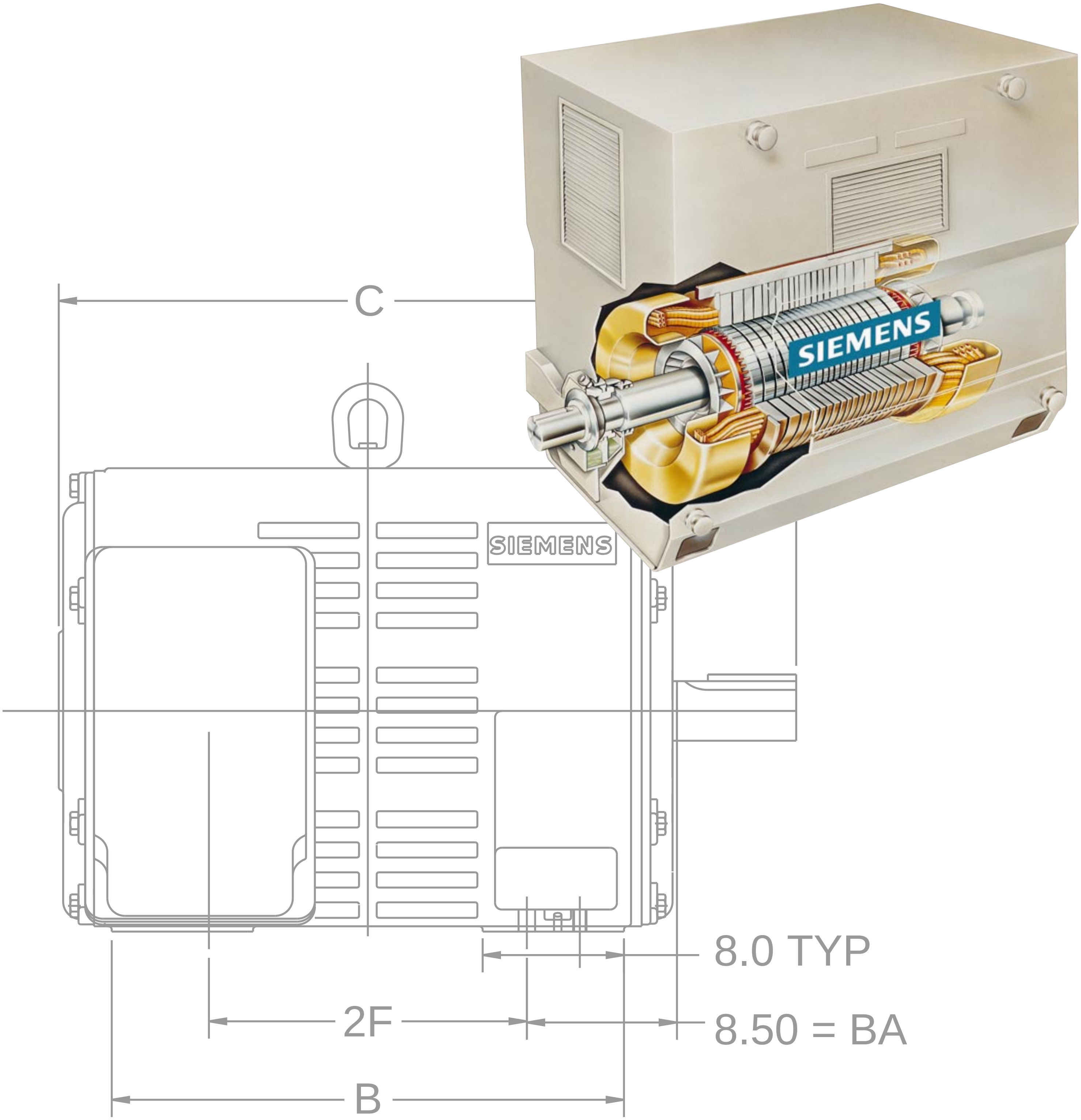
SIEMENS

Application Manual for Above NEMA Motors



ANCD-40000-0996

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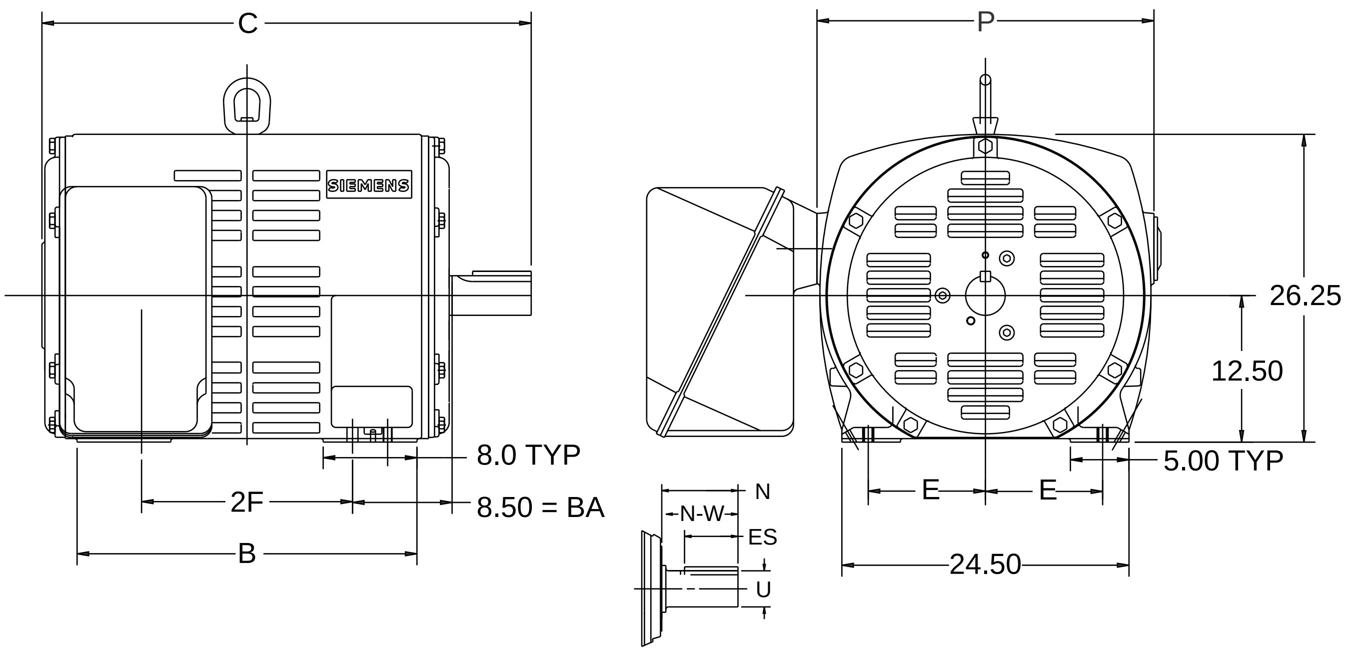


Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	505S	3600	29	40.3	10.0	18	5.5	5.25	28.3	2.275	.625	2.625	5.0	3.5	2900
Short	505S	1800 & Slower	29	41.8	10.0	18	7.0	6.75	28.3	2.88	.875	3.375	6.5	5.0	2900
Short	508S	3600	36	48.8	10.0	25	5.5	5.25	28.3	2.275	.625	2.625	5.0	3.5	3500
Short	508S	1800 & Slower	36	48.8	10.0	25	7.0	6.75	28.3	2.88	.875	3.375	6.5	5.0	3500
Long	505	1800 & Slower	29	44.5	10.0	18	9.75	9.5	28.3	3.436	1.0	4.0	9.25	8.0	2900
Long	508	1800 & Slower	36	52.1	10.0	25	9.75	9.5	28.3	3.436	1.0	4.0	9.25	8.0	3500

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.

Shims may be necessary under motor feet for direct connection.
3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

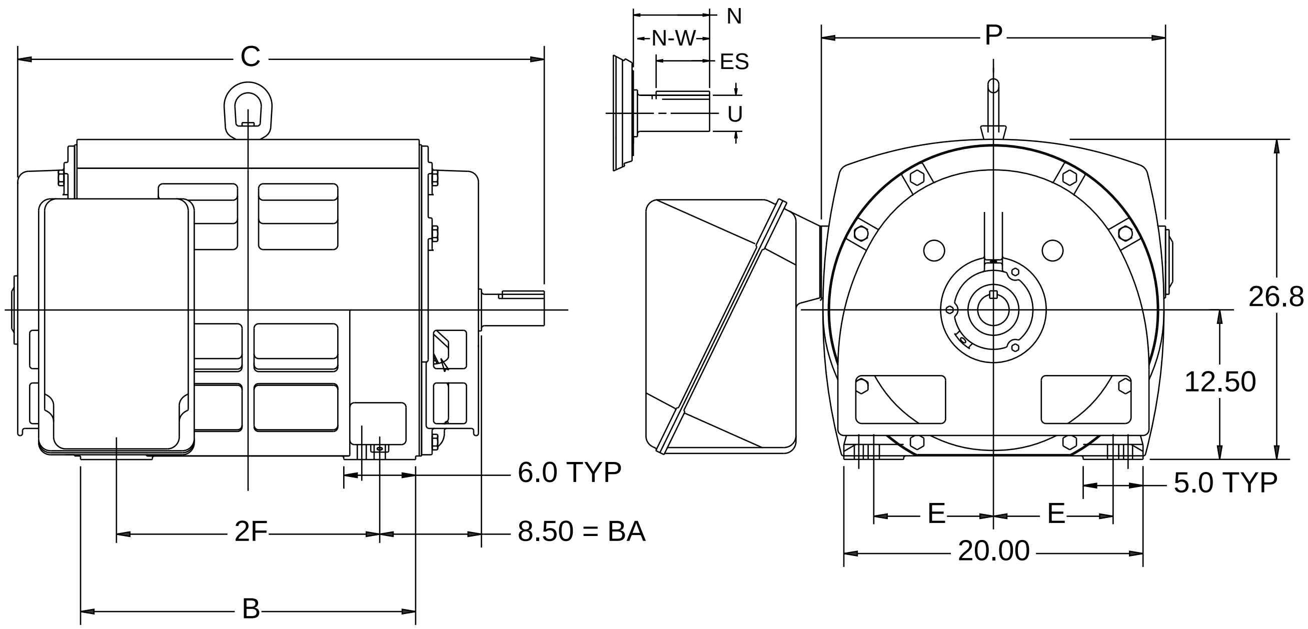
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I Anti-Friction Bearing Frames 507-509-5011



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	507S	3600	28	44.0	10.0	22	5.5	5.25	28.8	2.275	.625	2.625	5.0	3.5	3000
Short	507S	1800 & Slower	28	45.5	10.0	22	7.0	6.75	28.8	2.88	.875	3.375	6.5	5.0	3100
Short	509S	3600	34	50.0	10.0	28	5.5	5.25	28.8	2.275	.625	2.625	5.0	3.5	3500
Short	509S	1800 & Slower	34	51.5	10.0	28	7.0	6.75	28.8	2.88	.875	3.375	6.5	5.0	3600
Short	5011S	1800 & Slower	42	59.5	10.0	36	7.0	6.75	28.8	2.88	.875	3.375	6.5	5.0	4700
Long	507	1800 & Slower	28	48.3	10.0	22	9.75	9.5	28.8	3.436	1.0	4.0	9.25	8.0	3200
Long	509	1800 & Slower	34	54.3	10.0	28	9.75	9.5	28.8	3.436	1.0	4.0	9.25	8.0	3700
Long	5011	1800 & Slower	42	62.3	10.0	36	9.75	9.5	28.8	3.436	1.0	4.0	9.25	8.0	4700

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.

Shims may be necessary under motor feet for direct connection.
3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

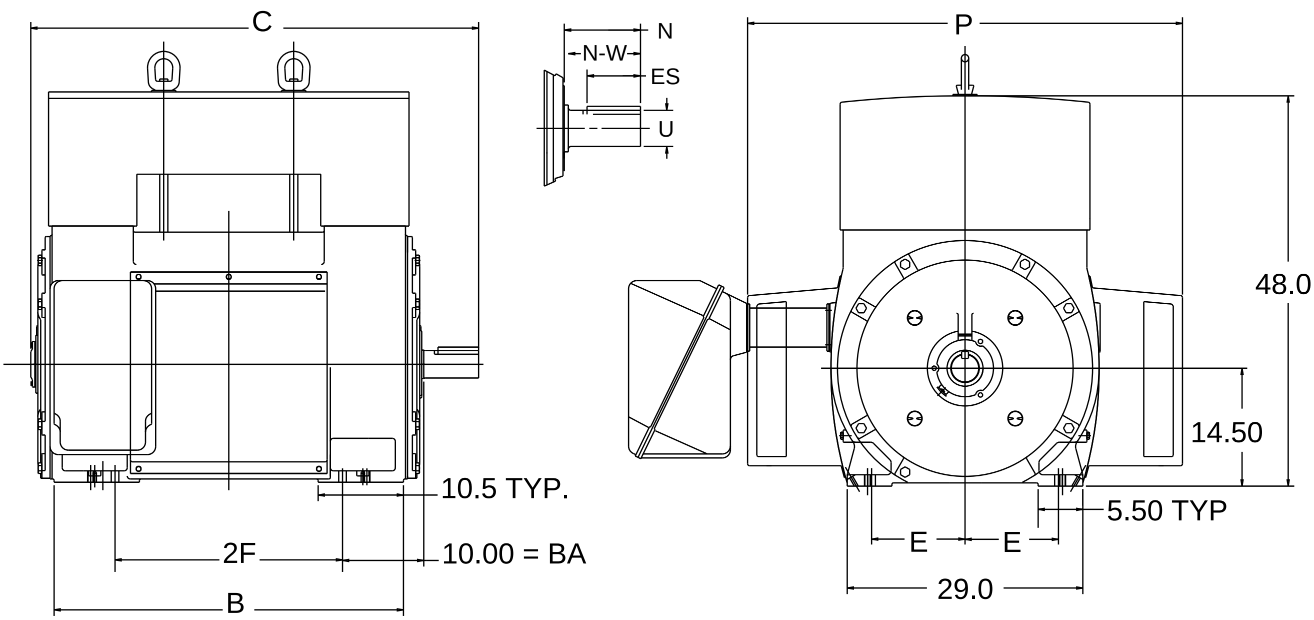
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I Anti-Friction Bearing Frames 588-5810 — 3600 and 1800 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	588S	3600	43	55.1	11.5	28	7.0	6.75	53.5	2.45	.75	2.875	6.50	5.0	5400
Short	588S	1800	43	56.4	11.5	28	8.25	8.0	53.5	3.436	1.0	4.0	7.75	6.0	5600
Short	5810S	3600	51	63.1	11.5	36	7.0	6.75	53.5	2.45	.75	2.875	6.5	5.0	6350
Short	5810S	1800	51	64.4	11.5	36	8.25	8.0	53.5	3.436	1.0	4.0	7.75	6.0	6550
Long	588	1800	43	63.0	11.5	28	14.9	14.62	53.5	4.169	1.25	4.875	14.38	13.0	5600
Long	5810	1800	51	71.0	11.5	36	14.9	14.62	53.5	4.169	1.25	4.875	14.38	13.0	6550

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.

Shims may be necessary under motor feet for direct connection.
3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

Certification

Customer P.O. S.O. Item

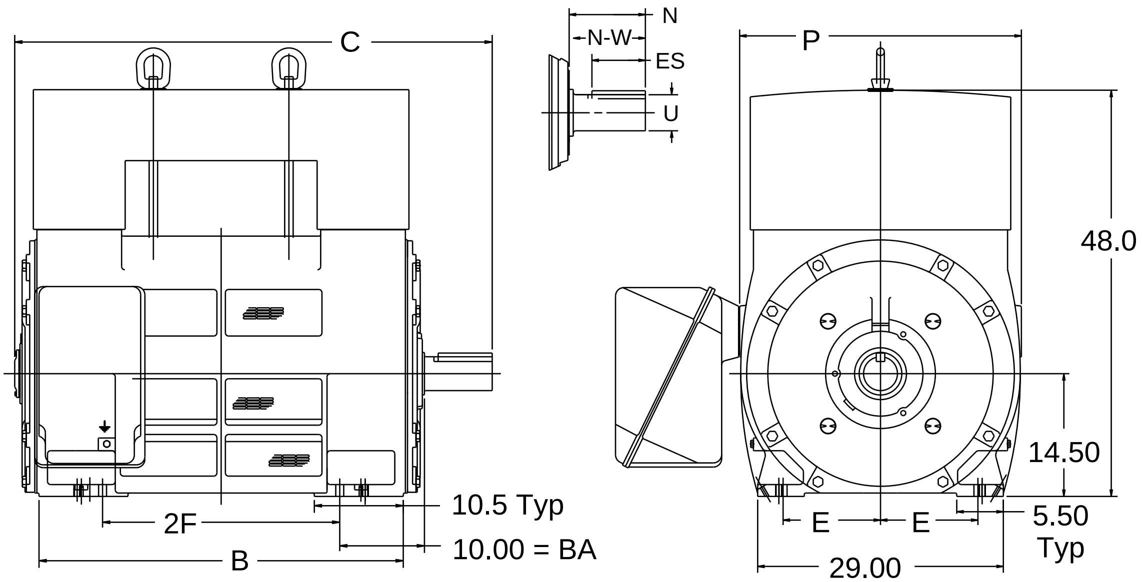
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I Anti-Friction Bearing Frames 588-5810 — 1200 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	588S	1200 & Slower	43	56.4	11.5	28	8.25	8.0	33.3	3.436	1.0	4.0	7.75	6.0	5400
Short	5810S	1200 & Slower	51	64.4	11.5	36	8.25	8.0	33.3	3.436	1.0	4.0	7.75	6.0	6400
Long	588	1200 & Slower	43	63.0	11.5	28	14.87	14.62	33.3	4.169	1.25	4.875	14.37	13.0	5400
Long	5810	1200 & Slower	51	71.0	11.5	36	14.87	14.62	33.3	4.169	1.25	4.875	14.37	13.0	6400

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.

Shims may be necessary under motor feet for direct connection.
Machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

Certification

Customer ____ P.O. ____ S.O. ____ Item ____

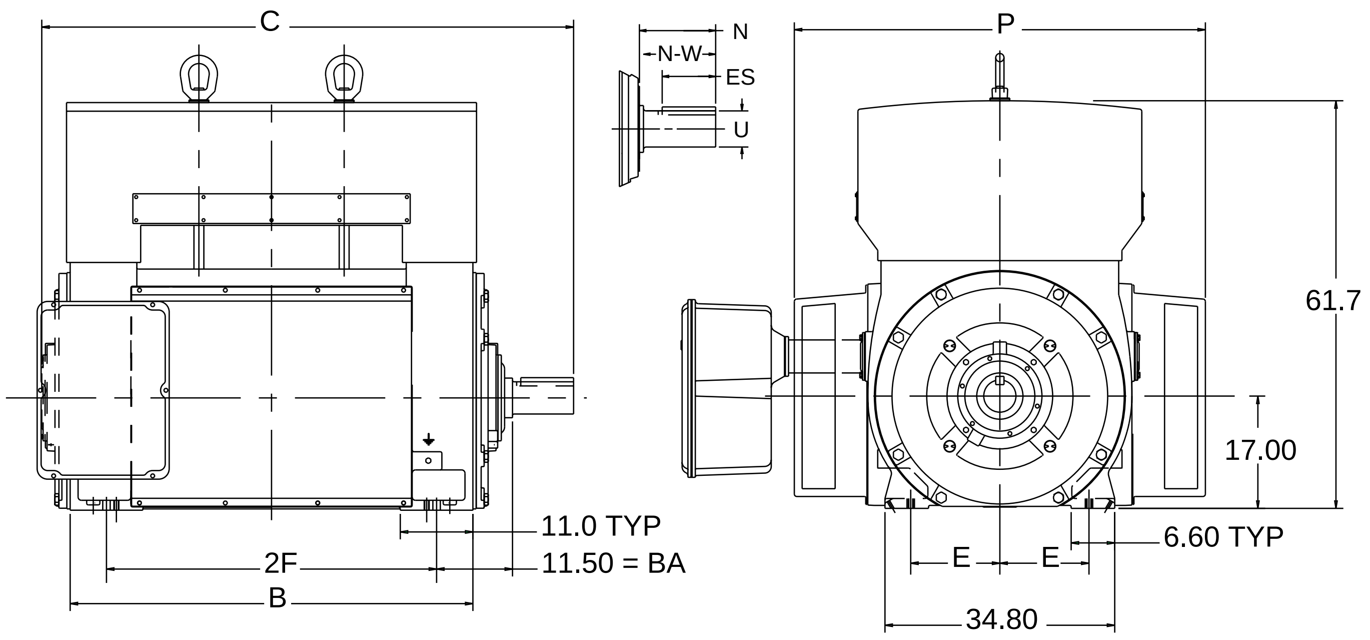
HP ____ RPM ____ FR. ____ PH/HZ/Volts ____

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ____ Date ____

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I
Anti-Friction Bearing — Direct Connected
Frames 6811-6813 — 1800 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	6811	1800	61	80.6	13.5	50	10.45	9.25	62.3	4.169	1.25	4.875	9.0	8.0	12000
Short	6813	1800	74	93.6	13.5	63	10.45	9.25	62.3	4.169	1.25	4.875	9.0	8.0	14700

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.

Shims may be necessary under motor feet for direct connection.
Machines may rotate in either direction.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

Certification

Customer P.O. S.O. Item

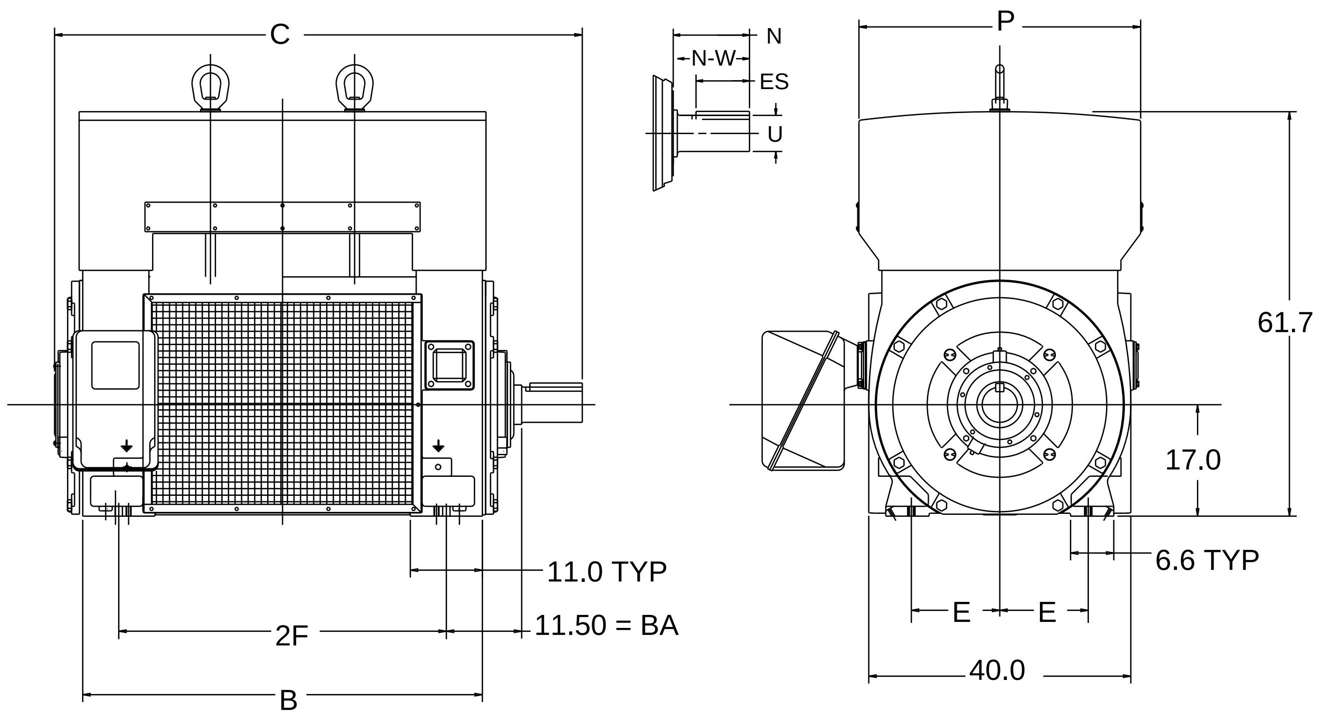
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I
Anti-Friction Bearing — Direct Connected
Frames 6811-6813 — 1200 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	6811	1200 & Slower	61	80.6	13.5	50	10.45	9.25	43.0	4.676	1.25	5.375	9.0	8.0	11800
Short	6813	1200 & Slower	74	93.6	13.5	63	10.45	9.25	43.0	4.676	1.25	5.375	9.0	8.0	14200

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.

Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.
Machines may rotate in either direction.

Certification

Customer P.O. S.O. Item

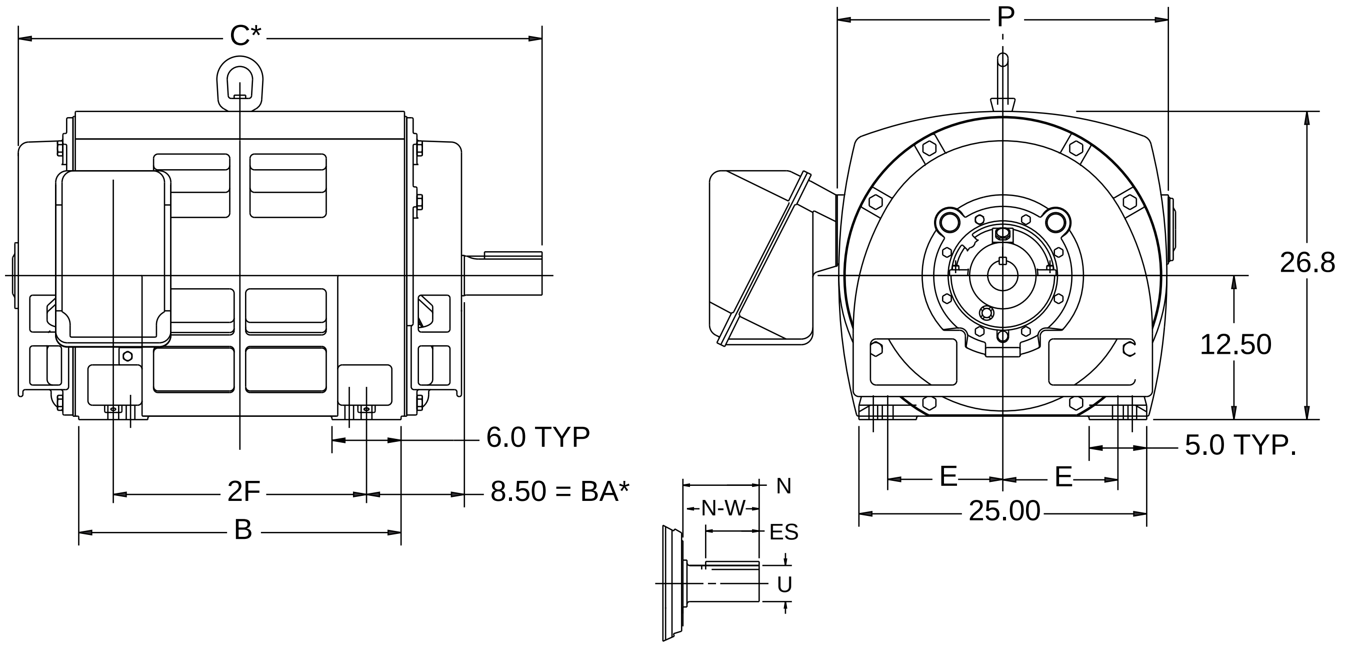
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Drip Proof — Weather Protected Type I
Sleeve Bearing — Direct Connected
Frames 507-509-5011



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	507S	3600	28	44.0	10.0	22	5.5	5.25	28.8	2.275	.625	2.625	5.0	3.5	3000
Short	507S	1800 & Slower	28	45.5	10.0	22	7.0	6.75	28.8	2.880	.875	3.375	6.5	5.0	3100
Short	509S	3600	34	50.0	10.0	28	5.5	5.25	28.8	2.275	.625	2.625	5.0	3.5	3500
Short	509S	1800 & Slower	34	51.5	10.0	28	7.0	6.75	28.8	2.880	.875	3.375	6.5	5.0	3600
Short	5011S	1800 & Slower	42	59.5	10.0	36	7.0	6.75	28.8	2.880	.875	3.375	6.5	5.0	4700

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication	
3600 RPM	1800 RPM & Slower
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
0.8 qt. capacity	0.8 qt. capacity

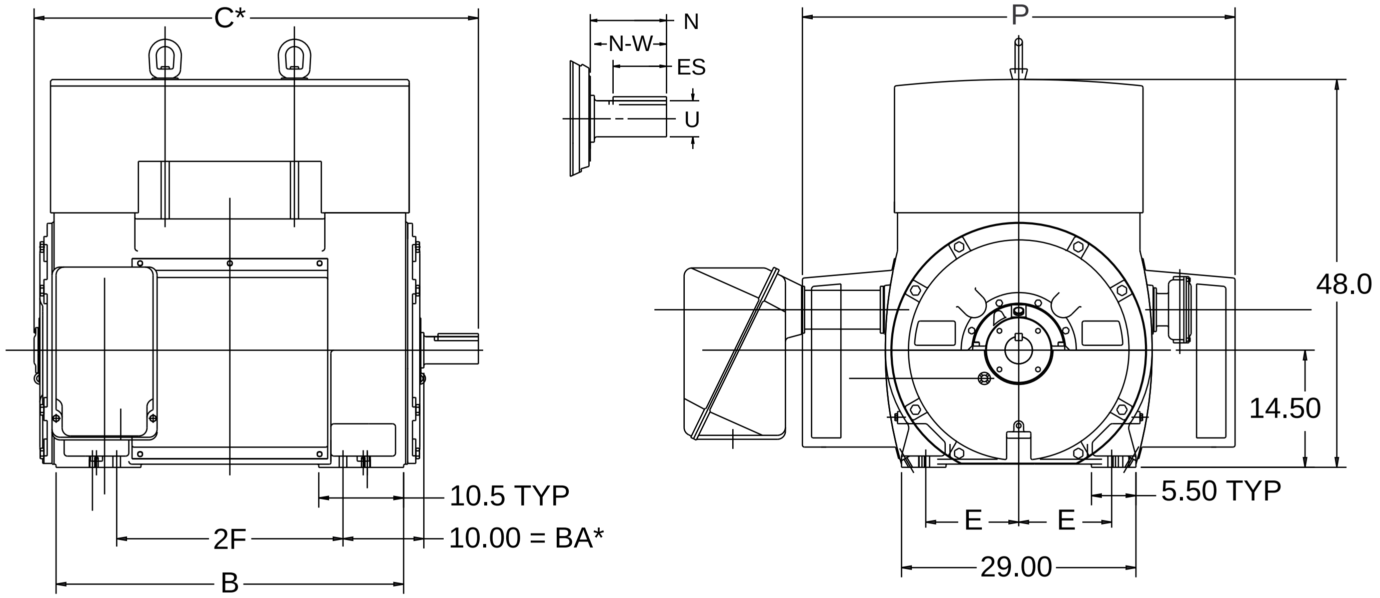
Certification

Customer ____ P.O. ____ S.O. ____ Item ____
HP ____ RPM ____ FR. ____ PH/HZ/Volts ____
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ____ Date ____

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I Sleeve Bearing — Direct Connected Frames 588-5810 — 3600 and 1800 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	588S	3600	43	55.0	11.5	28	7.13	6.75	53.5	2.88	.875	3.375	6.5	5.0	5400
Short	588S	1800	43	56.2	11.5	28	8.38	8.0	53.5	3.436	1.0	4.0	7.75	6.0	5600
Short	5810S	3600	51	63.0	11.5	36	7.13	6.75	53.5	2.88	.875	3.375	6.5	5.0	6500
Short	5810S	1800	51	64.2	11.5	36	8.83	8.0	53.5	3.436	1.0	4.0	7.75	6.0	6600

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication	
3600 RPM	1800 RPM
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
3.5 qt. capacity	3.5 qt. capacity

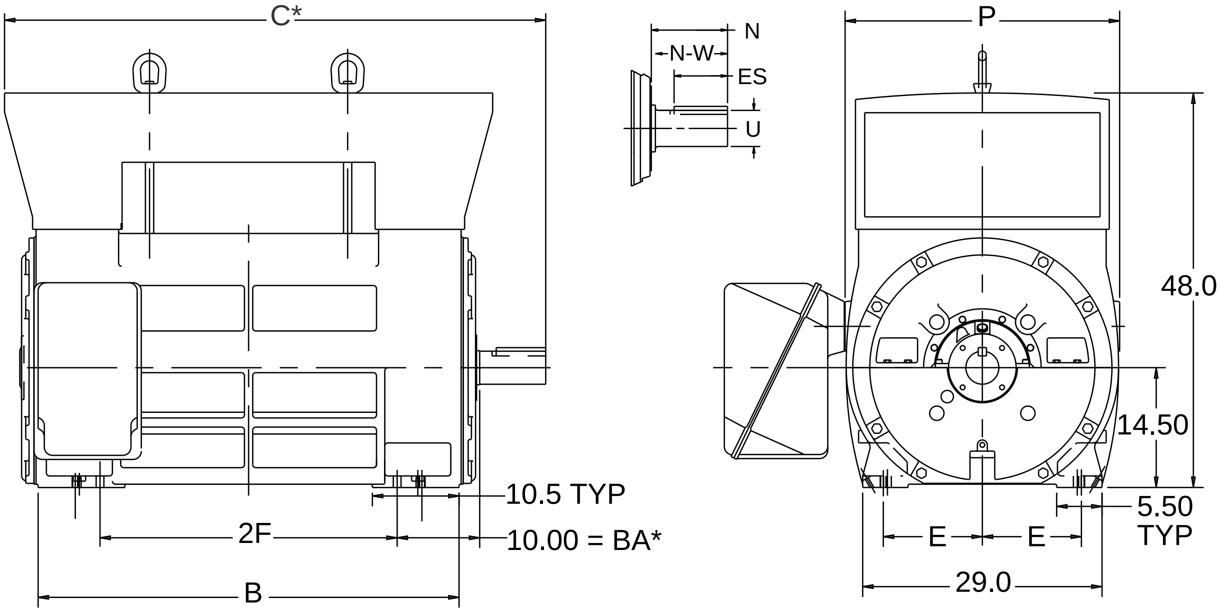
Certification

Customer ______ P.O. ______ S.O. ______ Item ______
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I Sleeve Bearing — Direct Connected Frames 588-5810 — 1200 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	588S	1200 & Slower	43	57.8	11.5	28	8.38	8.0	33.3	3.436	1.0	4.0	7.75	6.0	5100
Short	5810S	1200 & Slower	51	65.8	11.5	36	8.83	8.0	33.3	3.436	1.0	4.0	7.75	6.0	6000

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

Machines may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
290-350 SUS @ 100° F
3.5 qt. capacity

Certification

Customer P.O. S.O. Item

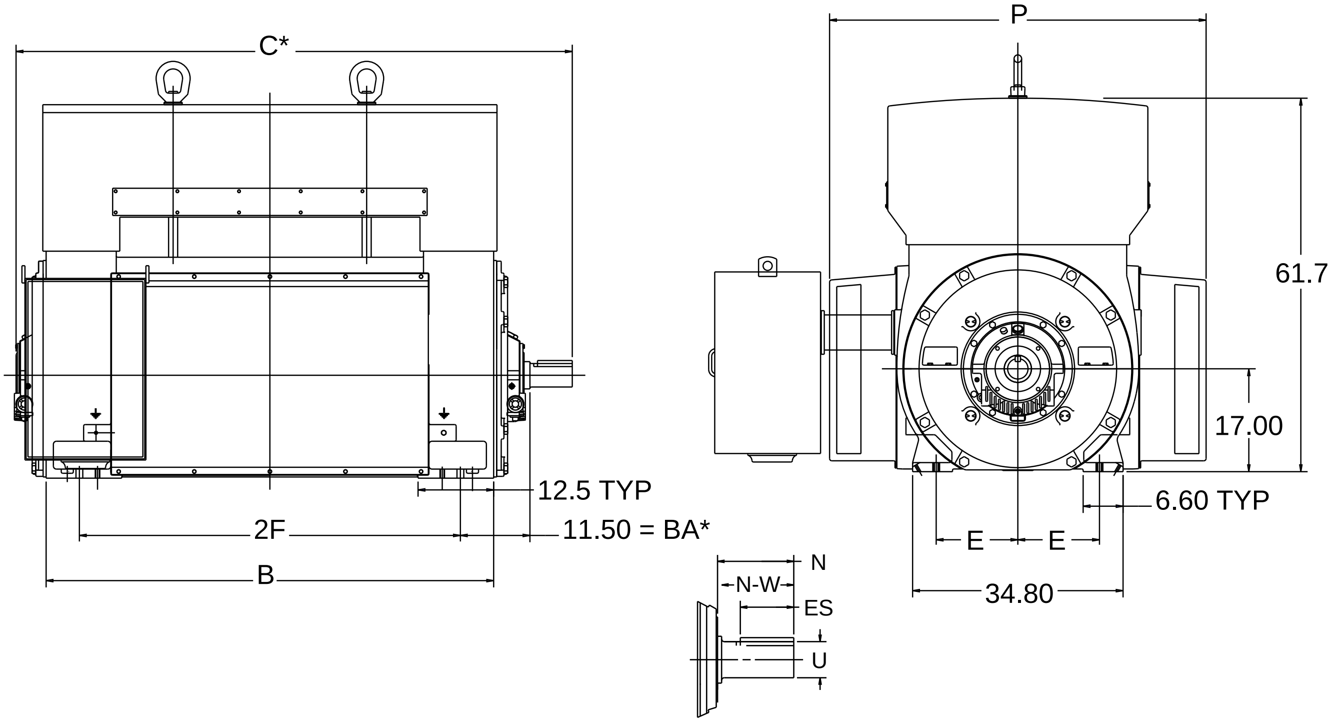
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I Sleeve Bearing — Direct Connected Frames 6811-6813 — 3600 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	6811	3600	61	79.0	13.5	50	7.97	7.0	62.3	3.007	.875	3.50	6.75	5.5	11200
Short	6813	3600	74	92.0	13.5	63	7.97	7.0	62.3	3.007	.875	3.50	6.75	5.5	13900

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
3600 RPM
140-160 SUS @ 100˚ F
3 qt. capacity

Certification

Customer P.O. S.O. Item

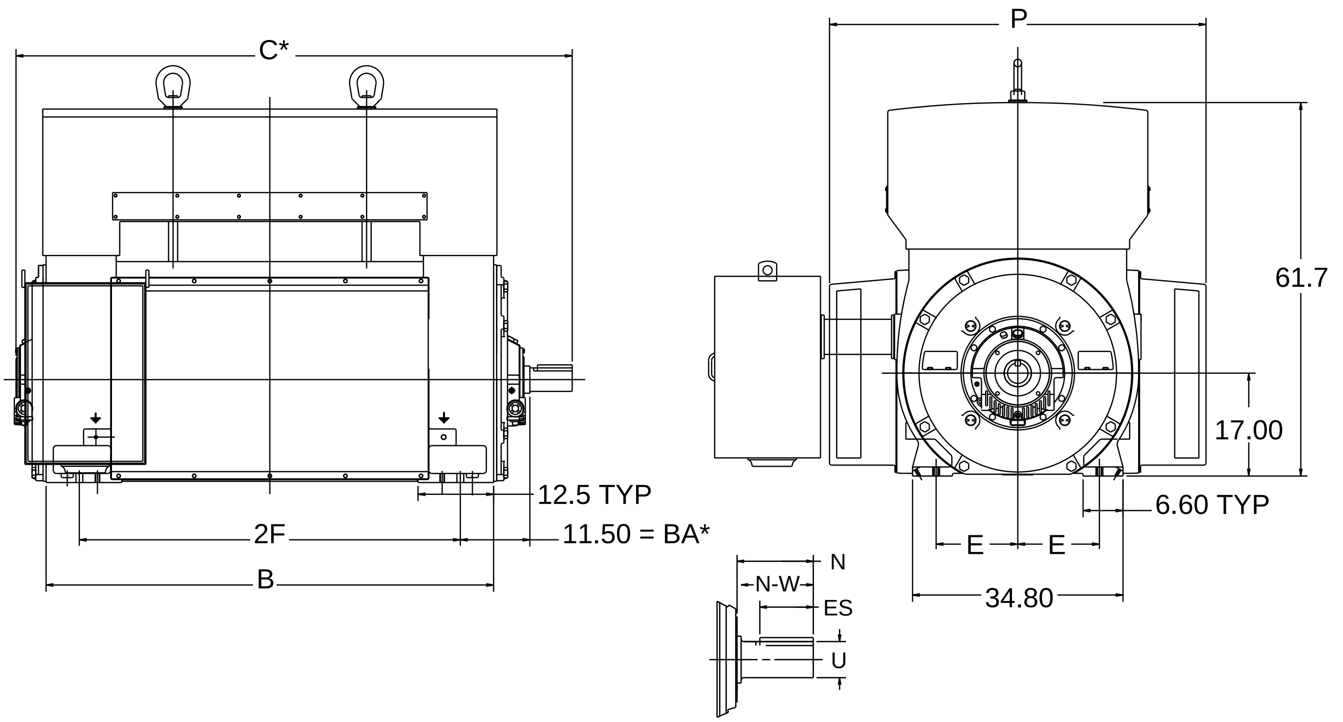
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I
Sleeve Bearing — Direct Connected
Frames 6811-6813 — 1800 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	6811	1800	61	81.3	13.5	50	10.22	9.25	62.3	4.169	1.25	4.875	9.0	8.0	12000
Short	6813	1800	74	94.5	13.5	63	10.22	9.25	62.3	4.169	1.25	4.875	9.0	8.0	14700

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

1800 RPM machines may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

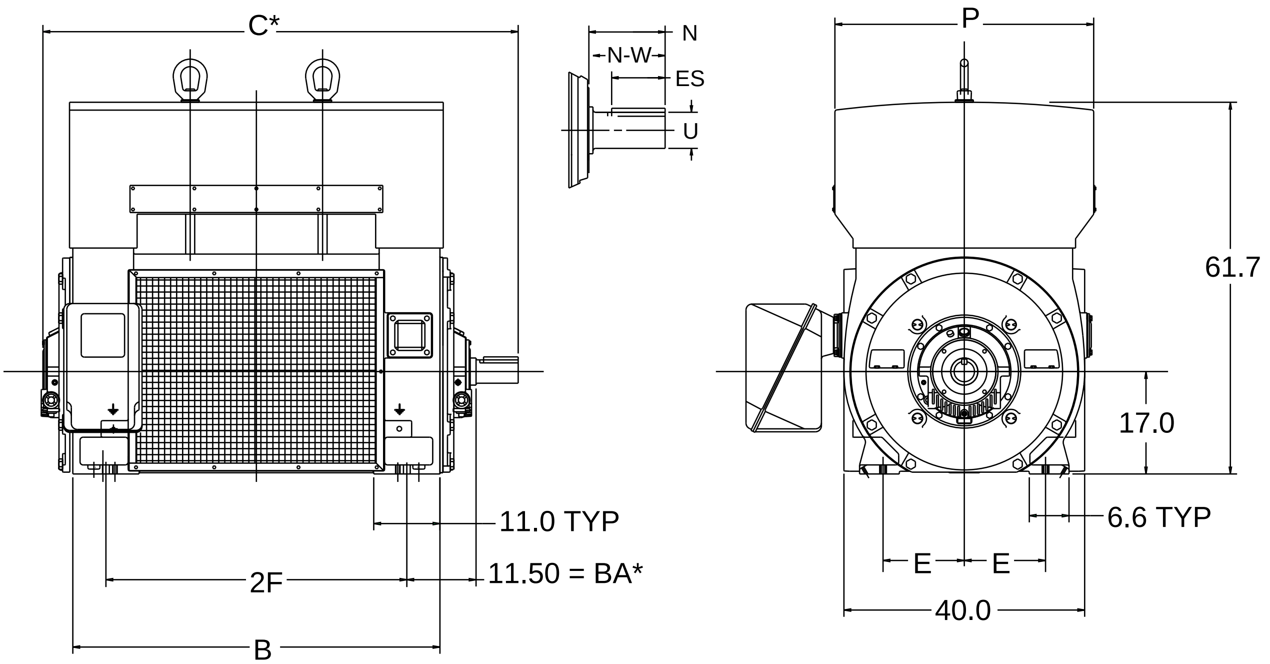
Lubrication
1800 RPM
290-350 SUS @ 100˚ F
3.0 qt. capacity

Certification

Customer ______ P.O. ______ S.O. ______ Item ______
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______
Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I Sleeve Bearing — Direct Connected Frames 6811-6813 — 1200 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	6811	1200 & Slower	61	81.3	13.5	50	10.22	9.25	43.0	4.676	1.25	5.375	9.0	8.0	11800
Short	6813	1200 & Slower	74	94.3	13.5	63	10.22	9.25	43.0	4.676	1.25	5.375	9.0	8.0	14200

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

Machines may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
290-350 SUS @ 100˚ F
3.0 qt. capacity

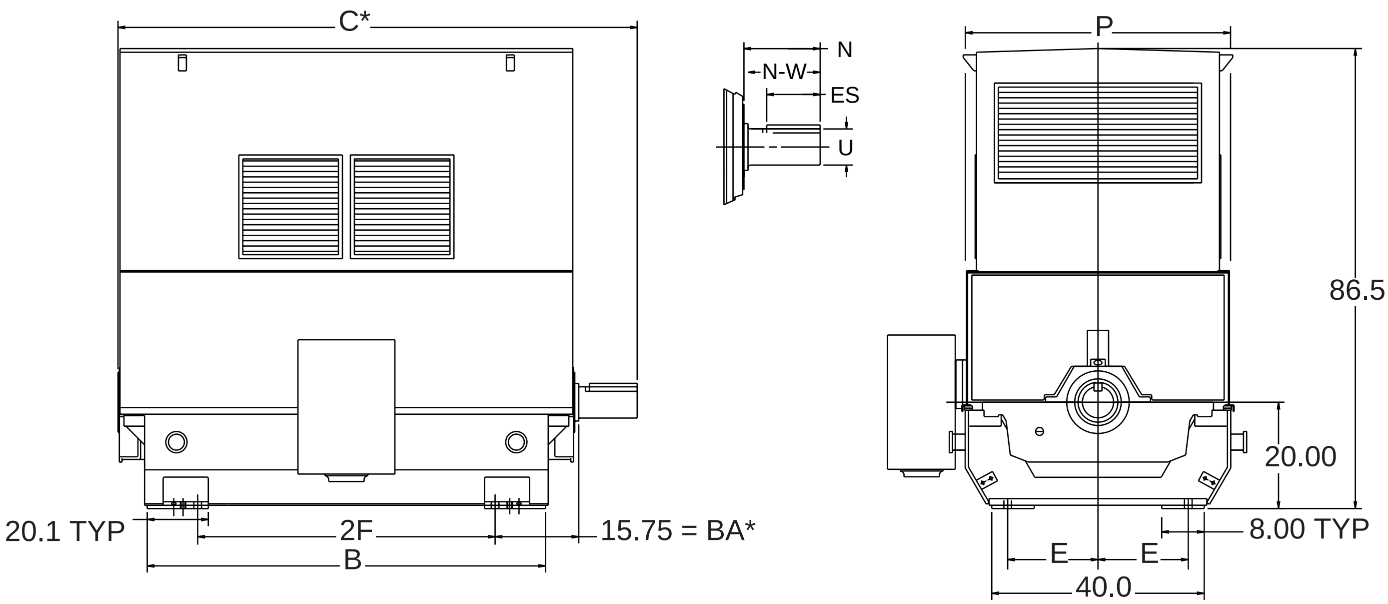
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type RG — Horizontal Custom — Open Drip Proof — Weather Protected Type I Sleeve Bearing — Direct Connected Frames 809-8012



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	809	3600	69	90.5	17.0	50	10.0	9.25	50.0	4.803	1.25	5.5	8.85	7.0	15000
Short	809	1800 & Slower	69	92.25	17.0	50	11.75	11.0	50.0	5.662	1.5	6.5	10.6	9.0	16000
Short	8010	3600	75	96.0	17.0	56	10.0	9.25	50.0	4.803	1.25	5.5	8.85	7.0	16000
Short	8010	1800 & Slower	75	97.75	17.0	56	11.75	11.0	50.0	5.662	1.5	6.5	10.6	9.0	17000
Short	8011	3600	82	103.0	17.0	63	10.0	9.25	50.0	4.803	1.25	5..5	8.85	7.0	17000
Short	8011	1800 & Slower	82	104.75	17.0	63	11.75	11.0	50.0	5.662	1.5	6.5	10.6	9.0	18000
Short	8012	3600	90	111.5	17.0	71	10.0	9.25	50.0	4.803	1.25	5.5	8.85	7.0	19000
Short	8012	1800 & Slower	90	113.25	17.0	71	11.75	11.0	50.0	5.662	1.5	6.5	10.6	9.0	20000

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication	
3600 RPM	1800 RPM & Slower
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
10.4 qt. capacity	10.4 qt. capacity

Certification

Customer ______ P.O. ______ S.O. ______ Item ______

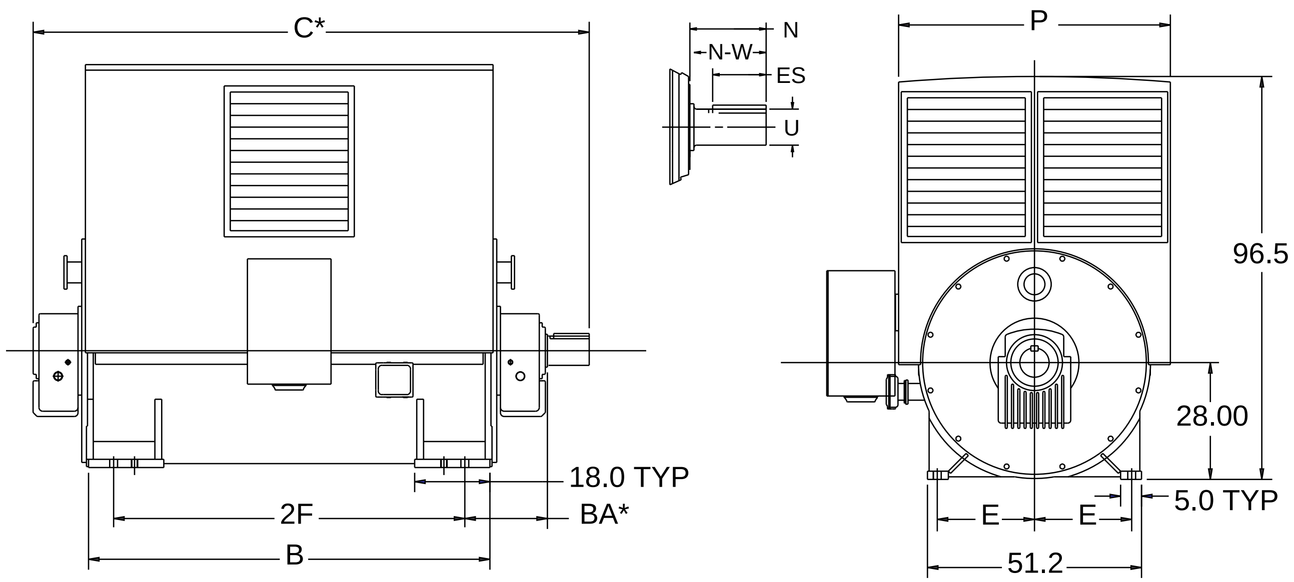
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I
Sleeve Bearing — Direct Connected
Frames 1122-1124 — 3600 and 1800 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	1122	3600	88		23.25	76			65.0						28500
Short	1122	1800	88		23.25	76			65.0						29500
Short	1124	3600	96		23.25	84			65.0						30500
Short	1124	1800	96		23.25	84			65.0						31500

Notes

See Section 6 for selection of main terminal box.
V(1)=Length of shaft available for coupling or pully.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

Machines rotate in one direction only.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication	
3600 RPM	1800 RPM
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
8.4 qt. capacity	8.4 qt. capacity

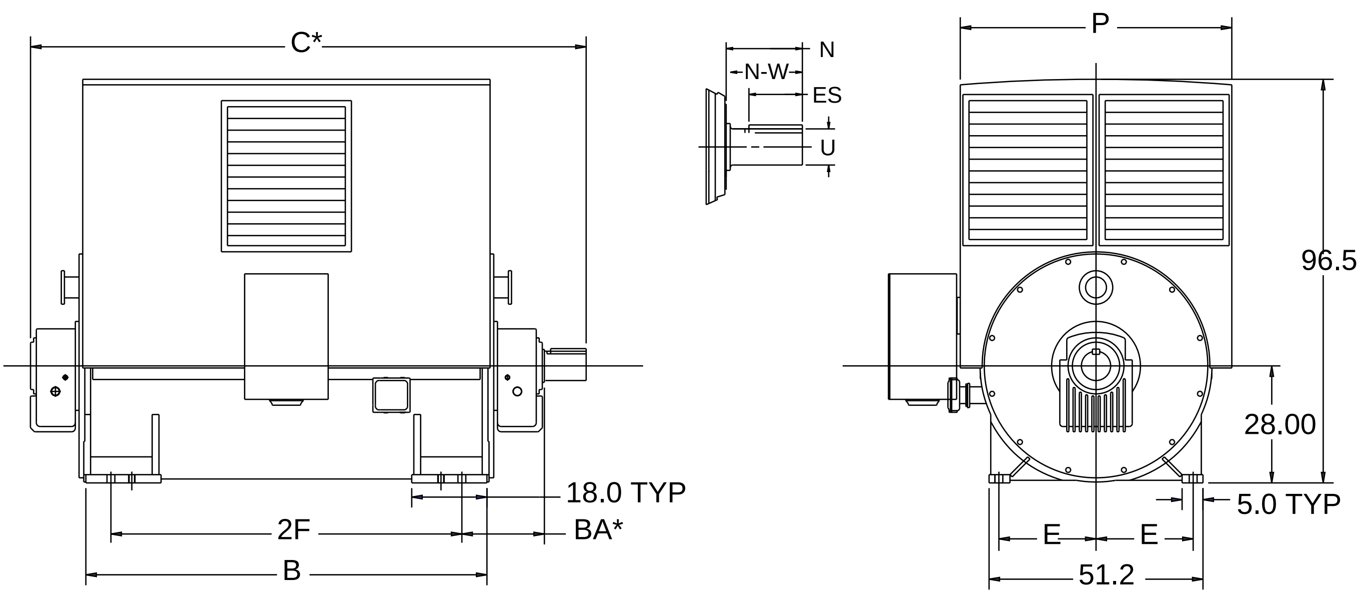
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CG — Horizontal Custom — Open Drip Proof — Weather Protected Type I Sleeve Bearing — Direct Connected Frames 1122-1124 — 1200 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	1122	1200 & Slower	88		23.25	76			65.0						29500
Short	1124	1200 & Slower	96		23.25	84			65.0						31500

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

Machines rotate in one direction only.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
290-350 SUS @ 100˚ F
13.6 qt. capacity

Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

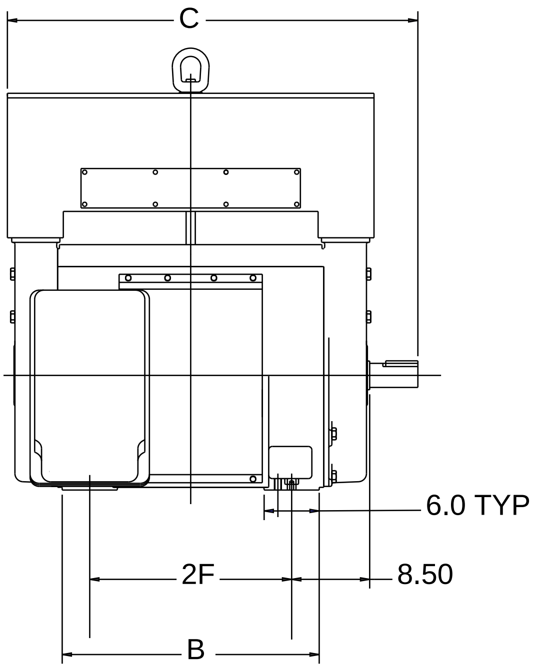
Not for construction, installation or application purposes unless certified.

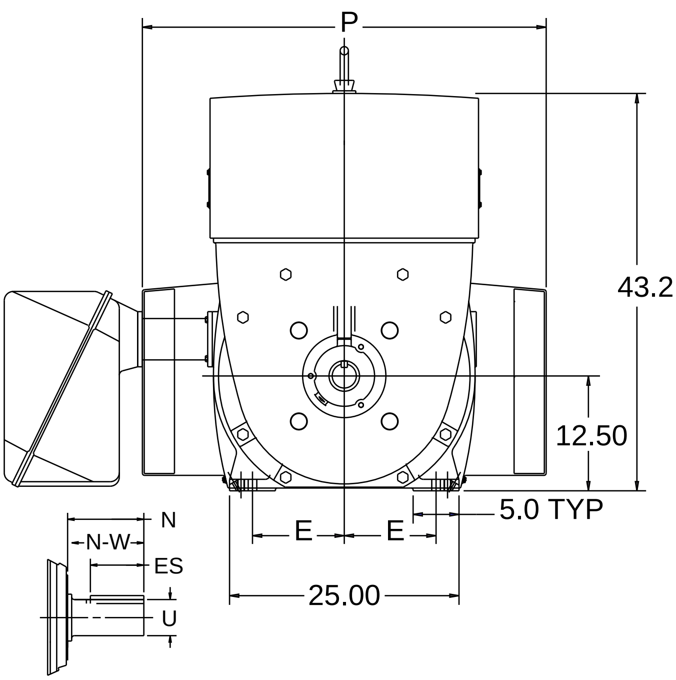
SIEMENS

Application Manual for Above NEMA Motors

Supersedes Page 7 Date 9/92

Type CGII — Horizontal Custom — Weather Protected Type II
Anti-Friction Bearing
Frames 507-509-5011





Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	507S	3600	28	44.7	10.0	22	5.5	5.25	44.0	2.275	.625	2.625	5.0	3.5	3500
Short	507S	1800 & Slower	28	46.2	10.0	22	7.0	6.75	44.0	2.88	.875	3.375	6.5	5.0	3500
Short	509S	3600	34	50.7	10.0	28	5.5	5.25	44.0	2.275	.625	2.625	5.0	3.5	4000
Short	509S	1800 & Slower	34	52.2	10.0	28	7.0	6.75	44.0	2.88	.875	3.375	6.5	5.0	4000
Short	5011S	1800 & Slower	42	60.2	10.0	36	7.0	6.75	44.0	2.88	.875	3.375	6.5	5.0	5200
Long	507	1800 & Slower	28	48.9	10.0	22	9.75	9.5	44.0	3.436	1.0	4.0	9.25	8.0	3500
Long	509	1800 & Slower	34	54.9	10.0	28	9.75	9.5	44.0	3.436	1.0	4.0	9.25	8.0	4000
Long	5011	1800 & Slower	42	62.9	10.0	36	9.75	9.5	44.0	3.436	1.0	4.0	9.25	8.0	5200

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

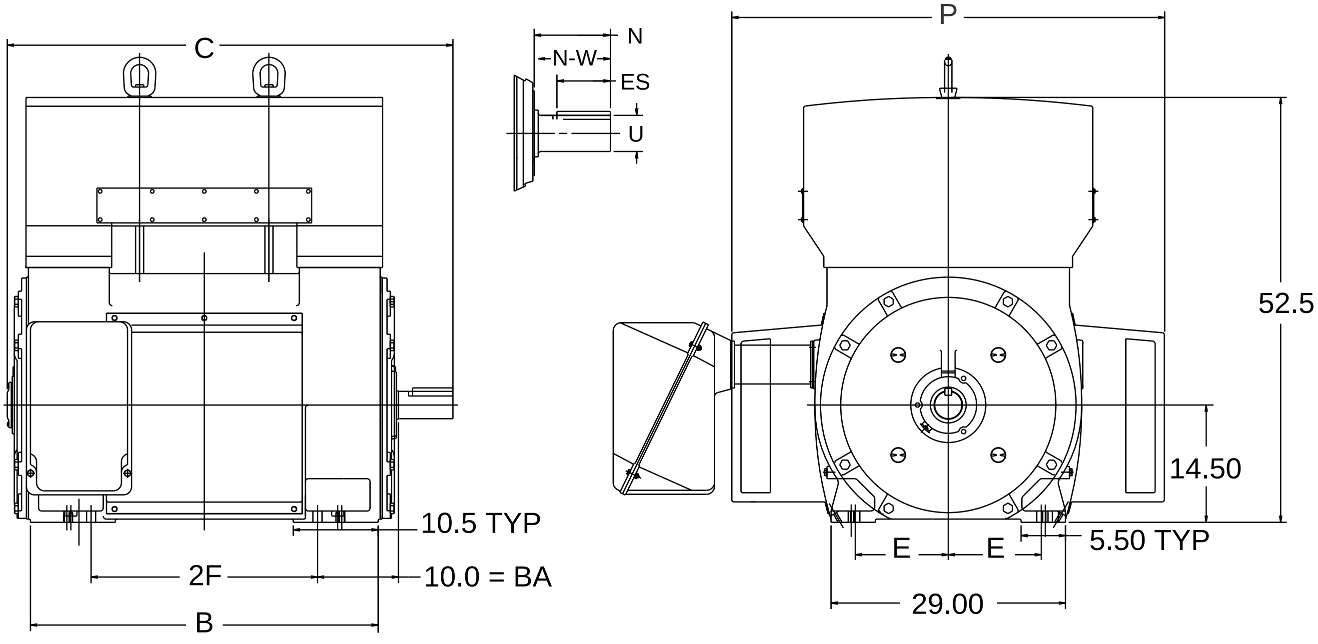
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGII — Horizontal Custom — Weather Protected Type II
Anti-Friction Bearing
Frames 588-5810



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	588S	3600	43	55.1	11.5	28	7.0	6.75	53.5	2.45	.875	2.85	6.5	5.0	5300
Short	588S	1800 & Slower	43	56.4	11.5	28	8.25	8.0	53.5	3.436	1.0	4.0	7.75	6.0	5600
Short	5810S	3600	51	63.1	11.5	36	7.0	6.75	53.5	2.45	.875	2.85	6.5	5.0	6500
Short	5810S	1800 & Slower	51	64.4	11.5	36	8.25	8.0	53.5	3.436	1.0	4.0	7.75	6.0	6800
Long	588	1800 & Slower	43	63.0	11.5	28	14.9	14.62	53.5	4.169	1.25	4.875	14.38	13.0	5600
Long	5810	1800 & Slower	51	71.0	11.5	36	14.9	14.62	53.5	4.169	1.25	4.875	14.38	13.0	6800

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

Certification

Customer P.O. S.O. Item

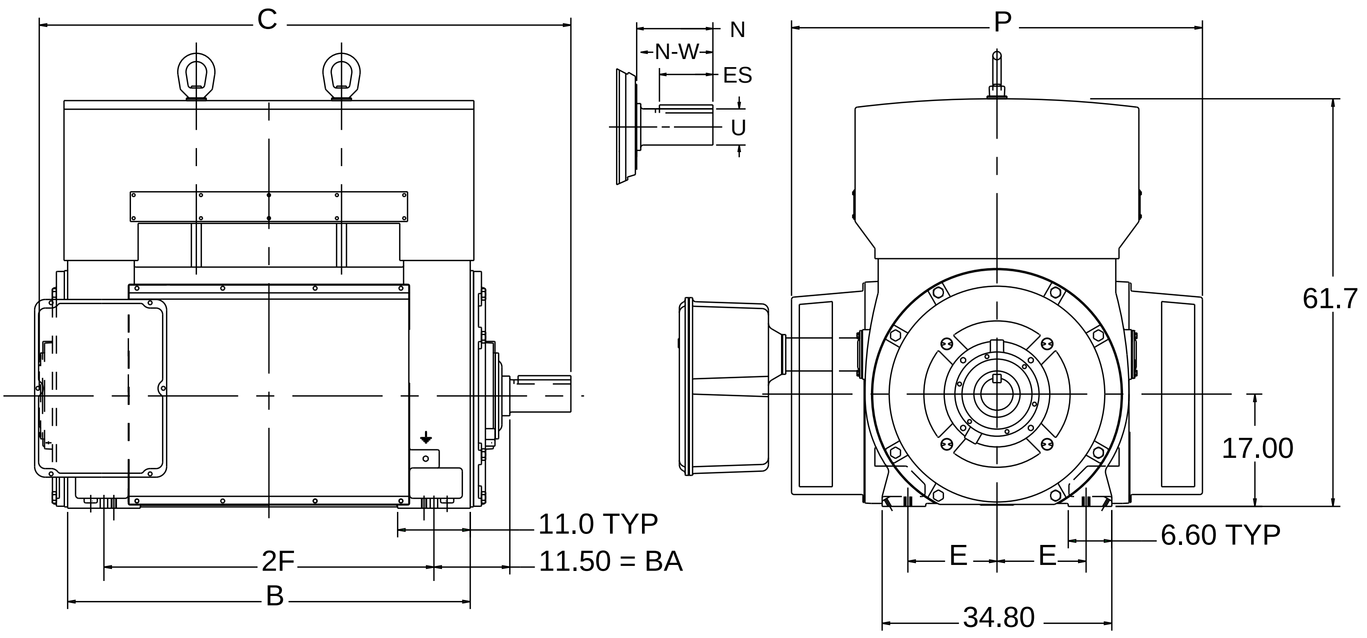
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGII — Horizontal Custom — Weather Protected Type II
Anti-Friction Bearing — Direct Connected
Frames 6811-6813 — 1800 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	6811	1800	61	80.6	13.5	50	10.45	9.25	62.3	4.169	1.25	4.875	9.0	8.0	12000
Short	6811	1200 & Slower	61	80.6	13.5	50	10.45	9.25	62.3	4.676	1.25	5.375	9.0	8.0	12000
Short	6813	1800	74	93.6	13.5	63	10.45	9.25	62.3	4.169	1.25	4.875	9.0	8.0	14700
Short	6813	1200 & Slower	74	93.6	13.5	63	10.45	9.25	62.3	4.676	1.25	5.375	9.0	8.0	14700

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.

Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.
Machines may rotate in either direction.

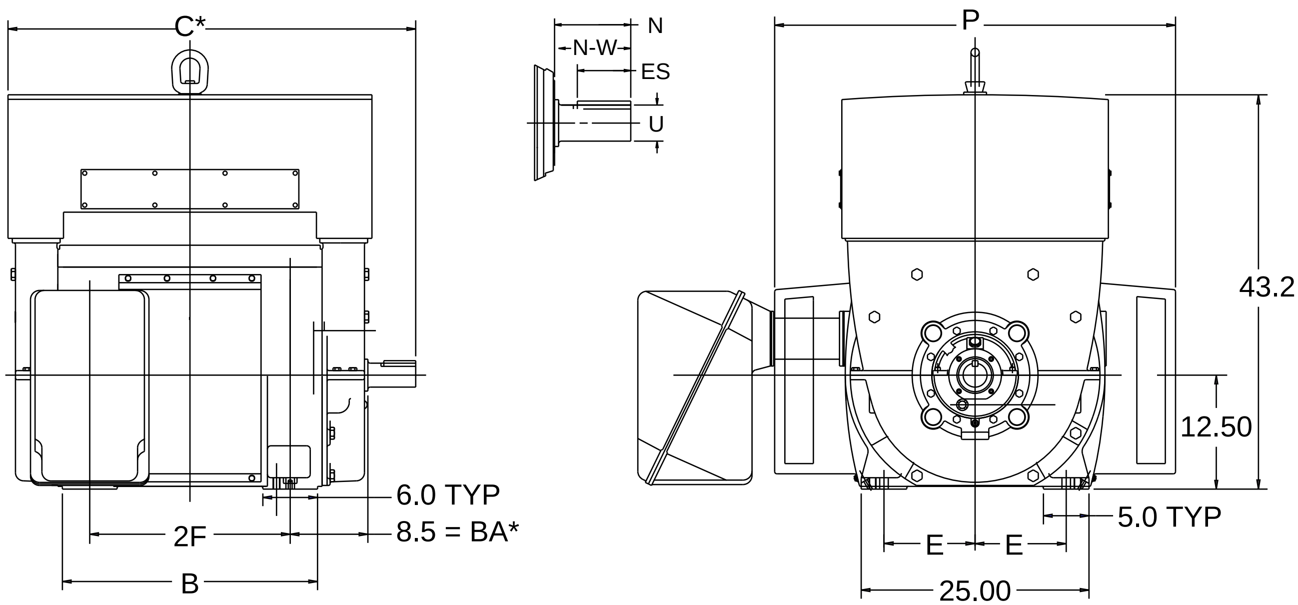
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGII — Horizontal Custom — Weather Protected Type II
Sleeve Bearing — Direct Connected
Frames 507-509-5011



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	507S	3600	28	44.7	10.0	22	5.5	5.25	44.0	2.275	.625	2.625	5.0	3.5	3500
Short	507S	1800 & Slower	28	46.2	10.0	22	7.0	6.75	44.0	2.88	.875	3.375	6.5	5.0	3500
Short	509S	3600	34	50.7	10.0	28	5.5	5.25	44.0	2.275	.625	2.625	5.0	3.5	4000
Short	509S	1800 & Slower	34	52.2	10.0	28	7.0	6.75	44.0	2.88	.875	3.375	6.5	5.0	4000
Short	5011S	1800 & Slower	42	60.2	10.0	36	7.0	6.75	44.0	2.88	.875	3.375	6.5	5.0	5200

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

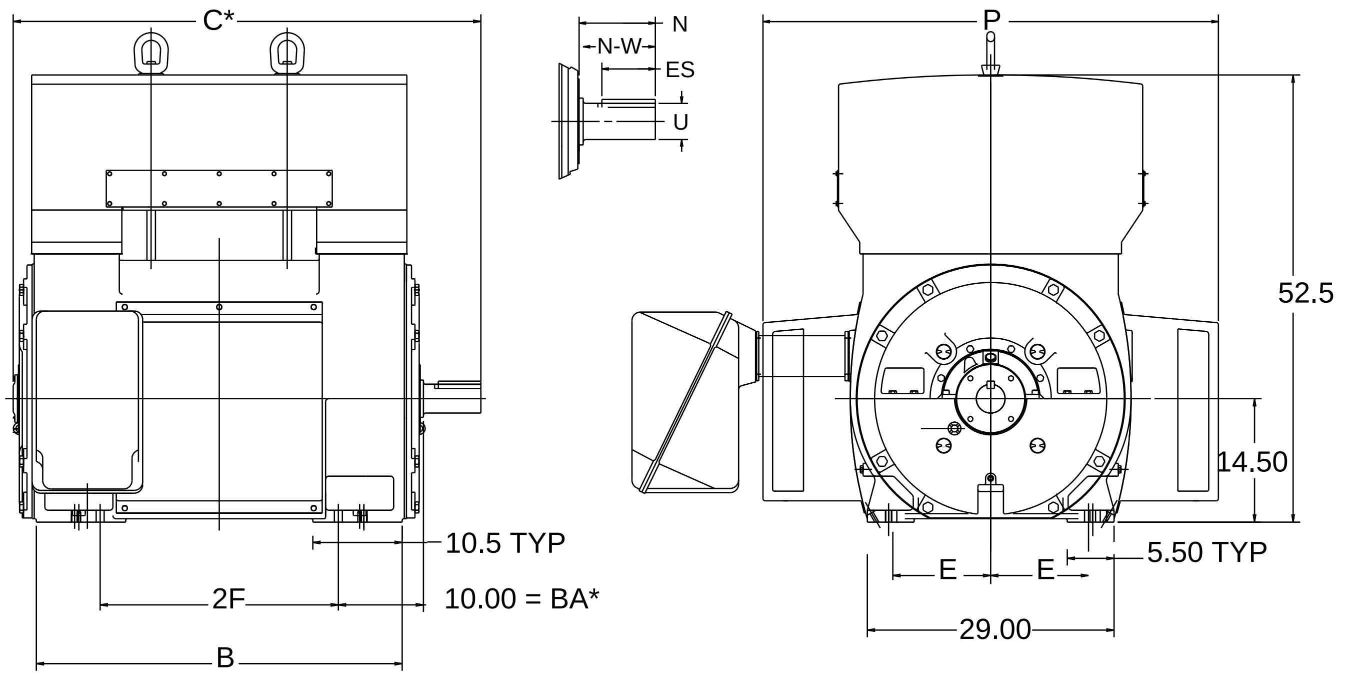
Lubrication	
3600 RPM	1800 RPM & Slower
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
0.8 qt. capacity	0.8 qt. capacity

Certification

Customer ______ P.O. ______ S.O. ______ Item ______
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______
Not for construction, installation or application purposes unless certified.

Type CGII — Horizontal Custom — Weather Protected Type II
Sleeve Bearing — Direct Connected
Frames 588-5810



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	588S	3600	43	55.0	11.5	28	7.13	6.75	53.5	2.88	.875	3.375	6.5	5.0	5300
Short	588S	1800 & Slower	43	56.2	11.5	28	8.38	8.0	53.5	3.436	1.0	4.0	7.75	6.0	5600
Short	5810S	3600	51	63.0	11.5	36	7.13	6.75	53.5	2.88	.875	3.375	6.5	5.0	6500
Short	5810S	1800 & Slower	51	64.2	11.5	36	8.38	8.0	53.5	3.436	1.0	4.0	7.75	6.0	6800

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication	
3600 RPM	1800 RPM & Slower
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
3.5 qt. capacity	3.5 qt. capacity

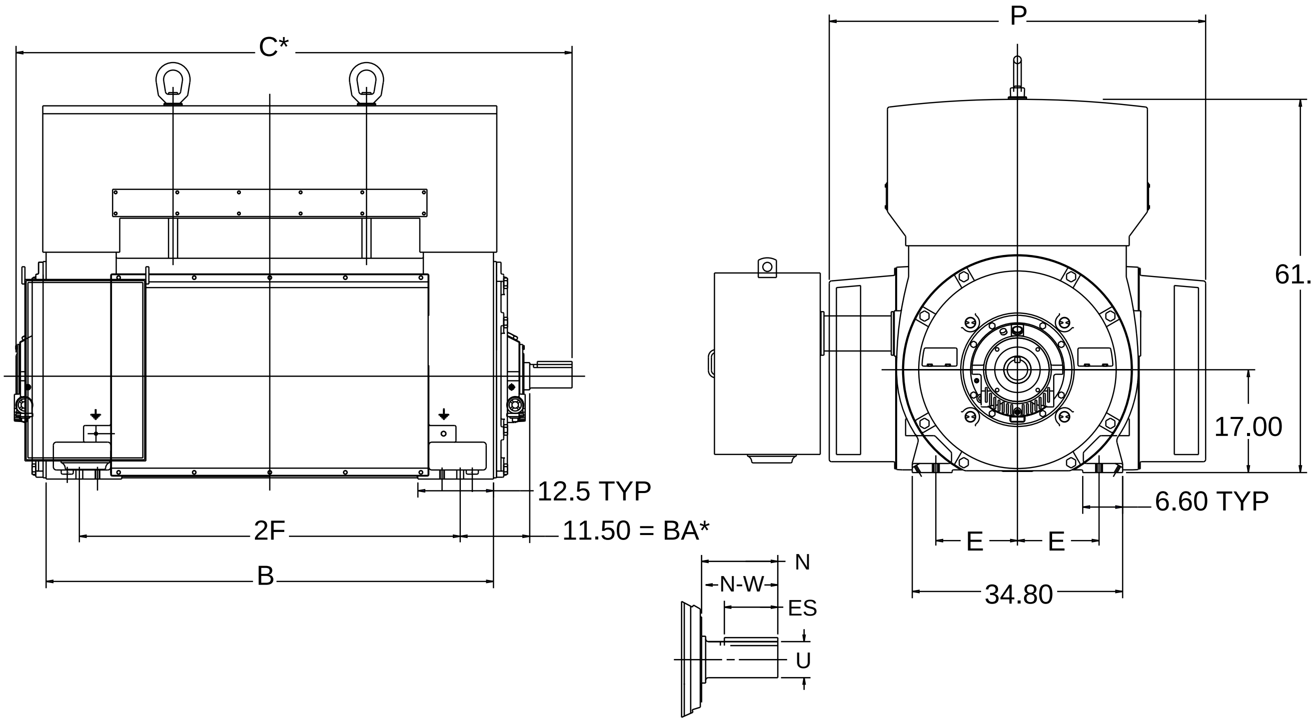
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGII — Horizontal Custom — Weather Protected Type II
Sleeve Bearing — Direct Connected
Frames 6811-6813 — 3600 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	6811	3600	61	79.0	13.5	50	7.97	7.0	62.3	3.007	.875	3.50	6.75	5.5	11200
Short	6813	3600	74	92.0	13.5	63	7.97	7.0	62.3	3.007	.875	3.50	6.75	5.5	13900

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
3600 RPM
140-160 SUS @ 100˚ F
3.0 qt. capacity

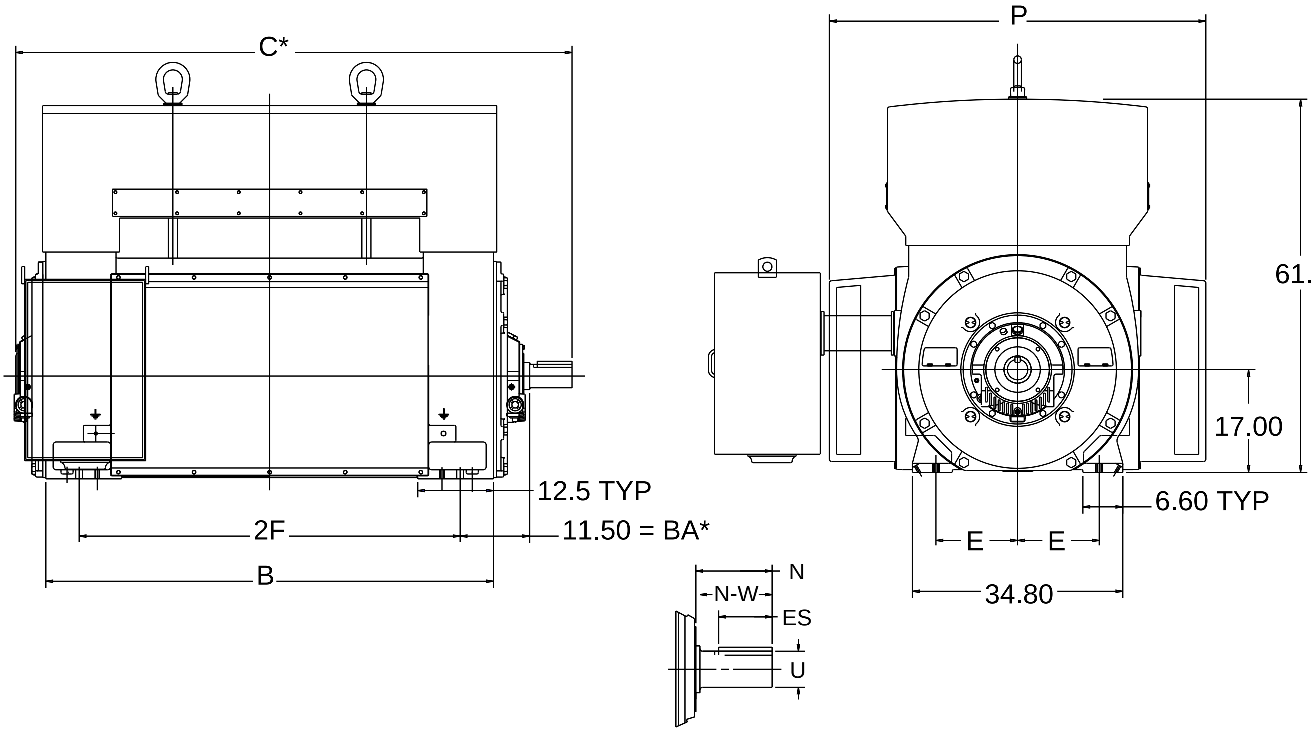
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGII — Horizontal Custom — Weather Protected Type II
Sleeve Bearing — Direct Connected
Frames 6811-6813 — 1800 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	6811	1800	61	81.3	13.5	50	10.22	9.25	62.3	4.169	1.25	4.875	9.0	8.0	12000
Short	6813	1800	74	94.5	13.5	63	10.22	9.25	62.3	4.169	1.25	4.875	9.0	8.0	14700

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

Machines rotate in one direction only.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
290-350 SUS @ 100˚ F
3.0 qt. capacity

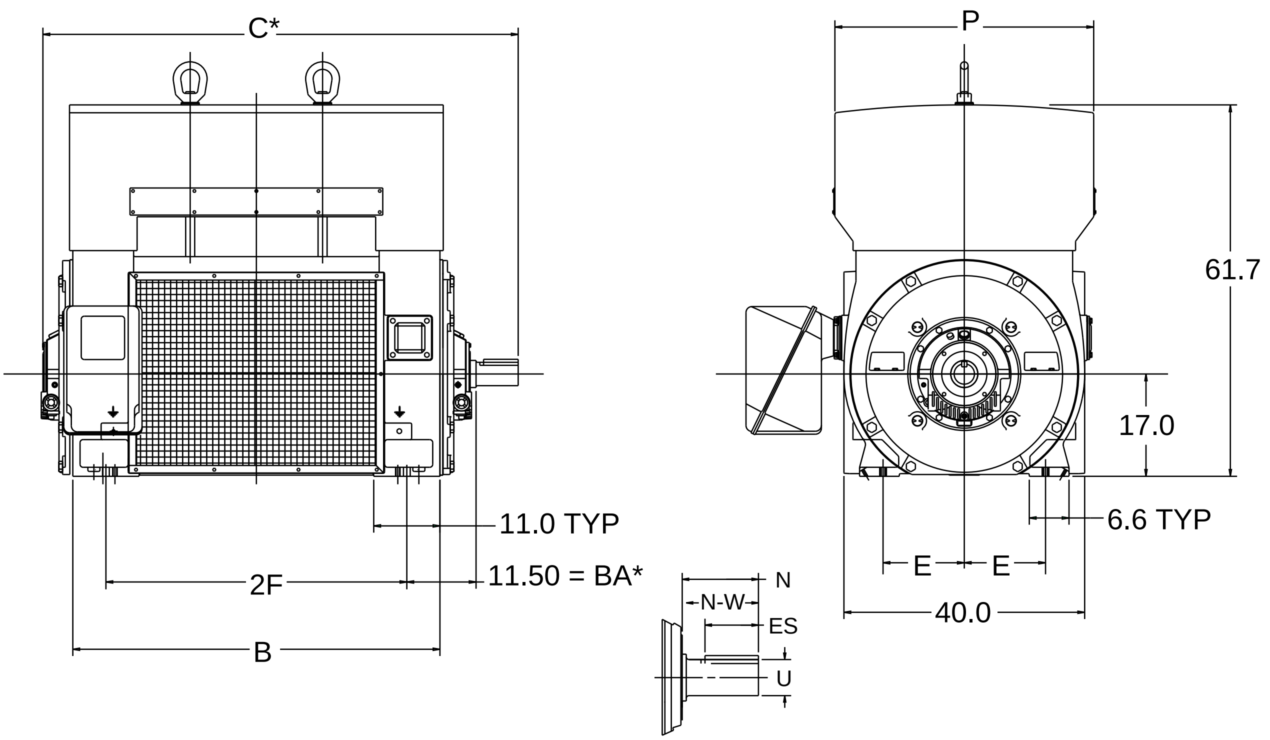
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGII — Horizontal Custom — Weather Protected Type II
Sleeve Bearing — Direct Connected
Frames 6811-6813 — 1200 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	6811	1200 & Slower	61	81.3	13.5	50	10.22	9.25	62.3	4.676	1.25	5.375	9.0	8.0	12000
Short	6813	1200 & Slower	74	94.3	13.5	63	10.22	9.25	62.3	4.676	1.25	5.375	9.0	8.0	14700

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
290-350 SUS @ 100˚ F
3.0 qt. capacity

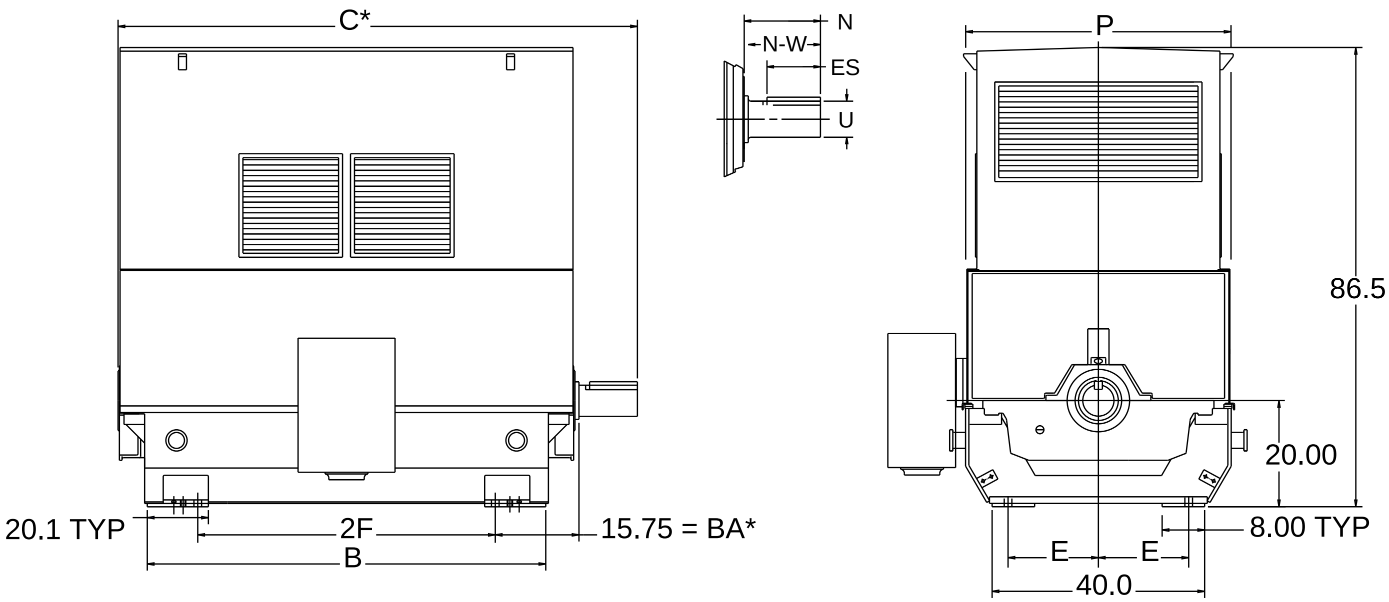
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type FOD — Horizontal Custom — Weather Protected Type II
Sleeve Bearing — Direct Connected
Frame 809-8012



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	809	3600	69	90.5	17.0	50	10.0	9.25	58.0	4.803	1.25	5.5	8.85	7.0	16000
Short	809	1800 & Slower	69	92.25	17.0	50	11.75	11.0	58.0	5.662	1.5	6.5	10.6	9.0	17000
Short	8010	3600	75	96.0	17.0	56	10.0	9.25	58.0	4.803	1.25	5.5	8.85	7.0	17000
Short	8010	1800 & Slower	75	97.75	17.0	56	11.75	11.0	58.0	5.662	1.5	6.5	10.6	9.0	18000
Short	8011	3600	82	103.0	17.0	63	10.0	9.25	58.0	4.803	1.25	5..5	8.85	7.0	18000
Short	8011	1800 & Slower	82	104.75	17.0	63	11.75	11.0	58.0	5.662	1.5	6.5	10.6	9.0	19000
Short	8012	3600	90	111.5	17.0	71	10.0	9.25	58.0	4.803	1.25	5.5	8.85	7.0	20000
Short	8012	1800 & Slower	90	113.25	17.0	71	11.75	11.0	58.0	5.662	1.5	6.5	10.6	9.0	21000

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

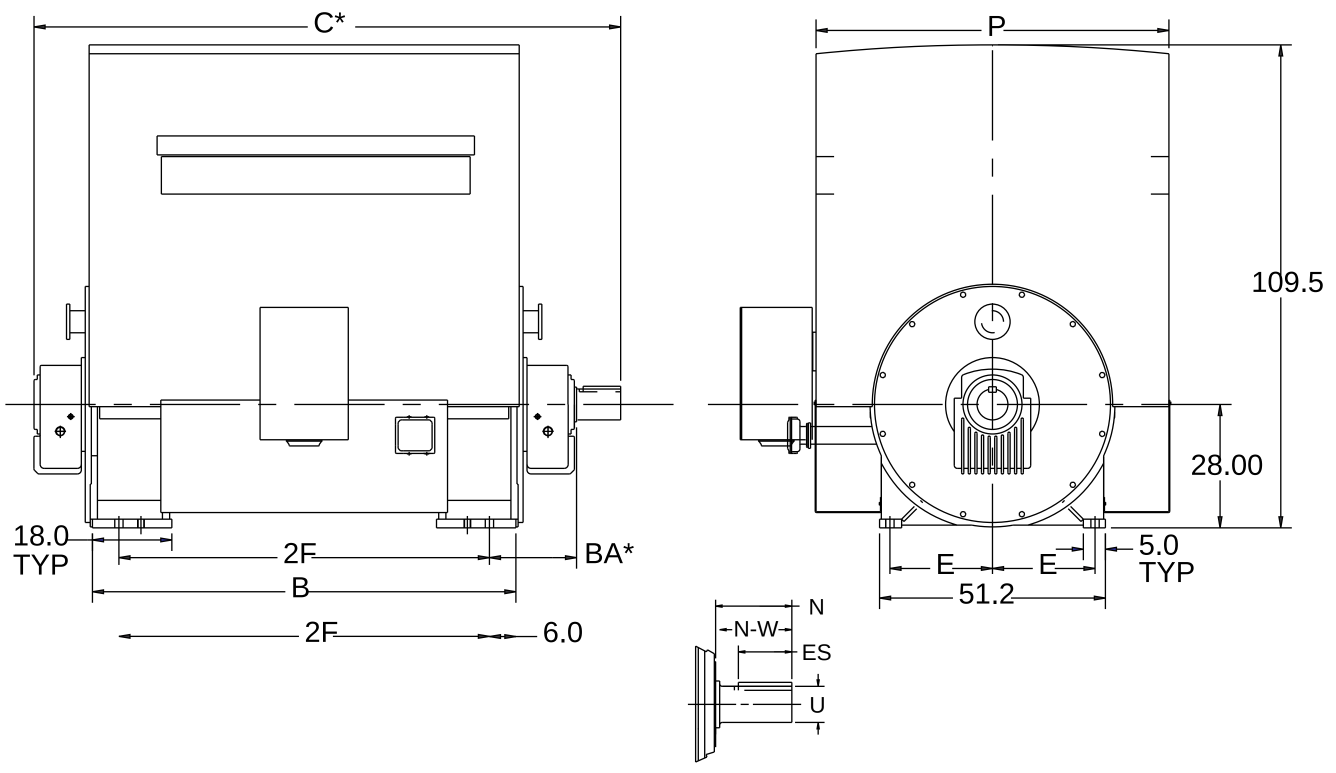
Lubrication	
3600 RPM	1800 RPM & Slower
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
10.4 qt. capacity	10.4 qt. capacity

Certification

Customer ____ P.O. ____ S.O. ____ Item ____
HP ____ RPM ____ FR. ____ PH/HZ/Volts ____
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ____ Date ____
Not for construction, installation or application purposes unless certified.

