for details about each baseline technology.

Table 2.1 Baseline Design Options

Parameter (Units)	Polyphase	CSIR	CSCR
Efficiency (%)	75.3	57.9	71.4
Power Factor	69.0	56.9	69.0
Speed (RPM)	1728	1730	1733
Torque (in-lbs)	36.8	18.3	27.3
Current (A)	3.52	9.49	9.99
Core Steel	24M56	.028M56	24M56
Stack Height (in)	3.0	2	3
Rotor Material	Al	Al	Al
Main Wire (AWG)	22	18.5	18
Auxiliary Wire (AWG)	N/A	21.5	19
Start Capacitance (μF)	N/A	333	433
Run Capacitance (μF)	N/A	N/A	7.5
Locked-Rotor Torque (in-lbs) (at 25˚ C)	123.2	64.0	89.7
Locked-Rotor Current (A) (at 25˚ C)	19.7	43.4	58.2
Service Factor	1.15	1.25	1.25

5A.3 COST-EFFICIENCY RESULTS

For each product class analyzed in the engineering analysis, DOE had its subcontractor create higher efficiency designs above the baseline efficiency level. The subcontractor modeled these designs after the baseline design, but altered several design specifications within the limits provided by DOE.

5A.4 COST-EFFICIENCY RELATIONSHIP VERIFICATION

Once the cost-efficiency relationships were determined using the subcontractor's designs, DOE tested 2 to 3 additional motors in each product class to corroborate the results gleaned from the subcontractor's design work. These motors all had the same pole configuration and horsepower rating as the representative product class, but they differed in rated efficiency from the previously tested baseline motor upon which the subcontractor based its designs. Figure 4.1 through Figure 4.3 show the results of these tested motors plotted with the cost-efficiency results

determined using the subcontractor's modeled designs. The max-tech point has been removed from these illustrations.

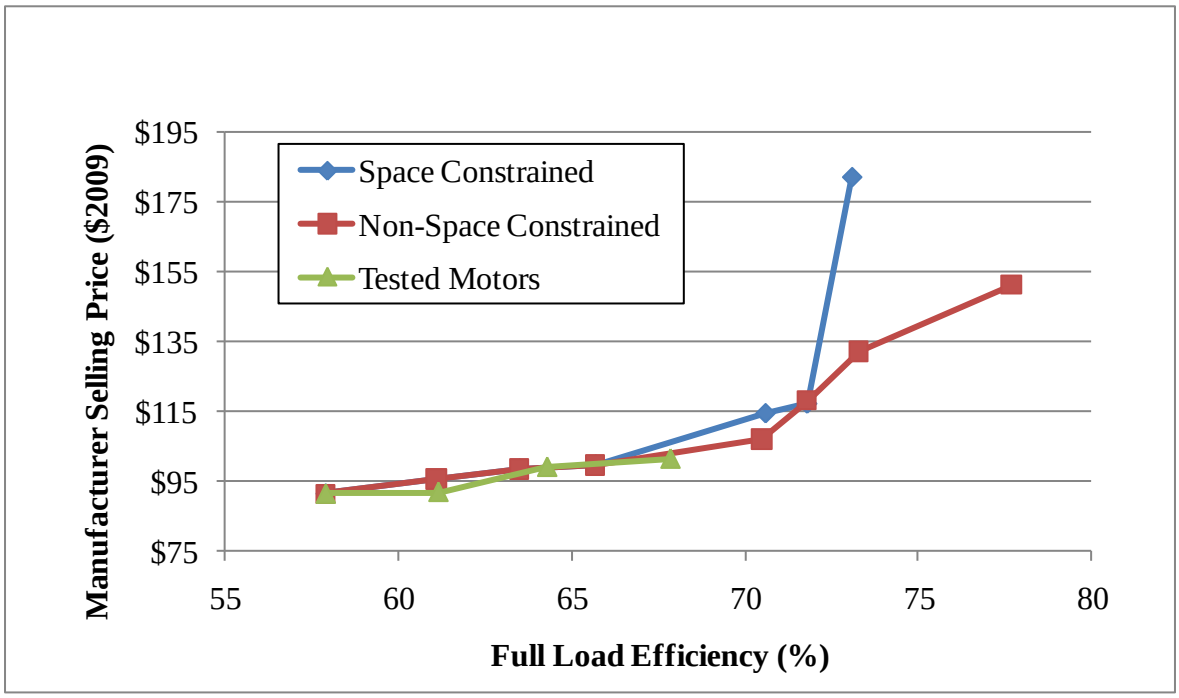

Figure 4.1 Capacitor-Start, Induction-Run, ½ Horsepower, 4-Pole, 48-Frame Engineering Analysis Curve with Tested Motor Results

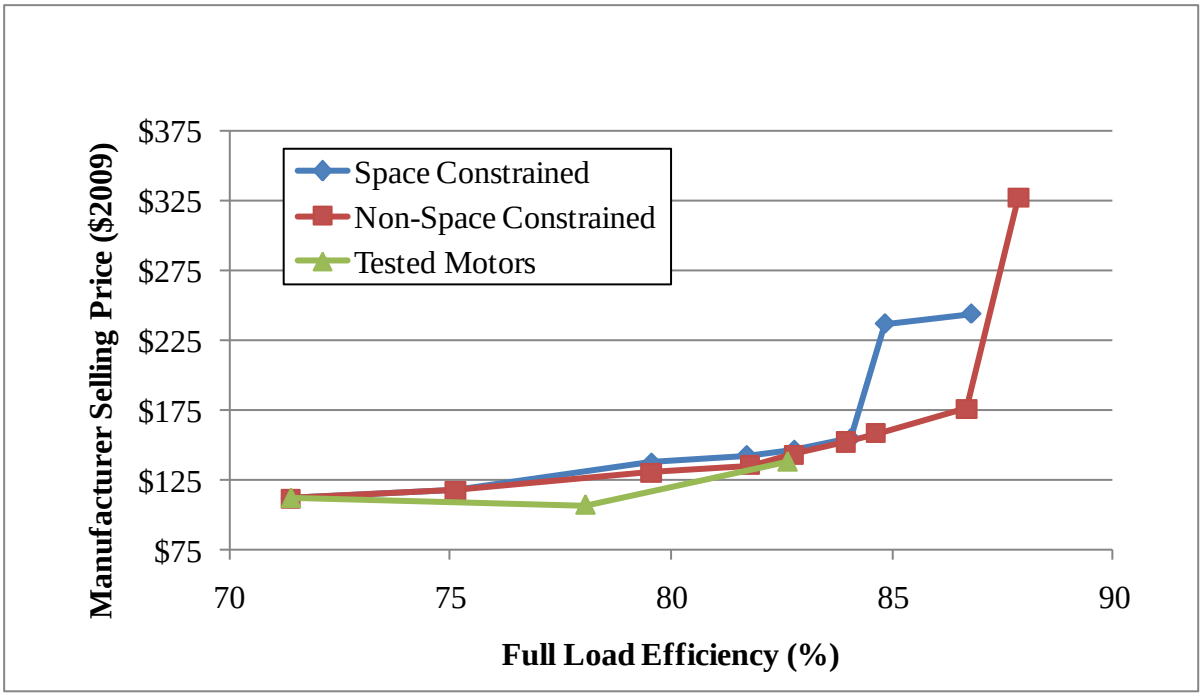

Figure 4.2 Capacitor-Start, Capacitor-Run ¾ Horsepower, 4-Pole, 56-Frame Engineering Analysis Curve with Tested Motor Results

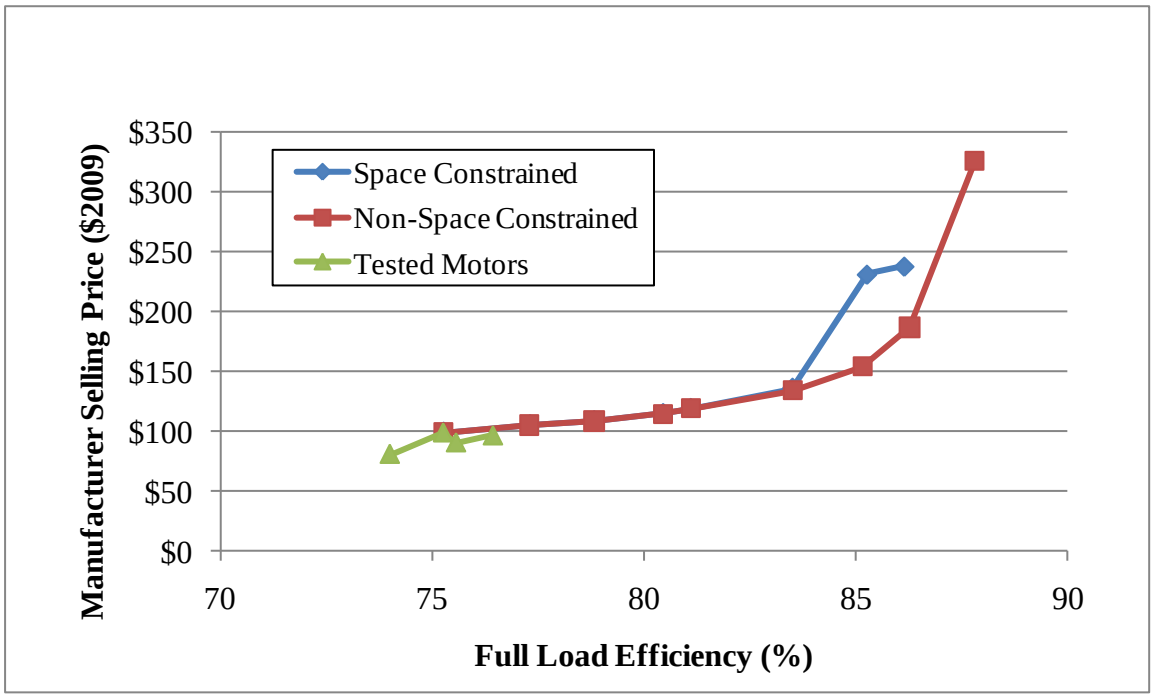

Figure 4.3 Polyphase 1 Horsepower, 4-Pole, 56-Frame Motor Engineering Analysis Curve with Tested Motor Results

The tested motors lie at or below the engineering analysis curves developed for all three motor categories: CSIR, CSCR, and polyphase. This confirms that DOE's cost-efficiency curves

are sufficient in estimating the actual cost of achieving an efficiency level above the baseline for these product classes. The tested motors from the polyphase product class shows one motor tested at an efficiency level below what DOE used for the baseline efficiency. As mentioned in TSD chapter 5, there can be variability of efficiency within a population of motors, which is why DOE performed additional efficiency tests for its polyphase baseline motor. In this case, the tested motor with an efficiency below the baseline motor actually tested at an efficiency lower than what it was listed at in the catalog.

5A.5 DESIGN SPECIFICATIONS OF BASELINE POLYPHASE MOTOR

5A.5.1 Stator Dimensions

Lamination Steel Type	Tempel M56
Length of the Stator Stack	3.0000 inch
Stacking Factor of the Stator	0.9800
Stator Slot Insulation Thickness	0.0100 inch
Number of Stator Poles	4 Poles
Outside Diameter of the Stator	5.4870 inch
Number of Stator Slots	24
Inside Diameter of the Stator	3.1740 inch
Thickness of mid slot separator	0.0000 inch
Stator Slot Width Next to Gap	0.1800 inch
Stator Slot Width at Bottom of Slot	0.3130 inch
Depth of Main Trapezoidal Part	0.6840 inch
Depth of Slot Mouth	0.0260 inch
Stator Slot Opening	0.1000 inch
Depth of Tooth Tip	0.0300 inch
Total Depth of Stator Slot	0.7400 inch

5A.5.2 Rotor Dimensions

Shaft Material	Magnetic
Outside Diameter of the Rotor	3.1558 inch
Inside Diameter of the Rotor	0.9350 inch
Length of the Rotor Stack	3.0100 inch
Stacking Factor of the Rotor	0.9800

5A.5.3 Rotor Slot Dimensions

Closed Bridge, Trap w/ Round Bottom	
Depth of Rotor Slot Opening	0.0000 inch
Width at Top of Rotor Slot	0.1400 inch
Width at Bottom of Rotor Slot	0.0700 inch
Depth of Main Trapezoidal Part	0.1750 inch
Depth of Slot Mouth	0.0100 inch
Depth of Bridge	0.0000 inch
Total Depth of Rotor Slot	0.2750 inch

Number of Rotor Slots	36 slots

5A.5.4 Ring & Coil Data

Inside Diameter of Ring 1	2.2000 inch
Outside Diameter of Ring 1	2.9400 inch
Axial Thickness at Outside of Ring 1	0.4250 inch
Axial Thickness at Inside of Ring 1	0.4250 inch
Inside Diameter of Ring 2	2.2000 inch
Outside Diameter of Ring 2	2.9400 inch
Axial Thickness at Outside of Ring 2	0.4250 inch
Axial Thickness at Inside of Ring 2	0.4250 inch
Conductivity of the Rotor Bar Material	0.5700
Conductivity of the End Ring Material	0.5700

5A.5.5 Electrical Data

Wire Insulation Type	Heavy
Terminal Voltage	230.00 Volts
Turns per Coil in Slot 1	62 Turns
Turns per Coil in Slot 2	27 Turns
Winding Wire Size	22.0 AWG
Line Frequency	60.0 Hz
Rotor Skew	1.50 bars
Winding Operating Temperature	70.50 deg C
Friction & Windage Loss at Idle Speed	2.3430 Watts
Stray Load Loss	2.4 %
Wire Stretch Factor	1.030

5A.5.6 Load Speed & Slip Info

Specified Load Speed	1728.0 RPM
Minimum Load Speed	0.0 RPM
Speed Increment	10.0 RPM

5A.5.7 No Load Performance

Synchronous Speed	1800.0 RPM
Actual No Load Speed	1799.6 RPM
Actual No Load Phase Current	2.52 Amps
No Load Phase Winding Current Density	2502.93 Amps/sq. in

5A.5.8 Locked Rotor Data (Full Load Temperature)

Locked Rotor Torque	120.05 lb-in
Locked Rotor Phase Current	18.340 Amps
Locked Rotor Phase Current Density	18240.12 A/sq. in.

5A.5.9 Breakdown Load Parameters (Full Load Temperature)

BreakDown Speed	997.6 RPM
BreakDown Torque	126.55 lb-in
BreakDown Current	13.95 Amps
BreakDown Output Power	1494.0 Watts
BreakDown Output Power	2.0027 Hp
BreakDown Efficiency	34.7 %
BreakDown Power Factor	77.532
BreakDown Input Power	4308.8 Watts
Phase Current Density at BreakDown	13874.71 A/sq. in.