Type CGII — Horizontal Custom — Weather Protected Type II
Sleeve Bearing — Direct Connected
Frames 1122-1124 — 3600 and 1800 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	1122	3600	88.1		23.25	76			80.0						30000
Short	1122	1800	88.1		23.25	76			80.0						31000
Short	1124	3600	96		23.25	84			80.0						32000
Short	1124	1800	96		23.25	84			80.0						33000

Notes

See Section 6 for selection of main terminal box.
V(1)=Length of shaft available for coupling or pully.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

Machines rotate in one direction only.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication	
3600 RPM	1800 RPM
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
8.4 qt. capacity	8.4 qt. capacity

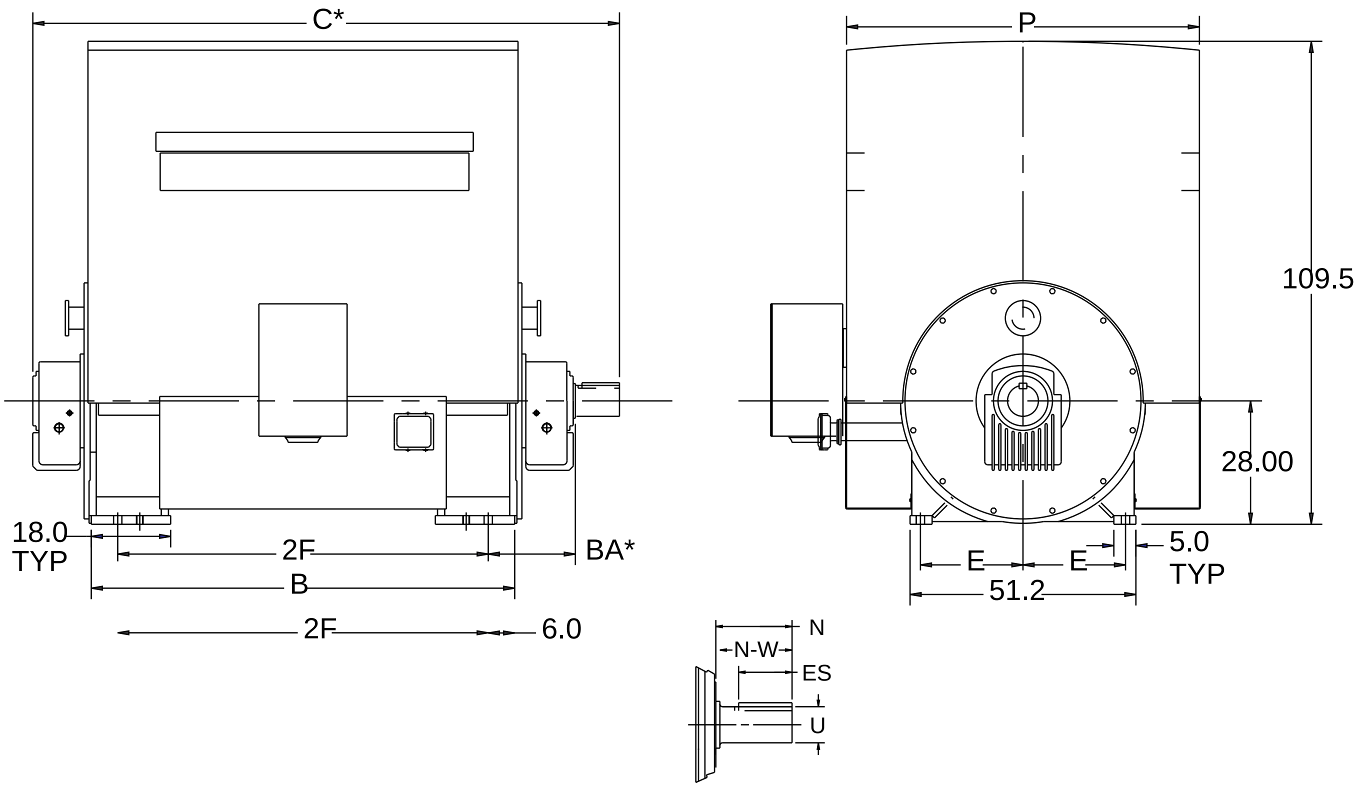
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGII — Horizontal Custom — Weather Protected Type II
Sleeve Bearing — Direct Connected
Frames 1122-1124 — 1200 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	1122	1200 & Slower	88.1		23.25	76			80.0						31000
Short	1124	1200 & Slower	96		23.25	84			80.0						33000

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

Machines rotate in one direction only.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
290-350 SUS @ 100˚ F
13.6 qt. capacity

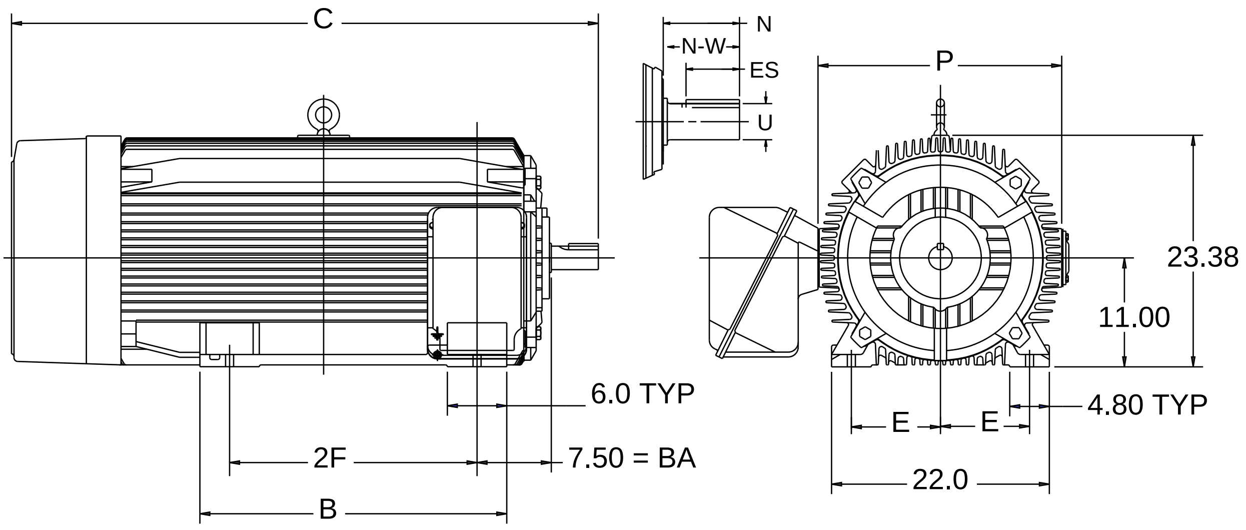
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled
Anti-Friction Bearing
Frame 449



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	449S	3600	31	59.8	9.0	25	5.44	5.25	24.6	2.275	.625	2.625	5.19	3.5	3100
Short	449S	1800 & Slower	31	59.8	9.0	25	5.44	5.25	24.6	2.275	.625	2.625	5.19	3.5	3500
Long	449	1800 & Slower	31	63.7	9.0	25	9.31	9.12	24.6	3.134	.875	3.625	9.0	7.5	3500

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

Certification

Customer P.O. S.O. Item

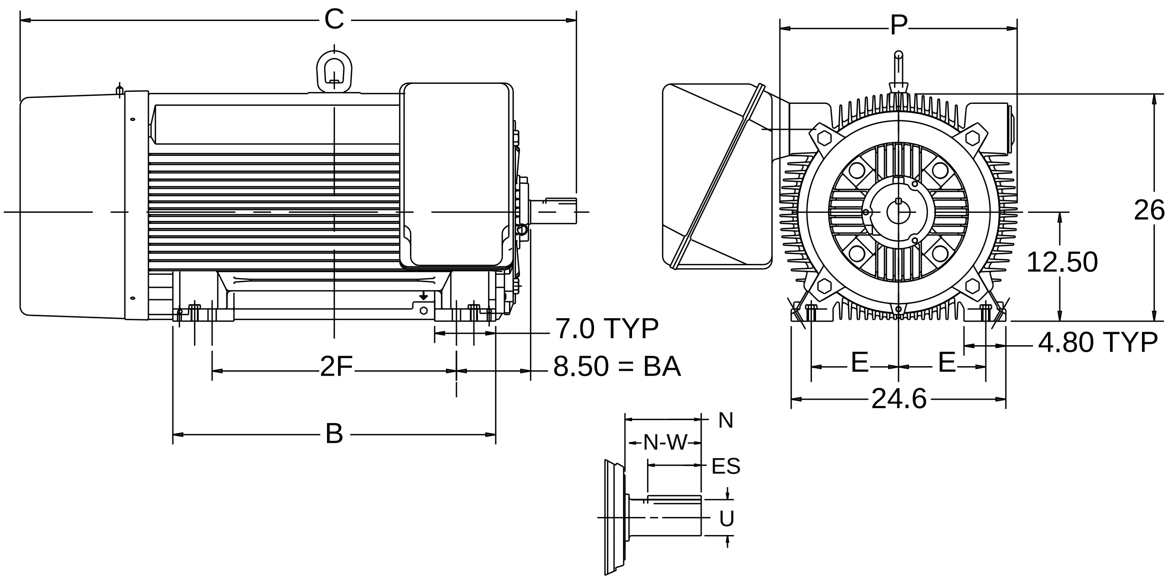
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled
Anti-Friction Bearing
Frames 507-509-5011



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	507S	3600	31	57.0	10.0	22	5.5	5.25	27.2	2.275	.625	2.625	5.0	3.5	3400
Short	507S	1800 & Slower	31	57.0	10.0	22	5.5	5.25	27.2	2.275	.625	2.625	5.0	3.5	3500
Short	509S	3600	37	64.0	10.0	28	5.5	5.25	27.2	2.275	.625	2.625	5.0	3.5	4000
Short	509S	1800 & Slower	37	64.0	10.0	28	5.5	5.25	27.2	2.275	.625	2.625	5.0	3.5	3900
Short	5011S	1800 & Slower	45	72.2	10.0	36	6.0	5.75	27.2	2.45	.75	2.875	5.5	4.0	4900
Long	507	1800 & Slower	31	61.3	10.0	22	9.75	9.5	27.2	3.436	1.0	4.0	9.25	8.0	3600
Long	509	1800 & Slower	37	68.3	10.0	28	9.75	9.5	27.2	3.436	1.0	4.0	9.25	8.0	3900
Long	5011	1800 & Slower	45	76.3	10.0	36	9.75	9.5	27.2	3.436	1.0	4.0	9.25	8.0	5000

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

Certification

Customer P.O. S.O. Item

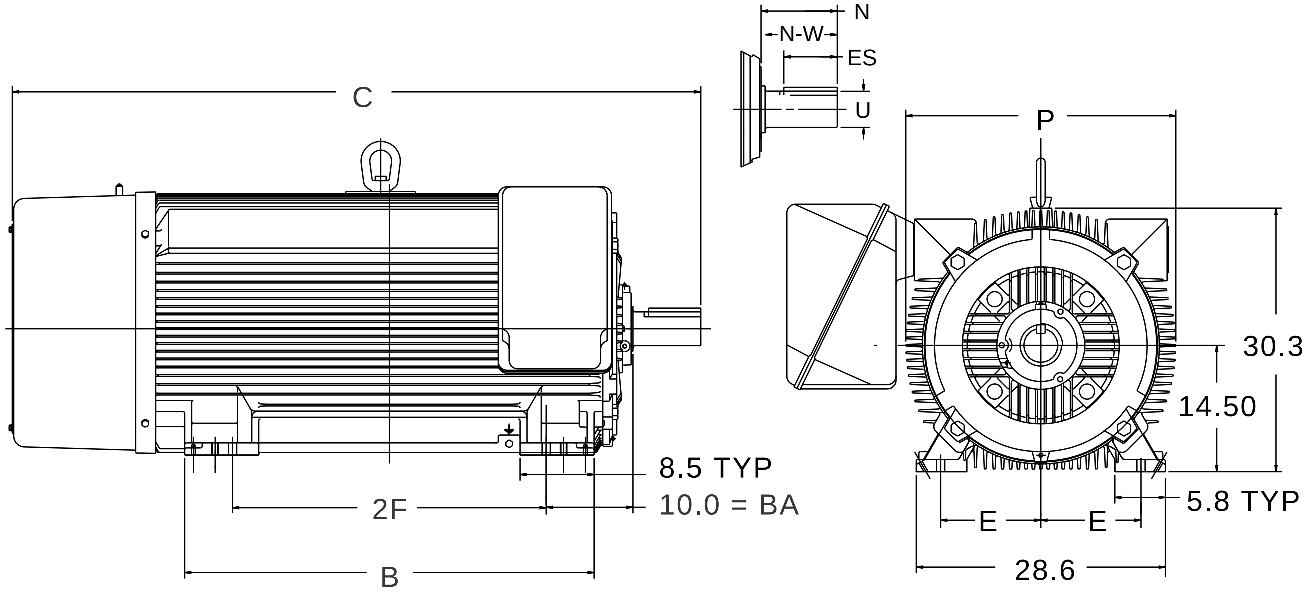
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled
Anti-Friction Bearing — Belted or Direct Connected
Frames 588-5810



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	588S	3600	39	70.0	11.5	28	7.0	6.75	31.0	2.45	.75	2.875	6.5	5.0	5200
Short	588S	1800 & Slower	39	71.0	11.5	28	8.0	7.75	31.0	3.309	1.0	3.875	7.5	6.0	5600
Short	5810S	3600	47	78.0	11.5	36	7.0	6.75	31.0	2.45	.75	2.875	6.5	5.0	6400
Short	5810S	1800 & Slower	47	79.0	11.5	36	8.0	7.75	31.0	3.309	1.0	3.875	7.5	6.0	6600
Long	588	1800 & Slower	39	77.9	11.5	28	14.87	14.62	31.0	4.169	1.25	4.875	14.37	13.0	5600
Long	5810	1800 & Slower	47	85.9	11.5	36	14.87	14.62	31.0	4.169	1.25	4.875	14.37	13.0	6600

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

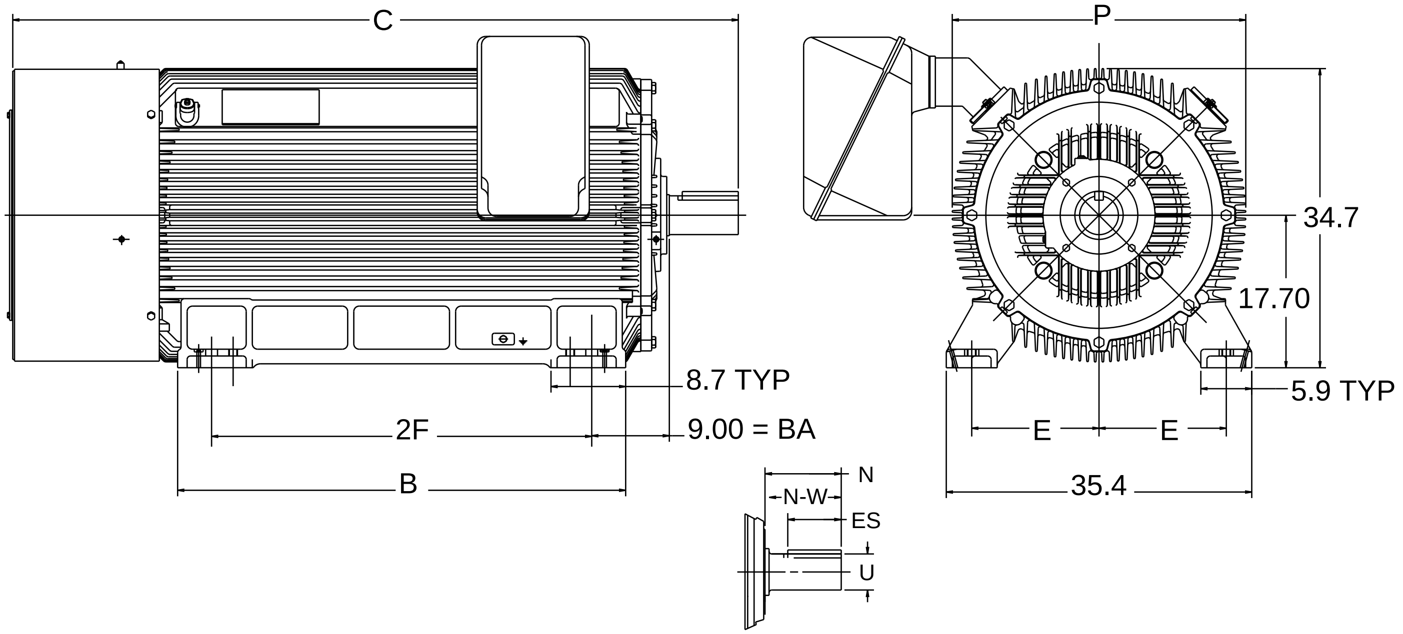
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled
Anti-Friction Bearing — Direct Connected
Frame 708 — 1800 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	708S	1800 & Slower	52	84.2	14.76	44.1	8.3	8.0	34.0	3.944	1.0	4.5	7.75	6.5	9900

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.

Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.
1800 RPM and slower machines may rotate in either direction.

Certification

Customer P.O. S.O. Item

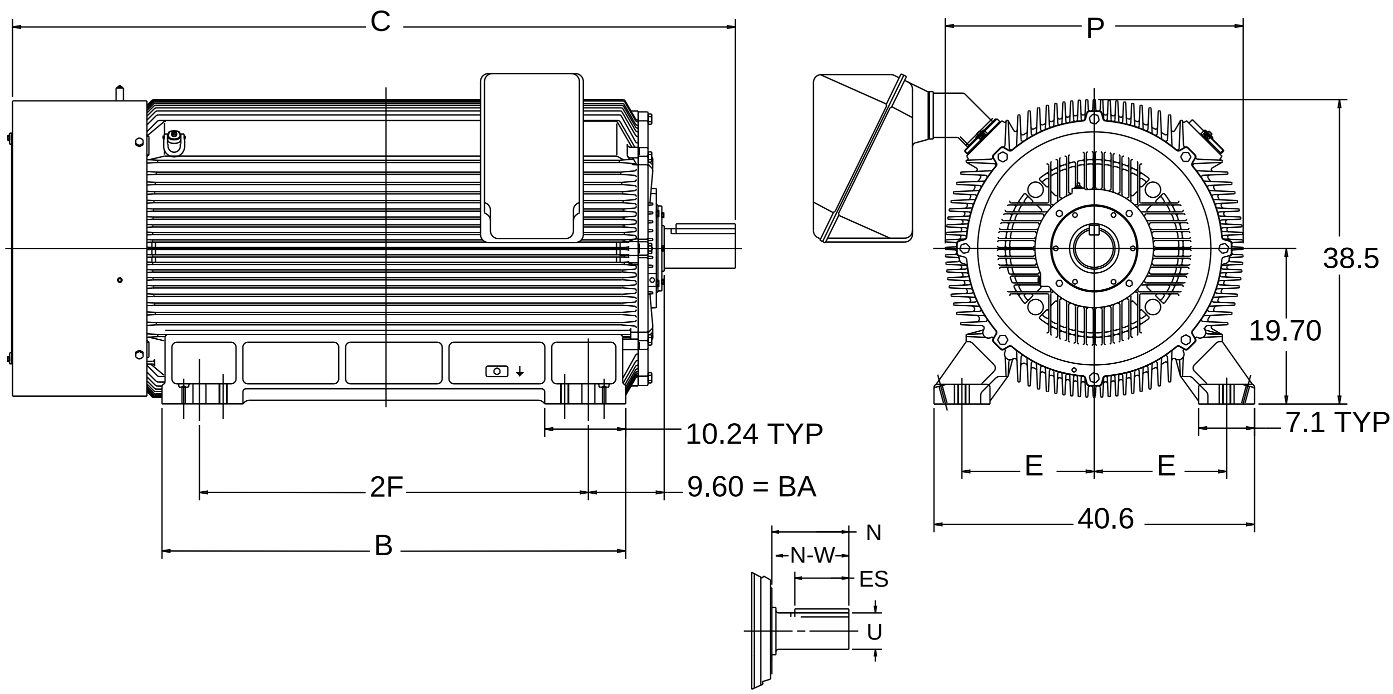
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled
Anti-Friction Bearing — Direct Connected
Frame 788 — 1800 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	788S	1800 & Slower	58.7	91.5	16.75	49.2	9.3	9.0	37.7	4.296	1.25	5.0	8.75	7.5	13600

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.

Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.
Machines may rotate in either direction.

Certification

Customer P.O. S.O. Item

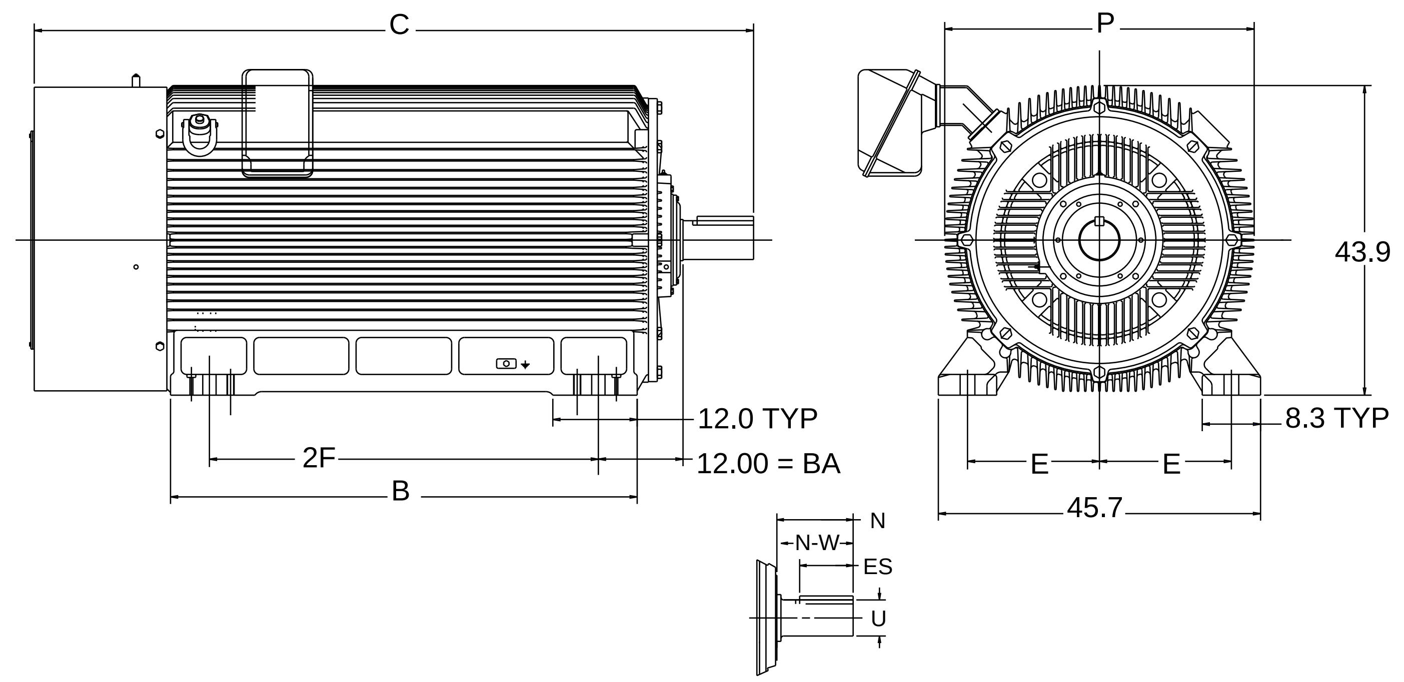
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled
Anti-Friction Bearing — Direct Connected
Frame 880 — 1800 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	880S	1800 & Slower	66.1	102.0	18.7	55.13	10.4	10.0	43.9	4.803	1.25	5.5	9.75	8.0	19400

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.

Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.
1800 RPM and slower machines may rotate in either direction.

Certification

Customer P.O. S.O. Item

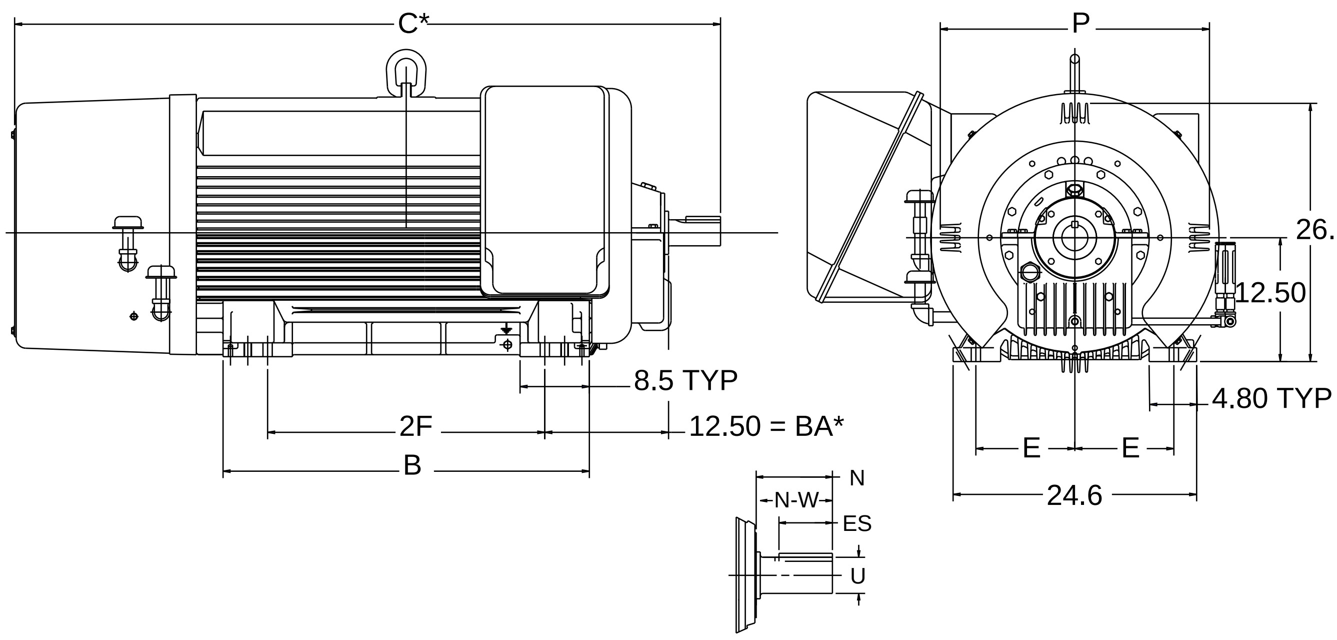
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled Sleeve Bearing — Direct Connected Frames 507-509 — 3600 RPM



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	507S	3600	31	57.0	10.0	22	5.63	5.25	27.2	2.275	.625	2.625	5.0	3.5	3400
Short	509S	3600	37	64.0	10.0	28	5.63	5.25	27.2	2.275	.625	2.625	5.0	3.5	4000

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
3600 RPM
140-160 SUS @ 100° F
2.6 qt. capacity

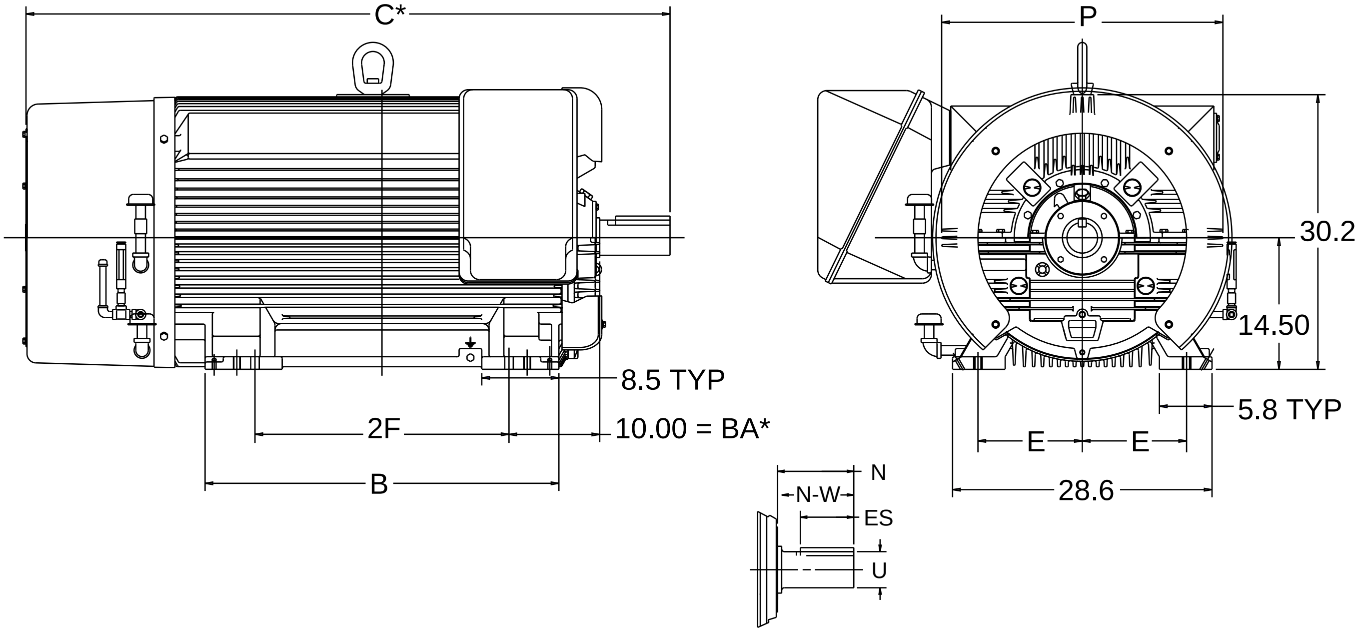
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled Sleeve Bearing — Direct Connected Frames 507-509-5011 — 1800 RPM and Slower



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	507S	1800 & Slower	31	57.0	10.0	22	5.63	5.25	27.2	2.275	.625	2.625	5.0	3.5	3500
Short	509S	1800 & Slower	37	64.0	10.0	28	5.63	5.25	27.2	2.275	.625	2.625	5.0	3.5	3900
Short	5011S	1800 & Slower	45	72.0	10.0	36	6.13	5.75	27.2	2.450	.75	2.875	5.5	4.0	4900

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

Machines may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication
290-350 SUS @ 100˚ F
1.2 qt. capacity

Certification

Customer P.O. S.O. Item

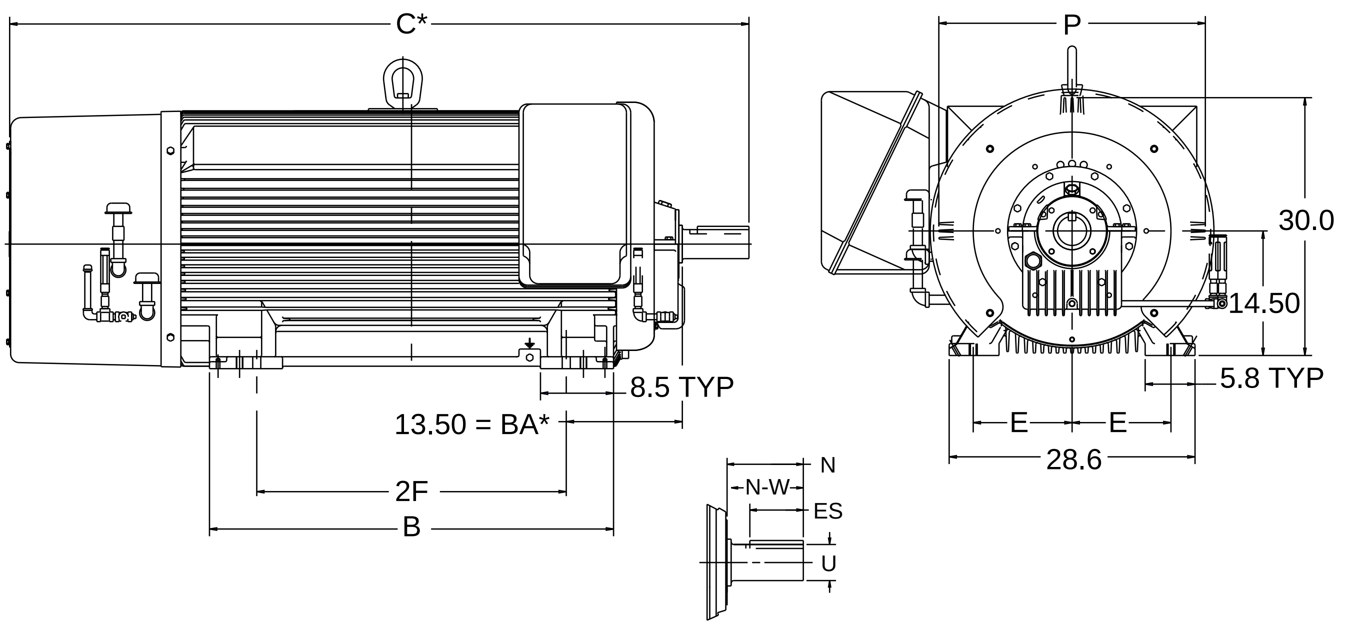
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled Sleeve Bearing — Direct Connected Frames 588-5810



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	588S	3600	39	77.0	11.5	28	7.15	6.75	31.0	2.88	.875	3.375	6.5	5.0	5200
Short	588S	1800 & Slower	39	78.0	11.5	28	8.0	7.75	31.0	3.309	1.0	3.875	7.5	6.0	5600
Short	5810S	3600	47	85.0	11.5	36	7.15	6.75	31.0	2.88	.875	3.375	6.5	5.0	6400
Short	5810S	1800 & Slower	47	86.0	11.5	36	8.0	7.75	31.0	3.309	1.0	3.875	7.5	6.0	6600

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication	
3600 RPM	1800 RPM & Slower
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
2.6 qt. capacity	2.6 qt. capacity

Certification

Customer P.O. S.O. Item

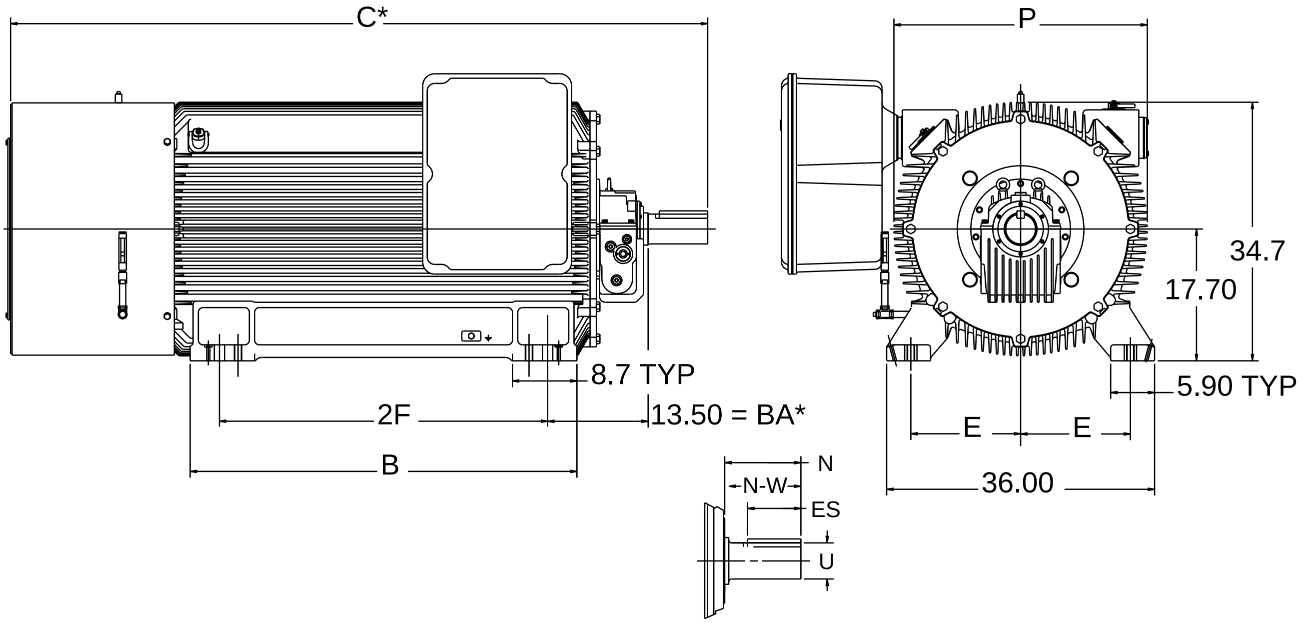
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled
Sleeve Bearing — Direct Connected
Frame 708



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	708S	3600	52	92.4	14.76	44.1	7.3	6.75	34.0	2.88	.875	3.375	6.25	5.0	9900
Short	708S	1800 & Slower	52	93.7	14.76	44.1	8.6	8.0	34.0	3.436	1.0	4.0	7.75	6.5	9900

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication	
3600 RPM	1800 RPM & Slower
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
3.0 qt. capacity	3.0 qt. capacity

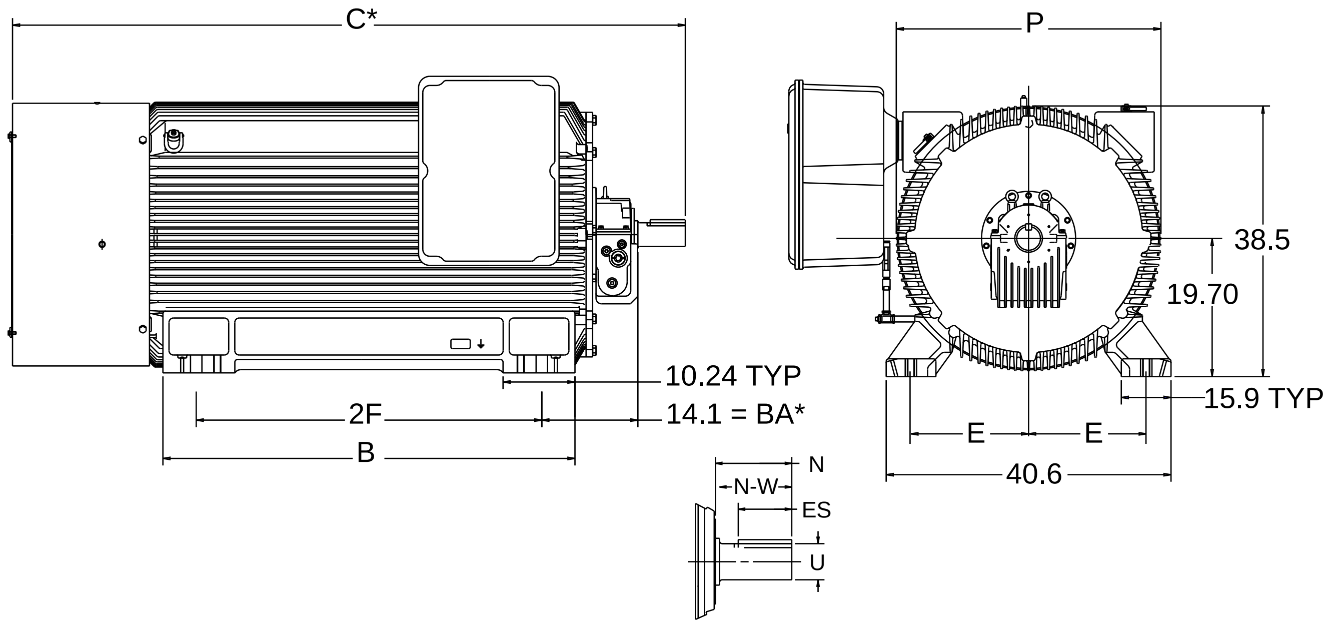
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZ — Horizontal Custom — Totally Enclosed — Fan Cooled
Sleeve Bearing — Direct Connected
Frame 788



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	788S	3600	58.7	96.2	16.75	49.2	7.3	6.75	37.7	2.88	.875	3.375	6.25	5.0	13600
Short	788S	1800 & Slower	58.7	97.5	16.75	49.2	8.6	8.0	37.7	3.944	1.0	4.0	7.75	6.5	13600

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

3600 RPM machines rotate in one direction only.
1800 RPM and slower may rotate in either direction.
* On machines equipped with provisions for or with proximity type probes the BA and C dimensions will change. Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"

Lubrication	
3600 RPM	1800 RPM & Slower
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
3.0 qt. capacity	3.0 qt. capacity

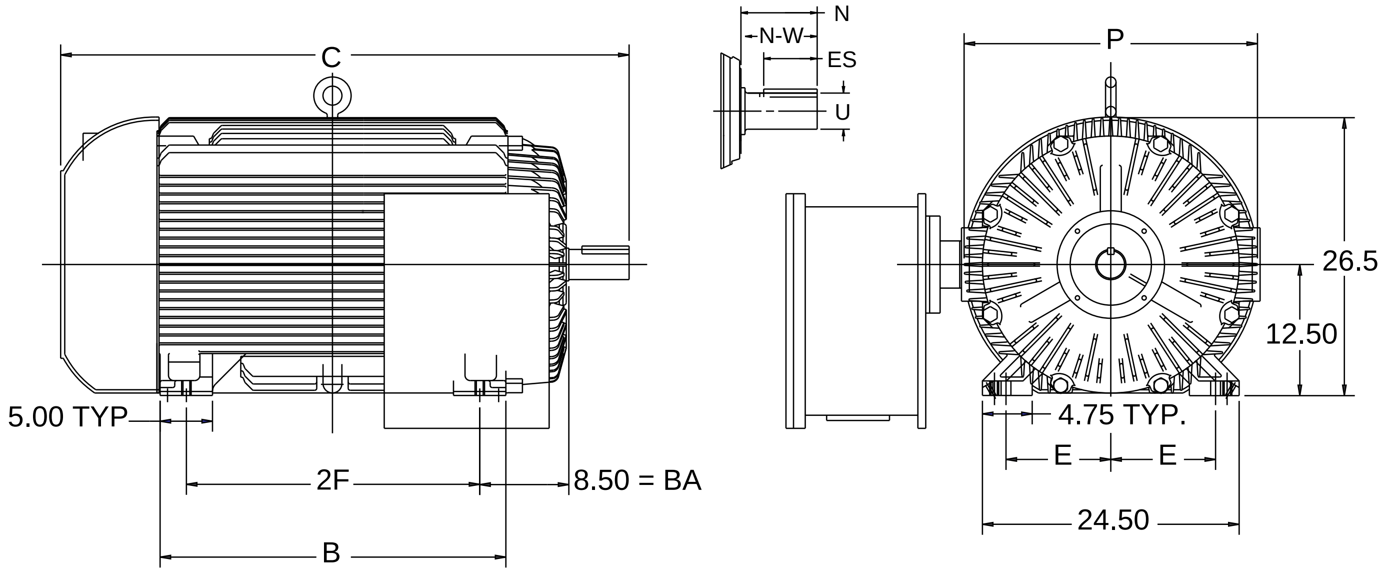
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type RGZZ — Horizontal Custom — Totally Enclosed — Fan Cooled — Explosion Proof
Anti-Friction Bearing
Frames 505-509



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	505US	3600 & Slower	21	43.8	10.0	18	5.5	5.25	28.0	2.275	.625	2.625	5.0	3.5	3500
Short	507US	3600	27	49.78	10.0	22	5.5	5.25	28.0	2.275	.625	2.625	5.0	3.5	4000
Short	507US	1800 & Slower	27	47.8	10.0	22	5.5	5.25	28.0	2.275	.625	2.625	5.0	3.5	4000
Short	509US	3600	33	55.78	10.0	28	5.5	5.25	28.0	2.275	.625	2.625	5.0	3.5	4500
Short	509US	1800 & Slower	33	54.25	10.0	28	6.0	5.75	28.0	2.45	.75	2.875	5.5	4.5	4500
Long	505U	1800 & Slower	21	48.6	10.0	18	10.4	10.12	28.0	2.88	.875	3.375	9.88	8.5	3500
Long	507U	1800 & Slower	27	52.6	10.0	22	10.4	10.12	28.0	2.88	.875	3.375	9.88	8.5	4000
Long	509U	1800 & Slower	33	60.12	10.0	28	11.87	11.62	28.0	3.309	1.0	3.875	11.38	10.0	4500

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.

Shims may be necessary under motor feet for direct connection.
3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

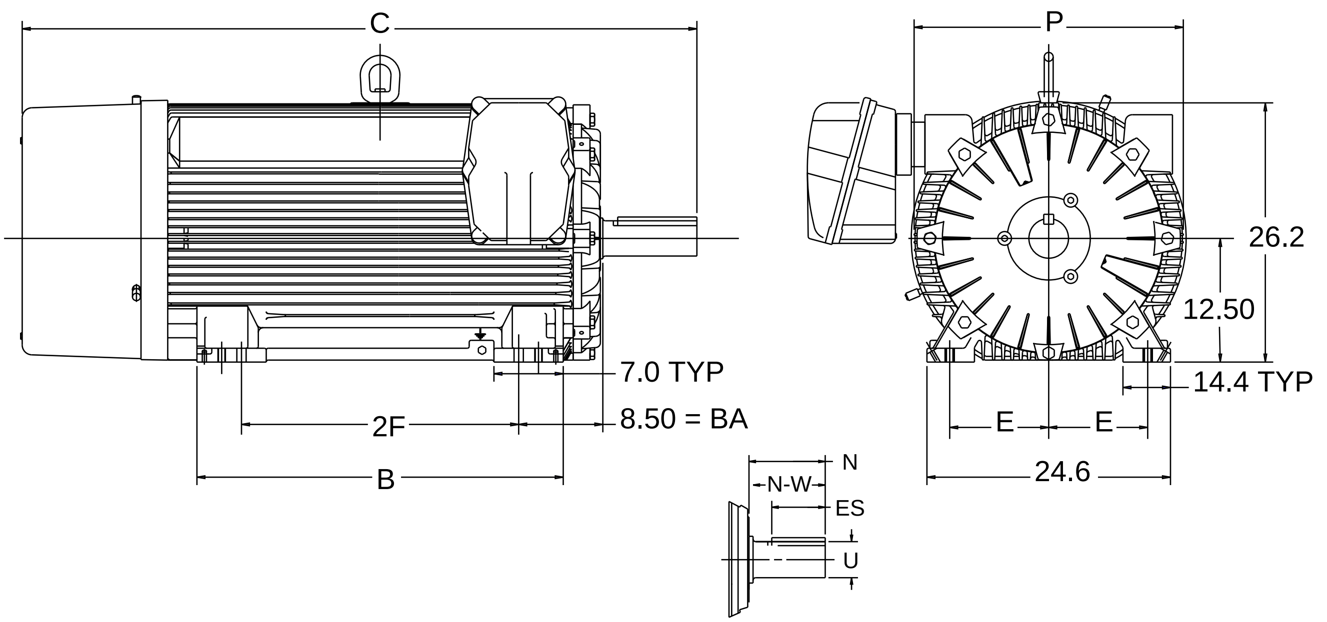
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGZZ — Horizontal Custom — Totally Enclosed — Fan Cooled — Explosion Proof Anti-Friction Bearing Frame 507-509-5011



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	507S	3600	31	57.0	10.0	22	5.5	5.25	27.2	2.275	.625	2.625	5.0	3.5	4000
Short	507S	1800 & Slower	31	57.0	10.0	22	5.5	5.25	27.2	2.275	.625	2.625	5.0	3.5	4100
Short	509S	3600	37	64.0	10.0	28	5.5	5.25	27.2	2.275	.625	2.625	5.0	3.5	4800
Short	509S	1800 & Slower	37	64.0	10.0	28	5.5	5.25	27.2	2.275	.625	2.625	5.0	3.5	4800
Short	5011S	1800 & Slower	45	72.5	10.0	36	6.0	5.75	27.2	2.45	0.75	2.875	5.5	4.0	5850
Long	507	1800 & Slower	31	61.3	10.0	22	9.75	9.5	27.2	3.436	1.0	4.0	9.25	8.0	4100
Long	509	1800 & Slower	37	68.3	10.0	28	9.75	9.5	27.2	3.436	1.0	4.0	9.25	8.0	4800
Long	5011	1800 & Slower	45	76.3	10.0	36	9.75	9.5	27.2	3.436	1.0	4.0	9.25	8.0	5850

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.

Shims may be necessary under motor feet for direct connection.
3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.
Short shaft is for direct connection only.
Long shaft may be either belt drive or direct connect depending on bearing installed in motor.

Certification

Customer ______ P.O. ______ S.O. ______ Item ______

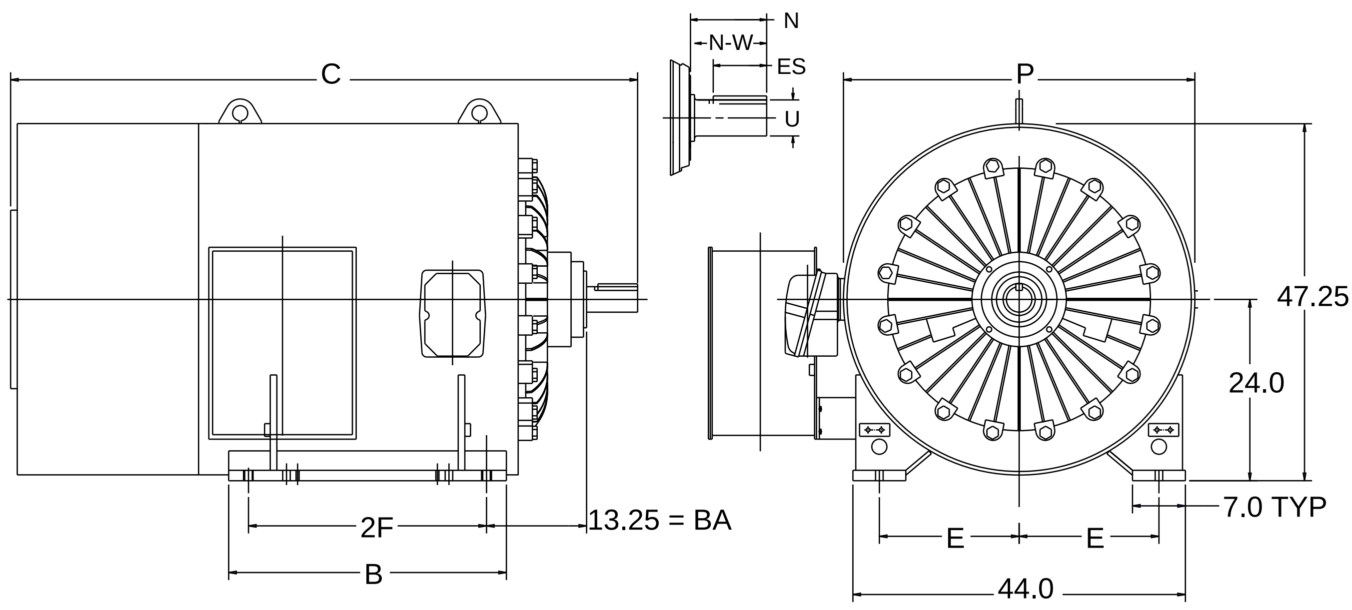
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______

Not for construction, installation or application purposes unless certified.

Type AZZ — Horizontal Custom — Totally Enclosed — Fan Cooled — Explosion Proof
Anti-Friction Bearing — Direct Connected
Frame 30



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	30BS8	1800	32.2	79.2	18.5	27	7.1	6.75	46.5	2.88	.875	3.375	6.5	5.25	7600
Short	30JJS8	1800	36.8	83.7	18.5	31.5	7.1	6.75	46.5	2.88	.875	3.375	6.5	5.25	8600
Short	3020S8	1800	41.2	88.2	18.5	36	7.1	6.75	46.5	2.88	.875	3.375	6.5	5.25	10000
Short	3023S8	1800	44.2	91.2	18.5	39	7.1	6.75	46.5	2.88	.875	3.375	6.5	5.25	11000
Short	3030S8	1800 & Slower	51.3	103	18.5	46	8.1	7.75	46.5	3.309	1.0	3.875	7.5	6.0	11400
Short	30ES8	1200 & Slower	32.2	81.6	18.5	27	8.1	7.75	46.5	3.309	1.0	3.875	7.5	6.0	7600
Short	30KKS8	1200 & Slower	36.8	86.6	18.5	31.5	8.1	7.75	46.5	3.309	1.0	3.875	7.5	6.0	8600
Short	30LS8	1200 & Slower	41.2	90.6	18.5	36	8.1	7.75	46.5	3.309	1.0	3.875	7.5	6.0	10000
Short	30LLS8	1200 & Slower	44.2	93.6	18.5	39	8.1	7.75	46.5	3.309	1.0	3.875	7.5	6.0	11000

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.

Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.
Machines rotate in one direction only.

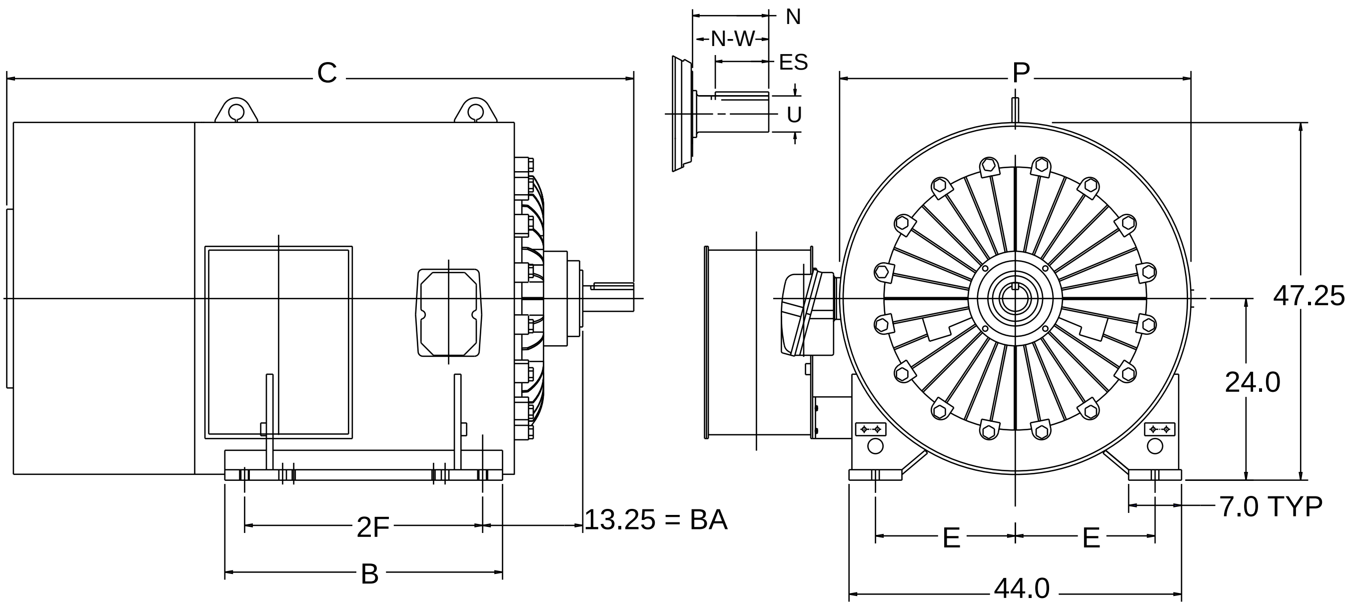
Certification

Customer ______ P.O. ______ S.O. ______ Item ______
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______

Not for construction, installation or application purposes unless certified.

Type AZZ — Horizontal Custom — Totally Enclosed — Fan Cooled — Explosion Proof Anti-Friction Bearing Frame 30



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Long	30E8	1200 & Slower	32.2	88.5	18.5	27	15.0	14.62	46.5	4.169	1.25	4.875	14.38	13.0	7600
Long	30KK8	1200 & Slower	36.8	93.0	18.5	31.5	15.0	14.62	46.5	4.169	1.25	4.875	14.38	13.0	8600
Long	30L8	1200 & Slower	41.2	97.5	18.5	36	15.0	14.62	46.5	4.169	1.25	4.875	14.38	13.0	10000
Long	30LL8	1200 & Slower	44.2	100.5	18.5	39	15.0	14.62	46.5	4.169	1.25	4.875	14.38	13.0	11000

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft
S(3)=Width of keyset
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.

Shims may be necessary under motor feet for direct connection.
Machines rotate in one direction only.
Long Shaft may be either belt drive or direct connect depending on bearing installed in motor.

Certification

Customer P.O. S.O. Item

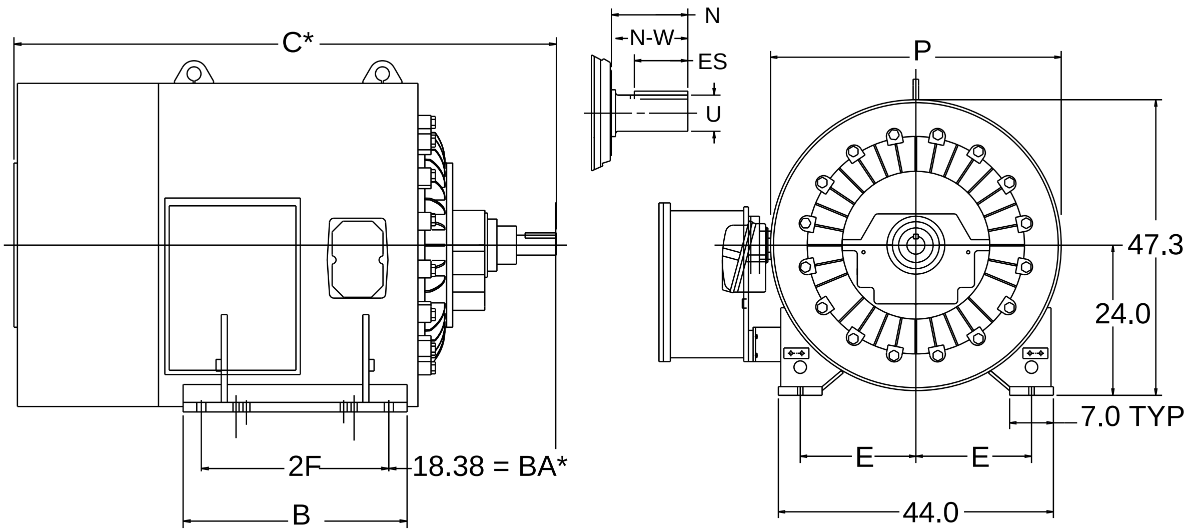
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type AZZ — Horizontal Custom — Totally Enclosed — Fan Cooled — Explosion Proof Sleeve Bearing — Direct Connected Frame 30



Standard Dimensions in Inches

Shaft	Frame	RPM	B	C	E	2F	N	N-W	P	R(2)	S(3)	U	V(1)	ES	Approx. Ship Wt. (Lbs.)
Short	30NS6	3600	32.2	78.1	18.5	27	8.55	5.75	46.5	2.45	.75	2.875	5.5	4.5	7600
Short	30RS6	3600	36.8	82.6	18.5	31.5	8.55	5.75	46.5	2.45	.75	2.875	5.5	4.5	8600
Short	3020SS6	3600	41.2	87.1	18.5	36	8.55	5.75	46.5	2.45	.75	2.875	5.5	4.5	10000
Short	3023SS6	3600	44.2	90.1	18.5	39	8.55	5.75	46.5	2.45	.75	2.875	5.5	4.5	11000
Short	30BS6	1800	32.2	84.3	18.5	27	9.55	6.75	46.5	2.88	.875	3.375	6.5	5.25	7600
Short	30JJS6	1800	36.8	88.8	18.5	31.5	9.55	6.75	46.5	2.88	.875	3.375	6.5	5.25	8600
Short	3020S6	1800	41.2	93.3	18.5	36	9.55	6.75	46.5	2.88	.875	3.375	6.5	5.25	10000
Short	3023S6	1800	44.2	96.3	18.5	39	9.55	6.75	46.5	2.88	.875	3.375	6.5	5.25	11000
Short	3030S6	1800	51.3	103	18.5	46	9.55	6.75	46.5	2.88	.875	3.375	6.5	5.25	11400
Short	30ES6	1200 & Slower	32.2	86.8	18.5	27	10.55	7.75	46.5	3.309	1.0	3.875	7.5	6.0	7600
Short	30KKS6	1200 & Slower	36.8	90.0	18.5	31.5	10.55	7.75	46.5	3.309	1.0	3.875	7.5	6.0	8600
Short	30LLS6	1200 & Slower	44.2	97.5	18.5	39	10.55	7.75	46.5	3.309	1.0	3.875	7.5	6.0	11000
Short	30LS6	1200 & Slower	41.2	94.3	18.5	36	10.55	7.75	46.5	3.309	1.0	3.875	7.5	6.0	10000
Short	3030S6	1200 & Slower	51.3	103	18.5	46	10.55	7.75	46.5	3.309	1.0	3.875	7.5	6.0	11400

Notes

See Section 6 for selection of main terminal box.
R(2)=Bottom of key to opposite side of shaft.
S(3)=Width of keyset.
V(1)=Length of shaft available for coupling or pully.
Jack screw holes and dowel holes are provided at each foot.
Shims may be necessary under motor feet for direct connection.

* On motors equiped with provisions for or with proximity type probes the BA and C dimensions will change.
Consult factory for specific dimensions.
Rotor end float = 0.5"
End float of LEF coupling = 0.19"
Machines rotate in one direction only.

Lubrication	
3600 RPM	1800 RPM & Slower
140-160 SUS @ 100˚ F	290-350 SUS @ 100˚ F
2 qt. capacity	2 qt. capacity

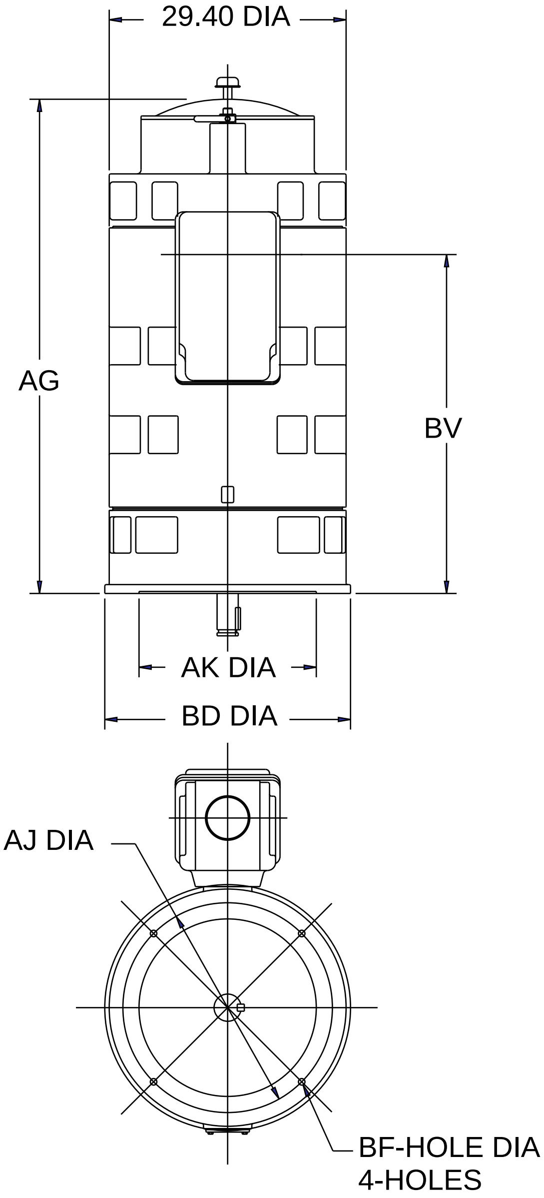
Certification

Customer ______ P.O. ______ S.O. ______ Item ______
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______

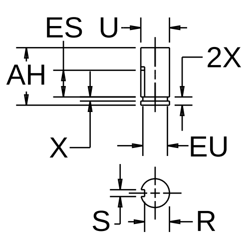
Not for construction, installation or application purposes unless certified.

Type CGV — Vertical Solid Shaft — Open Drip Proof — Weather Protected Type I
NEMA P Flange — Anti-Friction Bearing
Frames 507-509



Standard Dimensions in Inches

Frame	507	507	509	509
RPM	3600	1800 & Slower	3600	1800 & Slower
AG(1)	58.8	58.8	64.8	64.8
AH	5.25	6.75	5.25	6.75
BV	36	36	42	42
ES	2.75	4.25	2.75	4.25
EU	2.25	3.0	2.25	3.0
R	2.275	2.88	2.275	2.88
S	.625	.875	.625	.875
U	2.625	3.375	2.625	3.375
X	.375	.375	.375	.375
Standard				
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
Alternate				
BD	24.5	24.5	24.5	24.5
AJ	14.75	14.75	14.75	14.75
AK	13.5	13.5	13.5	13.5
BF	.688	.688	.688	.688
Approx. Ship Wt. (Lbs.)	4100	4200	4900	6400



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.

Certification

Customer | P.O. | S.O. | Item

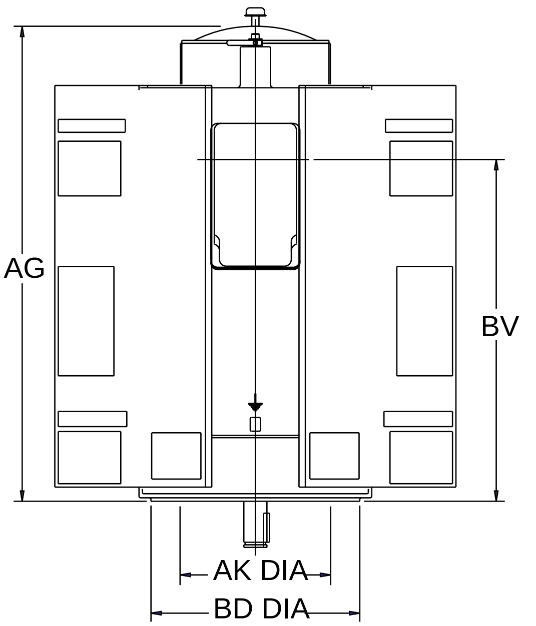
HP | RPM | FR. | PH/HZ/Volts

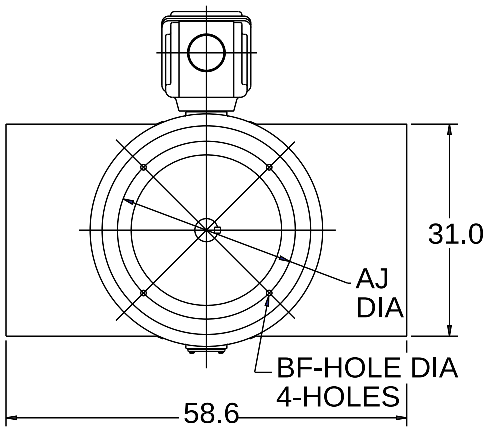
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By | Date

Not for construction, installation or application purposes unless certified.

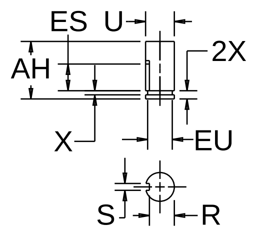
Type CGV — Vertical Solid Shaft — Open Drip Proof — Weather Protected Type I NEMA P Flange — Anti Friction Bearing — 3600 & 1800 RPM Frames 588-5810





Standard Dimensions in Inches

Frame	588	588	5810	5810
RPM	3600	1800	3600	1800
AG(1)	65	65	73	73
AH	6.75	7.0	6.75	7.0
BV	42	42	50	50
ES	4.25	4.5	4.25	4.5
EU	3.0	3.375	3.0	3.375
R	2.88	3.309	2.88	3.309
S	.875	1.0	.875	1.0
U	3.375	3.875	3.375	3.875
X	.375	0.5	.375	0.5
Standard				
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
Alternate				
BD	24.5	24.5	24.5	24.5
AJ	14.75	14.75	14.75	14.75
AK	13.5	13.5	13.5	13.5
BF	.688	.688	.688	.688
Approx. Ship Wt. (Lbs.)	6400	6500	7400	4600



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.

Certification

Customer P.O. S.O. Item

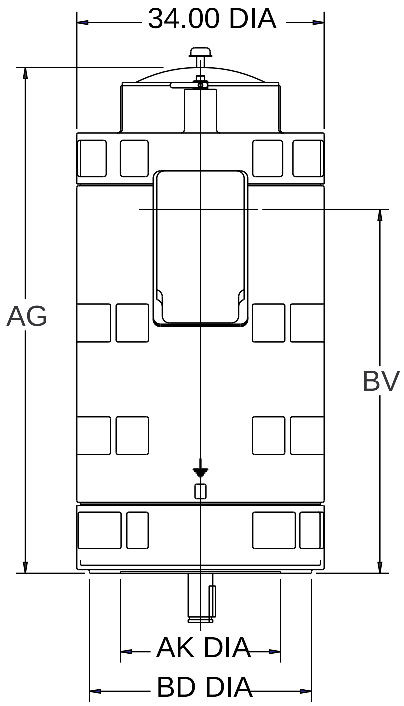
HP RPM FR. PH/HZ/Volts

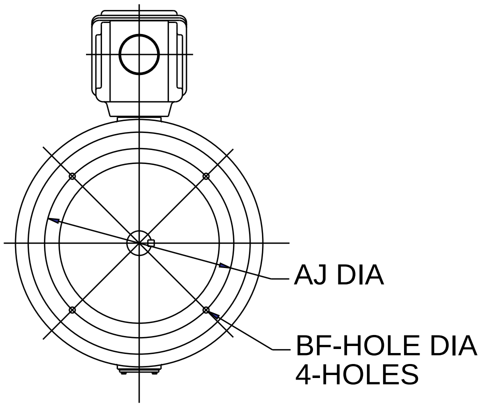
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

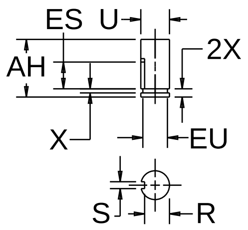
Type CGV — Vertical Solid Shaft — Open Drip Proof — Weather Protected Type I NEMA P Flange — Anti-Friction Bearing — 1200 RPM and Slower Frames 588-5810





Standard Dimensions in Inches

Frame	588	5810
RPM	1200 & Slower	1200 & Slower
AG(1)	65	73
AH	7.0	7.0
BV	42	50
ES	4.5	4.5
EU	3.375	3.375
R	3.309	3.309
S	1.0	1.0
U	3.875	3.875
X	0.5	0.5
	Standard	
BD	30.5	30.5
AJ	26	26
AK	22	22
BF	.812	.812
	Alternate	
BD	24.5	24.5
AJ	14.75	14.75
AK	13.5	13.5
BF	.688	.688
Approx. Ship Wt. (Lbs.)	6000	7100



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

Certification

Customer P.O. S.O. Item

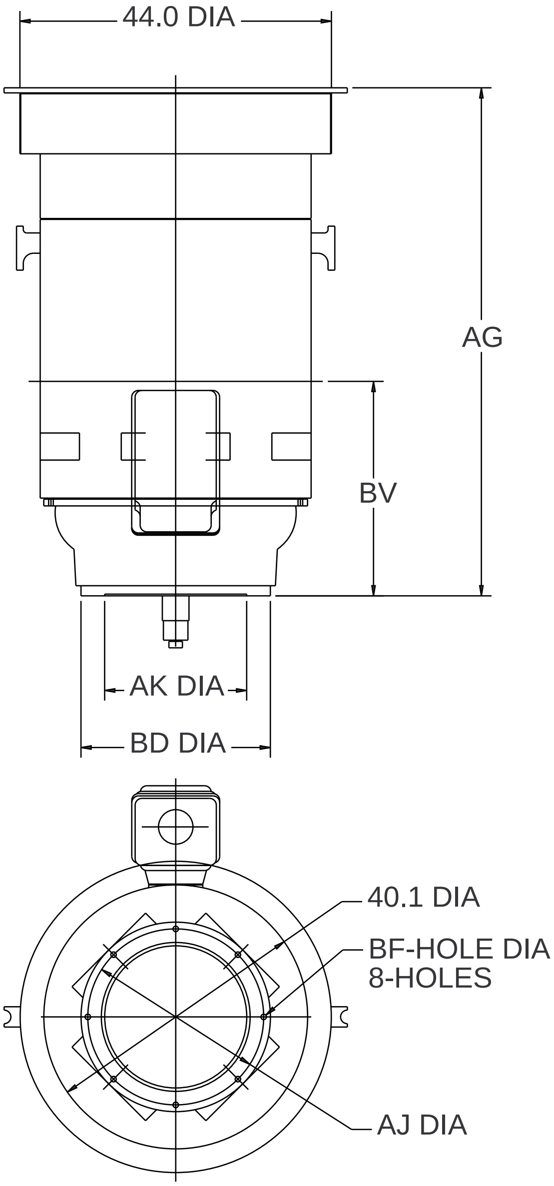
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

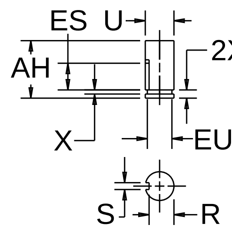
Not for construction, installation or application purposes unless certified.

Type RGV – Vertical Solid Shaft – Weather Protected Type I
NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower
Frame 30



Standard Dimensions in Inches

Frame	30JJ	30KK	3020	3023
RPM	1800 & Slower	1800 & Slower	1800 & Slower	1800 & Slower
AG(1)	60.1	60.1	64.6	67.6
AH	7.0	7.0	7.0	7.0
BV	27.5	27.5	29.8	31.2
ES	4.5	4.5	4.5	4.5
EU	3.375	3.375	3.375	3.375
R	3.309	3.309	3.309	3.309
S	1.0	1.0	1.0	1.0
U	3.875	3.875	3.875	3.875
X	0.5	0.5	0.5	0.5
Standard				
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
Alternate				
BD	24.5	24.5	24.5	24.5
AJ	14.75	14.75	14.75	14.75
AK	13.5	13.5	13.5	13.5
BF	.688	.688	.688	.688
Approx. Ship Wt. (Lbs.)	5300	5300	6200	6800



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

Certification

Customer P.O. S.O. Item

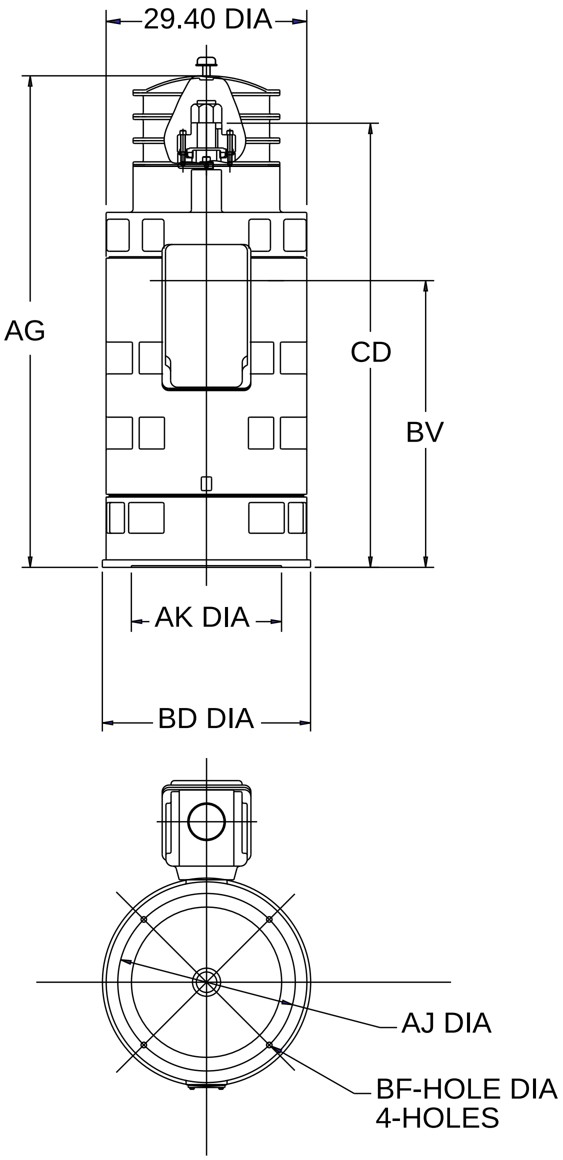
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

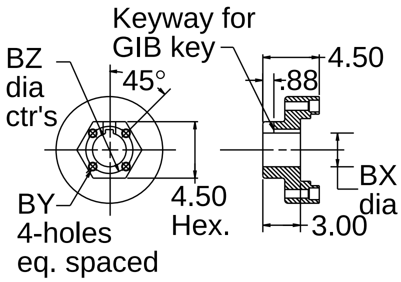
Type CGHS — Vertical Hollow Shaft — Open Drip Proof — Weather Protected Type I NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower Frames 507-509



Standard Dimensions in Inches

Frame	507	509
AG(1)	66.0	72.0
CD(1)	59.12	65.12
BV	36.0	42.0
Standard		
BD	30.5	30.5
AK	26	26
AJ	22	22
BF	.812	.812
Alternate		
BD	24.5	24.5
AK	14.75	14.75
AJ	13.5	13.5
BF	.688	.688
Approx. Ship Wt. (Lbs.)	4200	4900

Standard Bore Sizes			
BX	BY	BZ	KEY
1.688	.25 - 20	2.5	0.5
1.938	.375 - 16	3.25	0.5
2.188	.375 - 16	3.25	0.5
2.438	.375 - 16	3.25	.625
2.501	.375 - 16	3.25	.625
2.688	.375 - 16	3.75	.625



Notes

See Section 6 for selection of main terminal box.
AG(1) & CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.
Pump shaft adjusting nut and locking screws are not supplied with machine.

Certification

Customer P.O. S.O. Item

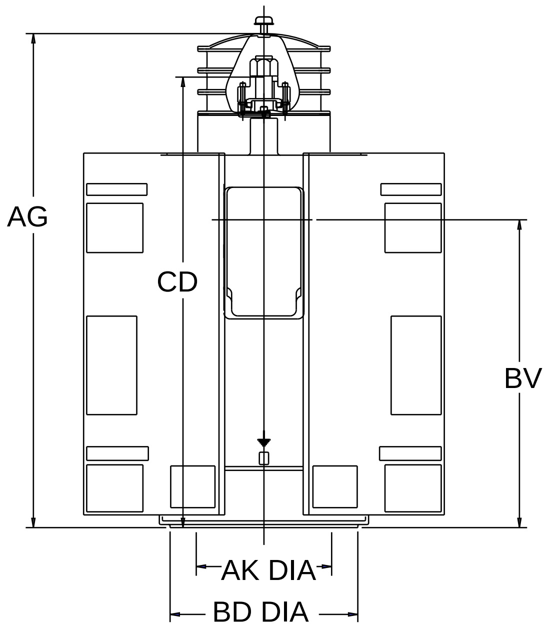
HP RPM FR. PH/HZ/Volts

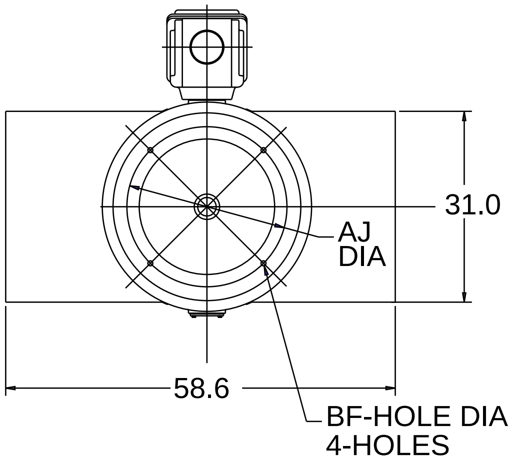
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGHS — Vertical Hollow Shaft — Open Drip Proof — Weather Protected Type I NEMA P Flange — Anti-Friction Bearing — 1800 RPM Frames 588-5810

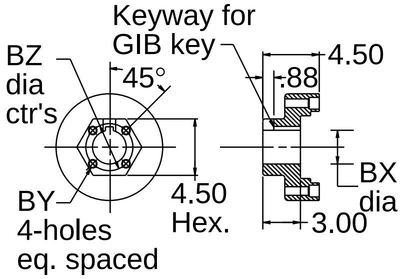




Standard Dimensions in Inches

Frame	588	5810
AG(1)	72.3	80.3
CD(1)	65.37	73.37
BV	42	50
Standard		
BD	30.5	30.5
AK	22	22
AJ	26	26
BF	.812	.812
Alternate		
BD	24.5	24.5
AK	13.5	13.5
AJ	14.75	14.75
BF	.688	.688
Approx.Ship Wt. (Lbs.)	6500	7600

Standard Bore Sizes			
BX	BY	BZ	KEY
1.688	.25 - 20	2.5	0.5
1.938	.375 - 16	3.25	0.5
2.188	.375 - 16	3.25	0.5
2.438	.375 - 16	3.25	.625
2.501	.375 - 16	3.25	.625
2.688	.375 - 16	3.75	.625



Notes

See Section 6 for selection of main terminal box.
AG(1) & CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.
Pump shaft adjusting nut and locking screws are not supplied with machine.

Certification

Customer P.O. S.O. Item

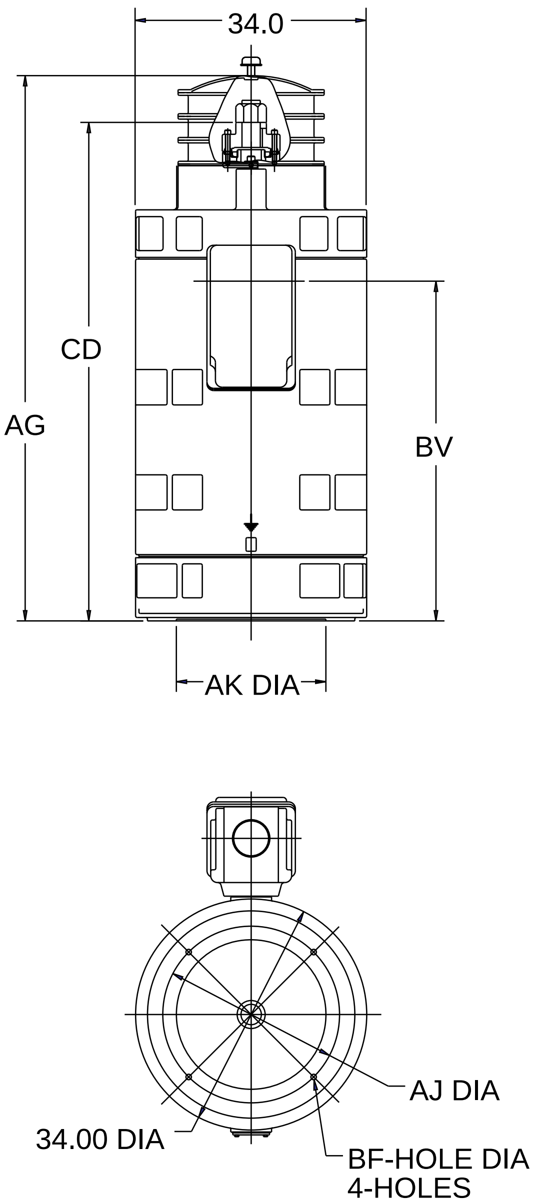
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGHS — Vertical Hollow Shaft — Open Drip Proof — Weather Protected Type I NEMA P Flange — Anti-Friction Bearing — 1200 RPM and Slower Frames 588-5810

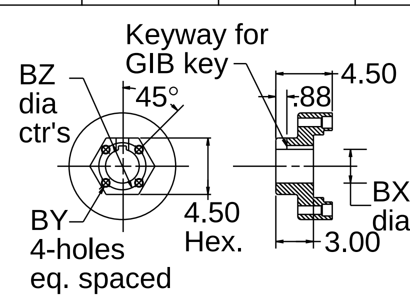


Standard Dimensions in Inches

Frame	588	5810
AG(1)	72.3	80.3
CD(1)	65.37	73.37
BV	42.0	50.0
Standard		
BD	30.5	30.5
AK	22	22
AJ	26	26
BF	.812	.812
Alternate		
BD	24.5	24.5
AK	13.5	13.5
AJ	14.75	14.75
BF	.688	.688
Approx. Ship Wt. (Lbs.)	6000	7100

Standard Bore Sizes

BX	BY	BZ	KEY
1.688	.25 - 20	2.5	0.5
1.938	.375 - 16	3.25	0.5
2.188	.375 - 16	3.25	0.5
2.438	.375 - 16	3.25	.625
2.501	.375 - 16	3.25	.625
2.688	.375 - 16	3.75	.625



Notes

See Section 6 for selection of main terminal box.
AG(1) and CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

Pump shaft adjusting nut and locking screws are not supplied with machine.

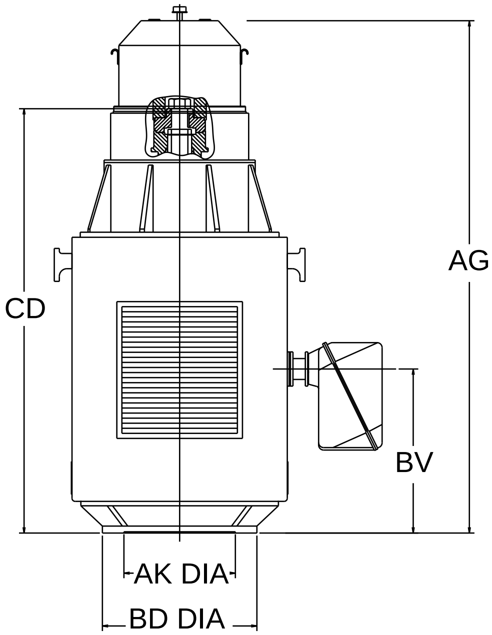
Certification

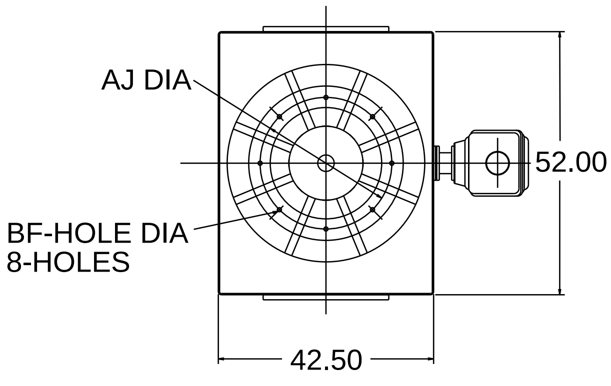
Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type HSHG — Vertical Hollow Shaft — Open Drip Proof — Weather Protected Type I NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower Frames 30



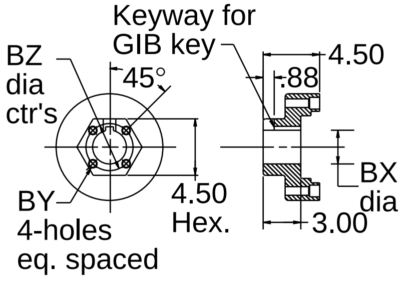


Standard Dimensions in Inches

Frame	30JJ	30KK	3020	3023
AG(1)	71.1	71.1	75.6	78.6
CD(1)	63.5	63.5	68.0	71.0
BV	27.5	27.5	29.8	31.2
Standard				
BD	30.5	30.5	30.5	30.5
AK	22	22	22	22
AJ	26	26	26	26
BF	.812	.812	.812	.812
Alternate				
BD	24.5	24.5	24.5	24.5
AK	13.5	13.5	13.5	13.5
AJ	14.75	14.75	14.75	14.75
BF	.688	.688	.688	.688
Approx. Ship Wt. (Lbs.)	5300	5300	6200	6800

Standard Bore Sizes

BX	BY	BZ	KEY
1.688	.25 - 20	2.5	0.5
1.938	.375 - 16	3.25	0.5
2.188	.375 - 16	3.25	0.5
2.438	.375 - 16	3.25	.625
2.501	.375 - 16	3.25	.625
2.688	.375 - 16	3.75	.625



Notes

See Section 6 for selection of main terminal box.
AG(1) & CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.
Pump shaft adjusting nut and locking screws are not supplied with machine.

Certification

Customer ______ P.O. ______ S.O. ______ Item ______

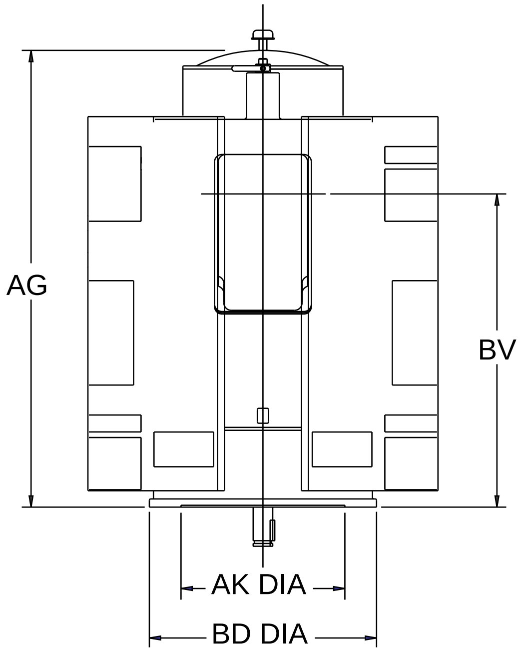
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______

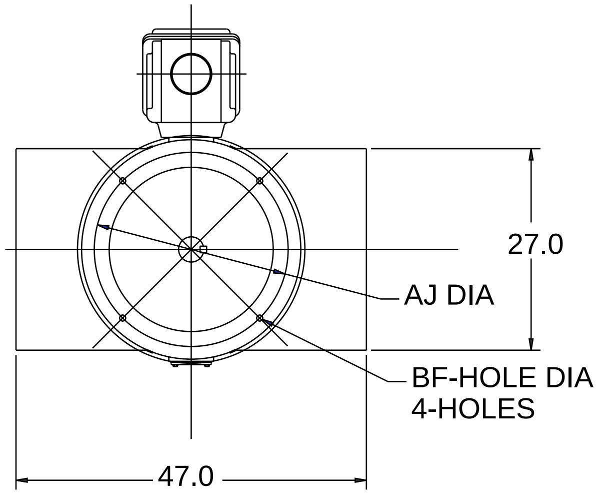
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______

Not for construction, installation or application purposes unless certified.

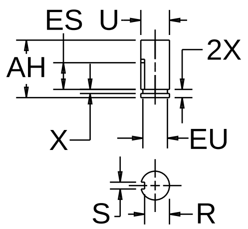
Type CGIIV — Vertical Solid Shaft — Weather Protected Type II NEMA P Flange — Anti-Friction Bearing Frames 507-509





Standard Dimensions in Inches

Frame	507	507	509	509
RPM	3600	1800 & Slower	3600	1800 & Slower
AG(1)	58.8	58.8	64.8	64.8
AH	5.25	6.75	5.25	6.75
BV	36	36	42	42
ES	2.75	4.25	2.75	4.25
EU	2.25	3.0	2.25	3.0
R	2.275	2.88	2.275	2.88
S	.625	.875	.625	.875
U	2.625	3.375	2.625	3.375
X	.375	.375	.375	.375
Standard				
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
Alternate				
BD	24.5	24.5	24.5	24.5
AJ	14.75	14.75	14.75	14.75
AK	13.5	13.5	13.5	13.5
BF	.688	.688	.688	.688
Approx Ship Wt. (Lbs.)	4500	4500	5100	5300



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.

Certification

Customer ____ P.O. ____ S.O. ____ Item ____

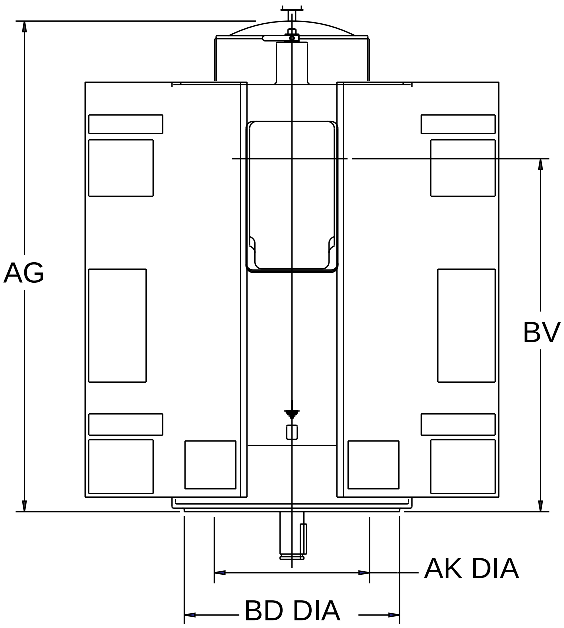
HP ____ RPM ____ FR. ____ PH/HZ/Volts ____

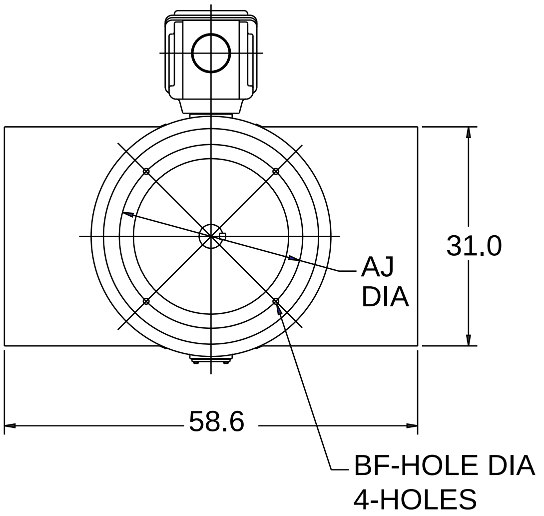
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ____ Date ____

Not for construction, installation or application purposes unless certified.

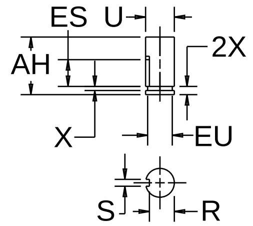
Type CGIIV — Vertical Solid Shaft — Weather Protected Type II NEMA P Flange — Anti-Friction Bearing Frames 588-5810





Standard Dimensions in Inches

Frame	588	588	5810	5810
RPM	3600	1800 & Slower	3600	1800 & Slower
AG(1)	65	61.5	73	69.5
AH	6.75	7.0	6.75	7.0
BV	42	42	50	50
ES	4.25	4.5	4.25	4.5
EU	3.0	3.375	3.0	3.375
R	2.88	3.309	2.88	3.309
S	.875	1.0	.875	1.0
U	3.375	3.875	3.375	3.875
X	.375	0.5	.375	0.5
		Standard		
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
		Alternate		
BD	24.5	24.5	24.5	24.5
AJ	14.75	14.75	14.75	14.75
AK	13.5	13.5	13.5	13.5
BF	.688	.688	.688	.688
Approx. Ship Wt. (Lbs.)	6400	6500	7400	7600



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.

Certification

Customer P.O. S.O. Item

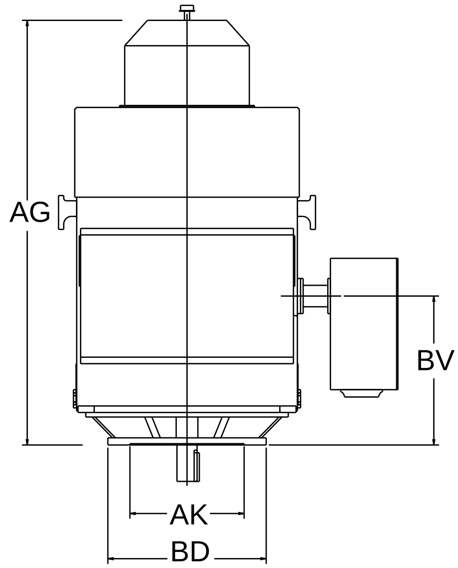
HP RPM FR. PH/HZ/Volts

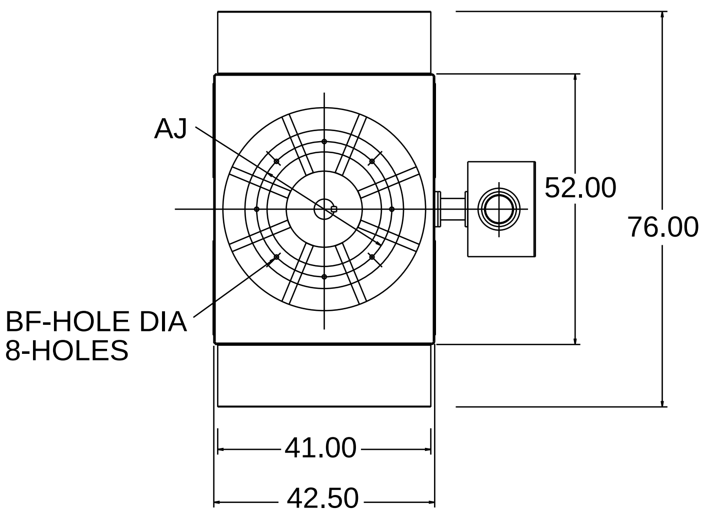
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

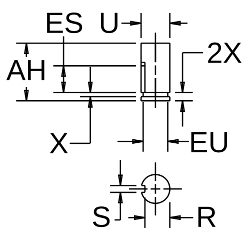
Type FODV — Vertical Solid Shaft — Weather Protected Type II NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower Frame 30





Standard Dimensions in Inches

Frame	30JJ	30KK	3020	3023
RPM	1800 & Slower	1800 & Slower	1800 & Slower	1800 & Slower
AG(1)	63.4	63.4	67.9	70.9
AH	7.0	7.0	7.0	7.0
BV	28.6	28.6	30.9	32.4
ES	4.5	4.5	4.5	4.5
EU	3.375	3.375	3.375	3.375
R	3.309	3.309	3.309	3.309
S	1.0	1.0	1.0	1.0
U	3.875	3.875	3.875	3.875
X	0.5	0.5	0.5	0.5
Standard				
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
Alternate				
Approx. Ship Wt. (Lbs.)	7560	7560	8200	8900



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

Certification

Customer P.O. S.O. Item

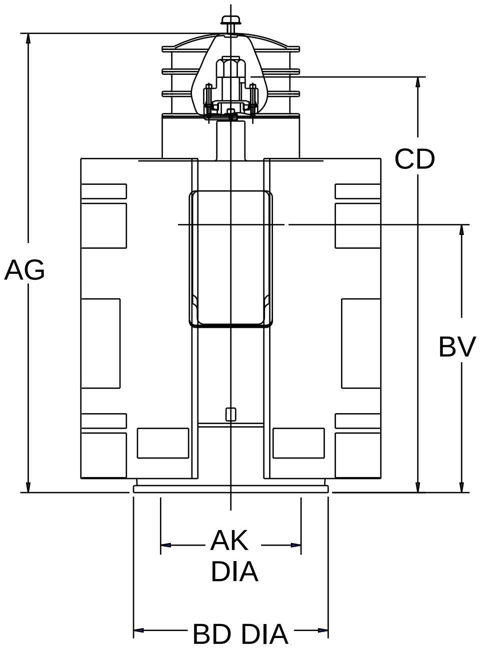
HP RPM FR. PH/HZ/Volts

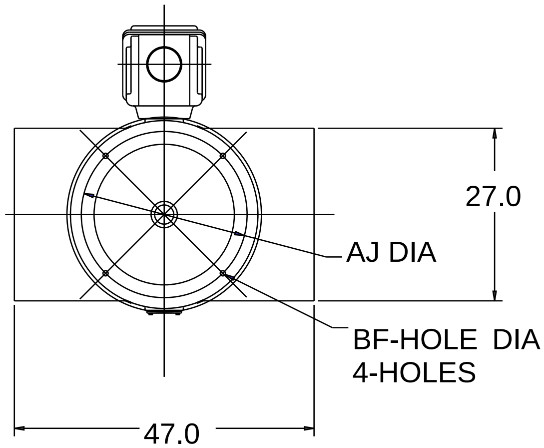
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Type CGIIHS — Vertical Hollow Shaft — Weather Protected Type II NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower Frames 507-509

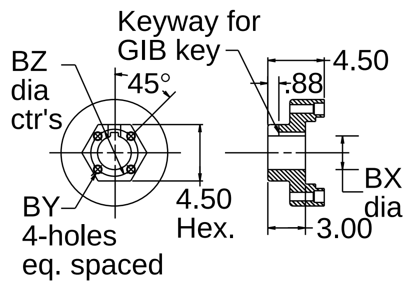




Standard Dimensions in Inches

Frame	507	509
AG(1)	66.0	72.0
CD(1)	59.12	65.12
BV	36.0	42.0
Standard		
BD	30.5	30.5
AK	22	22
AJ	26	26
BF	.812	.812
Alternate		
BD	24.5	24.5
AK	13.5	13.5
AJ	14.75	14.75
BF	.688	.688
Approx. Ship Wt. (Lbs.)	4500	5300

Standard Bore Sizes			
BX	BY	BZ	KEY
1.688	.25 - 20	2.5	0.5
1.938	.375 - 16	3.25	0.5
2.188	.375 - 16	3.25	0.5
2.438	.375 - 16	3.25	.625
2.501	.375 - 16	3.25	.625
2.688	.375 - 16	3.75	.625



Notes

See Section 6 for selection of main terminal box.
AG(1) & CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.
Pump shaft adjusting nut and locking screws are not supplied with machine.

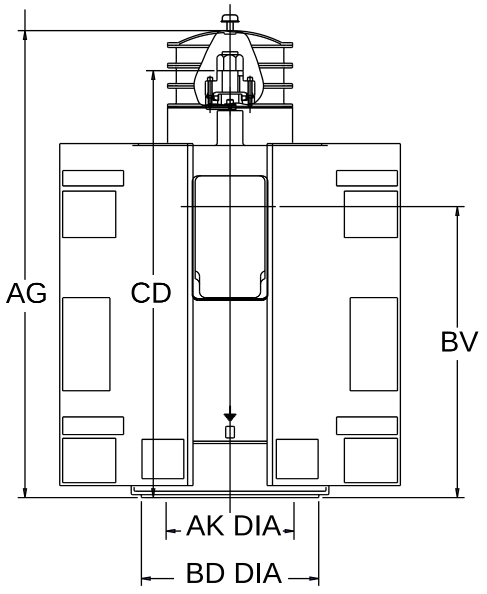
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

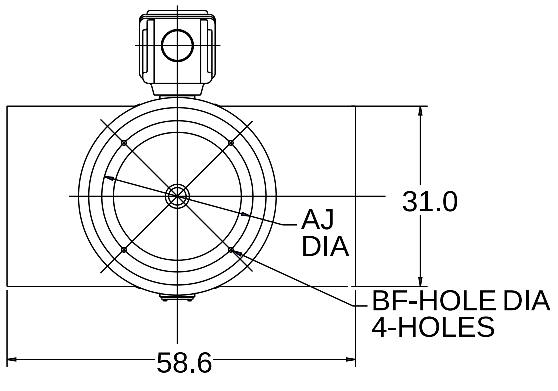
Not for construction, installation or application purposes unless certified.

Type CGIIHS — Vertical Hollow Shaft — Weather Protected Type II NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower Frames 588-5810

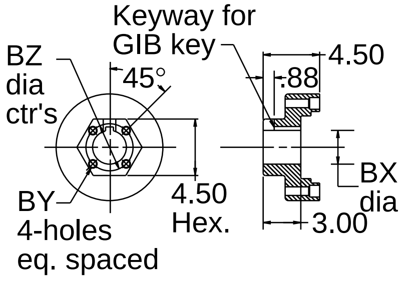


Standard Dimensions in Inches

Frame	588	5810
AG(1)	72.3	80.3
CD(1)	65.37	73.37
BV	42.0	50.0
Standard		
BD	30.5	30.5
AK	22	22
AJ	26	26
BF	.812	.812
Alternate		
BD	24.5	24.5
AK	13.5	13.5
AJ	14.75	14.75
BF	.688	.688
Approx. Ship Wt. (Lbs.)	6500	7600



Standard Bore Sizes			
BX	BY	BZ	KEY
1.688	.25 - 20	2.5	0.5
1.938	.375 - 16	3.25	0.5
2.188	.375 - 16	3.25	0.5
2.438	.375 - 16	3.25	.625
2.501	.375 - 16	3.25	.625
2.688	.375 - 16	3.75	.625



Notes

See Section 6 for selection of main terminal box.
AG(1) & CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.
Pump shaft adjusting nut and locking screws are not supplied with machine.

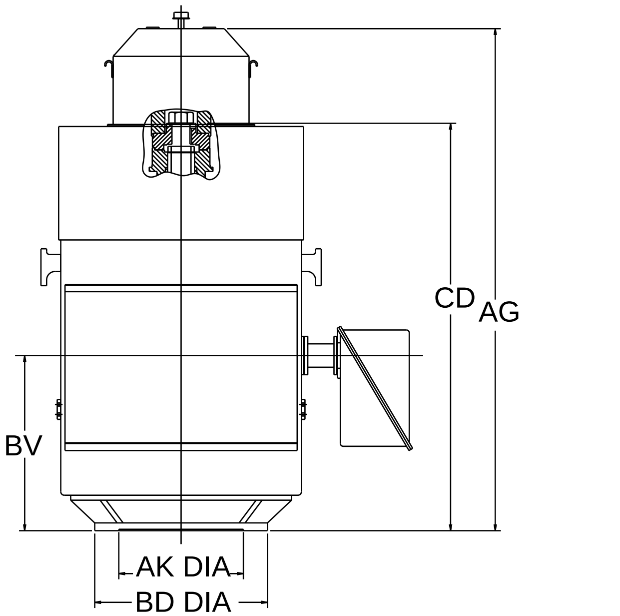
Certification

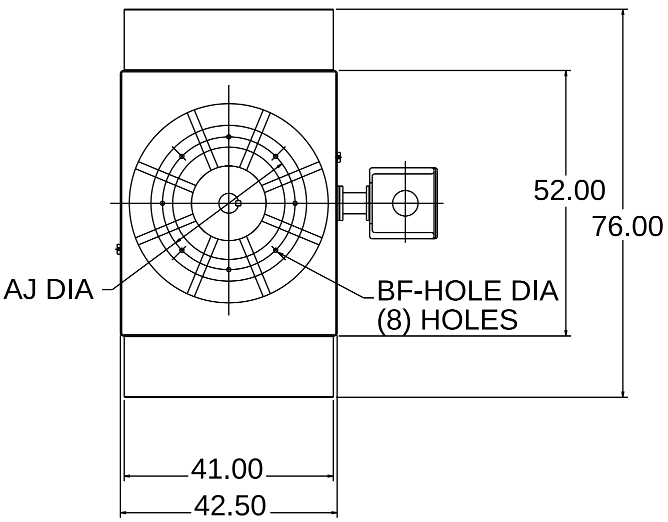
Customer ______ P.O. ______ S.O. ______ Item ______
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______

Not for construction, installation or application purposes unless certified.

Type HSFOD — Vertical Hollow Shaft — Weather Protected Type II NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower Frames 30

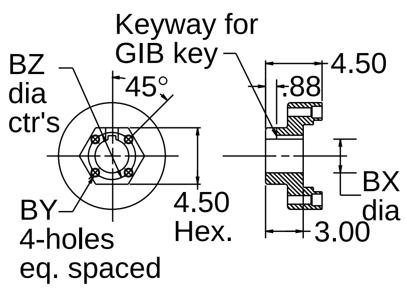




Standard Dimensions in Inches

Frame	30JJ	30KK	3020	3023
AG(1)	71.9	71.9	76.4	79.4
CD(1)	65.38	65.38	69.88	72.88
BV	28.6	30.9	30.9	32.4
Standard				
BD	30.5	30.5	30.5	30.5
AK	22	22	22	22
AJ	26	26	26	26
BF	.812	.812	.812	.812
Approx. Ship Wt. (Lbs.)	7560	7560	8200	8900

Standard Bore Sizes			
BX	BY	BZ	KEY
1.688	.25 - 20	2.5	0.5
1.938	.375 - 16	3.25	0.5
2.188	.375 - 16	3.25	0.5
2.438	.375 - 16	3.25	.625
2.501	.375 - 16	3.25	.625
2.688	.375 - 16	3.75	.625



Notes

See Section 6 for selection of main terminal box.
AG(1) & CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

Machines may rotate in either direction.
Pump shaft adjusting nut and locking screws are not supplied with machine.

Certification

Customer P.O. S.O. Item

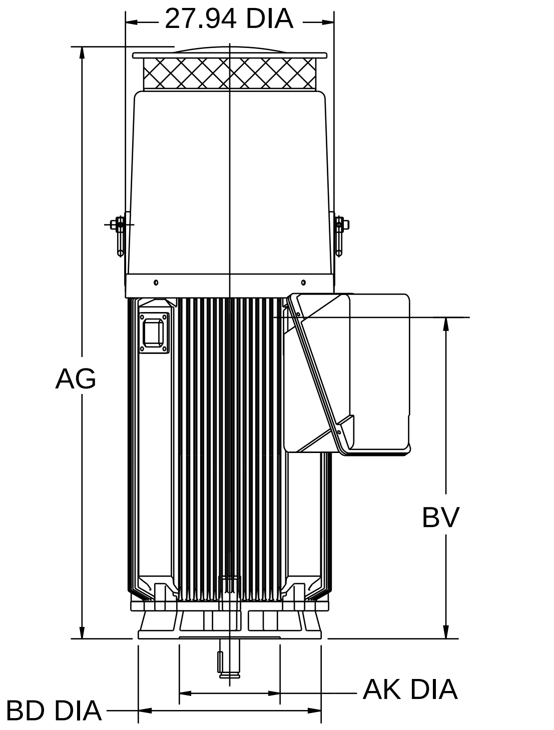
HP RPM FR. PH/HZ/Volts

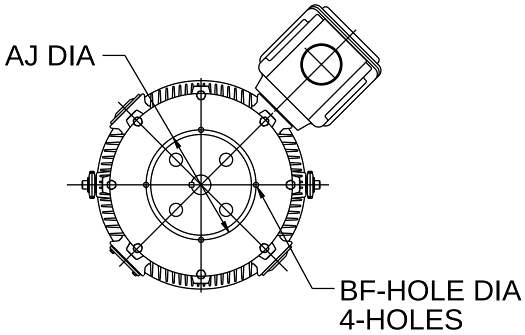
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

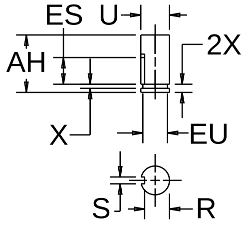
Type CGZV — Vertical Solid Shaft — Totally Enclosed — Fan Cooled
NEMA P Flange — Anti-Friction Bearing
Frames 507-509





Standard Dimensions in Inches

Frame	507	507	509	509
RPM	3600	1800 & Slower	3600	1800 & Slower
AG(1)	72.4	72.4	79.4	79.4
AH	5.25	5.25	5.25	5.25
BV	34.5	34.5	41	41
ES	2.75	2.75	2.75	2.75
EU	2.25	2.25	2.25	2.25
R	2.275	2.275	2.275	2.275
S	.625	.625	.625	.625
U	2.625	2.625	2.625	2.625
X	.375	.375	.375	.375
Standard				
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
Alternate				
BD	24.5	24.5	24.5	24.5
AJ	14.75	14.75	14.75	14.75
AK	13.5	13.5	13.5	13.5
BF	.688	.688	.688	.688
Approx. Ship Wt. (Lbs.)	4500	4700	4900	4900



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.

Certification

Customer ______ P.O. ______ S.O. ______ Item ______

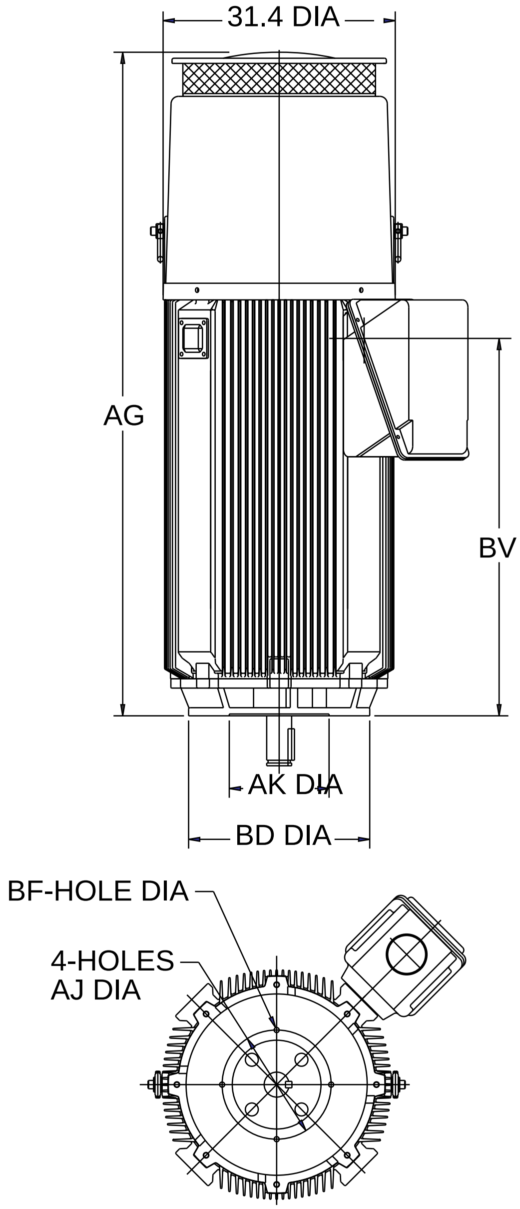
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______

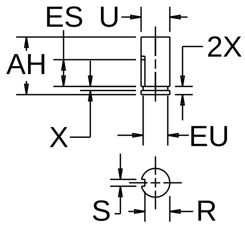
Not for construction, installation or application purposes unless certified.

Type CGZV — Vertical Solid Shaft — Totally Enclosed — Fan Cooled
NEMA P Flange — Anti-Friction Bearing
Frame 588-5810



Standard Dimensions in Inches

Frame	588	588	5810	5810
RPM	3600	1800 & Slower	3600	1800 & Slower
AG(1)	81.7	81.7	89.7	89.7
AH	6.75	7.0	6.75	7.0
BV	43	43	51	51
ES	4.25	4.5	4.25	4.5
EU	3	3.375	3	3.375
R	2.88	3.309	2.88	3.309
S	.875	1.0	.875	1.0
U	3.375	3.875	3.375	3.875
X	.375	0.5	.375	0.5
		Standard		
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
		Alternate		
BD	24.5	24.5	24.5	24.5
AJ	14.75	14.75	14.75	14.75
AK	13.5	13.5	13.5	13.5
BF	.688	.688	.688	.688
Approx. Ship Wt. (Lbs.)	6300	6500	7500	7400



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

3600 RPM machines rotate in one direction only.
1800 RPM and slower machines may rotate in either direction.

Certification

Customer P.O. S.O. Item

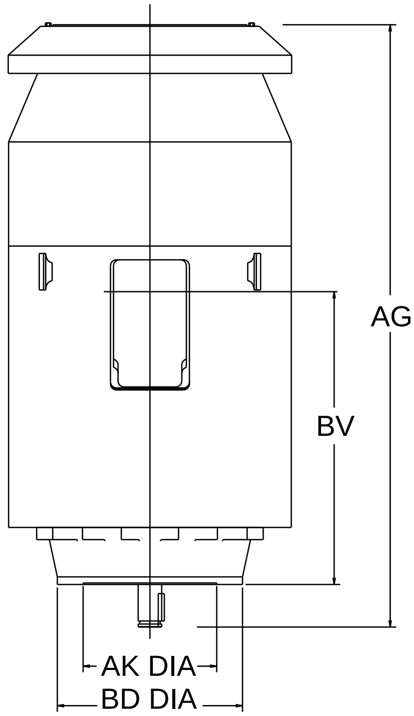
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

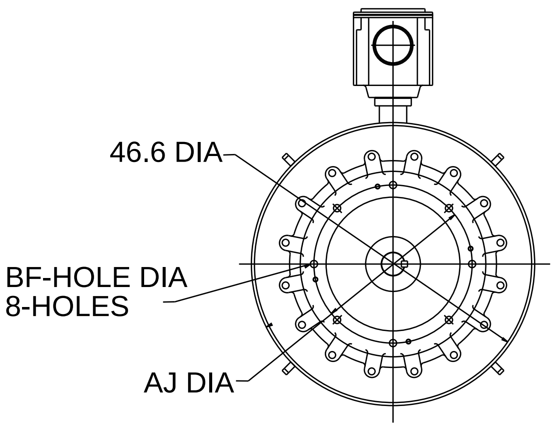
Not for construction, installation or application purposes unless certified.

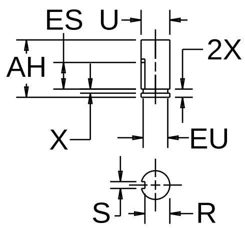
Type AZV — Vertical Solid Shaft — Totally Enclosed — Fan-Cooled NEMA P Flange — Anti-Friction Bearing Frames 30 — 1800 RPM & Slower



Standard Dimensions in Inches

Frame	30B / 30E	30JJ / 30KK	30L / 3020	30LL / 3023
RPM	1800 & Slower	1800 & Slower	1800 & Slower	1800 & Slower
AG(1)	69.8	74.2	78.8	81.8
AH	7.0	7.0	7.0	7.0
BV	36	40.5	45	48
ES	4.5	4.5	4.5	4.5
EU	3.375	3.375	3.375	3.375
R	3.309	3.309	3.309	3.309
S	1.0	1.0	1.0	1.0
U	3.875	3.875	3.875	3.875
X	0.5	0.5	0.5	0.5
Standard				
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
Alternate				
Approx. Ship Wt. (Lbs.)	7200	8200	9500	10200





Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.
Machines rotate in one direction only.

Certification

Customer P.O. S.O. Item

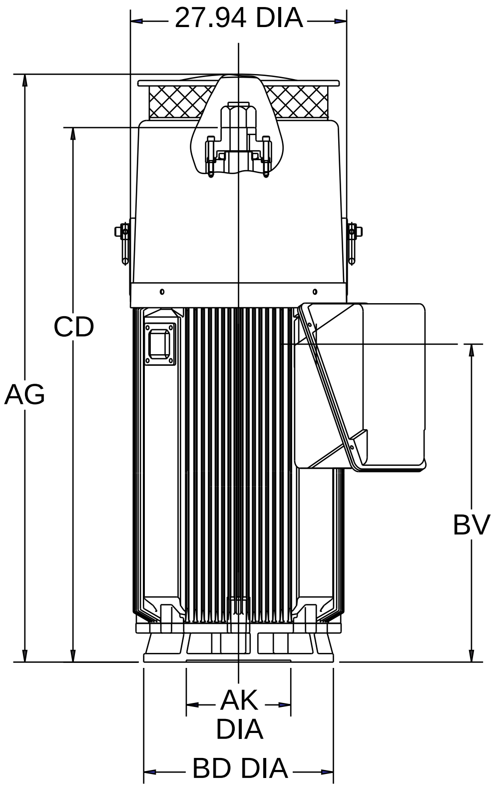
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

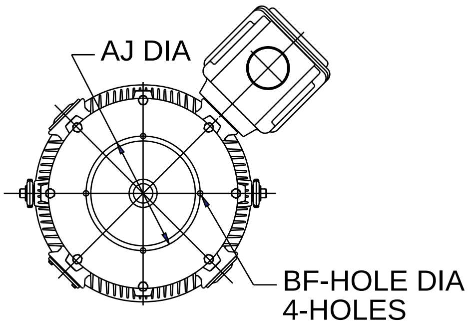
Type CGZHS — Vertical Hollow Shaft — Totally Enclosed — Fan Cooled NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower Frames 507-509

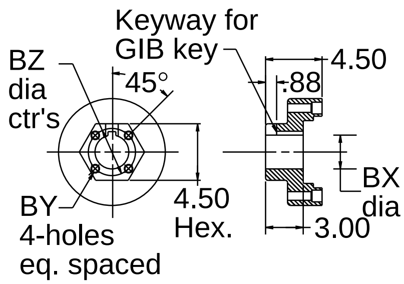


Standard Dimensions in Inches

Frame	507	509
AG(1)	72.4	79.4
CD(1)	65.15	72.15
BV	34.5	41.0
Standard		
BD	30.5	30.5
AK	22	22
AJ	26	26
BF	.812	.812
Alternate		
BD	24.5	24.5
AK	13.5	13.5
AJ	14.75	14.75
BF	.688	.688
Approx. Ship Wt. (Lbs.)	4700	4900

Standard Bore Sizes			
BX	BY	BZ	KEY
1.501	.25 - 20	2.12	.375
1.688	.25 - 20	2.5	.500
1.938	.375 - 16	3.25	.500
2.188	.375 - 16	3.75	.500





Notes

See Section 6 for selection of main terminal box.
AG(1) & CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.
Pump shaft adjusting nut and locking screws are not supplied with machine.

Certification

Customer ______ P.O. ______ S.O. ______ Item ______

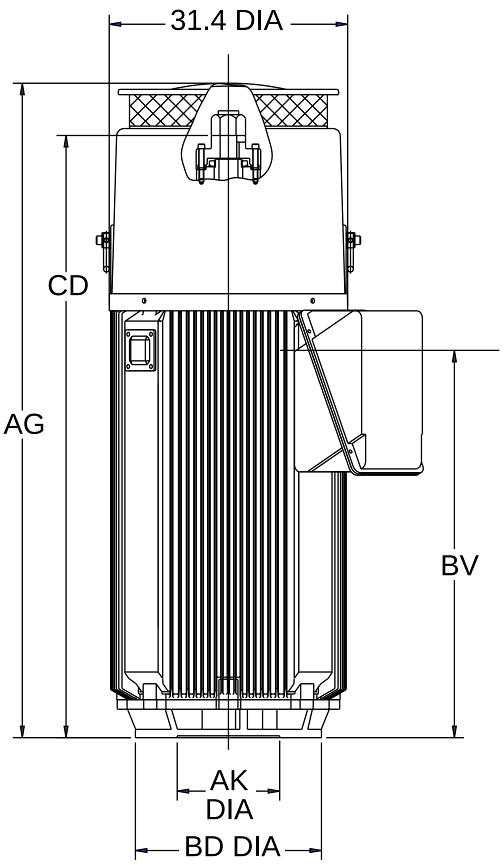
HP ______ RPM ______ FR. ______ PH/HZ/Volts ______

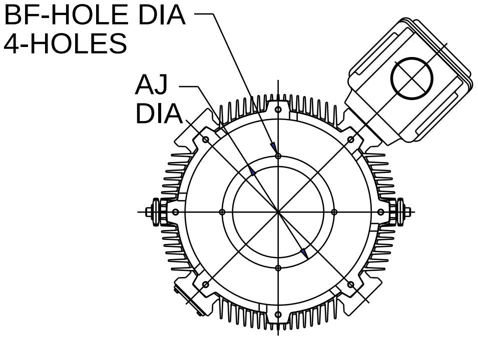
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By ______ Date ______

Not for construction, installation or application purposes unless certified.

Type CGZHS — Vertical Hollow Shaft — Totally Enclosed — Fan Cooled NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower Frames 588-5810

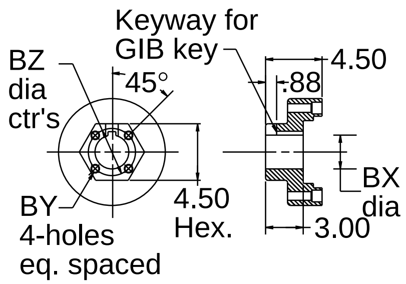




Standard Dimensions in Inches

Frame	588	5810
AG(1)	81.7	89.7
CD(1)	74.45	82.45
BV	43.0	51.0
Standard		
BD	30.5	30.5
AK	22	22
AJ	26	26
BF	.812	.812
Alternate		
BD	24.5	24.5
AK	13.5	13.5
AJ	14.75	14.75
BF	.688	.688
Approx. Ship Wt. (Lbs.)	6500	7400

Standard Bore Sizes			
BX	BY	BZ	KEY
1.501	.25 - 20	2.12	.375
1.688	.25 - 20	2.5	.500
1.938	.375 - 16	3.25	.500
2.188	.375 - 16	3.75	.500



Notes

See Section 6 for selection of main terminal box.
AG(1) & CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.
Pump shaft adjusting nut and locking screws are not supplied with machine.

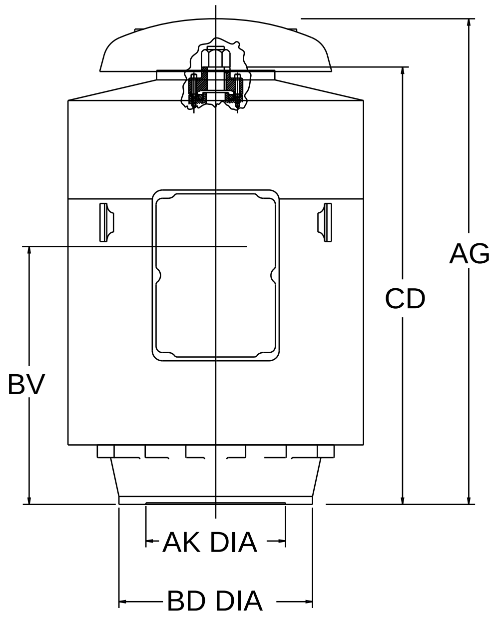
Certification

Customer P.O. S.O. Item
HP RPM FR. PH/HZ/Volts
Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

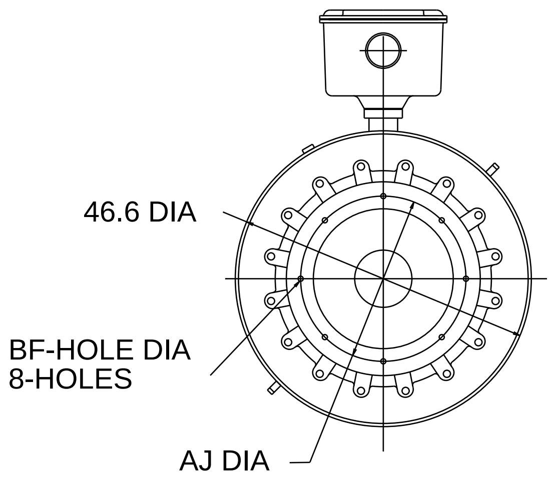
Type HSZ — Vertical Hollow Shaft — Totally Enclosed — Fan Cooled NEMA P Flange — Anti-Friction Bearing — 1800 RPM and Slower Frames 30

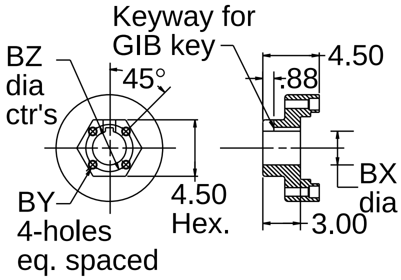


Standard Dimensions in Inches

Frame	30B/30E	30JJ/30KK	30L/3020	3023
AG(1)	69.8	74.2	78.8	81.8
CD(1)	64.4	68.9	73.4	76.4
BV	36.0	40.5	45.0	48.0
Standard				
BD	30.5	30.5	30.5	30.5
AK	22	22	22	22
AJ	26	26	26	26
BF	.812	.812	.812	.812
Approx. Ship Wt. (Lbs.)	7200	8200	9500	10200

Standard Bore Sizes			
BX	BY	BZ	KEY
1.688	.25 - 20	2.5	0.5
1.938	.375 - 16	3.25	0.5
2.188	.375 - 16	3.25	0.5
2.438	.375 - 16	3.25	.625
2.501	.375 - 16	3.25	.625
2.688	.375 - 16	3.75	.625





Notes

See Section 6 for selection of main terminal box.
AG(1) & CD(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.

Machines may rotate in one direction only.
Pump shaft adjusting nut and locking screws are not supplied with machine.

Certification

Customer P.O. S.O. Item

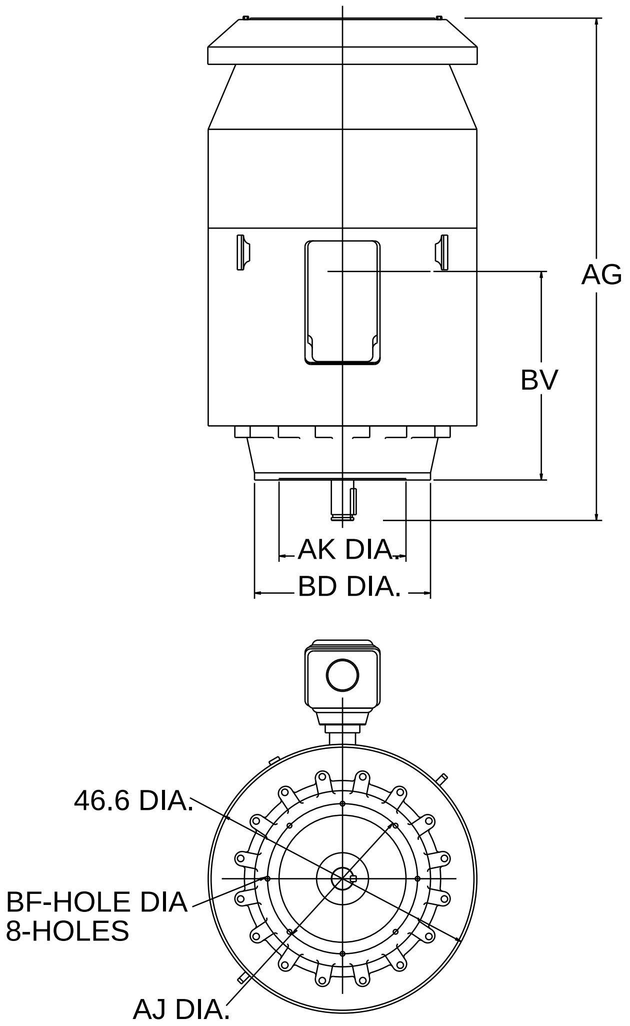
HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

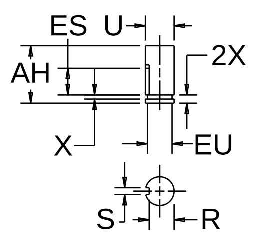
Not for construction, installation or application purposes unless certified.

Type AZZV — Vertical Solid Shaft — Explosion-Proof NEMA P Flange — Anti-Friction Bearing Frames 30 — 1800 RPM and Slower



Standard Dimensions in Inches

Frame	30B / 30E	30JJ / 30KK	30L / 3020	30LL / 3023
RPM	1800 & Slower	1800 & Slower	1800 & Slower	1800 & Slower
AG(1)	69.8	74.2	78.8	81.8
AH	7.0	7.0	7.0	7.0
BV	36	40.5	45	48
ES	4.5	4.5	4.5	4.5
EU	3.375	3.375	3.375	3.375
R	3.309	3.309	3.309	3.309
S	1.0	1.0	1.0	1.0
U	3.875	3.875	3.309	3.309
X	0.5	0.5	0.5	0.5
Standard				
BD	30.5	30.5	30.5	30.5
AJ	26	26	26	26
AK	22	22	22	22
BF	.812	.812	.812	.812
Alternate				
Approx. Ship Wt. (Lbs.)	7200	8200	9500	10200



Notes

See Section 6 for selection of main terminal box.
AG(1) dimension is a maximum value. Actual dimension will vary with bearing selection. Consult factory for specific dimension.
Machines rotate in one direction only.

Certification

Customer P.O. S.O. Item

HP RPM FR. PH/HZ/Volts

Rotating Facing Shaft Extension CW ☐ CCW ☐ Either ☐

By Date

Not for construction, installation or application purposes unless certified.

Index of Products

Product Range and Scope

Open Enclosures

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<tr><th>HP/Speed</th><th>3600</th><th>1800</th><th>1200</th><th>900</th><th>720</th><th>600</th><th>514</th><th>450</th></tr>
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<tr><td>10000</td><td></td></tr>
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Exact division between frame series is dependent on voltage, frequency, orientation and service factor of motor.

Product Range and Scope

TEFC Enclosures - Anti-Friction Bearing

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Exact division between frame series is dependent on voltage, frequency, orientation and service factor of motor.

Product Range and Scope

TEFC Enclosures - Sleeve Bearing

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Exact division between frame series is dependent on voltage, frequency, orientation and service factor of motor.

Standard Construction Features

Horizontal Standard
Open Dripproof and Weather Protected Type I Enclosure
Type IG-505 and 508 Frames

AIR DEFLECTORS - Fiberglass.

BEARINGS:
Anti-Friction - Open grease lube bearings are only available.

BEARING HOUSING - Cast iron with cast ventilation openings.

BEARING SEALS:
Anti-Friction - Cast iron inner bearing cap.

CONDUIT BOX - Cast iron, diagonally split, gasketed. Conduit box location F1 or F2. Low voltage above 540 amps will be fabricated steel.

HARDWARE - Zinc plated Grade 5 steel hex head bolts and cap screws.

ROTOR
- Die cast aluminum rotors are standard.
- Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element. Unidirectional fans on 2-pole motors.

SHAFT - Hot rolled carbon steel.

SCREEN/LOUVERS - IG line has cast grills in both bearing housing and yoke.

STATOR CORE - Laminations made from high grade silicon steel, stacked and compressed, and keyed in yoke. Secured in yoke by heavy retaining ring and welded snap ring.

STATOR WINDING - Form wound stators are vacuum pressure impregnated and varnished. Random wound coils are dipped in polyester varnish.

Standard Construction Features

Horizontal Standard
Open Dripproof and Weather Protected Type I Enclosure
Type IG-505 and 508 Frames (Cont'd)

VENTILATION - The air intakes are on the ends of the motor and discharges through openings located on sides of the motor.

YOKE - Yokes are cast iron construction with integrally cast feet. Drain holes are provided, as well as provisions for dowels and vertical jackscrews in feet. 505 frame feet can be drilled for 503 or 504 frame 2F dimension. 508 frame feet can be drilled for 509 frame 2F dimension.

Standard Construction Features

Horizontal Custom
Open Drip-Proof and Weather-Protected Type I
Type CG-500, 580, and 680 Frames

AIR DEFLECTORS	-	Fiberglass.
BEARINGS:		
Anti-Friction	-	Open grease lube bearings standard on all frames, except 580 frame 2-pole (1500 HP and higher) and 680 frame 2-pole which have sleeve bearings only.
Split Sleeve	-	Available on all frame sizes and all speeds.
BEARING HOUSING	-	Cast iron with ventilation openings. Air gap inspection holes on sleeve bearing units.
BEARING SEALS:		
Anti-Friction	-	Cast iron inner bearing cap.
Sleeve Bearing	-	External and Internal: Labyrinth type stationary shaft seals. Internal: Labyrinth type positive pressurized vapor seal on two-pole 680 frames.
CONDUIT BOX	-	Cast iron, diagonally split, gasketed. Conduit box location F1 or F2. Low voltage above 540 amps will be fabricated steel.
HARDWARE	-	Zinc plated Grade 5 steel hex head bolts and cap screws.
ROTOR	-	Die cast aluminum rotors are standard on all 500 and most 580 and on 2 & 4-pole 680 frames.
	-	Copper bar rotors are standard on 680 6-pole & slower frames. Copper bars are induction brazed to end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots
	-	Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element. Unidirectional fans on 2-pole motors.
SHAFT	-	Hot rolled carbon steel.
STATOR CORE	-	Laminations made from high grade silicon steel stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring.

Standard Construction Features

Horizontal Custom
Open Drip-Proof and Weather-Protected Type I
Type CG-500, 580, and 680 Frames (Cont'd)

STATOR WINDING
- Form wound stators are vacuum pressure impregnated and dipped in epoxy varnish.
- Random wound coils are dipped in polyester varnish.

VENTILATION
- The air intakes are on the ends of the motor and discharges through openings located on sides of the motor. On 580 and 680 frames, all intakes and discharges have stainless steel screens and are located in the top cover.

YOKE
- Frame yokes are cast iron construction with integrally cast feet. Drain holes are provided, as well as provisions for dowels and vertical jackscrews in feet.

Standard Construction Features

Horizontal Custom
Open Dripproof and Weather-Protected Type I Enclosure
Type RG-800 and CG-1120 Frames

AIR DEFLECTORS - Fiberglass.

BEARINGS - Sleeve bearings are standard on 800 and most 1120 frames. Tilting pad bearings are required on 2 and 4 pole 1120 frames.

BEARING BRACKET - Cast iron. Air gap inspection holes on sleeve bearing units.

BEARING SEALS:
Anti-Friction - Cast iron inner bearing cap.
Sleeve Bearing - External and Internal: Labyrinth type stationary shaft seals. Internal: Labyrinth type positive pressurized vapor seal on 2-pole and 4-pole 800 and 1120 frames.

CONDUIT BOX - Cast iron, diagonally split, gasketed. Conduit box location F-1 or F-2. Fabricated boxes on special applications and higher horsepowers.

HARDWARE - Zinc plated Grade 5 steel hex head bolts and cap screws.

ROTOR - Copper bar construction. Copper bars are induction brazed into copper end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots. Unidirectional fans on 2-pole motors.

SHAFT - Hot rolled carbon steel.

STATOR CORE - Laminations are made from high grade silicon steel stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring.

STATOR WINDING - Form wound stators are vacuum pressure impregnated and dipped in epoxy varnish.

VENTILATION - Air intake on ends and discharge through sides of top cover. All openings are louvered.

YOKE - Fabricated steel plate.

Standard Construction Features

Horizontal Custom
Weather Protected Type II Enclosure
Type CGII-500, 580, and 680 Frames

AIR DEFLECTORS	-	Fiberglass.
AIR DUCTS	-	Steel .
BEARINGS:		
Anti-Friction	-	Open grease lube bearings standard on all frames, except 580 frame 2-pole (1500 HP and higher) and 680 frame 2-pole which have sleeve bearings.
Split Sleeve	-	Available on all frame sizes and all speeds.
BEARING HOUSING	-	Cast iron. Air gap inspection holes on sleeve bearing motors.
BEARING SEALS:		
Anti-Friction	-	Cast iron inner bearing cap. Bronze rotating external shaft seal.
Split Sleeve	-	External and Internal: Labyrinth type stationary shaft seals. Internal: Labyrinth type positive pressurized vapor seal on 2-pole 680 frame motors.
CONDUIT BOX		
Split Sleeve	-	Cast iron, diagonally split, gasketed. Conduit box location F1 or F2. Low voltage above 540 amps will be fabricated steel.
HARDWARE	-	Zinc plated Grade 5 steel hex head cap screws.
ROTOR	-	Die cast aluminum rotors are standard on all 500 and most 580 and on 2 & 4-pole 680 frames, as well as some 30 frame motors.
	-	Copper bar rotors are standard on 680 6-pole & slower frames. Copper bars are induction brazed to end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots.
	-	Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element. Unidirectional fans on 2-pole motors.
SHAFT	-	Hot rolled carbon steel.

Standard Construction Features

Horizontal Custom
Weather Protected Type II Enclosure
Type CGII-500, 580, and 680 Frames (Cont'd)

SCREENS/LOUVERS	-	Stainless steel screens are supplied on air discharge and intake.
STATOR CORE	-	Laminations made from high grade silicon steel, stacked, compressed and secured in yoke by heavy retaining ring and welded snap ring.
STATOR WINDING	-	Form wound stators are vacuum pressure impregnated and dipped in epoxy varnish.
	-	Random wound coils are dipped in polyester varnish.
SPACE HEATER	-	Standard.
YOKE	-	Frame yokes are cast iron construction with integrally cast feet. Drain holes are provided, as well as provisions for dowels and vertical jackscrews in feet.

Standard Construction Features

Horizontal Custom
Weather-Protected Type II Enclosure
Type FOD 800 and CGII-1120 Frames

AIR DEFLECTORS	-	Fiberglass.
BEARINGS	-	Sleeve bearings are standard on 800 and most 1120 frames. Tilting pad bearings are required on 2 and 4 pole 1120 frames.
BEARING BRACKET	-	Cast iron. Air gap inspection holes on sleeve bearing units.
BEARING SEALS:		
Anti-Friction	-	Cast iron inner bearing cap.
Sleeve Bearing	-	External and Internal: Labyrinth type stationary shaft seals. Internal: Labyrinth type positive pressurized vapor seal on 2-pole and 4-pole 800 and 1120 frames.
CONDUIT BOX	-	Cast iron, diagonally split, gasketed. Conduit box location F-1 or F-2. Fabricated boxes on special applications and higher horsepowers.
HARDWARE	-	Zinc plated Grade 5 steel hex head bolts and cap screws.
ROTOR	-	Copper bar construction. Copper bars are induction brazed into copper end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots. Unidirectional fans on 2-pole motors.
SHAFT	-	Hot rolled carbon steel.
STATOR CORE	-	Laminations are made from high grade silicon steel stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring.
STATOR WINDING	-	Form wound stators are vacuum pressure impregnated and dipped in epoxy varnish.
VENTILATION	-	Air intake on ends and discharge through sides of top cover. All openings are louvered.
YOKE	-	Fabricated steel plate.

Standard Construction Features

Horizontal Custom
TEFC (Fin-cooled) Enclosure
Type CGZ-500, 580, 708, 788, and 880 Frames

BEARINGS:

Anti-Friction - Open, grease lube bearings standard on all frames.

Split Sleeve - Available on all frames, except 880 frame.

BEARING HOUSING - Cast iron split sleeve construction. Air gap inspection holes on sleeve bearing units.

BEARING SEALS:

Anti-Friction - Cast iron inner bearing cap, bronze or non-metallic rotating external shaft seal.

Split Sleeve - External and Internal: Labyrinth type stationary shaft seals.

CONDUIT BOX - Cast iron, diagonally split, gasketed. Conduit box location F-1 or F-2. Fabricated boxes on special applications and higher horsepowers.

EXTERNAL FAN - The fans on CGZ 2-pole line are of heavy duty plastic. All others are heavy duty aluminum. For other materials refer to factory. Fans are unidirectional on 2-pole motors.

FAN HOUSING - Fiberglass is standard.

HARDWARE - Zinc plated Grade 5 steel, hex headed bolts and cap screws.

ROTOR
- Die cast aluminum rotors are standard on most 500 and 580 frames.
- Copper bar rotors are standard on 708, 788 and 880. Copper bars are induction brazed to end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots.
- Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element. Unidirectional fans on 2-pole motors.

SHAFT - Hot rolled carbon steel.

Standard Construction Features

Horizontal Custom
TEFC (Fin-cooled) Enclosure
Type CGZ-500, 580, 708, 788, and 880 Frames (Cont'd)

STATOR WINDING
- Form wound stators are vacuum pressure impregnated and dipped epoxy varnish.
- Random wound coils on 500 and 580 frames are dipped in polyester varnish.

STATOR CORE
- Laminations are made from high silicon grade steel stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring.

YOKE
- Cast iron construction with integrally cast feet. Drain holes are provided, as well as provisions for dowels and vertical jackscrews in feet.

Standard Construction Features

Horizontal Custom
TEFC (Tube-cooled) Enclosures
Type RAZ-680 and 800 Frames

BEARINGS:

Split Sleeve - Are standard.

Anti-Friction - Open, grease lube bearings are available on 680 frames and 30 frames, 4p and slower.

BEARING HOUSING - Cast iron. Air gap inspection holes on sleeve bearing units.

BEARING SEALS:

Split Sleeve - External and internal labyrinth type. Positive pressurized vapor seal on 2-pole and 4-pole 680 and 800 frame motors.

Anti-Friction - Cast iron inner bearing cap, bronze or non-metallic rotating external shaft seal.

CONDUIT BOX - Cast iron, diagonally split, gasketed. Conduit box location F1 or F2. Low voltage above 540 amps will be fabricated steel.

EXTERNAL FAN - Heavy duty aluminum. For other materials refer to factory. Fans are unidirectional on all motors

FAN HOUSING - Sheet steel. All housings will have separate bolted on screens.

HARDWARE - Zinc plated Grade 5 steel, hex headed bolts and cap screws.

ROTOR - Copper bar rotors are standard. Copper bars are induction brazed to end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots.

- Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element. Unidirectional fans on 2-pole motors.

SHAFT - Hot rolled carbon steel.

Standard Construction Features

Horizontal Custom
TEFC (Tube-cooled) Enclosures
Type RAZ-680 and 800 Frames (Cont'd)

STATOR WINDING - Form wound stators are vacuum pressure impregnated and dipped epoxy varnish.

STATOR CORE - Laminations are made from high grade stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring. Stator core is prebuilt outside of yoke and bolted and doweled in place.

TUBES - Aluminum is standard. Consult factory for other materials.

YOKE - Fabricated steel plate.

Standard Construction Features

Horizontal Custom
Explosion Proof Enclosure
CGZZ and RGZZ 500 Frames

BEARINGS:		
Anti-Friction	-	Open, grease lube bearings standard on all frames.
Split Sleeve	-	Not available.
BEARING HOUSING	-	Cast iron.
BEARING SEALS:		
Anti-Friction	-	Cast iron inner bearing cap, bronze or non-metallic rotating external shaft seal.
CONDUIT BOX		
Anti-Friction	-	Cast iron, diagonally split, gasketed. Conduit box location F-1 or F-2. Fabricated boxes on special applications and higher horsepowers.
EXTERNAL FAN		
Anti-Friction	-	The fans on CGZZ 2-pole motors are of heavy duty plastic. All others are heavy duty aluminum. For other materials refer to factory. Fans are unidirectional on 2-pole motors.
FAN HOUSING	-	Fiberglass used on CGZZ motors.
HARDWARE	-	Zinc plated Grade 5 steel, hex headed bolts and cap screws.
ROTOR	-	Die cast aluminum rotors are standard on most 500 frames.
	-	Copper barr rotors are available. Copper bars are induction brazed to end connectors. Steel solt liners are sized to ensure rotor bars are tight in slots.
	-	Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element. Unidirectional fans on 2-pole motors.
SHAFT	-	Hot rolled carbon steel.

Standard Construction Features

Horizontal Custom
Explosion Proof Enclosure
CGZZ and RGZZ 500 Frames (Cont'd)

STATOR WINDING
- Form wound stators are vacuum pressure impregnated and dipped epoxy varnish.
- Random wound coils are dipped in polyester varnish.

STATOR CORE
- Laminations are made from high grade silicon steel stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring.

YOKE
- Cast iron construction with integrally cast feet. Drain holes are provided, as well as provisions for dowels and vertical jackscrews in feet.

Standard Construction Features

Horizontal Custom
Explosion Proof Enclosure
Type AZZ-30 Frames

BEARINGS:		
Anti-Friction	-	Open, grease lube bearings standard on 30 frames, 4p and slower.
Split Sleeve	-	Available on all frames.
BEARING HOUSING	-	Cast iron. Air gap inspection holes on sleeve bearing units.
BEARING SEALS:		
Anti-Friction	-	Cast iron inner bearing cap, bronze or non-metallic rotating external shaft seal.
Sleeve Bearing	-	External and internal labyrinth type. Positive pressurized vapor seal on 2-pole 30 frames motors.
CONDUIT BOX	-	Cast iron, diagonally split, gasketed. Conduit box location F1 or F2. Low voltage above 540 amps will be fabricated steel.
EXTERNAL FAN	-	Heavy duty aluminum. For other materials refer to factory. Fans are unidirectional on all motors
FAN HOUSING	-	Sheet steel. All housings will have separate bolted on screens.
HARDWARE	-	Zinc plated Grade 5 steel, hex headed bolts and cap screws.
ROTOR	-	Die cast aluminum rotors are standard on some 30 frames.
	-	Copper bar rotors are standard on most 30 frames. Copper bars are induction brazed to end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots.
	-	Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element. Unidirectional fans on 2-pole motors.
SHAFT	-	Hot rolled carbon steel.
STATOR WINDING	-	Form wound stators are vacuum pressure impregnated and dipped epoxy varnish.
	-	Random wound coils on low voltage frames are dipped in polyester varnish.

Standard Construction Features

Horizontal Custom
Explosion Proof Enclosure
Type AZZ-30 Frames (Cont'd)

STATOR CORE - Laminations are made from high grade stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring. Stator core is prebuilt outside of yoke and bolted and doweled in place.

TUBES - Aluminum is standard. Consult factory for other materials.

YOKE - Fabricated steel plate.

Induction Motor Type Designations

Electrical and Insulation Features

T - NEMA Design C or Similar High Starting Torque, Low Slip
H - NEMA Design D or Similar High Torque, High Slip

Basic Designations and Mechanical Features

RG - ODP, WPI, Frames 30, 680, 800, and 1120
CG - ODP, WPI Medallion 507, 509, 5011, 580,and 680 Frames
IG - ODP, WPI Medallion 505, and 508 Frames
A - Tube Cooled 30 Frames
CGII - WPII Medallion 507, 509, 5011, 580, and 680 Frames
FOD - WPII 30, 680, 800 and 1120 Frames
RAZ - Totally Enclosed, Air to Air Cooled 588,5810,680, and 800 Frames
RGG - Totally Enclosed Water to Air Cooled, (TEWAC), 30, 680, 800, and 1120 Frames
CGG - TEWAC Medallion 507, 509, 5011, 580 and 680 Frames
Z - Totally Enclosed, Fan Cooled (TEFC)
ZZ - TEFC, Explosion Proof and/or Dust Ignition Proof

Special Duty, Service or Configuration

F - Flanged Housings, Horizontal 580 Frame, or Smaller Only
I - Partial Motor
P - Pipe-Ventilated Motor
V - Vertical Motor
HS - Vertical Motor with Hollow Shaft
M - TEFC Motor with Separate Fan Motor (TEAO), Medallion Only
HSZ - Tube Cooled, TEFC, Vertical 30 Frame Motor with Hollow Shaft

NEMA Motor Dimensions

Dimension sheets shall be lettered in accordance with the following (also see Figures 2.4.1 through 2.4.5).

Any letter dimension normally applying to the drive end of the machine will, when prefixed with the letter F, apply to the end opposite the drive.

Letter dimensions other than those listed below used by individual manufacturers shall be designed by the prefix letter X followed by A, B, C, D, E, etc.

NEMA Letter	IEC Letter	Dimension Indicated
A	AB	Overall dimension across feet of horizontal machine (end view).
B		BB Overall dimension across feet of horizontal machine (side view).
C	L	Overall length of single shaft extension machine. (For overall length of double shaft extension machine, see letter dimension FC.)
D	H	Centerline of shaft to bottom of feet.
E	...	Centerline of shaft to centerline of mounting holes in feet (end view).
2E	A	Distance between centerlines of mounting holes in feet or base of machine (end view).
2F	B	Distance between centerlines of mounting holes in feet or base of machine (side view).
G	HA	Thickness of mounting foot at H hole or slot.
H	K	Diameter of holes or width of slot in feet of machine.
J	AA	Width of mounting foot at mounting surface.
K	...	Length of mounting foot at mounting surface.
N	...	Length of shaft from end of housing to end of shaft, drive end.
O	HC	Top of horizontal machine to bottom of feet.
P	AC	Maximum width of machine (end view) including pole belts, fins, etc., but excluding terminal housing, lifting devices, feet, and outside diameter of face or flange.
R	G	Bottom of keyseat or flat to opposite side of shaft or bore.
S	F	Width of keyseat.
T	...	Height of eye bolt above top of machine.

NEMA Motor Dimensions

NEMA Letter	IEC Letter	Dimension Indicated
U	D	Diameter of shaft extension. (For tapered shaft, this is diameter at a distance V from the threaded portion of the shaft.)
V	...	Length of shaft available for coupling, pinion, or pulley hub, drive end. (On a straight shaft extension, this is a minimum value.)
W	...	For straight and tapered shaft, end of housing to shoulder. (For shaft extensions without shoulders, it is a clearance to allow for all manufacturing variations in parts and assembly.)
X	...	Length of hub of pinion when using full length of taper, drive end.
Y	...	Distance from end of shaft to outer end of taper, drive end.
Z	...	Width across corners of nut or diameter of washer, on tapered shaft, drive end.
AA	...	Threaded or clearance hole for external conduit entrance (expressed in conduit size) to terminal housing.
AB	AD	Centerline of shaft to extreme outside part of terminal housing (end view).
AC	...	Centerline of shaft to centerline of hole AA in terminal housing (end view).
AD	...	Centerline of terminal housing mounting to centerline of hole AA (side view).
AE	...	Centerline of terminal housing mounting to bottom of feet (end view).
AF	...	Centerline of terminal housing mounting to hole AA (end view).
AG	LB	Mounting surface of face, flange, or base of machine to opposite end of housing (side view).
AH	...	Mounting surface of face, flange, or base of machine to end of shaft.
AJ	M	Diameter of mounting bolt circle in face, flange, or base of machine.
AK	N	Diameter of male or female pilot on face, flane, or base of machine.
AL	...	Overall length of sliding base or rail.
AM	...	Overall width of sliding base or outside dimensions of rails.
AN	...	Distance from centerline of machine to bottom of sliding base or rails.
AO	...	Centerline of sliding base or rail to centerline of mounting bolt holes (end view).
AP	...	Centerline of sliding base or rails to centerline of inner mounting bolt holes (motor end view).
AR	...	Distance between centerlines of mounting holes in sliding base or distance between centerlines of rail mounting bolt holes (side view).
AT	...	Thickness of sliding base or rail foot.
AU	...	Size of mounting holes in sliding base or rail.
AV	...	Bottom of sliding base or rail to top of horizontal machine.

NEMA Motor Dimensions

NEMA Letter	IEC Letter	Dimension Indicated
AW	...	Centerline or rail or base mounting hole to centerline of adjacent motor mounting bolt.
AX	...	Height of sliding base or rail.
AY	...	Maximum extension of sliding base (or rail) adjusting screw.
AZ	...	Width of slide rail.
BA	C	Centerline of mounting hole in nearest foot to the shoulder on drive end shaft. (For machines without a shaft shoulder, it is the centerline of mounting hole in nearest foot to the housing side of N-W dimension.)
BB	T	Depth of male or female pilot of mounting face, flange, or base of machine.
BC	R	Distance between mounting surface of face, flange, or base of machine to shoulder on shaft. (For machine without a shaft shoulder, it is the distance between the mounting surface of face, flange, or base of machine to housing side of N-W dimension).
BD	P	Outside diameter of mounting face, flange, or base of machine.
BE	LA	Thickness of mounting flange or base of machine.
BF	S	Threaded or clearance hole in mounting face, flange, or base of machine.
BH	...	Outside diameter of core or shell (side view).
BJ	...	Overall length of coils (side view). Actual dimensions shall be permitted to be less depending on the number of poles and winding construction.
BK	...	Distance from centerline of stator to lead end of coils.
BL	...	Diameter over coils, both ends (BL = two times maximum radius).
BM	...	Overall length of stator shell.
BN	...	Diameter of stator bore.
BO	...	Length of rotor at bore.
BP	...	Length of rotor over fans.
BR	...	Diameter of finished surface or collar at ends of rotor.
BS	...	Centerline of foot mounting hole, shaft end, to centerline of terminal housing mounting (side view).
BT	...	Movement of horizontal motor on base or rail.
BU	...	Angle between centerline of terminal housing mounting and reference centerline of motor (end view).
BV	...	Centerline of terminal housing mounting to mounting surface of face or flange (side view).

NEMA Motor Dimensions

NEMA Letter	IEC Letter	Dimension Indicated
BW	...	Inside diameter of rotor fan or end ring for shell-type and hermetic motors.
BX	...	Diameter of bore in top drive coupling for hollow-shaft vertical motor.
BY	...	Diameter of mounting holes in top drive coupling for hollow-shaft vertical motor.
BZ	...	Diameter of bolt circle for mounting holes in top drive coupling for hollow-shaft vertical motor.
CA	...	Rotor bore diameter.
CB	...	Rotor counterbore diameter.
CC	...	Depth of rotor counterbore.
CD	...	Distance from the top of coupling to the bottom of the base on Type P vertical motors.
CE	...	Overall diameter of mounting lugs.
CF	...	Distance from the end of the stator shell to the end of the rotor quill at compressor end. Where either the shell or quill is omitted, the dimension refers to the driven load end of the core.
CG	...	Distance from the end of the stator shell to the end of the stator coil at compressor end.
CH	...	Distance from the end of the stator shell to the end of the stator coil at end opposite the compressor.
CL	...	Distance between clamp-bolt centers for two-hole clamping of universal motor stator cores.
CO	...	Clearance hole for maximum size of clamp bolts for clamping universal motor stator cores.
DB	...	Outside diameter of rotor core.
DC	...	Distance from the end of stator shell (driven load end) to the end of rotor fan or end ring (opposite driven load end). Where the shell is omitted, the dimension is to the driven load end of the stator core.
DD	...	Distance from the end of stator shell (driven load end) to the end of rotor fan or end ring (driven load end). Where the shell is omitted the dimension is to the driven load end of the stator core.
DE	...	Diameter inside coils, both ends (DE = 2 times minimum radius).
DF	...	Distance from driven load end of stator core or shell to centerline of mounting hole in lead clip or end of lead if no clip is used.
DG	...	Distance from driven load end of stator core or shell to end of stator coil (opposite driven load end).

NEMA Motor Dimensions

NEMA Letter	IEC Letter	Dimension Indicated
DH	...	Centerline of foot mounting hole (shaft end) to centerline of secondary terminal housing mounting (side view).
DJ	...	Centerline of secondary lead terminal housing inlet to bottom of feet (horizontal).
DK	...	Centerline of machine to centerline of hole “DM” for secondary lead conduit entrance (end view).
DL	...	Centerline of secondary lead terminal housing inlet to entrance for conduit.
DM	...	Diameter of conduit (pipe size) for secondary lead terminal housing.
DN	...	Distance from the end of stator shell to the bottom of rotor counterbore (driven load end). Where the shell is omitted, the dimension is to the driven load end of the stator core.
DO	...	Dimension between centerlines of base mounting grooves for resilient ring mounted motors or, on base drawings, the dimension of the base which fits the groove.
DP	...	Radial distance from center of Type C face at end opposite drive to center of circle defining the available area for disc brake lead opening(s).
DQ	...	Centerline of shaft to extreme outside part of secondary terminal housing (end view).
EL	...	Diameter of shaft after emergence from the mounting surface of face or flange.
EM	...	Diameter of shaft first step after EL.
EN	...	Internal threaded portion of shaft extension.
EO	...	Top of coupling to underside of canopy of vertical hollow-shaft motor.
EP	...	Diameter of shaft at emergence from bearing (face or flange end).
EQ	...	Length of shaft from mounting surface of face or flange to EL-EM interface.
ER	...	Length of shaft from EP-EL interface to end of shaft.
ES	...	Usable length of keyseat.
ET	...	Length of shaft from mounting surface of face or flange to EM-U interface.
EU	...	Diameter of shaft at bottom of ring groove.
EV	...	Distance between centerline of H hole and end of motor foot at shaft end (side view).
EW	...	Width of the ring groove or gib head keyseat.
EX	...	Distance from end of shaft to opposite side of ring groove keyseat.
FC	...	Overall length of double shaft extension machine. (For overall length of single shaft extension machine, see letter dimension C.)