5A.5.10 Reactance Values

Primary Slot Leakage	0.9407 Ohms
Secondary Slot Leakage	0.8460 Ohms
End Leakage	0.5551 Ohms
Skew Leakage	0.5275 Ohms
Zig Zag Leakage	1.2111 Ohms
Belt Leakage	0.1758 Ohms
Primary Leakage Reactance	2.7855 Ohms
Rotor Leakage	2.2060 Ohms
Magnitizing Reactance	49.2724 Ohms

5A.5.11 Winding Information

Hot Rotor Resistance	2.8656 Ohms
Rotor Resistance Ratio	0.5741
Cold Winding Resistance	2.2125
Hot Winding Resistance	2.5999 Ohms
Winding Distribution Factor	0.966
Total Winding Conductors per Phase	356.00 Conductors
Effective Winding Conductors per Phase	343.9 Conductors
Slot 1 % Fill	50.12 %
Slot 2 % Fill	21.82 %
Slot 3 % Fill	0.00 %
Slot 4 % Fill	0.00 %
Slot 5 % Fill	0.00 %
Slot 6 % Fill	0.00 %
Slot 7 % Fill	0.00 %
Slot 8 % Fill	0.00 %
Total Weight of the Copper	3.1936 lbs
Electrical Area of One Rotor Bar	0.0261 sq. in.
Electrical Area of All Rotor Bars	0.9386 sq. in.
Weight of Stator Steel	13.3193 lbs
Weight of Rotor Steel	6.0995 lbs
Weight of Stator and Rotor Steel	19.4188 lbs

Weight of Rotor Aluminum	0.5348 lbs

5A.5.12 Magnetic Circuit Data

Magnetic Length of Air Gap	0.0115 inch
Total Air Gap Flux per Pole	266.4 kilolines
Flux Density in Air Gap	53.4 Klines/in^2
Flux Density in Stator Yoke	101.2 Klines/in^2
Flux Density in Stator Teeth	89.3 Klines/in^2
Flux Density in Rotor Yoke	50.1 Klines/in^2
Flux Density in Rotor Teeth	109.5 Klines/in^2
MMF Drop in Air Gap	192.5 A-T
MMF Drop in Stator Yoke	19.8 A-T
MMF Drop in Rotor Yoke	1.2 A-T
MMF Drop in Statot Teeth	3.3 A-T
MMF Drop in Rotor Teeth	14.0 A-T
Total MMF Drop	230.9 A-T

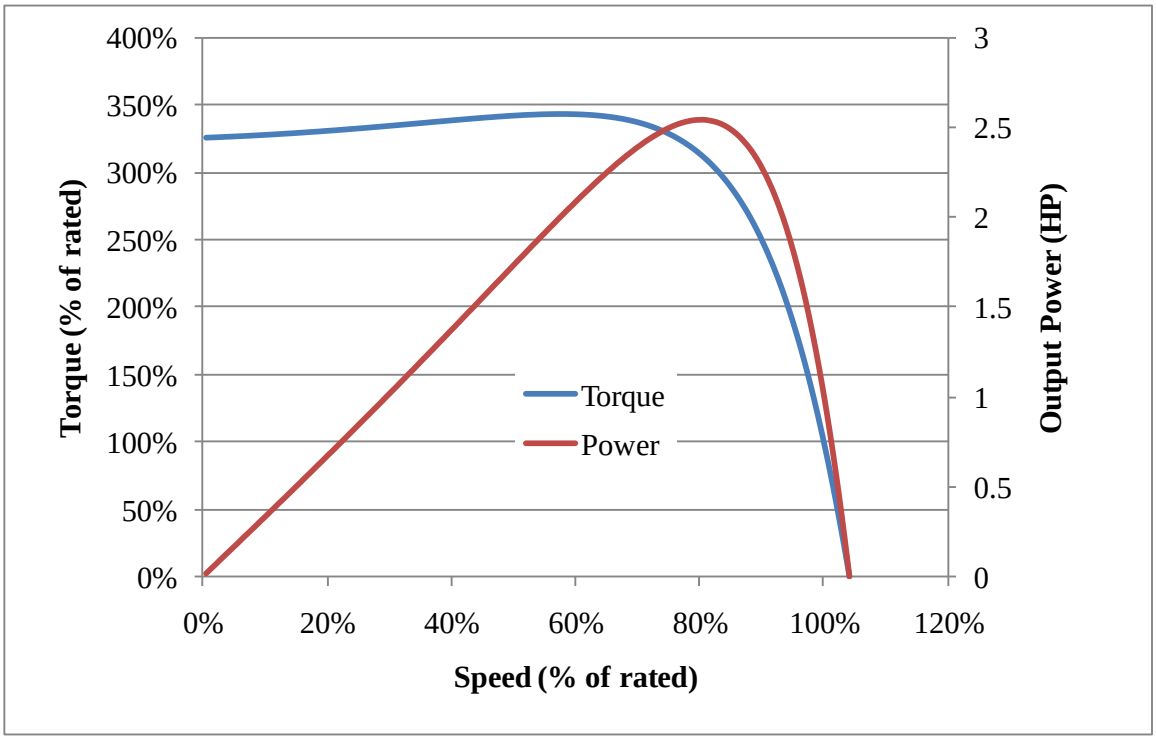

Figure 5.1 Torque and Output Power versus Speed for Baseline Polyphase Motor

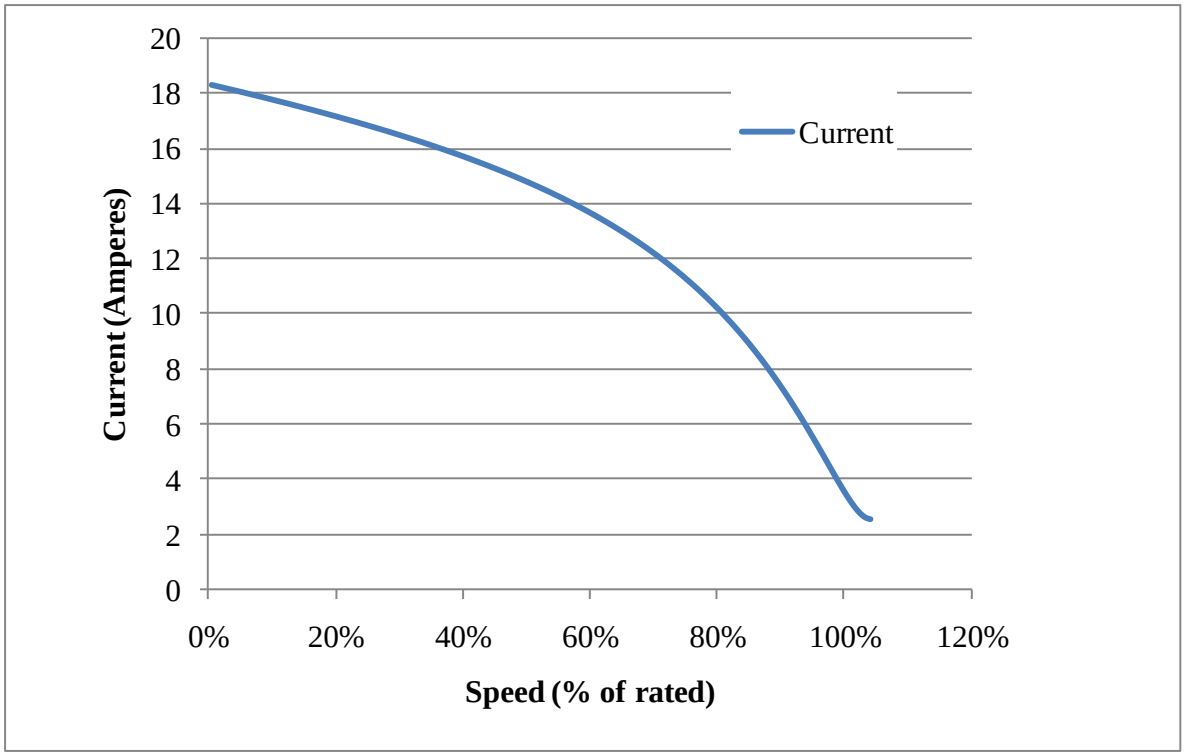

Figure 5.2 Current versus Speed for Baseline Polyphase Motor

5A.6 DESIGN SPECIFICATIONS OF POLYPHASE TSL 4B (EL 4B SPACE CONSTRAINED) DESIGN

5A.6.1 Stator Dimensions

Lamination Steel Type	M 19
Length of the Stator Stack	3.6000 inch
Stacking Factor of the Stator	0.9800
Stator Slot Insulation Thickness	0.0100 inch
Number of Stator Poles	4 Poles
Outside Diameter of the Stator	5.4870 inch
Number of Stator Slots	24
Inside Diameter of the Stator	3.1740 inch
Thickness of mid slot separator	0.0000 inch
Stator Slot Width Next to Gap	0.1800 inch
Stator Slot Width at Bottom of Slot	0.3130 inch
Depth of Main Trapezoidal Part	0.6840 inch
Depth of Slot Mouth	0.0260 inch
Stator Slot Opening	0.1000 inch
Depth of Tooth Tip	0.0300 inch
Total Depth of Stator Slot	0.7400 inch

5A.6.2 Rotor Dimensions

Shaft Material	Magnetic
Outside Diameter of the Rotor	3.1558 inch
Inside Diameter of the Rotor	0.9350 inch
Length of the Rotor Stack	3.6000 inch
Stacking Factor of the Rotor	0.9800

5A.6.3 Rotor Slot Dimensions

Closed Bridge, Trap w/ Round Bottom	
Depth of Rotor Slot Opening	0.0000 inch
Width at Top of Rotor Slot	0.1400 inch
Width at Bottom of Rotor Slot	0.0700 inch
Depth of Main Trapezoidal Part	0.1750 inch
Depth of Slot Mouth	0.0100 inch
Depth of Bridge	0.0000 inch
Total Depth of Rotor Slot	0.2750 inch
Number of Rotor Slots	36 slots

5A.6.4 Ring & Coil Data

Inside Diameter of Ring 1	2.0000 inch
Outside Diameter of Ring 1	2.9400 inch
Axial Thickness at Outside of Ring 1	0.4000 inch
Axial Thickness at Inside of Ring 1	0.4000 inch
Inside Diameter of Ring 2	2.0000 inch
Outside Diameter of Ring 2	2.9400 inch
Axial Thickness at Outside of Ring 2	0.4000 inch
Axial Thickness at Inside of Ring 2	0.4000 inch
Conductivity of the Rotor Bar Material	0.5700
Conductivity of the End Ring Material	0.5700

5A.6.5 Electrical Data

Wire Insulation Type	Heavy
Terminal Voltage	230.00 Volts
Turns per Coil in Slot 1	45 Turns
Turns per Coil in Slot 2	45 Turns
Winding Wire Size	20.0 AWG
Line Frequency	60.0 Hz
Rotor Skew	1.50 bars
Winding Operating Temperature	47.37 deg C
Friction & Windage Loss at Idle Speed	2.3430 Watts
Stray Load Loss	2.4 %
Wire Stretch Factor	1.030

5A.6.6 Load Speed & Slip Info

Specified Load Speed	1728.0 RPM
Minimum Load Speed	0.0 RPM
Speed Increment	10.0 RPM

5A.6.7 No Load Performance

Synchronous Speed	1800.0 RPM
Actual No Load Speed	1799.6 RPM
Actual No Load Phase Current	1.88 Amps
No Load Phase Winding Current Density	1168.61 Amps/sq. in

5A.6.8 Locked Rotor Data (Full Load Temperature)

Locked Rotor Torque	113.50 lb-in
Locked Rotor Phase Current	17.368 Amps
Locked Rotor Phase Current Density	10797.45 A/sq. in.

5A.6.9 Breakdown Load Parameters (Full Load Temperature)

BreakDown Speed	1111.7 RPM
BreakDown Torque	127.31 lb-in
BreakDown Current	12.67 Amps
BreakDown Output Power	1674.9 Watts
BreakDown Output Power	2.2452 Hp
BreakDown Efficiency	47.2 %
BreakDown Power Factor	70.368
BreakDown Input Power	3551.0 Watts
Phase Current Density at BreakDown	7875.34 A/sq. in.

5A.6.10 Reactance Values

Primary Slot Leakage	1.0297 Ohms
Secondary Slot Leakage	1.0347 Ohms
End Leakage	0.5327 Ohms
Skew Leakage	0.7325 Ohms
Zig Zag Leakage	1.4862 Ohms
Belt Leakage	0.2378 Ohms
Primary Leakage Reactance	3.3942 Ohms
Rotor Leakage	2.9340 Ohms
Magnitizing Reactance	66.6401 Ohms

5A.6.11 Winding Information

Hot Rotor Resistance	3.0006 Ohms
Rotor Resistance Ratio	0.4742
Cold Winding Resistance	1.4440

Hot Winding Resistance	1.5683 Ohms
Winding Distribution Factor	0.966
Total Winding Conductors per Phase	360.00 Conductors
Effective Winding Conductors per Phase	347.7 Conductors
Slot 1 % Fill	57.16 %
Slot 2 % Fill	57.16 %
Slot 3 % Fill	0.00 %
Slot 4 % Fill	0.00 %
Slot 5 % Fill	0.00 %
Slot 6 % Fill	0.00 %
Slot 7 % Fill	0.00 %
Slot 8 % Fill	0.00 %
Total Weight of the Copper	5.3344 lbs
Electrical Area of One Rotor Bar	0.0261 sq. in.
Electrical Area of All Rotor Bars	0.9386 sq. in.
Weight of Stator Steel	15.9832 lbs
Weight of Rotor Steel	7.2950 lbs
Weight of Stator and Rotor Steel	23.2782 lbs
Weight of Rotor Aluminum	0.6278 lbs

5A.6.12 Magnetic Circuit Data

Magnetic Length of Air Gap	0.0115 inch
Total Air Gap Flux per Pole	280.7 kilolines
Flux Density in Air Gap	48.3 Klines/in^2
Flux Density in Stator Yoke	88.8 Klines/in^2
Flux Density in Stator Teeth	78.5 Klines/in^2
Flux Density in Rotor Yoke	45.3 Klines/in^2
Flux Density in Rotor Teeth	99.0 Klines/in^2
MMF Drop in Air Gap	173.8 A-T
MMF Drop in Stator Yoke	16.8 A-T
MMF Drop in Rotor Yoke	0.7 A-T
MMF Drop in Statot Teeth	4.9 A-T
MMF Drop in Rotor Teeth	13.8 A-T
Total MMF Drop	210.0 A-T