NEMA Motor Dimensions

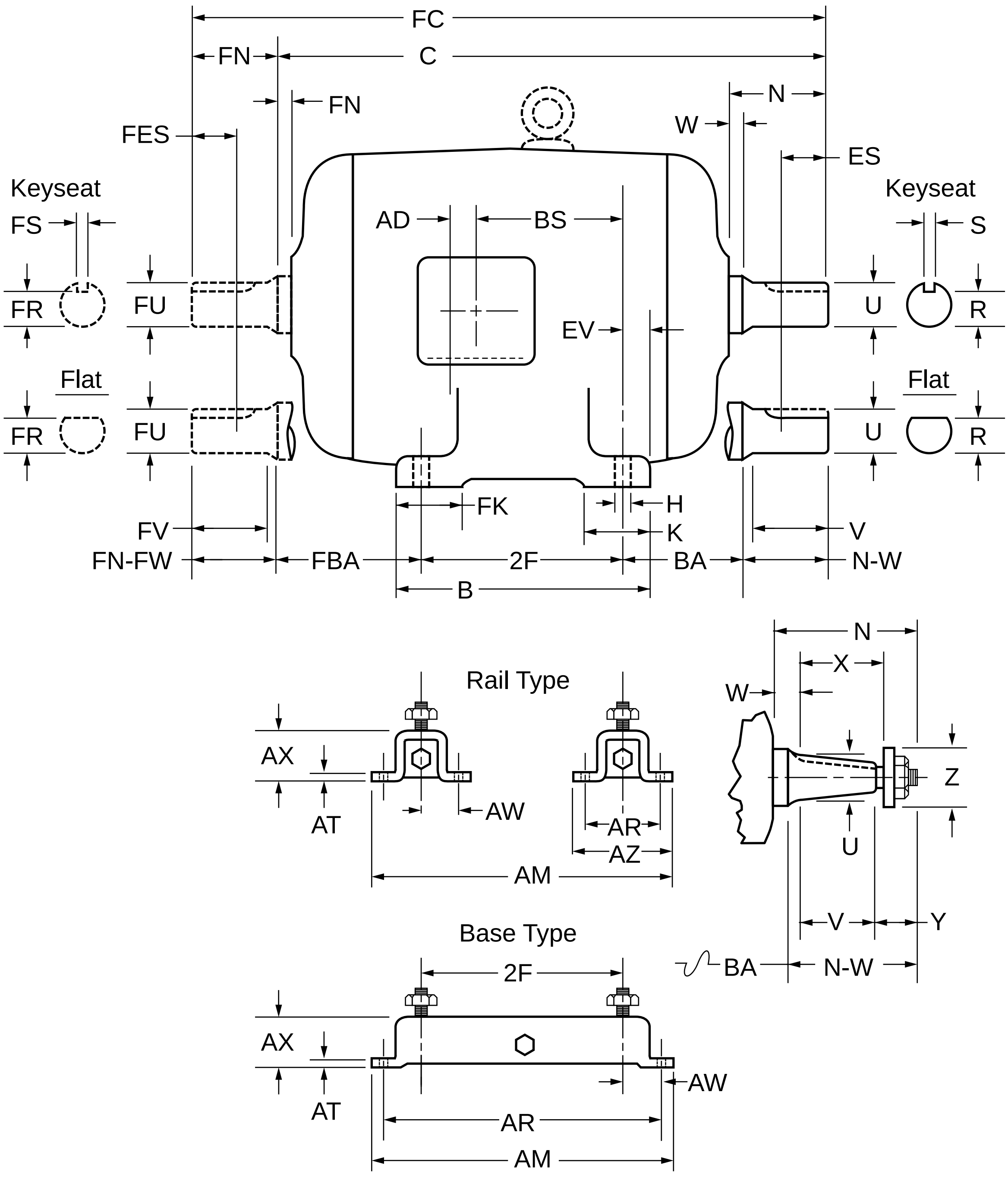


Figure 2.4.1
Lettering of Dimension Sheets for foot-mounted machines-side view

NEMA Motor Dimensions

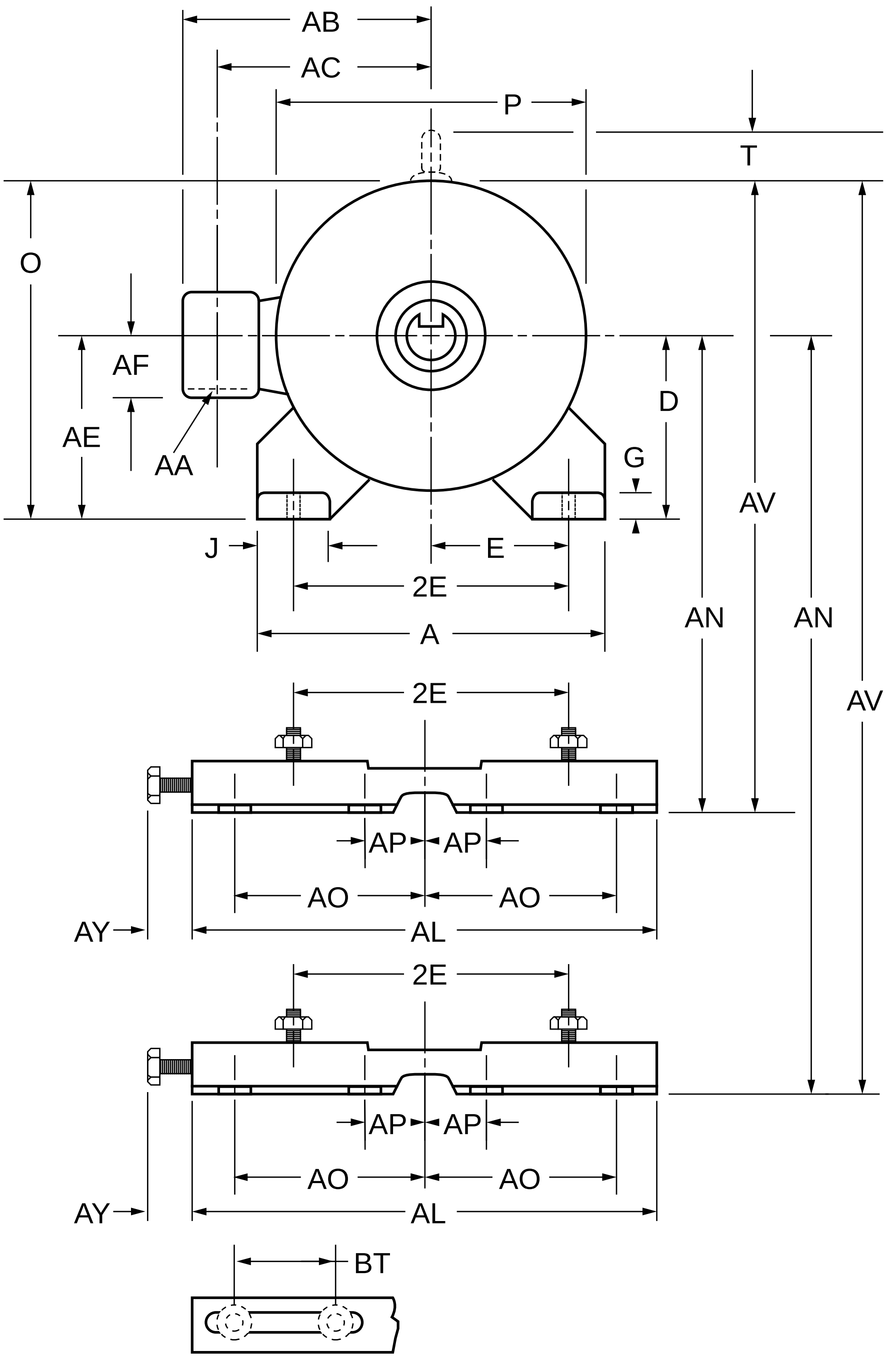


Figure 2.4.2
Lettering of Dimension Sheets for foot-mounted machines-drive end view

NEMA Motor Dimensions

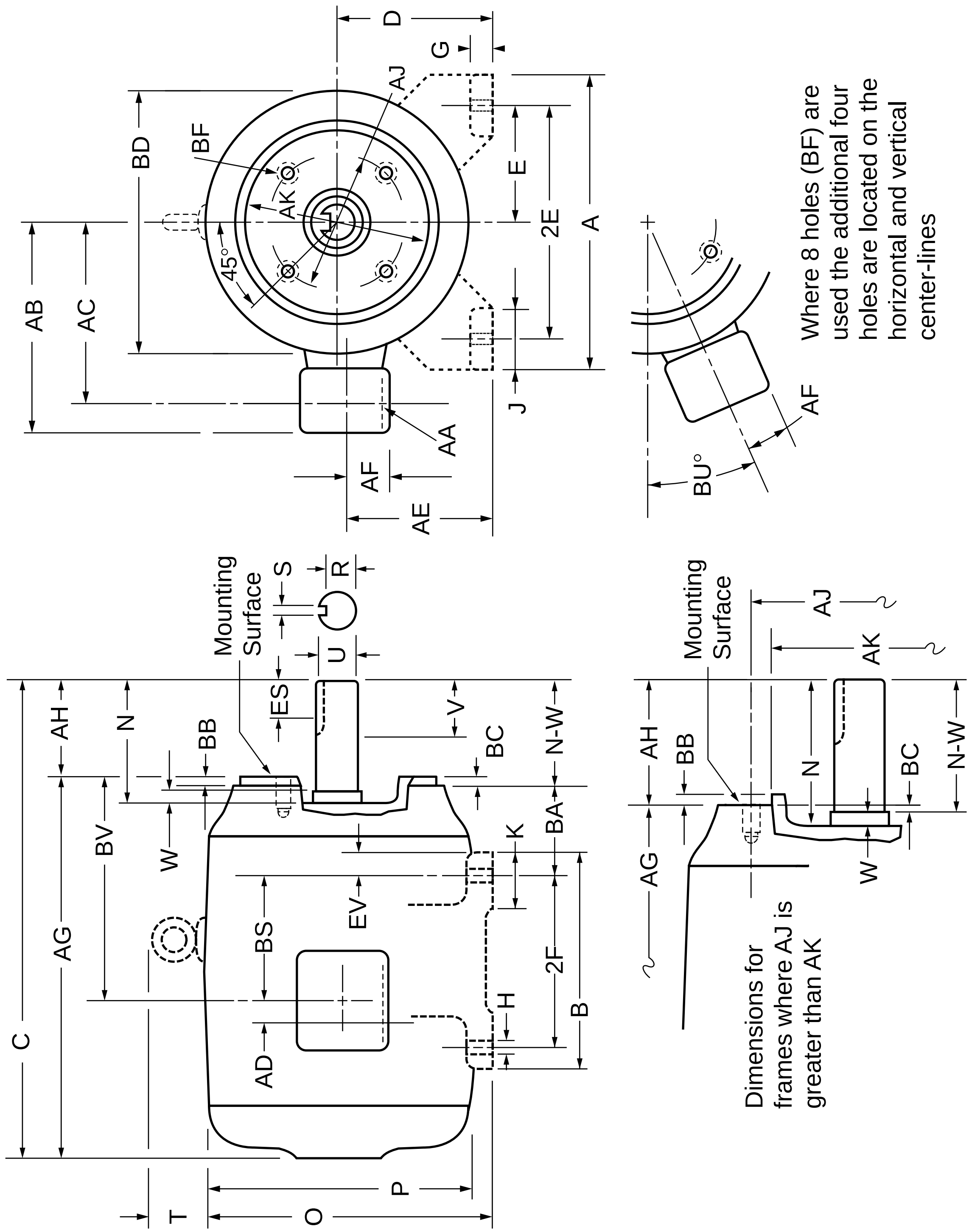


Figure 2.4.3
Lettering of Dimension Sheets for Type C Face-mounting foot or footless machines

NEMA Motor Dimensions

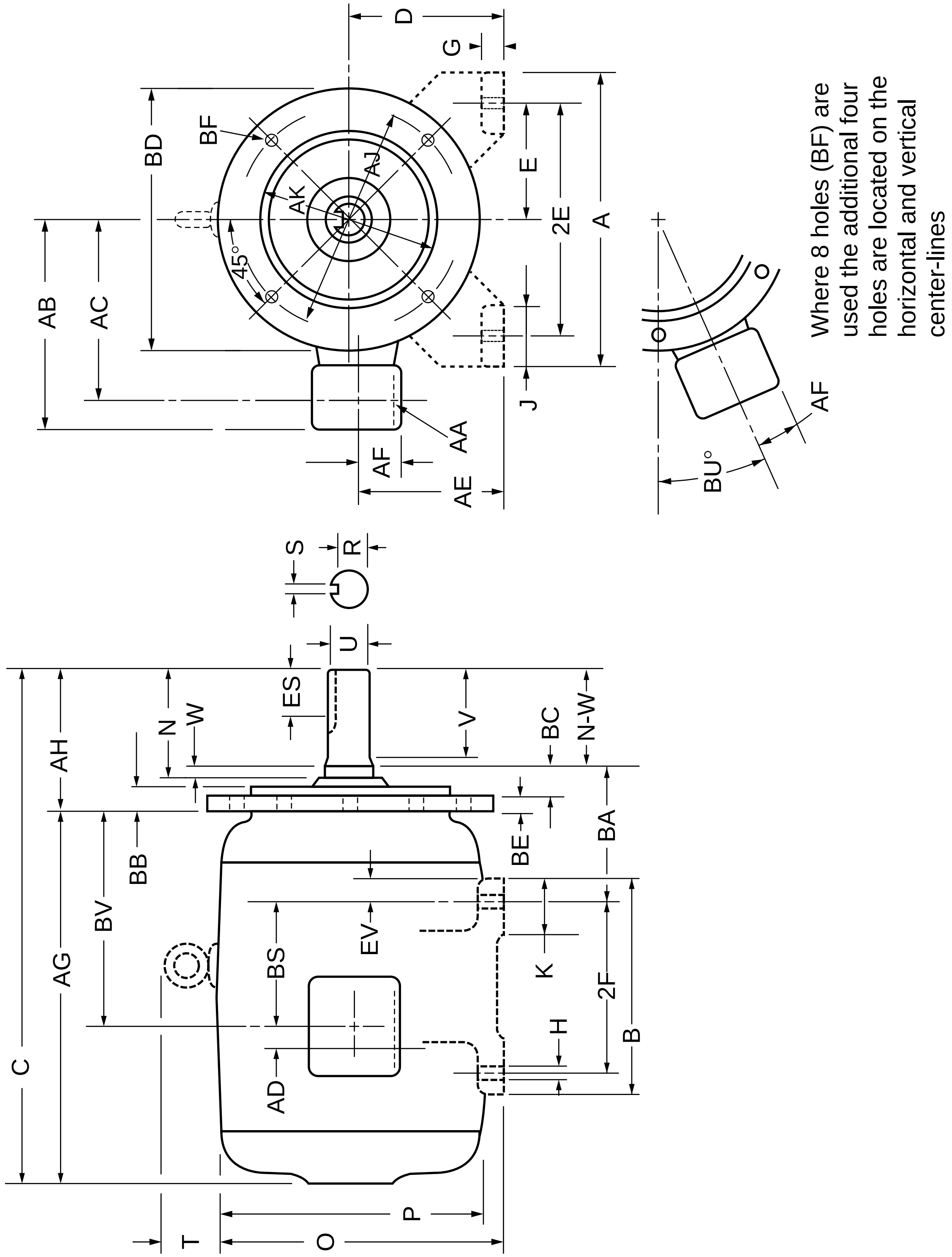


Figure 2.4.4
Lettering of Dimension Sheets for Type D Flange-mounting or footless machines

NEMA Motor Dimensions

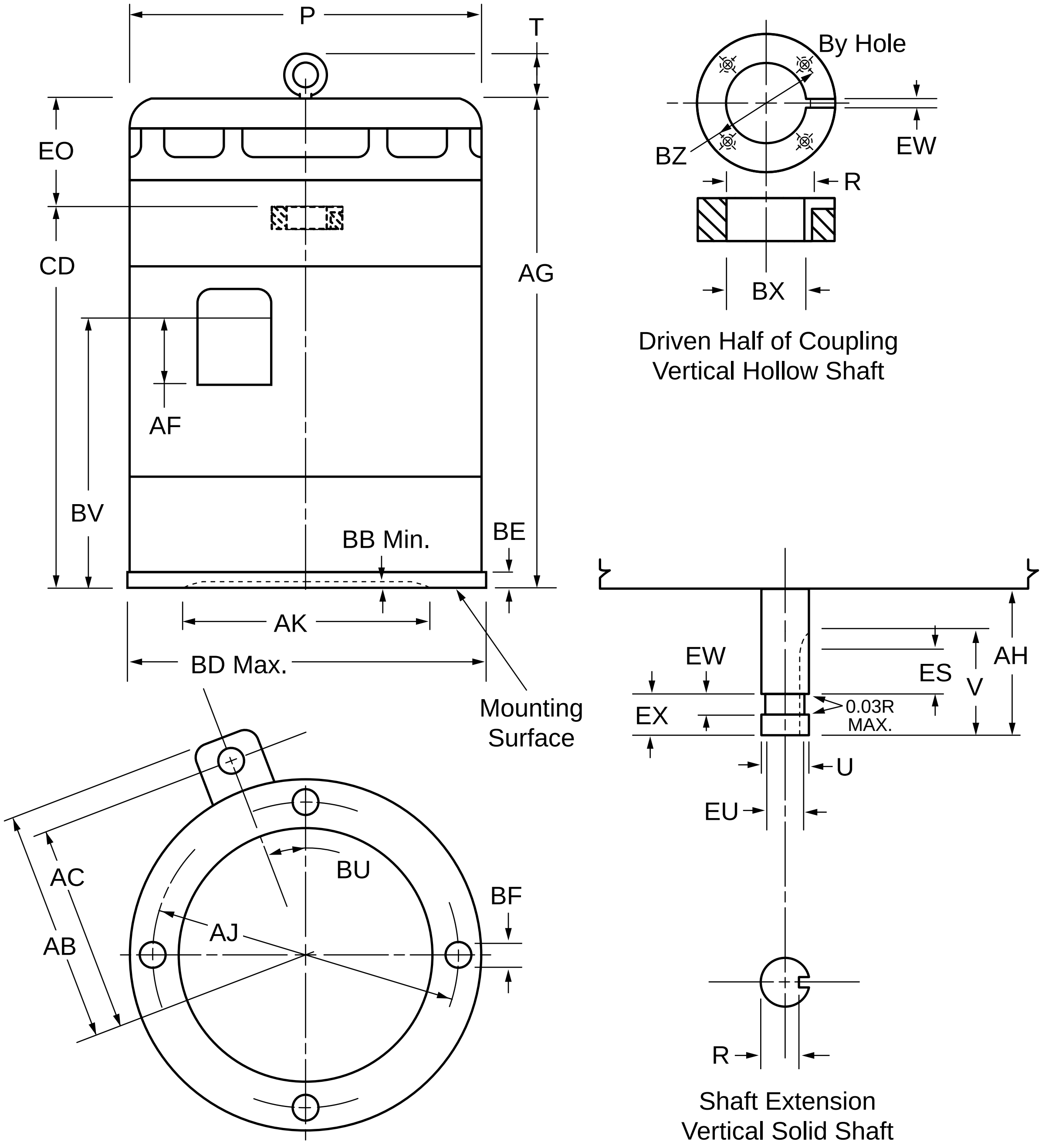


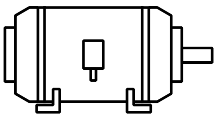
Figure 2.4.5
Lettering of Dimension Sheets for vertical machines

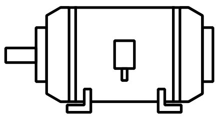
NEMA Motor Dimensions

Symbols for machine mounting assemblies

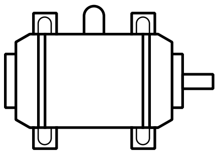
Assembly symbols for floor-, wall-, and ceiling-mounting machines shall be as follows

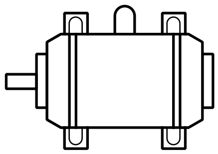
Floor Mountings

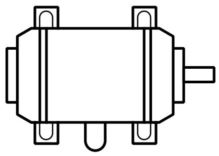

Assembly F-1

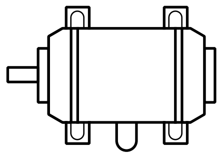

Assembly F-2

Wall Mountings


Assembly W-1


Assembly W-2


Assembly W-3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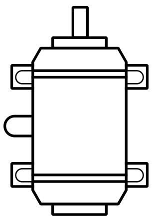
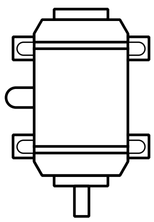
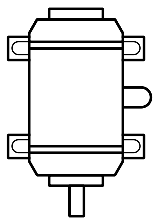
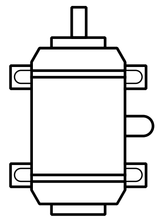
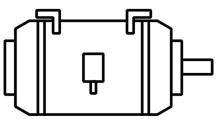

Assembly W-5

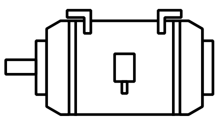

Assembly W-6


Assembly W-7


Assembly W-8

Ceiling Mountings


Assembly C-1


Assembly C-2

Assembly symbols F-1, W-2, W-3, W-6, W-8, and C-2 show the terminal housing in the same relative location with respect to the mounting feet and the shaft extension.

Basic Theory Index

Electric Motor Theory

Electric motors provide one of the most versatile sources of mechanical power for industry. A motor is a device which converts or transforms electrical energy into mechanical energy.

In order to understand how a motor operates, it is necessary to be familiar with magnetism and the effect of magnetic fields on ferrous or iron material placed in close proximity to the magnet. Consider a common permanent bar "horseshoe" shaped magnet. If we placed a transparent paper above the magnet and sprinkled iron shavings onto the paper, we would notice that the shavings would be attracted to the ends of the magnet. We shall call these points of concentrated magnetic strength "poles". For convenience we can label these poles north and south. Separate poles actually do not exist, however, there must always be two poles (a pair of poles) in every magnet. We can see that the magnetic field is the strongest between the poles of a magnet (See Figure 3.1.1.)

Just as we have named the poles north and south for sake of clarity, we can establish a means of defining the magnetic field strength. Magnetic field strength is proportional to the quantity or density of the invisible lines of force present. These lines of force are called "flux" and the number of lines of force per unit area is called "flux density" (See Figure 3.1.2).

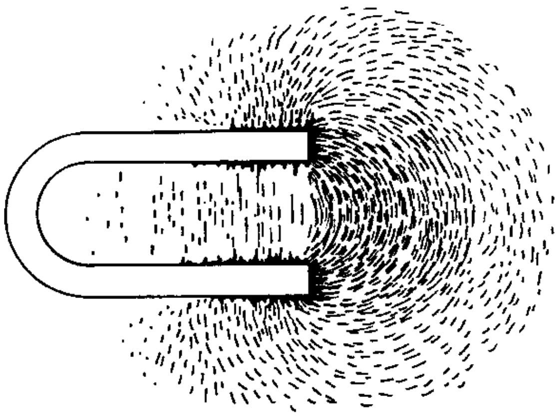


Figure 3.1.1

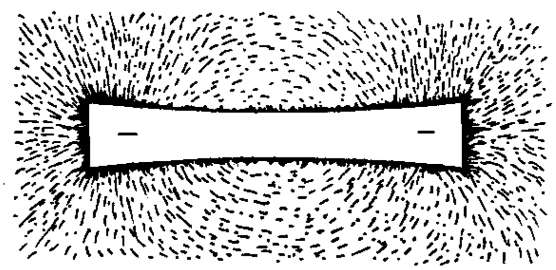


Figure 3.1.2

By further experimentation using two magnets, we can quickly show that each pole of a magnet is different since placing the magnet together with ends touching, we will note that in one position the poles attract, whereas in the reverse position, the poles repel each other. It can quickly be deduced that like poles repel and unlike poles attract each other (See Figure 3.1.3).

Electric Motor Theory

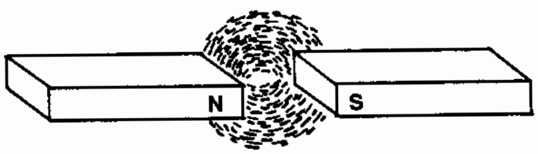


Figure 3.1.3

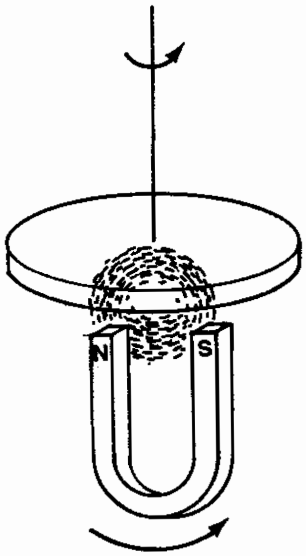


Figure 3.1.4

If we now suspend an iron disk from a string and then place the "horseshoe" magnet below, without touching the disk, and rotate the magnet, we will note the disk also turns. In essence, we have induced magnetic poles into the disk and these poles cause the disk to follow the rotation of the permanent magnet (See Figure 3.1.4).

A field, its lines of flux, can also be produced by passing an electric current through a wire conductor. An electric current is the flow of electric charges from one point to another. Current flows from positive to negative and is dependent upon electrical pressure, voltage, impressed across these two points. As the voltage is increased, the current is also increased. Field, and flux, can be increased by increasing the current. This can be accomplished by either increasing the voltage or increasing the number of wires carrying a current of constant magnitude. To improve flux concentration, the wires are formed into a coil (See Figure 3.1.5).

Flux density is dependent upon the magnetic field present and the ability of the surrounding materials to carry the flux. The ability to carry the flux is called permeability. Since air has a very low permeability, we can increase the flux density by inserting into the coil a material having a higher permeability such as iron.

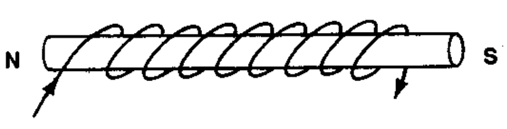


Figure 3.1.5

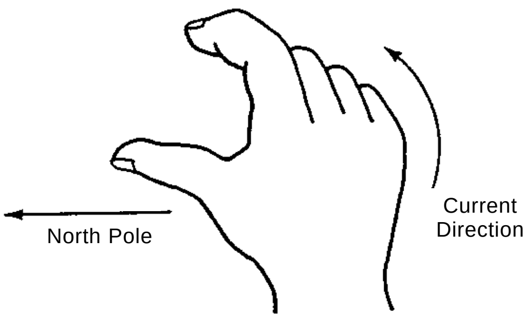


Figure 3.1.6

The relationship of field intensity, flux density, current, and permeability can be explained as follows:

1. Field intensity is directly proportional to current (H ∞ I)

2. Current is directly proportional to voltage (I ∞ V)

3. Flux density is directly proportional to magnetic field intensity
   and permeability (B µ H)

   where
   B = flux density
   I = current
   V = voltage
   µ = relative permeability, air equals 1 and iron is more than 1
   H = field intensity

Experimentation shows that the polarity of the poles can be predetermined and is dependent upon the direction of current flow in the coil. If we place our right hand with the palm towards the coil so that our fingers point in the direction of current flow, our thumb will point toward the north pole (See Figure 3.1.6).

Let us now make a crude motor consisting of a stationary U shaped iron bar having a wire coiled around it and another iron bar, free to turn, placed between the openings of the stationary member. The stationary member is called a stator and the rotating "free to turn" bar is called a rotor. The rotor also has a coil of wire wrapped around it, however, the rotor coil is continuous; that is, its ends are

Electric Motor Theory

connected together. If we pass a current through the stator wire, poles will be established in the stator. The magnetic field established by the stator poles will induce a voltage in the rotor coil causing a current to flow in the rotor coil. This induced rotor current establishes its own magnetic field and poles. The inducing of current in the rotor by the stator field is called transformer action. The stator is often referred to as the "primary" and the rotor as the "secondary".

The interaction of stator poles and induced rotor poles exerts a force causing the rotor to align itself or turn 90 degrees. If the stator is de-energized just as the rotor completes the first 90 degrees of rotation, it will coast. Let us allow the rotor to coast until it is slightly past the midpoint between poles. Now re-energize the stator winding or coil, however, reverse the direction of current flow. This causes the stator poles to be reversed in polarity and causes continued rotation of the rotor.

Again the coil must be de-energized until the rotor coasts slightly past the midpoint between poles completing 360 degrees of rotation. Again we can change direction of current flow, reverse the polarity of the stator and continue the cycle causing the rotor to continuously turn.

This is an electric motor (See Figure 3.1.7).

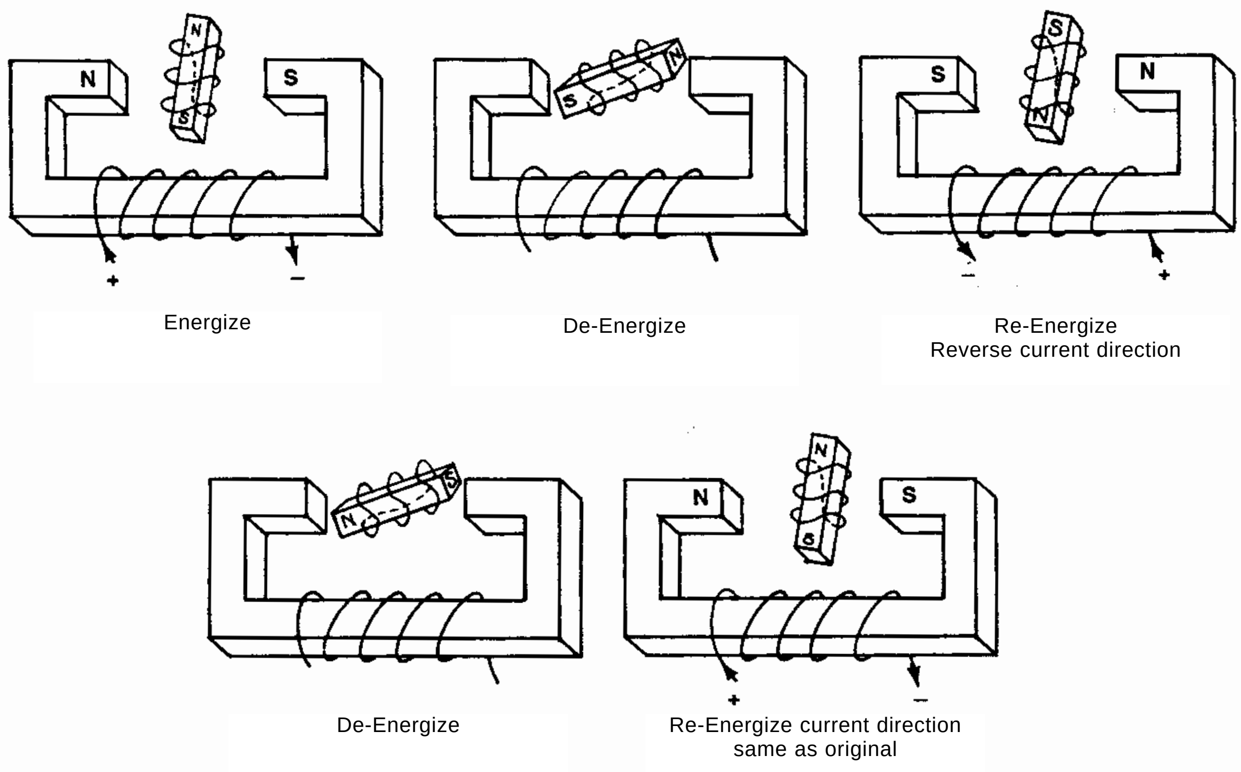


Figure 3.1.7

Electric Motor Theory

In our crude motor it was necessary to produce a magnetic field in the stator which by transformer action, caused the rotor to turn. Continuous rotation was accomplished by mechanically switching the direction of current flow in the stator coil.

Let us investigate a more practical way of obtaining a pulsating electrical field by employing an alternating current source of power. Alternating current, A.C., is an electric current having a regularly changing polarity. In other words, the current is continually changing direction or cycling from positive to negative. The rapidity of polarity change per second is referred to as cycles per second or merely frequency. The rate of polarity change is constant, however, the current magnitude is constantly changing with respect to time. This can be represented by a curve-plotting current magnitude versus time (See Figure 3.1.8).

In a motor, the relative direction of flux, current and motion can best be explained by Flemings left hand rule. If we place thumb, index and middle finger so as to form three axes of a coordinate system and then point the finger in the direction of the stator flux, (north to south) the middle finger in the direction of current in the rotor conductor, the thumb will indicate the direction of force and, therefore, the resulting motion. The force referred to in Flemings rule is the result of the interaction of stator poles and rotor poles. The rotor poles are caused by voltages and currents induced into the rotor by the magnetic stator field (See Figure 3.1.9).

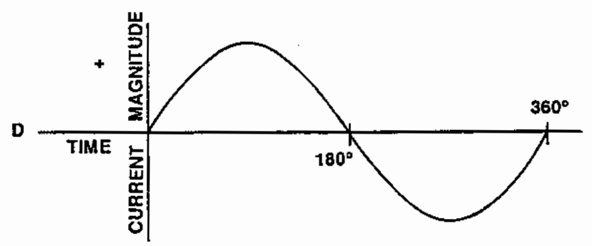


Figure 3.1.8

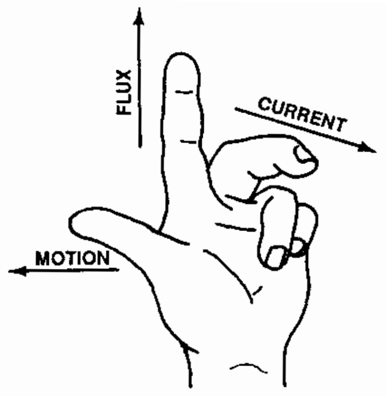


Figure 3.1.9

The continual fluctuation of the current, both in magnitude and polarity, causes a continually changing, alternating, magnetic field and resulting force.

In actual practice the winding is distributed in slots around the stator. We can consider this a concentrated coil. The stator current, stator field, and flux are all alternating in magnitude.

Electric Motor Theory

In our crude motor stator, a disproportionate share of the flux and field strength produced by the current carrying coils is wasted or ineffective.

As a material is magnetized, the internal molecular alignment changes. Small elementary magnets are set up within the material. As a magnetic field passes through a material, it induces north and south poles in the elementary fields which, in turn, align and cause the material itself to have a north and south pole. When the magnetic field is removed, the elementary magnets called dipoles will tend to return to their original position because of the inherent molecular stresses in the material itself. Each time the magnetic field is applied or removed, the dipoles change their physical position. This movement generates heat and is defined as hysteresis loss. The magnitude of this loss is dependent upon flux density and the grade and quality of the material (See Figure 3.1.10).

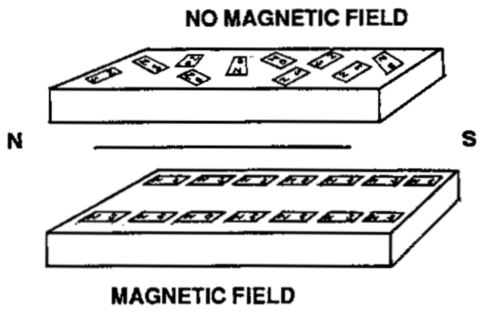


Figure 3.1.10

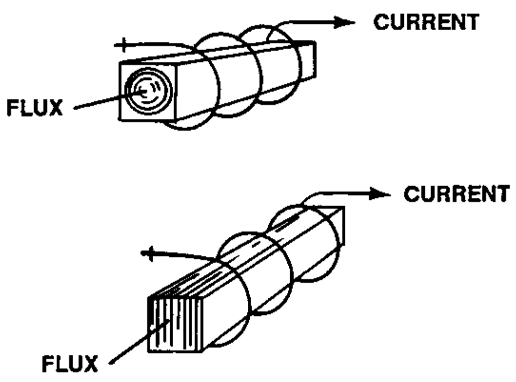


Figure 3.1.11

Small recirculating currents called eddy currents are induced within a material as the flux through the material is changed (either increased or decreased). These eddy currents create internal losses within the material and display themselves in heat. By constructing the stator core of thin laminations insulated from each other, these eddy currents can be restricted to each lamination. By this restriction, their magnitude can be decreased (See Figure 3.1.11).

The choice of material, thickness used, and its chemical content is made by the Design Engineer based on such considerations as permeability, heat transmission, handling ease in manufacturing and cost. In general, special electrical grade sheet steel having a thickness of .01 to .03 inches is used. The insulating barrier between laminations consists of an oxidized film on the lamination itself or special plating of the lamination steel with varnishes or resins. These insulating barriers generally have a thickness of .0003 inches or less.

Electric Motor Theory

Although it would be possible to wrap the coils of wire around the laminated stator core in order to produce the magnetic field, it is more practical to place the coils in slots formed in the inside diameter or the bore of the stator. This is done to provide a more even flux distribution, maximum flux concentration and to utilize both sides of the coil.

It is necessary to isolate or insulate the current carrying members from the stacked stator laminations or stator core to prevent electrical shorting. The materials used to isolate the copper wire from the stator core are called insulators and are further defined as to their use. Insulators, materials which resist the flow of electrical currents, must be provided around each wire and within the stator slot.

The coils are physically placed in the stator slot in such a manner that when energized, the magnetic field and its corresponding poles are produced.

It has been determined that laminated electrical grade steel should be used to form the stator core to reduce the eddy current and hysteresis losses. For the same reasons, the rotor should be made up of laminated electrical grade steel which has been formed with grooves in the periphery. Current carrying bars or conductors are placed in these rotor grooves or slots so as to facilitate the passage of the induced currents. The bars are then connected at the ends of the rotor by means of rings which complete the electrical circuit. The bars and end rings look somewhat like an exercise cage for squirrels, hence the rotor is termed a squirrel cage type.

Rotor Bars and End Rings
Squirrel Cage Rotor

Laminated Core

Figure 3.1.12

Electric Motor Theory

The pulsating field strength can be graphically shown by considering a coil having A.C. current flowing through it. The field will build up and collapse at right angles to the coil. At time (T1) the field is at maximum strength and we will assume north polarity. At time (T2) the field is still of north polarity, however, slightly reduced in magnitude. At time (T3) no current is flowing, therefore, the field is at zero strength. At time (T4) the field is again building up, however, is of south polarity because the current flow has been reserved. At time (T5) the field is at maximum strength and south polarity.

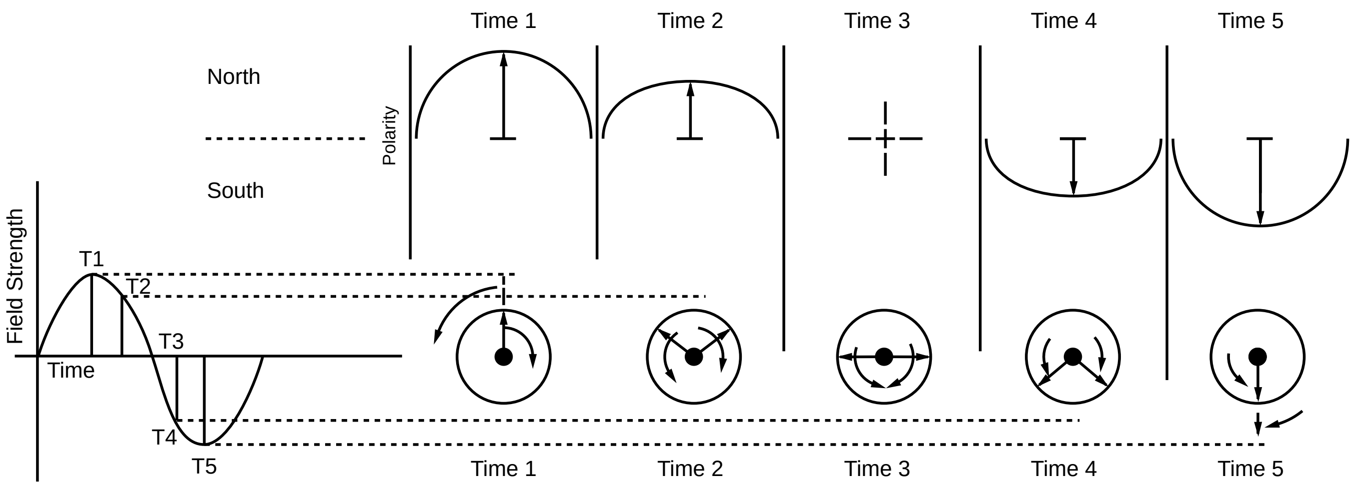


Figure 3.1.13
Field Strength with Respect to Time

Since we know the field strength is pulsating at a constant rate with respect to time, it can be represented by a curve plotting field strength with respect to time.

This curve, representing magnetic field strength at specific points in time, is obtained by considering the field strength as a vector, a line having both magnitude and direction. The magnetic field strength vector is stationary in space, but continually alternating with respect to time. For theoretical purposes and to better understand the operation of a motor, we can consider the field strength vector as the sum of two opposing revolving field strength vectors equal in magnitude. Since there is only one stator winding and one stator current, the same stator current must and does set up both revolving and opposing fields.

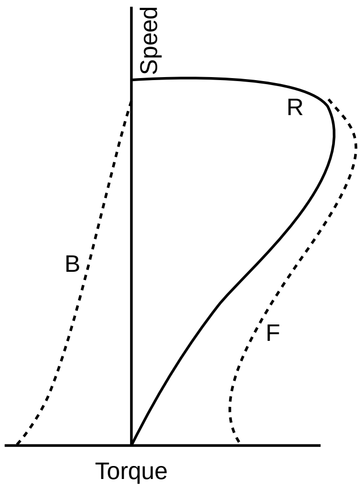
Electric Motor Theory

When the rotor is at rest, and the stator energized, the opposing revolving fields cancel each other resulting in a pulsating field. Because the stator field is pulsating, currents are induced into the rotor by transformer action. These induced rotor currents produce a magnetic rotor field opposing the stator field. Since the stator and rotor fields are in line and opposing each other, no turning effort or torque is produced and the motor won't start. In essence, the motor is merely a transformer with a shorted secondary.

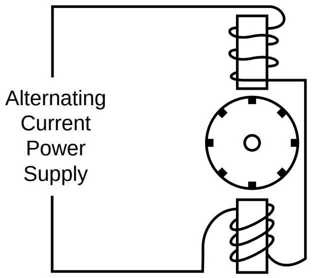
If the rotor is made to turn (started by auxiliary means eg. by hand), the rotor bars or conductors pass through the flux lines produced by the stator field and voltages and currents are induced in the rotor bars. The induced rotor voltages and currents set up their own field, poles, etc. which adds to the stator flux of the stator "forward rotating field" and decreases the stator flux of the "backward rotating field".

The resulting rotating stator flux is stronger in the forward direction of rotation.

The resultant stator field and induced rotor field will try to align. This causes the rotor to continue to turn. The effective increase in the forward flux and decrease in the backward flux which causes the rotor to continually turn after it is mechanically started is slight at low speeds, but improved as the rotor speed increases (See Figure 3.1.14).



F = Speed/Torque curve Foward Rotating Field
B = Speed/Torque curve Backward Rotating Field
R = Resultant or Actual Speed/Torque



Simple Alternating Current
Electric Motor

Figure 3.1.14

Electric Motor Theory

The motor discussed in Section 3 would continually run if supplied with an A.C. current, however, this motor would not start by itself. This motor is energized by a single A.C. current source or phase supplied to the stator, hence is called a single phase A.C. motor.

Let us consider multiple, separate A.C. currents supplying the stator at the same time via separate stator windings. Each current will be displaced in time from any other current. Each separate source is referred to as a phase. An A.C. 3 phase motor then actually has 3 current sources.

Let us mount 6 metal bars equally spaced within a circular frame. Now place coils of wire around these bars and connect the coils which are physically spaced 180 degrees apart, together in pairs. Let us now supply each pair of stator coils with a separate alternating current. Each alternating current must be "electrically timed" so that each current reaches its positive maximum in proper sequence.

Probably the easiest way to understand the electrical timing is to consider a circle (360 degrees). When the maximum current of phase A is electrically at 0 degrees, the maximum currents of phase B and C will be at 120 and 240 degrees respectively. We have already seen, that supplying the stator coils with alternating current, a pulsating magnetic field and flux resulted. This in turn produced a field which rotated simultaneously both in the forward and backward direction. If the rotor was manually turned, the energized stator would create a rotating field due to the transformer action between rotor and stator (See Figure 3.1.15).

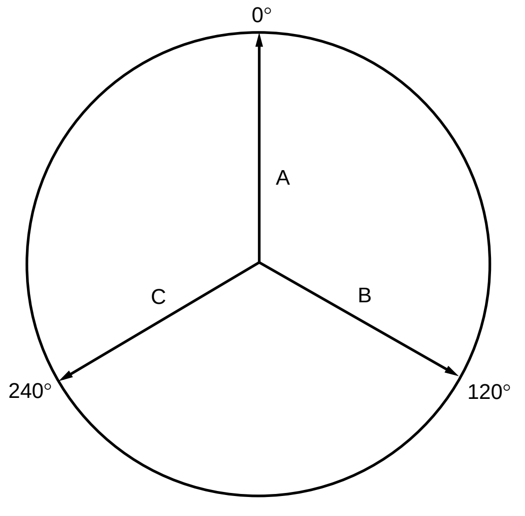


Figure 3.1.15
Phase Relationship

Electric Motor Theory

Our multiple or 3 phase motor is essentially 3 single phase motors combined into one unit. Each phase is providing a pulsating field in perfect time sequence (120 electrical degrees apart from the previous phase).

The coils in the stator are connected so that they produce "positive" or "negative" coil groups. In other words, a positive connected coil group will produce a north pole when the current flowing through it is positive and will produce a south pole when the current flowing through it is negative. Conversely, the negative coil group produces a north pole when the current flowing is negative (See Figure 3.1.16).

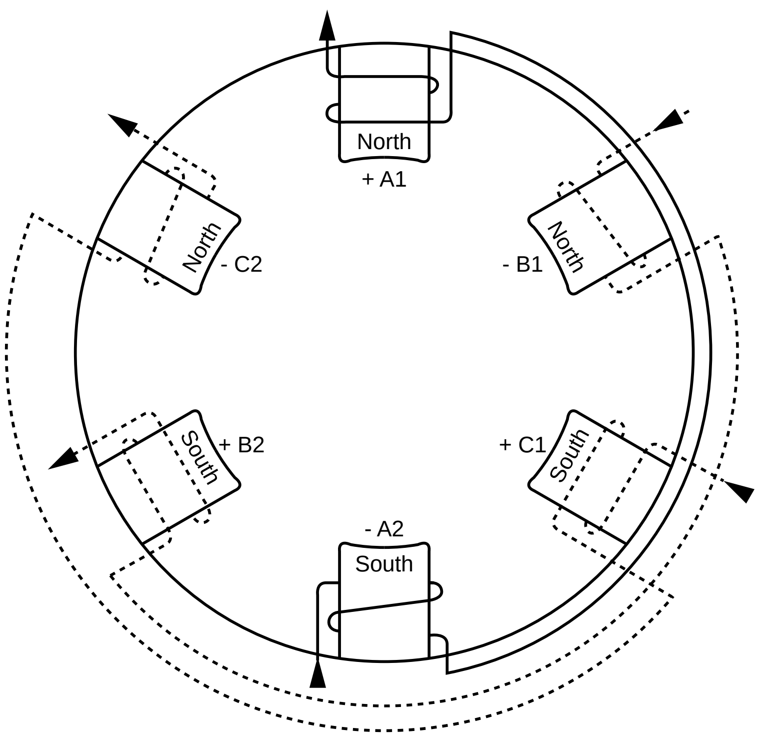


Figure 3.1.16
Coil Identification and Connection Polarity
Current Flow (Direction) Shown at Time T1

The effect of magnitude and direction of the flux wave can be illustrated by a graphical display of the pulsating current for each phase at specific instants of time. We must simultaneously consider the direction of the flux produced by the current flow in each phase. This can best be seen by unfolding the coil groups shown in Figure 3.1.16 into a straight line. We will assign the same connection polarity of the coil groups as shown in Figure 3.1.16.

General Power Supply Variation

Induction motors will operate successfully under the following conditions of voltage and frequency variation, but not necessarily in accordance with the standards established for operating under rated conditions:

1. Where the variation in voltage does not exceed 10% above or below normal, with all phases balanced
2. Where the variation in frequency does not exceed 5% above or below normal.
3. Where the sum of the voltage and frequency variations does not exceed 10% above or below normal (provided the frequency variation does not exceed 5%).

The approximate variations in motor performance, caused by these deviations from nameplate values, are discussed on the following pages.

The effect of electrical supply variations on motor performance should be considered when selecting and applying A.C. Induction Motors. Variation in motor supply voltage and frequency may cause:

1. An increase in motor torque and/or speed which may be damaging to the driven machine.
2. A decrease in motor torque and/or speed which may cause a reduction in output of the driven machine.
3. Damage to the motor.

Although the A.C. Induction Motor is designed to successfully operate when subjected to slight variations in power supply voltage and frequency, the performance (torque, speed, operating temperature, efficiency, power factor) is optimum when the power supply voltage and frequency is in accordance with the motor nameplate values.

Power supply variations may be classified into three categories:

1. Frequency variation from rated.
2. Unbalanced voltage between phases.
3. Balanced phase voltage with voltage variation from rated value.

For ease of understanding, we shall consider the singular effect each of the preceding categories has on motor performance. In actual practice, it is common to simultaneously encounter a combination of two or more of the power supply variations listed in the preceding three categories, hence the combined effect will be resultant of each singular effect; in other words, the effect of a particular variation will be superimposed upon the effect of another variation.

Unbalanced Voltage Between Phases

The multiple phase A.C. induction motor is designed for use on a balanced voltage system; that is, the voltage in each phase is equal. When the voltage of each phase is unequal, a small rotating magnetic field is created. This magnetic field rotates in the opposite direction of the main magnetic field, therefore, it in effect is a "bucking" field causing induced voltages and resultant high currents. To determine the effect of unbalanced phase voltages on motor performances, it is necessary to express the voltage unbalance in percent as shown in the following formula:

Example: $$\%\ \text{Volts Unbalance} = \frac{\text{Max. Volts deviation from avg. volts}}{\text{avg. volts}} \times 100$$

Actual phase voltages at motor terminal of 3 phase motor are 236, 229, 225 volts.

$$\text{Average Voltage} = \frac{236 + 229 + 225}{3} = 230 \text{ volts}$$

Determine Maximum Voltage Deviation From Average Voltage.

236 Volts	230 Volts	230 Volts
230 Volts	229 Volts	225 Volts
6	1	5

Maximum Voltage Deviation from Average Voltage = 6 Volts

$$\%\ \text{Voltage Unbalanced} = \frac{6}{230} \times 100 = 2.61\%$$

Current

In general, a small voltage unbalance on any type of induction motor results in a considerably greater current unbalance. For a given voltage deviation, the current deviation is greatest at no load and decreases with loading with the least effect being exhibited under locked conditions. This phenomenon is conveniently shown in the following graph (Figure 3.1.17).

Electric Motor Theory

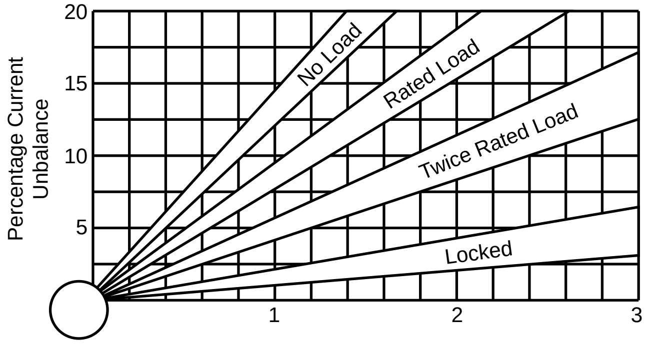


Figure 3.1.17
Percent Voltage Unbalanced

Full Load Speed

Unbalance phase voltage does not appreciably affect full load motor speed. There is a slight tendency for the full load speed to be reduced as the percentage of phase voltage unbalance increases.

Torque

Unbalanced phase voltages have little practical effect on A.C. induction motor torques.

$$\text{Torque with unbalanced phase voltage expressed as a percent of full load torque} = \text{Torque with balanced phase voltage expressed as a percent of full load torque} \times K \times \left[1 - \left(\frac{\%\ \text{voltage unbalanced}}{100}\right)^2\right]$$

Where K = 1 for locked rotor torque (LRT) and 2 for breakdown torque (BDT)

Electric Motor Theory

Example:
Let locked rotor torque (balanced) = 150% of full load torque and voltage unbalance = 2.61%

$$\text{Torque with unbalanced phase voltage expressed as a percent of full load torque} = 150 \times 1 \times \left[1 - \left(\frac{2.61}{100}\right)^2\right] = 149.9\%$$

Motor Temperature
A small unbalanced phase voltage will cause a significant increase in motor temperature. Although there is no exact formula to determine the effect of voltage phase unbalance on temperature rise, laboratory tests indicate the percentage increase in motor temperature is approximately equal to twice the square of the percentage voltage unbalance. This can be expressed by the following formula:

$$\text{Temp. rise on unbalanced system} = \text{Temp. rise on unbalanced system} \times \left[1+2\left(\frac{\%\text{ voltage unbalanced}}{100}\right)^2\right]$$

Example:
Let the voltage unbalance = 2.61 % and the full load motor temperature rise at balanced voltage be equal to 80°C.

$$\text{Temp. rise on unbalanced system} = 80°\text{C} \times \left[1+2\left(\frac{(2.61\%)}{100}\right)^2\right]$$

$$\text{Temp. rise on unbalanced system} = 80°\text{C} \times 1.136 = 90.9°\text{C}$$

Electric Motor Theory

Efficiency

A marked reduction of motor efficiency results when unbalanced phase voltages exist. The increased currents caused by the reverse rotating "bucking magnetic field" cause a reduction in full load efficiency.

Power Factor

Full load power factor decreases as the degree of voltage unbalance increases.

Voltage Variation From Rated Value With Balanced Phase Voltages

Current

Three motor currents are often used when dealing with induction motors. They are: locked-rotor or starting, no-load, and full-load current.

Locked rotor current varies nearly directly with the applied voltage; a 10% voltage increase results in approximately a 10% current increase.

No-load current consists primarily of magnetization current; this current establishes the magnetic field in the electrical steel within the motor. Increased applied voltages result in higher no-load currents; conversely, a reduction of no-load current results when the applied voltage is decreased. The degree of no-load or magnetization current change is a function of the motor design or geometry of electrical motor parts, type of materials used, and degree of magnetic loading.

Full-load current is actually a summation of two currents; these are the no-load (magnetization) component and the load component of the full-load current.

As mentioned above, the no-load (magnetization) current increases with a voltage increase; the amount of increase is a function of the motor design.

The load component of the full-load current varies approximately inversely to the voltage variation. A voltage increase tends to result in a corresponding decrease in the load component of the full-load current. This phenomenon can be explained by considering the fact that electrical power is basically the product of voltage and current. Therefore, if the mechanical load of the motor remains constant, the electrical input power to the motor also remains nearly constant; hence the load component of the current is reduced when voltage is increased.

Since full-load current is the summation of both the no-load and load component currents, the manner in which the full load current varies with voltage depends on the way the two currents vary with voltage.

Electric Motor Theory

In general, the magnetizing (no-load) current of small motors is a large percent of the full load current. The motor magnetizing current increases when voltage is increased; hence an increase in impressed motor voltage on small A.C. induction motors causes an increase in full load current.

As the motor HP increases, the magnetizing current becomes a lesser percent of the total full load current; therefore, the full load current tends to decrease with increased voltage.

It should be pointed out that the magnetization (no-load) and load component currents are added vectorially and not arithmetically.

Torque
Locked, pull-up (minimum) and breakdown torque vary approximately as the square of the applied voltage.

Motor Temperature
Motor temperature is predominately influenced by motor current. Heating due to motor current is directly proportional to the square of the motor current.

A 10% increase or decrease in voltage from the nameplate voltage may increase motor heating, however such an increase in heating will not exceed safe limits provided motor is operated at values of nameplate HP and ambient temperature or less.

Efficiency (Full load)
Efficiency is a measure of the amount of electrical power wasted in the form of heat compared to the mechanical power delivered to the load. Higher motor currents cause higher motor temperatures which in turn result in a lower motor efficiency.

Power Factor (Full load)
Power factor is directly related to magnetization or no-load current. Higher voltages cause higher magnetization currents which in turn result in a lower power factor.

Speed (Full load)
Full-load speed increases slightly with a voltage increase.

Frequency Variation From Rated Value With Rated Balance Voltage Applied

Current
No load, locked rotor and full load current vary inversely with a change in applied frequency. The change in no-load and locked rotor current magnitude resulting from a change in frequency within a 5% of rated frequency is approximately 5% or less, whereas the change in full load current is negligible.

Torque
Locked rotor, dip, and breakdown torques vary approximately inversely as the square of the frequency change.

Motor Temperature
Motor temperature is predominately influenced by motor current. Heating due to the motor current is directly proportional to the square of the motor current. A 5% increase or decrease in frequency from the nameplate frequency may increase motor heating, however such an increase in heating will not exceed safe limits provided motor is operated at values of nameplate HP and ambient temperature or less.

Efficiency
Since a variance in frequency within a 5% of rated frequency has a negligible effect on full load motor current, the effect of frequency change on full load motor efficiency is also negligible.

Power Factor
An increase in applied frequency causes a reduction in the magnitude of the magnetizing current component of the full load current which causes a slight increase in power factor.

Speed (Full-Load)
Since the full load speed is directly proportional to frequency, a 5% frequency increase will result in a correspondent 5% increase in speed.

Electric Motor Theory

The effective flux polarity and magnitudes at time T1 through T7 are listed below.

Coil Number	A1		B1		C1		A2		B2		C2	
Phase	A		B		C		A		B		C	
Coil Connection	+		–		+		–		+		–	
	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE
Time T1	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2
T2	N	1/2	S	1/2	S	1	S	1/2	N	1/2	N	1
T3	S	1	S	1	S	1/2	N	1/2	N	1	N	1/2
T4	S	1/2	S	1/2	N	1/2	N	1	N	1/2	S	1/2
T5	S	1/2	N	1/2	N	1	N	1/2	S	1/2	S	1
T6	N	1/2	N	1	N	1/2	S	1/2	S	1	S	1/2
T7	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2

At time T1, phase A is a maximum positive current while phase B and C are negative and 1/2 their maximums. Since the flux and field are directly proportional to the current magnitude, we can plot this flux magnitude versus time. The effective flux polarity (north or south) is dependent upon the coil connection polarity and the polarity of the current.

At time T2, phase A and B are positive and 1/2 their maximum while phase C is negative maximum. At time T3, phase B is positive maximum and phase A and C are 1/2 their maximum and negative. At time T4, phase A is negative maximum and phase B and C are 1/2 their maximum and positive. At time T5, phase C is positive maximum and phase A and B are 1/2 their maximum and negative. At time T6, phase B is negative maximum and phase A and C are 1/2 their maximum and positive. At time T7, phase A is positive maximum and phase B and C are 1/2 their maximum and negative. We can see from the flux diagram plotted at time instants T1 through T7 that the maximum flux in moving toward the left.

Electric Motor Theory

Coil #	A1	B1	C1	A2	D2	C2
Phase	A	B	C	A	B	C
Coil Con. Polarity	+	–	+	–	+	–

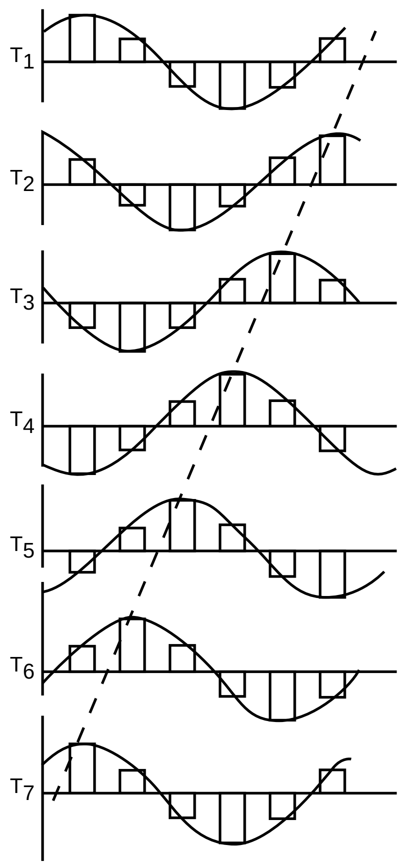


Figure 3.1.18
Field Strength vs. Time

Electric Motor Theory

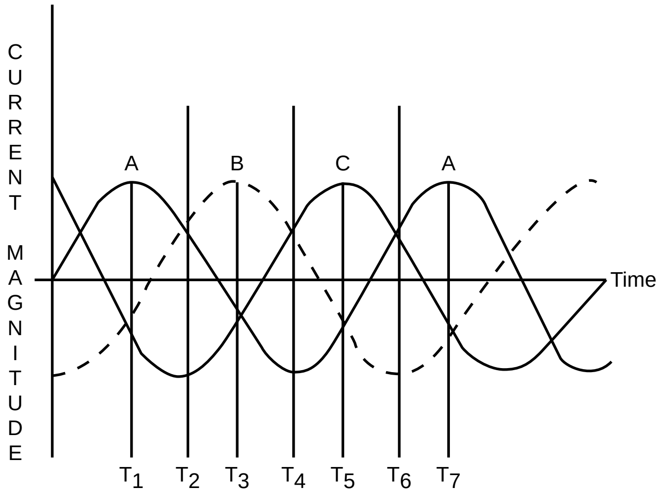


Figure 3.1.19
Current Magnitude vs. Times

If we now reconstruct the "coil groups" into a circle, we can pictorially show the strength of the fields at time T1 through T7. The arrow indicates the maximum strength north pole and is moving in counter clockwise direction. The entire field as well as the maximum or peak value is moving in the counter-clockwise direction and is hence a revolving field.

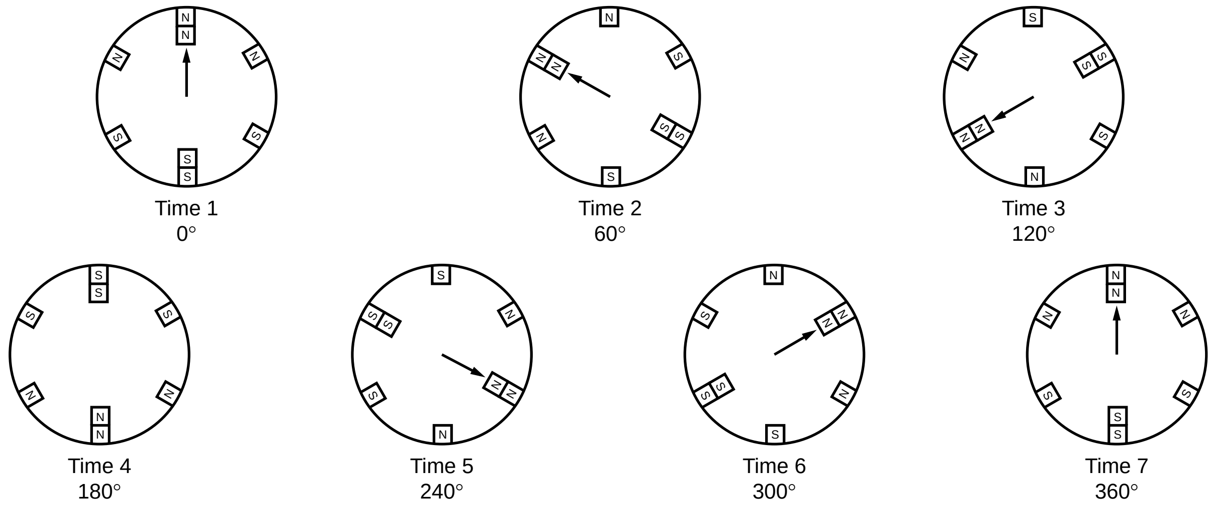


Figure 3.1.20
Magnetic Field Rotation, 3 Phase 2 Pole Motor

Electric Motor Theory

In our two pole motor (1 pair of poles) the stator field completes one revolution each time the alternating current completes one cycle of polarity change. If the source frequency is 60 cycles of polarity change per second, the rotational speed would then be 60 cycles per second times 60 seconds per minute or 3600 revolutions per minute.

The "coil groups" of a four pole motor are shown below. We can again, by referring to the curve of current versus time and the coil connection polarity for a 4 pole motor pictorially show the speed and strength of the rotating field.

If the stator is wound so that 4 poles (2 pairs of poles) per phase are created, the stator field or effective flux will complete only 1/2 revolution as the alternating current completes one cycle of polarity change.

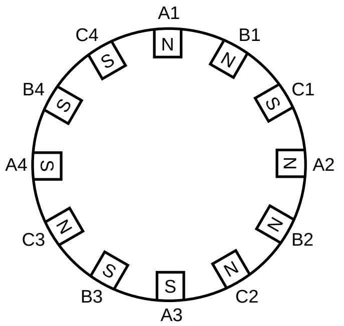


Figure 3.1.21
Coil Identification and Connection Polarity 3 Phase 4 Pole Motor

The effective flux polarity and magnitudes are listed below for a 3 phase 4 pole motor.

Coil Number	A1		B1		C1		A2		B2		C2		A3		B3		C3		A4		B4		C4	
Phase	A		B		C		A		B		C		A		B		C		A		B		C	
Coil Connector	+		–		+		–		+		–		+		–		+		–		+		–	
	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE	POLARITY	MAGNITUDE
Time T1	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2
T2	N	1/2	S	1/2	S	1	S	1/2	N	1/2	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2	N	1
T3	S	1/2	S	1	S	1/2	N	1/2	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2	N	1	N	1/2
T4	S	1	S	1/2	N	1/2	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2	N	1	N	1/2	S	1/2
T5	S	1/2	N	1/2	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2	N	1	N	1/2	S	1/2	S	1
T6	N	1/2	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2	N	1	N	1/2	S	1/2	S	1	S	1/2
T7	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2	N	1	N	1/2	S	1/2	S	1	S	1/2	N	1/2

Electric Motor Theory

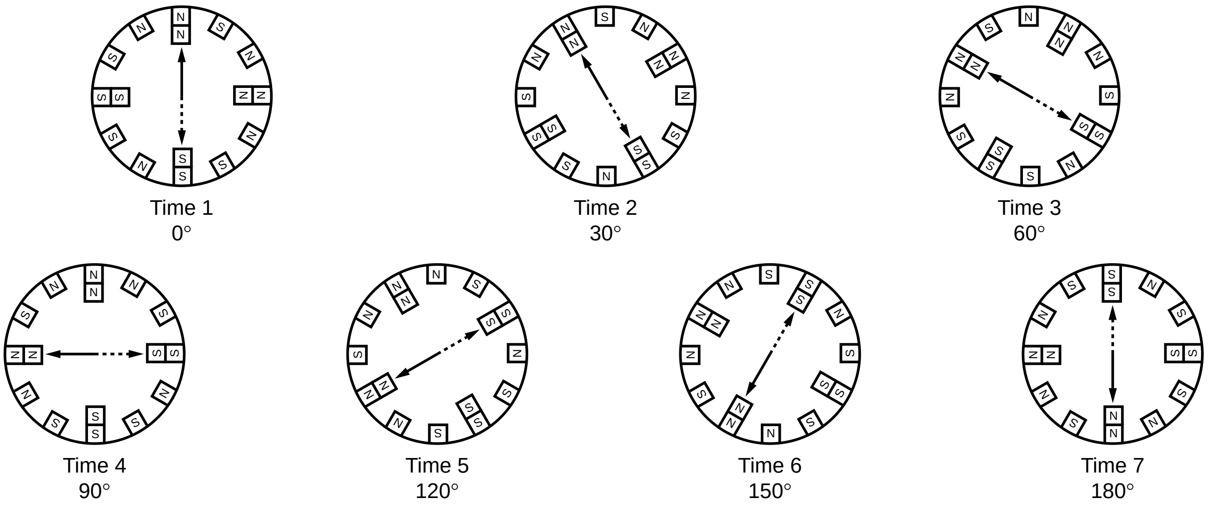


Figure 3.1.22
Magnetic Field Rotation, 3 Phase 4 Pole Motor

Note in the same complete current cycle, the 2 pole motor stator effective flux rotated through one complete revolution while the 4 pole motor stator effective flux completed only 1/2 revolution.

From the preceding pictorial displays, it is easily seen that rotational speed of the stator field of a single or multiple phase motor is directly proportional to the alternating current source frequency and inversely proportional to the number of pairs of wound stator poles.

If we have an alternating current source frequency of 60 cycles per second, the effective field rotational speed of the 2 pole motor (one pair of poles) is 3600 RPM and the 4 pole two pairs of poles) motor is 1800 RPM.

$$\text{Rotational Speed } (n_1) = \text{Frequency in Hertz (Field)} \times \frac{\text{60 sec. per min.}}{\text{Stator Pole Pairs Per Phase}}$$

2 pole motor
(one pair of poles)

$$n_1 = \frac{60 \times 60}{1} = 3600 \text{ RPM}$$

4 pole motor
(two pair of poles)

$$n_1 = \frac{60 \times 60}{2} = 1800 \text{ RPM}$$

Electric Motor Theory

Since it is common practice to speak not of pairs of poles, but in total poles (counting each N and S pole), the above formula can be rewritten to:

$$n_1 = \frac{60 \text{ sec. per min. x f}}{\text{Total Poles / 2}} = \frac{60 \text{ x f}}{P/2} = \frac{120 \text{ f}}{P}$$

Where P = Total Number of Poles
f = Frequency of A.C. Source
n_1 = Speed of Stator Field = Synchronous (RPM)

We have seen how a rotating field is set up by the stator and will now investigate how a corresponding rotating field is set up by the rotor.

For a better understanding, let us first consider a basic transformer since "transformed action" induces rotor voltages and current which in turn produces a rotor field and poles. A current passing through a wire sets up a magnetic flux or field around the wire. Conversely, a flux passing around a wire also sets up a current within the wire. In a basic transformer, the primary winding is supplied with alternating current. This primary winding sets up a flux in the laminated transformer core. The flux then passes through the secondary coil and sets up or induces a current in the secondary winding.

This entire cycle requires a certain amount of time; therefore, the load current or secondary current will lag the power current or primary current. The magnitude of the secondary current is dependent upon the number of turns of wire in the primary coil and secondary coil as well as the amount of load. The frequency of the secondary is identical to the frequency of the primary.

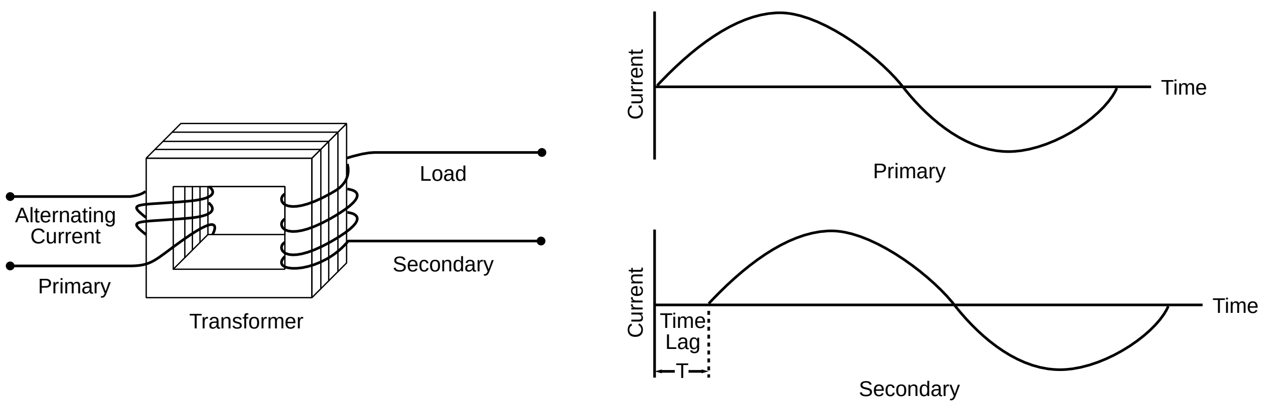


Figure 3.1.23

Electric Motor Theory

In an induction motor, the flux generated by the stator is or can be compared to the flux generated by the primary of a transformer. This stator produced flux passing through the rotor causes currents to flow in the rotor bars. These rotor currents, in turn, establish their own flux and poles. The rotor then can be compared to the secondary of a transformer.

The bars of the rotor provide an easy path for the currents induced by the stator flux to follow. The rotor bars terminate in end rings which form a continuous path for the current to flow from one bar to another. If we compare this with the transformer, we can see that the rotor bars and end rings form a closed loop for the induced currents.

When the stator is energized, supplied with alternating currents, with the rotor at rest or stationary, the stator field causes a corresponding rotor field which tries to align with the stator field.

The stator field is rotating at speed n_S and the rotor, acting as the secondary of a transformer, has an induced field rotating at the same speed n_S. The torque present at the moment of starting causes the rotor to turn and accelerate until running speed is attained. When running speed is attained, we will note the rotor turns slightly slower than the speed at which the stator field is rotating (n_S). This is caused by the restriction to the flow of current inherently present in the rotor bars.

This speed differential (stator field speed versus actual rotor speed) is defined as slip and generally is expressed as a percent of the stator field speed.

$$\text{Slip in percent} = \frac{\text{Stator field speed} - \text{Actual rotor speed}}{\text{Stator field speed}} \times 100$$

$$S = \frac{n_1 - n}{n_1} \times 100$$

Where S = Slip in percent of stator field speed
n_1 = stator field speed
n = actual rotor speed

Electric Motor Theory

We have previously determined that the stator field speed was proportional to the alternating current source frequency and the number of wound stator poles.

$$n_1 = \frac{120\, f_1}{P}$$

Where n_1 = stator field speed in RPM
f_1 = frequency of alternating current source in cycles per second
P = total number of poles

The above equation can be rewritten for the rotor field speed with respect to the rotor itself (at the instant of starting) since at this moment the rotor, acting as the secondary of a transformer, has a frequency identical to that of the stator. The poles induced in the rotor are equal in number to the stator wound poles. Therefore, the rotor induced field speed is equal to the stator field speed.

$$n_2 = \frac{120\, f_1}{P}$$

$$n_2 = n_1$$

Where n_2 = rotor field speed in RPM at the instant of starting

The turning rotor as previously stated has its own field which results from the voltages and currents induced by the stator. The frequency of the rotor induced alternating current is equal to the slip in percent times the stator A.C. source frequency divided by 100.

$$f_2 = S(f_1)$$

f_1 = stator frequency
f_2 = rotor frequency
S = slip in percent, where S in % = $\frac{n_1 - n_2}{n_1}$ (100)

$$f_2 = \frac{100\,(n_1 - n_2)}{n_1} \times \frac{f_1}{100}$$

Where n_1 = stator field speed (synchronous)
n_2 = actual motor mechanical speed

For a 2 pole, 60 cycle, A.C. induction motor having a full speed of 3480, the rotor frequency is:

$$f_2 = \frac{3600 - 3480}{3600} \times 60 = \frac{120}{3600} \times 60 = 2 \text{ cycles per second}$$

We have noted that as the rotor commences turning and attains full speed the rotor maximum mechanical speed is less than the stator field speed. The speed difference has previously been defined as the slip speed.

The currents induced in the rotor bars are dependent upon the magnitude of the voltage induced into the rotor by the stator. These induced voltages are dependent upon the rate at which the lines of force cut the rotor bars. The induced rotor voltages, currents, and rotor fields are proportional to rotor slip. As the slip increases, the rotor voltage, current, and resulting field increases.

Torque is produced by the interaction of the rotor field upon the stator field. Torque is proportional to the stator field magnitude, the rotor field magnitude resulting from the rotor current, and the lag between the induced rotor field and stator field. This lag is dependent upon the induced rotor voltage and current as well as the rotor bar material and shape.

As the rotor slip increases, the rotor bars are cut by more lines of stator flux, inducing greater voltages in the rotor. The increased rotor induced voltages cause increased rotor currents which increase the rotor field strength. The interaction of the rotor field of increased strength and the stator field of constant strength causes an increase in rotor torque as the fields try to align. It is this torque which causes the rotor to start and continue to run in a multiple phase A.C. induction motor.

Previous sections considered the basic theory of magnetism and single and multiple phase alternating current as related to the operation of the A.C. squirrel cage induction motor. The motors previously discussed were theoretically correct but extremely impractical. Before we can discuss methods of improving these basic theoretical motors, it is necessary to examine additional properties of alternating current power and its effect on the A.C. squirrel cage induction motor.

As previously stated, the motor stator or primary consists of laminated pieces of "doughnut" shaped electrical sheet steel which is notched to form slots in the "center hole" or bore. Laminated pieces, laminations, are stacked with the notched slots aligned to form grooves, and then welded together to form the stator core. Electrical conductors, generally copper wire, are wound into coils, placed into the stator slots and connected so that when energized, magnetic poles will be produced. The electrical conductors are insulated from the stator core as well as from each other.

When a voltage is impressed on the windings of the stator core, a current flows through the electrical conductors. The magnitude of current that will flow for a given value of impressed voltage depends on two electrical properties known as resistance and inductive reactance. Both of these electrical properties have the effect of opposing the flow of current through the windings of the induction motor. The combined effect of resistance and inductive reactance is known as impedance.

Electric Motor Theory

RESISTANCE

The electrical property of resistance is dependent upon:

1. Nature of the conductor material.
2. The physical dimensions of the conductors.

The nature of the material affects the degree of opposition to the flow of current through a conductor. This phenomena is called resistivity and is usually denoted by the Greek letter ρ (rho). For example, copper has a lower resistivity than aluminum; of two conductors, one copper and the other aluminum with the same physical dimensions, the copper conductor would have less resistance.

The greater the length of the conductor, the greater the resistance; a 100 foot long conductor will have twice the resistance of a 50 foot long conductor. A conductor having a greater cross sectional area will have less resistance; more current will flow through the conductors with the larger cross-sectional area. This effect is similar to the flow of water through a garden hose; the hose with the larger cross-sectional area will permit more water to flow through it.

$$R = \rho \frac{L}{A}$$

Where R = resistance measured in ohms
ρ = resistivity measured in circular mil-foot
L = length measured in feet
R = cross-sectional area measured in square feet

A conductor having a higher temperature usually results in an increase in resistance.

The following formula applies:

$$R_2 = \frac{R_1 (K + T_2)}{K + T_1}$$

Where T_1 = initial conductor temerature in degree C
T_2 = final conductor temerature in degree C
R_1 = final resistance in ohms at T_1
R_2 = final resistance in ohms at T_2
K = constant, for copper = 234.5

Electric Motor Theory

For all practical purposes, the resistance of a conductor remains the same whether the current is changing in polarity or not.

In an alternating current circuit with pure resistance, the current and voltage are in phase; that is, both voltage and the resulting current are at maximum at the same instant (See Figure 3.1.24).

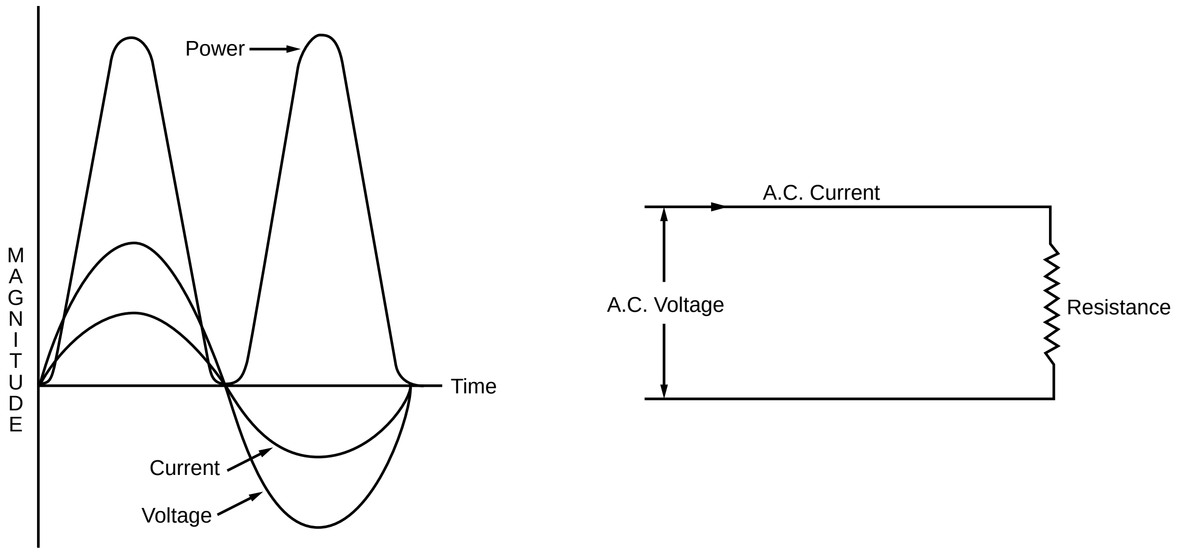


Figure 3.1.24

Instantaneous power is the product of the instantaneous current and voltage. The curve showing instantaneous power is shown in Figure 1. Notice that this power is at any instant always positive or zero. Instantaneous power reaches zero once every half cycle because both the current and the voltage reach zero at this point. Since the power curve is symmetrical, the average value is one half the maximum. Apparent power, however, is equal to the product of the effective current and effective voltage. The effective current and voltage are equal to the RMS value of the instantaneous current and voltages and are approximately equal to .707 times the maximum current and voltage respectively. The RMS values of current and voltage are the square root of the average of the summation of the instantaneous values of current and voltage squared respectively.

Electric Motor Theory

$$I \text{ effective} = \text{RMS current} = \sqrt{\text{average of } i_1^2 + i_2^2 + i_3^2 \text{ etc.}}$$

$$E \text{ effective} = \text{RMS current} = \sqrt{\text{average of } e_1^2 + e_2^2 + e_3^2 \text{ etc.}}$$

Where i_1^2 = value of instantaneous current at time $_1$ squared

i_2^2 = value of instantaneous current at time $_2$ squared

e_1^2 = value of instantaneous current at time $_1$ squared

e_2^2 = value of instantaneous current at time $_2$ squared

apparent power can be expressed as

P = EI

Where P = apparent power measured in volt ampres

E = effective voltage measured in volts (meter reading) and

I = effective current measured in amps (meter reading)

In an A.C. circuit having only resistance, the power supplied is dissipated in heat. This power is often referred to as resistive, active or actual power.

Inductive Reactance

The electrical property of inductive reactance also has the effect of offering opposition to current flow in the conductors that make up the windings in an A.C. squirrel cage induction motor. Unlike resistance, inductive reactance is only present if the polarity of current is changing. Since an alternating current induction motor has a voltage applied to it that is always changing in magnitude and polarity the resultant current also changes in magnitude and polarity. This alternating current, therefore, causes inductive reactance or opposition to the flow of current.

The amount of inductive reactance or opposition to alternating current flow is determined by:

1. the inductance
2. the frequency of the applied voltage

The amount of inductance is dependent upon:

1. geometrical factors
2. materials of the magnetic circuit

Electric Motor Theory

As previously stated, the stator of an induction motor consists of an iron core with slots that contain coils of wire. The rotor also consists of an iron core with slots containing the bars of the squirrel cage connected at their ends by rings. The rotor and stator then consist of current carrying conductors surrounded by iron.

The geometrical factors that affect the amount of inductance are:

1. the number of turns in the stator coils and the number of rotor bars
2. the area of the iron enclosed by the coils and the rotor bars
3. the length of the path of the magnetic circuit

Magnetic Flux Relationships in a Polyphase Induction Motor

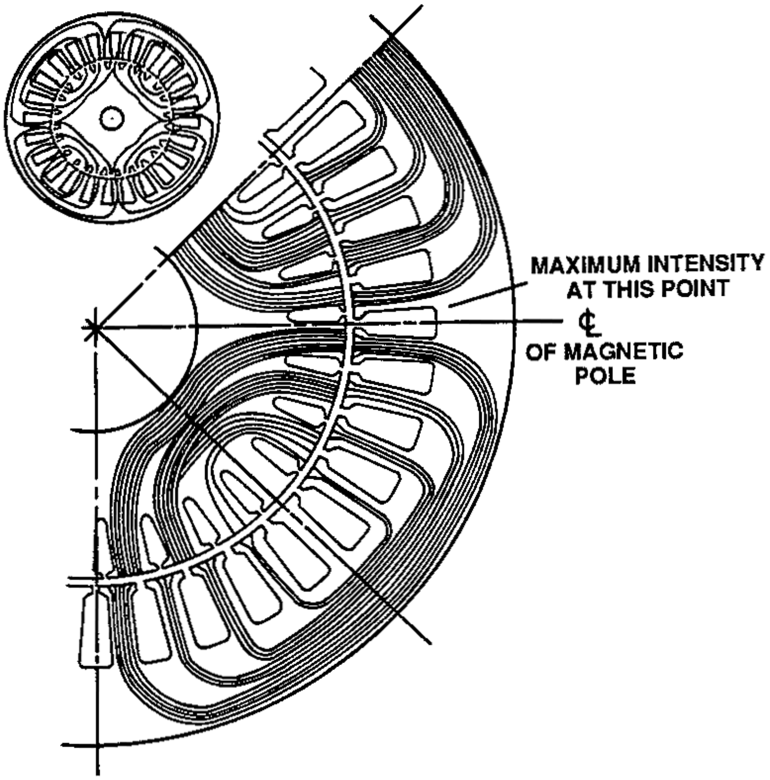


Figure 3.1.25

Figure 3.1.25 shows the path of the magnetic circuit through the stator core, across the air gap, through the rotor iron core, and again across the air gap completing a closed loop in the stator iron core. Therefore, the materials used for the magnetic circuit are iron and air. The ease with which a material such as iron and steel will permit magnetic lines of force or flux to flow through them is called permeability and is designated by the Greek letter μ.

Electric Motor Theory

Inductance is directly proportional to the permeability of the materials (iron and air) in the magnetic circuit and length of the magnetic circuit, the area the coils enclose and the square of the number of turns per coil.

This can be expressed as follows:

$$L \propto \mu N^2 l A$$

Where L = inductance
μ = permeability of the magnetic circuit
N = turns per coil
l = length of the magnetic circuit
A = area that the coils enclose

Although it is impossible to have a coil of wire and not have resistance, we can theoretically consider such a coil to better analyze the choking effect (inductive reactance) which occurs when an alternating voltage is impressed on the coil. Inductive reactance of a coil is directly proportional to the inductance (L) of the coil and the frequency of the voltage. This can be expressed as:

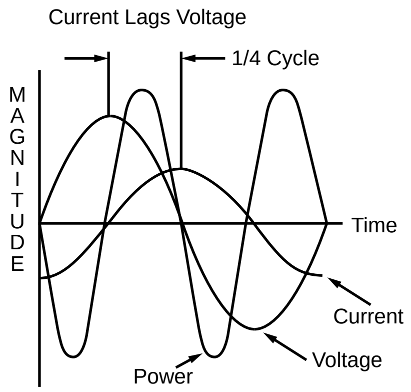
$$X_L = 2 \pi f L$$

Where X_L = inductive reatance measured in ohms
2π = a constant = 6.28
f = frequency (cycles per second)
L = inductance (henries)

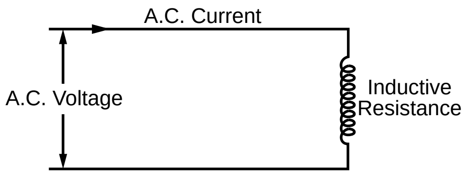
In a theoretical coil having only inductive reactance, the current lags the impressed voltage by 90 degrees (out of phase by 1/4 cycle). The curve, Figure 3.1.26, for instantaneous current, voltage, and power in a theoretical coil with only inductive reactance shows current lags the voltage by 90 degrees or one quarter cycle. The average power in a circuit having pure reactive inductance is zero. This is expressed in the figure by the fact that the positive area enclosed by the power curve is equal in magnitude to the negative area.

This power can be considered to be in the form of stored magnetic energy which is recoverable. In the A.C. circuit with pure inductive reactance, the source power is used to establish a magnetic field around the coil. When the magnetic field around the coil collapses, power is generated and returned to the power source. This power is termed reactive power in contrast to the ohmic or active power.

Electric Motor Theory



Power curve showing instantaneous valves of power for circuit having pure inductive reactance.



Electrical circuit with pure inductive reactance.

Figure 3.1.26

Impedance

Both resistance and inductive reactance oppose the flow of an alternating current but in different ways as described above. Both resistance and inductive reactance are present in all induction motors. The net effect of the resistance and inductive reactance present in the stator and rotor coils of the induction motor is to impede the flow of alternating current; hence the net effect is called impedance. It is measured in ohms and expressed by the symbol Z.

We have seen that pure resistance impedes the flow of current, but does not cause a delay of current with respect to voltage. Inductive reactance, however, causes the current to lag behind the voltage. Considering the resistive and the inductive effects as vectors with both magnitude and direction, the total impedance and the net delay of the current can be determined.

By vectorially adding the resistance (measured in ohms) and the inductive reactance (measured in ohms) the total impedance of the circuit is obtained. In like manner, we can determine the actual current lag caused by the inductive reactance. This is graphically (vectorially) shown in Figure 3.1.27.

Electric Motor Theory

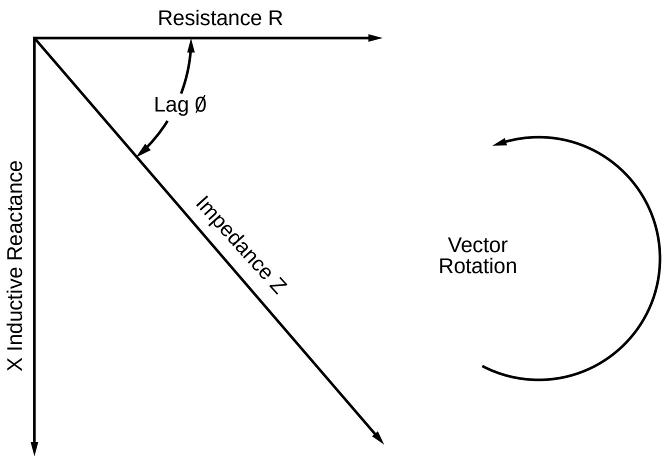


Figure 3.1.27

The total impedance can be determined by:

$$Z = \sqrt{R^2 + X_L^2}$$

Where Z = impedance

R^2 = resistance squared

X_L^2 = inductive reactance squared

The time lag of the current behind the voltage can be expressed either as an angle, or more conveniently by the cosine of that angle. Power factor, which is the cosine of the angle theta (θ), is equal to the resistance divided by the impedance.

$$PF = \cos(\theta) = \frac{R}{Z}$$

Where $\cos(\theta)$ = power factor

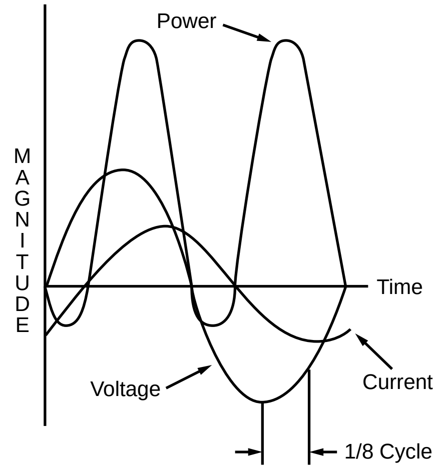
θ = the angular lag of current with the respect to voltage

R = resistance

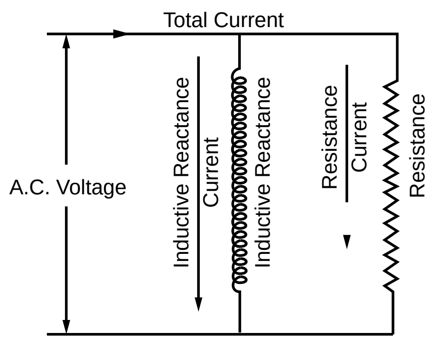
Z = impedance

The curve of instantaneous power in a coil with resistance and inductive reactance of equal magnitude is shown in Figure 3.1.28. Note the current lags the impressed voltage by 45 degrees, i.e. is out of phase by 1/8 of a cycle.

Electric Motor Theory



Voltage lags the current by 1/8 cycle or 45 degrees. Power curve showing instantaneous values of power for circuit having equal quantity of resistance and inductive reactance



Circuit showing inductive reactance and resistance

Figure 3.1.28

Power Factor

In a circuit with both resistance and reactance, the apparent power is equal to the product of the voltage and current as measured by A.C. volt meters and ammeters. Actual power measured in watts is equal to apparent power measured in volt-amps multiplied by power factor.

Actual power in watts = (PF) X (apparent power)

This has been shown graphically in Figure 3.1.29 for an A.C. circuit with both resistance and inductive reactance.

An A.C. induction motor having a lower power factor requires additional current to overcome the choking effect of the inductive reactance. The increased current results in increased heating. If we compare two A.C. induction motors with the same HP and the same supply voltage, frequency and number of phases but with different power factors, we will note that the motor with the higher power factor will require less current.

Electric Motor Theory

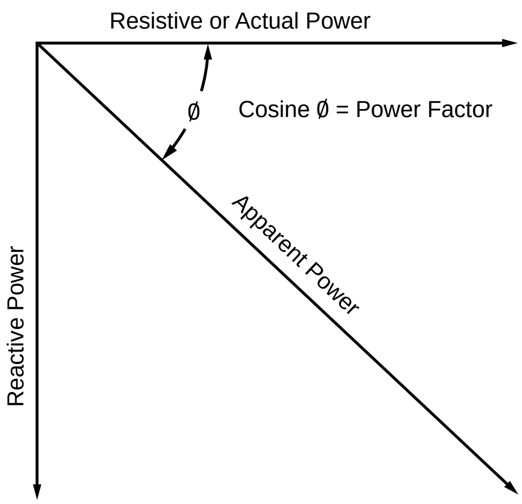
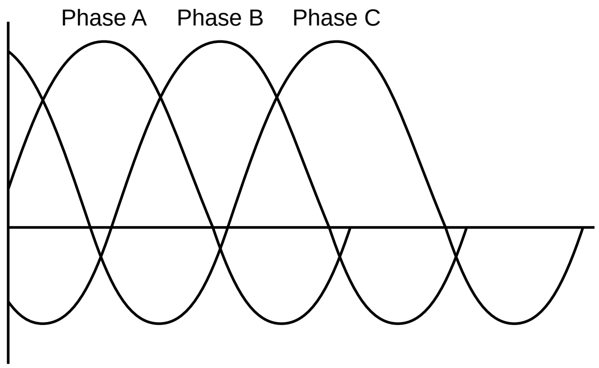


Figure 3.1.29



Multiple phase power curve for circuit 3 phases and equal quantity of resistance and inductive reactance

Figure 3.1.30

The discussion thus far concerning circuits with pure resistance or pure inductive reactance, or a combination of both has dealt with a singular source of power or single phase power. A multiple phase power supply operates in the same manner with the prime exception that the power curve tends to be smoothed out (See Figure 3.1.30).

In the analysis of multiple phase equipment, the powers for each phase are added in order to obtain the total power. Power is equal to the product of phase voltage, plus current, power factor and number of phases.

For a 3 phase system

$$P = \frac{F \bullet I}{\sqrt{3}} \; PF \bullet 3 = EI \bullet (PF) \sqrt{3}$$

Where P = power (watts)
E = voltage (volts)
I = current (amperes)
PF = power factor (pure number)

Electric Motor Theory

We have now looked at what power factor is and some of its consequences. In order to improve the power factor of a motor, the design engineer must change the total impedance of the motor. More specifically, he must change the inductive reactance since this is the only part of the impedance which affects the "out of phase" portion of the current. Inductive reactance is affected by the A.C. power source frequency and the inductance of the motor stator and rotor. Since the frequency generally is constant, the designer must then change the inductance. This inductance by definition is the product of the permeability of the iron and air, and also the number of turns per coil, the length of the magnetic circuit and the area enclosed by the coils.

The permeability of the magnetic circuit can be changed with a change in stator and rotor iron material or the density level at which the iron is worked. An iron having greater permeability or being worked at a lesser density will cause a reduction in inductance. Within reason, the number of turns per coil can be reduced so as to decrease the inductance. The length of the magnetic circuit can be reduced to produce a lower inductance by shortening the coil span, reducing the air gap or moving the current carrying conductors of stator and rotor closer to the air gap.

The area the coils enclose can be reduced and will cause a reduction in inductance primarily by changing the stator tooth configuration. The greatest change in inductance can be accomplished by changing the air gap. Since the permeability of air is very low, reduction of the air gap causes the most marked decrease of inductance. Reducing the inductance in an A.C. induction motor must be balanced with other considerations such as motor torques, locked current, etc. The design engineer must compromise to produce a balanced design and the best machine for a specific application. The power factor of an A.C. motor can also be improved by applying capacitors in parallel with the A.C. power source. A capacitor is a device capable of storing electrical energy. By storing electrical energy, a capacitor, used in an A.C. circuit causes the current to lead the voltage and therefore can be used to overcome the inductive reactance effect present in all A.C. induction motors so that the power line only has to carry the active power. The motor itself, however, will still carry the same current whether or not compensating capacitors are used.

Efficiency

Efficiency is the measure of effectiveness of a machine. In an A.C. induction motor electrical energy is converted into mechanical energy. In the conversion process, some electrical energy is wasted and produces useless heat. The lost electrical energy, generally termed motor losses, is usually broken down into the following categories.

<u>Stator Winding or Primary Copper Losses</u>

Primary copper losses are caused by the current flowing through the stator conductors. A certain amount of electrical energy is used up merely to cause the current to flow in the windings. The stator copper loss is directly proportional to the stator resistance and the square of the current flowing in the stator windings.

Electric Motor Theory

Rotor Winding or Secondary Copper Loss or Slip Loss

As we have seen, the magnetic field created by the stator induces currents into the rotor bars and end rings. These induced currents flowing in the rotor produce losses just as the currents flowing in the stator. The rotor winding losses are directly proportional to the rotor winding resistance and the square of the current flowing within the rotor conductors. More commonly, they are expressed as the slip (in percent) times the total power produced by the motor.

Iron Loss

The constantly changing magnetic fields produce hysteresis and eddy current losses within the iron of the stator. Since the field changes very slowly in the rotor, its iron losses are usually negligible.

Friction Loss

The physical rotation of the rotor with respect to the stator produces friction in the support bearings. The friction loss in the bearings appears as heat.

Windage Loss

Cooling fans mounted on the motor shaft itself or directly on the rotor end ring are required to provide air movement for cooling of the motor. The energy required by the fan to move the cooling air is considered a motor loss as the energy is not available to do useful work at the motor shaft extension.

Stray Load Losses

All other losses within the A.C. motor are described or defined as stray load losses. Stray load losses are generally attributed to leakage flux which causes secondary eddy currents in the iron and conductors as well as adjacent metal parts.

$$\text{Efficiency} = \frac{\text{power output (mechanical) at shaft}}{\text{electrical power input}}$$

$$= \frac{\text{horsepower}}{\text{actual power}}$$

Electric Motor Theory

Efficiency in percent for single phase A.C. motor

$$P = \frac{\text{(horsepower) (746 watts per HP)}}{\text{(voltage) (current) (power factor)}} \times 100$$

$$P = \frac{\text{(HP) (746)}}{\text{(E) (I) (PF)}} \times 100$$

Efficiency in percent for three phase A.C. motor

$$P = \frac{\text{(HP) (746)}}{(\sqrt{3}) \text{ (E) (I) (PF)}} \times 100$$

Where HP = horespower output at motor shaft
E = voltage (volts)
I = current (amps)
PF = power factor in percent

The efficiency of an A.C. induction motor is determined by dividing the power output at the shaft by the electrical power input.

Speed–Torque

It has been shown that the rotational sped of the stator magnetic field is a function of the power source frequency and the number of poles present in the stator winding. The manner in which the stator is made controls the motor torque to some extent. The strength of the magnetic field generated by the stator winding directly controls the torque available in the motor itself. This is a function of the flux density and is affected by the number of turns per coil, the span of the coils, the type of connection used, the source voltage and frequency.

Figure 3.1.31 shows a typical speed torque curve for a 3 phase A.C. induction motor. Four specific points are identified on this curve. These are described below:

A. Starting Torque - this is the amount of torque available at the instant of starting.
B. Dip torque or Minimum Torque - this point is affected by frequency harmonics which occur because the windings concentrated in slots and not distributed uniformly around the periphery.
C. Breakdown Point - the point at which maximum torque is developed.
D. Full Load Operating Torque - the full load operating torque is developed at full load speed and is equivalent to the nameplate HP of the motor time 5252 and divided by the full load speed.

Increasing the magnetic field strength of the stator, provided the rotor is unchanged, ill cause an increase in starting, minimum and breakdown torque. This is shown in Figure 3.1.32.

Electric Motor Theory

For specific motor applications, it is desirable at times to change the shape of the speed torque curve by increasing or decreasing starting torque, minimum torque, or breakdown torque, or causing these points to occur at different speeds. This in effect changes the shape of the speed torque curve and is most economical accomplished by changes in rotor design because these torques depend greatly on the rotor bar configuration with which both rotor resistance and rotor inductive reactance can be varied. Rotor slot configuration and bar cross sections as well as the speed torque curve resulting from their use are shown in Figure 3.1.33.

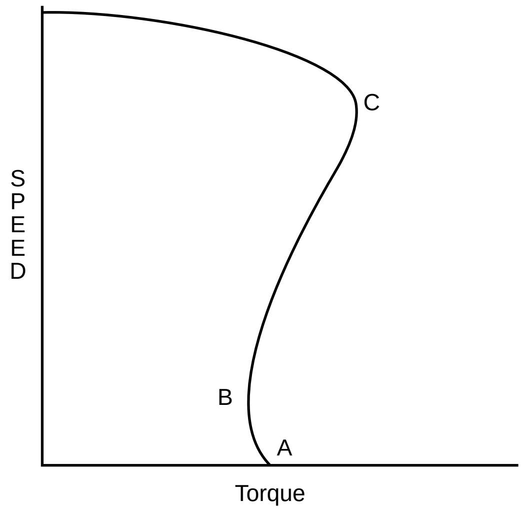


Figure 3.1.31

Typical Speed Torque Curve

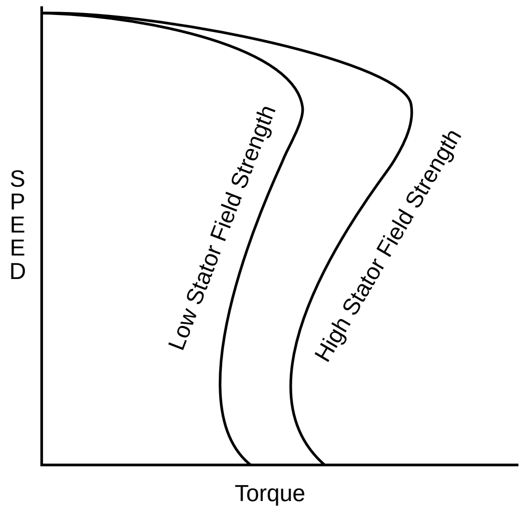


Figure 3.1.32

Comparison of speed torque curves of two motors having different stator magnetic field strength.

Electric Motor Theory

Variations in Motor Characteristics Obtained By Variations in Rotor Design

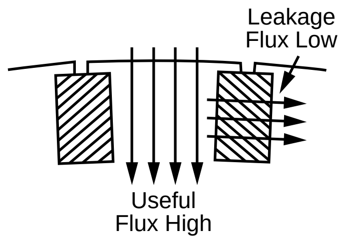
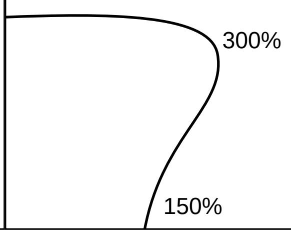
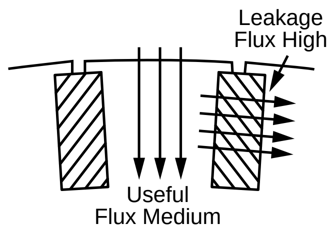
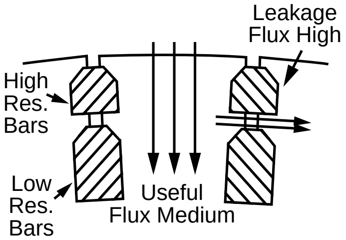
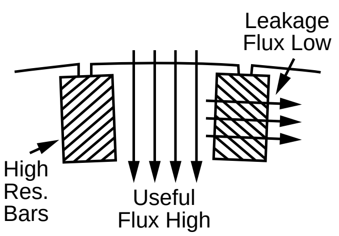
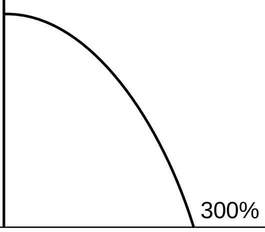
NEMA* Design	Rotor Slot Section	Typical Torque Curve	Motor Characteristics
A			Locked Torque - high Locked Current - high Full Load Current - normal Breakdown Torque - high Efficiency - high Power Factor - low Full Load Slip - low
B			Locked Torque - normal Locked Current - normal Full Load Current - normal Breakdown Torque - normal Efficiency - normal Power Factor - normal Full Load Slip - normal **Reference**
C			Locked Torque - high Locked Current - low Full Load Current - high Breakdown Torque - low Efficiency - normal Power Factor - low Full Load Slip - low
D			Locked Torque - high Locked Current - normal Full Load Current - high Breakdown Torque - none Efficiency - low Power Factor - low Full Load Slip - high

Figure 3.1.33

* NEMA is The National Electrical Manufacturers Association. Standards have been established by NEMA for minimum starting and breakdown torques etc. for various designs (referred to as NEMA Design A, B, etc.) for A.C. Induction motors.

Noise Theory

Introduction

This section is intended to describe the information, data and terms used when discussing or measuring noise produced by rotating electrical machines. Among reasons for making a noise analysis are: checking for compliance with a specification, code, ordinance or acoustical criterion, as in user acceptance testing; or to obtain information on exposure of personnel or equipment to noise, as in a sound survey. Noise analysis supplies data necessary to rate the machine according to its acoustic power output, establish sound control measures or predict sound pressure levels produced by the machine in a given enclosure or environment.

Also included is an IEEE paper titled "Noise in Induction Motors - Causes and Treatment." It is included to explain the possible causes of noise in an induction motor, and how they can be predicted and reduced.

In addition, an IEEE paper titled "Specifying And Measuring The Noise Level Of Electric Motors In Operation" is included to explain a new testing procedure using the sound intensity method which we have perfected here at Norwood, and we are helping to establish it as an industry wide practice for testing motors under load.

Definitions And Terminology

Noise (Sound)

Sound is a physical disturbance which results in a sensation in the ear of the listener. It is usually the result of a mechanical vibration transferred to the air and then airborne to the ear of the listener.

If it is pleasing and acceptable to the ear of the listener it is called "SOUND". If it is unpleasant and unwanted by the listener it is called "NOISE". Sound emanating from a recording can be "music" to a teenager while it is considered "noise" by his parents. Thus, individual judgment and difference between hearing sensitivity in individuals play a large part in the difference between sound and noise.

Cause of Sound

A particle moving back and forth in a specific pattern is said to be vibrating. The sequence of repeated movement is called periodic motion. Each unique sequence of motions is a cycle, and the time required to move through one cycle is called the period. The FREQUENCY of the periodic motion is the number of cycles that occur per unit of time. This is usually measured in cycles per second or "HERTZ".

This vibrating motion causes the air particles near it to undergo vibration. This produces a variation in the normal atmospheric pressure. As the disturbance spreads, if it reaches the ear drum of a listener it will initiate vibration motion of the ear drum and the listener will experience the sensation of sound.

Noise Theory

Sound travels in a wave form at a constant speed of 1127 ft./second in air. This speed is not affected by the frequency. However, the particle velocity or the rate at which a given particle of air moves to and fro when a sound wave passes, is proportional to the frequency. Therefore, the frequency of the sound must be investigated when determining the effect of sound on the human ear.

Sound Pressure

When a sound wave is initiated it produces a fluctuation in the atmospheric pressure. This fluctuation in air pressure around the normal atmospheric pressure is called SOUND PRESSURE.

Normal atmospheric pressure is approximately 1 million dynes per cm^2. By definition 1 dyne per cm^2 is equal to 1 microbar or to .10 Pascals. Therefore, atmospheric pressure is approximately 1 million microbars or 10^5 Pascals. This is equal to 14.7 pounds per square inch which is the more common term we are used to seeing.

Microphones used in noise measurement are sensitive to sound pressure, hence sound pressure has enjoyed more popularity in the acoustical field.

Level

In acoustics, a level is the logarithm of the ratio of a quantity to a reference quantity of the same kind. The base of the logarithm, reference quantity and kind of level must be specified.

Decibel and Sound Pressure Level

Sound pressure produced by different sources can vary over a wide range. Sound sources can cause pressure fluctuations as low as .0002 or as high as 200 microbars. This represents a range of 200/.0002 or a million to one. Because of this extensive range it is more convenient to use logarithmetic rather than linear scales in the acoustic field. Thus, values are expressed in SOUND PRESSURE LEVEL (Lp) rather than in sound pressure.

The unit used to express this Lp is called DECIBEL (dB). It is a dimensionless unit which expresses logarithmically the ratio of the quantity under consideration (in this case sound pressure) to a reference value of the same dimensions as the quantity.

.0002 microbars was chosen as the reference level because it is the minimum sound pressure discernible by a sensitive human ear at 1000 Hertz.

By definition

$$LP = 20 \log_{10} \frac{P}{P_o} \quad \text{(dB)}$$

Where P = sound pressure in microbars produced by sound source

P_o = reference pressure in microbars taken as .002 microbars which is equal to .002 dynes/cm^2 or 20×10^{-6} Pascals

Noise Theory

Sound Power

Microphones used in recording sound are sensitive to sound pressure. The values recorded express the sound level of the area surrounding the equipment. However, they do not adequately express the energy produced by the generating source. The recorded sound levels are affected by the direction of the sound, the distance between the sound and the microphone and the acoustical properties of the room in which the measurement is taken. They will vary from a maximum in a reverberant room to a minimum in an atmosphere where sound waves are free to travel continuously away from the noise source in all directions (FREE FIELD).

Because of the inability to duplicate these variables everywhere, the sound pressure level recorded cannot be used for scientific analysis until it has been modified to compensate for these variables.

The modified data is called SOUND POWER which is defined as the total sound energy radiated by a source per unit of time.

Again, this is expressed as SOUND POWER LEVEL (Lw) in decibels. Mathematically it is expressed as follows:

L_W provides data which the acoustic designer can use in determining the actual overall noise level at

$$L^W = 10 \log_{10} \frac{W}{W_o} \quad \text{(dB)}$$

Where W = sound power in watts produced by sound source

W_o = Reference power taken as 10^{-12} watts or 1 picowatt (see ANSI S1.8-1964).

a given spot due to all noise generating sources.

"A" and "C" Scales

The human ear is not equally sensitive to all frequencies. Instead the human ear is more sensitive to higher frequencies and less responsive to lower frequencies. A 1000 HZ sound will appear much louder to the ear than a 100 HZ sound even though they both have the same level. Therefore, in order to determine the effect of various frequencies it is necessary to determine the actual sound levels of these frequencies which appear to be equally "loud" to the human ear. This has been done through testing a large cross section of the human race.

By plotting these results as a family of curves and smoothing out the irregularities, it has been determined that "weighting networks" can be designed to approximate these values. Sound picked up by the microphone and passed through these weighing networks can be recorded by the sound meter similar to the levels that the ear thinks it hears. The two most commonly used are the "C" network and the "A" network.

The "C" network (or C Scale) represents a higher "loudness level" and has a relatively flat curve. It weighs each frequency equally and therefore gives true values of sound levels emanating from the source.

The "A" network (or A Scale) represents a lower "loudness level". It discriminates primarily against the lower frequencies. Therefore, it comes closest to the discrimination of the ear both for loudness of low level noises and to hearing damage risk from loud noises. This "A" Scale was selected by the Walsh-Healey Act as the basis for reporting overall sound pressure levels.

Conversions Between "A" and "C" Scales

The various frequencies are weighted differently for the "A" and "C" scales. Therefore, in order to convert from one scale to another each band of frequencies must be adjusted individually.

The following are the correction factors to convert from "C" Scale to "A" Scale.

Octave Band	**Correction (dB)**
63	-26
125	-16
250	-9
500	-3
1000	0
2000	+1
4000	+1
8000	-1

The correction factors can only be used when converting between scales when both scales are on the same basis, either Sound Power or Sound Pressure. They cannot be used for converting between Scales when one Scale is on Sound Power basis and the other Scale is on Sound Pressure basis.

Band Level

Band level is the total level of all noise in a specified frequency band.

Narrow Band

A narrow band is generally defined as a band of frequencies whose width is not less than one percent or more than eight percent of the band center frequency.

Noise Theory

Band Center Frequency

Band center frequency is the geometric mean between the extreme frequencies of the band.

$$f_c = \sqrt{f_h \cdot f_l}$$

where:

f_c = the band center frequency

f_h = high frequency limit of the band

f_l = low frequency limit of the band

Free Field Over a Reflective Plane

Free field conditions exist when sound from the source can travel freely and continuously away from the source and in which the effects of the boundaries are negligible over the region of interest. In this environment the sound pressure level decreases 6 dB each time the distance from the source is doubled.

Broad Band, Octave Band, and Third Octave

The average human ear can hear over a wide range of frequencies varying from 20Hz to 16,000Hz. In order to simplify calculations this range is broken into ten parts called "OCTAVE BANDS". Each band covers a 2 to 1 range of frequencies. The higher frequency is twice the lower. In order to further simplify matters, each band is generally referred to by its center (geometrically mean) frequency. In most cases the two lowest and the highest band contribute very little valuable data and therefore are omitted. The 7 bands normally considered are with center frequencies as follows: 125Hz, 250Hz, 500Hz, 1000Hz, 2000Hz, 4000Hz, 8000Hz.

Laboratory equipment selects only the sound in the frequency band under consideration and records it exclusive of all other frequencies. Thus, the sound content from a source is available in 7 distinct bands for engineering analysis.

When engineering analysis requires more detailed frequency data, equipment is available to further subdivide each octave into three parts. These are called "ONE-THIRD OCTAVES" which divide the full octave geometrically rather than arithmetically. A one-third octave is a band width in which the ratio of extreme frequencies is equal to the cube root of 2 or 1.260.

Sometimes it is of interest to study discrete frequencies of sound. Equipment is also available to measure the sound level of any such pure tones which might emanate from a sound source.

Noise Theory

Anechoic Room

An anechoic room is one constructed so that all the sound striking the boundaries of the room is absorbed. This is also called a Free Field room.

Reverberant Room

A reverberant room is an enclosure in which all the surfaces have been made as sound reflective as possible. In a reverberant room the measured sound pressure level is independent of the distance from the source and is essentially constant when measured beyond the near field region.

Airborne Noise

Airborne noise is undesired sound in the air. This is the noise that is received by the ear of the observer.

Structureborne Noise

Structureborne noise is undesired vibration in or of solid bodies such as machinery, foundations or structures.

Frequencies for Acoustical Measurements

Until 1960 the variety of frequencies used for acoustical measurements made comparison of results inconvenient. The 1960 issue of the American Standard of Preferred Frequencies S1.6-1960 establishes an octave center frequency series based on multiples of 1000 cycles per second. This simplification affords a maximum number of center frequencies common to both the Octave Band series and One-Third Octave Band series.

Preferred Frequencies For acoustical Measurements

Octave Band Edge Frequencies	Octave Band Center Frequency
90/180	125
180/355	250
355/710	500
710/1400	1000
1400/2800	2000
2800/5600	4000
5600/11200	8000

Noise Theory

Sound Pressure vs. Sound Power

The definitions of sound pressure level, sound power level and vibration acceleration level are of academic interest only. Sound level instruments are calibrated to read or record sound pressure levels directly in dB. Sound power is obtained only by calculation from measured values of sound pressure levels. Sound pressure levels are useful in determining the noise level of an area surrounding a piece of equipment. They do not, however, adequately express the noise produced by the equipment itself. Sound pressure levels are influenced by the room environment, by the presence of other sound sources and by the distance and location of the microphone. For the same source, they will be highest in a reverberant room and lowest under anechoic or free field conditions. It is evident then, that sound pressure levels can never be repeated or duplicated except under identical test conditions.

Sound power of a source is the total sound energy radiated by the source per unit of time. It is then essentially independent of the environment in which the source is located or distance from the source. Sound power is the only basic measure of the acoustic properties of a machine, and every effort should be made to encourage expression of noise test results and noise limit specifications in terms of sound power levels.

In a free field over a reflecting plane, sound pressure can be converted to sound power by the following formula:

$$L_W = L_p + 10 \, \mathrm{Log}_{10} \frac{2 \pi r^2}{1.0}$$

r = raduis from the center of the motor at which the pressure was measured in meters.

Combining Sound Levels

Of major importance to the plant operators is the sound pressure level at a specific spot in the plant, usually at the operators station. This can be determined if the sound levels are known from each generating source.

Keep in mind that sound levels are energy values and therefore they must be combined on an energy basis not arithmetically. Knowing the sound level of each source, one can calculate the sum total, using the following chart, or the following formula.

$$LP = 10 \log_{10} \left[\text{antilog}_{10} \frac{Lp\,(1)}{10} + \text{antilog}_{10} \frac{Lp\,(2)}{10} + \ldots + \text{antilog}_{10} \frac{Lp\,(n)}{10} \right]$$

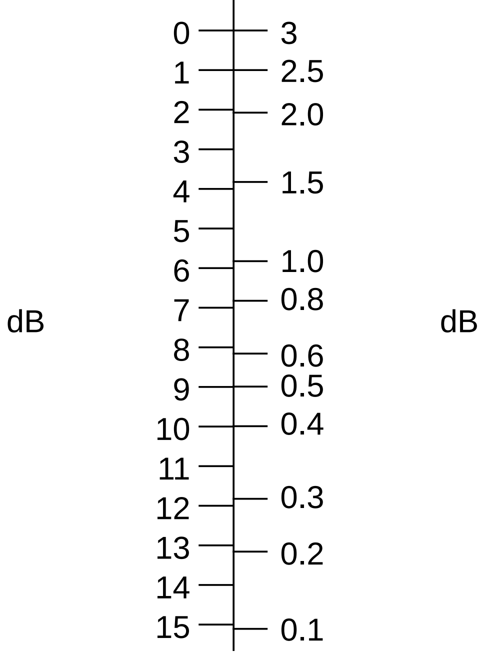
L_p = total sound pressure level or total sound level.

L_{p1} = level in decibels of the first measurement.

L_{pn} = level in decibels in the nth measurement.

dB Adjustments for Combining Sound Sources

Difference Between Two Levels to be Combined	Value to be Added to the Higher of the Two Levels to be Combined



Noise Theory

For example, assume a motor at 80 dBA and a compressor at 82 dBA are installed together. The difference is 2 dBA, therefore, the overall noise will be 84.1 dBA (82 + 2.1 increase).

Assume a duplicate unit is now installed right next to the first unit. Combine that new unit (84.1 dBA) with the existing unit (84.1 dBA). The difference is zero, therefore, the result of the two units will be 87.1 dBA.

If a third unit is now added, you combine 87.1 with an 84.1. The difference is 3 dBA, which results in a 1.75 dBA increase, for a total of 88.85.

A fourth unit would result in an increase of about 1.25 dBA overall, or a total of just over 90 dBA, which is a 6 dBA increase over the original single unit.

Each 3 dBA increase represents a doubling of the sound level at the operator's station; that is, 83 dBA is approximately twice as loud as 80 dBA.

Note that when the difference between two pieces of equipment is greater than 10 dBA, there is virtually no change in the overall level caused by adding the quieter machine.

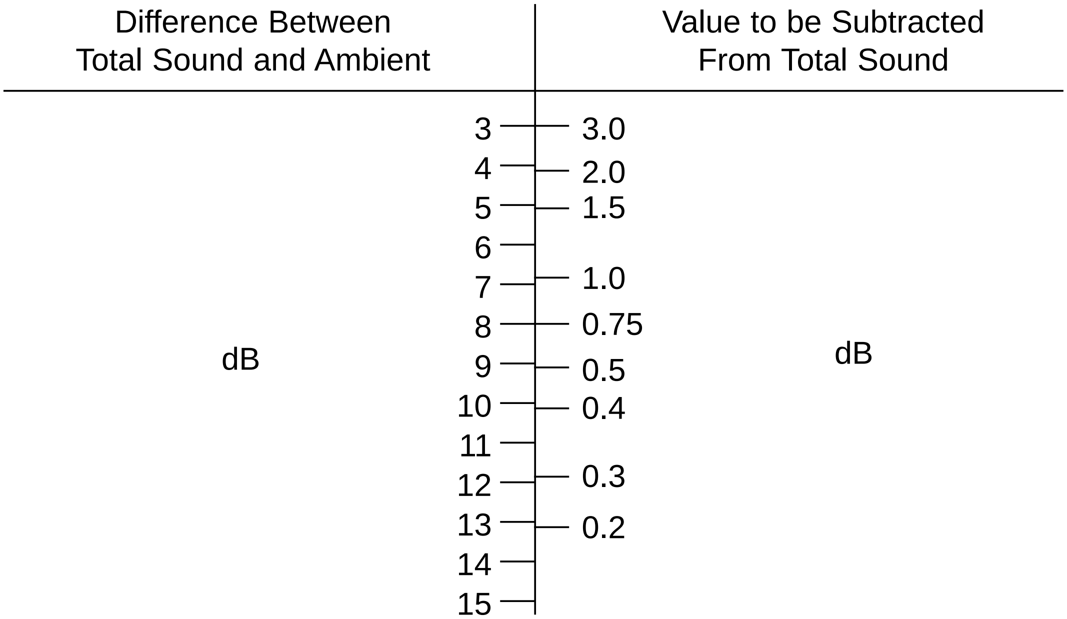
The chart shown previously can also be used to determine the overall sound level of a motor when the individual octave bands are known. The bands are combined two at a time, using the result of the previous combination with the next band level. For example, assume a motor has a following spectrum:

Octave Band:	125	250	500	1000	2000	4000	8000
A Scale Sound Level:	80	86	84	88	85	80	70

Following similar calculations gives an overall level of 92.6 dBA.

The following chart shows adjustments to estimate the sound coming from a source in a plant location. For example, if the sound level in the plant with the motor operating is 90 dBA, and with the motor shut down is 86 dBA, then the sound level of the motor above would be 87.8 dBA (90 - 2.2).

Noise Theory



Effect of Distance

In a free field where sound from a point source can spread out equally in all directions, the sound pressure decreases with distance. Tests have proven that the product of pressure times the distance is a constant. Noise levels at other distances can be calculated from the following:

$$L_{p2} = L_{p1} + 20 \, Log_{10} \frac{r1}{r2}$$

Where: L_{p1} = sound pressure at distance r1
L_{p2} = sound pressure at distance r2
r1 and r2 are radius from the center of the motor

On a motor four feet wide, three feet from the surface would have an r = $\frac{4}{2}$ + 3 = 5. Five feet from the surface would have an r = 7. The value for r1 and r2 can both be in either meters or feet.

Facilities

All noise testing and analysis performed at the Norwood Plant is conducted in a specially constructed reverberant room with skewed walls and ceiling, measuring 28 x 34 x 18 feet, totaling 17,500 cubic feet. A 10 x10 foot door services the room. Voltages, frequencies and loads are available to meet almost any requirement. Bruel and Kjaer sound analyzing instruments suitable for Octave, Third Octave or Narrow Band analysis of Airborne noise is used exclusively. Bruel and Kjaer high speed recorders provide permanent spectrograms of noise levels. All instruments are calibrated in standard intervals and two complete sets of noise analyzing equipment assures continuous operation of our sound room. Additional equipment is available for special noise measurements.

Noise Theory

Testing

All testing and calculations are made in strict accordance with the latest issues of "American Standard Method for the Physical Measurement of Sound" and with IEEE No. 85 "Test Procedure for Airborne Noise Measurements on Rotating Electric Equipment." Complete Octave, Third Octave and Narrow Band results are not required on every study. Sufficient information only is developed to satisfy the requirements of the problem or situation.

Sound Intensity Method of Noise Testing

We have developed the procedure and acquired the equipment to conduct sound intensity testing of motors under load. This enables accurate determination of the sound power level produced by loaded motors. This method is available upon request. Industry standards have not yet been fully established for this method, but we are working closely with ANSI, IEEE and IEC to establish these standards. To understand this approach, see the IEEE article "Specifying And Measuring The Noise Level Of Electric Motors In Operation".

Walsh-Healey Act

The Federal Government saw the need for keeping noise "pollution" within reasonable limits and also the need for limiting noise levels to "safe" values by current medical and acoustical standards. Therefore, the Walsh-Healey Act was passed and amended in 1969 setting these limits.

The limits are based on the hours per day human beings are exposed to the noise level. The acceptable levels range from a maximum of 115 dBA for 15 minutes to 90 dBA for 8 hours or more.

These levels are overall levels as measured on the "A" Scale of a standard sound level meter at slow response.

NEMA Noise Levels

NEMA has published overall sound power levels that should not be exceeded by polyphase squirrel-cage motors. It should be recognized that the distribution of noise as a function of frequency affects the acceptance of sound and that machines with the same overall sound level can have different noise qualities.

Low Noise Machines

Modifications are usually necessary if a machine is to be classified as having low noise. Most of the work done to lower noise levels is aimed at sound absorption or a reduction in vibration of mechanical components in frequencies most sensitive to the ear. Under usual conditions in the area near a machine a 1.0 decibel change in noise level is about the minimum that can be detected by the average individual. On this basis, a 1.0 dB reduction would hardly be important. A reduction of 3 dB is usually significant and 6 dB is certainly worthwhile.

Noise Theory

Airborne noise produced by a motor can be attenuated by treatment with sound absorbing materials. Directional fans and careful attention to air flow and velocity can be expected to result in considerable noise reduction at the fundamental and harmonics of the blade passing frequency.

Different types of machines require different methods of noise reduction depending upon their construction. Noise can be caused by anyone, or all, of several sources. Magnetic forces varying periodically, turbulent air flow and fan configuration, mechanical unbalance and bearings, fits and friction forces and the mounting arrangement on a base or structure can all be potential sources. Each must be considered individually to make sure that its contribution to the total noise level of the motor is as small as possible. For more details, see the article on "Noise in Induction Motors - Causes and Treatment" elsewhere in this Section.

Customer Specification

Our customers usually express their noise limit specifications to us in terms of overall sound pressure level or sound power level at no-oad.

Since the speech interference level is defined as the arithmetic average of the sound pressure level of the noise in each of the octave bands 710 to 1400 Hz,1400 to 2800 Hz, and 2800 to 5600 Hz, specifications will be in terms of full octave band sound pressure levels when this is the prime consideration.

When the user is concerned with the noise radiated by a machine in relation to other sources of noise in the same areas, he might well specify octave band sound power or pressure levels.

Sound power levels are always related to sound pressure levels that would exist under free field conditions. Using sound power, it is possible for the user to predict the sound pressure levels that will exist in the space environment in which the machine will ultimately be used. Overall sound pressure or sound power level can also be computed. Because of these and other advantages, our customers should be strongly encouraged to base their noise requirements on sound power. As far as testing procedure is concerned, however, the type of specification is immaterial since the results can easily be converted.

Noise In Induction Motors – Causes And Treatments

Paper No. PCIC-90-06
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Abstract:

In order to effectively reduce the overall noise level around an induction motor, it is first necessary to understand the motor's many noise sources, and then how noise is transmitted from the motor. In addition, it must be understood how noise is additive and how the surrounding area will affect the overall noise level. Determining the noise level of a fully loaded motor is especially difficult, when the ambient noise is louder than the motor. However, it is possible to estimate when the noise source and associated frequencies are understood. Only after this, can the proper recommendation be made as to what type of noise treatment, if any, to apply to the motor. Time and effort is better spent treating the equipment that is the primary source of the noise.

Introduction

This paper consists of three parts. The first part identifies causes and frequencies of windage and magnetic noise in an induction motor. Specific problems that are unique to various motors are also identified.

In the second part of the paper, a testing procedure is established that can be followed to determine the full load noise level of an induction motor. Also included is a testing procedure to determine the nature and origin of the noise so that it can be treated in the proper manner.

In the third part of the paper, the most effective methods of reducing motor noise levels in the field and at the factory will be discussed.

Causes and Frequencies of Noise in an Induction Motor Windage Noise

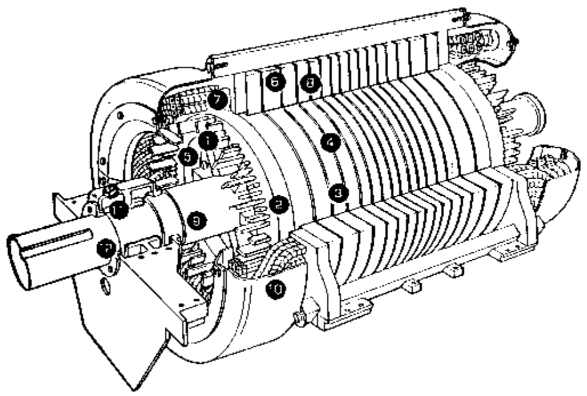

Figure 1
View of a typical open motor which has the bars extended to act as fans.

Windage noise is generated by the interaction of moving parts of the rotor with the cooling air which passes through the motor. Noise is also generated by the interaction of the moving air with stationary parts of the motor. Windage noise is airborne, and will not produce vibration of the yoke as does structureborne magnetically generated noise (see Fig. 1 & 2). The primary sources of air flow and windage noise in an induction motor are the fans, and the rotor bars in the vent areas and at the rotor ends.

Noise In Induction Motors – Causes And Treatments

Open Motors have a free exchange of internal and external air as shown in Figure 1 and 2. The two internal fans or extended bars draw in ambient air from each end of the motor. This air is used to cool the coil ends of the stator winding. On vented rotors the rotor bars act like fans and draw ambient air into the motor and through the axial and radial vents in the rotor. This air is then blown through radial vents in the stator. It then mixes with the air coming through the coil ends and is exhausted from the motor. Exiting with the air out of the motor is any airborne noise generated inside the motor.

On some open two pole motors, the rotor fans assist in forcing the air simultaneously through the rotor and coil ends. This method of cooling is more efficient because it forces more air through the rotor and stator where the majority of the losses are generated, and the cooling air is needed. This type of fan design will also generate less noise and lower windage losses. However, it is more costly to install these separately mounted fans. An example of this cooling arrangement is shown in Fig. 2

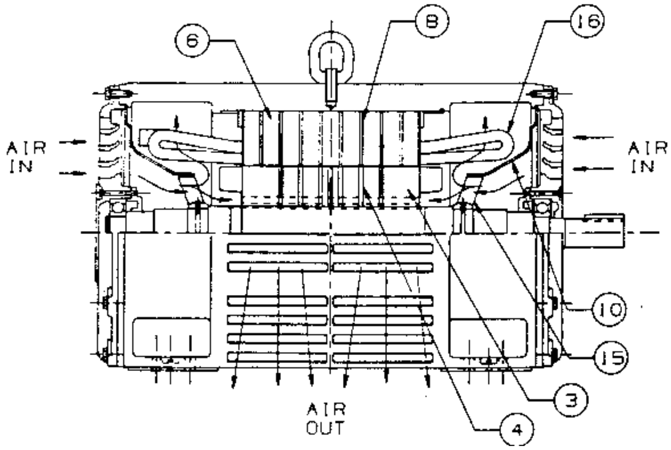

Figure 2
Air flow pattern with fans forcing air through rotor

1. Extended Rotor Bars	10. Air Deflector
2. Rotor End Rings	11. Bearings
3. Rotor Laminations	12. Labyrinth Seal
4. Rotor Vents	13. Air In
5. Rotor Spider	14. Air Out
6. Stator Laminations	15. Rotor Fans
7. Stator Winding	16. Stator Coils
8. Stator Vents	17. Core and Enclosure
9. Rotor Shaft	

Totally Enclosed Fan Cooled Motors (TEFC).

A fin cooled motor has an external fan that is used to blow air over the external fins. Whereas, on a totally enclosed air to air cooled motor (TEAAC), an external fan is used to blow air through tubes in the air to air heat exchanger as shown in Figure 3. There is little concern with any internally generated windage noise. No exchange of internal and external air takes place; therefore, very little noise can escape the motor enclosure. The main source of windage noise on a TEFC motor is the external fan.

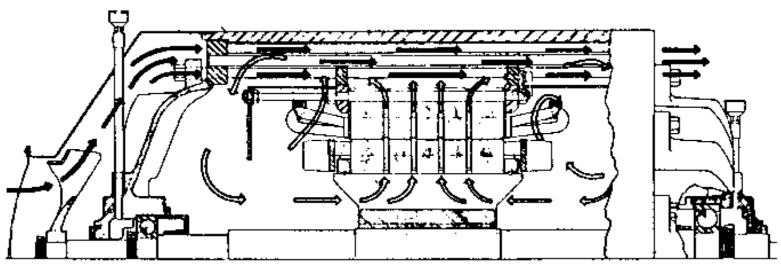

Figure 3:
View of totally enclosed motor with air to air heat exchanger (TEAAC)

Noise In Induction Motors – Causes And Treatments

Frequency of Windage Noise

The frequency of windage noise is equal to the passing frequency of the fan blades or rotor bars. The passing frequency is the frequency at which the bars or fan blades pass by a fixed reference point. The passing frequency in Hertz is calculated by the following equations;

Passing frequency of fan blades is equal to

$$\frac{\text{(No. of fan blades) RPM}}{60} \qquad \text{(Eq. 1)}$$

Passing frequency of rotor bars is equal to

$$\frac{\text{(No. of fan bars) RPM}}{60} \qquad \text{(Eq. 2)}$$

Where: RPM equals revolution per minute of rotor.

The noise generated is virtually the same at full load and no load, since there is little change in rotational speed. The following is a table of typical passing frequencies for induction motors:

Typical Passing or Forcing Frequencies in Hertz

Fan	Rotor	Bars
2 pole	300 – 540	2340 – 3060
4 pole	210 – 510	1380 – 1740
6 pole	180 – 340	1120 – 1380
8 pole	135 – 255	870 – 1035

Frequencies may vary with manufacturers and machine size.

It is important to note that the passing frequency and noise for the rotor bars are at a higher and more irritating frequency than that of the fans. When correcting for A-weighting, which takes into account the sensitivity of the human ear to various frequencies, noise levels at the above fan frequencies would be reduced by 3 to 16 dB. Whereas, noise levels at the above rotor bar frequencies would not be reduced at all, and in the 2000 Hertz band levels would be increased by 1 dB. In general, the high levels of windage noise on an open motor, will come from the rotor bar fan action, not from the fans.

Noise In Induction Motors – Causes And Treatments

Magnetic Noise

Magnetic noise should be minimized in the original design since it is extremely difficult to reduce in an existing motor. Magnetic noise is primarily structureborne, and cannot be reduced by internal sound lining. Structureborne noise results from the vibration of the stator core or teeth. There are no practical ways of isolating the stator core laminations from the enclosure. Therefore this noise is transmitted out of the motor by the enclosure structure, and then becomes airborne from the vibration of the outer surface.

Constant level magnetic noise is a result of the forces and vibration that are generated by the interaction of the fundamental magnetic flux wave, with the rotating magnetic parts of the rotor. This noise does not change in magnitude with load. It can be minimized by the proper rotor and stator slot combination. Many of the rules for the proper slot combination were established years ago by Gabriel Kron [1]. Motor manufacturers have added to these rules over the years. It has been proven that if these rules are followed, constant level magnetic noise will not be a problem. In addition, this noise exists at no load, which makes it easy to detect during a routine factory test. A new rotor with a change in slot quantity would be required to reduce the noise.

Load related magnetic noise is generated when current is induced into the rotor bars under an increasing load. The electrical current in the bars creates a magnetic field around the bars which applies an attracting force on the stator teeth. These radial and tangential forces, which are applied to the stator teeth, create vibration and noise.

The forces applied to the stator teeth are not evenly distributed to every tooth at any instant in time. They are applied with different magnitudes at different teeth dependent on the relative rotor and stator tooth location. This results in force waves over the stator circumference that will produce flexural modes (m) of vibration, as shown in Fig. 6.

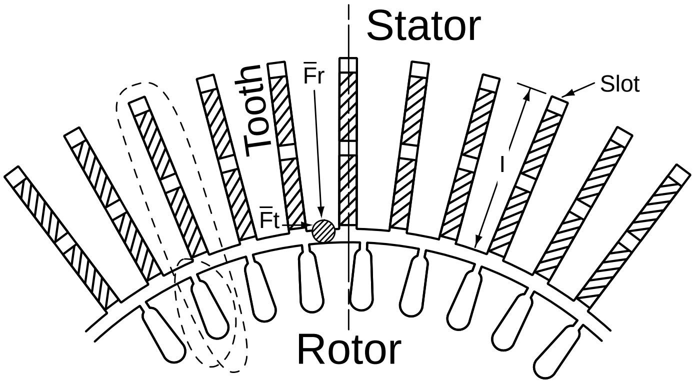

Fig. 5: Magnetic field around rotor bar and resulting forces

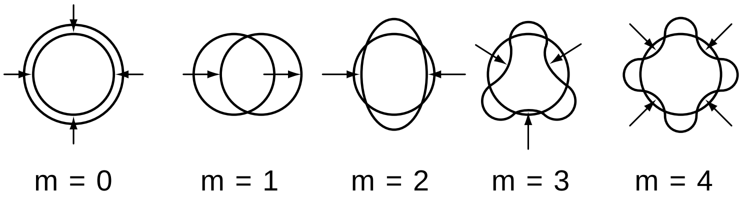

Figure 6: Mode Shapes

Noise In Induction Motors – Causes And Treatments

The mode shape is a result of the difference between the number of rotor and stator slots as shown in Equation 3. If the resonant frequency of the core is close to the forcing frequency, a high level of magnetic noise will result. The lower modes of vibration may produce resonant frequencies which are close to the forcing frequencies.

$$m = (Ns - Nr) +/- KP \qquad \text{(Eq. 3)}$$

Where Ns = Number of Stator Slots
Nr = Number of Rotor Slots
P = Number of Poles
K = All integers 0, 1, 2, 3, etc.

To understand the resonant frequency of the core at a mode of vibration, the core can be represented as a beam. The beam is simply supported on both ends and flexes about the ends due to forces applied on the beam. The length of the beam is equal to the circumferential length of the mean diameter of the stator core for one-half the mode wave length. See Fig. 7.

$$fo = \frac{36{,}700\, m\, (m^2 - 1)h}{Ds^2\, [R(m^2 + 1)]^{1/2}}$$

Where h = Depth of stator core behind slot in inches. (Eq. 4) [2]

$$R = \frac{\text{Weight of core plus teeth}}{\text{Weight of core}}$$

Ds = O.D. - h In Inches
m = Mode of vibration

Figure 7b. is a linear representation of the stator core for one-half a wave length of the 4th mode force wave shown in Figure 7a. Points A and B are points of zero displacement about which the beam is flexing. It is the resonant frequency of this beam length which is of concern and must not coincide with the frequencies of the forces being applied.

$$L = \frac{3.14\, Ds}{2\, m} = \frac{3.14\, Ds}{2 \times 4}$$

Noise In Induction Motors – Causes And Treatments

The frequency of stator tooth resonance is also a concern. A resonant condition in the tooth can be excited by the tangential forces applied to the teeth. The tooth is a cantilever beam supported at the root by the core. The resonant frequency of the cantilever beam as calculated in equation 5, is a function of the beam length and width. It is normally preferred to keep the resonant frequency of the tooth above the forcing frequencies. A longer and narrower beam will produce a lower resonant frequency. Therefore, it is necessary to limit the stator slot depth and width.

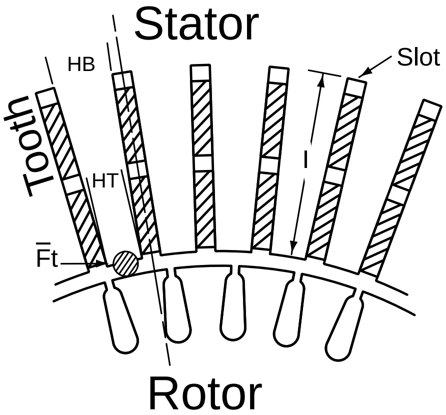

Figure 8: View of tooth and forces

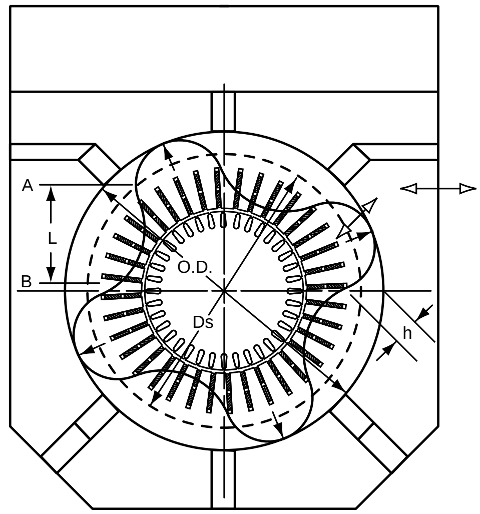

Figure 7a

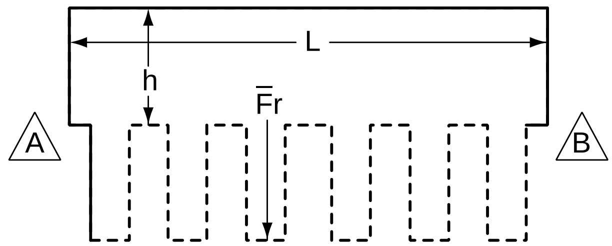

Figure 7b

Figure 7: Fourth mode of vibration and linear representation of core for one-half a wave length of force.

Noise In Induction Motors – Causes And Treatments

$Fo_{(tooth)} =$

$$\frac{Fo_{(Rect)} \times_{(Rect)}^{1/2}}{\times_{(Trap)}^{1/2}} = \frac{32825\ HB[1.5(HT + HB)]^{1/2}}{1^2[2HT + HB]^{1/2}} \qquad \text{(Eq. 5)} \quad [7\ \&\ 9]$$

Where $Fo_{(Rect)} = \dfrac{32825\ HB}{l^2}$ = Natural frequency of an iron rectangular cantilever beam

$\dfrac{X_{(Rect)}}{X_{(Trap)}} = \dfrac{1.5(HT + HB)}{2HT + HB}$ = Ratio of moment per area between a rectangular and trapezoidal beam. This ratio will give the approximate resonant frequency of a tapered cantilever beam knowing tl resonant frequency of a rectangular beam.

l = Tooth length
HB = Tooth width at root
HT = Tooth width at tooth tip

The frequencies of the load related magnetic forces applied to the stator teeth and core, are equal to the passing frequency of the rotor bars plus side bands at +/- 2f, 4f, 6f, and 8f Hertz. A fundamental force is generated at the passing frequency of the rotor slot. The side bands are created when the amplitude off this force is modulated at two times the frequency (f) of the power source. On a 60 Hertz system, this 120 Hz modulation produces the side bands.

The force applied to each tooth, produces displacement of the tooth and the core, which translates directly into noise. This displacement and noise will have a greater amplification the closer the forcing frequency is to the resonant frequency of the core or tooth.

$$\text{Amplification factor} = \frac{1}{1-(f/fo)^2} \qquad \text{(Eq. 6) [5]}$$

Noise In Induction Motors – Causes And Treatments

Knowing the frequency and the displacement of the core teeth, the calculation of noise is as follows:

$$dB = 20 \log(1.13 \times 10^6 \, f \, p\text{-}p) + 121 + 20 \log (p\text{-}p \, f) \qquad \text{(Eq. 8) [2 \& 5]}$$

Where $$p\text{-}p = \frac{19.56 \text{ [No. of g's]}}{f^2} = \frac{v}{3.14 \times f}$$

p-p = Displacement peak to peak in inches
v = Velocity in inches per second
f = Line frequency
fo = Resonant frequency of the core
g's = Acceleration in inches per sec^2

Load related magnetic noise is the most difficult noise to identify because it does not exist at no load, and will not be present during a routine factory test. If a complete factory test, including a load test is performed, the test stand loading equipment may have noise levels in excess of that of the motor. This would make the motor noise difficult to detect. In addition, slight manufacturing variations can cause a major change in the amplification factor. Therefore, load related magnetic noise may vary greatly between duplicate machines when operating close to a resonant condition.

Variable Frequency Dries (VFD) will cause an increase in magnetic noise. This increase is a result of the additional magnetic forces which are generated in the motor by the higher frequency voltage harmonics coming from the VFD.

Six pulse inverter drives can increase the noise level by up to 2 to 6 dB. Whereas a pulse width modulated (PWM) drive can increase the noise level by as much as 5 to 9 dB.

There may also be speeds within the operating speed range where the core or enclosure is resonant at the frequency of the force being produced by the voltage harmonics. In order to avoid excessive noise, the speeds where the resonance occurs must be blocked out.

The additional magnetic noise created in the motor due to VFD can be minimized by the following:

1. The noise can be minimized by filtering the incoming voltage from the VFD.
2. The noise can be minimized by reducing the magnetic field in the motor’s air gap. Forces in the gap applied to the stator teeth are a function of the square of the gap density. This can be reduced by increasing the core length and/or frame size and diameter
3. On a PWM be especially careful to avoid a core resonance at the commutation frequency.

Noise In Induction Motors – Causes And Treatments

Unique Windage Noise Problems:

Two pole motors are prone to the generation of excessive windage noise. Windage noise can also become a problem on large diameter four and six pole machines. Windage noise varies as a function of the rotor or fan diameter. Equation 9 shows how sound pressure (Lp) will vary with RPM or diameter.

$$Lp_1 = LP_2 + 50 \log \frac{RPM_1}{RPM_2} + 70 \log \frac{Diameter_1}{Diameter_2} \qquad \text{(Eq. 9) [9]}$$

On a TEFC motor it is difficult to attenuate the noise generated by the external fan. Therefore, to minimize noise generation, a careful fan design is required.

Unique Magnetic Noise Problems

Stator tooth resonance is a major concern on two and four pole, small and medium horsepower (Hp) motors. Two and four pole motors are built on smaller stator bore diameters and have deeper stator slots than the higher pole machines. These deep stator slots cause the stator teeth to be long and have a relatively low resonant frequency. This, along with the higher forcing frequencies associated with two and four pole motors, can cause the tooth resonant frequency to be very close to the forcing frequency. When this happens, the noise level can increase 10 dB or more under load. The stator slot is normally sized to produce a tooth resonant frequency much higher than the forcing frequency. Note, the relative tooth height and core depth in Figure 9.

Excessive stator core load related noise is more common on 6 pole and slower motors. The stator core back iron has less depth and will vibrate at a greater magnitude with smaller forces. It is also more difficult to avoid the resonant conditions of the many different modes of vibration. Compare the relative core depths in Figure 9.

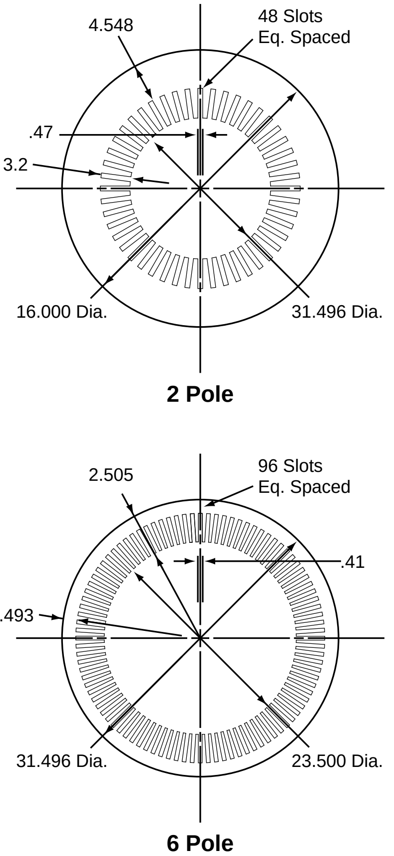

Figure 9: Comparison of two pole and six pole punching

Noise In Induction Motors – Causes And Treatments

Field Testing Procedure for Noise:

The following is an outline of a test procedure that can be performed on any induction motor. From this procedure, the nature and magnitude of noise under load can be determined. The following testing procedure requires the use of a hand held octave band noise analyzer and a discrete frequency (narrow band) spectrum analyzer with noise pickup.

Step 1. While the motor is running a no load turn the power off and monitor the noise.

a) If the noise goes away as soon as the power is turned off, the noise is magnetically generated. This could be either constant level magnetic noise or the motor could be operating very close to a resonance, causing some load related magnetic noise. Even at no load, there will be a small amount of current in the rotor bars, producing small forces that may excite a resonant condition.

b) If the noise does not decrease immediately but reduces gradually as the motor coasts down, the noise is mechanical or windage in nature. Excessive mechanical bearing noise can be generated by antifriction bearings. The use of precision bearings can help minimize the noise. Normally, bearing noise can be identified due to the location and frequencies of the noise. In this paper, only mechanical windage noise will be discussed. See reference [10] for more information on bearing noise.

Step 1 will only determine the noise source at no load. To determine if there is a significant increase in magnetic noise under load, steps two, three, four, and five must be followed.

Step 2. Determine the overall no load sound pressure Lp_{NL} at 3 feet in a free field over a reflective plane as defined in IEEE 85 and NEMA MG 3 [3 & 4]. For this $Lp(n)_{NL}$, $Lp(n)_{amb}$ and $L(n)_{C}$ must be tested for and equation 10 and 11 solved.

Noise In Induction Motors – Causes And Treatments

$Lp(n)_{NL}$ = No load noise at test point n corrected for free field and other noise sources (ambient noise).

$Lp(n)_{amb}$ = Sound pressure ambient at point n.

$L(n)_{C}$ = Free field dB correction at point n per MG 3.

$Lp(n)_{NL@df(x)}$ = No load sound pressure at point n at discrete frequency x.

$Lp(n)_{FL@df(x)}$ = Full load sound pressure at point n at discrete frequency x.

Where: NL = No load
FL = Full load
n = Test point loaction. There are 11 points for a medium sized machine. It becomes very time consuming to handle too many points in a field test, and it may be impossible to get the three readings above the motor, and the one on the drive end. For the purpose intended here 7 or 11 points will achieve the needed results, but for a more accurate estimate of overall noise try to get all 11 points. When working on a larger machine and greater accuracy is required, increase the number of test points as stated in IEEE 85.
C = Corrected for free field and ambient noise sources.
Lp(n) = Sound pressure at point n
df(x) = Discrete frequency x. There are 9 frequencies in total.

Note, log and antilog are base 10.

For this overall no load test, the motor must be located in a quiet area with no reflective surfaces except the floor, within five feet of the motor. Some motor manufacturers may use a reverberant room and test in accordance with IEEE 85, but this is not practical for a field test. In the field, it is necessary to take overall dBA readings three feet or greater from the outer surface of the motor ($Lp(n)_{NL}$). These readings must be taken at test points (n) as shown in Figure 10 around and over the top of the motor, while the motor is running at no load (NL).

Noise In Induction Motors – Causes And Treatments

Figure 10 has been reproduced from IEEE Std 85 1973, IEEE Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery, copyright c 1973 by The Institute of Electrical and Electronics Engineers, In., with the permission of the IEEE Standards Department.

Now a test must be performed to determine the correction for free field $L(n)_C$. This correction is typically 2 to 3 dB, but could be much greater in a highly reverberant field. To test for this correction, similar readings must be taken at double the distance from the center of the motor, as were the first set of no load readings. Note, this distance is from the center of the motor and not from the outer surface. Knowing the change in sound pressure at the two test locations, the room constant (R) can be determined from the second graph in Figure 11. With this room constant, use the first graph in Figure 11 and find the difference in noise at the distance in question, due to the R of the room versus an R equal to infinity. This difference will be the free field correction $L(n)_C$. For more details on this, see the example in the later field test.

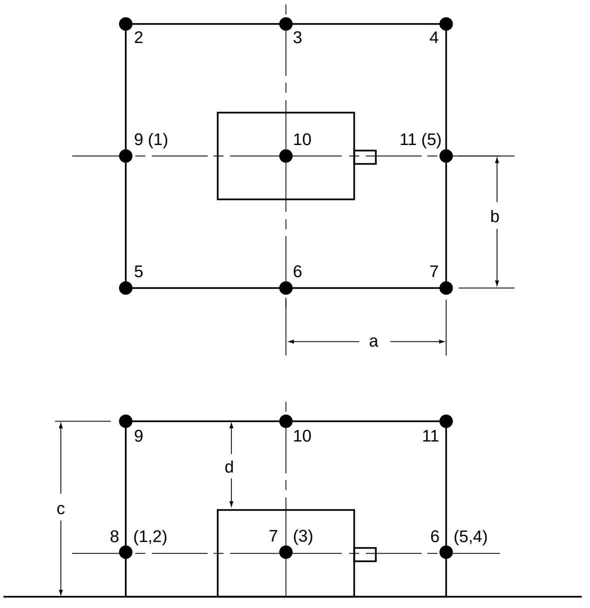

Figure 10: Prescribed Points, Medium Machine (all points of measurement shall be located on the rectilinear planes prescribed, where d is equal to 1 m or greater).

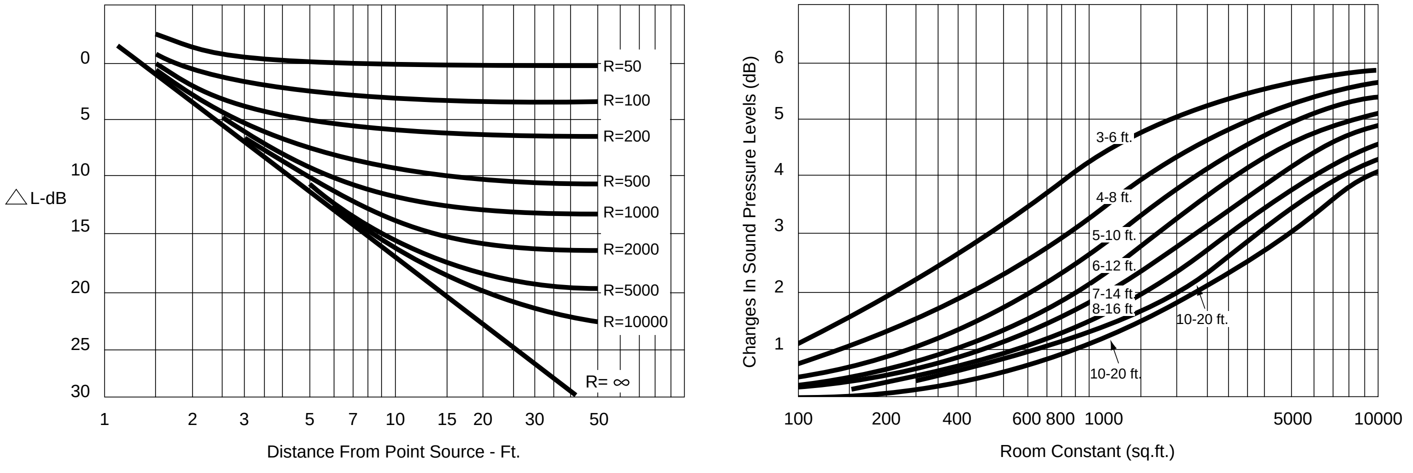

Figure 11: Graphs from MG 3*

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Noise In Induction Motors – Causes And Treatments

Next, with the motor not running, take overall readings in dBA of the background ambient noise $Lp(n)_{amb}$. These readings are to be taken at the same eleven points. This information will be used to make the correction for other noise sources as shown in Equation 10.

Solve equation 10 to find the free field no load noise at each test location around motor.

$$Lp(n)_{NL} = 10 \log \left[\text{antilog } \frac{Lp(n)_{NL}}{10} - \text{antilog } \frac{Lp(n)_{amb}}{10}\right] - L(n)_C \qquad \text{(Eq. 10)}$$

Solve equation 11 to find the average no load noise around the motor

$$Lp_{NL} = 10 \log \frac{1}{n} \left[\text{antilog } \frac{Lp(1)_{NL}}{10} + \ldots + \text{antilog } \frac{Lp(n)_{NL}}{10}\right] \qquad \text{(Eq. 11)}$$

If the noise levels are within 4 dB of each other, it would introduce little error to make a simpler arithmetic average of the dBA level instead of the calculation in Equation 11. This also applies to the later averages calculated in Equations 12 and 14.

Step 3. While the motor is operating at full load, take noise readings at the 9 discrete frequencies which are associates with load related magnetic noise. This test will require the use of a spectrum analyzer. These frequencies are the rotor bar passing frequency, and the side bands at +/- 2f, 4f, 6f, and 8f. This is similar to what will be done in Step 4 at no load. Note, the rotor slot passing frequency at full load is lower than that at no load by the ratio of (full load RPM)/ (no load RPM).

In addition, take octave band readings in the one or two octave bands which contain the frequencies of magnetic noise. Take these readings at the points shown in Figure 10 and at twice the distance from the center of the motor. This will be used to determine the value for $L(n)_C$ needed in Equation 12. Determine $L(n)_C$ for each test point in a similar manner to that done in Step 2.

For each of the 9 discrete frequencies take the averages of the readings tested at each location (n) and correct for free field as shown in equation 12.

$$Lp_{FL@df\,(X)} = 10 \log \frac{1}{n} \left[\text{antilog } \frac{Lp(1)_{FL@df\,(x)} - L(1)_c}{10} + \ldots + \text{antilog } \frac{Lp(n)_{FL@df\,(x)} - L(n)_c}{10}\right]$$

(Eq. 12)

Noise In Induction Motors – Causes And Treatments

Now make a logarithmic addition of the average noise levels at each discrete frequency calculated in Equation 12. This calculation shown in Equation 13 will give the total noise at full load at the frequencies of load related magnetic noise.

$$Lp_{FL@df} = 10 \log \left[\text{antilog} \frac{Lp_{FL@df\,(1)}}{10} + \ldots + \text{antilog} \frac{Lp_{FL@df\,(x)}}{10}\right] \quad \text{(Eq. 13)}$$

Step 4. While the motor is running at no load measure the noise levels at the discrete frequencies of load related magnetic noise. This information is needed so it can be determined how much noise exists at no load at these frequencies. Take all no load readings in dBA, 3 feet from the motor at the same points defined in Figure 10. Record the noise levels $Lp(n)_{NL@df(x)}$ at the 9 discrete frequencies which are associated with load noise. These frequencies are the rotor slot passing frequency, and the side bands +/- 2f, 4f, 6f, and 8f Hertz. Note, that the rotor slot frequency here is based on synchronous speed, and will vary in frequency from readings taken in Step 3 under load.

In addition, determine $L(n)_C$ for each test location in the same way as previously done in Step 3. If the motor is located in the same area, then the same correction may be used here.

For each of the 9 discrete frequencies take the averages of the readings taken at the test locations and correct for free field as shown in equation 14.

$$Lp_{FL@df\,(x)} = 10 \log \frac{1}{n} \left[\text{antilog} \frac{Lp(1)_{NL@df\,(x)} - L(1)_C)}{10} + \ldots + \text{antilog} \frac{(Lp(n)_{NL@df\,(x)} - L(n)_C)}{10}\right] \quad \text{(Eq. 14)}$$

Now make a logarithmic addition of the average noise levels at each discrete frequency calculated in Equation 14. This calculation shown in Equation 15 will give the total noise at no load at the frequencies of load related magnetic noise.

$$Lp_{NL@df} = 10 \log \left[\text{antilog} \frac{Lp_{NL@df\,(1)}}{10} + \ldots + \text{antilog} \frac{Lp_{NL@df\,(x)}}{10}\right] \quad \text{(Eq. 15)}$$

Correcting for ambient noise is normally not necessary in Step 3 or 4. It is reasonable to assume that there will not be other noise sources at these exact discrete frequencies. To verify this while the motor is not running, take noise readings around the motor at the same discrete frequencies. Then while the motor is driving the load, verify that the discrete frequency noise levels are higher near the motor than they are near the driven equipment.

Step 5. Calculate the total overall full load noise Lp_{FL} in a free field. This is shown in equation 16 using the results from equations 11, 13, and 15.

$$Lp_{FL} = 10 \log \left[\text{antilog} \frac{Lp_{NL}}{10} + \text{antilog} \frac{Lp_{FL@df}}{10} - \text{antilog} \frac{Lp_{NL@df}}{10}\right] \qquad \text{(Eq. 16)}$$

An Example of a Field Test

Recently in a field test of four duplicate motors, one motor was found to be generating a much higher level of noise at a very irritating frequency. It was noted that although the noise levels were considerably lower on three of the motors, the noise generated was at exactly the same discrete frequencies. The following tests were performed on the motor which was generating the excessive noise. Equipment used was a 2215 B & K Octave Band Analyzer, and a Nicolet Spectrum Analyzer.

Step 1: Prior to my arrival, a no load noise test was performed with the motor uncoupled from the compressor it was intended to drive. The overall noise level measured was less than 85 dBA and it was reported that the noise decreased gradually with speed after the power was turned off. As was outlined in Step 1 of the testing procedure, this would establish the noise to be windage in nature.

Previously, in a loaded noise test, the user was measuring overall noise levels in excess of 97 dBA. The user did not understand that the motor noise could increase under load. Therefore, an incorrect assumption was made that the noise was not coming from the motor.

Step 2. The following overall no load test data was the result of a factory test. There was inadequate time to uncouple and relocate the motor to rerun this test. The same results would have been achieved by following the field test procedure in Step 2.

	Frquency Bands								
	63	125	250	500	1000	2000	4000	8000	Lp_{NL}
dBA at 3 ft.	45	65	72	73	76	83	76	64	34.9

Noise In Induction Motors – Causes And Treatments

Step 3. In the following test, the motor was loaded by the compressor it was driving. Noise levels were measured with a spectrum analyzer at the 9 discrete frequencies as outlined in Step 3. The passing frequency is equal to 2230 Hz, as calculated by equation 2 for a 39 slot rotor rotating at 3585 RPM. The test showed that the noise levels at the passing frequency and at the +/-120 Hz side bands were much greater than the high order side bands. Noise levels 15 dBA or more below the highest peak may be ignored to reduce testing time as was done here. This will introduce less than a .75 dB error.

Next, the free field correction must be determined by test. Since the calculated rotor slot frequency and the +/- 120 Hz side bands fell within the 2000 Hz band, the test for the free field correction was accomplished by taking readings in 2000 Hz octave band on rectilinear planes 6 and 12 feet from center of motor. The noise levels were found to drop approximately 2 dB when moving from 6 to 12 feet. Since this was fairly consistent at all locations around the motor, only one free field correction needed to be calculated. If it had not been consistent, a different correction at each test point would have been required. Looking at Graph 2 of Figure 11 a 2 dB drop on the G-12 curve would represent a room constant of 900. Note, 5 feet from the center of this motor equals 3 feet from the outer surface, since this motor has a maximum dimension of 4 feet. As shown in Graph 1 of Figure 11 for a distance of 5 feet from the center of the motor and using the R equal to 900 curve the drop is equal to -9 dB. This can then be compared to -12 on the R equal to infinity curve. As is shown in the following calculation, this would give a free field correction of 3 dB.

$$
\begin{array}{rcrl}
dB & = & 12 & \text{for } R = \text{infinity (free field)} \\
-dB & = & 9 & \text{for } R = 900 \\
\hline
L(n)_c & = & 3 & \text{for } n = 1 \text{ thru } 11
\end{array}
$$

Taking the average of the readings, and subtracting 3 dB at each point per equation 12, the results are as follows:

Full Load RPM 3585

Frequencies	2210	2330	2450	2000 Hz octave band	Overall
$Lp_{NL@df(x)}$ uncorrected	85.9	90	94.5	96.2	99.5
$Lp_{NL@df(x)}$	82.9	87	91.5	93.2	

All other noise levels at other discrete frequencies were below 75 dBA and not recorded.

Noise In Induction Motors – Causes And Treatments

The following is the sum of the noise levels at the discrete frequencies at full load:

$$Lp_{FL@df} = 10 \log \left[\text{antilog} \frac{82.9}{10} + \text{antilog} \frac{87}{10} + \text{antilog} \frac{91.5}{10}\right] = 93.2 \text{ dBA} \qquad \text{(Eq. 13)}$$

It appeared that most of the noise in the 2000 Hz octave band was coming from the motor and was load related magnetic noise.

Step 4. In the following test the motor was in the same location as in Step 3, but uncoupled from the compressor. Noise levels were recorded at the rotor slot frequency of 2340 Hz and the +/- 120 Hz side bands. Equation 14 calculates the average of the discrete frequency no load noise levels measured around the motor. The results of this equation are as follows, and have already been corrected for free field.

Frequencies	2220	2340	2460
$Lp(n)_{NL@df(x)}$	75.2	74.6	73.9

$$Lp_{NL@df} = 10 \log \left[\text{antilog} \frac{75.2}{10} + \text{antilog} \frac{74.6}{10} + \text{antilog} \frac{73.9}{10}\right] = 79.4 \text{ dBA at 3 freet in a free field}$$

(Eq. 15)

Step 5. Now determine the overall full load noise level corrected for free field and ambient noise as shown in Equation 16.

$$Lp_{FL} = 10 \log \left[\text{antilog} \frac{84.9}{10} + \text{antilog} \frac{93.2}{10} - \text{antilog} \frac{79.4)}{10} = 94 \text{ dBA} \qquad \text{(Eq. 16)}$$

This test showed the noise level to increase 9 dB under load and proved it to be magnetically generated load related noise.

Noise In Induction Motors – Causes And Treatments

Similar test on one of the three quiet motors. This test result is included here as a comparison. It is interesting to see how noise levels can vary between duplicate machines when operating too close to a resonance.

	2210 Hz	2330 Hz	2450 Hz
$Lp_{FL@df(x)}$ =	76.8	78.2	80.9

$Lp_{FL@df}$ = 83.7 (Eq. 13)

$Lp_{NL@df(x)}$ = 79.0 (Eq. 15)

$$Lp_{FL} = 10 \log \left[\text{antilog} \frac{84.9}{10} + \text{antilog} \frac{83.7}{10} - \text{antilog} \frac{79}{10}\right. = 37.9 \text{ dBA} \qquad \text{(Eq. 16)}$$

The noise on this motor only increased 3dB under load, as compared to the first motor which increased 9dB.

Methods of reducing Noise

Only a few years ago, 90 dBA at no load was considered a low noise level for an induction motor. Nowadays many users are requiring motor manufacturers to limit the motor noise to 85, or even 82 dBA. In the past, these noise levels were typically achieved by either 1) adding sound insulation, 2) some type of enclosure change or baffle arrangement, 3) fan diameter reduction. In the future, motor manufacturers can expect to see noise limitations drop to 80 dBA or below. Many times, windage noise is not the main concern, even on the higher speed motors. On many motors, the magnetic noise will tend to exceed these levels even when they are not operating close to a resonant condition.

It is also important to understand that the noise level measured around the motor will be much higher than the free field no load noise level. When adding other noise sources, and the reverberant room effects, the results could be as follows:

dBA of Motor no load, free field	85
Typical Increase in motor noise under load	3
dBA for equipment motor is driving	88
Typical addition for room ambient noise	1
Typical addition for semireverberant effects of room	3

$$Lp_{total} = 10 \log \left[\text{antilog} \frac{(85+3)}{10} + \text{antilog} \frac{(88)}{10}\right] + 1 + 3 = 95.0 \text{ dBA}$$

As is shown here, though the free field noise of the motor may increase less than 3dB under load, the noise level around the motor could possibly be 10 dB above the no load level of the motor.

Noise In Induction Motors – Causes And Treatments

Windage Noise Reduction

Windage noise is airborne which makes it easier to reduce in an existing motor than magnetically generated structureborne noise. The generation of windage noise can be reduced, or existing noise can be attenuated in the following ways:

1. By a reduction in the fan diameter which will reduce the generation of windage noise by the following:

   $$\text{dB Reduction} = 70 \log(\text{diameter}_2/\text{diameter}_1)$$

   Where: Diameter_2 = New fan diameter

   Diameter_1 = Original fan diameter

2. By the use of a fan which has an air foil or backwards bent blade design that will reduce the generation of windage noise.
3. By reducing the number of rotor vents.
4. By band taping the bar extensions on fabricated rotors between the rotor core and end connector.
5. By lining the existing air chambers with sound absorbent insulation.
6. By the use of lined baffles to deflect the air at the intakes or exhausts. The line of sight, from the exhaust and/or intake to the noise producing source, should be blocked. When designed properly this can be done without any significant cooling reduction.

Items 1, 2, 3, and 4 above, must be performed at the factory or service shop and should be considered in the original design. Modifications in items 5 and 6 can be handled in the field, but are most cost effective and technically correct if included in the original design.

Most of the windage noise of open motors comes from the fan action of the rotor bars, not the fans. Therefore, a fan diameter reduction will not always cause a significant reduction in noise. The cause of the noise can be determined by comparing the frequency of the noise to the passing frequency of the bars and fans. If the rotor fans on the open motor are assisting in forcing the air through the rotor, then the fan reduction may have a significant effect, but it will not follow the fan laws. On TEFC motors, an external fan diameter reduction is very effective. Any fan or vent reduction will cause the motor to run hotter. This will have to be compensated for by either reducing horsepower output, or by increasing frame size and cost.

Installing sound insulation in the top covers where space allows, and/or the introduction of baffles will reduce windage noise significantly. It is not unusual to be able to reduce noise level by as much as 10 dB, without increasing the motor temperature.

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When using baffles or sound insulation caution must be taken to avoid restricting the air flow. To accomplish this, the air flow requirement must be known and baffles located in such a way that the air speed and pressure drop is not excessive. A general rule for the maximum air velocity in a short run of ducts is given in the following formulas. The CFM required to cool a motor can be measured on an existing motor, or estimated by the following:

$$CFM = P \, (KW_{Loss}) \qquad \text{(Eq. 17)}$$

Where: P = 60 to 100. Use 100 to be safe.

$$KW\ loss = \frac{(.746\ Horsepower)}{Efficiency} - .746\ Horsepower$$

$$\text{Maximum air velocity} = (.15)(D_F)(3.14)(RPM) \qquad \text{(Eq. 18)}$$

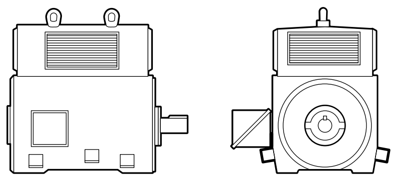
Where: D_F = Diameter of fan or rotor in feet.

Velocity = Feet per minute

Noise levels can be minimized on new designs by the use of enclosures with increasing weather protection as illustrated below.

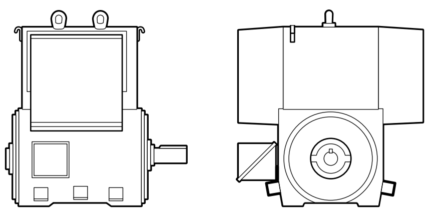
Open drip proof

Least control of windage noise.



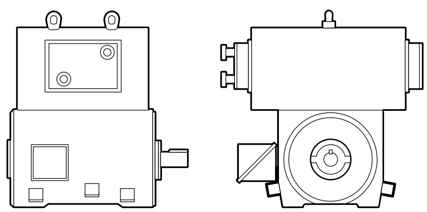
Weather protected type II

Has a much greater control of windage noise since the air must make multiple bends, which can all be lined with sound insulation.



Totally enclosed water cooled

Has the greatest control of windage noise, sine there is no exchange of the internal and external air. The enclosure is made of thick enough steel to minimize the transmission of noise.



Noise In Induction Motors – Causes And Treatments

Magnetic Noise Reduction

In the first example above, the motor was found to have excessive noise in the 2000 Hz band. It was proven to be magnetically generated load related noise. Magnetic noise is the most difficult noise to reduce since it is structureborne, and is difficult to isolate from the external surface of the motor. The following are ways that magnetic noise can be controlled or reduced:

1. Change the stator slot design or rotor slot quantity to achieve a greater margin between the forcing frequencies and the resonant frequencies of the core or teeth. By changing the stator slot size the resonant frequencies of the core and teeth will be changed. Whereas, changing the quantity of rotor slots will change the forcing frequencies and mode of vibration.
2. Build the rating on a larger core length or frame size to reduce the magnetic field density in the air gap. The force applied to the stator teeth is proportional to the square of the flux density. In addition, a larger machine will also increase the strength of the teeth and core thereby reducing vibration and noise.
3. Install magnetic wedges in the stator slot. This will reduce the tangential forces being applied to the teeth.
4. Build an enclosure around the motor to stop the transmission of structueborne noise. The enclosure and air ducting must be isolated from the motor, either by air space or through isolation bushings. The bushings must be designed not to transmit the frequencies in question. The enclosure can be made of any material thick enough to effectively attenuate the transmission of sound. It should be lined on the inside with 2 to 4 inches of sound insulation to prevent the build up of noise inside the enclosure. The air ducts must be sized, so that air flow is not restricted. They must also be sealed to prevent the exhaust air from mixing with the intake air. The temperature of the cooling air entering the motor must not exceed the design ambient. Although most open motors do not rely on heat radiation from the yoke to cool the motor, they may require cool ambient air around the bearing capsules to cool the bearings. The enclosure should be vented, to keep the air inside the enclosure around the bearings at ambient temperature.

Only the modification in item 4 can be performed in the field. The other items will require extensive work at the factory or service shop. Items 1, 2, and 3 should be considered in the original design, where it would be more cost effective and technically correct.

Reducing the noise on the motor in the field test example. When reviewing the design of the motor presented here, the stator tooth resonance was calculated to be 2585 Hz. This is too close to the forcing frequencies of 2210, 2330, and 2450 Hertz, and may periodically cause excessive noise. Several manufacturing variations can affect the tooth resonance or dampen the vibration. These include core pressure, steel grade, coil placement in slot, tightness of slot wedges, and penetration of the VPI insulation.

Noise In Induction Motors – Causes And Treatments

A test on a modified design which had a higher calculated resonant frequency of 2975 Hertz, showed a considerable improvement in the noise level. This higher resonant frequency is due a reduction in the stator slot height from 3.5 inches to 3.2 inches.

Tested no load noise

Oct. Band	63	125	250	500	1000	2000	4000	8000	L_{pNL}
dBA @ 3'	60	64	70	73	71	76.7	70.8	52.3	79.7

Under load the following noise levels were found:

	2210 Hz	2330 Hz	2450 Hz	2570 Hz
$Lp_{FL@df(x)}$	70.6	70.4	75.8	72.0

$Lp_{FL@df}$ = Noise at full load at discrete frequencies = 78.8

$Lp_{NL@df}$ = Noise at no load at discrete frequencies = 74.1

Lp_{FL} = Total full load noise level = 81.6

This motor tested 5 dBA lower at no load than the best of the previous motors, and only increased 2 dB from no load to full load.

Summary

1. When trying to reduce induction motor noise, first determine the noise source within the motor. This must be established before the proper treatment to the motor can be determined.
2. Estimate the actual overall full load noise level of the motor. This will help determine whether or not applying noise treatment to the motor is beneficial. If the motor is not the primary noise source, a large reduction in motor noise may not achieve a significant reduction in the overall noise level.
3. Further noise reductions that may be required in the future to achieve levels below 80 dBA, will be accomplished by frame size increases and/or isolation type enclosures built around the motor.
4. If low noise is required, it is best to consider it in the original motor design than to make modifications in the field.

References

[1] C. Kron, “Induction Motor Slot Combination,” presented at the Winter Convention of the A.I.E.E., New York, NY, January 26-30, 1931.

[2] P.L. Alger, Induction Machines, New York, Gordan and Breach Science Publishers, 1970, Ch. 10, pp. 368-377.

[3] IEEE Rotating Machinery Committee, IEEE Std. 85, IEEE Press, 1973.

[4] Motor and Generator Section of NEMA, “MG 3 Sound Level Prediction for Installed Rotating Electrical Machines.”

[5] W.R. Ringland, “Magnetic Noise in Salient Pole Synchronous machines,” presented at A.I.E.E. Middle Eastern District Meeting, Toledo, Ohio, October 28-30, 1952.

[6] Buffalo Forge Company, Fan Engineering, Buffalo, New York, Buffalo Forge Company Publisher, Ch. 8, pp. 226-227.

[7] S. Timoshenki, Vibration Problems in Engineering, New Jersey, D. Van Nostrand Company, Inc., Publishers, 1955, Ch. 5, pp. 331-356.

[8] J.P. Den Hartog, Mechanical Vibrations, York, PA., McGraw-Hill Book Company, Inc., 1956, Appendix, pp. 431-432.

[9] Raymond J. Roark, Formulas for Stress and Strain, New York, McGraw-Hill Book Company, 1954, Ch. 6, pp. 70-71.

[10] Robert W. Smeaton, Motor Application and Maintenance Handbook, New York, McGraw-Hill Book Company, Ch. 20, Robert C. Bartheld, Motor Noise, pp. 1-23.