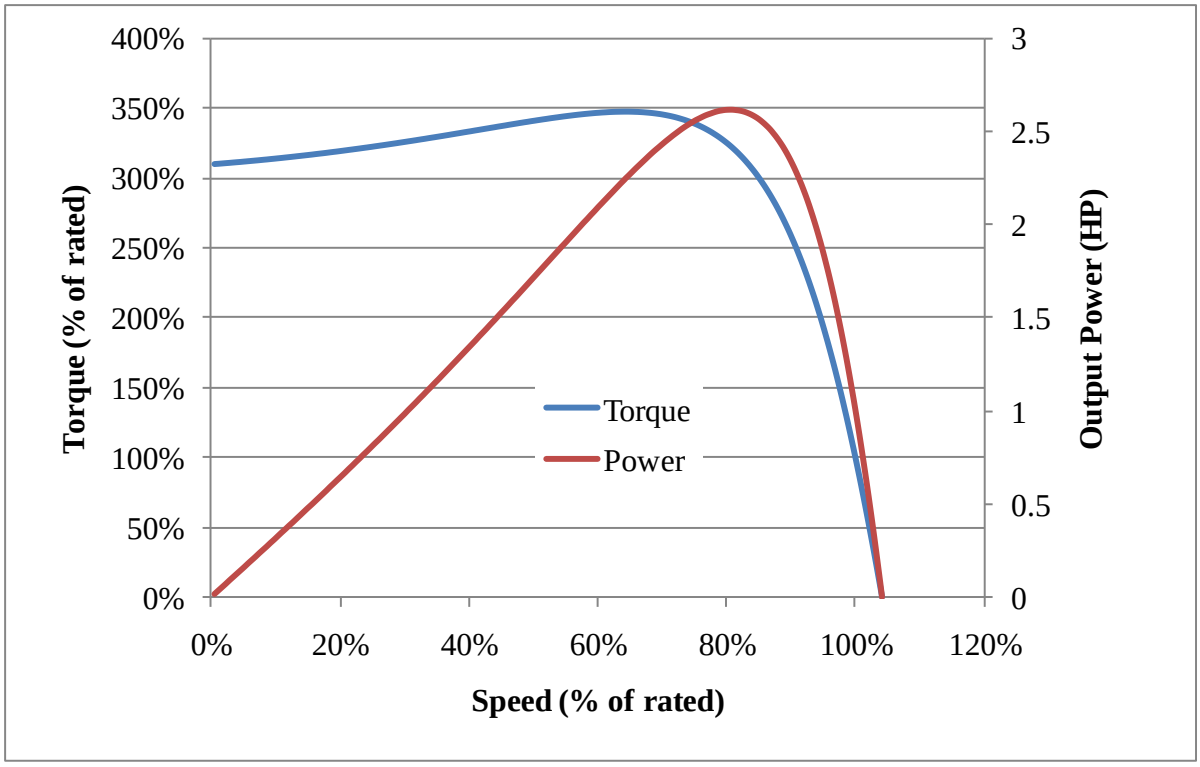

Figure 6.1 Torque and Output Power versus Speed for Efficiency Level 4b, Space-Constrained, Polyphase Motor

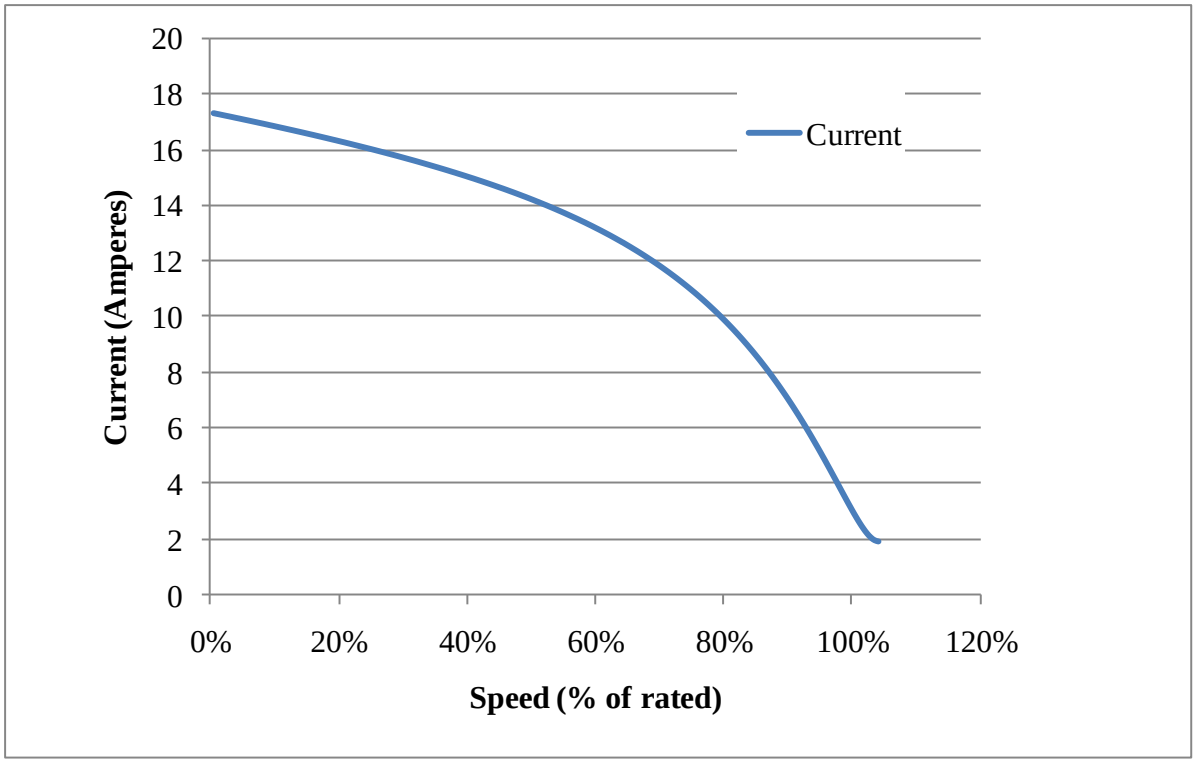

Figure 6.2 Current versus Speed for Efficiency Level 4b, Space-Constrained, Polyphase Motor

5A.7 DESIGN SPECIFICATIONS OF BASELINE CSIR MOTOR

5A.7.1 Stator Dimensions

Lamination Steel Type	Tempel M56
Length of the Stator Stack	1.9780 inch
Stacking Factor of the Stator	0.9800
Stator Slot Insulation Thickness	0.0100 inch
Number of Stator Poles	4 Poles
Outside Diameter of the Stator	5.8000 inch
Number of Stator Slots	32
Inside Diameter of the Stator	3.2524 inch
Thickness of mid slot separator	0.0000 inch
Stator Slot Width Next to Gap	0.1650 inch
Stator Slot Width at Bottom of Slot	0.2730 inch
Depth of Main Trapezoidal Part	0.6980 inch
Depth of Slot Mouth	0.0300 inch
Stator Slot Opening	0.1000 inch
Depth of Tooth Tip	0.0300 inch
Total Depth of Stator Slot	0.7580 inch

5A.7.2 Rotor Dimensions

Shaft Material	Magnetic
Outside Diameter of the Rotor	3.2292 inch
Inside Diameter of the Rotor	0.6250 inch
Length of the Rotor Stack	2.0150 inch
Stacking Factor of the Rotor	0.9800

5A.7.3 Rotor Slot Dimensions

Closed Bridge, Trap w/ Round Bottom	
Depth of Rotor Slot Opening	0.0000 inch
Width at Top of Rotor Slot	0.1450 inch
Width at Bottom of Rotor Slot	0.0300 inch
Depth of Main Trapezoidal Part	0.1650 inch
Depth of Slot Mouth	0.0725 inch
Depth of Bridge	0.0120 inch
Total Depth of Rotor Slot	0.2650 inch
Number of Rotor Slots	44 slots

5A.7.4 Ring & Coil Data

Inside Diameter of Ring 1	2.0900 inch
Outside Diameter of Ring 1	3.1070 inch
Axial Thickness at Outside of Ring 1	0.1800 inch

Axial Thickness at Inside of Ring 1	0.1800 inch
Inside Diameter of Ring 2	2.0900 inch
Outside Diameter of Ring 2	3.1070 inch
Axial Thickness at Outside of Ring 2	0.3900 inch
Axial Thickness at Inside of Ring 2	0.3900 inch
Conductivity of the Rotor Bar Material	0.5700
Conductivity of the End Ring Material	0.5700

5A.7.5 Electrical Data

Wire Insulation Type	Heavy
Terminal Voltage	115.00 Volts
Turns per Coil in Main Slot 1	50 Turns
Turns per Coil in Main Slot 2	42 Turns
Turns per Coil in Main Slot 3	40 Turns
Main Winding Wire Size	18.5 AWG
Turns per Coil in Aux. Slot 1	58 Turns
Turns per Coil in Aux. Slot 2	20 Turns
Turns per Coil in Aux. Slot 3	15 Turns
Auxiliary Wire Size	21.5 AWG
Running Capacitance	0.0000 mfd
Starting Capacitance	333.0000 mfd
Line Frequency	60.0 Hz
Rotor Skew	2.00 bar
Winding Operating Temperature	81.90 deg C
Friction & Windage Loss at Idle Speed	14.0000 Watts
Stray Load Loss	1.8 %
Wire Stretch Factor	1.040

5A.7.6 Load Speed & Slip Info

Specified Load Speed	1730.0 RPM
Minimum Load Speed	0.0 RPM
Speed Increment	10.0 RPM

5A.7.7 No Load Performance

Synchronous Speed	1800.0 RPM
Actual No Load Speed	1794.6 RPM
Actual No Load Line Current	8.47 Amps
No Load Main Winding Current Density	3714.57 Amps/sq. in
No Load Aux. Winding Current Density	0.00 Amps/sq. in

5A.7.8 Locked Rotor Data (Full Load Temperature)

Locked Rotor Torque	54.92 lb-in
Locked Rotor Line Current	39.941 Amps
Locked Rotor Main Current Density	13745.46 A/sq. in.

Locked Rotor Aux. Current Density	20759.31 A/sq. in.

5A.7.9 Breakdown Load Parameters (Full Load Temperature)

BreakDown Speed	1409.4 RPM
BreakDown Torque	48.70 lb-in
BreakDown Current	20.95 Amps
BreakDown Output Power	812.4 Watts
BreakDown Output Power	1.0890 Hp
BreakDown Efficiency	42.3 %
BreakDown Power Factor	0.779
BreakDown Input Power	1919.0 Watts
Main Current Density at BreakDown	9186.60 A/sq. in.
Aux. Current Density at BreakDown	0.00 A/sq. in.

5A.7.10 Reactance Values

Primary Slot Leakage	0.5834 Ohms
Secondary Slot Leakage	0.3506 Ohms
End Leakage	0.3500 Ohms
Skew Leakage	0.6189 Ohms
Zig Zag Leakage	0.7103 Ohms
Belt Leakage	0.1378 Ohms
Main Winding Leakage Reactance	1.6669 Ohms
Rotor Leakage Referred to Main	1.0841 Ohms
Auxiliary Winding Leakage Reactance	4.7419 Ohms
Magnitizing Reactance of Main Winding	22.5465 Ohms

5A.7.11 Winding Information

Hot Rotor Resistance	1.4402 Ohms
Rotor Resistance Ratio	0.5235
Cold Auxiliary Resistance	5.3646 Ohms
Cold Main Winding Resistance	0.8715
Hot Main Winding Resistance	1.0623 Ohms
Hot Aux. Winding Resistance	6.5390 Ohms
Main Winding Distribution Factor	0.804
Aux. Winding Distribution Factor	0.880
Total Main Winding Conductors	528.00 Conductors
Total Aux. Winding Conductors	744.00 Conductors
Effective Main Winding Conductors	424.7 Conductors
Effective Aux. Winding Conductors	654.8 Conductors
Turns Ratio	1.54
Slot 1 % Fill	51.04 %
Slot 2 % Fill	50.78 %
Slot 3 % Fill	51.38 %
Slot 4 % Fill	30.59 %

Slot 5 % Fill	0.00 %
Slot 6 % Fill	0.00 %
Slot 7 % Fill	0.00 %
Slot 8 % Fill	0.00 %
Total Weight of the Main Winding	2.2040 lbs
Total Weight of the Aux. Winding	0.8428 lbs
Electrical Area of One Rotor Bar	0.0250 sq. in.
Electrical Area of All Rotor Bars	1.0978 sq. in.
Weight of Stator Steel	6.7755 lbs
Weight of Rotor Steel	3.9309 lbs
Weight of Stator and Rotor Steel	10.7064 lbs
Weight of Rotor Aluminum	0.4396 lbs

5A.7.12 Magnetic Circuit Data

Magnetic Length of Air Gap	0.0145 inch
Total Air Gap Flux per Pole	197.0 kilolines
Flux Density in Air Gap	52.0 Klines/in^2
Flux Density in Stator Yoke	93.6 Klines/in^2
Flux Density in Stator Teeth	113.5 Klines/in^2
Flux Density in Rotor Yoke	40.9 Klines/in^2
Flux Density in Rotor Teeth	116.9 Klines/in^2
MMF Drop in Air Gap	235.3 A-T
MMF Drop in Stator Yoke	7.9 A-T
MMF Drop in Rotor Yoke	1.0 A-T
MMF Drop in Statot Teeth	66.1 A-T
MMF Drop in Rotor Teeth	86.4 A-T
Total MMF Drop	396.7 A-T