Specifying and Measuring The Noise Level of Electronic Motors in Operation

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Abstract

Present industry standards show how to test for the noise output of unloaded electric motors, but do not directly address a method of measuring the noise of loaded motors. However, electric motors are almost never operated without load by the users. Since the noise produced when loaded can be different than when unloaded, there is need for a method to make this determination. Existing IEEE methods can be adapted to this type of testing only if the surrounding ambient conditions, including noise output of the load, are suitably quieter than the motor. Also, the surrounding area must have suitable acoustic characteristics. Unfortunately, those conditions are not often found in motor load testing areas or in installations. The Sound Intensity method of noise testing was developed to achieve accurate results in the presence of other noise sources and in acoustical environments unsuitable for noise testing via conventional procedures. In this paper a sound intensity noise testing approach specifically for rotating electrical machinery is described. Tests have been performed on actual motors to demonstrate the method, and results are presented to illustrate its validity. It is concluded that loaded motors can be successfully tested for noise output, and it is urged that IEEE noise testing standards be expanded to include the testing of loaded machines, including use of the sound intensity method.

I. Introduction

Ever since noise levels have been measured for electric motors, it has been the practice to test with the motors operating at no-load conditions. This was done to isolate the motor noise output from effects of its load and its environment. It also reflected the difficulty in making accurate noise measurements on loaded motors. However, the users of electric motors nearly always operate them under load, and their main concern is what the noise level is at the motor's installed location. Here also, there can be noise contributions from the driven machinery and other equipment running in the vicinity. In addition, the effects of room reverberation and noise reflection from nearby surfaces can influence observed noise levels.

Papers have been written which provided general information on the effect of motor noise output under load [1]. An increase of 0 to 4 dB(A) is usually assumed. However, this is not true of all motors, and this sometimes results in unpleasant surprises at the jobsite.

The true noise output of an electric motor or other piece of equipment is described by its sound power level (see Appendix A). The no-load noise output of motors is defined in these terms in several industry standards, such a NEMA MG1 [2] and ANSI C50.41 [3].

Methods are also provided to convert those values into approximate sound pressure levels in a free field over a reflecting plane at a distance of 1 meter from the motor.

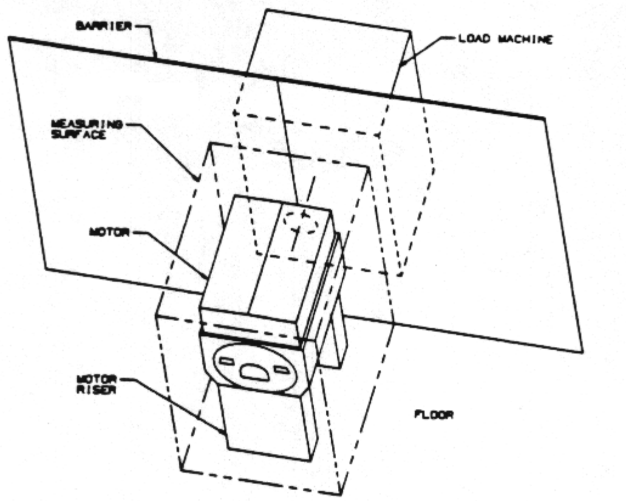
To predict the noise level which will occur at an installation, the system designer should know the sound power output of all equipment in a facility when operating at rated conditions. He must also have knowledge of the characteristics of the enclosing room. With this information it is possible to predict at the design stage what noise level can be expected in the final installation. NEMA MG3 [4] addresses this type of determination.

There are several methods available to electric motor manufacturers to determine the sound power of loaded electric motors. they include 1) achieving a quiet ambient noise level in the load test area by quieting surrounding equipment as necessary, 2) providing a special enclosure around the motor being tested to control it immediate surroundings for noise testing under load, and 3) utilizing the sound intensity measuring technique [5].

In the first approach, the ambient noise level in the load test area must be kept low with respect to the noise produced by the motors being tested. then the same test procedures as used for no- load conditions per IEEE 85 can be employed. The second approach requires that the test enclosure isolates the motor on test from the ambient noise in the area and provides a suitable internal environment within the enclosure for accurate noise testing. The information for designing and sizing such an enclosure is known. Suitability of this approach depends on specific conditions in the load test area and the economics involved. The sound intensity method of measuring the noise output is a more recently developed approach, and its use for this purpose will be discussed in this paper.

II. Measuring The Sound Power Output Of Electric Motors Via The Sound Intensity Method

The sound intensity method of measuring the noise produced by a piece of equipment has been substantially developed and refined within the last fifteen years. The nature of this type of testing is reviewed in Appendix B. It utilizes a two-microphone probe which enables measuring both magnitude and direction of the flow of sound energy. As a result it has the advantage that it can compensate for a relatively poor acoustical environment with reverberations and reflecting surfaces. It can also compensate for an ambient sound pressure level higher than that produced by the machine being tested. These characteristics make the sound intensity method attractive for performing noise tests in adverse conditions such as for loaded motors in a shop test area or in a field installation.



Sound intensity readings are taken at points on each of the four planes of the measuring surface.

Figure 1. Arrangement of reflecting barrier

Noise In Induction Motors – Causes And Treatments

Substantial testing has been performed to demonstrate the accuracy of the sound intensity method in determining the noise output of loaded electric motors [5]. This work has shown the usefulness of a reflective sound attenuating barrier placed between the motor and its load as shown in Figure 1. The barrier blocks direct noise impingement from the loading machinery and reflects noise produced by the motor on test. This approach enables accurate determination of the noise output of loaded motors when using the sound intensity method, even in the case of very noisy load machines.

Table 1 shows a comparison of sound power levels determined at no- load per IEEE 85 [6] in a reverberant sound laboratory versus that measured at no-load via the sound intensity method with the motor coupled to an unloaded dynamometer. Note that very good comparisons are achieved under no-load conditions. For this particular motor there was an increase of 1.3 dB(A) in the overall noise output when the motor was loaded, with a smaller increase in the linear noise level.

Table 1
Noise Testing of 1250 HP, 2-Pole Motor [5]
(All values are Sound Power Level, Ref. 10^{-12} watts)
(Sound Pressure Level at 1 meter in a free Field is 12.4 dB lower)

	Octave Band Center Freq.							**Overall**	
	125	250	500	1000	2000	4000	8000	A	Lin
Tested at No Load in a Reverberant Sound Lab	94.6	95.5	91.9	87.7	89.1	83.7	72.2	95.3	100.5
Tested w/o shaft load while coupled to dynamometer with barrier in place, using sound intensity method	93.2	96.9	92.6	88.2	89.1	83.9	73.0	95.5	100.2
Tested at 1.15 SF load while coupled to dynamometer with barrier in place, using sound intensity method	92.7	97.2	91.6	87.8	91.9	88.2	71.9	96.8	100.5

Table II shows a similar comparison for another motor with the no-load sound power level determined per IEEE 85 versus that determined via the sound intensity method. In this test, the no- load motor noise by sound intensity was determined with measuring surfaces as in Figure 1 which were established at three different distances from the motor. Again note that very good consistency was achieved, but with increasing changes from the values determined per IEEE 85 as the distance of the measuring surface from the motor was increased. When this motor was loaded there was a noticeable decrease in windage noise due to the increased slip. Note the lower levels in the 2000 Hz and 4000 Hz octave bands under load. This, combined with a very low magnetic noise content, resulted in a decrease in noise output when the motor was loaded. Also note that the noise output of the loaded motor was consistent when measuring surfaces were chosen at two different distances from the motor.

The comparisons in Table 2 show the best correlation with results taken in the reverberant sound laboratory when a measuring surface closer to the motor with the smaller spacing between points is used. It requires significant testing time to make this type of measurement, particularly for physically larger motors. However, this approach is considered the most accurate means for getting detailed noise measurements at each octave band as needed in a “type test” to prove the detailed characteristics for a given line of motors.

Means were also explored to determine the feasibility of a simpler test which could be used for more routine commercial testing of loaded motors in a manufacturer’s shop. This test approach involves using a measuring surface which is 24 inches from the motor to minimize the effects of variations in the near field. Then only two test points are taken on each of the four planes of the measuring surface. Points are 24 inches apart at shaft height on the vertical planes, and above the motor centerline on the horizontal top plane. Table 3 shows the result of this type of test on the same motor which was tested in Table 2. Note here that correlation with values obtained in the sound laboratory is not quite as good at the lower frequency octave bands. However, the overall dB(A) sound power levels are in reasonable agreement – certainly within the +/–3 dB(A) accuracy which is recognized via IEEE 85 methods. Since many users specify motor noise requirements in terms of overall dB(A) quantities, the use of the reduced “8-point” test would produce the accuracy needed to verify the overall A-weighted sound produced.

III. Conclusions and Recommendations

Based on the preceding discussion and review of test data a number of conclusions and a recommendation can be reached regarding the specifying and testing of the noise produced by electric motors. They are;

A. For the most practical benefit to the user, the noise output of electric motors should be specified and tested for fully loaded operation of the motor.

B. The most practical and useful approach to stating the noise output of electric motors is via the sound power level produced by the motor. The present widely used approach of specifying sound pressure level at some distance in a free field is of interest, but the sound power information is what is needed in the acoustical design of systems and facilities where the motor will be applied.

C. The noise output of a loaded electric motor can be measured by the manufacturer by at least three different methods which include; 1. Testing in a suitably quiet area. 2. Providing a special enclosure for noise testing. 3. Testing via the sound intensity method.

D. It is urged that industry standards which deal with the noise testing of electric motors (such as IEEE 85) be expanded in scope to address specifically the testing of the noise output of loaded motors. Also, they should include the sound intensity measurement method as one of the approved approaches.

Noise In Induction Motors – Causes And Treatments

Table 2
Noise Testing of 700 HP, 2-Pole Motor [5]
(All values are Sound Power Level, Ref. 10^{-12} watts)
(Sound Pressure Level at 1 meter in a free Field is 11.2 dB lower)

			Octave Band Center Freq.							**Overall**	
			125	250	500	1000	2000	4000	8000	A	Lin
Tested at No-Load in a Reverberant Sound Lab			85.5	91.4	95.4	95.6	94.8	92.9	86.2	101.2	101.6
Tested coupled to dynamometer with barrier in place, using sound intensity method											
Load	Measuring Surface										
	Distance from Motor	Spacing on Surface									
None	10"	18"	88.1	92.6	94.2	94.3	94.5	93.5	85.7	100.8	101.7
None	24"	24"	89.0	94.3	95.7	95.9	94.0	92.6	84.6	100.9	102.3
None	36"	36"	90.5	92.2	94.0	93.7	93.6	92.4	85.7	99.9	101.3
Full Load	10"	18"	87.8	92.5	94.2	94.3	92.6	90.8	87.4	99.6	100.9
Full Load	24"	24"	89.0	91.6	93.4	92.9	91.3	89.6	85.7	98.1	100.0

Table 3
Noise Testing of 700 HP, 2-Pole Motor
Comparison of Abbreviated Sound Intensity Method with More Comprehensive Sound Intensity Method
(All values are Sound Power Level, Ref. 10^{-12} watts)
(Sound Pressure Level at 1 meter in a free Field is 11.2 dB lower)

			Octave Band Center Freq.							**Overall**	
			125	250	500	1000	2000	4000	8000	A	Lin
Tested at No-Load in a Reverberant Sound Lab			85.5	91.4	95.4	95.6	94.8	92.9	86.2	101.2	101.6
Tested coupled to dynamometer with barrier in place, using sound intensity method											
Load	Measuring Surface										
	Distance from Motor	Spacing on Surface									
None	10"	18"	88.1	92.6	94.2	94.3	94.5	93.5	85.7	100.8	101.7
None	24"	8-Point Test	89.5	95.6	97.3	97.1	96.6	95.9	89.7	103.2	104.4
Full Load	10"	18"	87.8	92.5	94.2	94.3	92.6	90.8	87.4	99.6	100.9
Full Load	24"	8-Point Test	89.5	95.2	96.6	95.3	93.9	91.8	88.0	100.8	102.5

Noise In Induction Motors – Causes And Treatments

References

[1] R. Brozek, "No Load to Full Load Airborne Noise Level Change on High Speed Polyphase Induction Motors," IEEE/PCI Conference Paper No. PCI-72-8, Fig. 21 through 27.

[2] National Electrical Manufacturers Association, Motors and Generators, NEMA Publication No. MG1-1987.

[3] American National Standards Institute, Inc., American National Standard for Polyphase Induction Motors for Power Generating Stations, ANSI C50.41-1982.

[4] National Electrical Manufacturers Association, Sound Level Prediction for Installed Rotating Electrical Machines, NEMA Publication No. MG3-1974 (R 1979, 1984).

[5] J.L. Craggs, "Measuring the Noise Level of Loaded Electric Motors," presented at the IEEE/IAS Conference of the Pulp and Paper Industry, Montreal, Quebec, June 3-7, 1991.

[6] The Institute of Electrical & Electronic Engineers, Inc., IEEE Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery, IEEE Standard 85-1973 (R 1980).

[7] Gunnar Rasmussen, "Intensity – Its Measurement and Uses," Sound and Vibration, Vol. 23, Number 3, March 1989, p. 12-21.

[8] International Organization for Standardization, Acoustics – Determination of Sound Power levels of Noise Sources using Sound Intensity – Measurement at Discrete Points, Draft International Standard ISO/DIS 9614-1.

[9] American National Standards Institute, Engineering Method for Determination of Sound Power Levels of Noise Sources using Sound Intensity, Proposed ANSI S12.12 – 198X (ASA XX).

Appendix A

Review of Terminology to Express Sound [5]

As a background for the noise testing information in this paper, some of the various means of expressing sound should be reviewed. Basically, a source of sound radiates sound power into the surrounding atmosphere. The effect of this radiated sound power is pressure. This pressure is what is sensed when the ear hears a sound [7].

Sound power which is radiated from a sound source is stated in watts. It is a fixed entity for a given sound source, and it is unaffected by environmental considerations. The term “sound power level” is used to define the wattage being radiated from a sound source. It is expressed as a ratio to a standard reference level. The standard way of expressing this quantity is as 10 times the logarithm to the base 10 of the ratio of a given sound power to the reference power [6].

$$Lw = 10 \log_{10} \left[\frac{P}{P_o} \right] \qquad (1)$$

where Lw = sound power level, in decibels
P = total sound power radiated from a sound source, in watts
P_o = reference power of 10^{-12} watts, or 1pW

Sound pressure, which is the observable result of a radiated sound, is what is heard by the human ear, and also what is measured by a conventional sound level meter. This pressure is expressed as a ratio to a reference pressure. The standard way of expressing this quantity is as 20 times the logarithm to the base 10 of the ratio of the sound pressure to the reference pressure [6].

$$Lp = 20 \log_{10} \left[\frac{P}{P_o} \right] \qquad (2)$$

where Lw = sound power level in decibels
p = measured wound pressure
p_o = reference sound pressure of 20 x 10^{-6} Pascals

The sound pressure level observed is dependent upon distance from the sound source and upon the effects of other sound sources. It is also affected by room reverberations, reflected sound, and atmospheric conditions.

Noise In Induction Motors – Causes And Treatments

However, if the sound power level of a sound source is known, its sound pressure level in a free field over a reflecting plane at any distance from the source can be readily determined.

Sound Intensity describes the rate of flow of sound energy through a particular area [7]. Thus, if one considers a sound source to be completely enclosed by a theoretical surface, the average intensity of the flow of sound power through that surface would be the sound power divided by the area of the surface. The standard way of expressing this quantity is as 10 times the logarithm to the base 10 of the ratio of the sound intensity to the reference intensity [8].

$$L_{In} = 10 \log_{10} \left[\frac{I_n}{I_o} \right] \qquad (3)$$

where L_{In} = sound intensity level in decibles
I_n = sound intensity normal to the surface being considered
I_o = reference intensity of $1 pW/m^2$

Sound power level is used to define the noise produced by electric motors in NEMA and ANSI standards [2] [3]. However, many users specify the sound pressure level at 1 meter from the motor in a free sound field. IEEE 85 prescribes how to determine the sound power level of an unloaded motor under controlled conditions. It also shows how to convert that value into the sound pressure level which would be observed at a specified distance from the motor in a free sound field over a reflecting plane [6].

Appendix B

Description of Sound Intensity Measurement Method [5]
As presented in Appendix A, sound intensity is expressed as [8]:

$$L_{In} = 10 \log_{10} \left[\frac{I_n}{I_o} \right] \text{dB} \qquad (4)$$

where I_n = sound intensity normal to the surface being considered
I_o = reference level of $1\ pW/m^2$

Noise In Induction Motors – Causes And Treatments

The sound power emitted through a portion of a surface is then [8]:

$$P_i = I_{ni} S_i \qquad (5)$$

where I_{ni} = the signed magnitude of the normal sound intensity component measured at position i of a measuring surface

S_i = area of segment i of the measuring surface

Using this approach, a measuring surface can be established around the object being tested (in this case, an electric motor). The total measuring surface can be divided into several convenient parts for testing, and the sound power can be determined for each individual portion of the measuring surface via sound intensity measurements. The total sound power level of the source is then expressed in decibels with reference to 10^{-12} watts. Thus [8]:

$$L_{WI} = 10 \log_{10} \left[\sum_{1=1}^{N} \frac{P_i}{P_o} \right] \qquad (6)$$

where N = total number of measuring surface segments

P_o = reference level of 1pW

The sound intensity as measured includes reflected sound from closely located reflective surfaces (such as the floor) as part of its input. More than one reflective surface can be used and still allow correct results to be achieved.

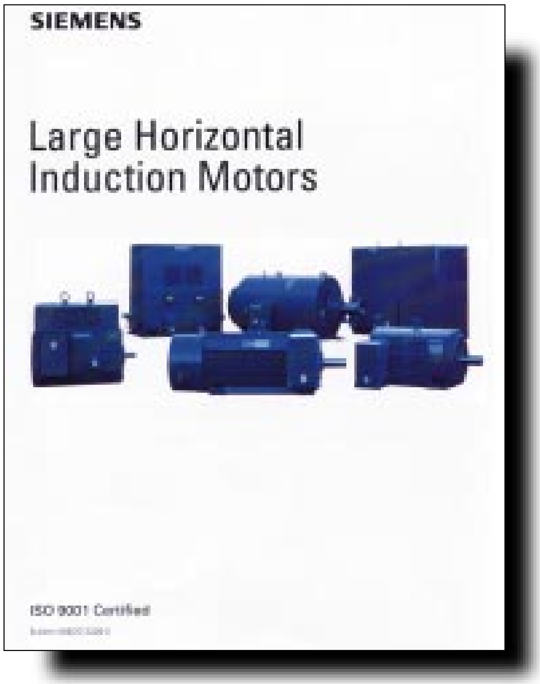
Several standards for measuring the sound power level of an object are in the draft stage both in Europe and in the USA at the time of writing this paper. They are:
ISO/DIS 9614-1 [8]
ANSI S12.12-198X [9]

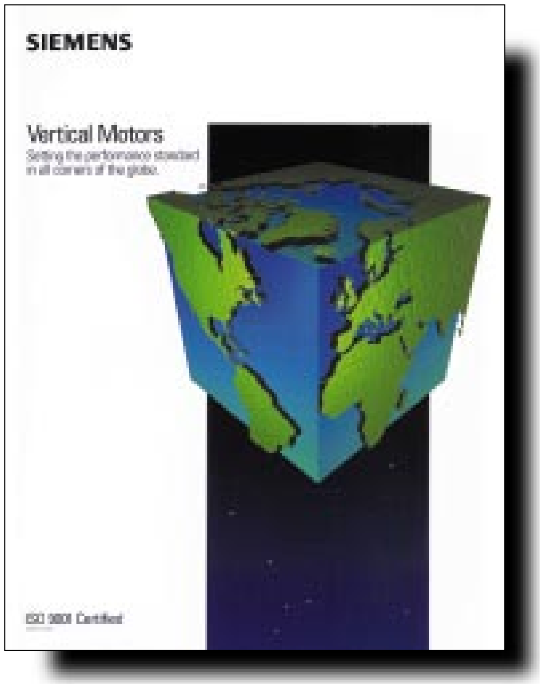
Both dwell heavily on measuring techniques and on evaluations to determine that sufficient accuracy is being obtained. Since they are standards for general applications, they must be very general in nature to handle all situations, and this then makes them quite complex.

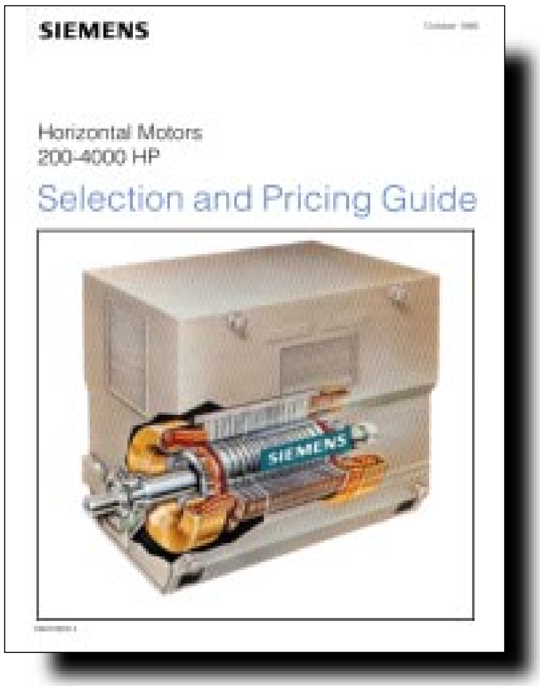
Present experience indicates that the sound intensity measurements on electric motors are accurate with ambient noise levels up to approximately 10 dB higher than that of the object being tested if extraneous noise sources are at a distance (15 to 20 ft.) from the motor. Measurements can be accurate with ambient noise up to 5 dB higher if the source is very close (3 to 6 ft.) to the test object. It should be noted from the above that the sound intensity method is applicable when the ambient noise level is higher than that of the object being tested.

Literature

Siemens offers a variety of literature in the form of brochures, Selection and Pricing Guides, specialized articles, and instruction manuals to fulfill your needs or to enhance your written proposals. To obtain information and/or copies please contact your local Siemens Sales representative.







Electrical Information

Frame Assignments

Horizontal Standard — Type IG
Open Drip-Proof — Weather Protected Type I Enclosure

Speed												
Rating	**3600 RPM – 2 Pole**			**1800 RPM – 4 Pole**			**1200 RPM – 6 Pole**			**900 RPM – 8 Pole**		
Voltage												
HP	**Low**	**2300**	**4000**	**Low**	**2300**	**4000**	**Low**	**2300**	**4000**	**Low**	**2300**	**4000**
150		505			505			505			505	
200		505			505			505			505	
250		505	505		505	505		505	505	508	508	508
300		505	505		505	505	508	508	508	508	508	508
350		505	508		505	505	508	508	508			
400		508	508	508	505	505	508	508	508			
450		508	508	508	508	508						
500		508	508	508	508	508						
600	508	508	508	508	508	508						
700	508	508	508	508	508	508						

Class B Temperature Rise by Resistance @ 1.0 S.F.

Frame Assignments

Horizontal Custom
Open Enclosures

	Speed																
HP	SF	3600 RPM – 2 Pole				1800 RPM – 4 Pole				1200 RPM – 6 Pole				900 RPM – 8 Pole			
		Voltage															
		Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600
200	1.00	-	507	507	-	-	507	507	-	-	507	507	-	-	507	507	-
200	1.15	-	507	507	-	-	507	507	-	-	507	507	-	-	507	507	-
250	1.00	-	507	507	-	-	507	507	-	-	507	507	-	507	509	509	-
250	1.15	-	507	507	-	-	507	507	-	-	507	507	-	507	509	509	-
300	1.00	-	507	507	-	-	507	507	-	507	507	507	-	509	509	509	-
300	1.15	-	507	507	-	-	507	507	588	507	507	507	-	509	509	588	-
350	1.00	-	507	507	588	-	507	507	588	509	509	509	-	509	588	588	588
350	1.15	-	507	507	588	-	507	507	588	509	509	509	-	509	588	588	588
400	1.00	-	507	507	588	507	507	507	588	509	509	509	-	588	588	588	588
400	1.15	-	507	507	588	507	509	509	588	509	509	509	-	588	588	588	588
450	1.00	-	507	507	588	507	509	509	588	509	509	5011	-	588	588	588	588
450	1.15	-	507	507	588	507	509	509	588	509	5011	5011	-	588	588	588	588
500	1.00	-	509	509	588	509	509	509	588	5011	5011	5011	588	588	588	588	5810
500	1.15	-	509	509	588	509	509	509	588	5011	5011	5011	588	588	588	588	5810
600	1.00	507	509	509	588	509	509	509	588	5011	5011	5011	588	588	5810	5810	5810
600	1.15	509	509	509	588	509	509	509	588	5011	5011	5011	588	5810	5810	5810	5810
700	1.00	509	509	509	588	509	5011	5011	588	5011	5011	588	5810	5810	5810	5810	5810
700	1.15	509	509	588	588	509	5011	5011	588	588	588	588	5810	5810	5810	5810	6811
800	1.00	588	588	588	588	5011	5011	5011	5810	588	588	5810	5810	5810	5810	5810	6811
800	1.15	588	588	588	588	5011	5011	5011	5810	588	588	5810	5810	-	6811	6811	6811
900	1.00	-	588	588	588	-	5810	5810	5810	-	5810	5810	6811	-	6811	6811	6811
900	1.15	-	588	588	588	-	5810	5810	5810	-	5810	5810	6811	-	6811	6811	6811
1000	1.00	-	588	588	5810	-	5810	5810	5810	-	5810	5810	6811	-	6811	6811	6811
1000	1.15	-	588	588	5810	-	5810	5810	5810	-	6811	6811	6811	-	6811	6811	6811
1250	1.00	-	5810	5810	5810	-	5810	5810	5810	-	6811	6811	6811	-	6811	6811	6811
1250	1.15	-	5810	5810	5810	-	5810	5810	5810	-	6811	6811	6811	-	6811	6811	6811
1500	1.00	-	5810	5810	5810	-	5810	5810	6811	-	6811	6811	6811	-	6813	6813	6813
1500	1.15	-	5810	5810	5810	-	6811	6811	6811	-	6811	6811	6813	-	6811	6811	6813
1750	1.00	-	5810	5810	6811	-	6811	6811	6811	-	6811	6811	6813	-	6813	6813	6813
1750	1.15	-	5810	5810	6811	-	6811	6811	6811	-	6813	6813	6813	-	6813	6813	6813
2000	1.00	-	5810	5810	6811	-	6811	6811	6811	-	6813	6813	6813	-	6813	6813	8010
2000	1.15	-	6811	6811	6811	-	6811	6811	6811	-	6813	6813	6813	-	809	809	8010

Frame Assignments

Horizontal Custom Open Enclosures

		Speed															
HP	SF	3600 RPM – 2 Pole				1800 RPM – 4 Pole				1200 RPM – 6 Pole				900 RPM – 8 Pole			
		Voltage															
		Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600
2250	1.00	-	6811	6811	6811	-	6811	6811	6811	-	6813	6813	6813	-	809	809	8010
2250	1.15	-	6811	6811	6811	-	6811	6811	6811	-	6813	6813	6813	-	809	809	8011
2500	1.00	-	6811	6811	6813	-	6811	6811	6813	-	6813	6813	8011	-	809	809	8011
2500	1.15	-	6811	6811	6813	-	6811	6811	6813	-	809	809	8012	-	8010	8010	8011
3000	1.00	-	6813	6813	6813	-	6813	6813	6813	-	8010	8010	8012	-	8010	8010	1122
3000	1.15	-	6813	6813	6813	-	6813	6813	6813	-	8010	8010	8012	-	8010	8010	1122
3500	1.00	-	6813	6813	6813	-	6813	6813	6813	-	8011	8011	1122	-	8011	8011	1122
3500	1.15	-	6813	6813	6813	-	6813	6813	8011	-	8011	8011	1122	-	8011	8011	1122
4000	1.00	-	6813	6813	6813	-	6813	6813	8011	-	8011	8011	1122	-	8012	8012	1122
4000	1.15	-	6813	6813	8011	-	8010	8010	8011	-	8012	8012	1122	-	1122	1122	1122
4500	1.00	-	6813	6813	8011	-	8011	8011	8011	-	8012	8012	1122	-	1122	1122	1122
4500	1.15	-	8010	8010	8011	-	8011	8011	8011	-	1122	1122	1122	-	1122	1122	1124
5000	1.00	-	8011	8011	8011	-	8011	8011	8012	-	1122	1122	1122	-	1122	1122	1124
5000	1.15	-	8011	8011	8012	-	8011	8011	8012	-	1122	1122	1124	-	1124	1124	1124
5500	1.00	-	8011	8011	8012	-	8012	8012	8012	-	1122	1122	1124	-	1124	1124	1124
5500	1.15	-	8012	8012	8012	-	8012	8012	1122	-	1122	1122	1124	-	1124	1124	-
6000	1.00	-	8012	8012	-	-	8012	8012	1122	-	1122	1122	1124	-	1124	1124	-
6000	1.15	-	8012	8012	-	-	8012	8012	1122	-	-	1124	1124	-	-	-	-
7000	1.00	-	-	-	-	-	-	1122	1122	-	-	1124	1124	-	-	-	-
7000	1.15	-	-	-	-	-	-	1124	1124	-	-	1124	-	-	-	-	-
8000	1.00	-	-	-	-	-	-	1124	1124	-	-	1124	-	-	-	-	-
8000	1.15	-	-	-	-	-	-	1124	1124	-	-	-	-	-	-	-	-
9000	1.00	-	-	-	-	-	-	1124	1124	-	-	-	-	-	-	-	-
9000	1.15	-	-	-	-	-	-	1124	-	-	-	-	-	-	-	-	-
10000	1.00	-	-	-	-	-	-	1124	-	-	-	-	-	-	-	-	-

Class B Temperature Rise by Resistance

Frame Assignments

Horizontal Custom
TEFC Enclosures

HP	SF	Speed															
		3600 RPM – 2 Pole				1800 RPM – 4 Pole				1200 RPM – 6 Pole				900 RPM – 8 Pole			
		Voltage															
		Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600
200	1.00	-	507	507	-	-	507	507	-	-	507	507	-	509	509	509	-
200	1.15	-	507	507	-	-	507	507	-	-	507	507	-	509	509	509	-
250	1.00	-	507	507	-	-	507	507	-	509	509	509	-	5011	5011	5011	-
250	1.15	-	507	507	-	-	507	507	-	509	509	509	-	5011	5011	5011	-
300	1.00	-	509	509	-	-	507	507	-	509	509	509	-	588	588	588	-
300	1.15	-	509	509	-	509	509	509	-	509	5011	5011	-	588	588	588	-
350	1.00	509	509	509	588	509	509	509	588	5011	5011	5011	5810	588	5810	5810	5810
350	1.15	509	509	509	588	509	509	509	588	5011	5011	5011	5810	588	5810	5810	5810
400	1.00	509	509	509	588	509	5011	5011	588	5011	5011	5011	5810	588	5810	5810	5810
400	1.15	509	509	509	588	5011	5011	5011	588	588	588	588	5810	5810	5810	5810	5810
450	1.00	509	509	509	5810	5011	5011	5011	588	588	588	588	5810	5810	5810	5810	708
450	1.15	588	588	588	5810	5011	5011	5011	588	588	588	5810	5810	5810	5810	708	708
500	1.00	588	588	588	5810	5011	5011	5011	588	588	5810	5810	5810	708	708	708	708
500	1.15	588	588	588	5810	5011	5011	5011	588	588	5810	5810	5810	708	708	708	708
600	1.00	588	5810	5810	5810	588	588	588	5810	5810	5810	5810	708	708	708	708	788
600	1.15	5810	5810	5810	5810	588	588	5810	5810	5810	5810	708	708	708	708	708	788
700	1.00	5810	5810	5810	5810	5810	5810	5810	5810	708	708	708	708	708	708	708	788
700	1.15	5810	5810	5810	708	5810	5810	5810	708	708	708	708	708	708	708	708	788
800	1.00	5810	5810	5810	708	5810	5810	5810	708	708	708	708	708	708	788	788	788
800	1.15	5810	5810	5810	708	708	708	708	708	708	708	708	708	708	788	788	788
900	1.00	-	5810	5810	708	708	708	708	708	708	708	708	708	788	788	788	788
900	1.15	-	708	708	708	708	708	708	708	708	788	788	788	788	788	788	880
1000	1.00	-	708	708	788	708	708	708	708	788	788	788	788	788	788	788	880
1000	1.15	-	708	708	788	708	708	708	708	788	788	788	788	788	788	880	880
1250	1.00	-	788	788	788	788	708	708	788	788	788	788	788	788	880	880	880
1250	1.15	-	788	788	788	788	788	788	788	788	788	880	788	880	880	880	8010
1500	1.00	-	788	788	6811	788	788	788	788	880	880	880	788	880	880	880	8010
1500	1.15	-	788	788	6812	788	788	788	880	880	880	880	8011	-	809	809	8011
1750	1.00	-	788	788	6813	788	788	788	880	880	880	880	8011	-	809	809	8011
1750	1.15	-	6811	6811	6813	788	880	880	880	-	880	8010	8012	-	809	809	8011
2000	1.00	-	6812	6812	6813	880	880	880	809	-	8010	8010	8012	-	8010	8010	8012
2000	1.15	-	6812	6812	6813	880	880	880	8010	-	8010	8010	8012	-	8010	8010	8012

Class B Temperature Rise by Resistance

Frame Assignments

Horizontal Custom TEFC Enclosures

HP	SF	Speed															
		3600 RPM – 2 Pole				1800 RPM – 4 Pole				1200 RPM – 6 Pole				900 RPM – 8 Pole			
		Voltage															
		Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600
2250	1.00	-	6813	6813	8010	880	880	880	8010	-	8010	8010	-	-	-	-	-
2250	1.15	-	6813	6813	8010	-	880	880	8010	-	8011	8011	-	-	-	-	-
2500	1.00	-	6813	6813	8010	-	8010	8010	8011	-	8011	8011	-	-	-	-	-
2500	1.15	-	6813	6813	8011	-	8010	8010	8011	-	8011	8011	-	-	-	-	-
3000	1.00	-	8010	8010	8011	-	8010	8010	8011	-	8012	8012	-	-	-	-	-
3000	1.15	-	8010	8010	8011	-	8011	8011	8012	-	8012	8012	-	-	-	-	-
3500	1.00	-	8011	8011	8012	-	8011	8011	8012	-	-	-	-	-	-	-	-
3500	1.15	-	8011	8011	8012	-	8011	8011	8012	-	-	-	-	-	-	-	-
4000	1.00	-	8012	8012	-	-	8012	8012	-	-	-	-	-	-	-	-	-
4000	1.15	-	8012	8012	-	-	8012	8012	-	-	-	-	-	-	-	-	-

Class B Temperature Rise by Resistance

Frame Assignments

Horizontal Custom
Explosion-Proof and Dust-Ignition Proof Enclosures

		Speed															
HP	SF	3600 RPM – 2 Pole				1800 RPM – 4 Pole				1200 RPM – 6 Pole				900 RPM – 8 Pole			
		Voltage															
		Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600
200	1.0		507	507			507	507			507	507		5011	5011	5011	
250	1.0		507	507			507	507		509	509	509		509•	509•	509•	
300	1.0	509	509	509		509	509	509		5011	5011	5011		30E	30E	30E	
350	1.0	509	509	509	30N	5011	5011	5011	30B	5011	5011	5011	30E	30E	30E	30E	30KK
400	1.0	509•	509•	509•	30N	5011	5011	5011	30B	30E	30E	30E	30KK	30E	30E	30E	30L
450	1.0	30N	30N	30N	30N	5011	5011	5011	30B	30E	30E	30E	30KK	30E	30KK	30KK	30L
500	1.0	30N	30N	30N	30N	30B	30B	30B	30JJ	30E	30KK	30KK	30L	30KK	30KK	30KK	30L
600	1.0	30N	30N	30N	30R	30B	30B	30B	30JJ	30KK	30KK	30KK	30LL	30L	30L	30L	30LL
700	1.0	30N	30N	30N	30R	30JJ	30JJ	30JJ	30JJ	30L	30KK	30KK	30LL	30L	30L	30L	3030
800	1.0	30R	30R	30R	3020	30JJ	30JJ	30JJ	3020	30L	30L	30L	3030	30LL	30LL	3030	
900	1.0		30R	30R	3023		30JJ	30JJ	3023		30L	30LL	3030		3030	3030	
1000	1.0		3020	3020	3023		30JJ	3020	3030		30LL	3030					
1250	1.0		3023	3023			3023	3023			3030	3030					
1500	1.0						3030	3030									
1750	1.0						3030	3030									

Class B Temperature Rise by Resistance

Note: Frames 509 with a bullet suffix ("•") are Type RGZZ.
All other 500 frames are Type CGZZ.

Frame Assignments

Horizontal Custom
Explosion-Proof and Dust-Ignition Proof Enclosures

HP	SF	Speed															
		720 RPM – 10 Pole				600 RPM – 12 Pole				514 RPM – 14 Pole				450 RPM – 16 Pole			
		Voltage															
		Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600	Low	2300	4000	6600
200	1.0	509•	30E	30E		30E	30E	30KK		30KK	30KK	30KK		30KK	30KK	30KK	
250	1.0	30E	30E	30E		30E	30KK	30KK		30KK	30KK	30KK		30KK	30KK	30L	
300	1.0	30E	30E	30E		30KK	30KK	30KK		30KK	30L	30L		30L	30L	30LL	
350	1.0	30KK	30KK	30KK	30KK	30L	30L	30L	30LL	30L	30L	30L		30LL	30LL	30LL	
400	1.0	30KK	30KK	30KK	30L	30L	30L	30L	3030	30LL	30LL	30LL			3030	3030	
450	1.0	30KK	30KK	30KK	30L	30LL	30LL	30LL			3030	3030			3030		
500	1.0	30L	30L	30L	30LL	30LL	30LL	3030			3030	3030					
600	1.0	30L	30LL	30LL	3030	3030	3030	3030									
700	1.0	30LL	30LL	30LL													
800	1.0	3030	3030	3030													

Class B Temperature Rise by Resistance

Note: Frames 509 with a bullet suffix ("•") are Type RGZZ.
All other 500 frames are Type CGZZ.

Frame Assignments

Horizontal Custom
Open Enclosures — 13.2KV

HP	SF	Speed				
		3600 RPM – 2 Pole	1800 RPM – 4 Pole	1200 RPM – 6 Pole	900 RPM – 8 Pole	720 RPM – 10 Pole
2250	1.0	8011	8011	8012	1122	1124
	1.15	8011	8011	8012	1122	1124
2500	1.0	8011	8011	8012	1122	
	1.15	8011	8011	1122	1122	
3000	1.0	8012	8012	1122	1124	
	1.15	8012	8012	1122	1124	
3500	1.0	8012	8012	1122		
	1.15		1122	1122		
4000	1.0		1122	1122		
	1.15		1122	1124		
4500	1.0		1122	1124		
	1.15		1124	1124		
5000	1.0		1124			
	1.15		1124			

Class B Temperature Rise by Resistance

Electrical Performance Data

Horizontal Standard — Type IG
Open Enclosures
460-4000 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
460 Volt														
250	885	508	322.0	114.7	1623	94.2	94.9	95.1	77.1	74.6	66.2	1483	1083	2833
300	1181	508	358.0	99.9	2248	94.5	95.1	95.2	83.0	81.7	75.8	1334	1067	3028
300	885	508	397.0	154.1	2041	94.1	94.8	95.0	75.2	72.0	62.7	1780	1317	3560
350	1179	508	416.0	99.7	2396	94.4	95.1	95.3	83.4	83.3	79.0	1559	1154	3227
400	1771	508	462.0	135.1	3123	94.6	95.0	94.9	85.7	83.8	77.3	1186	1032	2514
400	1178	508	483.0	119.9	2632	94.2	95.0	95.2	82.3	82.2	77.6	1783	1266	3548
450	1768	508	524.0	152.2	3317	94.5	95.0	95.0	85.1	83.3	77.0	1336	1109	2672
500	1770	508	586.0	183.5	3873	94.5	95.0	95.0	84.5	82.2	75.0	1483	1305	3114
600	3564	508S	649.0	160.6	3959	95.3	95.7	95.8	90.8	90.2	87.1	884	707	2121
600	1770	508	702.0	219.5	4724	94.7	95.2	95.2	84.5	82.2	75.0	1780	1620	3791
700	3554	508S	783.7	163.9	4428	94.5	95.3	95.6	88.5	87.7	83.7	1034	744	1923
700	1764	508	821.0	247.6	5320	94.8	95.4	95.5	84.2	82.2	75.5	2079	1844	4283
2300 Volt														
250	3566	505S	58.1	19.6	369	93.3	93.4	92.5	85.9	82.7	74.8	368	276	850
250	1766	505	60.6	20.9	346	93.2	93.6	93.1	82.9	80.0	72.0	743	535	1412
250	1175	505	63.3	21.4	321	92.7	93.2	92.9	79.8	77.4	69.6	1117	804	2044
250	882	508	65.5	24.4	329	93.0	93.5	93.1	76.9	73.9	65.1	1488	1250	2634
300	3563	505S	66.7	17.3	430	93.6	93.9	93.3	89.5	87.8	82.4	442	349	999
300	1765	505	71.7	23.7	415	93.4	93.7	93.2	83.9	81.5	74.2	892	669	1713
300	1175	505	75.3	23.7	373	92.9	93.5	93.3	80.3	78.5	71.5	1340	965	2372
300	883	508	77.4	28.2	406	93.3	93.7	93.4	77.8	74.9	68.3	1784	1588	3283
350	3562	505	79.0	22.4	502	93.5	93.9	93.5	88.3	86.2	79.9	516	413	1146
350	1767	505	83.7	28.4	516	93.6	93.8	93.4	83.7	80.8	72.9	1040	863	2142
350	1178	508	85.2	25.4	469	93.5	93.9	93.7	82.3	80.7	74.1	1560	1264	3026
400	3560	508S	87.1	18.4	560	93.8	94.3	94.1	91.2	90.3	86.6	590	484	1298
400	1769	505	93.2	29.8	612	93.8	94.1	93.7	85.2	82.7	75.4	1187	1068	2552
400	1178	508	96.1	26.9	541	93.6	94.1	93.8	83.3	82.0	76.1	1783	1516	3459
450	3564	508S	99.6	26.1	665	94.1	94.6	94.2	89.4	87.7	82.1	663	557	1538
450	1769	508	105.3	33.6	693	94.0	94.3	93.8	85.1	82.5	75.2	1336	1202	2899
500	3561	508S	108.8	23.6	703	94.2	94.7	94.5	90.9	90.0	86.0	737	604	1644
500	1767	508	117.5	36.9	740	94.0	94.3	94.0	84.8	82.5	75.3	1486	1308	3091
600	3560	508S	132.4	32.7	832	94.2	94.8	94.7	89.6	88.1	83.1	885	717	1929
600	1770	508	139.9	44.7	942	94.4	94.7	94.3	85.1	82.5	75.1	1780	1673	3952
700	3562	508S	152.3	35.1	1020	94.5	95.1	95.0	90.6	89.3	84.9	1032	908	2374
700	1764	508	162.8	44.7	943	94.2	94.7	94.7	85.5	84.1	78.4	2083	1666	3958

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Standard — Type IG
Open Enclosures
460-4000 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
4000 Volt														
250	3566	505S	33.5	22.7	217	92.8	93.0	92.2	86.2	83.0	74.9	365	288	847
250	1764	505	34.7	23.1	190	92.7	93.2	92.9	83.2	80.7	73.0	744	521	1339
250	1178	505	35.9	24.3	198	92.6	93.1	92.6	81.0	78.3	70.4	1114	880	2161
250	885	508	37.5	14.9	211	92.8	93.2	92.8	77.3	73.5	63.9	1483	1409	2907
300	3563	505S	38.6	20.2	248	93.2	93.6	93.1	89.4	87.7	82.2	442	349	981
300	1772	505	41.9	16.1	291	93.2	93.3	92.5	82.7	78.7	69.3	889	836	2063
300	1179	508	42.4	27.6	245	93.0	93.4	93.4	82.0	79.6	72.0	1336	1122	2699
300	883	508	44.7	16.4	234	92.8	93.3	93.1	77.8	74.9	66.2	1784	1570	3247
350	3564	508S	44.0	10	294	93.7	94.1	93.7	91.0	89.8	85.5	516	423	1187
350	1768	505	49.0	18	311	93.1	93.4	92.9	82.6	79.1	70.2	1039	904	2182
350	1177	508	49.1	14.3	267	93.0	93.5	93.4	82.6	81.1	74.8	1561	1249	2935
400	3564	508S	50.6	12.4	339	93.8	94.2	93.9	90.3	88.8	83.8	589	483	1355
400	1770	505	54.6	18.4	360	93.6	93.9	93.3	84.3	81.4	73.4	1186	1044	2574
400	1178	508	55.5	15.6	311	93.1	93.7	93.6	83.4	82.0	76.0	1783	1498	3423
450	3563	508S	57.3	14.7	374	93.8	94.3	94.0	89.6	88.0	82.6	663	544	1492
450	1769	508	60.8	19.6	401	93.8	94.1	93.7	85.0	82.4	74.9	1336	1202	2874
500	3561	508S	62.7	13.8	406	93.9	94.5	94.3	90.9	89.9	85.8	737	604	1621
500	1767	508	67.8	21.6	427	93.7	94.1	93.8	84.8	82.3	75.0	1486	1308	3046
600	3560	508S	76.5	19.2	480	93.9	94.5	94.5	89.5	87.9	82.8	885	717	1903
600	1770	508	80.6	26.1	548	94.2	94.5	94.2	85.1	82.4	74.8	1780	1709	3969
700	3562	508S	87.9	20.5	590	94.3	94.9	94.8	90.5	89.2	84.6	1032	908	2332
700	1764	508	93.7	26.1	548	94.0	94.5	94.3	85.6	84.1	78.2	2083	1708	3958

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
Open Enclosures
460 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
200	3563	507	225.0	41.0	1450	93.9	93.9	93.2	88.8	88.2	85.3	295	207	516
200	1777	507	233.0	79.0	1450	94.4	94.3	93.6	85.0	82.0	74.0	591	473	1330
200	1180	507	234.0	66.0	1450	94.1	94.6	94.4	85.2	83.4	77.1	890	890	1958
200	880	507	246.0	86.0	1450	93.6	94.0	93.8	81.3	78.2	69.8	1492	1492	2984
250	3564	507	282.0	58.0	1825	94.2	94.3	93.7	88.0	87.1	83.3	368	258	644
250	1772	507	279.0	60.0	1825	94.4	94.8	94.5	88.8	88.3	84.6	741	593	1482
250	1180	507	296.0	95.0	1825	94.4	94.8	94.7	83.8	81.2	73.5	1113	1113	2671
250	880	507	305.0	104.0	1815	93.7	94.3	94.2	81.8	78.9	70.7	1492	1492	2984
300	3563	507	331.0	55.0	2200	94.6	94.8	94.4	89.6	89.3	86.8	442	309	774
300	1774	507	348.0	108.0	2200	94.6	94.9	94.6	85.4	83.1	76.0	888	710	1998
300	1179	507	345.0	89.2	2170	94.4	95.0	95.2	86.2	84.8	79.4	1336	1336	2993
300	880	509	364.0	114.0	2184	93.7	94.4	94.5	82.3	80.1	72.8	1790	1790	3401
350	3561	507	388.0	62.0	2550	94.5	94.8	94.6	89.5	89.3	87.0	516	361	903
350	1774	507	402.0	118.0	2550	94.9	95.2	94.9	86.0	84.0	77.4	1036	829	2383
350	1180	509	404.0	108.0	2622	94.5	95.0	95.2	85.9	84.3	78.5	1557	1557	3581
350	880	509	422.0	125.0	2532	93.7	94.5	94.7	82.8	81.1	74.5	2089	2089	3760
400	3560	507	444.0	74.0	2900	94.6	94.9	94.8	89.1	88.8	86.4	590	413	1033
400	1773	507	444.0	93.4	2877	94.8	95.3	95.4	89.0	88.6	85.1	1184	947	2510
400	1176	509	463.0	108.0	2622	94.2	95.0	95.3	85.9	85.3	80.9	1786	1552	3581
400	885	588	483.0	152.0	2898	94.5	95.0	95.0	82.0	80.0	72.9	2374	2347	4748
450	3562	507	504.0	98.0	3250	94.8	95.1	94.8	88.2	87.5	84.2	663	464	1160
450	1773	507	502.0	110.0	3213	94.8	95.3	95.5	88.6	88.0	84.2	1333	1066	2813
450	1177	509	511.0	106.0	2989	94.4	95.2	95.6	87.3	87.0	83.6	2007	1726	4114
450	885	588	563.0	207.0	3378	94.4	94.9	94.8	79.3	76.2	67.3	2671	2938	5609
500	3560	507	552.0	91.0	3627	94.8	95.2	95.1	89.4	89.1	86.7	738	517	1292
500	1773	509	556.0	118.0	3586	94.9	95.5	95.6	88.7	88.3	84.8	1481	1185	3125
500	1176	5011	569.0	116.0	3260	94.4	95.2	95.6	87.2	87.1	83.8	2232	1897	4464
500	885	588	606.0	196.0	3636	94.6	95.1	95.2	81.7	79.5	72.1	2967	3264	6231
600	3560	507	673.0	134.0	4341	94.9	95.5	95.6	87.9	87.1	83.5	885	531	1549
600	1770	509	676.0	143.0	4002	94.7	95.4	95.7	87.7	87.6	84.1	1780	1424	3507
600	1178	5011	678.0	142.0	4162	94.6	95.3	95.7	87.4	87.1	83.6	2674	2640	5642
600	890	588	744.0	264.0	4278	94.9	95.3	95.2	79.6	76.8	68.4	3541	3187	7081
700	3560	509	772.0	125.0	5018	95.2	95.8	95.9	89.2	89.1	86.7	1033	723	2169
700	1771	509	774.0	152.0	4930	95.0	95.6	95.9	89.1	89.0	86.0	2075	1660	4295
700	1179	5011	797.0	188.0	5061	94.8	95.5	95.8	86.8	86.0	81.4	3118	3118	7171
700	886	5810	850.0	251.0	5525	95.0	95.7	96.1	81.2	79.8	73.3	4148	3484	8503
800	3570	588	879.0	187.0	4615	95.4	95.7	95.6	89.3	88.8	85.1	1177	863	2413
800	1771	5011	891.0	185.0	5791	95.0	95.7	95.9	88.5	88.3	84.9	2371	2134	4979
800	1185	588	905.0	220.0	5204	94.7	95.2	95.3	87.4	86.5	81.9	3543	3543	7440
800	892	5810	924.0	304.0	6006	95.4	95.6	95.3	85.0	82.2	74.3	4721	5193	10622

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
Open Enclosures
2300 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
200	3570	507	45.9	14.3	285	94.1	94.1	93.4	86.6	83.9	76.7	294	235	706
200	1776	507	46.1	7.6	295	93.1	93.4	93.7	87.2	85.1	78.8	591	591	1390
200	1180	507	47.8	15.6	270	92.8	93.4	93.1	84.4	81.2	72.5	890	890	1914
200	876	507	49.4	15.9	259	92.5	93.3	93.3	81.9	79.6	72.1	1199	1319	2278
250	3570	507	58.2	18.8	340	94.0	94.0	93.3	85.6	82.8	75.2	368	257	828
250	1779	507	57.7	16.9	367	93.4	93.7	93.0	86.8	84.6	78.1	738	664	1734
250	1180	507	62.4	23.5	334	92.4	92.8	92.3	81.2	77.0	66.8	1113	1113	2337
250	880	509	61.9	20.8	365	92.6	93.3	93.1	81.7	79.0	71.0	1492	1641	3059
300	3574	507	67.3	18.3	417	94.6	94.8	94.3	88.2	86.3	80.3	441	375	1036
300	1778	507	68.5	18.7	432	93.7	94.0	93.5	87.5	85.7	79.8	886	798	2038
300	1180	507	70.1	19.9	403	93.3	93.8	93.6	85.9	82.6	76.4	1335	1469	2804
300	880	509	74.1	25.6	437	93.0	93.6	93.4	81.5	78.5	70.2	1790	1970	3849
350	3574	507	79.8	23.9	495	94.4	94.5	94.0	87.0	84.6	77.7	514	411	1209
350	1778	507	81.2	12.3	508	93.8	94.1	93.7	86.0	83.7	76.7	1034	930	2378
350	1177	507	82.5	23.3	495	93.7	94.3	94.2	84.8	83.0	76.7	1562	1718	3358
350	885	588	86.1	31.2	504	93.7	94.1	93.8	81.2	78.1	69.4	2077	2492	4362
400	3570	507	88.5	21.4	531	94.8	95.2	95.0	89.2	87.8	82.9	588	441	1324
400	1778	507	90.1	22.6	577	94.0	94.3	94.1	88.4	87.0	81.9	1182	1122	2718
400	1175	509	93.1	25.3	535	93.8	94.5	94.5	85.8	84.2	78.3	1788	1788	3755
400	884	588	98.9	35.3	554	93.7	94.2	93.9	80.8	77.9	69.5	2376	2613	4752
450	3571	507	102	28.6	629	94.5	94.7	94.2	87.8	85.7	79.4	662	529	1555
450	1778	509	101	25.7	659	94.1	94.4	94.1	88.3	86.8	81.6	1329	1329	3124
450	1175	509	105	24.9	678	93.8	94.5	94.6	86.0	85.1	80.5	2011	2212	4023
450	885	588	110	39.8	660	93.9	94.3	94.0	81.3	78.2	69.6	2671	3339	5609
500	3571	509	111	27.7	691	95.0	95.2	94.8	89.1	87.6	82.4	735	588	1728
500	1778	509	113	29.1	719	94.1	94.5	94.2	87.9	86.4	81.0	1477	1403	3397
500	1175	5011	115	25.3	650	93.7	94.4	94.4	86.6	86.1	82.2	2235	2235	4358
500	890	588	124	49.7	769	94.5	94.7	94.3	79.8	75.8	66.0	2951	2951	6787
600	3568	509	134	34.5	785	94.8	95.1	94.7	88.3	86.7	81.4	883	707	1943
600	1778	509	134	33.0	874	94.5	94.9	94.6	88.4	87.1	82.2	1772	1772	4076
600	1177	5011	142	37.8	795	93.9	94.6	94.7	84.5	83.1	77.6	2677	2945	5221
600	890	5810	149	60.2	939	94.6	94.8	94.4	79.6	75.5	65.7	3541	3895	8144
700	3570	509	155	39.3	976	95.2	95.5	95.3	88.8	87.2	81.9	1030	927	2317
700	1776	5011	155	32.9	962	94.6	95.0	95.0	89.3	88.6	84.9	2070	2070	4554
700	1187	5011	159	43.7	1034	94.8	95.4	95.4	87.2	85.4	79.5	3097	3097	6969
700	889	5810	170	58.9	978	94.5	95.0	94.8	81.4	78.8	70.7	4135	4135	8270
800	3572	588	173	33.7	1084	95.3	95.5	95.2	90.6	89.9	86.6	1176	1000	2705
800	1776	5011	176	35.3	1093	94.7	95.1	95.0	89.7	89.3	86.0	2366	2366	5205
800	1186	588	181	47.0	1113	94.8	95.4	95.6	87.1	85.8	80.5	3543	3543	7440
800	890	5810	195	73.7	1219	94.8	95.1	94.8	80.9	77.4	68.4	4721	5193	10622

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
Open Enclosures
2300 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
900	3571	588	194	35.7	1205	95.5	95.7	95.5	90.8	90.4	87.6	1324	1059	2978
900	1782	5810	199	40.9	1264	94.8	94.9	94.4	89.3	88.8	85.4	2653	2387	5968
900	1187	5810	204	54.1	1295	94.9	95.5	95.5	87.1	85.7	80.1	3982	4380	8761
900	893	6811	208	65.2	1313	95.1	95.4	95.2	85.0	82.7	75.5	5293	3705	10586
1000	3570	588	216	38.7	1298	95.4	95.6	95.4	90.7	90.4	87.7	1471	1250	3310
1000	1782	5810	223	50.2	1407	94.8	95.0	94.6	88.4	87.6	83.6	2947	2653	6779
1000	1187	5810	223	53.9	1450	95.1	95.6	95.7	88.2	87.2	82.5	4425	4867	9734
1000	893	6811	231	75.9	1504	95.3	95.6	95.4	84.9	82.1	74.3	5881	4411	12351
1250	3578	5810	271	61.6	1734	95.5	95.8	95.7	90.3	89.2	84.9	1835	1284	4496
1250	1782	5810	277	60.3	1803	95.0	95.2	94.9	88.8	88.1	84.3	3684	3684	8473
1250	1190	6811	278	65.1	1778	95.4	95.7	95.5	88.3	87.4	83.1	5517	3586	11034
1250	892	6811	285	85.0	1768	95.4	95.8	95.8	86.0	84.3	78.3	7360	5152	14720
1500	3572	5810	322	55.8	2096	95.8	96.1	96.0	90.9	90.5	87.9	2205	2095	5293
1500	1786	5810	329	65.3	2107	95.5	95.7	95.5	89.3	89.0	85.9	4411	3529	9925
1500	1190	6811	331	85.5	2152	95.6	96.0	95.9	88.7	88.1	84.2	6620	4634	13240
1500	892	6811	342	96.1	2122	95.4	95.8	95.8	86.0	84.3	78.3	8832	6182	17664
1750	3571	5810	377	71.4	2448	95.9	96.3	96.3	90.7	90.1	86.9	2574	2445	5920
1750	1788	6811	385	88.0	2506	95.7	96.0	95.7	88.8	88.0	83.8	5140	3084	10795
1750	1190	6811	386	85.5	2511	95.6	96.0	95.9	88.7	88.1	84.2	7724	5406	15447
1750	893	6813	398	114	2584	95.6	96.0	95.9	86.2	84.3	78.0	10292	7719	21614
2000	3600	5810	429	72.0	2617	95.8	96.2	96.2	91.1	91.1	88.8	2918	1897	6565
2000	1788	6811	439	90.7	2763	95.9	96.1	95.9	89.0	88.7	85.4	5875	3525	12337
2000	1190	6813	439	92.7	2851	95.7	96.0	96.0	89.2	88.7	85.1	8827	6179	17654
2000	892	6813	452	122	2891	95.7	96.1	96.1	86.6	85.1	79.5	11776	8243	23552
2250	3581	6811	487	104	2970	95.7	95.7	95.2	90.4	89.6	85.8	3300	1980	6930
2250	1788	6811	495	110	3215	96.0	96.2	96.0	88.7	88.0	83.1	6609	3965	13879
2250	1190	6813	492	101	3196	95.7	96.0	96.0	89.5	89.1	85.7	9930	6951	20854
2500	3582	6811	546	129	3276	96.1	96.1	95.6	89.2	88.1	83.6	3666	2199	7331
2500	1788	6811	544	112	3537	96.3	96.5	96.2	89.3	88.9	85.8	7343	4406	15421
2500	1190	6813	545	110	3540	96.0	96.4	96.3	89.5	89.2	86.0	11034	7724	23171
3000	3581	6813	651	142	3904	96.1	96.2	95.7	89.8	89.0	85.2	4400	2640	8800
3000	1787	6813	650	114	4031	96.3	96.5	96.4	89.7	90.0	87.8	8817	5290	17634
3500	3581	6813	751	159	4806	96.3	96.3	95.9	90.6	89.8	86.1	5133	3080	10780
3500	1788	6813	758	144	4925	96.5	96.7	96.6	89.6	89.6	86.8	10281	6168	21590
4000	3582	6813	865	203	5622	96.4	96.5	96.1	89.8	88.6	84.1	5865	3812	12903
4000	1788	6813	869	172	5648	96.5	96.7	96.6	89.3	89.1	86.1	11749	8225	25849

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
Open Enclosures
4000 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
200	3573	507	25.4	6.2	164	94.2	94.4	94.0	89.9	88.4	83.4	294	235	720
200	1779	507	27.1	8.6	168	92.6	92.8	92.0	85.9	83.2	75.8	590	531	1357
200	1180	507	28.3	9.7	170	92.3	92.7	92.3	82.4	79.2	70.8	890	1068	1869
200	885	507	29.2	11.9	183	91.6	92.0	91.4	80.4	76.1	66.0	1187	1602	2671
250	3572	507	31.9	7.8	198	94.3	94.7	94.4	89.4	87.9	83.0	368	294	845
250	1778	507	33.2	9.5	206	93.2	93.5	93.1	87.0	85.0	78.6	738	665	1662
250	1180	507	34.4	10.9	206	92.5	93.1	93.0	84.6	82.1	74.6	1113	1224	2337
250	884	509	35.4	13.1	218	92.7	93.2	93.0	81.9	78.3	69.2	1485	1857	3342
300	3573	507	38.8	10.8	248	94.2	94.5	94.0	88.3	86.2	80.0	441	353	1058
300	1779	507	39.6	11.2	253	93.4	93.8	93.4	87.3	85.2	78.9	886	886	2081
300	1181	507	40.7	12.2	250	92.7	93.3	93.1	85.6	83.4	76.6	1334	1668	2868
300	882	509	42.5	14.6	242	92.1	92.8	92.7	82.5	79.6	71.4	1786	2233	3662
350	3573	507	46.4	14.7	278	93.9	94.1	93.4	86.5	83.7	76.3	514	437	1260
350	1776	507	46.3	12.3	273	93.3	93.8	93.7	87.3	85.7	80.1	1035	983	2225
350	1182	509	47.9	15.7	311	92.9	93.4	93.1	84.7	81.9	74.1	1555	2099	3577
350	889	588	50.2	18.6	284	93.1	93.4	92.9	80.6	77.2	68.3	2068	2068	4549
400	3568	507	52.5	14.7	289	94.2	94.7	94.5	87.1	85.2	79.0	589	471	1236
400	1778	507	52.2	13.6	332	93.6	94.1	93.8	88.1	86.5	81.0	1182	1182	2718
400	1180	509	53.0	13.6	323	93.3	94.0	94.1	87.1	85.8	80.5	1780	2225	3739
400	888	588	57.2	20.5	314	93.2	93.6	93.0	80.8	77.8	69.2	2366	2247	4968
450	3571	507	58.2	16.0	361	94.3	94.7	94.5	88.2	86.1	80.0	662	563	1555
450	1778	509	58.5	15.1	380	93.9	94.3	94.1	88.2	86.6	81.2	1329	1329	3124
450	1181	5011	59.7	16.3	379	93.4	94.1	94.1	86.9	85.2	79.3	2001	2602	4403
450	888	588	65.4	24.7	360	93.2	93.5	93.0	79.5	76.1	67.0	2661	2661	5722
500	3571	509	63.9	16.0	403	94.4	94.8	94.6	89.2	87.7	82.4	735	625	1728
500	1777	509	65.1	16.4	407	93.8	94.3	94.2	88.1	86.7	81.5	1478	1330	3325
500	1182	5011	65.8	17.6	414	93.7	94.3	94.3	87.3	85.6	79.9	2222	2999	4999
500	889	588	72.0	27.2	414	93.5	93.8	93.3	79.9	76.4	67.4	2954	3249	6499
600	3569	509	75.3	16.0	459	94.9	95.3	95.3	90.4	89.5	85.6	883	750	1987
600	1779	509	77.0	18.7	501	94.4	94.8	94.5	88.8	87.5	82.6	1771	1771	4163
600	1182	5011	80.3	22.7	506	93.9	94.4	94.1	85.7	82.8	75.5	2666	3732	5865
600	889	5810	86.1	33.1	516	93.9	94.1	93.6	79.9	76.3	67.0	3545	4254	8153
700	3568	509	88.7	20.5	532	95.0	95.3	95.2	89.4	88.2	83.8	1030	824	2215
700	1776	5011	89.5	18.6	537	94.3	94.8	94.8	89.3	88.8	85.2	2070	1863	4451
700	1184	588	92.3	24.4	581	94.2	94.7	94.6	86.7	85.3	79.7	3105	3105	6831
700	889	5810	100.2	37.5	601	94.0	94.3	93.8	80.0	76.4	67.5	4135	4963	9305

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
Open Enclosures
4000 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
800	3573	588	101	20.5	654	95.1	95.4	95.0	90.0	88.6	84.0	1176	941	2822
800	1777	5011	101	20.3	648	94.5	95.0	94.9	90.0	89.5	86.2	2364	2364	5320
800	1185	5810	106	30.7	689	94.4	94.8	94.7	86.0	84.0	72.6	3546	3900	8332
800	888	5810	112	35.1	588	94.5	95.1	95.2	81.3	79.5	72.6	4732	4495	8753
900	3571	588	112	19.8	681	95.2	95.5	95.4	91.2	91.1	88.4	1324	1059	2978
900	1781	5810	115	21.7	699	94.6	94.9	94.6	89.4	89.3	86.5	2654	2256	5706
900	1184	5810	117	27.5	732	94.3	94.9	95.0	87.7	86.9	82.4	3992	3992	8583
900	892	6811	120	38.0	756	94.9	95.2	95.0	84.9	82.5	75.2	5299	3709	10598
1000	3572	588	124	25.1	796	95.4	95.7	95.4	90.7	90.0	86.6	1470	1250	3308
1000	1781	5810	129	28.4	774	94.6	94.9	94.5	88.2	87.6	83.8	2949	2507	6488
1000	1188	5810	130	34.1	834	95.1	95.6	95.7	86.8	85.4	81.0	4421	4421	9726
1000	893	6811	133	43.7	865	95.0	95.3	95.2	85.0	82.2	74.4	5881	4117	12350
1250	3570	5810	156	28.0	957	95.3	95.7	95.7	90.7	90.3	87.6	1839	1471	4046
1250	1779	5810	160	29.2	934	94.7	95.1	94.9	89.0	89.2	86.7	3690	3321	7565
1250	1190	6811	160	37.9	1008	95.1	95.5	95.3	88.2	87.3	82.9	5517	3862	11034
1250	892	6811	166	50.6	1029	95.1	95.5	95.4	85.2	83.1	76.2	7360	5152	14720
1500	3572	5810	186	32.5	1206	95.7	96.0	96.0	90.9	90.4	87.7	2205	2095	5293
1500	1786	5810	190	38.2	1194	95.5	95.8	95.6	89.2	88.8	85.6	4411	3749	9925
1500	1191	6811	191	45.4	1242	95.3	95.7	95.5	88.7	87.7	83.1	6615	4631	13892
1500	892	6811	197	55.8	1221	95.1	95.6	95.6	86.1	84.3	78.2	8832	6182	17664
1750	3577	5810	215	37.4	1377	95.8	96.0	95.9	91.4	91.2	88.6	2569	2056	6038
1750	1788	6811	222	51.4	1443	95.6	95.9	95.6	88.8	87.9	83.6	5140	3084	11308
1750	1190	6811	222	48.3	1421	95.4	95.8	95.8	88.8	88.3	84.5	7724	5407	15448
1750	892	6813	228	62.2	1436	95.3	95.8	95.8	86.6	85.1	79.3	10304	7213	20608
2000	3585	5810	246	49.4	1602	96.0	96.1	95.7	91.0	90.2	86.7	2930	1904	6739
2000	1788	6811	253	54.7	1645	95.7	96.0	95.8	90.7	88.4	84.7	5875	3525	12338
2000	1190	6813	253	54.0	1645	95.4	95.8	95.8	88.1	88.6	85.0	8827	6179	18537
2000	892	6813	263	70.9	1683	95.4	95.9	95.9	86.6	85.1	79.3	11776	8243	23552
2250	3582	6811	281	65.8	1800	95.7	95.7	95.2	90.0	88.8	84.3	3299	1979	7258
2250	1788	6811	284	56.9	1789	95.8	96.1	96.0	89.1	89.0	85.8	6609	3965	13879
2250	1191	6813	284	62.5	1846	95.6	96.0	95.9	89.2	88.5	84.6	9922	7938	20836
2500	3582	6811	315	79.7	1922	96.1	96.1	95.5	88.9	87.4	82.2	3666	2200	7699
2500	1788	6811	314	63.2	1978	96.2	96.4	96.2	89.1	88.9	85.8	7343	4406	15420
2500	1190	6813	315	66.0	2048	95.8	96.2	96.2	89.2	88.8	85.3	11034	7724	22068
3000	3581	6813	376	87.5	2258	96.1	96.2	95.7	89.3	88.3	83.9	4400	2640	8800
3000	1787	6813	375	68.4	2325	96.2	96.5	96.4	89.5	89.7	87.2	8817	5290	17634
3500	3581	6813	432	92.2	2678	96.3	96.3	95.9	90.5	89.6	85.9	5132	3079	10777
3500	1788	6813	437	84.1	2841	96.3	96.6	96.5	89.6	89.5	86.6	10281	6169	22618
4000	3582	6813	498	118.0	3237	96.4	96.4	96.1	89.8	88.5	84.0	5865	3812	12903
4000	1788	6813	502	106.0	3263	96.4	96.7	96.5	89.0	88.5	85.0	11749	8224	25848

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
Open Enclosures
6600 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
350	3566	588	27.2	5.8	177	93.3	93.2	92.3	90.0	89.1	85.4	515	619	1186
350	1783	588	27.5	6.1	179	92.7	92.6	91.4	89.6	88.7	84.8	1031	825	2423
350	1200	Not Available												
350	890	588	30.2	11.5	196	93.2	93.5	93.1	81.2	77.4	68.0	2065	2065	4749
400	3574	588	30.3	5.5	197	94.1	94.1	93.4	91.5	90.9	88.1	588	529	1381
400	1778	588	31.5	7.1	205	92.7	92.7	91.8	89.4	88.4	84.3	1178	1001	2709
400	1200	Not Available												
400	888	588	34.2	11.5	198	93.0	93.6	93.4	82.0	79.4	71.5	2366	2011	4850
450	3567	588	35.0	8.0	228	93.7	93.8	93.0	89.4	88.2	83.8	663	795	1524
450	1783	588	36.0	8.5	231	93.0	93.0	92.1	88.8	87.6	83.0	1326	1127	3049
450	1200	Not Available												
450	888	588	39.4	14.8	227	92.9	93.4	93.1	80.2	76.8	67.7	2661	2395	5589
500	3573	588	38.0	8.0	239	94.1	94.3	93.7	90.1	89.3	85.6	735	588	1654
500	1783	588	40.0	10.0	249	93.2	93.3	92.5	87.9	86.6	81.6	1473	1178	3314
500	1185	588	39.8	10.2	249	93.5	94.0	93.9	87.7	86.7	81.0	2216	2216	4764
500	888	5810	43.2	15.0	242	92.9	93.4	93.1	81.2	78.5	70.4	2957	2661	6062
600	3573	588	45.0	8.6	295	94.6	94.8	94.4	91.1	90.5	87.4	882	794	2073
600	1782	588	47.0	10.0	295	93.5	93.7	93.0	89.3	88.6	85.0	1768	1503	3979
600	1186	588	48.0	13.3	312	93.6	94.1	94.0	87.1	85.3	79.2	2657	2928	6111
600	888	5810	50.9	16.5	287	93.4	93.9	93.6	82.4	80.1	72.7	3549	3371	7452
700	3570	588	53.0	10.4	340	94.9	95.1	94.7	90.7	90.0	86.6	1029	875	2367
700	1781	588	54.0	10.3	326	93.8	94.1	93.6	89.6	89.4	86.6	2064	1651	4335
700	1183	5810	55.4	12.5	333	93.5	94.2	94.4	88.1	87.4	83.3	3108	3108	6216
700	890	5810	59.8	20.7	344	93.8	94.2	93.9	81.3	78.5	70.4	4131	4544	8262
800	3572	588	60.2	10.8	379	95.0	95.3	95.0	91.2	90.8	88.0	1176	1000	2647
800	1782	5810	61.7	12.2	392	94.2	94.4	93.9	89.8	89.4	86.3	2358	2122	5305
800	1186	5810	63.4	17.3	421	94.1	94.6	94.5	87.5	85.7	79.8	3543	4251	8502
800	893	6811	65.3	22.3	424	94.4	94.8	94.5	84.7	81.6	73.4	4703	3527	10112
900	3573	588	68.2	14.0	450	95.1	95.4	95.1	90.5	89.6	86.0	1323	1257	3175
900	1782	5810	69.4	13.9	451	94.3	94.6	94.1	89.7	89.3	86.1	2653	2387	5968
900	1190	6811	70.7	18.7	446	94.7	95.0	94.7	87.7	86.2	80.7	3971	2581	8537
900	892	6811	72.6	22.8	457	94.6	95.0	94.9	85.5	83.1	75.8	5297	3708	10859
1000	3570	5810	75.1	12.2	458	95.0	95.4	95.2	91.4	91.3	89.1	1471	1177	3237
1000	1781	5810	76.7	13.8	483	94.3	94.6	94.3	90.2	90.2	87.7	2949	2654	6488
1000	1190	6811	78.0	19.8	507	94.7	95.0	94.8	88.3	86.9	81.8	4412	3088	9265
1000	893	6811	80.5	25.8	523	94.7	95.1	95.0	85.6	82.9	75.4	5879	4703	12640
1250	3570	5810	93.1	15.0	619	95.2	95.7	95.7	92.0	92.0	90.3	1839	1655	4321
1250	1782	5810	95.8	18.3	622	94.7	95.0	94.7	89.9	89.7	86.8	3684	3684	8473
1250	1191	6811	96.9	23.1	630	94.9	95.3	95.2	88.7	87.7	83.1	5510	3857	11571
1250	892	6811	99.6	29.3	637	94.8	95.3	95.3	86.4	84.2	77.7	7387	5518	15082

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
Open Enclosures
6600 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
1500	3577	5810	112	18.1	698	95.4	95.8	95.7	91.9	91.8	89.6	2202	1542	5066
1500	1788	6811	115	25.1	724	95.5	95.7	95.5	89.2	88.5	84.8	4404	2643	9249
1500	1190	6813	115	25.5	749	95.1	95.5	95.5	89.3	88.6	84.6	6618	4963	13897
1500	892	6813	119	33.0	771	94.8	95.3	95.4	87.1	85.3	79.3	8828	7504	18098
1750	1787	6811	134	26.8	828	95.5	95.8	95.6	89.5	89.2	86.1	5141	3085	10540
1750	1190	6813	134	26.4	832	95.1	95.6	95.7	89.5	89.4	86.3	7721	5404	14669
1750	892	6813	138	39.9	900	94.9	95.4	95.4	86.9	84.9	78.5	10300	8755	21630
2000	3582	6811	152	33.8	940	95.2	95.1	94.3	90.4	89.4	85.3	2931	1759	6449
2000	1787	6811	153	29.6	946	95.5	95.9	95.8	89.6	89.5	86.5	5876	3525	12045
2000	1190	6813	153	31.1	995	95.2	95.7	95.7	89.6	89.3	86	8824	6618	17647
2250	3583	6811	173	45.5	1124	95.2	95.2	94.5	89.2	87.4	81.9	3297	2143	7583
2250	1788	6811	171	36.2	1113	95.7	96.0	95.9	89.6	89.0	85.5	6607	3964	14865
2250	1190	6813	172	33.8	1101	95.3	95.8	95.7	89.6	89.4	86.4	9926	7445	19853
2500	3582	6813	188	41.3	1187	95.6	95.6	95.0	90.6	89.7	85.7	3664	2382	8061
2500	1788	6813	188*	34.6	1206	96.1	96.3	96.2	90.1	90.1	87.6	7341	4771	15415
3000	3582	6813	224	46.4	1454	96.0	96.0	95.4	91.2	90.4	86.7	4397	3078	9893
3000	1787	6813	226	40.3	1466	96.1	96.4	96.4	90.3	90.4	88	8814	5729	18509
3500	3582	6813	262	56.9	1703	96.0	96.1	95.7	90.8	89.9	85.9	5130	3591	11542
3500	1787	6813	264	46.3	1662	96.1	96.4	96.3	90.1	90.3	88	10283	6684	21593
4000	3581	6813	297	55.6	1813	96.1	96.2	96.0	91.4	91.0	88.2	5864	4105	12315

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
TEFC Enclosure
460 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
200	890	509	247.0	87.0	1482	94.2	94.6	94.2	80.4	77.2	68.6	1180	1180	2124
250	1780	507	277.0	47.4	1717	94.0	94.0	93.1	89.9	90.1	88.0	738	590	1476
250	1180	509	286.0	64.3	1816	94.0	94.3	94.0	87.1	86.3	82.1	1113	1113	2337
250	890	5011	309.0	108.0	1823	94.4	94.8	94.5	80.3	77.3	68.8	1475	1475	2655
300	3570	509	323.0	52.9	2100	94.8	94.8	94.1	91.6	91.2	88.9	441	309	882
300	1780	507	334.0	58.5	2071	94.3	94.3	93.6	89.3	89.6	87.4	885	708	1682
300	1180	5011	343.0	77.4	2178	94.2	94.6	94.4	87.0	86.2	82.0	1335	1335	2804
300	890	588	369.0	135.0	2288	94.5	94.5	94.0	80.6	77.2	68.3	1770	1770	4071
350	3565	509	375.0	51.9	2363	94.9	95.0	94.6	92.1	92.1	90.6	516	361	980
350	1780	509	388.0	65.8	2406	94.5	94.6	94.1	89.4	89.8	87.8	1033	826	1963
350	1175	5011	394.0	81.1	2266	94.6	95.0	94.9	87.9	87.6	84.2	1564	1564	3128
350	890	588	426.0	146.0	2599	94.7	94.8	94.3	81.2	78.4	70.2	2064	1961	4541
400	3570	509	429.0	67.3	2789	94.9	95.1	94.7	91.9	91.6	89.5	588	412	1176
400	1780	5011	442.0	78.1	2785	94.6	94.8	94.3	89.6	89.7	87.4	1180	944	2360
400	1175	5011	454.0	93.5	2815	94.3	94.9	94.9	87.4	87.1	83.6	1788	1788	3576
400	889	588	480.0	139.0	2544	94.6	94.9	94.6	82.5	81.0	75.8	2361	1889	4722
450	3565	509	481.0	68.6	3127	95.1	95.4	95.1	92.2	92.1	90.4	663	464	1326
450	1780	5011	495.0	82.4	3069	94.8	95.0	94.6	89.7	90.1	88.1	1328	1062	2523
450	1188	588	514.0	130.0	3187	94.9	95.2	94.9	86.3	85.1	80.0	1989	1691	4376
450	890	5810	537.0	158.0	2954	94.8	95.1	94.9	82.8	81.1	74.6	2654	2256	5308
500	3580	588	572.0	163.0	3718	95.2	95.0	94.0	88.0	83.7	77.2	733	623	1833
500	1780	5011	548.0	85.1	3308	95.0	95.2	94.9	89.9	90.5	88.9	1475	1328	2802
500	1188	588	569.0	144.0	3642	95.1	95.3	95.0	86.5	85.2	80.0	2209	1988	4970
500	895	708	624.0	288.0	4156	95.4	95.4	94.8	78.6	72.8	61.2	2394	2024	8157
600	3580	588	680.0	188.0	4420	95.4	95.3	94.5	86.5	84.4	78.2	880	792	2200
600	1784	588	671.0	158.0	4294	95.0	94.9	94.2	88.1	87.0	82.5	1766	1589	4052
600	1188	5810	676.0	158.0	4325	95.4	95.7	95.6	87.1	86.2	81.7	2551	2386	5832
600	895	708	760.0	362.0	5154	95.2	95.1	94.3	77.6	71.6	59.7	3521	2570	9894
700	3578	5810	763.0	140.0	4807	95.6	95.6	95.0	89.9	89.4	87.4	1027	873	2259
700	1785	5810	776.0	180.0	5044	95.3	95.3	94.7	88.5	87.5	83.0	2059	1853	4942
700	1192	708	796.0	246.0	5906	95.9	96.1	95.8	85.9	83.3	76.1	3084	3053	7895
700	895	708	897.0	443.0	6645	95.3	95.2	95.4	76.7	70.3	58.1	4108	3533	12365
800	3581	5810	884.0	202.0	5745	95.8	95.7	95.1	88.5	87.2	82.6	1173	997	2815
800	1785	5810	884.0	199.0	5745	95.4	95.4	94.9	88.8	87.8	83.5	2353	2118	5412
800	1193	708	908.0	289.0	7115	96.1	96.2	96.0	85.8	83.0	75.4	3522	3733	9615
800	895	708	988.0	445.0	7000	95.7	95.6	95.0	79.2	73.7	62.3	4695	3803	13193

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
TEFC Enclosure
2300 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
200	3575	507	44.5	10.5	289	94.1	93.7	92.4	89.5	88.1	83.5	294	264	735
200	1786	507	46.4	14.0	297	93.8	93.4	92.0	84.0	84.0	77.6	588	588	1382
200	1182	507	48.8	17.3	258	93.7	93.9	93.3	78.9	78.9	70.5	889	1067	1867
200	889	509	50.5	19.2	290	93.7	94.0	93.5	75.5	75.5	66.3	1182	1418	2364
250	3574	507	54.9	11.9	357	94.5	94.3	93.3	90.2	89.1	85.1	368	331	920
250	1787	507	57.4	17.5	373	94.3	94.0	92.8	86.5	84.1	77.4	735	735	1764
250	1184	509	61.6	22.2	342	93.6	93.5	92.4	81.2	78.1	69.7	1109	1442	2329
250	889	5011	62.3	22.5	358	94.1	94.4	94.1	79.8	76.6	67.9	1477	1772	2954
300	3577	509	66.2	17.4	430	95.1	95.1	94.3	89.2	87.4	81.9	440	330	1012
300	1786	507	68.8	19.4	385	94.8	94.7	93.9	86.1	84.4	78.5	882	706	1897
300	1186	509	75.5	28.2	419	94.5	94.6	94.0	78.7	75.0	65.8	1328	1527	2723
300	890	5810	75.3	29.0	467	94.5	94.5	93.8	79.0	75.1	65.6	1770	1593	4071
350	3576	509	76.0	16.8	475	95.3	95.4	94.8	90.5	89.4	85.3	514	360	1131
350	1786	509	80.3	22.9	450	95.0	95.1	94.4	85.9	84.1	78.1	1029	875	2213
350	1185	5011	87.3	31.9	467	94.7	94.8	94.3	79.3	75.8	66.8	1551	1784	3258
350	890	5810	88.2	34.9	547	94.7	94.7	94.1	78.5	74.3	64.5	2065	1858	4749
400	3575	509	87.3	20.0	524	95.5	95.6	95.2	89.8	88.7	84.4	588	412	1205
400	1786	5011	91.1	24.8	501	95.2	95.3	94.7	86.3	84.8	79.3	1176	1000	2470
400	1186	5011	98.9	33.7	504	94.9	95.2	94.8	79.8	76.9	68.8	1771	1771	3542
400	890	5810	100.0	38.4	620	94.9	95.0	94.4	78.8	75.0	65.5	2360	2124	5192
450	3576	509	97.5	21.4	600	95.7	95.8	95.4	90.3	89.3	85.4	661	463	1388
450	1786	5011	103.0	32.2	572	95.4	95.5	95.1	85.8	84.1	78.1	1323	1125	2845
450	1190	5810	111.0	42.1	688	95.0	95.0	94.3	79.8	76.1	66.9	1985	1985	4565
450	890	5810	113.0	45.2	689	94.9	95.0	94.5	78.6	73.5	63.5	2654	2388	5838
500	3579	588	113.0	28.6	712	95.1	95.0	94.1	87.2	85.5	80.2	733	601	1722
500	1786	5011	113.0	29.4	633	95.5	95.6	95.2	86.8	85.6	80.4	1470	1250	3088
500	1190	5810	121.0	43.1	726	95.2	95.2	94.7	81.0	77.8	69.6	2226	2316	5673
500	893	708	125.0	53.0	790	95.7	95.8	95.5	78.0	73.6	63.3	2940	2358	5880
600	3579	588	132.0	27.0	821	95.4	95.4	94.7	89.0	88.2	84.5	880	730	1989
600	1783	588	136.0	35.4	789	94.9	94.8	94.1	87.1	85.8	80.6	1767	1590	3534
600	1190	5810	147.0	55.2	911	95.3	95.4	94.8	80.0	76.4	67.2	2647	2911	6352
600	893	708	150.0	62.6	959	95.8	96.0	95.7	78.3	74.0	63.7	3528	2822	7056
700	3579	5810	154.0	31.1	958	95.7	95.7	95.1	89.1	88.3	84.7	1027	853	2310
700	1784	5810	158.0	43.6	958	95.2	95.2	94.7	87.0	85.3	79.5	2050	2039	4388
700	1192	708	167.0	52.6	1068	95.8	95.9	95.5	82.0	80.2	73.3	3084	2005	6768
700	893	708	174.0	73.0	1130	95.9	96.1	95.8	78.6	74.1	63.8	4117	3294	9057
800	3580	5810	175.0	35.1	1138	95.9	95.9	95.4	89.5	88.5	85.0	1173	1055	2791
800	1785	5810	180.0	50.1	1170	95.3	95.4	94.9	87.2	85.4	79.4	2353	2447	5200
800	1192	708	190.0	60.8	1235	95.9	96.0	95.7	82.2	80.1	73.1	3525	2468	7579
800	894	788	203.0	88.7	1279	95.9	96.0	95.6	77.1	72.4	61.7	4699	3289	10338

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

SIEMENS

Electrical Performance Data

Horizontal Custom
TEFC Enclosure
4000 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
200	3575	507	25.7	6.1	167	93.8	93.5	92.3	89.5	88.1	83.4	294	264	676
200	1786	507	26.7	8.1	171	93.5	93.2	91.9	86.2	84.0	77.5	588	588	1382
200	1182	507	28.2	10.1	159	93.2	93.4	92.7	82.0	79.0	70.6	889	1067	1822
200	889	509	29.2	11.1	168	93.1	93.5	93.1	79.2	75.6	66.3	1182	1418	2364
250	3570	507	31.6	6.9	205	94.3	94.2	93.2	90.1	89.0	85.0	368	257	846
250	1787	507	33.0	10.2	218	94.2	93.9	92.7	86.5	84.1	77.2	735	735	1801
250	1182	509	35.4	12.1	189	93.1	93.1	92.3	81.6	79.0	71.2	1111	1333	2222
250	889	5011	36.0	13.1	203	93.8	94.2	93.9	79.6	76.5	67.7	1477	1625	2880
300	3578	509	38.1	10.1	251	94.9	94.9	94.1	89.2	87.4	81.7	440	308	1013
300	1786	507	39.6	11.3	226	94.5	94.5	93.7	86.2	84.4	78.4	882	706	1941
300	1186	509	43.5	16.4	246	94.3	94.5	93.9	78.7	75.0	65.7	1328	1527	2788
300	890	5810	43.4	16.8	269	94.3	94.3	93.6	79.0	75.0	65.7	1990	1593	4071
350	3578	509	43.7	9.8	275	95.2	95.2	94.7	90.5	89.4	85.2	514	360	1131
350	1786	509	46.2	13.4	259	94.9	94.9	94.3	85.9	84.0	77.9	1029	875	2213
350	1185	5011	50.4	18.5	270	94.5	94.7	94.2	79.2	75.6	66.6	1551	1784	3268
350	890	5810	51.0	20.3	316	94.5	94.6	93.9	78.3	74.2	64.5	2065	1858	4779
400	3577	509	50.4	11.7	302	95.3	95.4	94.9	89.7	88.6	84.2	587	411	1203
400	1786	5011	52.6	14.4	289	95.0	95.1	94.6	86.2	84.7	79.1	1176	941	2470
400	1186	5011	57.0	19.6	290	94.8	95.0	94.6	79.7	76.8	68.6	1771	1771	3542
400	890	5810	58.0	22.3	360	94.7	94.8	94.2	78.7	74.8	65.3	2360	2124	5192
450	3576	509	56.2	12.5	343	95.5	95.6	95.3	90.3	89.3	85.1	661	463	1388
450	1786	5011	59.3	18.3	335	95.2	95.3	94.9	85.8	84.0	77.9	1323	1125	2845
450	1189	588	62.5	20.7	356	94.9	95.0	94.9	81.7	79.2	71.5	1987	1987	4173
450	890	5810	65.2	25.6	411	94.8	94.9	94.4	78.4	74.3	64.5	2654	2521	6104
500	3579	588	65.0	16.8	410	95.1	94.8	93.9	87.0	85.3	79.8	734	587	1688
500	1786	5011	64.9	17.1	367	95.5	95.7	95.4	86.8	85.5	80.1	1470	1323	3161
500	1190	5810	70.0	25.1	420	95.1	95.1	92.8	80.9	77.9	69.0	2205	2316	5073
500	893	708	72.1	30.6	454	95.4	95.6	95.3	78.3	73.7	63.3	2940	2352	6174
600	3579	588	76.1	15.8	472	95.4	95.3	94.5	88.9	88.1	84.4	881	704	1938
600	1783	588	78.0	19.9	460	94.8	94.7	94.0	87.5	86.2	91.2	1767	1590	3534
600	1190	5810	84.5	32.1	541	95.3	95.3	94.7	80.1	76.4	67.0	2646	2911	6350
600	893	708	86.3	36.8	561	95.6	95.8	95.5	78.3	73.7	63.2	3528	2822	7762
700	3579	5810	88.5	18.1	558	95.5	95.6	94.9	89.0	88.2	84.6	1027	872	2259
700	1785	5810	91.6	27.2	595	95.2	95.1	94.5	88.4	84.2	77.5	2058	2161	4529
700	1192	708	95.9	30.5	624	95.7	95.8	95.4	82.1	80.1	73.1	3084	2159	6168
700	893	708	100.0	42.4	650	95.8	96.0	95.7	78.5	74.0	63.6	4117	3294	9057
800	3580	5810	100.0	20.5	650	95.9	95.8	95.3	89.4	88.5	84.8	1173	1055	2815
800	1785	5810	103.0	28.7	670	95.4	95.3	94.7	87.3	85.5	79.5	2353	2588	5177
800	1192	708	109.0	35.3	711	95.8	95.9	95.6	82.2	80.1	72.9	3525	2468	7579
800	894	788	117.0	51.5	737	95.8	95.9	95.5	77.1	72.2	61.4	4700	3290	10340

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
TEFC Enclosure
4000 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
900	3579	5810	114.0	23.6	718	95.9	95.9	95.5	88.9	88.0	84.3	1320	1122	3036
900	1789	708	119.0	35.5	750	95.9	96.0	95.6	84.6	82.9	76.5	2641	1585	5282
900	1192	708	123.0	38.8	797	95.9	96.1	95.7	82.4	80.4	73.4	3965	2776	8525
900	894	788	131.0	56.8	825	95.9	96.0	95.7	77.4	72.7	62.0	5287	3701	11631
1000	1789	708	132.0	38.8	832	96.0	96.1	95.8	84.8	83.1	77.0	2934	1760	5868
1000	1193	788	131.0	41.6	852	96.0	96.2	95.9	85.3	82.8	75.4	4402	2641	9684
1000	894	788	146.0	66.2	949	96.0	96.1	95.7	76.9	71.7	60.5	5875	4113	13513
1250	1790	708	164.0	45.7	1066	96.2	96.4	96.1	85.5	84.1	78.4	3667	2200	7701
1250	1193	788	163.0	49.2	1060	96.2	96.4	96.2	85.9	83.6	76.8	5502	3301	12104
1250	895	880	178.0	69.7	1139	96.3	96.4	96.0	78.6	75.0	65.6	7335	5135	15404
1500	1793	788	196.0	62.0	1277	96.4	96.5	96.1	85.3	82.8	75.5	4394	2636	9227
1500	1193	788	196.0	60.0	1294	96.4	96.5	96.3	85.3	82.9	75.8	6603	4292	11518
1500	895	880	213.0	84.7	1385	96.4	96.5	96.1	78.6	74.8	65.3	8802	6161	19364
1750	1792	788	229.0	70.4	1489	96.5	96.7	96.3	85.3	83.0	76.0	5129	3077	10258
1750	1194	880	228.0	67.4	1482	96.4	96.5	96.2	85.8	83.7	77.2	7698	4619	16166
2000	3583	6812	245.0	39.4	1592	94.9	94.7	93.6	92.7	92.5	90.5	2932	2052	6744
2000	1792	880	257.0	72.5	1669	96.4	96.4	96.0	87.0	85.1	79.0	5862	3517	12310
2000	1193	880	261.0	73.2	1618	96.4	96.6	96.4	85.4	83.8	77.7	8805	5723	18490
2250	3584	6813	274.0	44.7	1822	95.2	95.0	94.0	92.7	92.5	90.4	3297	2308	7748
2250	1792	880	287.0	77.6	1866	96.5	96.5	96.2	87.4	85.7	80.0	6594	3956	13847
2500	3583	6813	303.0	44.0	1924	95.5	95.4	94.6	93.0	93.1	91.5	3665	2566	8063
2500	1792	880	323.0	35.8	2164	96.5	96.3	95.6	86.2	85.0	77.3	7327	5129	16486

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
TEFC Enclosure
6600 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
350	3578	588	26.4	5.1	164	94.6	94.7	93.9	91.3	90.7	87.6	514	437	1182
350	1785	588	28.1	8.1	183	93.5	93.4	92.3	86.9	84.8	78.6	1030	824	2318
350	1191	5810	29.1	9.8	170	94.5	94.6	93.9	82.9	80.0	72.0	1543	1466	3317
350	891	5810	30.6	11.4	184	93.9	94.3	94.1	79.4	75.7	66.4	2063	2269	4435
400	3579	588	30.9	6.1	200	94.1	94.0	93.1	89.6	88.9	85.5	587	499	235
400	1784	588	32.0	8.7	195	93.8	93.7	92.8	86.9	85.2	79.5	1178	884	2474
400	1191	5810	33.4	11.5	200	94.7	94.8	94.2	82.6	79.4	71.2	1764	1676	3969
400	893	5810	34.8	13.8	216	94.2	94.5	94.2	79.7	75.5	65.5	2353	2235	5177
450	3579	5810	34.6	6.7	225	94.5	94.4	93.5	89.8	89.1	85.7	660	594	1585
450	1784	588	36.0	9.4	207	94.0	94.0	93.3	86.8	85.3	80.0	1325	994	2782
450	1190	5810	37.5	12.8	221	94.7	94.8	94.3	82.6	79.6	71.5	1986	1887	4369
450	892	708	39.5	15.3	217	94.5	94.9	94.6	78.7	75.0	65.4	2650	2120	5432
500	3579	5810	37.8	7.6	238	94.8	94.8	94.1	91.0	90.3	86.8	734	661	1652
500	1785	588	39.9	10.8	243	94.2	94.3	93.6	86.7	84.9	79.1	1471	1177	3236
500	1193	5810	42.9	16.8	268	95.2	95.3	94.8	79.8	75.7	66.0	2201	1871	4952
500	893	708	43.9	17.3	248	94.7	95.0	94.7	78.5	74.6	64.8	2941	2353	6323
600	3578	5810	44.8	7.8	273	95.3	95.3	94.8	91.6	91.3	88.9	881	749	1938
600	1784	5810	47.6	12.5	286	94.8	94.8	94.2	86.8	85.2	79.7	1766	1413	3797
600	1191	708	48.5	14.1	284	95.2	95.4	95.0	84.8	83.0	76.7	2646	2117	5821
600	893	788	53.4	23.5	310	95.2	95.3	94.8	77.0	72.0	61.2	3529	2647	7940
700	3582	5810	52.4	10.4	359	95.6	95.6	95.0	91.2	90.4	87.1	1026	718	2411
700	1785	5810	55.3	14.7	340	95.1	95.1	94.6	86.8	85.1	79.5	2060	1648	4532
700	1192	708	56.6	17.2	345	95.4	95.6	95.2	84.6	82.4	75.5	3084	2467	7093
700	893	788	61.6	25.9	351	95.4	95.5	95.1	77.7	73.2	62.9	4117	3088	9057
800	1789	708	63.8	18.0	415	95.5	95.5	95.0	85.7	84.0	78.0	2349	1762	5285
800	1192	708	64.6	19.6	397	95.5	95.7	95.4	84.6	82.5	75.6	3525	2996	8108
800	893	708	70.1	29.1	403	95.5	95.6	95.3	77.9	73.6	63.4	4705	3529	10116
900	1788	708	71.4	18.8	450	95.6	95.7	95.3	86.0	84.7	79.3	2644	1851	5552
900	1191	708	72.2	19.8	415	95.6	95.9	95.7	85.0	83.6	77.9	3969	3175	8533
900	893	788	78.6	31.9	452	95.5	95.7	95.4	78.2	74.1	64.1	5293	4234	11380
1000	1788	708	78.8	19.7	492	95.8	95.9	95.6	86.4	85.4	80.5	2937	2203	6021
1000	1193	788	79.9	24.8	507	95.8	96.0	95.6	85.2	82.8	75.6	4402	3081	10125
1000	895	880	92.3	44.0	540	96.0	96.1	95.6	73.6	68.1	56.6	5868	4401	12616
1250	1791	788	97.4	26.6	618	96.0	96.1	95.6	87.2	85.3	79.4	3666	2383	8432
1250	1193	788	99.6	30.8	647	96.1	96.3	96.0	85.2	82.8	75.6	5503	3852	12932
1250	895	880	113.0	49.8	633	96.2	96.3	96.0	75.0	70.3	59.6	7335	5134	14303
1500	3584	6811	113.0	19.9	701	94.0	93.5	92.1	92.1	91.8	89.4	2198	1319	4946
1500	1791	788	115.7	28.6	708	96.1	96.3	96.0	88.0	86.7	81.7	4399	2859	9458
1500	1193	788	119.2	35.6	756	96.1	96.4	96.2	85.4	83.2	76.4	6604	4263	14859
1750	3583	6813	130.0	21.5	813	94.4	94.2	93.1	93.0	93.0	91.3	2565	1667	5721
1750	1788	6813	131.0	21.5	865	95.0	95.1	94.5	92.2	92.1	90.0	5140	4626	12079
2000	3583	6813	148.0	21.9	962	94.8	94.6	93.6	93.2	93.2	91.5	2932	2052	6744

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Electrical Performance Data

Horizontal Custom
Explosion-Proof Enclosure
460 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
250	1180	509	284.0	63.0	1789	94.0	94.4	94.1	87.1	86.5	82.5	1113	1002	2226
250	885	509*	302.0	113.0	1825	94.5	94.7	94.4	82.0	78.0	69.0	1483	1483	2595
300	3575	509	321.0	41.6	2006	94.8	94.9	94.3	92.3	92.5	91.1	442	309	840
300	1780	509	334.0	58.5	2071	94.3	94.3	93.6	89.3	89.6	87.4	885	708	1682
300	1190	5011	343.0	77.4	2178	94.2	94.6	94.4	87.0	86.2	82.0	1335	1335	2804
300	885	30E	359.0	142.0	2200	94.3	94.6	94.2	82.6	80.7	73.6	1780	1068	3115
350	3575	509	375.0	51.9	2363	94.9	95.0	94.6	92.1	92.1	90.6	516	361	980
350	1780	5011	383.0	72.2	2490	95.1	95.2	94.7	90.0	89.8	87.0	1030	927	2163
350	1190	5011	394.0	81.1	2266	94.6	95.0	94.9	87.9	87.6	84.2	1564	1564	3128
350	885	30E	421.0	148.0	2550	93.5	93.6	93.2	93.1	79.1	70.4	2076	1246	3633
400	3570	509*	423.0	62.0	2900	95.2	95.5	95.0	93.0	92.6	90.0	588	412	1030
400	1790	5011	442.0	78.1	2785	94.6	94.8	94.3	89.6	89.7	87.4	1180	994	2360
400	1190	30E	465.0	135.0	2900	94.5	94.8	92.8	85.0	82.5	75.0	1765	1412	3530
400	885	30E	469.0	137.0	2900	93.8	94.0	93.8	85.3	83.4	77.2	2373	1424	4153
450	3575	30N	482.0	80.0	3250	94.7	94.9	94.0	91.5	91.0	88.7	660	462	1155
450	1790	509*	509.0	138.0	3250	94.9	94.6	93.2	87.1	86.2	82.8	1320	1056	2310
450	1190	30E	521.0	170.0	3250	94.6	95.5	94.6	85.5	76.8	66.0	1985	1191	3474
450	885	30E	522.0	124.0	3250	93.8	94.3	94.0	86.1	85.1	81.0	2669	1601	4671
500	3575	30N	562.0	98.0	3625	94.7	94.9	94.1	88.0	87.5	84.8	734	514	1285
500	1790	30B	574.0	187.0	3625	94.8	94.8	93.0	86.2	84.0	76.5	1466	1173	2566
500	1190	30E	581.0	189.0	3625	94.7	95.1	94.7	85.2	81.9	76.3	2206	1324	3861
500	885	30KK	594.0	203.0	3625	93.9	94.0	93.4	84.0	82.0	72.5	2966	1780	5191
600	3575	30N	675.0	112.0	4350	94.7	94.3	94.2	88.0	87.5	86.8	881	529	1542
600	1785	30B	689.0	172.0	4350	94.9	95.5	95.0	86.1	85.3	79.0	1765	1059	3090
600	1190	30KK	688.0	189.0	4350	94.9	95.3	94.7	86.2	84.2	79.3	2647	1588	4632
600	890	30L	695.0	230.0	4350	95.2	95.1	94.4	84.9	81.2	72.7	3541	3541	8852
700	3580	30N	800.0	190.0	5200	94.6	94.3	93.1	86.5	83.5	76.4	1027	719	2362
700	1785	30JJ	816.0	163.0	5304	94.5	94.2	93.0	85.0	82.0	74.0	2060	2060	4738
700	1185	30L	793.0	167.0	5155	95.0	94.7	93.6	87.0	85.5	80.5	3102	3102	6980
700	892	30L	804.0	290.0	5306	95.3	95.4	94.9	85.6	82.8	75.2	4122	4534	9893
800	3575	30R	886.0	211.0	5759	94.7	94.6	93.7	89.3	88.4	85.0	1175	705	2703
800	1785	30LL	893.0	179.0	5805	94.5	94.1	92.8	88.8	55.2	85.3	2354	2354	5414
800	1185	30L	903.0	190.0	5870	95.3	95.4	95.2	87.0	86.5	82.5	3546	3546	8865
800	892	30LL	918.0	286.0	6059	95.3	95.4	94.9	85.6	82.8	75.2	4710	5181	11304

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.
509* denotes Type RGZZ. All other 500 frames are Type CGZZ.

Electrical Performance Data

Horizontal Custom
Explosion-Proof Enclosure
2300 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
200	3575	507	44.5	10.5	289	94.1	93.7	92.4	89.5	88.1	83.5	294	264	735
200	1786	507	46.4	14.0	297	93.8	93.4	92.0	84.0	84.0	77.6	588	588	1382
200	1180	507	48.8	16.5	259	93.1	93.2	92.4	82.4	79.8	72.1	890	801	1780
200	890	509*	48.2	17.2	289	94.8	94.9	94.4	82.0	79.0	70.8	1180	1180	2478
250	1180	509	284.0	63.0	1789	94.0	94.4	94.1	87.1	86.5	82.5	1113	1002	2226
250	885	509*	302.0	113.0	1825	94.5	94.7	94.4	82.0	78.0	69.0	1483	1483	2595
300	3575	509	321.0	41.6	2006	94.8	94.9	94.3	92.3	92.5	91.1	442	309	840
300	1780	509	334.0	58.5	2071	94.3	94.3	93.6	89.3	89.6	87.4	885	708	1682
300	1190	5011	343.0	77.4	2178	94.2	94.6	94.4	87.0	86.2	82.0	1335	1335	2804
300	885	30E	359.0	142.0	2200	94.3	94.6	94.2	82.6	80.7	73.6	1780	1068	3115
350	3575	509	375.0	51.9	2363	94.9	95.0	94.6	92.1	92.1	90.6	516	361	980
350	1780	5011	383.0	72.2	2490	95.1	95.2	94.7	90.0	89.8	87.0	1030	927	2163
350	1190	5011	394.0	81.1	2266	94.6	95.0	94.9	87.9	87.6	84.2	1564	1564	3128
350	885	30E	421.0	148.0	2550	93.5	93.6	93.2	93.1	79.1	70.4	2076	1246	3633
400	3570	509*	423.0	62.0	2900	95.2	95.5	95.0	93.0	92.6	90.0	588	412	1030
400	1790	5011	442.0	78.1	2785	94.6	94.8	94.3	89.6	89.7	87.4	1180	994	2360
400	1190	30E	465.0	135.0	2900	94.5	94.8	92.8	85.0	82.5	75.0	1765	1412	3530
400	885	30E	469.0	137.0	2900	93.8	94.0	93.8	85.3	83.4	77.2	2373	1424	4153
450	3575	30N	482.0	80.0	3250	94.7	94.9	94.0	91.5	91.0	88.7	660	462	1155
450	1790	509*	509.0	138.0	3250	94.9	94.6	93.2	87.1	86.2	82.8	1320	1056	2310
450	1190	30E	521.0	170.0	3250	94.6	95.5	94.6	85.5	76.8	66.0	1985	1191	3474
450	885	30E	522.0	124.0	3250	93.8	94.3	94.0	86.1	85.1	81.0	2669	1601	4671
500	3575	30N	562.0	98.0	3625	94.7	94.9	94.1	88.0	87.5	84.8	734	514	1285
500	1790	30B	574.0	187.0	3625	94.8	94.8	93.0	86.2	84.0	76.5	1466	1173	2566
500	1190	30E	581.0	189.0	3625	94.7	95.1	94.7	85.2	81.9	76.3	2206	1324	3861
500	885	30KK	594.0	203.0	3625	93.9	94.0	93.4	84.0	82.0	72.5	2966	1780	5191
600	3575	30N	675.0	112.0	4350	94.7	94.3	94.2	88.0	87.5	86.8	881	529	1542
600	1785	30B	689.0	172.0	4350	94.9	95.5	95.0	86.1	85.3	79.0	1765	1059	3090
600	1190	30KK	688.0	189.0	4350	94.9	95.3	94.7	86.2	84.2	79.3	2647	1588	4632
600	890	30L	695.0	230.0	4350	95.2	95.1	94.4	84.9	81.2	72.7	3541	3541	8852
700	3580	30N	800.0	190.0	5200	94.6	94.3	93.1	86.5	83.5	76.4	1027	719	2362
700	1785	30JJ	816.0	163.0	5304	94.5	94.2	93.0	85.0	82.0	74.0	2060	2060	4738
700	1185	30L	793.0	167.0	5155	95.0	94.7	93.6	87.0	85.5	80.5	3102	3102	6980
700	892	30L	804.0	290.0	5306	95.3	95.4	94.9	85.6	82.8	75.2	4122	4534	9893
800	3575	30R	886.0	211.0	5759	94.7	94.6	93.7	89.3	88.4	85.0	1175	705	2703
800	1785	30LL	893.0	179.0	5805	94.5	94.1	92.8	88.8	55.2	85.3	2354	2354	5414
800	1185	30L	903.0	190.0	5870	95.3	95.4	95.2	87.0	86.5	82.5	3546	3546	8865
800	892	30LL	918.0	286.0	6059	95.3	95.4	94.9	85.6	82.8	75.2	4710	5181	11304

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509* denotes Type RGZZ. All other 500 frames are Type CGZZ.

Electrical Performance Data

Horizontal Custom
Explosion-Proof Enclosure
2300 Volt

HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
900	3583	30R	196.0	43.5	1245	94.9	94.7	93.7	90.4	89.4	85.4	1319	792	3034
900	1785	30JJ	202.0	47.0	1305	94.9	95.1	94.7	87.9	85.5	79.5	2647	1588	4632
900	1185	30L	200.0	45.0	1305	94.8	94.9	94.5	88.9	87.5	83.1	3989	3191	7978
900	890	3030	206.0	62.0	1305	95.3	95.4	94.9	85.9	82.8	75.2	5311	5311	12746
1000	3584	3020	215.0	41.5	1450	95.1	95.0	94.2	91.7	91.1	88.0	1465	1026	3370
1000	1785	30JJ	225.0	37.4	1450	94.5	94.2	93.8	88.0	87.5	81.5	2941	1765	5147
1000	1185	30LL	222.0	63.0	1450	94.7	94.9	94.5	89.0	87.8	83.6	4432	3516	8864
1250	3583	3023	267.0	48.0	1736	95.6	95.6	95.0	91.8	91.4	88.8	1832	1282	4031
1250	1785	3023	277.0	70.0	1800	95.6	95.4	94.6	88.4	86.0	80.0	3668	2934	8070
1250	1190	3030	276.0	63.0	18001	95.0	95.1	94.6	89.4	87.6	82.7	5517	5517	12137
1500	1785	3030	327.0	62.0	2150	95.9	95.8	95.2	89.6	88.6	86.0	4413	3089	8826
1750	1785	3030	382.0	72.5	2500	95.9	95.9	95.5	89.4	88.4	84.8	5149	3604	10298

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.
509* denotes Type RGZZ. All other 500 frames are Type CGZZ.

Electrical Performance Data

Horizontal Custom
Explosion-Proof Enclosure
4000 Volt

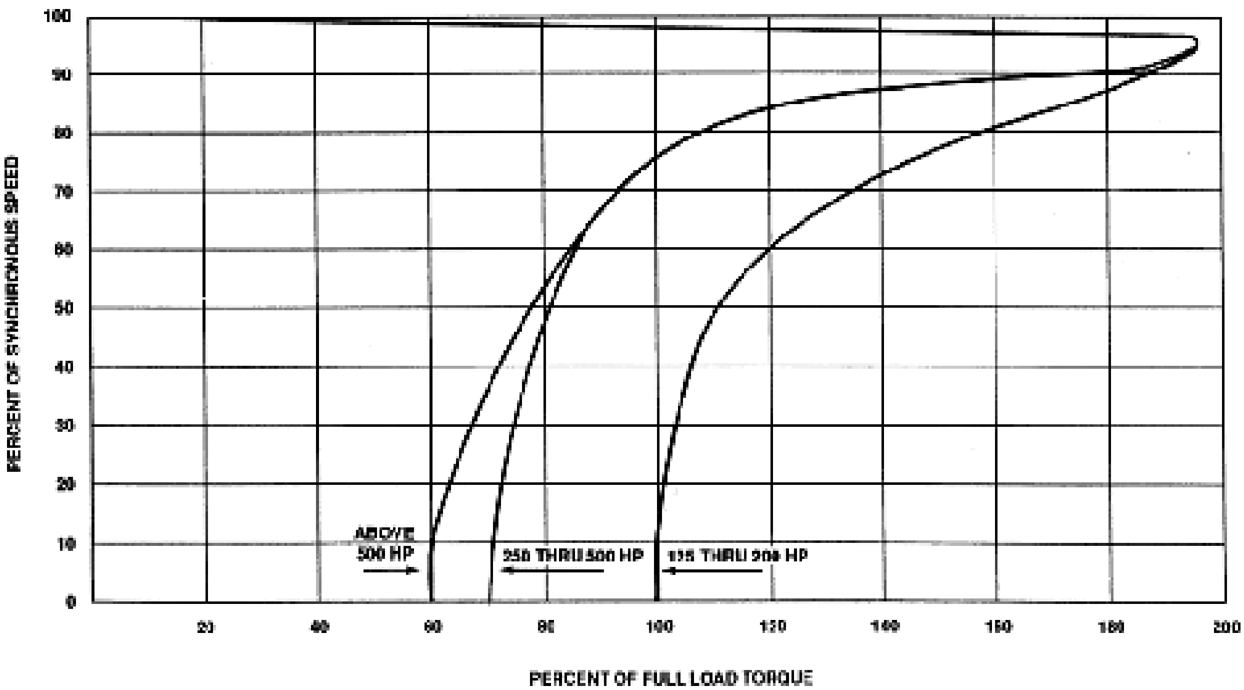
HP	FL RPM	Frame	Amps			Percent Efficiency			Percent Power Factor			Torque (Lb-Ft)		
			FL	NL	LR	FL	3/4	1/2	FL	3/4	1/2	FL	LR	BD
800	3583	30R	101.0	21.1	625	94.5	94.3	93.3	90.7	90.0	86.4	1172	704	2638
800	1780	30JJ	104.0	25.0	667	94.8	95.2	94.6	87.5	81.0	61.7	236	1416	4130
800	1190	30L	103.0	28.7	667	94.3	94.3	93.6	88.9	86.5	79.7	352	2117	6176
800	890	3030	105.0	32.0	667	94.9	95.0	94.5	86.2	83.0	75.2	472	4721	11802
900	3583	30R	113.0	25.4	735	94.7	94.6	93.6	90.5	89.4	85.3	1319	923	3034
900	1785	30JJ	115.0	20.7	762	94.8	94.6	93.4	88.7	91.5	89.0	2647	1588	4632
900	1190	30LL	115.0	26.0	762	94.7	94.8	94.2	89.1	87.3	82.3	3972	3178	8738
900	890	3030	119.0	36.0	762	95.1	95.2	94.8	85.8	82.7	75.0	5311	5311	12746
1000	3584	3020	124.0	24.1	834	95.0	94.9	94.1	91.7	91.0	87.9	1465	1026	3370
1000	1780	3020	128.0	23.0	834	94.6	94.8	94.4	88.9	92.3	90.6	2949	1769	5161
1000	1190	3030	127.0	28.0	834	94.8	94.8	94.2	89.6	88.1	83.6	4413	3972	8826
1250	3583	3023	154.0	28.0	1001	95.0	95.5	94.9	91.8	91.4	88.7	1832	1282	4031
1250	1790	3023	160.0	41.0	1035	95.5	95.4	94.5	88.3	85.9	79.8	3668	2934	8070
1250	1190	3030	159.0	36.0	1035	95.0	95.2	94.6	89.3	87.6	82.6	5517	5517	12137
1500	1785	3030	188.0	35.0	1236	95.7	95.5	95.2	89.6	88.7	85.3	4413	3089	8826
1750	1790	3030	220.0	42.5	1437	95.9	95.9	95.4	89.3	88.3	84.6	5149	3604	10298

Typical electrical performance data may not be certified or guaranteed unless confirmed by the factory. Data is based on 3 phase, 60 hertz, 1.0 service factor, and maximum 80 degrees C rise by resistance.

Speed Torque Curves

Typical Speed Torque Curves of 3600 RPM Machines

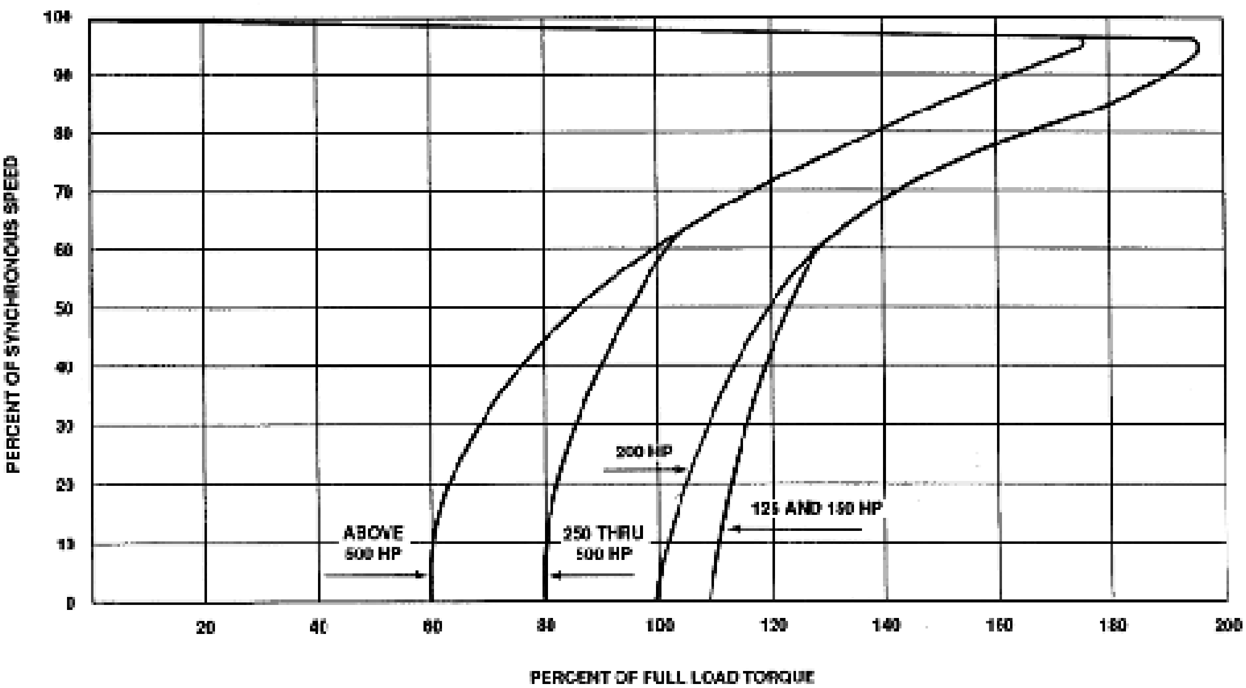
Note: Typical torque curves of general-purpose, polyphase, squirrel-cage motors with rated voltage and frequency applied.



Speed Torque Curves

Typical Speed Torque Curves of 1800 RPM Machines

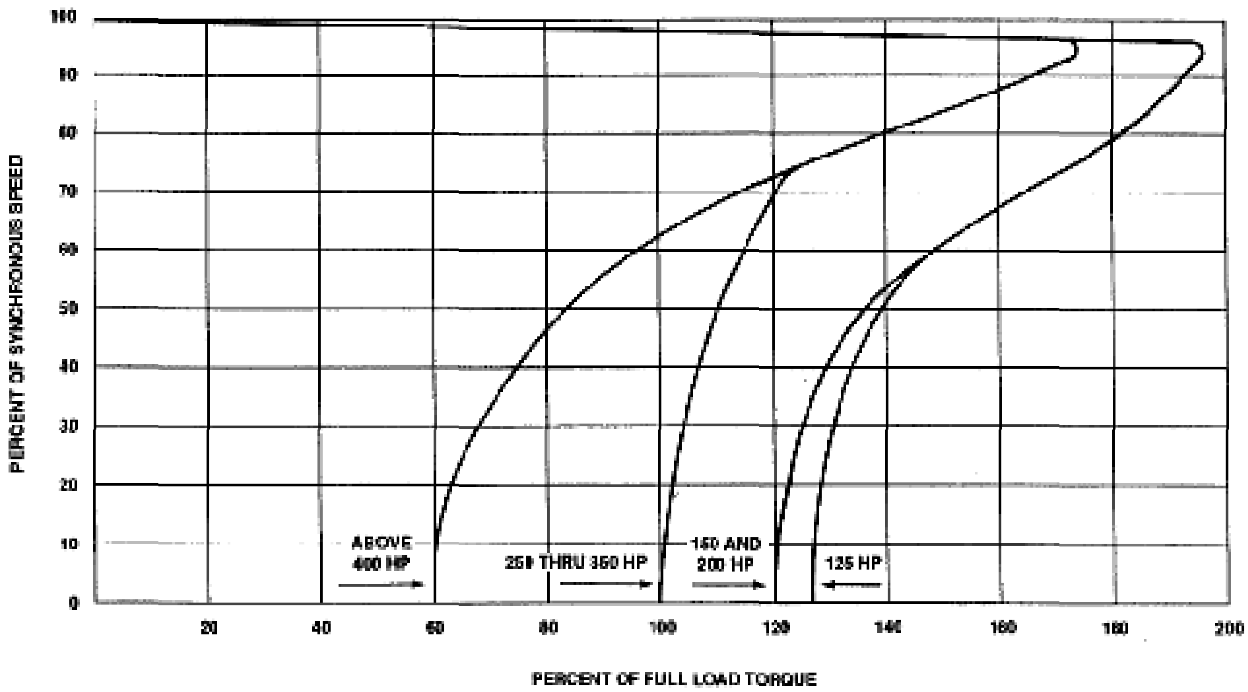
Note: Typical torque curves of general-purpose, polyphase, squirrel-cage motors with rated voltage and frequency applied.



Speed Torque Curves

Typical Speed Torque Curves of 1200 RPM Machines

Note: Typical torque curves of general-purpose, polyphase, squirrel-cage motors with rated voltage and frequency applied.



Shipping Weights

Approximate Shipping Weights In Pounds

Frame	ODP & WPI	WPII	TEFC	XP
449	-	-	3500	-
505	2900	-	-	3500
507	3100	3500	3500	4100
508	3500	-	-	-
509	3600	4000	4000	4800
5011	4700	5200	5000	5850
588	5600	5600	5600	-
5810	6550	6800	6600	-
30B / 30E / 30N	-	-	-	7600
30JJ / 30KK / 30R	-	-	-	8600
3020 / 30L	-	-	-	10000
3020 / 30LL	-	-	-	11000
3030	-	-	-	11400
708	-	-	9900	-
788	-	-	13600	-
880	-	-	19400	-
6811	12000	12000	-	-
6813	14700	14700	-	-
809	15000	17000	-	-
8010	17000	18000	-	-
8011	18000	19000	-	-
8012	20000	21000	-	-
1122	29500	31000	-	-
1124	31500	33000	-	-

Insulation Systems

Insulation System (600 volts and lower only)

Conductor is Class H heavy polyester/amide-imide enamel insulated round copper wire wound as a group of coils (Each wire of a turn is one continuous piece of wire per group of coils).

A slot liner made of a polyester fiber/polyester film laminate is placed in each slot. When the coils are loose in the slots, they are tightened by using additional slot liner material. A center trough made of polyester fiber/polyester film laminate is placed between top and bottom coils in the slot.

After the coils have been placed in the slots, a piece of acrylic varnished glass tubing is placed on each lead. The phase groups are insulated on both ends with sheets of varnished glass cloth. The slot liner is folded over the coils and a polyester glass mat laminate top stick is inserted in the stick notches.

Jumper and neutral connections are made with compression type solderless connectors and insulated with acrylic glass tubing. Jumpers, neutrals, leads and the end opposite leads are securely tied with polyester tie tape.

The completely wound stator is dipped two times in Class "F" polyester insulating baking varnish and baked after each dip.

ML-CLAD Insulation System (0-7200 volts)

The conductors are made of rectangular copper insulated with heavy polyester/amide-imide enamel or heavy polyester/amide-imide enamel plus varnished single Dacron glass. In some cases, the conductors are insulated with glass-Dacron reinforced mica tape. Strands of the wound coil loop are bonded with a polyester bonding resin during a hot pressing operation. The loop is then spread and properly shaped.

The entire coil is taped with glass-Dacron reinforced mica tape. The number of layers of tape is increased with the voltage. The entire coil is taped with a protective polyester armor tape. When corona protection is needed, conductive armor tape is used on the slot portion of the coil.

When corona protection is not required, the coils are placed in the stator slots with polyester film, polyester fiber combination slot liners. The slot liners are trimmed flush with the bottoms of the slot stick notches and top sticks made from glass mat epoxy are inserted in the stick notches.

The coils are lashed to coil supports with polyester tie tape and blocked with polyester glass laminate and polyester felt. Coil to coil connections are insulated with acrylic glass tubing or with mica tape and polyester armor tape. Lead connections are insulated with silicone rubber tape and polyester armor tape.

Insulation Systems

The completely wound and connected stator is vacuum pressure impregnated with a 100% solids, thermosetting resin. The VPI treatment subjects the entire stator assembly to a high vacuum, drawing out entrapped air and gases in the insulation system. The stator is then flooded with the epoxy resin and the tank is pressurized to several times atmospheric pressure. The assembly is then baked to cure the catalyzed resin, producing a solid sealed insulation system impervious to moisture and chemical attack.

ML-CLAD Insulation System (7210-15,000 volts)

The conductors are made of rectangular copper insulated with heavy polyester/amide-imide enamel. The turns are then insulated with glass-Dacron reinforced mica tape. The turns of the wound coil loop are bonded with a polyester bonding resin during a hot pressing operation. The loop is then spread and properly shaped.

The entire coil is taped with glass-Dacron reinforced mica tape. The number of layers of tape is increased with the voltage. The end turns of the coil are taped with a protective polyester armor tape. To provide corona protection, conductive armor tape is used on the slot portion of the coil and semi-conductive grading tape is applied at each end of the slot portion.

The coils are lashed to coil supports with polyester tie tape and blocked with polyester glass laminate and polyester felt. Coil to coil connections are insulated with mica tape and polyester armor tape. Lead connections are insulated with silicone rubber tape and polyester armor tape.

The completely wound and connected stator is vacuum pressure impregnated with a 100% solids, thermosetting resin. The VPI treatment subjects the entire stator assembly to a high vacuum, drawing out entrapped air and gases in the insulation system. The stator is then flooded with the epoxy resin and the tank is pressurized to several times atmospheric pressure. The assembly is then baked to cure the catalyzed resin, producing a solid sealed insulation system impervious to moisture and chemical attack.

Lead cable is insulated with silicone rubber.

External Load Wk^2 Capabilities

External load capability polyphase squirrel-cage induction motors required by NEMA

Hp	SYNCHRONOUS SPEED RPM					
	3600	1800	1200	900	720	600
	Load WK^2 (Exclusive of Motor WK^2), Lb-Ft^2					
100	92	441	1181	2372	4070	6320
125	113	542	1452	2919	5010	7790
150	133	640	1719	3456	5940	9230
200	172	831	2238	4508	7750	12060
250	210	1017	2744	5540	9530	14830
300	246	1197	3239	6540	11270	17550
350	281	1373	3723	7530	12980	20230
400	315	1546	4199	8500	14670	22870
450	349	1714	4666	9460	16320	25470
500	381	1880	5130	10400	17970	28050
600	443	2202	6030	12250	21190	33110
700	503	2514	6900	14060	24340	38080
800	560	2815	7760	15830	27440	42950
900	615	3108	8590	17560	30480	47740
1000	668	3393	9410	19260	33470	52500
1250	790	4073	11380	23390	40740	64000
1500	902	4712	13260	27350	47750	75100
1750	1004	5310	15060	31170	54500	85900
2000	1096	5880	16780	34860	61100	96500
2250	1180	6420	18440	38430	67600	106800
2500	1256	6930	20030	41900	73800	116800
3000	1387	7860	23040	48520	85800	136200
3500	1491	8700	25850	54800	97300	154800
4000	1570	9460	28460	60700	108200	172600
4500	1627	10120	30890	66300	118700	189800
5000	1662	10720	33160	71700	128700	206400
5500	1677	11240	35280	76700	138300	222300
6000	. . .	11690	37250	81500	147500	237800
7000	. . .	12400	40770	90500	164900	267100
8000	. . .	12870	43790	98500	181000	294500
9000	. . .	13120	46330	105700	195800	320200
10000	. . .	13170	48430	112200	209400	344200

External Load Wk^2 Capabilities

External load capability polyphase squirrel-cage induction motors required by NEMA

Hp	SYNCHRONOUS SPEED RPM					
	514	450	400	360	327	300
	Load WK^2 (Exclusive of Motor WK^2), $Lb\text{-}Ft^2$					
100	9180	12670	16830	21700	27310	33690
125	11310	15610	20750	26760	33680	41550
150	13410	18520	24610	31750	39960	49300
200	17530	24220	32200	41540	52300	64500
250	21560	29800	39640	51200	64400	79500
300	25530	35300	46960	60600	76400	94300
350	29430	40710	54200	69900	88100	108800
400	33280	46050	61300	79200	99800	123200
450	37090	51300	68300	88300	111300	137400
500	40850	56600	75300	97300	122600	151500
600	48260	66800	89100	115100	145100	179300
700	55500	76900	102600	132600	167200	206700
800	62700	86900	115900	149800	189000	233700
900	69700	96700	129000	166900	210600	260300
1000	76600	106400	141900	183700	231800	286700
1250	93600	130000	173600	224800	283900	351300
1500	110000	153000	204500	265000	334800	414400
1750	126000	175400	234600	304200	384600	476200
2000	141600	197300	264100	342600	433300	537000
2250	156900	218700	293000	380300	481200	596000
2500	171800	239700	321300	417300	528000	655000
3000	200700	280500	376500	489400	620000	769000
3500	228600	319900	429800	559000	709000	881000
4000	255400	358000	481600	627000	796000	989000
4500	281400	395000	532000	693000	881000	1095000
5000	306500	430800	581000	758000	963000	1198000
5500	330800	465600	628000	821000	1044000	1299000
6000	354400	499500	675000	882000	1123000	1398000
7000	399500	565000	764000	1001000	1275000	1590000
8000	442100	626000	850000	1114000	1422000	1775000
9000	482300	685000	931000	1223000	1563000	1953000
10000	520000	741000	1009000	1327000	1699000	2125000

External Load Wk² Capabilities

The table lists load inertia which induction motors having performance characteristics in accordance with NEMA standards can accelerate successfully under the following conditions:

1. Applied voltage and frequency with variation in the voltage +/-10% of rated voltage with rated frequency, or with variation in the frequency +/-5% of rated frequency with rated voltage.

2. During the accelerating period, the connected load torque should be equal to, or less than, a torque which varies as the square of the speed and is equal to rated torque at rated speed.

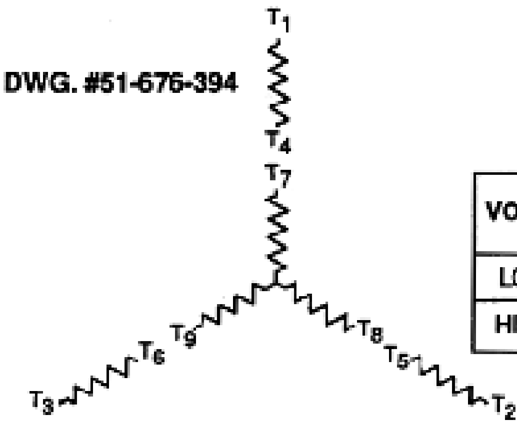
3. Two starts in secession (coasting to rest between starts) with the motor initially at ambient temperature (cold start), or one start with the motor initially at temperature not exceeding its rated operating temperature (hot start).

NOTE: Designs are available which can safety accelerate considerably more inertia without changing frame size. For motors of 1000 HP and smaller, designs are available to accelerate twice these values In same frame. For higher HP or Inertia, consult factory.

External Connection Diagrams

Single Speed

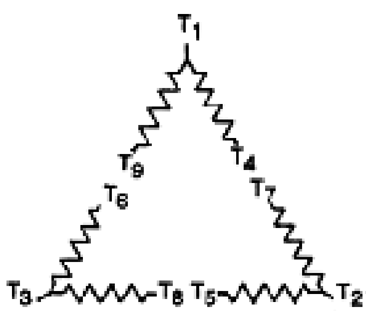
DWG. #51-676-394



3 PHASE – 9 LEAD – WYE

VOLTS	LINES			CONNECTED TOGETHER	CONN.
	L1	L2	L3		
LOW	T_1 T_7	T_2 T_8	T_3 T_9	T_4 T_5 T_6	YY
HIGH	T_1	T_2	T_3	T_4 T_7 – T_5 T_8 – T_6 T_9	Y

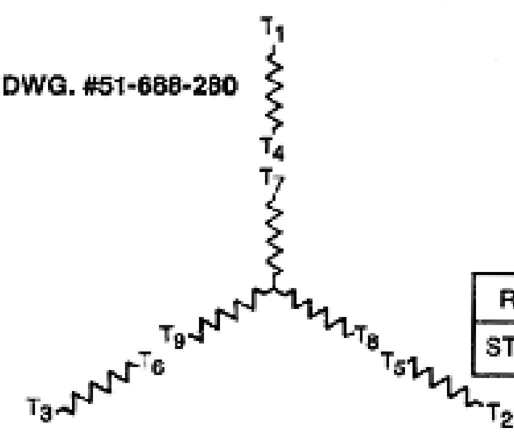
DWG. #51-676-397



3 PHASE – 9 LEAD – DELTA

VOLTS	LINES			CONNECTED TOGETHER	CONN.
	L1	L2	L3		
LOW	$T_1T_6T_7$	$T_2T_4T_8$	$T_3T_5T_9$		ΔΔ
HIGH	T_1	T_2	T_3	T_4 T_7 – T_5 T_8 – T_6 T_9	Δ

DWG. #51-668-280



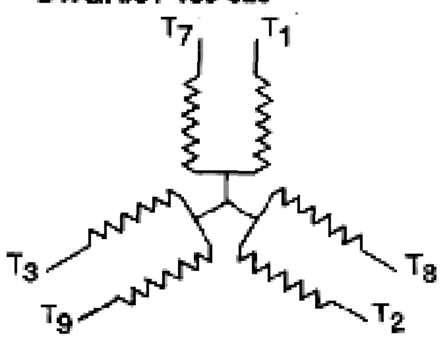
PART WINDING START
3 PHASE – 9 LEAD – WYE

	LINES			CONNECTED TOGETHER	CONN.
	L1	L2	L3		
RUN	T_1 T_7	T_2 T_8	T_3 T_9	T_4 T_5 T_6	YY
START	T_1	T_2	T_3	T_4 T_5 T_6	Y

External Connection Diagrams

Single Speed

DWG. #51-406-529

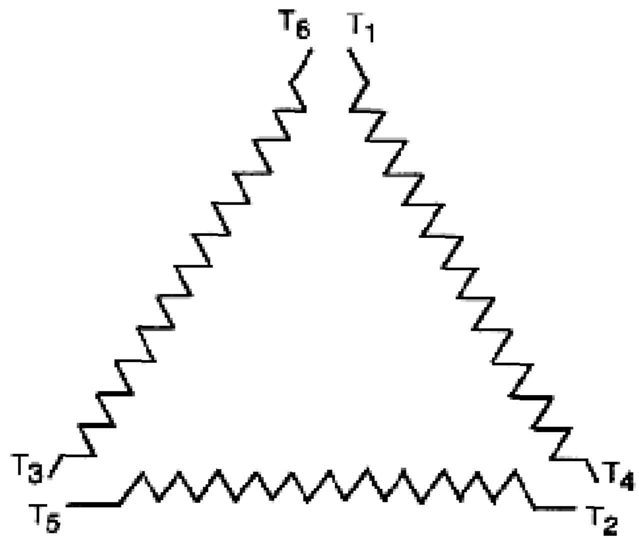


PART WINDING START
3 PHASE – 6 LEAD – WYE

LINES	L1	L2	L3	
START	T_1	T_2	T_3	T_7 T_8 T_9 OPEN
RUN	T_1 T_7	T_2 T_8	T_3 T_9	

DWG. #51-697-465

6 LEAD WYE DELTA START



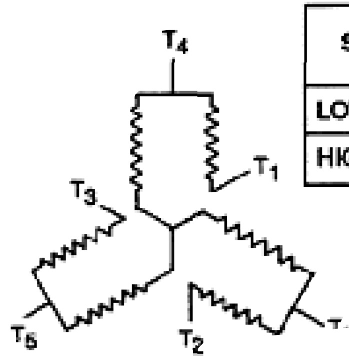
	LINES			CONNECTED TOGETHER	CONN.
	L1	L2	L3		
START	T_1	T_2	T_3	T_4 T_5 T_6	Y
RUN	T_1 T_6	T_2 T_4	T_3 T_5		Δ

External Connection Diagrams

2 Speeds

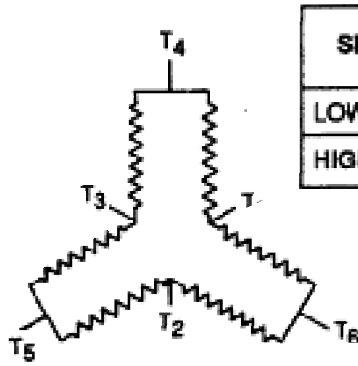
Class of Service and Drwg. Number — **Single Winding**

#51-110-063
Variable Torque



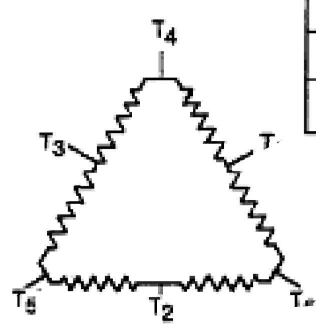
SPEEDS	LINES				CONN.
	L1	L2	L3		
LOW SPEED	T_1	T_2	T_3	T_4 T_5 T_6 OPEN	Y
HIGH SPEED	T_6	T_4	T_5	T_1 T_2 T_3 TOGETHER	YY

#51-110-060
Constant Torque



SPEEDS	LINES				CONN.
	L1	L2	L3		
LOW SPEED	T_1	T_2	T_3	T_4 T_5 T_6 OPEN	Δ
HIGH SPEED	T_6	T_4	T_5	T_1 T_2 T_3 TOGETH[illegible]	[illegible]

#51-110-069
Constant Horse-Power



SPEEDS	LINES				CONN
	L1	L2	L3		
LOW SPEED	T_1	T_2	T_3	T_4 T_5 T_6 TOGETHER	YY
HIGH SPEED	T_6	T_4	T_5	T_1 T_2 T_3 OPEN	Δ

External Connection Diagrams

2 Speeds

Class of Service and Drwg. Number

Double Winding

#51-110-062

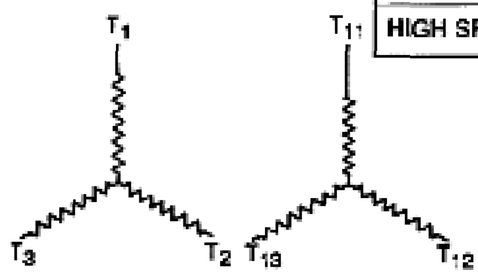
1) Variable Torque

or

2) Constant Torque

or

3) Constant Horse-Power



SPEEDS	LINES			OPEN	CONN.
	L1	L2	L3		
LOW SPEED	T_1	T_2	T_3	T_{11} T_{12} T_{13}	Y
HIGH SPEED	T_{11}	T_{12}	T_{13}	T_1 T_2 T_3	Y

Temperature Rise Standards

When operated at rated voltage and rated frequency, the observable temperature rise of the motor windings, above the temperature of the cooling air, shall not exceed the values in the following table. Note that separate values are given for motors with 1.0 service factor and 1.15 service factor. The values in the table labeled "1.0 service factor" are for motors with 1.0 service factor when operated at rated load. Likewise, the values labeled "1.15 service factor" are for motors with a 1.15 service factor when operated at service factor load. These two parts of the table apply individually to a particular motor rating (that is 1.0 or 1.15 service factor), and it is not intended or implied that they may be applied as a dual rating to an individual motor.

Method of Temperature Determination	Motor Rating and Voltage	Maximum Winding Temperature Rise °C						
		1.0 Service Factor				1.15 Service Factor		
		Class A	Class B	Class F	Class H	Class A	Class B	Class F
Resistance	All	60	80	105	125	70	90	115
Embedded Detector	1500 HP or Less	70	90	115	140	80	100	125
	More than 1500 HP: a. 7000 Volts or Less	65	85	110	135	75	95	120
	b. More than 7000 Volts	60	80	105	125	70	90	115

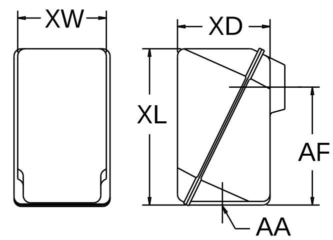
Temperature rise in table is based on a reference ambient temperature of 40°C.

Embedded detectors are located within the slot of the machine and usually are resistance elements but may be thermocouples. For motors equipped with embedded detectors, this method shall be used to demonstrate conformity with the standard.

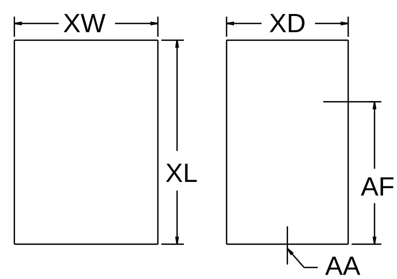
Mechanical Index

Terminal Boxes

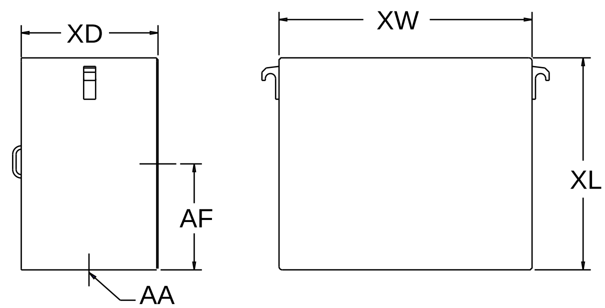
For main terminal box selection use Table 6.1 for all enclosures except explosion-proof.
For explosion-proof enclosures use Table 6.2 for 500 frames or Table 6.3 for 30 frames.



Cast Iron



Fabricated Steel #1



Fabricated Steel #2

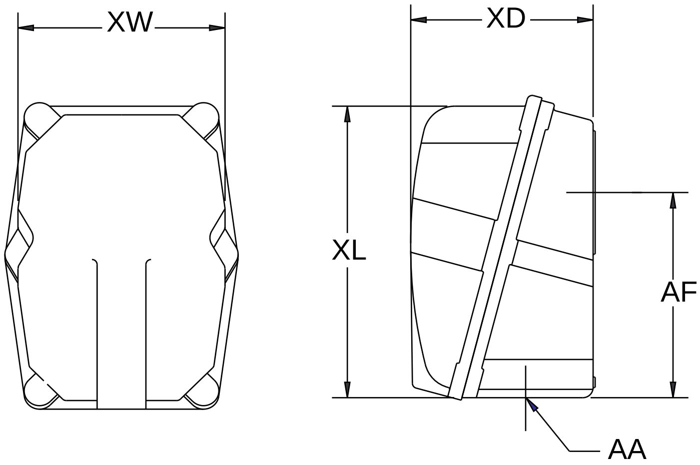
Terminal Box Assignment				
HP	**460V or 575V**	**2300V**	**4000V**	**6000V**
Up to 300	2	1	2	-
301-500	2	2	2	G
501-600	F	2	2	G
601-700	F	2	2	G
701-1000	G	2	2	G
1001-1750	-	F	G	G
1751-3000	-	G	G	G
3001-5000	-	-	G	H
5001-7000	-	-	H	H

Table 6.1						
		Dimensions in inches				
Box	**Material**	**AF**	**XD**	**XL**	**XW**	**Internal Volume (cu. in.)**
1	Cast Iron	10.0	9.0	15.1	9.0	960
2	Cast Iron	16.0	12.5	21.8	12.0	2620
3	Cast Iron	18.0	14.88	26.9	18.0	6370
E	Fab. Steel #1	-	10.25	18.05	11.5	2016
F	Fab. Steel #1	-	11.5	21.5	14.25	3324
G0	Fab. Steel #1	-	12.75	25.25	18.25	5625
H	Fab. Steel #1	-	14.25	30.25	20.25	8400
G1	Fab. Steel #2	-	20.0	25.0	19.0	9020
G2	Fab. Steel #2	-	20.0	31.0	37.0	21750
G3	Fab. Steel #2	-	26.0	37.0	37.0	33800
G4	Fab. Steel #2	-	27.0	43.0	49.0	54000

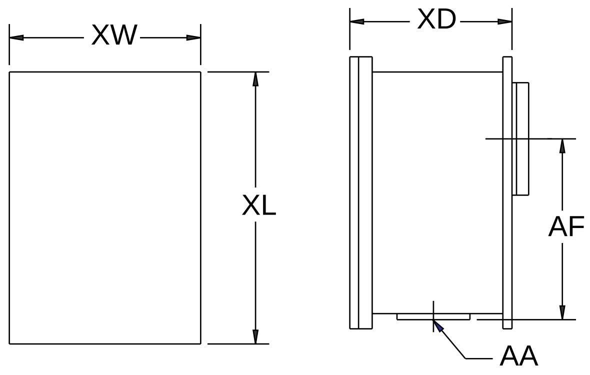
Notes: AA dimension is 5.0 on all except for box 1 which is 3.0 inches.
All cast iron boxes have a neoprene gasket between the halves.
All fabricated steel boxes are a minimum 1/8-inch sheet steel.
All fabricated steel boxes have a neoprene gasket, drip shields, and hinged lids.
Box 3 is not diagonally split.
Box G1 is sized for but does not include standoff insulators.
Box G2 is sized for but does not include lightning arrestors, or surge capacitors, or 3-4 current transformers.
Box G3 is sized for but does not include lightning arrestors and surge capacitors or surge capacitors and 3-4 current transformers.
Box G4 is sized for but does not include lightning arrestors, surge capacitors and 3-4 current transformers.
Boxes G3 and G4 are free-standing boxes with feet and will require support from beneath.

Terminal Boxes

Terminal Box Dimensions for Explosion-Proof Enclosure, Frame 500



Cast Iron



Fabricated Steel

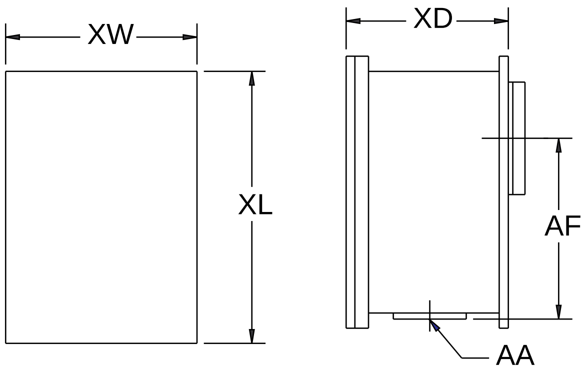
Terminal Box Assignment			
HP	**460 or 575V**	**2300V**	**4000V**
Up to 300	P	P	Q1
201-350	Q1	Q1	Q1

Table 6.2

Term Box	Material	Dimensions in Inches					Int. Vol. cu. in
		AA	AF	XD	XL	XW	
P	Cast Iron	4.0	10.0	8.9	14.3	10.0	740
Q1	Fab. Steel	4.0	15.0	13.2	22.4	15.8	2900

Terminal Boxes

Terminal Box Dimensions For Explosion-Proof Enclosure, 30 Frame



Fabricated Steel

Terminal Box Size Assignment:				
HP	**460 or 575V**	**2300V**	**4000V**	**6600V**
Up to 600	Q	Q	Q	S
601 - 700	S	Q	Q	S
701 - 1000	S	Q	Q	S

Table 6.3

Terminal Box Size (Dimensions In Inches):						
Term Box	**Int. Vol. (cu.In.)**	**AA**	**AF**	**XD**	**XL**	**XW**
Q	2900	4.0	15.0	13.2	22.4	15.8
S	6700	4.0	18.0	14.3	25.4	19.5

Balance

The easiest vibration to trace and reduce to a minimum is caused by unbalance in the rotor and its influence on the vibration of the yoke and bearing housing.

The rotors of all motors are dynamically balanced in high speed precision balancing machines at Norwood Plant to a degree that insures that the vibration measured at the rotational frequency of the motor on the bearing housing will be below the following limits established by NEMA. MG 1-20.52.

Speed	Maximum Amplitude of Vibration
3000 and above	0.001 inch (peak to peak)
1500 to 2999 RPM	0.002 inch (peak to peak)
1000 to 1499 RPM	0.0025 inch (peak to peak)
999 and below	0.003 inch (peak to peak)

These limits apply only when the motor is placed on resilient pads in accordance with NEMA Standards. MG 1-20.53.

If low vibration limits on the application requires more precise balance, special care must be taken in the rotor manufacture. A low level of balance cannot be obtained in the presence of mechanical looseness, misalignment, bent shafts or rotor runout. These must be prevented by very close control of tolerances, fits, machinings and finishes before a low level of balance is attempted. Theoretically, rotor balancing will reduce only the vibration whose frequency is equal to rotational frequency. However, a low level of balance attenuates the possibility of other parts being excited to vibrate in resonance at their natural frequency.

Shaft Material

The standard shaft material is a medium carbon steel, AISI or SAE 1045 steel, for all speed motors.

When proximity probes or provisions for proximity probes are specified, special shaft material must be used to provide the necessary magnetic properties for the probes. For all shafts without welded spider arms, medium carbon chromium molybdenum alloy steel, AISI (SAE) 4140 containing 0.4% carbon will be used. For all shafts with welded spider arms, a medium carbon chromium molybdenum alloy steel AISI (SAE) 4130 containing 0.3% carbon will be used.

All shaft materials are fine grained and are hot rolled into round bars of special quality and straightness. All 3600 RPM motors are built with shaft without welded spider arms. All 1800 RPM and slower motors have spider arms welded onto the shaft except the 500 frame IG and CG lines.

Motors built to API 541 standards have the following special requirements:

API 541 2nd Edition, November 1987

- Shafts of 6.0” in diameter and less may be machined from hot rolled steel.
- Shafts over 6.0” in diameter for all motors shall be forged.
- For motors classified as Part 2, Special Purpose Motors, the shaft will be ultra-sonic inspected.

API 541 3rd Edition, April, 1995

- For all 3600 RPM motors and all flexible shaft motors, the shaft shall be forged.
- If specified by customer, the forging shall be ultra-sonic inspected before the rotating element is assembled.
- For all motors operating at 1800 RPM or slower and all motors operating below the first lateral critical speed, a hot rolled shaft will be used.

Bearings

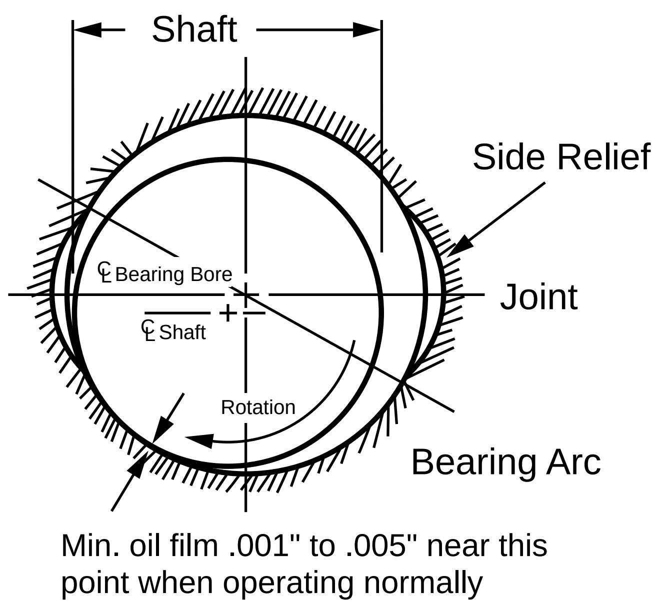
Bearing - Anti-Friction and Sleeve

Bearings are a minor item in relation to the manufacturing cost of an electric motor, but viewing the motor from a standpoint of economy of operation and cost of maintenance, the bearings become an item of major importance. Regardless of how reliable a motor may be, bearing failure will not only cause motor shutdown but result in costly repairs and loss of valuable production time.

There are two principal groups of bearings used in the electric motor industry today: (1) antifriction bearings and (2) cylindrical sleeve bearings. The vast majority of the general purpose motors are equipped with antifriction bearings.

Anti-friction bearings are designed to support and locate rotating shafts in motors. They transfer loads between rotating and stationary members and permit relatively free rotation with minor friction. They consist of rolling elements (balls or rollers) between an outer and inner ring. Cages are used to space the rolling elements from each other.

Sleeve bearings are designed to create a load carrying film of fluid between the shaft and bearing. Sleeve bearings are designed to have approximately a 0.002-inch shaft diameter clearance. The primary function of the bearing clearance is to provide a wedge shaped area that the oil film utilizes to create hydrodynamic pressure. This pressure is sufficient to carry the rotating assembly weight applied to the bearing. Please see the diagram below:



Bearings

Bearing Selection

The table below, together with the explanations appearing below the table, should be helpful in selecting bearings.

Table 3 - Comparison of Anti-Friction and Sleeve Bearings

Item No.	Factor	Anti-Friction	Sleeve
1	Long Life		x
2	Availability	x	
3	Maintenance Ease	x	
4	Quietness		x
5	Flexibility in Application	x	
6	Thrust Loads	x	
7	Heavy Belt Drives	x	
8	Prior Indication of Failure Due to Wear		x
9	Compactness	x	

Item 1 - A life of anti-friction bearings are rated in L10 life (see description this section). They have a predicted finite life based on a myriad of factors. Sleeve bearings in theory have an indefinite life as the shaft rides on a film of oil and no mechanical part wear.

Item 2 - Ball bearings are standardized to a very fine degree, and widely used, making it possible to secure replacement bearings quite easily. There is no standardization in sleeve bearings because there is no possibility of oil leakage. Ball bearing replacement can be quickly and easily accomplished, as no fitting of bearings is required.

Item 3 – The ease of maintenance of ball bearing motors is greater than sleeve bearing motors. Sleeve bearings must be inspected more often. Housekeeping is less of a problem with ball bearings because there is no possibility of oil leakage. Ball bearing replacement can be quickly and easily accomplished, as no fitting of bearings is required.

Item 4 – The higher noise level of ball bearings is sometimes critical in air conditioning applications.

Item 5 – Motors having ball bearings may be mounted on a wall, tilted, or placed in a vertical position. Sleeve bearings will not operate in any of these positions.

Item 6 – Continuous thrust loads cannot be carried by sleeve bearings.

Item 7 – Heavy belt drives interfere with the formation of the oil wedge on which the operation of the sleeve bearing depends.

Item 8 – Wear of a sleeve bearing may be measured by noting changes in air gap. The rate of wear is slow, giving ample warning time. Ball bearings fail quite rapidly after unusual noise develops.

Item 9 – Ball bearings do not require large oil reservoirs. Ball bearings distribute loads over a smaller area.

Bearings

Bearing Arrangements

Frame	Ball Bearings	Sleeve Bearings	Tilting Pad Bearings
500 IG	Standard	Not Available	Not Available
500 CG/CGII	Standard	Optional	Not Available
500 CGZ	Standard	Optional	Not Available
580 CG/CGII	Standard	Optional	Optional
580 CGZ	Standard	Optional	Optional
30 AZZ - 2 Pole	Not Available	Standard	Optional
30 AZZ - 4 Pole and Slower	Standard	Optional	Optional
680 RAZ - 2 Pole	Not Available	Standard	Optional
680 RAZ - 4 Pole and Slower	Optional	Standard	Optional
708/788 CGZ - 4 Pole and Slower	Standard	Optional	Not Available
880 CGZ	Standard	Not Available	Not Available
800 RG/FOD/RAZ	Not Available	Standard - Note 1	Optional
1120 CG/CGII - 2 and 4 Pole and Special	Not Available	Not Available	Standard
1120 CG/CGII - 6 Pole and Slower	Not Available	Standard	Optional

All ball bearing machines are grease lubricated
All sleeve bearing machines are ring oil lubricated. Some require flood lubrication - See Part 4C
All tilting pad bearing machines are forced lubricated

Alarm and Shutdown Temperature Settings		
	Alarm (˚C)	**Shutdown (˚C)**
Sleeve and Thrust	90	95
Anti-Friction	100	105

Bearings

Ball Bearing

In a ball bearing, the race is curved in an axial direction as well as in the circumferencial direction. Since the ball and race are elastic materials the contact between ball and race becomes an elliptical area (See Figure 6.4.1). Looking at the ball race cross section (See Figure 6.4.2) it is apparent that different ball radii are in contact with the race and the only true rolling can occur at one radius (R2) hence there must be sliding at the other radii. Actually there is sliding in areas A and B (See Figure 6.4.1) opposite each other and rolling along the two lines that separate the areas. The areas must balance each other. This sliding friction shows the need of good lubrication in these areas since the area is actually small and the unit load is very high. This constant stressing and relieving also causes heating due to internal metal friction.

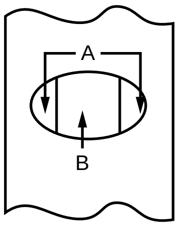


Figure 6.4.1

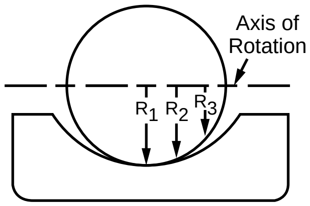


Figure 6.4.2

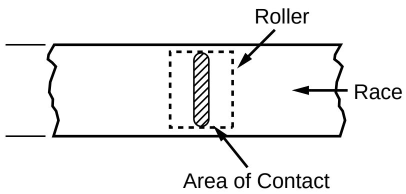


Figure 6.4.3

Roller Bearings

In a cylindrical roller the radius of the roller is constant and hence true rolling exists along the contact line. Since the parts are elastic, an area of contact exists as shown in Figure 6.4.3. Very high unit loads exist since the width is small, however, the area of contact at any particular moment is considerably greater than that of a ball against raceway in a ball bearing. For this reason, the roller bearing can carry considerably greater radial loads than the equivalent size ball bearing.

Limiting Speeds

The maximum speed at which a particular bearing can be operated is affected by many factors. Principally these are bearing size and type, method of lubrication, operating load and temperature, bearing design and tolerances, speed, cage type and material and required bearing life.

The bearing manufacturers publish limiting speed tabulations, however, because there are so many variables, the tabulations are necessarily only a general guide.

As the bearing size increases for a constant motor speed, the ball must travel a greater distance (measured in feet per minute) per revolution.

Bearings

The increased speed under constant loading causes an increase in heating and metal fatigue resulting in a reduction in bearing life. In addition, higher peripheral speeds make effective lubrication more difficult.

Bearing Standards

The Anti-Friction Bearing Manufacturer's Association, a non-profit bearing standards group, consisting of most bearing manufacturers, have established standards for tolerances, sizes and types of bearings. Most ball bearings are ordinarily supplied with standard Internal clearances between balls and raceways, commonly called bearing fit up. Part of this original built in internal clearance disappears after the bearing has been mounted, because the inner ring is expanded when pressed on the shaft leaving the correct amount for smooth operation in service. The numerical amount of internal clearance is a variable dependent upon the physical size and type of the bearing itself. Special Internal clearances may on occasion be required for special applications.

Fit up is given little publicity but is extremely important and can vary from a tight assembly where the balls are under compression to a looseness between the balls and races. It is usually detected by radial play in the bearing in a radial direction and by end shake in the direction parallel to the bore. Fit up has no relation to quality, and different fit up can be obtained in all quality bearings. Siemens uses as standard bearing fit up, AFBMA-3.

In addition to the AFBMA standards, the Annular Bearing Engineers Committee (ABEC) have established quality standards to give standardization to tolerances. The ABEC numbers, designating standard, specially selected, super precision and ultra super precision bearings are ABEC 1, 3, 5 and 7 respectively. Standard motors use ABEC 1 quality bearings. Higher quality bearings are used in special motors where closer shaft run outs or low noise and vibration levels are required.

The Anti-Friction Bearing Manufacturers Association (AFBMA) recently established a standard nomenclature system. Although this identification system is not in general use because it is quite cumbersome, it does provide a standard means of identifying bearings. Norwood Siemens uses the AFBMA nomenclature for identifying bearings.

Bearing – Ball and Roller

Bearings are a minor item in relation to the manufacturing cost of an electric motor, but viewing the motor from a standpoint of economy of operation and cost of maintenance, the bearings become an item of major importance. Regardless of how reliable a motor may be, bearing failure will not only cause motor shutdown but result in costly repairs and loss of valuable production time.

There are two principal groups of bearings used in the electric motor industry today: (1) antifriction bearings and (2) cylindrical sleeve bearings. The vast majority of the general purpose motors are equipped with antifriction bearings.

Bearings

Antifriction Bearings

There are six main types of antifriction bearings in use at Norwood Plant; (1) Radial deep groove ball bearings, (2) maximum-type ball bearings, (3) cylindrical roller bearings, (4) double row spherical roller bearings, (5) angular contact ball bearings, and (6) spherical roller thrust bearings.

Every antifriction bearing consists of four basic parts:

1. The outer ring or outer raceway – mounts in the bearing chamber or housing.
2. An inner ring or inner raceway – mounts on the motor shaft.
3. The balls – space the inner and outer rings.
4. The cage, retainer or separator – evenly spaces the balls.

Figure 6.4.4 shows a typical bearing with the various parts identified. Various bearing manufacturers may use slightly different terminology, however, those indicated are the most commonly used.

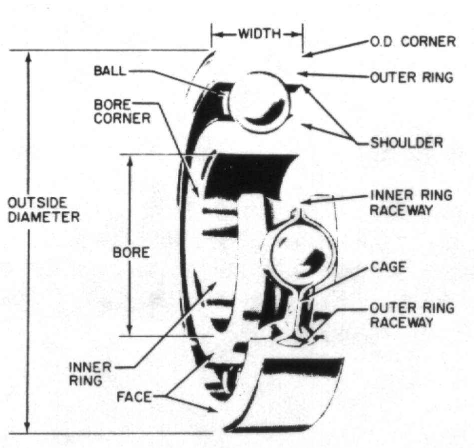


Figure 6.4.4

Bearings are designed to carry specific type loads. For example, some bearings are designed to carry loads in only one direction while others can carry loads in two directions.

Thrust (axial) loads are defined as forces acting parallel with the motor shaft (Figure 6.4.5). Radial loads are defined as forces acting perpendicular to the motor shaft.

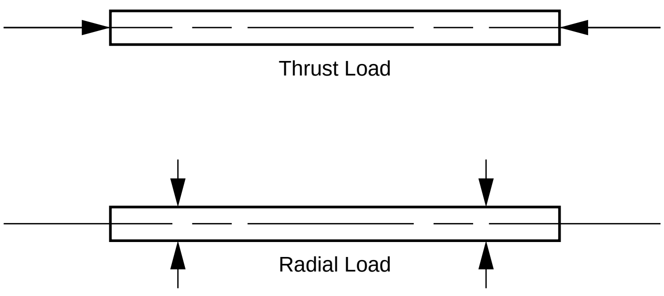


Figure 6.4.5 - Two types of loads carried on motor shafts

Bearings

Most bearing manufacturers use a numerical designation to indicate bearing size. The last two digits of the basic bearing number indicate the bearing bore size, while the first one or two digits indicate the bearing series. For example: in a 207 size bearing, the 07 represents the bore size while the 2 shows that the bearing is a light or a 200 series bearing. Additional identification is used as a prefix or suffix to the basic bearing size to indicate a specific type of bearing. Bearing nomenclature also indicates accessories which may be mounted directly on the bearings such as shields, seals, etc.

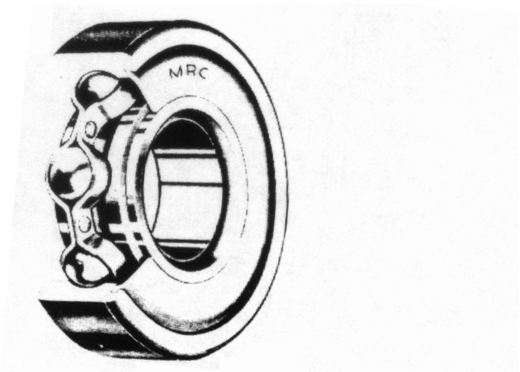
Bearing Series

There are three common series of ball bearings: light or 2000 series, medium or 3000 series, and heavy or 400 series. For a given size (205, 305, 405), the bore is the same but the diameter of the outer race is progressively larger, meaning that the balls are progressively larger in diameter. The larger the ball, the greater the load-carring capacity; hence the nomenclature light, medium and heavy series.

Bearing Types (Shields and Seals)

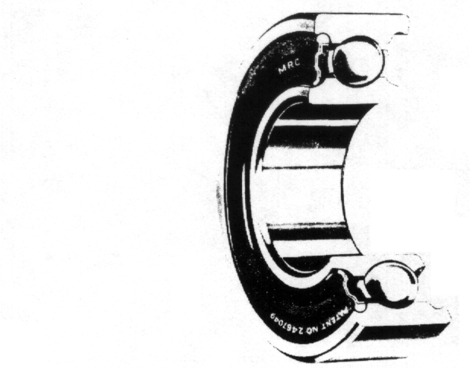
Many bearings can be supplied with accessories such as shields or seals. A bearing shield consists of a pressed steel plate which is mounted, by crimping, on the outer ring. A radial clearance is maintained between the shield and the inner rotating ring of the bearing. This clearance is sufficient to allow passage of lubricant into the ball of the bearing itself, however, is sufficiently small to prohibit the entrance of foreign particles. In many cases, shields are used on both sides of the bearing. Figure 6.4.7 shows a typical bearing with a singular shield.

Many types of bearing seals are available. The most commonly used type consists of a neoprene or synthetic material bonded to a pressed steel plate. The pressed steel plate is used as a means of support for the synthetic material. The seal is crimped in the outer ring of the bearing and rubs on a polished surface of the inner ring of the bearing. Figure 6.4.8 depicts a typical bearing with a singular rubbing seal mounted in place.



Courtesy of Marlin-Rockwell Co. Division of TRW Inc.

Figure 6.4.7 - Single Shielded Conrad Bearings, Type SF.



Courtesy of Marlin-Rockwell Co. Division of TRW Inc.

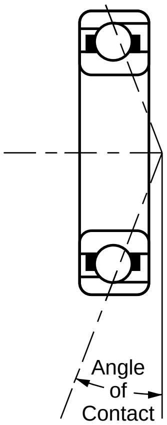
Figure 6.4.8 - Single Sealed Conrad Bearings, Type SZ.

Bearings

Since seals have direct contact with the inner ring, they are highly efficient in preventing entrance of foreign matter and in retaining the bearing lubricant. Because the seal actually rubs on the bearing inner ring, there is a slightly greater "torque drag" than experienced with a shielded bearing of the same size. The rubbing action also generates heat, therefore, seals are not used on large bearings having high peripheral speeds or bearings having operating temperatures exceeding the seal material temperature capabilities. Other types of seals are available, however, in general they are considerably wider and therefore, require an increase in bearing width.

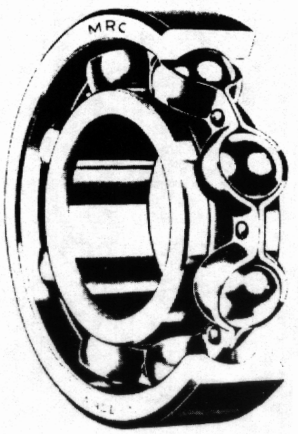
Angle of Contact

The term "angle of contact" refers to the angle at which the ball contacts the inner and outer rings. In essence, this is the angle at which the effective force is transmitted. This angle of contact varies with different types of bearings from O to 40 degrees. The higher the angle of contact, the greater the capability of the bearing to carry axial loading. Figure 6.4.9 shows a typical angle of contact.



Courtesy of SKF Industries, Inc.

Figure 6.4.9 - Angle of contact.



Courtesy of- Marlin-Rockwell Co. Division of TRW Inc.

Figure 6.4.10 - Single-row, open enclosure deep-groove ball bearing.

Radial Deep-Groove Ball Bearings

The most generally used type of antifriction bearing is the radial deep-groove ball bearing. This bearing is designed not only to carry radial loads but also moderate thrust loads in either direction, simultaneous with, or independent of, radial load.

Open Enclosure Bearings

Open enclosure bearings consist of an inner and outer race, the ball retainer ring, and balls (Figure 6.4.10). This bearing can be relubricated without disassembling the motor, but the open construction affords slight protection against overgreasing. There is no protection against foreign elements that may be in the grease or in the atmosphere when the motor is dismantled.

Another disadvantage of the open construction is the churning of the grease supply in the reservoir caused by the balls and retainer ring rotating. The rotation of the ring churns the grease and will increase grease oxidation. Dust particles which may enter along the shaft will mix with the grease and come in contact with the bearing.

Double-Shielded Bearings

Double-shielded bearings are simply open-type bearings with a shield rolled into the outer raceway on each side (Figure 6.4.12). The shield has a close running clearance with the inner race. This clearance is sufficient to permit passage of grease but is small enough to protect the balls and raceways from large dirt particles which may enter the grease during assembly or maintenance. This bearing is also prelubricated, but it can be relubricated while in service.

The double shield, while it does not completely eliminate the possibility of overgreasing, it definitely minimizes this possibility. These shields also serve to keep grease in the ball path when the motor is mounted vertically, by effectively preventing slumping of the grease supply, resulting in increased grease life.

The double-shielded bearing gives users the desirable features of both the open and double sealed bearings, and also eliminates most of the respective disadvantages. See Table 1 for Comparison of Bearing Features.

Figure 6.4.12 - Single row, double-shielded ball bearing

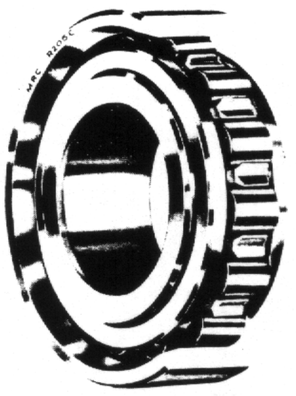
Table 1 - Comparison of Radial Deep-Groove Bearing Features

Features	Open	Sealed	Shielded
Bearing protected from forign material when removed from its housing enclosure	No	Yes	Yes
Lubrication in service	Yes	No	Yes
Protection against vapor contanimation	Yes	Yes	Yes
Relative bearing cost	Lower	Higher	Intermediate

Cylindrical Roller Bearing

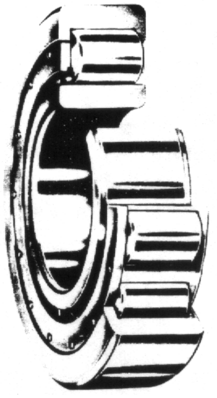
When the radial load imposed on the bearing is in excess of the capacity of a ball bearing, such as may occur when the load is belt driven, the cylindrical roller bearing is used. A 222 cylindrical roller bearing is capable of carrying 186% more radial load than the same size (6222) ball bearing.

Physically, this bearing is interchangeable with the ball bearing in any given size, but it does have operating limitations. The range of operating speeds for roller bearings is much less than the ball type because of noise and friction heat. The roller bearings can carry no axial loads and are usually used on the drive end only with a deep groove ball bearing on the non-drive end to control rotor float. Axial movement of the outer raceway of the roller bearing must be limited to keep it from disengaging from the inner race (Figure 6.4.13 and Figure 6.4.14).



Courtesy of- Marlin-Rockwell Co. Division of TRW Inc.

Figure 6.4.13 - Cylindrical Roller Bearing, Type N



Courtesy of SKF Industries, Inc.

Figure 6.4.14 - Cylindrical Roller Bearing, Type NV.

Bearing Quality and Life

Electric Motor Quality (EMQ) is a term used to designate ball bearings produced for electric motors where low noise and vibration is of prime importance. It is generally recognized that bearings in electric motors are made exclusively from vacuum-degassed steel of the highest quality; and close tolerances are maintained in the manufacture of the balls and races. All of the ball bearings supplied by Siemens are EMQ.

Bearings

The life which 90% of a group of bearings will exceed is known as the minimum L10 life. Bearings selected for Siemens motors will have an L10 life which depends upon the method of connection to the load. Direct connected motors will have a minimum design L10 life of 15 years in continuous service. The bearing life of motors connected by belt drives is determined by the characteristics of the belt drive, including the pitch diameter of the sheaves, number and type of belts, and center distance. If the recommended belt drive limitations are followed and the drive is properly aligned and lubricated, the minimum design L10 life will be two years in continuous service.

When a group of identical bearings are run under a set condition of speed and load there will be a considerable variation in the fatigue lives. The exact cause of this dispersion is not known. Since all bearings do not fail at the same time, it is necessary to treat the problem statistically. The life which 50% of a group of bearings will exceed is the median life, sometimes known as L50 life. The average life is approximately five times the L10 life.

Cages - Materials

Cages, also referred to as separators or retainers, serve the purpose of maintianing uniform rolling element spacing in the inner and outer rings of the bearings as the rolling elements pass in and out of load zones. There are various cage type material and configurations meet specified service requirements. The following material is for informational purposes only. Please note: Refer any and all specified cage material requests to Norwood, before commiting to any requests. Siemens standard cage material for all bearings is pressed steel or cast brass. However, the anti-friction bearings for 680 frames contain machine brass cages as standard .