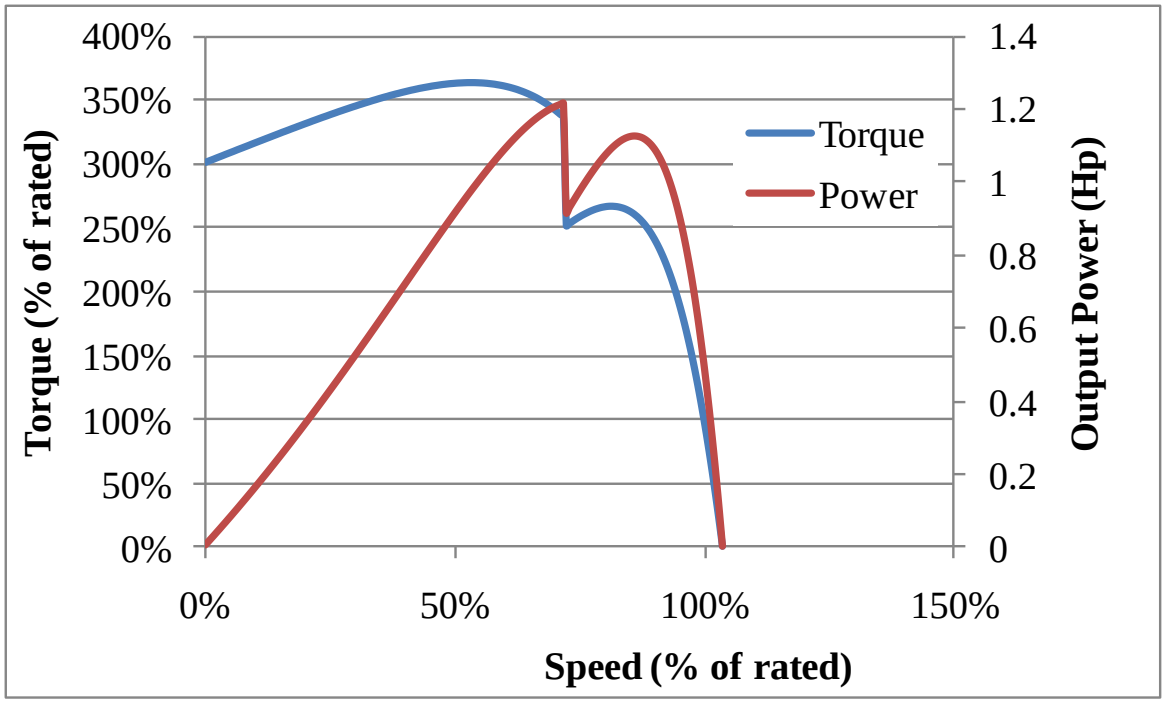

Figure 7.1 Torque and Output Power versus Speed for Baseline CSIR Motor

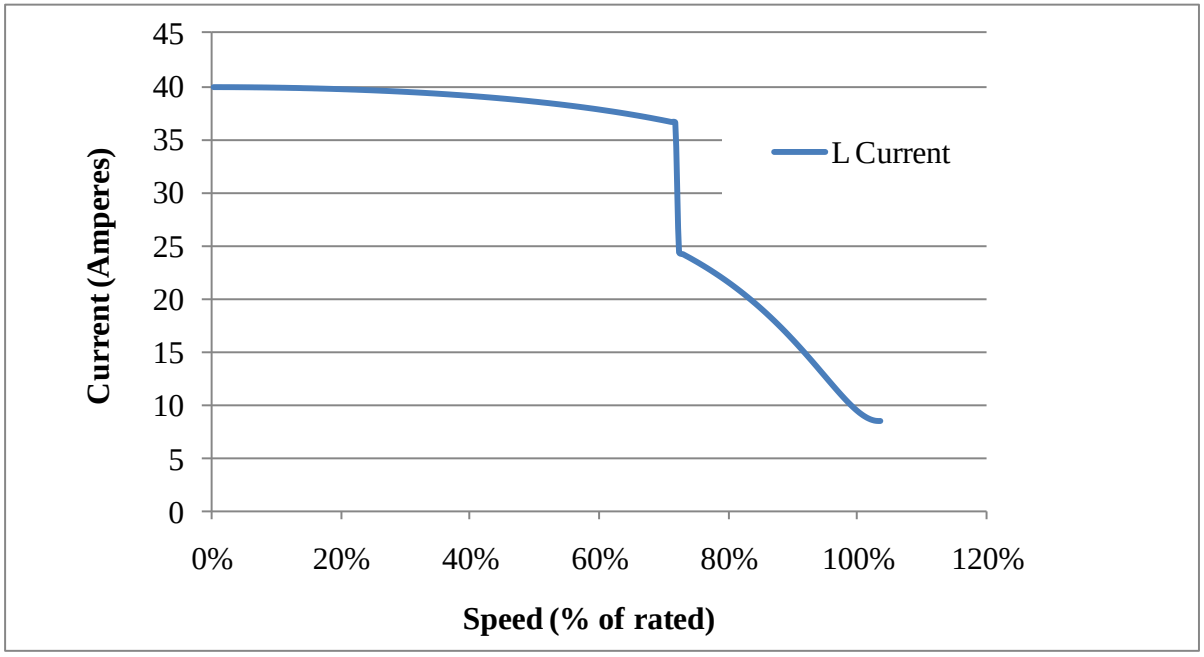

Figure 7.2 Line Current versus Speed for Baseline CSIR Motor

5A.8 DESIGN SPECIFICATIONS OF CSIR TSL 7 (EL 7 SPACE CONSTRAINED) DESIGN

5A.8.1 Stator Dimensions

Lamination Steel Type	Hiperco 50A
Length of the Stator Stack	2.4000 inch
Stacking Factor of the Stator	0.9800
Stator Slot Insulation Thickness	0.0100 inch
Number of Stator Poles	4 Poles
Outside Diameter of the Stator	5.8000 inch
Number of Stator Slots	32
Inside Diameter of the Stator	3.2524 inch
Thickness of mid slot separator	0.0000 inch
Stator Slot Width Next to Gap	0.1650 inch
Stator Slot Width at Bottom of Slot	0.2730 inch
Depth of Main Trapezoidal Part	0.6980 inch
Depth of Slot Mouth	0.0300 inch
Stator Slot Opening	0.1000 inch
Depth of Tooth Tip	0.0300 inch
Total Depth of Stator Slot	0.7580 inch

5A.8.2 Rotor Dimensions

Shaft Material	Magnetic
Outside Diameter of the Rotor	3.2292 inch
Inside Diameter of the Rotor	0.6250 inch
Length of the Rotor Stack	2.4000 inch
Stacking Factor of the Rotor	0.9800

5A.8.3 Rotor Slot Dimensions

Closed Bridge, Trap w/ Round Bottom	
Depth of Rotor Slot Opening	0.0000 inch
Width at Top of Rotor Slot	0.1450 inch
Width at Bottom of Rotor Slot	0.0300 inch
Depth of Main Trapezoidal Part	0.1650 inch
Depth of Slot Mouth	0.0725 inch
Depth of Bridge	0.0120 inch
Total Depth of Rotor Slot	0.2650 inch
Number of Rotor Slots	44 slots

5A.8.4 Ring & Coil Data

Inside Diameter of Ring 1	2.4000 inch
Outside Diameter of Ring 1	3.1070 inch
Axial Thickness at Outside of Ring 1	0.1000 inch

Axial Thickness at Inside of Ring 1	0.1000 inch
Inside Diameter of Ring 2	2.4000 inch
Outside Diameter of Ring 2	3.1070 inch
Axial Thickness at Outside of Ring 2	0.1000 inch
Axial Thickness at Inside of Ring 2	0.1000 inch
Conductivity of the Rotor Bar Material	1.0000
Conductivity of the End Ring Material	1.0000

5A.8.5 Electrical Data

Wire Insulation Type	Heavy
Terminal Voltage	115.00 Volts
Turns per Coil in Main Slot 1	49 Turns
Turns per Coil in Main Slot 2	46 Turns
Turns per Coil in Main Slot 3	44 Turns
Main Winding Wire Size	20.5 AWG
Turns per Coil in Aux. Slot 1	45 Turns
Turns per Coil in Aux. Slot 2	12 Turns
Turns per Coil in Aux. Slot 3	8 Turns
Auxiliary Wire Size	21.5 AWG
Running Capacitance	0.0000 mfd
Starting Capacitance	380.0000 mfd
Line Frequency	60.0 Hz
Rotor Skew	2.00 bar
Winding Operating Temperature	43.76 deg C
Friction & Windage Loss at Idle Speed	14.0000 Watts
Stray Load Loss	1.8 %
Wire Stretch Factor	1.040

5A.8.6 Load Speed & Slip Info

Specified Load Speed	1734.0 RPM
Minimum Load Speed	0.0 RPM
Speed Increment	10.0 RPM

5A.8.7 No Load Performance

Syn Synchronous Speed	1800.0 RPM
Snl Actual No Load Speed	1796.4 RPM
Inl Actual No Load Line Current	4.44 Amps
GnlM No Load Main Winding Current Density	1539.83 Amps/sq. in
GnlA No Load Aux. Winding Current Density	0.00 Amps/sq. in

5A.8.8 Locked Rotor Data (Full Load Temperature)

Locked Rotor Torque	62.43 lb-in
Locked Rotor Line Current	34.064 Amps

Locked Rotor Main Current Density	8551.82 A/sq. in.
Locked Rotor Aux. Current Density	32162.91 A/sq. in.

5A.8.9 Breakdown Load Parameters (Full Load Temperature)

BreakDown Speed	1481.4 RPM
BreakDown Torque	43.19 lb-in
BreakDown Current	16.25 Amps
BreakDown Output Power	757.3 Watts
BreakDown Output Power	1.0151 Hp
BreakDown Efficiency	54.5 %
BreakDown Power Factor	0.740
BreakDown Input Power	1389.7 Watts
Main Current Density at BreakDown	5635.10 A/sq. in.
Aux. Current Density at BreakDown	0.00 A/sq. in.

5A.8.10 Reactance Values

Primary Slot Leakage	0.7789 Ohms
Secondary Slot Leakage	0.4542 Ohms
End Leakage	0.3749 Ohms
Skew Leakage	1.2435 Ohms
Zig Zag Leakage	0.9375 Ohms
Belt Leakage	0.2769 Ohms
Main Winding Leakage Reactance	2.3827 Ohms
Rotor Leakage Referred to Main	1.6832 Ohms
Auxiliary Winding Leakage Reactance	3.4063 Ohms
Magnitizing Reactance of Main Winding	45.2998 Ohms

5A.8.11 Winding Information

Hot Rotor Resistance	1.5746 Ohms
Rotor Resistance Ratio	0.3873
Cold Auxiliary Resistance	4.1125 inch
Cold Main Winding Resistance	0.7775
Hot Main Winding Resistance	0.8337 Ohms
Hot Aux. Winding Resistance	4.4094 Ohms
Main Winding Distribution Factor	0.797
Aux. Winding Distribution Factor	0.901
Total Main Winding Conductors	556.00 Conductors
Total Aux. Winding Conductors	520.00 Conductors
Effective Main Winding Conductors	443.0 Conductors
Effective Aux. Winding Conductors	468.5 Conductors
Turns Ratio	1.06
Slot 1 % Fill	64.73 %
Slot 2 % Fill	64.98 %
Slot 3 % Fill	64.45 %

Slot 4 % Fill	23.73 %
Slot 5 % Fill	0.00 %
Slot 6 % Fill	0.00 %
Slot 7 % Fill	0.00 %
Slot 8 % Fill	0.00 %
Total Weight of the Main Winding	3.1463 lbs
Total Weight of the Aux. Winding	0.6461 lbs
Electrical Area of One Rotor Bar	0.0250 sq. in.
Electrical Area of All Rotor Bars	1.0978 sq. in.
Weight of Stator Steel	8.2211 lbs
Weight of Rotor Steel	4.6819 lbs
Weight of Stator and Rotor Steel	12.9030 lbs
Weight of Rotor Aluminum	0.9867 lbs

5A.8.12 Magnetic Circuit Data

Magnetic Length of Air Gap	0.0145 inch
Total Air Gap Flux per Pole	188.9 kilolines
Flux Density in Air Gap	43.6 Klines/in^2
Flux Density in Stator Yoke	73.9 Klines/in^2
Flux Density in Stator Teeth	89.7 Klines/in^2
Flux Density in Rotor Yoke	34.6 Klines/in^2
Flux Density in Rotor Teeth	99.0 Klines/in^2
MMF Drop in Air Gap	197.4 A-T
MMF Drop in Stator Yoke	2.0 A-T
MMF Drop in Rotor Yoke	0.4 A-T
MMF Drop in Statot Teeth	1.2 A-T
MMF Drop in Rotor Teeth	0.5 A-T
Total MMF Drop	201.3 A-T

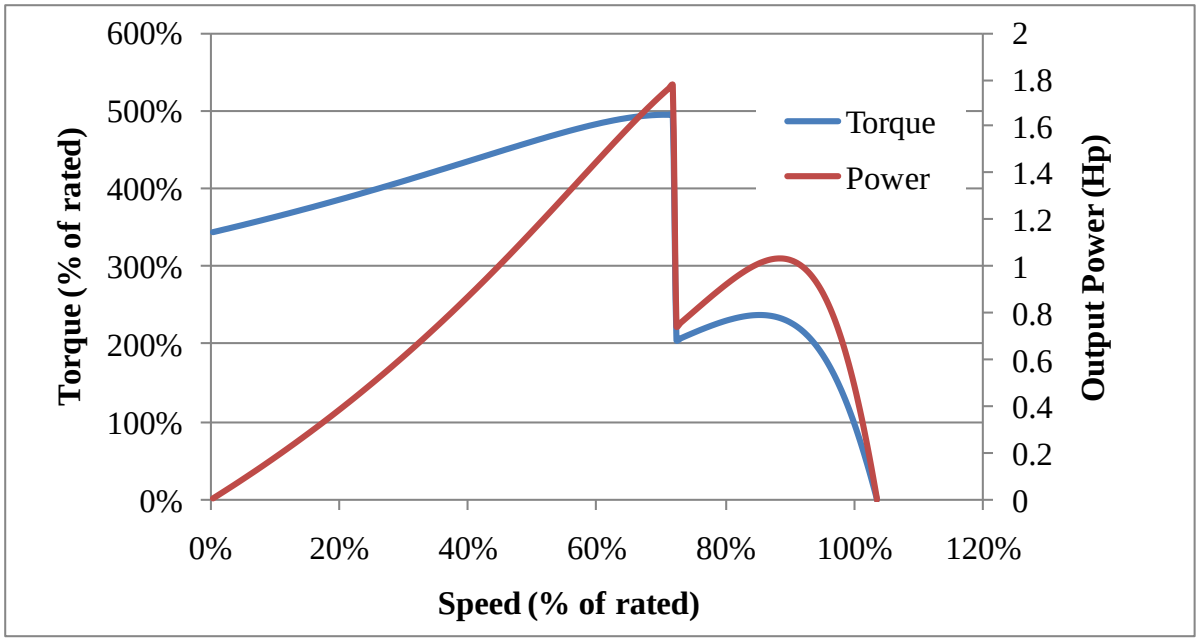

Figure 8.1 Torque and Output Power versus Speed for Efficiency Level 7, Space-Constrained, CSIR Motor

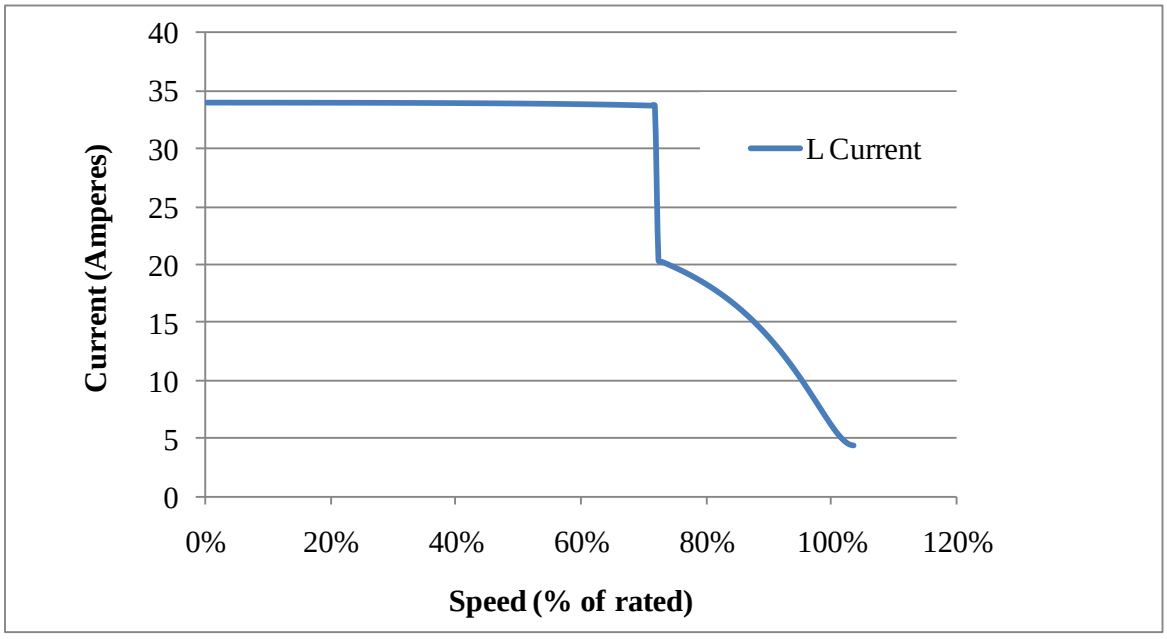

Figure 8.2 Line Current versus Speed for Efficiency Level 7, Space-Constrained, CSIR Motor

5A.9 DESIGN SPECIFICATIONS OF BASELINE CSCR MOTOR

5A.9.1 Stator Dimensions

Lamination Steel Type	Tempel M56
Length of the Stator Stack	3.0000 inch

Stacking Factor of the Stator	0.9800
Stator Slot Insulation Thickness	0.0100 inch
Number of Stator Poles	4 Poles
Outside Diameter of the Stator	5.5000 inch
Number of Stator Slots	32
Inside Diameter of the Stator	3.3750 inch
Thickness of mid slot separator	0.0000 inch
Stator Slot Width Next to Gap	0.1650 inch
Stator Slot Width at Bottom of Slot	0.2730 inch
Depth of Main Trapezoidal Part	0.6500 inch
Depth of Slot Mouth	0.0300 inch
Stator Slot Opening	0.1000 inch
Depth of Tooth Tip	0.0300 inch
Total Depth of Stator Slot	0.7100 inch

5A.9.2 Rotor Dimensions

Shaft Material	Magnetic
Outside Diameter of the Rotor	3.3500 inch
Inside Diameter of the Rotor	0.6250 inch
Length of the Rotor Stack	3.0000 inch
Stacking Factor of the Rotor	0.9800

5A.9.3 Rotor Slot Dimensions

Closed Bridge, Trap w/ Round Bottom	
Depth of Rotor Slot Opening	0.0000 inch
Width at Top of Rotor Slot	0.1360 inch
Width at Bottom of Rotor Slot	0.0300 inch
Depth of Main Trapezoidal Part	0.2200 inch
Depth of Slot Mouth	0.0680 inch
Depth of Bridge	0.0070 inch
Total Depth of Rotor Slot	0.3200 inch
Number of Rotor Slots	40 slots

5A.9.4 Ring & Coil Data

Inside Diameter of Ring 1	2.1500 inch
Outside Diameter of Ring 1	3.2250 inch
Axial Thickness at Outside of Ring 1	0.3900 inch
Axial Thickness at Inside of Ring 1	0.3900 inch
Inside Diameter of Ring 2	2.1500 inch
Outside Diameter of Ring 2	3.2250 inch
Axial Thickness at Outside of Ring 2	0.3900 inch
Axial Thickness at Inside of Ring 2	0.3900 inch
Conductivity of the Rotor Bar Material	0.5700
Conductivity of the End Ring Material	0.5700

5A.9.5 Electrical Data

Wire Insulation Type	Heavy
Terminal Voltage	115.00 Volts
Turns per Coil in Main Slot 1	45 Turns
Turns per Coil in Main Slot 2	33 Turns
Turns per Coil in Main Slot 3	20 Turns
Main Winding Wire Size	18.0 AWG
Turns per Coil in Aux. Slot 1	42 Turns
Turns per Coil in Aux. Slot 2	25 Turns
Turns per Coil in Aux. Slot 3	10 Turns
Auxiliary Wire Size	19.0 AWG
Running Capacitance	7.5700 mfd
Starting Capacitance	433.0000 mfd
Line Frequency	60.0 Hz
Rotor Skew	1.60 bar
Winding Operating Temperature	76.40 deg C
Friction & Windage Loss at Idle Speed	5.0000 Watts
Stray Load Loss	1.8 %
Wire Stretch Factor	1.040

5A.9.6 Load Speed & Slip Info

Specified Load Speed	1735.0 RPM
Minimum Load Speed	0.0 RPM
Speed Increment	10.0 RPM

5A.9.7 No Load Performance

Synchronous Speed	1800.0 RPM
Actual No Load Speed	1798.2 RPM
Actual No Load Line Current	7.14 Amps
No Load Main Winding Current Density	2095.30 Amps/sq. in
No Load Aux. Winding Current Density	490.76 Amps/sq. in

5A.9.8 Locked Rotor Data (Full Load Temperature)

Locked Rotor Torque	74.62 lb-in
Locked Rotor Line Current	52.334 Amps
Locked Rotor Main Current Density	14649.86 A/sq. in.
Locked Rotor Aux. Current Density	18559.90 A/sq. in.

5A.9.9 Breakdown Load Parameters (Full Load Temperature)

BreakDown Speed	1468.8 RPM
BreakDown Torque	62.50 lb-in
BreakDown Current	24.52 Amps

BreakDown Output Power	1086.4 Watts
BreakDown Output Power	1.4563 Hp
BreakDown Efficiency	49.2 %
BreakDown Power Factor	0.784
BreakDown Input Power	2209.3 Watts
Main Current Density at BreakDown	9480.86 A/sq. in.
Aux. Current Density at BreakDown	202.59 A/sq. in.

5A.9.10 Reactance Values

Primary Slot Leakage	0.5069 Ohms
Secondary Slot Leakage	0.3891 Ohms
End Leakage	0.2312 Ohms
Skew Leakage	0.5157 Ohms
Zig Zag Leakage	0.6773 Ohms
Belt Leakage	0.1546 Ohms
Main Winding Leakage Reactance	1.4139 Ohms
Rotor Leakage Referred to Main	1.0649 Ohms
Auxiliary Winding Leakage Reactance	4.0772 Ohms
Magnitizing Reactance of Main Winding	24.4992 Ohms

5A.9.11 Winding Information

Hot Rotor Resistance	1.0623 Ohms
Rotor Resistance Ratio	0.4286
Cold Auxiliary Resistance	2.8797 inch
Cold Main Winding Resistance	0.7054
Hot Main Winding Resistance	0.8449 Ohms
R1A Hot Aux. Winding Resistance	3.4492 Ohms
Main Winding Distribution Factor	0.844
Aux. Winding Distribution Factor	0.877
Total Main Winding Conductors	392.00 Conductors
Total Aux. Winding Conductors	616.00 Conductors
Effective Main Winding Conductors	330.7 Conductors
Effective Aux. Winding Conductors	540.3 Conductors
Turns Ratio	1.63
Slot 1 % Fill	54.17 %
Slot 2 % Fill	49.38 %
Slot 3 % Fill	48.21 %
Slot 4 % Fill	40.55 %
Slot 5 % Fill	0.00 %
Slot 6 % Fill	0.00 %
Slot 7 % Fill	0.00 %
Slot 8 % Fill	0.00 %
Total Weight of the Main Winding	2.2330 lbs
Total Weight of the Aux. Winding	1.4352 lbs
Electrical Area of One Rotor Bar	0.0275 sq. in.

Electrical Area of All Rotor Bars	1.1003 sq. in.
Weight of Stator Steel	7.7508 lbs
Weight of Rotor Steel	6.3664 lbs
Weight of Stator and Rotor Steel	14.1171 lbs
Weight of Rotor Aluminum	0.6625 lbs

5A.9.12 Magnetic Circuit Data

Magnetic Length of Air Gap	0.0154 inch
Total Air Gap Flux per Pole	253.0 kilolines
Flux Density in Air Gap	45.0 Klines/in^2
Flux Density in Stator Yoke	113.3 Klines/in^2
Flux Density in Stator Teeth	91.5 Klines/in^2
Flux Density in Rotor Yoke	36.9 Klines/in^2
Flux Density in Rotor Teeth	87.2 Klines/in^2
MMF Drop in Air Gap	216.3 A-T
MMF Drop in Stator Yoke	119.6 A-T
MMF Drop in Rotor Yoke	0.9 A-T
MMF Drop in Statot Teeth	3.5 A-T
MMF Drop in Rotor Teeth	1.4 A-T
Total MMF Drop	341.7 A-T

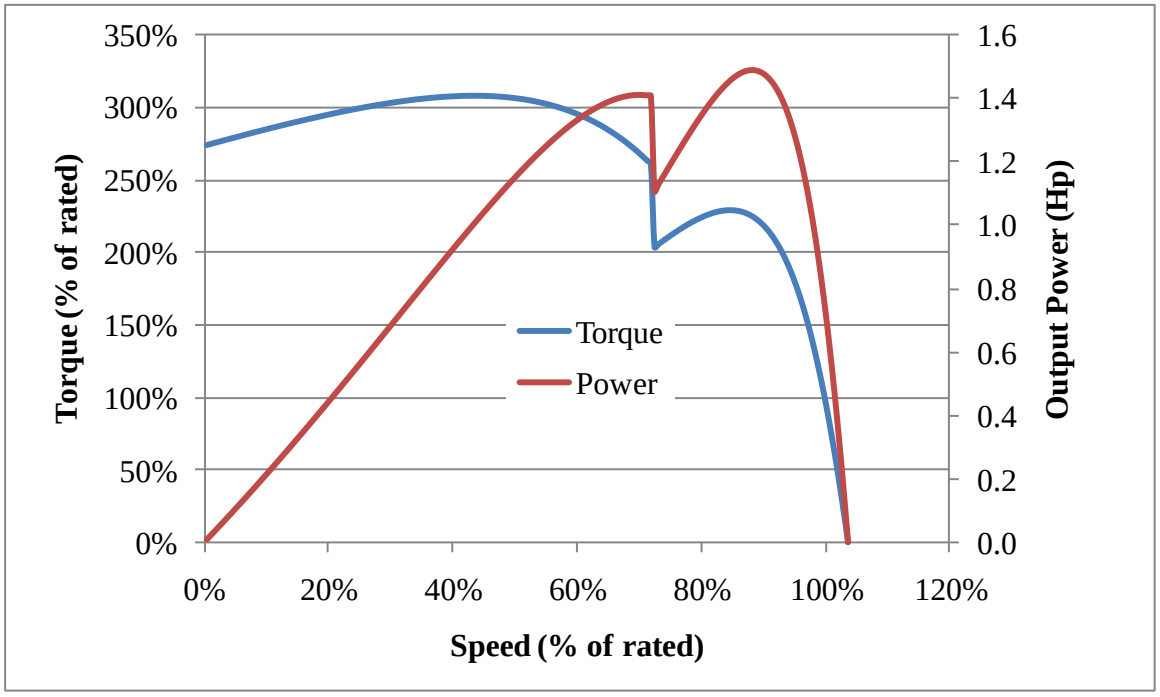

Figure 9.1 Torque and Output Power versus Speed for Baseline CSCR Motor

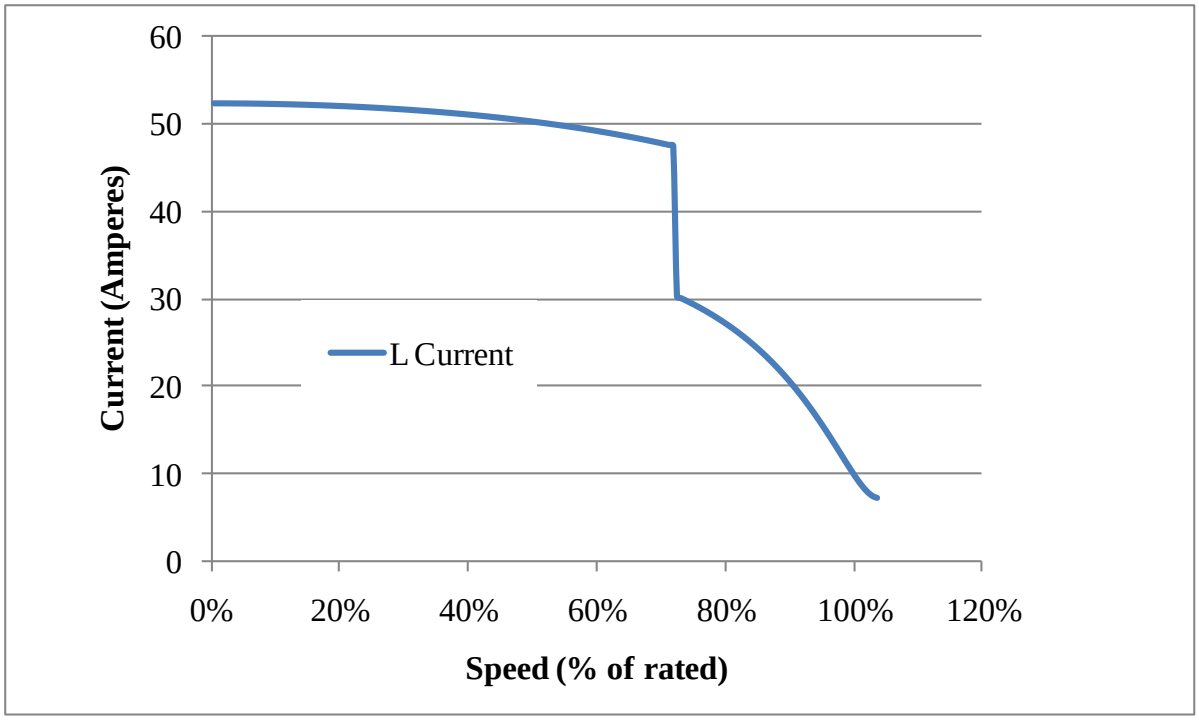

Figure 9.2 Line Current versus Speed for Baseline CSCR Motor

5A.10 DESIGN SPECIFICATIONS OF CSCR TSL 7 (EL 3 SPACE CONSTRAINED) DESIGN

5A.10.1 Stator Dimensions

Lamination Steel Type	M 19
Length of the Stator Stack	3.4500 inch
Stacking Factor of the Stator	0.9800
Stator Slot Insulation Thickness	0.0100 inch
Number of Stator Poles	4 Poles
Outside Diameter of the Stator	5.5000 inch
Number of Stator Slots	32
Inside Diameter of the Stator	3.3750 inch
Thickness of mid slot separator	0.0000 inch
Stator Slot Width Next to Gap	0.1650 inch
Stator Slot Width at Bottom of Slot	0.2730 inch
Depth of Main Trapezoidal Part	0.6500 inch
Depth of Slot Mouth	0.0300 inch
Stator Slot Opening	0.1000 inch
Depth of Tooth Tip	0.0300 inch
Total Depth of Stator Slot	0.7100 inch

5A.10.2 Rotor Dimensions

Shaft Material	Magnetic

Outside Diameter of the Rotor	3.3500 inch
Inside Diameter of the Rotor	0.6250 inch
Length of the Rotor Stack	3.4500 inch
Stacking Factor of the Rotor	0.9800

5A.10.3 Rotor Slot Dimensions

Closed Bridge, Trap w/ Round Bottom	
Depth of Rotor Slot Opening	0.0000 inch
Width at Top of Rotor Slot	0.1360 inch
Width at Bottom of Rotor Slot	0.0300 inch
Depth of Main Trapezoidal Part	0.2200 inch
Depth of Slot Mouth	0.0680 inch
Depth of Bridge	0.0070 inch
Total Depth of Rotor Slot	0.3200 inch
Number of Rotor Slots	40 slots

5A.10.4 Ring & Coil Data

Inside Diameter of Ring 1	2.1500 inch
Outside Diameter of Ring 1	3.2250 inch
Axial Thickness at Outside of Ring 1	0.3900 inch
Axial Thickness at Inside of Ring 1	0.3900 inch
Inside Diameter of Ring 2	2.1500 inch
Outside Diameter of Ring 2	3.2250 inch
Axial Thickness at Outside of Ring 2	0.3900 inch
Axial Thickness at Inside of Ring 2	0.3900 inch
Conductivity of the Rotor Bar Material	0.5700
Conductivity of the End Ring Material	0.5700

5A.10.5 Electrical Data

Wire Insulation Type	Heavy
Terminal Voltage	115.00 Volts
Turns per Coil in Main Slot 1	40 Turns
Turns per Coil in Main Slot 2	34 Turns
Turns per Coil in Main Slot 3	23 Turns
Main Winding Wire Size	20.0 AWG
Turns per Coil in Aux. Slot 1	42 Turns
Turns per Coil in Aux. Slot 2	23 Turns
Turns per Coil in Aux. Slot 3	7 Turns
Auxiliary Wire Size	21.0 AWG
Running Capacitance	25.0000 mfd
Starting Capacitance	433.0000 mfd
Line Frequency	60.0 Hz
Rotor Skew	1.60 bar
Winding Operating Temperature	50.11 deg C

Friction & Windage Loss at Idle Speed	5.0000 Watts
Stray Load Loss	1.8 %
Wire Stretch Factor	1.040

5A.10.6 Load Speed & Slip Info

Specified Load Speed	1747.0 RPM
Minimum Load Speed	0.0 RPM
Speed Increment	10.0 RPM

5A.10.7 No Load Performance

Synchronous Speed	1800.0 RPM
Actual No Load Speed	1798.2 RPM
Actual No Load Line Current	3.80 Amps
No Load Main Winding Current Density	1560.74 Amps/sq. in
No Load Aux. Winding Current Density	1586.46 Amps/sq. in

5A.10.8 Locked Rotor Data (Full Load Temperature)

Locked Rotor Torque	80.80 lb-in
Locked Rotor Line Current	55.417 Amps
Locked Rotor Main Current Density	11507.56 A/sq. in.
Locked Rotor Aux. Current Density	17557.66 A/sq. in.

5A.10.9 Breakdown Load Parameters (Full Load Temperature)

BreakDown Speed	1497.6 RPM
BreakDown Torque	70.73 lb-in
BreakDown Current	23.72 Amps
BreakDown Output Power	1253.6 Watts
BreakDown Output Power	1.6805 Hp
BreakDown Efficiency	58.0 %
BreakDown Power Factor	0.793
BreakDown Input Power	2162.0 Watts
Main Current Density at BreakDown	7224.22 A/sq. in.
Aux. Current Density at BreakDown	804.94 A/sq. in.

5A.10.10 Reactance Values

Primary Slot Leakage	0.5450 Ohms
Secondary Slot Leakage	0.4218 Ohms
End Leakage	0.2116 Ohms
Skew Leakage	0.5932 Ohms
Zig Zag Leakage	0.7343 Ohms
Belt Leakage	0.1765 Ohms
Main Winding Leakage Reactance	1.5085 Ohms
Rotor Leakage Referred to Main	1.1737 Ohms

Auxiliary Winding Leakage Reactance	4.4810 Ohms
Magnitizing Reactance of Main Winding	27.9669 Ohms

5A.10.11 Winding Information

Hot Rotor Resistance	1.0260 Ohms
Rotor Resistance Ratio	0.3825
Cold Auxiliary Resistance	2.3109 inch
Cold Main Winding Resistance	0.5843
Hot Main Winding Resistance	0.6408 Ohms
Hot Aux. Winding Resistance	2.5341 Ohms
Main Winding Distribution Factor	0.828
Aux. Winding Distribution Factor	0.892
Total Main Winding Conductors	388.00 Conductors
Total Aux. Winding Conductors	576.00 Conductors
Effective Main Winding Conductors	321.1 Conductors
Effective Aux. Winding Conductors	513.6 Conductors
Turns Ratio	1.60
Slot 1 % Fill	62.06 %
Slot 2 % Fill	61.41 %
Slot 3 % Fill	64.14 %
Slot 4 % Fill	51.97 %
Slot 5 % Fill	0.00 %
Slot 6 % Fill	0.00 %
Slot 7 % Fill	0.00 %
Slot 8 % Fill	0.00 %
Total Weight of the Main Winding	2.9416 lbs
Total Weight of the Aux. Winding	1.8298 lbs
Electrical Area of One Rotor Bar	0.0275 sq. in.
Electrical Area of All Rotor Bars	1.1003 sq. in.
Weight of Stator Steel	8.9134 lbs
Weight of Rotor Steel	7.3213 lbs
Weight of Stator and Rotor Steel	16.2347 lbs
Weight of Rotor Aluminum	0.7089 lbs

5A.10.12 Magnetic Circuit Data

Magnetic Length of Air Gap	0.0154 inch
Total Air Gap Flux per Pole	260.5 kilolines
Flux Density in Air Gap	40.7 Klines/in^2
Flux Density in Stator Yoke	101.4 Klines/in^2
Flux Density in Stator Teeth	81.9 Klines/in^2
Flux Density in Rotor Yoke	33.4 Klines/in^2
Flux Density in Rotor Teeth	78.8 Klines/in^2
MMF Drop in Air Gap	195.4 A-T
MMF Drop in Stator Yoke	96.7 A-T
MMF Drop in Rotor Yoke	0.5 A-T

MMF Drop in Statot Teeth	5.5 A-T
MMF Drop in Rotor Teeth	2.2 A-T
Total MMF Drop	300.3 A-T

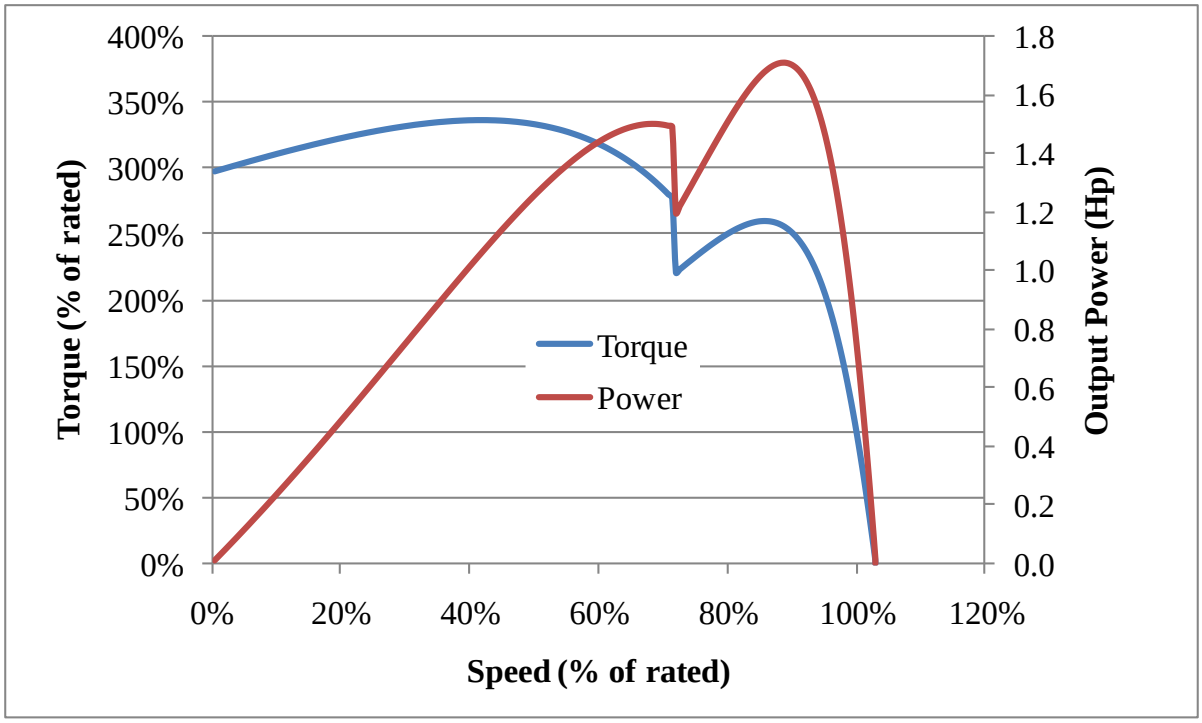

Figure 10.1 Torque and Output Power versus Speed for Efficiency Level 3, Space-Constrained, CSCR Motor

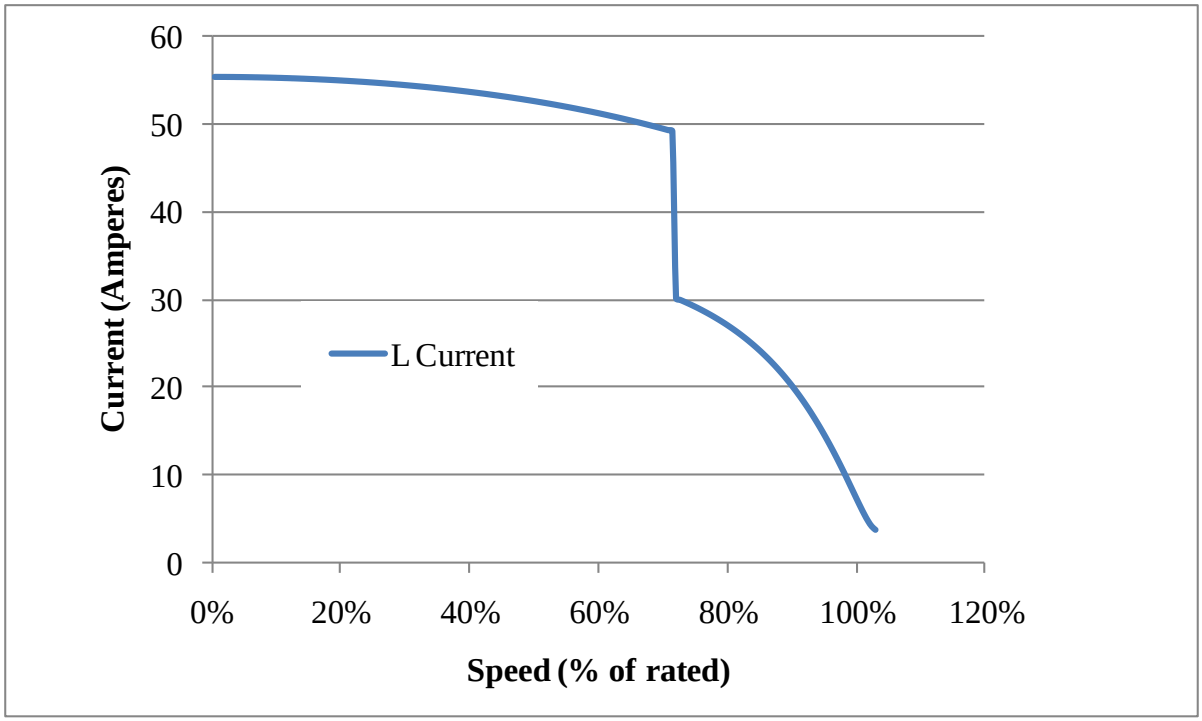

Figure 10.2 Line Current versus Speed for Efficiency Level 3, Space-Constrained, CSCR Motor

5A.11 COMMODITY PRICES

Commodities such as steel, copper, and aluminum make up a large portion of the input materials to small electric motors. As a result, any fluctuation in the price of these commodities can have a significant impact on the cost to produce these motors. Over the past several years, these commodity prices have fluctuated greatly compared to their historical trends. In an effort to best estimate the price of these underlying commodities, DOE has used an inflation adjusted five-year average price point for these commodities throughout the Engineering Analysis. In calculating the five-year average prices, DOE adjusted historical prices to $2009 using the historical Bureau of Labor Statistics Producer Price Indices (PPI)[1] for each commodity's industry. Table 11.1 summarizes the historical five-year prices in terms of 2009$, and also shows the average price point DOE used for its analysis.

Table 11.1 Five-Year Commodity Prices in 2009$

Commodity	Unit of Measure	2009	2008	2007	2006	2005	5-Year Average
Copper Wire							
Gauge 18.0	***$/lb***	$3.05	$3.06	$2.59	$2.50	$2.40	$2.72
Gauge 18.5	***$/lb***	$3.06	$3.07	$2.60	$2.51	$2.41	$2.73
Gauge 19.0	***$/lb***	$3.07	$3.08	$2.61	$2.52	$2.41	$2.74
Gauge 19.5	***$/lb***	$3.08	$3.09	$2.62	$2.53	$2.42	$2.75
Gauge 20.0	***$/lb***	$3.10	$3.10	$2.63	$2.54	$2.43	$2.76
Gauge 20.5	***$/lb***	$3.11	$3.11	$2.64	$2.55	$2.44	$2.77
Gauge 21.0	***$/lb***	$3.12	$3.12	$2.65	$2.56	$2.45	$2.78
Gauge 21.5	***$/lb***	$3.13	$3.13	$2.66	$2.57	$2.46	$2.79
Gauge 22.0	***$/lb***	$3.14	$3.15	$2.67	$2.58	$2.47	$2.80
Gauge 22.5	***$/lb***	$3.16	$3.16	$2.68	$2.59	$2.48	$2.81
Casting Materials							
Copper	***$/lb***	$1.77	$2.02	$2.05	$1.90	$1.13	$1.77
Aluminum	***$/lb***	$0.59	$0.65	$0.62	$0.61	$0.57	$0.61
Core Steel							
24M56	***$/lam***	$0.10	$0.14	$0.16	$0.13	$0.11	$0.13
24M19	***$/lam***	$0.16	$0.23	$0.25	$0.22	$0.18	$0.21
29M15	***$/lam***	$0.25	$0.36	$0.39	$0.34	$0.28	$0.32
29M19	***$/lam***	$0.22	$0.32	$0.35	$0.30	$0.25	$0.29
24M47	***$/lam***	$0.12	$0.18	$0.20	$0.17	$0.14	$0.16
Hiperco 50	***$/lam***	$1.22	$1.77	$1.94	$1.65	$1.37	$1.59

DOE based its Engineering Analysis on the five-year average price point for each commodity, but it also examined the five-year minimum and maximum price points to gauge the level of sensitivity around these prices. Table 11.2 to Table 11.7 present the resulting MSPs from using the five-year average price, the minimum price, and the maximum price for

polyphase, CSIR, and CSCR motors. Figure 11.1 through Figure 11.6 show the MSP-efficiency graphs associated with these values.

Table 11.2 Commodity Price Impact on MSP for Space Constrained Polyphase Motors

	Efficiency Level (%)	Minimum Prices (2009$)	Five-Year Average Prices (2009$)	Maximum Prices (2009$)
Baseline	75.3	90.40	98.54	106.39
EL 1	77.3	95.80	104.83	113.57
EL 2	78.8	98.36	108.17	117.67
EL 3	80.5	103.86	114.24	124.33
EL 4	81.1	107.58	118.54	129.22
EL 4b	83.5	120.29	135.62	150.37
EL 5	85.3	193.69	230.92	266.31
EL 6	86.2	198.75	237.70	273.95
EL 7	87.7	1,371.10	1,766.06	2,137.53

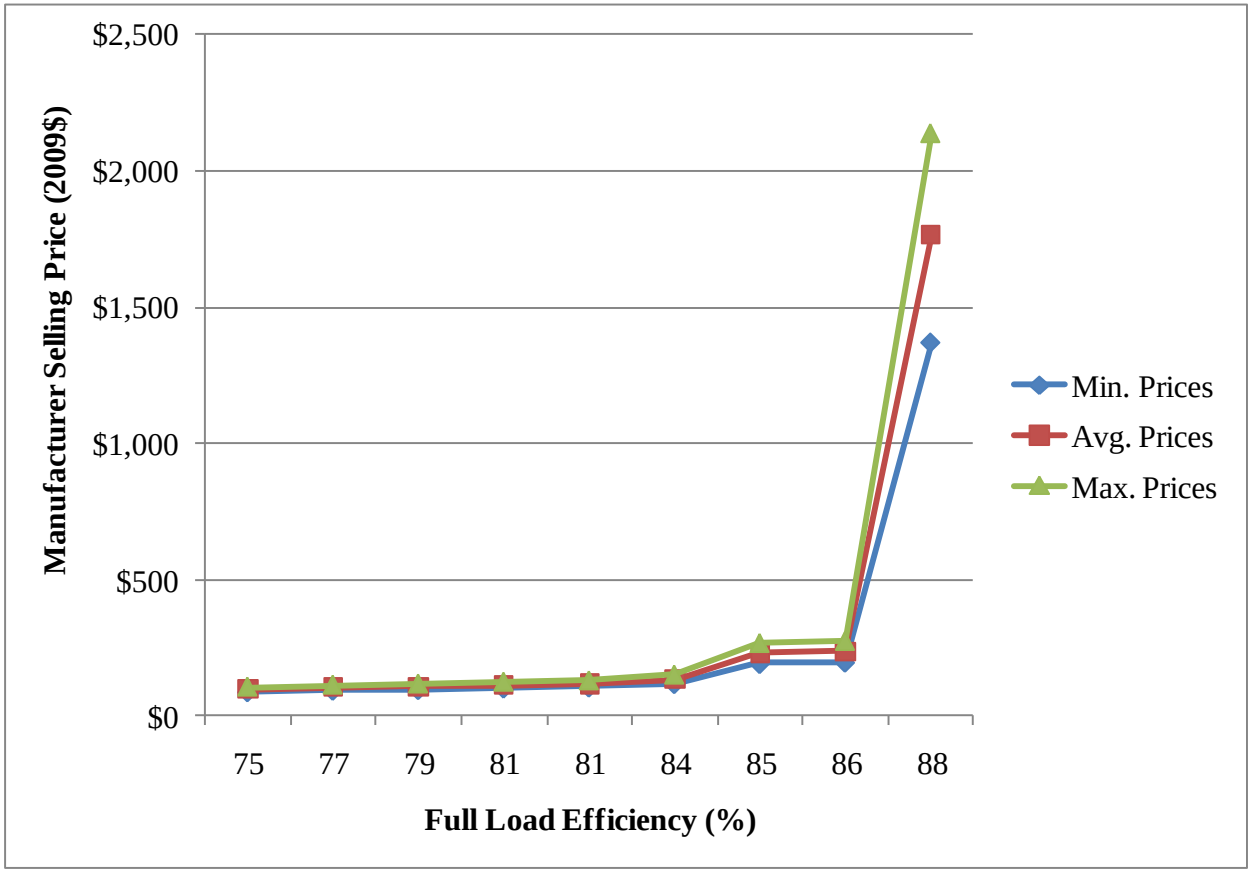

Figure 11.1 Commodity Price Impact on MSP for Space Constrained Polyphase Motors

Table 11.3 Commodity Price Impact on MSP for Non-Space Constrained Polyphase Motors*

	Efficiency Level (%)	MSP From Min. Prices (2009$)	MSP From Five-Year Avg. Prices (2009$)	MSP From Max. Prices (2009$)
EL 4b	83.5	119.39	134.04	148.14
EL 5	85.2	135.19	153.92	171.93
EL 6	86.3	161.55	186.37	210.20
EL 7	87.8	267.83	326.18	380.48

* Designs where the non-space constrained specifications are the same as the space constrained specifications have been omitted from this table. Since the specifications are the same, the resulting MSPs are the same. See the Table 11.2 for detail on these designs.

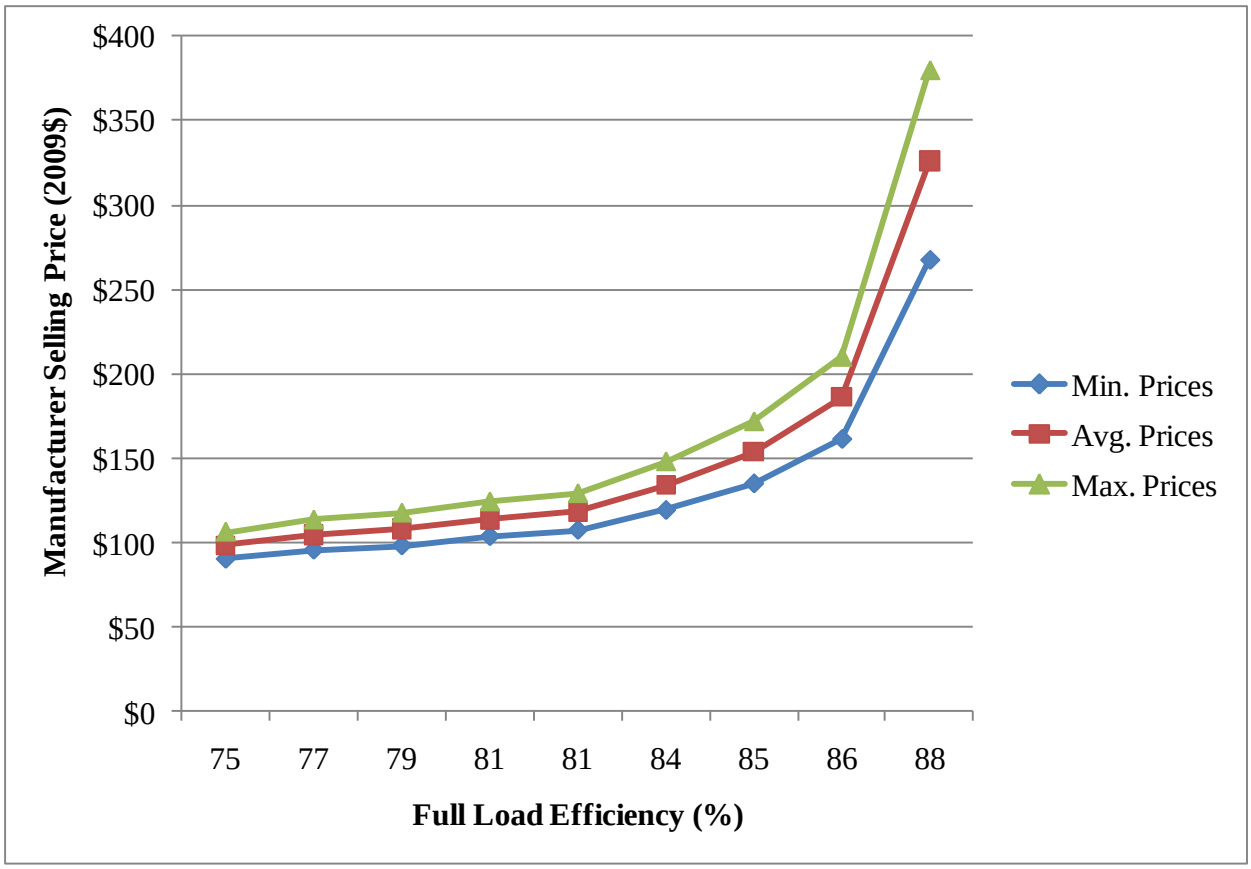

Figure 11.2 Commodity Price Impact on MSP for Non-Space Constrained Polyphase Motors

Table 11.4 Commodity Price Impact on MSP for Space Constrained CSIR Motors

	Efficiency Level (%)	Minimum Prices (2009$)	Five-Year Average Prices (2009$)	Maximum Prices (2009$)
Baseline	57.9	85.73	91.24	96.60
EL 1	61.1	89.08	95.43	101.61
EL 2	63.5	91.67	98.45	105.07
EL 3	65.7	92.57	99.58	106.41
EL 4	70.6	103.92	114.31	124.33
EL 5	71.8	105.85	117.07	127.27
EL 6	73.1	156.01	182.09	206.30
EL 7	77.6	937.65	1,200.98	1,448.57

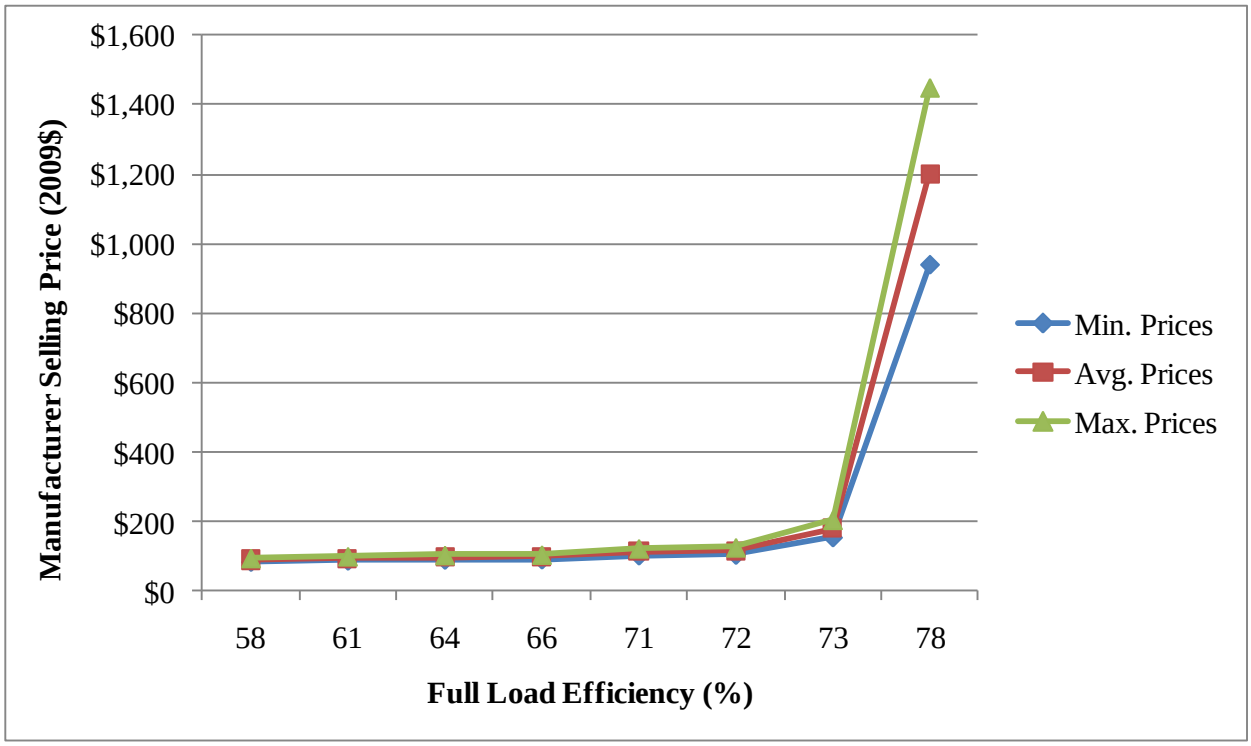

Figure 11.3 Commodity Price Impact on MSP for Space Constrained CSIR Motors

Table 11.5 Commodity Price Impact on MSP for Non-Space Constrained CSIR Motors*

	Efficiency Level (%)	MSP From Min. Prices (2008$)	MSP From Five-Year Avg. Prices (2008$)	MSP From Max. Prices (2008$)
EL 4	70.5	98.62	106.99	115.12
EL 5	71.8	107.16	118.00	128.46
EL 6	73.3	118.49	132.22	145.42
EL 7	77.7	133.32	151.25	167.56

* Designs where the non-space constrained specifications are the same as the space constrained specifications have been omitted from this table. Since the specifications are the same, the resulting MSPs are the same. See Table 11.4 for detail on these designs.

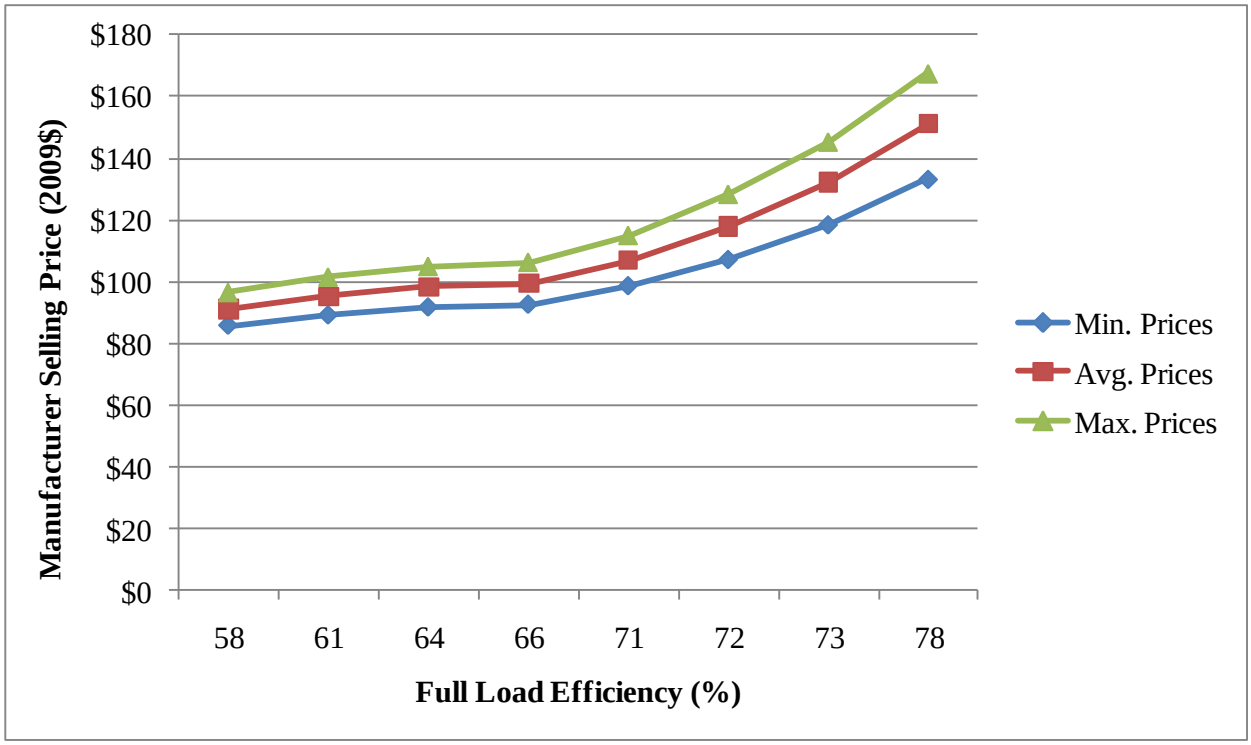

Figure 11.4 Commodity Price Impact on MSP for Non-Space Constrained CSIR Motors

Table 11.6 Commodity Price Impact on MSP for Space Constrained CSCR Motors

	Efficiency Level (%)	Minimum Prices (2009$)	Five-Year Average Prices (2009$)	Maximum Prices (2009$)
Baseline	71.4	103.37	111.72	119.81
EL 1	75.1	108.10	117.13	125.89
EL 2	79.5	123.53	137.20	150.34
EL 3	81.7	128.11	142.63	156.58
EL 4	82.8	131.33	146.44	160.96
EL 5	84.1	136.87	154.55	170.14
EL 6	84.8	200.34	236.98	271.76
EL 7	86.8	205.59	244.03	279.58
EL 8	88.1	1,377.22	1,771.47	2,142.06

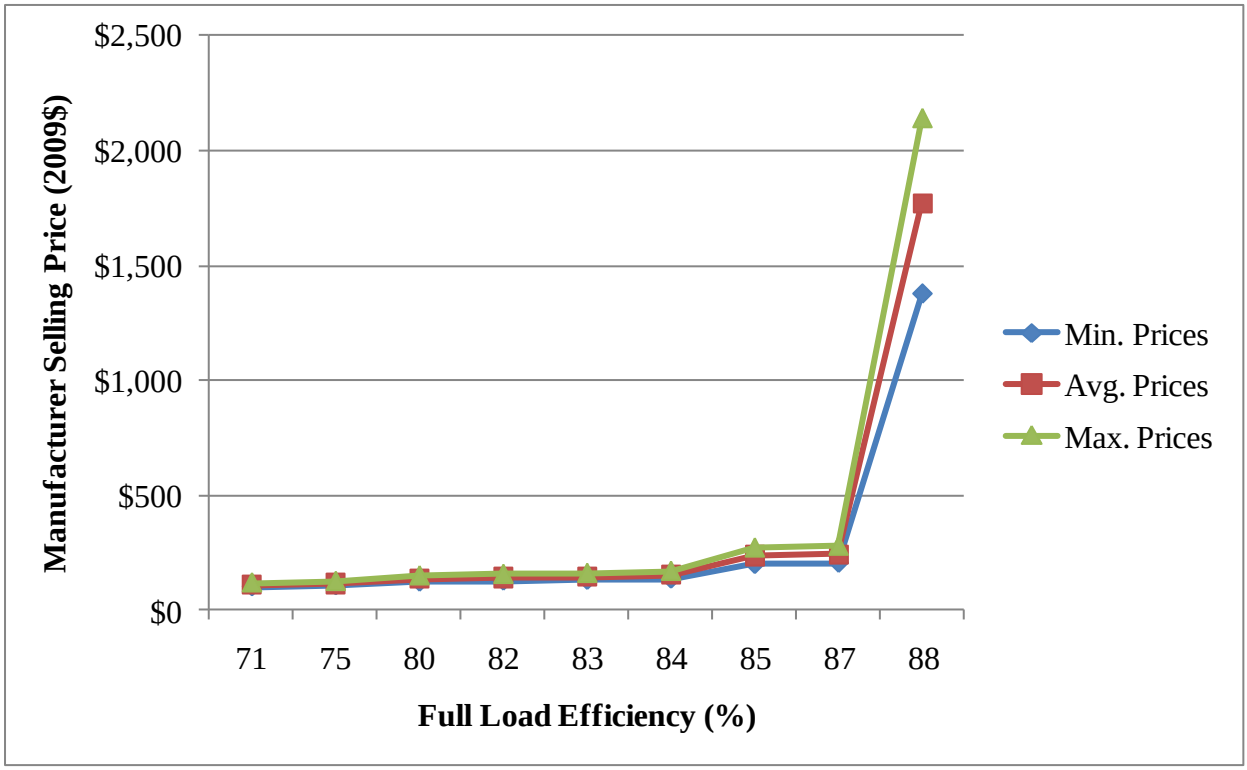

Figure 11.5 Commodity Price Impact on MSP for Space Constrained CSCR Motors

Table 11.7 Commodity Price Impact on MSP for Non-Space Constrained CSCR Motors*

	Efficiency Level (%)	MSP From Min. Prices (2009$)	MSP From Five-Year Avg. Prices (2009$)	MSP From Max. Prices (2009$)
EL 2	79.5	118.55	129.88	140.83
EL 3	81.8	123.26	135.56	147.43
EL 4	82.8	128.44	142.76	155.49
EL 5	84.0	135.70	151.91	166.05
EL 6	84.6	141.05	158.25	173.50
EL 7	86.7	153.92	175.75	195.23
EL 8	87.9	271.36	327.69	379.79

* Designs where the non-space constrained specifications are the same as the space constrained specifications have been omitted from this table. Since the specifications are the same, the resulting MSPs are the same. See Table 11.6 for detail on these designs.

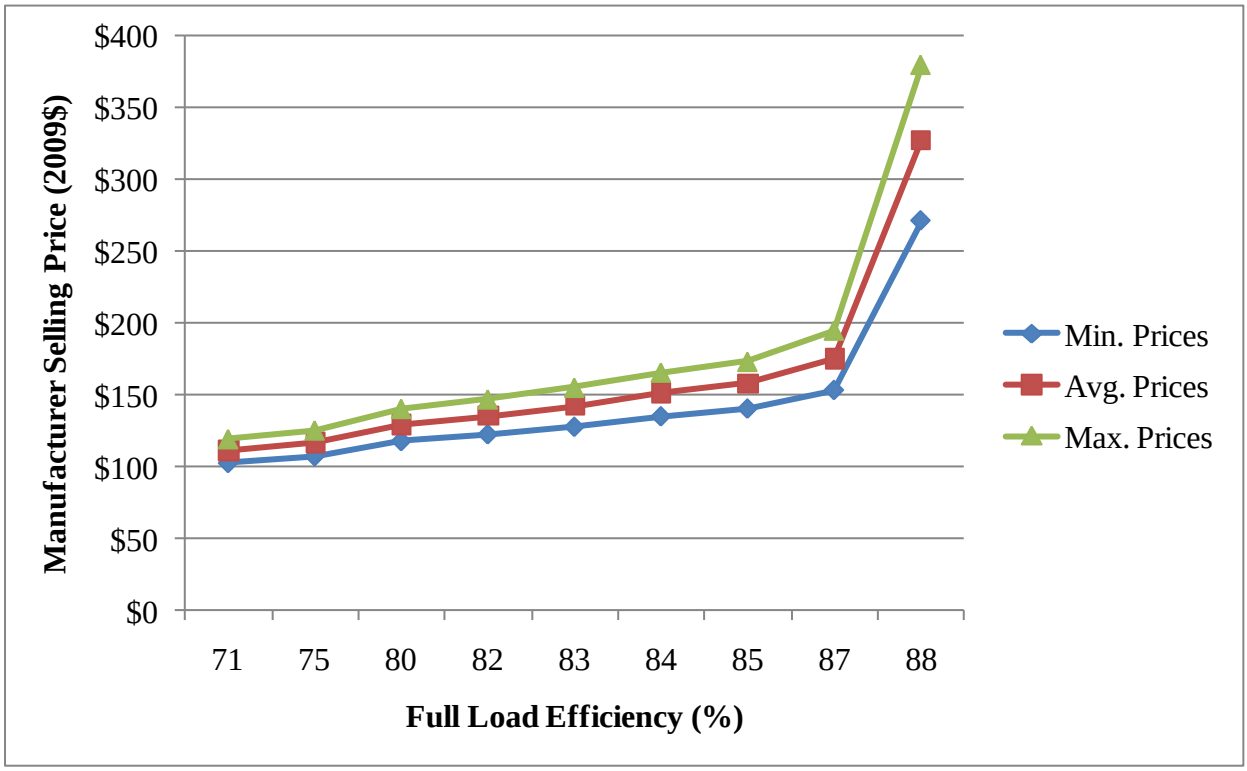

Figure 11.6 Commodity Price Impact on MSP for Non-Space Constrained CSCR Motors

5A.12 SCALING RELATIONSHIPS

As part of the scaling process, DOE used listed catalog efficiency data from various manufacturers, NEMA efficiency data, and test results performed by its subcontractor. The test results came from an independently accredited laboratory that tested the motors according to the applicable IEEE test procedures: IEEE 112 (test methods A and B) for polyphase motors and IEEE 114 for single-phase motors. Table 12.1 and Table 12.2 show the efficiency data collected through these test procedures for polyphase and CSIR motors. As noted in chapter 5 of the TSD,

no manufacturer offered a complete product line of CSCR motors, and therefore their scaling relationships were based upon the CSIR data.

Table 12.1 Test Results for Polyphase Motors

Horsepower/Standard Kilowatt Equivalent	Six Poles Efficiency (%)	Four Poles Efficiency (%)	Two Poles Efficiency (%)
1/4 hp/0.18 kW			
1/3 hp/0.25 kW	65.3	61.3	54.9
1/2 hp/0.37 kW			
3/4 hp/0.55 kW		71.8	65.7
1 hp/0.75 kW		74.0	68.3
1½ hp/1.1 kW			
2 hp/1.5 kW		75.7	78.8
≥ 3 hp/2.2 kW			

Table 12.2 Test Results for CSIR Motors

Horsepower/Standard Kilowatt Equivalent	Six Poles Efficiency (%)	Four Poles Efficiency (%)	Two Poles Efficiency (%)
1/4 hp/0.18 kW			
1/3 hp/0.25 kW		47.7	51.4
1/2 hp/0.37 kW	64.2		
3/4 hp/0.55 kW		66.5	55.3
1 hp/0.75 kW	75.7	67.7	
1½ hp/1.1 kW			
2 hp/1.5 kW		81.9	67.4
≥ 3 hp/2.2 kW			

Once the baseline efficiency levels were determined for product classes that were directly analyzed, DOE used its scaling tool to determine the appropriate efficiency levels for the remaining product classes. Table 12.3 through Table 12.5 show the scaled efficiency levels for each product class at the baseline efficiency level.

Table 12.3 Scaled Efficiency Levels for Baseline Polyphase Small Electric Motors

Horsepower/Standard Kilowatt Equivalent	Six Poles Efficiency (%)	Four Poles Efficiency (%)	Two Poles Efficiency (%)
1/4 hp/0.18 kW	67.5	69.5	65.6
1/3 hp/0.25 kW	71.4	73.4	69.5
1/2 hp/0.37 kW	75.3	78.2	73.4
3/4 hp/0.55 kW	81.7	81.1	76.8
1 hp/0.75 kW	83.8	83.5	82.5
1½ hp/1.1 kW	83.8	86.9	85.1
2 hp/1.5 kW		86.9	85.9
≥ 3 hp/2.2 kW		86.9	85.9

Table 12.4 Scaled Efficiency Levels for Baseline CSIR Small Electric Motors

Horsepower/Standard Kilowatt Equivalent	Six Poles Efficiency (%)	Four Poles Efficiency (%)	Two Poles Efficiency (%)
1/4 hp/0.18 kW	66.5	70.6	68.8
1/3 hp/0.25 kW	70.6	74.2	72.4
1/2 hp/0.37 kW	77.7	77.7	75.9
3/4 hp/0.55 kW	81.5	81.9	77.7
1 hp/0.75 kW		82.8	81.9
1½ hp/1.1 kW		83.9	83.0
2 hp/1.5 kW		84.7	84.2
≥ 3 hp/2.2 kW			85.4

Table 12.5 Scaled Efficiency Levels for Baseline CSCR Small Electric Motors

Horsepower/Standard Kilowatt Equivalent	Six Poles Efficiency (%)	Four Poles Efficiency (%)	Two Poles Efficiency (%)
1/4 hp/0.18 kW	62.2	68.5	66.6
1/3 hp/0.25 kW	66.6	72.4	70.5
1/2 hp/0.37 kW	76.2	76.2	72.4
3/4 hp/0.55 kW	80.2	81.8	76.2
1 hp/0.75 kW	81.1	82.6	80.4
1½ hp/1.1 kW		83.8	81.5
2 hp/1.5 kW		84.5	82.9
≥ 3 hp/2.2 kW			84.1

REFERENCES

[1] U.S. Department of Labor, Bureau of Labor Statistics, Producer Price Indices. Last accessed January 20, 2010. <http://www.bls.gov/ppi>.