Steel Cages

Steel cages are standard for many ball bearings. These cages have relatively high strength and low weight. Steel cages can be used up to operating temperature of 300 degrees C and are not affected by lubricants or solutions to clean bearings. The standard for small and medium sized bearings are pressed steel.

Brass Cages

Brass cages are generally utilized in bearings where the application would subject the bearing to heavily loaded conditions. Unlike the steel cages, brass cages come in cast brass or machined brass configurations.

Bearings

Typical Anti-Friction Bearing Usage

Frame	Short Shaft			Long Shaft		
	RPM	NDE	DE	NDE	Direct Connected DE	Belted DE
449	3600	75BC03JPP3	75BC03JPP3	-	-	-
449	1800 & Slower	75BC03JPP3	75BC03JPP3	75BC03JPP3	100BC03JPP3	100RU03M0
500	3600	75BC03J3	75BC03J3	-	-	-
500 (except CGZ, CGZZ & RGZZ	1800 & Slower	75BC03J3	90BC02J3	75BC03J3	110BC02J3	110RU22M30
500 CGZ(Z)	1800 & Slower	75BC03J3	75BC03J3	75BC03J3	110BC02J3	110RU22M30
500 RGZZ	1800 & Slower	75BC03J3	75BC03J3	95BC03J3	110BC02J3	110RU22M30
580	3600	75BC03J3	75BC03J3	-	-	-
580 OPEN	1800 & Slower	110BC02J3	110BC02J3	100BC03J3	130BC02J3	130RU22M30
580 TEFC	1800 & Slower	110BC02J3	110BC02J3	100BC03J3	130BC02J3	130RU22M30
680	1800 & Slower	160BC02M3	160BC02M3	-	-	-
708	1800 & Slower	120BC02J3	120BC02J3	-	-	-
788	1800 & Slower	140BC02J3	140BC02J3	-	-	-
880	1800 & Slower	140BC03J3	140BC03J3	-	-	-

Bearings

AFBMA Nomenclature - Ball Bearings

Bearing Bore	Bearing Type	Dimension Series	Modifications	Fitup & Tolerance	Lubricant
D D D	L L L	D D	L LL* L*	D** D**	L**

L designates a letter
D designates a digit

Lubricant (L):**
R - Low temperature silicone grease 100° F
H - High temperature grease 275° F
S - High temperature silicon grease 300°F

Tolerances (D):**
0 - Standard tolerances - ABEC 1
3 - More precision than 0 ABEC 3
5 - More precision than 3 - ABEC 5

Internal Clearances (D):**
0 - Standard fitup - AFBMA 0 or C/0
3 - Loose internal fitup - AFBMA 3 or C/3
4 - Looser than C/3 AFBMA 4 or C/4

Modifications, column 4 (L*):
G - Snap ring and groove in outer race
D - Single bearing modified for duplex mounting (DB, DF, or DT)

Column 2 or 3 Used for R, T, or U (LL*):
P - Single shielded - permanently fastened
PP - Double shielded - permanently fastened
E - Single sealed - permanently fastened
EE - Double sealed - permanently fastened
KK - Double labyrinth seals for cartridge bearings
R - Pair of bearings modified for duplex mounting - back to back (DB)
T - Pair of bearings modified for duplex mounting - in tandem (DT)
U - Pair of bearings modified for duplex mounting - face to face (DF)
X - None of the above - see footnote *
XX - None of the above - see footnote *

Type of Cage or Ball Retainer (L):
J - Standard - steel, sheet or strip form, centered by the balls
K - Bronze or brass, not sheet or strip, centered by one race
M - Bronze or brass, not sheet or strip, centered by the balls
D - Non-metallic (phenolic), centered by one race
X - Any type of cage
Y - Non-ferrous metal, sheet or strip form, center

Dimension Series (D D):
10 - Extra light, e.g., 100-KS (MRC) or 6000 (SKF)
02 - Light, e.g., 200-S (MRC) or 6200 (SKF)
03 - Medium, e.g., 300-S (MRC) or 6300 (SKF)
32 - Light series wide cartridge type sealed bearings, e.g., 200-SFFC (MRC)
33 - Medium series wide cartridge type sealed bearings, e.g., 300SFFC (MRC)

Type of Ball bearing (2 or 3 Letters) (L L L):
BC - Standard deep groove ball bearing, e.g., 206-S (MRC) 6308 (SKF)
BL - Maximum capacity ball bearing with filling slot, e.g., 222-M (MRC), 222-W (FAFNIR)
BH - Maximum capacity ball bearing double assembly, e.g., 222-R (MRC)
BT - Angular contact thrust bearing, e.g., 7313P (MRC)

Bearing Bore in Millimeters (2 or 3 Digits) (D D D):
e.g., 203 = 17, 204 = 20, 307 = 35, 222 = 110, i.e., the last two digits are multiplied by 5 to obtain the bore, excepting the 203 or 303 size bearing which is 17.

Example: 35BC02JPPO - Standard deep groove, light series, standard steel cage, double shielded, standard fitup and standard tolerances MRC 207-SFF or equivalent.
Example: 110BT03MT03 - This is a pair of 7322DT angular contact bearings mounted in tandem, standard fitup and ABEC3 tolerances.

* The letters for columns 2, 3 and 4 of modifications are omitted if none are applicable. If column 4 is applicable but not 3, or 2 and 3, an X or XX is used in column 3, or 2 and 3, e.g., 35 BC02J03 or 35 BT03MXD03
** If these three columns are omitted, standard fitup, tolerances, and greases are implied

Bearings

AFBMA Nomenclature - Roller Bearings

Bearing Bore	Bearing Type	Dimension Series	Modifications		Fitup & Tolerance	
D D D	L L L	D D	L	L	D	D

L designates a letter
D designates a digit

Fitup & Tolerance (second D):
0 - Standard tolerances - RBEC 1
3 - More precision than 0 RBEC 3
5 - More precision than 3 RBEC 5

Internal Clearances (first D):
0 - Normal internal clearance
3 - Internal clearance less than normal
4 - Internal clearance greater than normal

Modifications (second L):
NOT APPLICABLE - THIS COLUMN OMITTED

Type of Cage or Ball Retainer (first L):
X - Any type of cage
K - Brass or bronze, not in sheet or strip form, ring centered
M - Brass or bronze, not in sheet or strip form, centered by rolling element
H - Light metal, not in sheet or strip for, ring centered

Dimension Series:
02 Light series, e.g., N208 (SKF)
03 Medium series, e.g., N308 (SKF)
22 Series used for self aligning spherical roller bearings, e.g., 22222 (SKF)
23 Series used for self aligning spherical roller bearings, e.g., 22322 (SKF)
94 Series used for spherical roller thrust bearings, e.g., 29430

Type of Ball bearing (2 or 3 Letters):
RN - Cylindrical roller bearing, shoulders on inner ring
RU - Cylindrical roller bearing, shoulders on outer ring
RJ - Cylindrical roller bearing, shoulders on each side of outer ring and one side of inner ring
SC - Double row self-aligning roller bearing
SD - Double row self-aligning roller bearing
TS - Spherical roller thrust bearing, e.g., SKF 29430

Bearing Bore in Millimeters (2 or 3 Digits):
e.g., N208 = 40, 22222 = 110, i.e., the last two digits are multiplied by 5 to obrain the bore.

Sleeve Bearings

Split sleeve bearings are used in motors intended for direct connection to driven units.

Split sleeve bearings are split at the horizontal centerline and are held together with two tapered dowel pins and four screws. Bearing housings and capsules are also split. This permits inspection of the motor windings without complete disassembly of the bearing arrangement. Split bearings may also be changed without disturbing the coupling.

Babbitt Material

Standard bearings consist of babbitt material liner in either a cast iron or steel shell. The babbitt is bonded to the shell. The bonding consists of chemically removing the exposed graphite in the cast iron, tinning the cast iron surface and pouring the babbitt to adhere to the tinned surface.

The steel shell will go through a similar process except it is not necessary to chemically clean the surface.

The babbitt used is high in tin whose composition is close to SAE-11 and SAE-12. Specifically it is:

Tin	89.0 %
Antimony	7.5 %
Copper	3.5 %

Bearing Clearance

Normal bearing clearance will usually be from .001” to .002” for each inch of shaft journal diameter. Drawing tolerances permit a plus .002” to .003” variation. The primary function of bearing clearance is to provide a wedge-shaped space at each side of the journal as it rests on the bearing. As the shaft rotates, it pulls oil into the wedge. From the wedge, oil is pulled into the loaded area where it builds up a film pressure sufficient to carry the shaft. The amount of load the film can carry is dependent, among other things, on the area of the pressure film.

Journal and Bearing Finish

All important in the operation of a sleeve bearing is the surface finish of the journal and bearing. A surface that is not smooth will permit the oil to fill these pockets and an insufficient oil film will form. The shaft journal should be polished with crocus cloth. The bearing babbitt would have a finish of 32 micro-inches.

The shaft journal should be near perfectly round as an out of round shaft may cause vibration and pounding out of the babbitt.

Alignment and Coupling of Flexibly Coupled Sleeve Bearing Motors

Since sleeve bearings are capable of carrying only momentary thrust, it is essential that they be protected from all continuous thrust. All sources of damaging thrust are external to the motor. If the driven unit can develop thrust, it must have its own thrust bearing. Other possible sources of external thrust are:

Shaft not level.
Misalignment of flexible couplings of the free floating type.

It is recognized that shafts must be level, but the problem of coupling alignment is not so readily controlled. Good coupling alignment ordinarily eliminates coupling thrust on small motors. On larger motors, however, and particularly those operating at high speed, even the best practical alignment of the free floating type of coupling does not assure freedom from thrust developed within the coupling.

Motor End Play and Limited End Float of Couplings

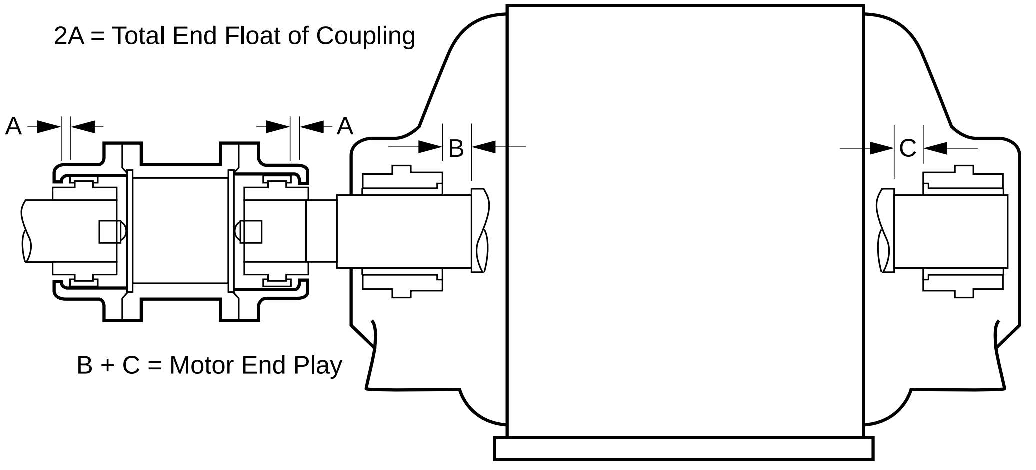
The limited end float coupling successfully prevents thrust from being transmitted to the bearings of the motor because the maximum end float inherent to the coupling is less than the total end play of the motor. Any thrust developed, which tends to separate the two halves of the coupling, is restrained by lips located at the ends of the coupling cover (Figure 6.4.23). Thrust tending to bring the coupling halves closer together is restrained by buttons located in the ends of the respective shafts.

Setting of End Play

Figure 6.4.23, in conjunction with end play, shows the method to follow to make the proper setting of a motor in relation to the driven shaft. The arrangement is shown with a gear type coupling, but applies also for pin and bushing or spring grid type couplings. The coupling is shown in the closed position. Normal coupling operation may be fully closed, fully spread, or at some intermediate position.

Dimensions in the table are for nominal values of motor end play. (Refer to National Electrical Manufacturers Association Catalog for Motors and Generators MG1-14.38 for ratings and end floats.) Motor end play has a tolerance and may vary from nominal value. Nameplate on motor gives data on actual end play when limited end float of coupling is required. Any variation of actual end play from nominal should be divided evenly between compensations to be made in B and C.

Sleeve Bearings



COUPLING AND BEARING SETTINGS(Dimensions In Inches)				
Minimum Motor End Play	**Limited Coupling End Float**	**A**	**B**	**C**
1/2	3/16	3/32	5/16	11/32

Figure 6.4.23 - Method of proper motor setting in relation to driven shaft.

Self Centering Couplings with Semi-Restricted End Play

The following types of couplings may be used without modification where limited end float couplings are specified:

The laminated metal disc type.
The rubber tire type (if designed for the speed).

These types of couplings are considered to be free from development of thrust and are approved for applications to motors of any rating and end play. No spacers, buttons, etc., are required to limit coupling float. When these couplings are used, the motor must be located relative to the driven unit so that the motor shaft is in the center of its end float. (Referring to motor in Figure 6.4.23, B will equal C.)

Unrestricted or Free Floating Couplings

Without modification, the following types of couplings have unlimited end play and are classed as free floating:

The pin and bushing type.
The spring grid type.
The gear type.

Limited end float models or versions of these couplings are available from several coupling manufacturers. Some means of limiting end float are discussed below.

Pin and Bushing Type – The end float of this type of coupling may be limited through the use of two special pins located at diametrically opposite positions. A spacer washer is mounted on each of these enlarged head pins. The details depend upon the particular coupling design.

Spring Grid Type – End float can be limited with spacer plates or buttons located between shaft ends, in conjunction with half-oval soft steel or copper inserts placed in the loops of the spring. These inserts are to be symmetrically located so as not to cause unbalance.

Gear Type – Spacer plates or buttons located between shaft ends may limit end float of this type of coupling. Hollow, spacer type couplings require plates at each end of the spacer.

General – The above methods are preferred for limitation of end float in free floating types of couplings. Spacer plates, spacer washers or buttons may be omitted at user's discretion.

The end float of free floating type couplings can then be limited by pressing one or both coupling hubs farther back on the shaft. Objections to this method are sometimes raised because the shaft ends may touch or because of the uncertainty of getting the hub back exactly at the same position, should it be temporarily removed.

Sleeve Bearings

Mechanical Center Adjustment

In order to adjust the mechanical center of bearings to the magnetic center of the rotor, shims are used in the bearing housing on either side of the flanged portion of the bearing. To determine how near the magnetic center is with respect to the mechanical center, mark the shaft while the motor is running. Stop the motor and rotate the shaft by hand, marking the shaft when it is pushed and pulled in each direction.

The shims are set at the factory and generally need not be rearranged, even when a new bearing is installed. Shims are not used in AZ(Z) motors and 680 and 800 frame motors. The rotor core is mounted precisely on the shaft so that the two centers line up.

Lubrication (Oil)

A high grade oil with an oxidation and rust inhibitor should be used. It should have a viscosity index NOT lower than 90. The higher the viscosity index the better the oil film at higher temperatures. The viscosity of the oil needed depends upon the unit pressure on the bearing, the rpm, the ambient and operating temperatures. The operator has no control of the above factors, but should record the oil temperatures periodically and note any great change in temperature. The following viscosities should be used.

ISO Grade	SUS at 100°F	Speed (rpm)
32	150	3600
68	300	1800 and slower

If the oil temperature exceeds 175°F on 1800 and 3600 rpm motors or 150°F on 1200 rpm and slower motors, use the next higher viscosity oil. Generally, the bearing temperature will run approximately 8°F higher than the oil temperature.

Cleanliness

The maintenance and care of electric motors includes cleanliness, particularly in the area of the bearings. The oil cavity must be kept clean and it is generally painted with a white sealer to prevent any sand from getting into the oil. When a bearing is disassembled for any reason, the cavity should be flushed out and cleaned and a cover put over it to keep out dust and dirt. Small dirt particles have imbedded themselves in the soft babbitt with no effects on the operation, however, it has been seen where one particle caught in the journal has plowed itself into the babbitt and caused a failure.

It is important that the oil be changed as required to keep it clean and that the oil cavity be flushed out before adding new oil.

Sleeve Bearing Motors

Flood Lube Requirements and Heat Rejection Rates

3600 RPM - Lube Oil 140 - 160 SUS @ 100˚F (ISO VG 32)		
Frame Size/Type	**Flood Lube G.P.M./Bearing (optional/required)**	**Heat Rejection Rate (BTU/minute/BRG**
500 TEFC	.15 GPM (optional)	19.1
500 WPI and WPII	.15 GPM (optional)	19.1
580 TEFC	.30 GPM (optional)	31.3
580 WPI and WPII	.15 GPM (optional)	31.3
500 All	.15 GPM (optional)	26.7
580 All	.15 GPM (optional)	33.9
708, 788	.50 GPM (optional)	29.7
30	.25 GPM (optional)	39.0
680	.20 GPM (optional)	43.7
800	1.25 GPM (req'd.)	105.0
1120	Consult Factory	Consult Factory

1800 RPM and Slower - Lube Oil 290 - 350 SUS @ 100˚F (ISO VG 68)		
Frame Size/Type	**Flood Lube G.P.M./Bearing (optional/required)**	**Heat Rejection Rate (BTU/minute/BRG**
500	.15 GPM (optional)	14.2
580 TEFC	.30 GPM (optional)	23.2
580 WPI and WPII	.15 GPM (optional)	23.2
708, 788	.30 GPM (optional)	26.3
880	.30 GPM (optional except 4-pole)	36.0
30	.25 GPM (optional)	30.3
680	.50 GPM (optional)	32.0
800	1.00 GPM (req'd.)	81.1
1120	1.0 GPM (optional except 4-pole)	105.0

Notes:

1: Flood lube oil pressure must be specified at the time of order.

2. Ambients of 50 degrees C or higher will require flood lubrication.

Sleeve Bearings

Oil Levels

Oil sight gauges are provided for each sleeve bearing for inspection of the oil level. Oil should be filled initially with the motor at a standstill and any rise or fall in the oil level should be noted. It is good practice to mark the running oil level. Too high an oil level can cause leakage and will slow the oil rings down, which may result in a hot bearing. Too low an oil level will cause the bearing to run hot and may result in failure. Inspection gauges are mounted near the top of the bearing cartridge for observing proper oil ring rotation.

Constant level oilers may be used to automatically maintain the required oil level in large motors.

These oilers are connected by pipe through the bottom or side wall of the lubrication reservoir. It is of extreme importance that the connecting pipes be installed level (See Figures 6.4.24 and 6.4.25).

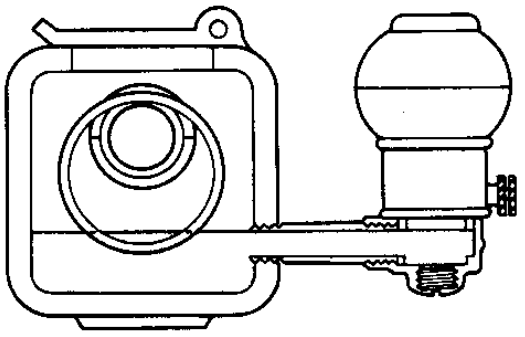


Figure 6.4.24 - Oiler and connecting pipe level.

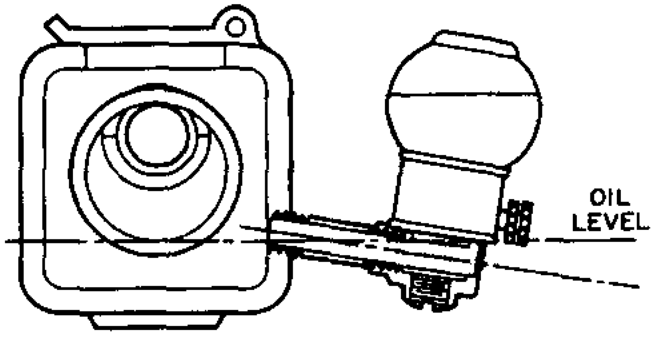


Figure 6.4.25 - Oiler and connecting pipe not level.

NOTE:

If the connecting pipe or stem is on an angle the oil will not flow from the oiler.

When oiler is properly installed and leveled, remove bottle reservoir and fill with correct lubricant. DO NOT ADD OIL THROUGH BOTTOM HOUSING OF OILER. Replace bottle and allow oil to flow into reservoir. When filling initially, it may be necessary to fill bottle several times before the level within the reservoir is equal to the level for which the oiler is adjusted.

Sleeve Bearings

Adjusting Oil Levels

A threaded level adjusting arm (A) (Figure 6.4.26) is provided to raise or lower oil level in bottom housing. When proper level is achieved the level adjusting arm is locked in place by arm (B). Once proper level is obtained further adjustments are not necessary.

Breather tubes are required where fans, blowers, pulleys, etc., suck oil out of bearings. If the pulleys or fans are enclosed in a housing, breather tube must be installed OUTSIDE of housing (See Figure 6.4.27).

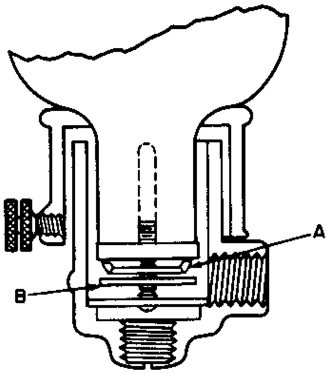


Figure 6.4.26 - Adjustment of the oil level.

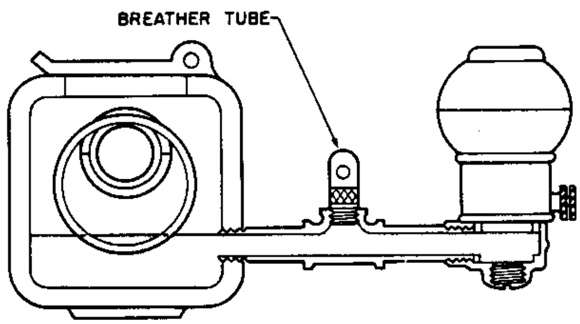


Figure 6.4.27 - Location of the breather tube.

Oil Rings

The oil ring is the most simple and reliable means for delivering oil to a bearing. The rings should, nevertheless, be checked from time to time to make sure they are functioning properly. Inspection ports are provided for this purpose. If a ring does not turn freely:

(1) It may be out of round from mishandling. Rings should be round within 1/16”.
(2) It may be fouling on a projection or rough spot on the casting.
(3) It may be unbalanced. The heavy side will tend to remain down.
(4) Rings are trapezoidal in cross section to reduce adhesion to the guide slot through the oil film. However, there may be enough adhesion to slow ring action.
(5) Oil may be too cold or too viscous, or the ring may be dripping too deeply in the oil reservoir.
(6) Ring will tend to bind if shaft is not level.
(7) Rings are likely to stop turning at low shaft speeds and generally will not turn freely at less than 25 rpm.

Pressure Feed Lubrication

Pressure lubricated or flood lubricated sleeve bearings are provided in motors where they will be used in high ambient temperatures or where customer specifications require them. We have supplied units where the oil pump is directly coupled to the motor shaft. Others have a separate close-coupled pump motor. Others use the oil supply from the driven equipment. In all cases oil rings are supplied with the bearings to provide insurance in case of an oil pump failure. The oil level will be maintained at its proper level in the bearing housing.

With pressure lubrication, it is important to control the amount of oil entering the bearing. Pressure should be controlled to 3 to 5 psi. If a high pressure is used, 12 to 15 psi, it will be necessary to put an orifice in the line or a pressure reducer. At 12 to 15 psi, a 1/16” diameter orifice 1” long will be sufficient. Too much oil entering the bearing will cause end leakage from the bearing and oil leakage to the outside of the motor.

Oil Leakage

It would not suffice to discuss sleeve bearings unless the problems encountered with them were also mentioned, particularly in the area of oil leakage. High speed motors are more susceptible to oil leakage and therefore are more critical with respect to oil guard clearances, bearing cavity pressures, sealants, etc.

The following are reasons for which oil leakage might occur:

A. Parts not sealed properly

Sealant (RTV or equal) shall be applied to the mating surfaces of parts, where oil is present, to prevent the seepage of oil. Even though joints seem to match perfectly, there are always minute clearances through which oil may leak.

Apply sealant to any joint or mating surface which may come in contact with oil even though there is a tight or press fit between them. Such surfaces include the following:

(1) Oil guards on sleeve bearing motors.
(2) Housing bores for lip or face type seals.
(3) Split sleeve bearing housings or capsules.
(4) Piping, oil sight gauges, drain pipes, etc.

INSTALLATION

(1) Surfaces shall be clean of dirt, grease, and old sealant. Use a solvent if necessary.
(2) The mating surfaces should be flat with no nicks raised above the surface. There should be no gap when mating surfaces are together.
(3) Apply a thin coat to both surfaces (about the thickness of a business card). Do not apply too much as excess will be squeezed out and get into labyrinth seals, bearing, oil cavities, etc.
(4) Assemble parts.

Sleeve Bearings

B. Bearing Clearance Too Large

Too large a bearing clearance or clogged oil return holes in the bearing will permit excessive oil to seep out the ends of the bearing. This seepage, combined with the rotation of the shaft, will create an oil mist inside the bearing cavity which will tend to leak through the oil guards. Excessive pressure in a forced feed lubrication system can also cause oil mist to build up as previously discussed.

C. Oil Guard

The primary purposes of the oil guards are three-fold.

(1) To prevent the entrance of dirt into the bearing cavity.
(2) To retain the oil in the bearing cavity.
(3) To provide a pressure drop from outside to inside the bearing cavity.

To achieve these purposes it is necessary that a specific radial clearance of oil guard to shaft be held. The cooling fans of the motor tend to create a suction or a pressure in the bearing cavity, which, if large enough, will push or draw oil out along the shaft. The close fitting oil guards give a pressure drop across it and minimize the differential pressure. Older motors use felt or cork as a means of sealing in the oil. Newer motors use labyrinth seals in the oil guard. These labyrinths may either be a straight bore as used in the enclosed tube type motors or V grooves.

The following is a tabulation of the diametrical clearances on standard oil guards.

		Oil Guard Clearance(Diametrical)	
Frame	**Motor Type**	**Inside**	**Outside**
500	G	.010-.015	.010-.015
500	CG & CGZ	.010-.014	.010-.014
580	RG	.010-.015	.010-.015
30	G	.020-.026	.020-.026
30	AZ	.037-.040	037-.040
30	AZZ	.027-.030	022-.025

The clearances on the explosion proof motors must be strictly within tolerances and never be exceeded. Clearances on others may be slightly larger and not hinder their performance.

Besides using close clearances to correct differential pressures, some oil guards are pressurized with air from the discharge side of the motor fans, others are vented to the atmosphere. It is important that the piping and venting for these oil guards be kept clean.

Sleeve Bearings

TEFC tube-cooled motors are critical with respect to the amount of pressure or suction existing in the bearing cavity. The maximum allowable is plus (+) or minus (-) 1/8” H_20 pressure. This is measured with a water manometer at the oil fill pipe. For a correction of a high or low reading it is important that all the tubes are rolled in right, that the partings and joints around the bearing cavity and oil guards are permatexed and that the conduit box is properly sealed. Condensation drains and breathers must be plugged. Any auxiliary equipment extending into the motor must be sealed to prevent a transfer of air from inside to outside the motor. If the reading is 1/8” H_20 with the motor running and without the external fan, everything is properly sealed. If a suction greater than 1/8” exists when the external fan is mounted, a cut must be taken on the auxiliary blades. These blades are either bolted to the inside of the external fan or cast integrally into the hub of the external fan. If a pressure greater than 1/8” exists, the auxiliary blades must be lengthened.

Lubrication

Lubrication-General

One of the most frequent questions asked is how to translate lubrication requirements defined in our instruction books or nameplates into specifications that will match products that are available from lubricant suppliers. No one lubricant is satisfactory for all uses. Speed, load, temperature, vibration, and bearing configuration will affect the type of lubricant that is used. It is the intent of this section to give a list of suppliers of oils and greases for use in various bearing types and applications. In addition, some of the basic terminology used in lubricants is defined.

Terminology

Penetration - is a measure of the grease consistency (hardness or stiffness). Grades (NLGI) 2 and 3 are the most common used in electric motors with the grade 3 being the stiffer. Stiffer greases are used where they must stay in place without slumping, such as in large vertical motors.

Rust Inhibitor - is a polar additive which adheres to metallic surfaces to provide protection against moisture.

Oxidation Inhibitor- is an additive which helps resist chemical changes in the oil or grease caused by aging or high temperatures.

Extreme Pressure (EP) - resistance is a property of grease that permits bearings to take very heavy loads and shocks. A high viscosity oil is usually used in this type of grease.

Viscosity - is the resistance of an oil to flow at a given temperature. The most common measure in the United States is Saybolt Universal Seconds (SUS). The proper viscosity is necessary to provide sufficient film between rotating parts.

Non-Foaming Oil - is one in which an additive has been used to reduce the surface tension of the oil, thus preventing foaming.

Turbine Oil - is a high quality, inhibited oil specially refined to give long life.

Grease

At Norwood our standard is a No. 2 grease (Chevron SRI #2). It is a premium type grease with a polyurea base, which gives longer life at higher temperatures. This grease is suitable for Class B and F insulated motors. This grease is used for standard ball bearing motors, as well as motors having roller bearings suitable for belt drives.

Lubrication

Bearings- Grease Capacity (oz.)

Frame	Opposite Shaft End Bearing	Shaft End Bearing	
		Short Shaft	Long Shaft
Medallion 500 IG-CG-CGZ	13	13	22
3600 RPM- 580 CG-CGZ	13	13	–
1800/Slower RPM - 580 CG-CGZ	22	22	24
1800/Slower RPM - 30 AZZ	20.5	20.5	28
1800/Slower RPM - 680 CG	32	32	–

Horizontal motors typically use open type bearings. The grease capacity given represents the initial grease fill which is 2/3 of the volume available on both sides of the bearing.

One ounce of grease has an average volume of 2 cu. in.

Lubrication

Grease

Group I – NLGI #2 Multipurpose

Manufacturer	Manufacturer's Trade-Name
American Oil Co.	Amolith #2
Ashland Oil Co.	Val-lith #2
Chevron Oil Co.	Dura-Lite #2
Cities Service	Trojan Grease H-2
Fiske Bros. Refining Co.	Multi-lube "A"
Keystone	Keystone #81 Light
Mobil Oil Corp.	Mobilux 2
Non Fluid Oil Corp.	G-60
Pennzoil	Multipurpose Lube 705
Phillips Petroleum Co.	Philube IB & RB
Shell Oil Co.	Alvania #2
	Dolium R
	Darina #2
Standard Oil Co. of Ohio	Factran #2
Sun Oil Co.	Prestige 42
Texaco Inc.	Regal AFB #2

Group II – NLGI #3 Multipurpose

Cities Service	Citgo Premium Lithum #3
Exxon	Unirex N3
Fiske Bros. Refining Co.	Lubriplate 630-A
Mobil Oil Corp.	Mobilux 3
Standard Oil Co. of Ohio	Factran #3

NOTE: Mixing of different base greases is not recommended.

Lubrication

Grease
Group III – Extreme Pressure

Manufacturer	Manufacturer's Trade-Name	Extreme Pressure (EP) Additive NGLI #2 Grease
American Oil Co.	Rykon	#2 EP
Continental Oil Co.	Conoco	EP Conolith #2
	Conoco	Super-STA
Gulf	Gulfcrown	EP #2
Mobil	Mobilux	EP #2
Non Fluid Oil Corp.		G-60/EPV
Chevron	Industrial Grease	Dura Lith EP
Cities Service Oil Co.	Citgo	SEP-2
Exxon	Lidox	EP 2
Fiske Bros. Refining Co.	Lubriplate	1200-2
Pennwalt	Keystone	S1 EP
Pennzoil	Multi-purpose Lubricant	#705
Shell	Alvania	EP 2
	Darina	EP 2
Standard Oil Co.	Bearing Gard	#2
Texaco	Multifak	EP 2
Union	Unoba EP	2

NOTE: Mixing of different base greases is not recommended.

Lubrication

Grease

Lubrication Anti-Friction Bearings
Prior to shipment, motor bearings are lubricated with the proper amount and grade of grease to provide satisfactory service under normal operating conditions. It is good practice, however, to visually check bearing grease of newly installed motors for proper lubrication after a few months operation.

All anti-friction bearing motors designed for unusual service conditions requiring special lubrication will have affixed a plate with lubricating instructions. The instructions on such a plate take precedence over this manual and should be followed to achieve optimum bearing life and to avoid consequential damage to rotating parts.

NOTE: A common mistake is over-lubrication of bearings which can result in hotter running bearings. When grease is added without removing the drain plug, the excess grease must go somewhere and usually it is forced into and through the inner bearing cap and is then thrown into the windings. Proper lubrication is desired, but some under lubrication is less dangerous than over-lubrication.

Mixing greases of different bases can soften greases, resulting in poor lubrication. Removal of all old grease is recommended before using a grease of a different base.

Operating temperature range should be from -15°F to +250°F for Class B insulation, and to +300°F for Class F and H. Most leading oil companies have special bearing greases that are satisfactory. For specific recommendations, consult the motor lubrication plate drawing or the factory.

Grease – Anti-Friction Bearing Relubrication

The frequency of relubricating bearings depends on three factors – speed, type of bearing, and service. As a guide the following is recommended.

	Motor Speed	Relubrication Frequency*
Direct Connected	3600 or 3000	4 months or 2000 Operating Hours
	1800 or less	6 months or 3000 Operating Hours
Belted	1800	3 months or 1500 Operating Hours
	1200	3 months or 1500 Operating Hours
	900 or less	6 months or 3000 Operating Hours

*Which ever comes first. Operating environment or application may dictate more frequent lubrication.

Lubrication

The frequency of relubrication in the table is based on bearings normally used. If the motor has special bearings, consult the motor outline, the motor lubrication plate, or the factory for possible special requirements.

Relubricate horizontal shaft motors as follows:

1. Stop the motor and lock out the switch.
2. Thoroughly clean and remove grease inlet plug and drain pipe from the outer bearing caps, or housing.
3. Add grease to inlet with hand gun until small amount of new grease is forced out of drain. Catch used grease in suitable container.
4. Remove excess grease from ports and replace inlet plug only.
5. Run at least one hour to expel any excess grease from drain opening.
6. Clean old grease from drain pipe. Replace cleaned drain pipe and drain plug.
7. Put the unit back in operation.

Anti-Friction Bearings - Pure Oil Mist

As outlined earlier our standard lubrication for anti-friction bearings is grease. As an option we can also offer a oil mist lubrication for anti-friction bearings. Please note we provide provisions only for the customer, it is the end users responsibility to provide the oil mist lubrication system including: oil mist generator, air filter, manifold, orifice fittings, and pressure regulator. To provide this option we provide a specially treated stator, specially sealed bearing housings, and stub piping for the customer to pipe up to. Please refer to factory for inlet and outlet pipe sizes (typically 1/4" NPT inlet and 3/8" NPT outlet. NOTE: Not available on 449 frame.

Bearing Size	Moderate Service - CFM	Heavy Service - CFM
313	.064	.128
315	.074	.148
316	.079	.158
318	.088	.177
319	.094	.187
320	.098	.197
222	.108	.216
226	.128	.256

Lubrication

Oils

Viscosity grade numbers for industrial high grade turbine oils are being changed to the International Standards Organization (ISO) viscosity classification system (ISO 3448). The American Society of Testing Materials (ASTM) has adopted the ISO system.

The ISO grade system is based on kinematic viscosity (centistokes) at 40 degrees C (104 degrees F). It is abbreviated cSt. The former ASTM system was based on Saybolt Universal Seconds (SUS) at 100 degrees F (37.8 degrees C).

The following list shows five of the 18 ISO grades of oil that are commonly used for electric motor bearings. The list compares the new designations with the old.

ISO Viscosity Grade Number	ISO Viscosity Range cSt at 40 degrees C	Viscosity (SUS) at 100 degrees F
32	28.8 – 35.2	140-160
46	41.4 – 50.6	200-225
68	61.2 – 74.8	300-350
100	90 – 110	450-500
150	135 – 165	700-800

Sleeve Bearing Motors:

Viscosity (SUS at 100 degrees F)	ISO Grade	Speed (RPM)
140-160	32	3600
300-350	68	1800 & slower

Angular Contact Thrust Ball Bearings:

Viscosity (SUS at 100 degrees F)	ISO Grade	Speed (RPM)
140-160	32	3600
300-350	68	1800 & slower

Spherical Roller Thrust Bearings:

All 1800 RPM motors (above NEMA sizes) have water cooled bearings. Most 1200 RPM and slower motors have self cooled bearings.

Viscosity (SUS at 100 degrees F)	ISO Grade	Speed (RPM)
700-800	150	1800 & slower

Lubrication

Kingsbury Thrust Bearing:

This plate type bearing is water cooled for all speeds. Its thrust capacity is dependent upon speed and oil viscosity. The capacity may be increased by as much as 30% over its nominal value by increasing the oil viscosity, however, increasing the oil viscosity generates more heat which may require more cooling.

Viscosity (SUS at 100 degrees F)	ISO Grade	Speed (RPM)
300-350	68	All speeds Normal Thrust
450-500	100	All speeds Extra Thrust

Oils

Group I

Lubrication Oils for Ball, Roller and Sleeve Bearing Motors

Manufacturer	Manufacturer's Trade-Name	Manufacturer's Grade or Type Designation Viscosity (ISO) 32	46	68	100	150
American Oil Co.	American Industrial Oils	#15	#21	#31	#51	#75
Chevron	Chevron EP Machine	#32	#46	#68	#100	#150
Citgo	Pacemaker	#15	#20	#30	#60	#80
Continental Oil Co.	Dectol	#15	#21	#33	#51	#76
	GP Dectol	#15	#33	#51	#76	
	Turbine Oil	#15	#21	#33	#51	#76
Exxon	Teresstic	#43	#47	#52	#56	#65
	Nuto	#43	#47	#53	#63	#76
Fiske Bros. Refining Co.	Lubriplate HO	#0	#1	#2	#2A	#3
	Lubriplate	#2	#3V	#3		
Gulf	Harmony	#44	#47	#53	#61	#69
Mobil	D.T.E.	Light	Med.	Hvy./ Med.	Hvy.	Extra/ Hvy.
Non Fluid Oil Corp.		A-88AF	A-89AF	A-90AF	A-59AF	A-60
Pennwalt	Keystone	#6	#5	#4A	#4	#3
Pennzoil	Hydraulic and General Purpose	H-150	H-215	H-315	H-465	H-700
Phillips	Magnus	#150	#215	#315	#465	#700
Shell	Tellus T	#32	#46	#68	#100	#150
Standard Oil Co.	Industron	#44	#48	#53		#66
Sun Oil Co.	Sunvis	#916	#921	#931	#951	#961/ #975
Texaco	Regal	#800	#815	#1505/	#1513/ #1512	#1568 #1509
	Ranbo	A	B	C	E	F
Union Turbine Oil		#150	#215	#315	#465	#700

Lubrication

Oils – Sleeve Bearings

Motors with sleeve bearings are shipped without oil. A rust-inhibiting film is applied at the factory to protect bearing and journal surfaces during shipment. Before attempting to operate any sleeve bearing motor, the following steps must be performed.

1. Visually inspect the bearing condition. Oil ring inspection ports and drain opening in the housing are normally provided for this purpose.
2. Check for any accumulation of moisture. If oxidation is discovered, all traces of it must be removed before machine is put in service.
3. Flush all oil piping. Fill bearing reservoirs to normal level.

NOTE: If oil temperature exceeds 175°F on 3600 and 1800 RPM motors, or 150°F on 1200 RPM and slower motors-use the next higher viscosity oil. The oil viscosity at operating temperature is very important in selecting proper oil, and may vary in different climates. If operating temperature is not known, consult factory for suggested oil selection.

4. Oil reservoirs should be filled to mark indicated on gauge or center of gauge.

CAUTION: Improper lubrication can cause equipment damage. Refer to lubrication instructions on motor or in this manual.

5. Rotate shaft several turns by hand to distribute oil over bearing parts. Make sure oil rings rotate freely.

It is important to maintain the correct oil level, as lack of lubrication is often the cause of bearing failure.

Inspect oil level and oil ring operation frequently. Oil ring operation can be observed through the sight glass mounted at the top of the bearing capsule. Oil rings should be perfectly round, free of burrs or rough edges, turn at constant speed and carry a noticeable amount of oil to the top of the journal. Failure of the oil ring to turn freely may be caused by:

1. Ring out of round (should be round to .062 inch).
2. Fouling on a projection of the bearing bushing.
3. Ring not balanced (heavy side will tend to remain down).
4. Adhesion to guide slot (trapezoidal section reduces adhesion).
5. Oil too cold or viscous, or oil level too high.
6. Shaft not level oil ring tends to bind.

At the first sign of oil discoloration or contamination, replace with new oil. Rapid discoloration is caused by bearing wear, often from vibration or thrust. Change oil as required to keep clean.

Lubrication

Sleeve Bearing - Oil Mist Purge

In certain especially harsh applications, it is advantageous to ensure that certain airborne contaminants do not have the ability to enter the bearing housing of sleeve bearing machines. To prevent this problem we offer an oil mist purge system. This system when applied to sleeve bearing oil ring lubricated bearings, provides a positive pressure above the oil level in the housing both during operation and at shut down.

A sleeve bearing motor requires the following modifications to convert to oil mist purge:

1. The bearing housing must be fitted with a vent to allow the positive air/oil pressure in the housing to escape outside the motor.
2. A constant level oiler assembly (TRICO) must be used on each bearing and fitted with an overflow provision to ensure condensed oil does not increase the oil level inside the bearing housing. If the motor has provisions for flood lubrication, the Trico Oilers are not required as any excess oil will drain out the oil outlet piping.
3. The area between the motor and the terminal box must be sealed to prevent any oil mist from getting into the terminal box.

The external oil mist system is supplied by the customer; Siemens will supply the provisions only.

V-Belt Applications

General

Motors to be used on V-belt drive applications normally have different shaft length and diameter than direct drive motors and have either spherical or cylindrical roller bearings on the drive end. Cylindrical roller bearings are the first choice because of longer intervals between bearing grease applications.

Sheave Size Limits

The sheave diameter shown in the table below is the minimum size that should be used for the rating and speed as shown. With proper belt tightening and with proper lubrication, these recommended minimum sizes should result in a two year minimum L10 life.

Sheave Location

The outline will specify the location of the sheave. Typically this location will be in the center of the full keyway. Th absence of an outline, the maximum distance from the sheave groove centerline to the shaft extension shoulder should be 5.5".

Minimum Sheave Diameters

	MOTOR RPM			
HP	**1800**	**1200**	**900**	**720**
150	11.0	12.5	14.0	15.0
200	12.0	14.0	15.5	16.5
250	13.0	15.0	16.5	18.0
300	14.0	16.0	17.5	Not Available
350	14.5	16.5	18.5	Not Available
400	15.0	*	Not Available	Not Available
450	**	18.0	Not Available	Not Available
500	16.5	Not Available	Not Available	Not Available
600	17.5	Not Available	Not Available	Not Available
700	18.5	Not Available	Not Available	Not Available

$D_{min} = 25 \sqrt[3]{HP/RPM}$

* - 18.0" for CG and IG motors, 17.5" for all others
** - 16.5" for CG motors, 16.0" for all others

Paint Process Standard – Norwood Plant

An epoxy coating system is the standard finish on motors at the Norwood Plant. The present color is Fjord Blue. A high quality primer is applied to all castings at the foundry and except for machined surfaces, this remains on the finished motor. All fabricated parts(both purchased or manufactured in-house) are primed with a high quality primer which is compatible with the finish coat.

The resistance of the epoxy finish coat to acids and alkalies is generally better than that of the air-dried alkyd paints. Epoxy finishes have proven themselves as long lasting paints in a wide range of adverse environments. Industry in general accepts epoxies for severe environments.

Naturally, the stainless steel nameplate and instruction plates are not painted. The shaft extension is also unpainted but does receive a coating of a rust preventative to protect the shaft until time to place the motor in service.

Prime Coat

Iron castings are blast cleaned at the foundry and primed with a high quality primer compatible with the finish paint. If repriming is required at the Norwood Plant, they receive a 1-2 mil coat of a compatible primer. Steel fabrications and miscellaneous parts also receive a 1-2 mil coat of a compatible primer.

Stator Assemblies

Stator assemblies with laminations stacked in the yoke receive a coating of epoxy (polyester on low voltage, random wound motors) on most surfaces during the stator treatment cycle. These coatings offer excellent corrosion protection and are compatible with most finish coats of paint. It is recommended that this coating not be removed during any subsequent processing. It is difficult to obtain as good a protection coat by other means.

Oil Reservoirs

Internal surfaces that come in contact with the lubricating oil such as oil well cavities of bearing brackets and cartridges are treated with a special polyurethane sealer.

Rotors

All rotors receive a coat of a special 2 part epoxy paint to prevent rust. The epoxy is applied after the rotor is turned to size and all surfaces including the rotor laminations, the end heads, fans and exposed portions of shafts are painted. Even the shaft and the support arms under the rotor core on slow speed machines receive this protective treatment.

Paint Process Standard – Norwood Plant

Finish Coat

The standard finish coat for all motors manufactured at the Norwood Plant is a 1-2 mil thick coating of epoxy paint. All machines are painted Fjord Blue (Munsell 7.5B3/2). Other colors can be supplied in an enamel finish. All exposed, unpainted metal parts, except nameplates, are coated with a rust preventative.

Special Paint Process

Special surface preparations, primers and finish coatings require additional time and effort and result in higher manufacturing costs. Many primers and finish coatings widely used in the past have been identified as being dangerous to apply and are no longer applied at the Norwood Plant. Availability of such finishes depends on success in locating a properly equipped subcontractor for the treatment process. Consult factory for price and availability. When special finish coats can be applied directly over the standard primers, a substantial cost savings can be realized.

Some special primers can only be applied after removal of the protective epoxy resin and varnish coating by an expensive blast cleaning process. As mentioned above, we strongly discourage the removal of this coating and recommend instead, the use of a prime coating compatible with the epoxy. Open type motors cannot be sandblasted because of the high risk of stator winding or lead wire damage, therefore, any special primer requiring bare metal before primer application is not available on finished open machines.

Metal dust primers (such as "Galvacote") are not compatible with insulation materials and cannot be used on frames with stack-in yoke construction or be used on open motors due to the necessity for blast cleaning. Other special treatments or materials to be used on parts or on the total machine must be individually evaluated before we can agree to supply them. This is especially true of stator yoke (frame) treatments where some materials may prevent proper curing of the stator resins and may even contaminate the entire supply of resin.

Motor Rotation

The following units are unidirectional:

Frame	Type(s)	Speeds
449	CGZ	3600
500	All	3600
580	All	3600
30	All	All
680	CG & CGII	3600
	RAZ (L)	All
800	RG (L), FOD (L)	3600

All verticals with non-reverse features are unidirectional.

Sound Pressure Levels

Typical Sound Pressure Levels
Sound Pressure Levels in Free Field at 1 Meter
"A" Scale (dBa)

	Standard Noise Level					Low Noise Level			
	3600	1800	1200	900		3600	1800	1200	900
Frame	**ODP / WPI Enclosure**								
500 Type IG	91	90	85	85		85	85	-	-
500 Type CG	91	87	85	81		85	-	-	-
580	85	83	85	83		81	83	77	77
680	95	90	86	86		90	86	84	84
800	96	95	92	85		90	87	87	83
	WPII Enclosure								
500	88	81	83	80		80	-	-	-
580	85	81	83	82		83	-	-	-
680	88	87	85	85		85	80	84	83
800	95	90	90	86		88	83	85	83
	TEFC / XP Enclosure								
449	86	83	73	75		78	-	-	-
500 RGZZ	86	84	79	78		-	-	-	-
500	86	84	79	78		82	-	-	-
580	87	86	78	74		84	84	-	-
30	91	86	83	83		85	83	-	80
708	-	82	81	76		-	-	-	-
788	-	87	83	78		-	-	-	-
880	-	89	84	79		-	-	-	-
680	95	90	87	86		88	86	83	83

In some instances to achieve the lower noise level may require a change in motor configuration and/or frame size.
These values are only meant as a guide. Consult factory with specific requirements.
Lower noise levels may be possible in some ratings. For lower noise levels or for guaranteed noise levels refer specific requirements to factory for review.

Low Tmeperature Motors

Mechanical Modifications for Low Temperature Motors

Temp.	Grease In Brg. & Hsg.	Anti-Friction Bearings	Shaft	Yoke and Brg. Housing	Rules
80°F					
60°F					
40°F	Standard		Standard		
20°F		Standard Materials		Standard Cast Iron or Carbon Steel	
0					
-20°F					
-40°F	Mobil SHC 100	Standard Materials with Special Grease (If Double Shielded)			
-60°F			Normalized C-1045 Steel		
-65°F					Below Minus (-) 65°F. Each case to be considered separately; a check is to be made of bearing and shaft load speeds, shock or vibration, etc.
80°F	Silicone Grease (Limited in Speed and Load Capability)	Special Materials and Special Grease (If Required)	Austenitic (Non-Magnetic) Stainless		
90°F					

Vibration

1. Causes of Vibration

Some possible sources of vibration excitation in electric motors are:

Unbalance in the rotor system

Eccentric rotor

Uneven air gap

Open rotor bar (broken bar, poor braze joint, or casting void)

Bearing oil-film instabilities (whirl or whip)

Internal rubs (oil guard rubs)

Misalignment at bearing or at coupling

Looseness in rotor or bearing supports

Anti-friction bearing disymmetries

Thermal bow of shaft, rotor assembly

Frame or foundation distortion

Operation at or near resonance or critical speed without sufficient damping.

2. Vibration Measurement

Vibration is commonly measured at the following locations:

Bearing Housing - Vibration is measured on the bearing housing in the Vertical, Horizontal, and Axial directions on both ends of the motor.

Shaft - Shaft radial vibration is usually taken only on sleeve bearing motors and may be taken by the following methods:

Stick

Where there are no special measurement provisions made, vibration is measured with a shaft stick or rider on or adjacent to the drive end shaft extension. Readings are also taken on the opposite end if a shaft extension or shoulder is available. Readings are commonly taken in the vertical and horizontal directions. This gives absolute shaft vibration.

Vibration

Proximeter Probes

Where proximeter probes are specified or available, vibration is measured on each end of the motor, usually at two locations, 90 degrees apart, at + or – 45 degrees from the vertical upward direction. These readings give relative vibration between the shaft and housing.

Units of Measurements

Housing and shaft stick measurements may be in either of the following units:

Displacement Amplitude - Mils (.001 in.) peak to peak double amplitude.

Velocity - Inches per second peak velocity.

Proximeter probe readings are in Displacement, peak to peak.

3. Vibration Limits

Vibration requirements for motors may be specified in accordance with various customer standards or per industry standards such as NEMA (ANSI) or API Standard 541 . NEMA standards specify only housing vibration limits while API Standard 541 specifies both housing and shaft limits. Where NEMA standards are specified, or where no specific vibration limits are required, motors are built to our Norwood in-house limits. These are basically one-half of the NEMA housing limits, but also include filtered bearing housing limits as well as shaft limits.

Norwood Limits for Horizontal Motors

Vibration Limits. Mils p-p. Cold

Synchronous RPM	Housing Unfiltered	Housing Filtered	Shaft Stick Unfiltered	Shaft Stick Filtered
3000-3600	.50	.50	2.5	2.0
1500-2999				
Med. Motors	.75	.75	3.0	2.5
Lg. Motors	1.00	1.00	3.0	2.5
1499 and below	1.00	1.00	3.00	2.5

NEMA Limits

Listed below are vibration limits given in NEMA standards for medium and large motors:

Housing Vibration Limits. Mils p-p. Cold

Synchronous RPM	Medium Motors MG 1-12.06	Large Motors MG 1-20.53
3000-4000, incl	1.0	1.0
1500-2999, incl	1.5	2.0
1000-1499, incl	2.0	2.5
999 and below	2.5	3.0

Vibration

Notes:
1) Limits are for uncoupled operation in factory test.
2) Large motor ratings are defined in Part 20. For 3600 and 1800 rpm, motors with a continuous rating of 500 HP and above are defined as large motors.

API Limits

Vibration limits for motors are also given in API Standard 541, second edition, Nov. 1987. These are given in chart form with charts for vibration measured on the shaft of sleeve bearing machines and on the bearing housings for sleeve and ball bearing machines. Separate housing vibration charts for sleeve bearing machines are given for general purpose and special purpose motors. Listed below are the shaft vibration limits for all two pole motors and the housing vibration limits for special purpose two pole motors, taken from Figures 2 and 5 respectively.

API Limits for Two Pole Motors

	Vibration Limits. Mils p-p		
	Bearing Housing	**Shaft Prox. Probe**	**Shaft Stick**
Unfiltered	0.50	2.00	2.00
1xRPM	0.40	1.50	1.50
2xRPM	0.30	1.00	1.00
Runout (1)	-	0.50	-

Notes:
1) Runout is total electrical and mechanical runout as measured by proximeter probe at slow roll.
2) Axial vibration limits on bearing housings are 0.8 times the radial limits.
3) Given limits are for cold or hot conditions.
4) Includes runout.

4. Practices Employed to Achieve Low Vibration

Some of the features and practices employed to achieve very low vibration in two pole motors are given below:

Precision design and manufacture of rotor parts for size and concentricity.

Interference fits between shaft and rotor core and fans which remain light at speed and temperature.

High precision balance at running speed.

Very low shaft runout.

Proximeter probe sensing areas and journals are ground simultaneously to a concentricity within .0002 inch or less.

Probe sensing surfaces are burnished and demagnetized and shaft materials are high grade alloy steels to reduce electrical runouts.

Precision machined rotor assemblies. Two pole rotor cores typically are ground with runouts of .001 inch or less.

High quality cast aluminum rotors without voids.

Copper rotor bars shimmed tight and designed to prevent breakage.

Induction brazed copper rotor bar-to-end ring joints.

Machines built and checked for uniform air gap.

Rugged frame and bearing housing structures.

Self aligning bearings of superior design.

Precision machining for good alignment of parts and low distortion.

Multi-circuit windings to reduce unbalanced magnetic pull.

Reduced machine ratings for very low vibration.

Machine critical speeds or resonances removed from operating speed and/or highly damped.

Thorough, state of the art, vibration testing, cold and hot.

5. Critical Speeds and Damped Rotor Resonances

The term "critical speed" was devised in the late 1800's in connection with factory overhead pulley shafting. Some investigators at that time incorrectly thought it to be an unstable condition, since at certain speeds shafts were observed to develop very large vibrations. Presently, we have the general understanding that the "critical speed" of a shaft is that speed in RPM which is equal to the frequency of the shaft lateral natural vibration in cycles per minute. It is also known as the rotor shaft system resonance speed.

Since the advent of high speed computers, a whole technology of Rotor Dynamics Analysis has been developed. We now have programs at Norwood which allow the complete rotor dynamic system to be taken into account including the rotor structure and mass, bearing properties for oil film or anti-friction bearings, and bearing support stiffness and mass. These programs are capable of calculating a synchronous response curve which approximates the vibration amplitude vs. speed curve of an actual motor coastdown. Undamped critical speed plots and system stability calculations can also be made.

These present day analyses, particularly with cylindrical, partial arc sleeve bearings, show that not only the system resonance speed (critical speed) is important, but also the system amplification factor which is determined primarily by bearing damping. Bearing damping is generally high with sleeve bearings. In many cases this damping approaches the level of "critical damping" which prevents oscillations under free harmonic vibration. It has been found that motors with high damping (with a low system amplification factor) will operate very well with stable vibration even when resonance speed corresponds to operating speed. This effect of damping on rotating system performance has been recognized and included in the requirements for "Critical Speed" given in API Standard 617, Fifth Edition for Centrifugal Compressors. An excerpt from this standard is given below:

2.9 Dynamics
2.9.1 Critical Speeds
2.9.1.1 When the frequency of a periodic forcing phenomenon (exciting frequency) applied to a rotor-bearing support system corresponds to a natural frequency of that system, the system may be in a state of resonance.

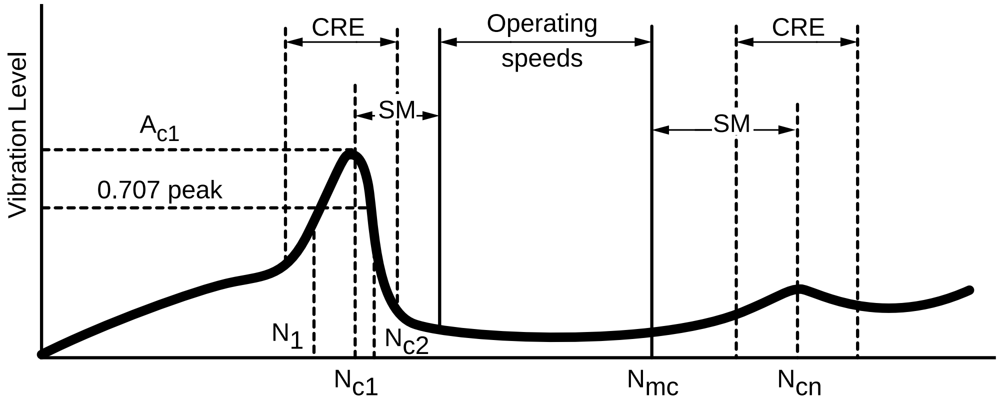
2.9.1.2 A rotor-bearing support system in resonance will have its normal vibration displacement amplified.

The magnitude of amplification and the rate of phase-angle change are related to the amount of damping in the system and the mode shape taken by the rotor.

Note: The mode shapes are commonly referred to as the first rigid (translatory or bouncing) mode, the second rigid (conical or rocking) mode, and the (first, second, third, . . ., *n*th) bending mode.

2.9.1.3 When the rotor amplification factor (see Figure 8), as measured at the vibration probe, is greater than or equal to 2.5, that frequency is called critical and the corresponding shaft rotational frequency is called a critical speed. For the purposes of this standard, a critically damped system is one in which the amplification factor is less than 2.5.

Vibration



N_{c1} = Rotor first critical, center frequency, cycles per minute.
N_{cn} = Critical speed, *n*th
N_{mc} = Maximum continuous speed, 105 percent.
N_1 = Initial (lesser) speed at 0.707 x peak amplitude (critical).
N_2 = Final (greater) speed at 0.707 x peak amplitude (critical).
$N_2 - N_1$ = Peak width at the half-power point.
AF = Amplification factor

$$= \frac{N_{c1}}{N_2 - N_1}$$

SM = Separation margin.
CRE = Critical response envelope.
A_{c1} = Amplitude at N_{c1*}
A_{cn} = Amplitude at N_{cn*}

Note: The shape of the curve is for illustration only and does not necessarily represent any actual rotor responce plot.

Figure 8 - Rotor Response Plot

2.9.1.4 Critical speeds shall be determined analytically by means of a damped unbalanced rotor response analysis and shall be confirmed by test-stand data.

2.9.1.5 An exciting frequency may be less than, equal to, or greater than the rotational speed of the rotor. Potential exciting frequencies considered in system design shall include but are not limited to the following sources:

a. Unbalance in the rotor system.
b. Oil-film instabilities (whirl).
c. Internal nubs.
d. Blade, vane, nozzle, and diffuser passing frequencies.
e. Gear-tooth meshing and side bands.
f. Coupling misalignment.

g. Loose rotor-system components.
h. Hysteretic and friction whirl.
i. Boundary-layerflow separation.
j. Acoustic and aerodynamic cross-coupling forces.
k. Asynchronous whirl.

2.9.1.6 Resonances of support systems within the vendor's scope of supply shall not occur within the specified operating speed range or the specified separation margins, unless the resonances are critically damped.

2.9.1.7 The vendor who is specified to have unit responsibility shall determine that the drive-train critical speeds (rotor lateral, system torsional, blading modes, and the like) are compatible with the critical speeds of the machinery being supplied and that the combination is suitable for the specific operating speed range.

The location of the critical speed of a particular machine in relation to its operating speed is largely determined by the machine speed, size and bearing type. For a given line of machines and rating, the parameters directly under the control of the rotor system designer are limited.

For the Norwood range of machines, essentially all machines with four or more poles (1800 rpm and below) have their critical speeds above operating speed. Two pole machines, however, may have the critical speed either above or below the operating speed of 3000 rpm or 3600 rpm (for 50 Hz or 60 Hz power, respectively).

Separation margins between operating speed and critical or resonance speeds are sometimes specified by customers. According to API 541 Part 11 for special purpose motors resonant response peaks of the motor shall be at least 15% removed from operating speed.

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NOTE: A specific device manufacturer should not be specified unless it is absolutely the only one that is acceptable for that application. The complete specification of the needed device without supplier identification is the preferred specification arrangement. Supplier identification with the statement "or equivalent" is the next preferred arrangement. The insistence on a specific supplier of a device can result in time delays since the item must be special ordered for that specific motor. The devices supplied by different manufacturers are quite often not interchangeable and the motor may have to be redesigned to match the specified device. This can result in time delays and additional costs.

CURRENT TRANSFORMERS

Current transformers are used with metering, relaying, and control equipment which cannot normally accommodate the relatively high line currents and voltages associated with large electric motors. Current transformers are used to provide currents of reduced value which are proportional to the currents to be measured.

Standard current transformers used are usually of the ring type or window construction. This type of current transformer consists of a ring shaped steel core wound with copper wire. The motor lead, which is the primary winding of a two winding transformer, passes through the center window of the current transformer. A current in this primary winding induces a current in the secondary winding. One or more current transformers are used to monitor line currents in one or more phases.

Current transformers are used in various ground fault differential protection arrangements. The two most common arrangements are the self-balancing method and the zone method.

a. Self-Balancing Differential Protection
In the self-balancing method, three current transformers are used, one for each phase. The motor windings may be either Wye or Delta connected and both ends of each phase winding are brought out of the motor and passed through one of the current transformers. Then the appropriate winding connection is made within the main terminal box. Under normal conditions, the currents in both leads are equal but flowing in the opposite direction at any particular instant (opposite polarity). Since the voltages induced in the current transformer winding by the lead currents are equal and vectorially opposed, the resulting induced voltage is zero and zero current flows in the secondary current transformer winding. Should a ground fault occur on the motor side of the current transformer, a flow of current from motor winding to ground will occur and the currents in both phase winding leads will no longer be equal. A resultant voltage will be induced in the current transformer winding and a current will flow to activate the protective equipment. Current transformers used in the self-balancing differential protection arrangement usually have a 50:5 transformation ratio.

b. Zone Differential Protection

Current transformers may also be used in the zone differential protection arrangement. In this arrangement, only the normally internal ends of the phase windings are passed through the current transformers mounted at the motor. The line currents are monitored by a second set of identical current transformers located elsewhere, usually at a panel board. In this arrangement, the full winding currents at both locations are compared. This arrangement will provide ground fault protection not only for the motor winding, but also for the main lead cable on the motor side of the panel board. Since the full value of the winding current is being measured, their arrangement may require current transformers with transformation ratios of up to 800:5 or higher. It should be noted that current transformers used in zone differential protection arrangements must be short circuited during motor start up since they would otherwise be measuring full locked rotor currents.

Current transformers may be provided by either Siemens or the user and must be mounted in a special main conduit box. The line leads must be longer than standard and, if the current transformers are to be used in a differential protection arrangement, the normally internal end of each phase winding must be brought out of the motor to the conduit box. The leads of the current transformer windings are brought out of the main conduit box to a terminal block in a special auxiliary terminal box mounted on the side of the main conduit box.

The self-balancing differential protection arrangement is the standard arrangement. If the zone arrangement or any other system is desired, details of such arrangements, including current transformer ratio and accuracy, should be forwarded to factory for evaluation and pricing.

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FILTERS

On the fundamental open motor, cooling ambient air enters into direct contact with the machine windings and can carry small-size dust particles into the machine interior. Electrically conducting particles can be a hazard to winding insulation. Also, compacting of air-borne dirt into the machine ventilating passages will impair ventilation and increase winding temperature. The entry of dirt particles can be minimized by equipping machine intake air passages with filters. This removes contaminating particles from the cooling air before entering the machine.

The standard filter is a permanent, dry, washable, high velocity, panel-type impingement filter. The filter divides incoming air into small turbulent streams, and causes foreign particles to collect on the wire mesh. As the dirt builds up from the entering side of the filters, air flow is diverted to the cleaner mesh where the filtering action continues. To guard against reduced air flow through dirty or clogged filters, differential pressure switches and/or thermal protection is optionally available. These devices are discussed elsewhere in this section.

The standard filter consists of a galvanized steel screen medium. Stainless steel or aluminum media are also available options. Other filter media may also be obtained but specific requirements must be referred to factory for pricing.

Filters are typically used on WPII enclosure. For ODP or WPI enclosures please forward specific requirements to factory for review.

ZERO-SPEED AND PLUGGING SWITCHES

The Allen-Bradley Bulletin 808 Speed Switch is available for horizontal, anti-friction bearing motors. It is used to provide plugging or anti-plugging of squirrel cage motors in conjunction with automatic starters arranged for reversing or plugging duty. It may also be used as a speed switch or “zero-speed” switch. The 808 switch is an electromagnetic device which employs the use of a disc shaped permanent magnet mounted on the switch shaft which rotates inside of a copper cup. Although the cup is free to turn, movement is restricted by an opposing spring force. An operating arm is mounted on the face of the cup to actuate either of two contacts located on each side of the arm. When the switch shaft rotates, a torque is developed in almost direction proportion to shaft speed which tends to cause the cup to move in the direction of shaft rotation. As the shaft speed increases from standstill, this rotational torque increases. When the torque is sufficient to overcome the opposing spring force, the actuating arm activates one of the contacts, depending upon the direction of rotation. Only one set of contacts is provided for each direction of rotation. In plugging operations, the forward or reverse contact is closed depending upon the direction of rotation at any point above the point at which the contact is set to operate. As the shaft speed is reduced, the torque holding the contact closed is also reduced until a point is reached at which the contact returns to the normally open position.

The speed at which the contacts will operate is easily adjusted by means of two external adjustment screws, one for each set of contacts. After the switch has reached its normal operating temperature, the screw is turned to adjust the point at which the contacts are to operate.

The 808 speed switch is available in three contact operating speed ranges, 15-60 RPM, 50-200 RPM and 150-900 RPM. The maximum shaft operating speeds are 1200 RPM for contacts operating in the 15-60 RPM range and 1800 RPM for the 50-200 RPM and 150-900 RPM ranges.

The switch is mounted on a base attached to the non-drive end bearing housing of the motor and the switch shaft is normally direct coupled, using a flexible coupling, to a stub shaft which extends from the non-drive end of the motor shaft. For maximum accuracy, the switch should be driven at the highest available speed within its maximum operating range. The coupling arrangement between the switch and motor must be positive to avoid slippage.

In plugging applications, the switch automatically interrupts reverse braking power as the motor approaches zero speed. The speed at which the switch contacts operate is easily adjusted so as to avoid coasting or reverse rotation. Contacts are normally open and arranged for plugging in one or both directions. In anti-plugging applications, the switch is used to apply reverse power when a selected safe speed is reached. In an anti-plugging application, the contacts are normally closed and arranged for anti-plugging in either direction.

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As a speed sensing switch, the switch may be used to sequence conveyors where it is essential for one conveyor to be running at nearly full speed before a second conveyor is started. It should be noted that although the switch has two sets of contacts, only one set is usable for each direction of rotation.

In some applications, an accidental turn of the shaft may close the switch contacts and start the motor. To guard against this possibility, the switch may be furnished with a lockout solenoid which mechanically prevents the contacts from operating unless the lockout coil is energized. This feature is special and must be specified. The 808 switch is furnished in NEMA 4,7 or 9 enclosures.

If the switch is directly coupled, as recommended, to the accessible non-drive end of the motor shaft, no more than one switch can be installed on a motor. If not directly coupled but connected through gears and a chain or timing belt, more than one switch may then be installed on a motor. The use of the speed switch is limited to horizontal, anti-friction bearing motors. The switch cannot be used with sleeve bearing motors because of the thrust involved if direct connected and end-float produced alignment problems if belt or chain connected.

PRESSURE DIFFERENTIAL DEVICES

a. Pressure Differential Switch

For machines equipped with air filters, the use of a pressure differential device is recommended to provide a warning of reduced air flow caused by dirty or clogged filters. When the differential pressure across the filter reaches a recommended limiting maximum value, filter replacement or cleaning is indicated. The differential pressure switch consists of two pressure chambers separated by a sensitive diaphragm. One pressure chamber is connected to the atmosphere and the other to the exhaust side of the filters. When a change occurs in the differential pressure between the two sides of the diaphragm, the spring loaded diaphragm moves, transmitting a force to a snap-action switch. The switch is designed to actuate upon an increasing differential pressure. The diaphragm motion is resisted by a calibrated spring. The spring determines the range of differential pressure within which the diaphragm motion will actuate an electric switch. The actuation point is set by adjusting the compression or tension of the spring. In this particular application, the differential pressure is the difference between atmospheric pressure and a negative air pressure within the machine enclosure. The switch is used to indicate a pressure differential across the filter and is connected to activate an alarm or control circuit provided by the customer. Pressure differential switches are recommended when the permanent installation of a pressure differential device is required. The standard switch is the Dwyer Model No. 1950 explosion-proof device.

b. Manometer

The displacement of a liquid (oil, water, etc.) in a manometer tube may also be used to measure pressure difference across a filter. The most simple form of manometer utilizes the familiar transparent "U" shaped tube. When the ends of the liquid column in the "U" tube are exposed to unequal pressures, the difference in pressure is related to the difference between the heights of the fluid column in the two legs of the tube. The manometer is a measuring instrument and not an alarm device, as is the pressure differential switch.

Pressure differential switches are normally used for this application when the permanent installation of a pressure differential device is required.

Manometers are not recommended for this purpose because of their relative fragility and difficulty in reading.

Siemens will normally provide an explosion-proof pressure differential switch for this application.

Accessories

SCREENS AND LOUVERS

Screens can be provided on open drip-proof machines to meet the NEMA "guarded" definition and are furnished as standard on all WPI and WPII enclosures. On WPI and WPII enclosures, 800 frame and larger, motors are supplied with enameled steel louvers.

Standard screen material is stainless steel with opening size 1.25 in. X 1.5 in. or .75 in. X .4375 in. Motors built to API541 specification are provided with screens having an opening size of .75 in. X .75 in.

SURGE PROTECTION

Surge protection is recommended for machines exposed to high voltage surges caused by switching, line faults, or lightning. A high voltage surge may be thought of as a steeply rising voltage wave traveling along the incoming line circuit. Lightning arresters are used to protect the ground wall insulation by reducing the magnitude of the voltage surge. Surge capacitors are used to protect the turn-to-turn insulation by reducing the slope of the wave front.

A complete surge protection unit consists of three station type valve arresters and, normally, a three phase surge capacitor all mounted in a special, fabricated steel, conduit/terminal box. The arrestors and surge capacitor are solidly grounded to the terminal box. All internal components are factory mounted and wired. The terminal box is a separate free-standing box and access is provided through a bolted-on, gasketed and hinged front cover. If no arrestors are required or supplied, then the front cover is not hinged. The conduit entrance is normally made through the bottom of the terminal box. Alternate entry is available but forward specific requirements to factory for review.

Accessories

ELASTIMOLD QUICK DISCONNECTS

Quick disconnect type connectors are used for easier installation and/or removal of a motor. A disconnect consists of two components, a connector and a bushing.

Two types of disconnects, the 320 Series and the 520 Series, are available as follow:
320 Series: For 150 amp - 7.2 KV class system
520 Series: For 600 amp - 15. KV class system

For disconnects on motors with full load currents above 600 amps, refer to factory.

If the customer uses on cable per phase, three disconnects are required; if two cables per phase, six disconnects are required.

For the factory to properly size and purchase Elastimold Quick Disconnects, the following minimum information ***is required***:

A) Cable Size (solid or stranded conductors)
B) Insulation Thickness (normal range 90-220 mils)
C) Type of Cable Shielding:
- (1) Metallic Tape
- (2) Metalic Drain Wires
- (3) Unishield
- (4) Lead
- (5) Nonshielded

D) Number of Feeder Cables Per Phase
E) Service Classification of Motor:
- (1) Power Plant
- (2) Industrial Plant
- (3) Steel
- (4) Pulp and Paper
- (5) Petro-Chemical
- (6) Textile
- (7) Rolling Mill
- (8) Sewage Treatment
- (9) Other

Accessories

SPACE HEATERS

Space heaters are used to maintain internal machine air temperature above the dew point during periods of motor shutdown. In this way, water accumulation caused by moisture condensation inside the machine is prevented. Space heaters are recommended for installations in damp locations and should be activated when the machine is de-energized. Space heater capacity is selected, depending upon the size and type of enclosure, to maintain the temperature within the machine approximately 5°C to 1 0°C above the ambient temperature.

Four basic types of space heaters are currently in use. Type selection depends upon frame size and enclosure as tabulated below:

FrameSize	Open Enclosures	TEFC Enclosures	XP Enclosures
440	-	F (2)	-
500	S (2) — Horizontal F (4) — Vertical	F (4)	S (1)
500 RGZZ	-	-	F (4)
580	S (2) — Horizontal F (4) — Vertical	F (4)	-
30	-	-	CT (2)
680	S (6)	T (4)	-
800	T (4)	T (4)	-
1120	S (6)	-	-

F - flexible, CT - circular and semi-circular tubular, T - straight tubular, S - strip, ( ) - number of heaters per motor.

The flexible space heater consists of a heating element enclosed within a silicone rubber jacket. The heater is normally tied to the ends of the winding and conforms to the shape of the coil end surface. Usually, one or more heaters are installed on each end of the machine winding.

The circular and semi-circular (banana) tubular space heaters consist of an inner heating element and an outer metallic protective enclosure or sheath. Brass, stainless steel or air black heat steel is used as the sheath material. The particular material used depends upon the machine rating and not all of the above sheath materials may be available for a particular rating. These types of space heaters are mounted vertically between the bearing housing and coil end.

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The straight type of tubular space heater consists of an inner heating element enclosed within an outer metallic sheath as in the case of the circular tubular described above. The discussion of sheath materials available for the circular tubular heater also applies to conventional tubular heaters. Conventional tubular heaters are usually "U" shaped and are mounted on an external surface of the enclosure with the heating element passing into the machine. Conventional tubular heaters may be easily removed and replaced without partial disassembly of the machine.

Strip heaters consist of a heating element enclosed within a rectangular bar shaped sheath. These heaters are available in various widths and lengths and are mounted on the interior base of the machine. Strip heaters are furnished with an aluminized steel sheath and other sheath materials are not available.

Space heater arrangements are available for operation with 115, 230 or 460 volts, single phase, power sources. The standard space heater data sheet included in this section indicates the total space heater wattage required for a particular type and size enclosure. Individual space heaters are arranged in series or parallel depending upon the supply voltage to obtain the desired total wattage.

Standard space heater arrangements may result in maximum sheath temperatures of up to 400°C. Special arrangements are available for applications requiring lower than standard sheath temperatures. Standard low sheath temperature arrangements which will limit the sheath temperature to a maximum of 200°C have been established. Lower maximum sheath temperatures are available down to 140°C. Consult factory.

Space heater leads will normally be terminated in the main conduit box of low voltage (600 volts and below) machines. For the Medallion line and higher voltage machines, an auxiliary terminal box will be supplied for the termination of space heater leads. Straight tubular type space heaters are normally furnished with terminal boxes which are integral with the heating element and additional provisions for lead termination are not required. Space heater leads will normally be terminated at a terminal block if an auxiliary terminal box is supplied.

Accessories

Standard Space Heater Data

HORIZONTAL						
FRAME	**OPEN**		**TEFC**		**XP**	
	VOLTS	**WATTS**	**VOLTS**	**WATTS**	**VOLTS**	**WATTS**
440	—	—	115	300	—	—
	—	—	230	300	—	—
	—	—	460	—	—	—
500	115	645	115	480	115	480
	230	645	230	480	230	480
	460	645	460	480	460	480
500 RGZZ	—	—	—	—	115	400
	—	—	—	—	230	400
	—	—	—	—	460	400
580	115	645	115	600	—	—
	230	645	230	600	—	—
	460	—	460	600	—	—
30	—	—	115	655	115	655
	—	—	230	655	230	655
	—	—	460	655	460	655
680	115	800	115	800	—	—
	230	800	230	800	—	—
	460	800	460	800	—	—
800	115	800	115	800	—	—
	230	800	230	800	—	—
	460	800	460	800	—	—
1120	115	1200	—	—	—	—
	230	1200	—	—	—	—
	460	1200	—	—	—	—
708	—	—	115	800	—	—
	—	—	230	800	—	—
	—	—	460	800	—	—
788	—	—	115	900	—	—
	—	—	230	900	—	—
	—	—	460	900	—	—
880	—	—	115	1200	—	—
	—	—	230	1200	—	—
	—	—	460	1200	—	—
VERTICAL						
500	115	480	115	480	—	—
	230	480	230	480	—	—
	460	480	460	480	—	—
500 RGZZV	—	—	—	—	115	400
	—	—	—	—	230	400
	—	—	—	—	460	400
580	115	645	115		—	—
	230	645	230		—	—
	460	645	460		—	—
30 Except WPII	115	600	115	655	115	655
	230	600	230	655	230	655
	460	600	460	655	460	655
30 WPII	115	920	—	—	—	—
	230	1000	—	—	—	—
	460	1000	—	—	—	—

THERMAL PROTECTIVE DEVICES

Thermal sensing devices are used to prevent possible damage to stator windings or bearings due to excessive temperatures. These various devices are classified into two principle categories: monitoring detectors and relays or switches. Monitoring detectors quantitatively measure temperature levels. Relays and switches open or close a circuit upon reaching a predetermined temperature level.

STATOR MONITORING DEVICES

a. Resistance Temperature Detectors (RTD's)
A stator RTD consists of a resistance element of fine wire molded into a thin plastic strip which is placed between coils in the stator slots. Normally, six RTD's, two per phase, are evenly placed around the stator.

The change in resistance of an RTD is proportional to temperature is change. Consequently, these changes in resistance values, when fed into an external instrumentation system, may enable any or all of the following functions to be performed:

1) Activate an alarm signal.
2) Automatic or "demand log" print-out of winding temperature via process computer.
3) Temperature read-out via panel meter or digital display.
4) Automatic shutdown.
5) Continuous trend chart recording.

Stator RTD's respond to temperature throughout the full length of wire element; consequently, they may be considered to measure "average hot spot" temperatures. Stator RTD's are Class H and use AWG 30 leadwire. The leads are brought to a terminal strip-type terminal block in an auxiliary box.

RTD's are available having various resistance vs. temperature characteristics.The following types are available and the particular type required must be specified at time of order;

- 10 OHMS at 25°C – copper
- 100 OHMS at 0°C – platinum (DIN Standard 43760 available on request)
- 120 OHMS at 0°C – nickel

In designing a temperature monitoring system, the possibility of lead wire compensation must be considered. The measuring leg of the monitoring bridge contains not only the resistance of the detector element but also the resistance of both lead wires connecting the detector to the bridge. These leads may be hundreds of feet long to reach a centrally located monitor serving a number of detectors. Adding a third lead wire to the detector can permit automatic compensation for lead wire variations by inserting equal lead wire resistance into both legs of the bridge. For this reason, RTD's are furnished with three leads as standard. Four-lead RTD's are available as an option. Spiral armor protective cabling is also available as an option.

Stator RTD's are available for all ratings manufactured at Norwood; however, the use of RTD's with machines using random wound coils is not recommended. The shifting of individual conductors of a random wound coil during winding may involve sufficient force to damage the RTD element.

b. Thermocouples (STC's)

A thermocouple is a temperature sensing device consisting of two dissimilar metal wires. The wires are welded together at one end to form a measuring "point sensitive" junction which is used to sense the winding temperature. The circuit develops a small DC voltage which is proportional to the temperature difference between the measuring junction and a reference junction. In actual operation, the reference junction is an external monitoring system which converts the voltage developed by the thermocouple to a temperature value. As in the case of stator RTD's, stator thermocouples are embedded between coils in the stator slots. Standard practice is to provide six thermocouples, two per phase, evenly spaced around the stator. Thermocouples are capable of enabling the performance of functions similar to those for stator RTD's.

The following types of thermocouples are available and the particular type required must be specified at time of order;

1) Copper Constantan – ANSI Type T
2) Chromel Constantan – ANSI Type E
3) Chromel Alumel – ANSI Type K
4) Iron Constantan – ANSI Type J

The use of 20 gage thermocouple wire is considered standard. Stator thermocouples are normally furnished as single element, ungrounded. Thermocouple leads are brought to a strip type terminal block in an auxiliary terminal box.

Stator thermocouples are available for all ratings manufactured at Norwood.

RELAYS AND SWITCHES

a. Thermostats

Thermostats use a snap-action, bi-metallic, disc type switch to open or close a circuit upon reaching a pre-selected temperature. When heated, the stresses in the disc cause it to reverse its curvature instantaneously when the bi-metal reaches a predetermined temperature. The action of the disc opens or closes a set of contacts in an energized control circuit. Thermostats are available with contacts for normally open or normally closed operation, but the same device cannot be used for both. Thermostats are precalibrated by the manufacturer and are not adjustable. The discs are hermetically sealed and are placed on the stator coil end turns. The output of a thermostat can either energize an alarm circuit, if normally open, or de-energize the motor contactor, if normally closed, and in series with the contactor. Since thermostats are located on the outer surface of the coil ends, they sense the temperature at that location. Thermostats are not considered suitable protection for stall or other rapidly changing temperature conditions.

Thermostat leads are normally brought to the main conduit box of low voltage (600 volts and below) machines or to an auxiliary terminal box in the case of higher voltage machines.

Thermostats are available for all frame sizes manufactured at Norwood.

Thermostats are standard on all explosion-proof and dust ignition proof motors manufactured at Norwood.

b. Thermistors

The thermistors used are positive temperature coefficient (PTC) sensors. They are embedded in the end turns of the winding. A set of sensors consists of three sensors, one per phase. The resistance of the sensor remains relatively low and constant over a wide temperature band and increases abruptly at a pre-determined temperature or trip point. When this occurs, the sensor acts as a solid state thermal switch and, when connected to a matched solid state electronic switch in an enclosed control module, it de-energizes a pilot relay. The relay, in turn, opens the motors control circuit or the control coil of an external line break contactor to shut down the protected equipment. When the winding temperature returns to a safe value, the module permits manual reset. The standard thermistor is a Texas Instrument type 7BA.

A typical temperature sensing system consists of and three thermistors and the optional control module. Sensor leads are normally brought to the main conduit box of low voltage (600 volts and below) motors or to an auxiliary terminal box for higher voltage motors.

Thermistors are available for all motors in all enclosures

<u>Thermistor Control Module</u>

The optional control module is unattached to the motor for installation at the location desired by the user. It should be noted that sensors are usually matched to a particular control module, consequently, control modules by one manufacturer are not necessarily usable with sensors by another manufacturer. Please forward specific requirements to factory for review.

The standard control module is a Texas Instruments type 50AA and is available in either 120 or 240 volt supply. The 120 volt module will be supplied if not specified otherwise at time of order.

Note: The positive temperature coefficient (PTC) thermistor system is considered fail safe since a broken sensor or sensor lead will result in an infinite resistance and develop a response identical to that of an elevated temperature, de-energizing the pilot relay.

BEARING MONITORING DEVICES

Bearing temperature devices are used mainly in sleeve bearing motors; however, bearing temperature devices may be used with anti-friction bearings in certain applications. Consult factory for applications involving anti-friction bearings.

Bearing temperature devices are not available on the 500 frame, Type IG line or on the 449 frame, Type CGZ line.

NOTE: Depending upon specific requirements, consult factory when more than one type of bearing protective device is required on a motor and/or when provisions for external pressure lubrication is requested or required.

a. Resistance Temperature Detectors (RTD's)

The basic operation and types of bearing RTD's are similar to that of stator RTD's.

The standard bearing RTD is a tip sensitive device consisting of a probe with a hermetically sealed tip inside of which is a resistance element in the form of a coil. The remainder of the assembly consists of a protective stainless steel sheath to which the probe is attached. The RTD leads are brought internally to a terminal block in an auxiliary terminal box.

Also available are spring-loaded RTD’s with or without a weather tight connection head. If the weather tight connection head is supplied, the RTD lead wires may either be field connected at the head to a remotely located monitoring system or brought externally to a terminal block in an auxiliary terminal box mounted on the motor. Consult factory for pricing of this arrangement or forward specific requirements for review.

When insulated bearings are specified, the bearing RTD's are also insulated.

If a particular type, manufacturer, or mechanical configuration (spring-loaded, etc.) of bearing RTD is required, please forward specific requirements to factory for review.

b. Thermocouples (BTC's)

The basic operation and types of bearing thermocouples are similar to that of stator thermocouples.

The standard bearing thermocouple is a tip sensitive device consisting of a probe inside of which is the thermocouple with the junction at the tip. The remainder of the assembly consists of a protective stainless steel sheath to which the probe is attached. It is a four lead, dual element, ungrounded, and non-spring-loaded thermocouple. The thermocouple leads are brought internally to a terminal block in an auxiliary terminal box.

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Also available are spring-loaded thermocouples with or without a weather tight connection head. If the weather tight connection head is supplied, the thermocouple lead wires may either be field connected at the head to a remotely located monitoring system or brought externally to a terminal block in an auxiliary terminal box mounted on the motor. Consult factory for pricing of this arrangement or forward specific requirements for review.

When insulated bearings are specified, the bearing thermocouples are also insulated.

If a particular type, manufacturer, or mechanical configuration (sheath material, spring-loaded, etc.) of bearing thermocouple is required please forward specific requirements to factory for review.

c. Thermometers

Dial type, indicating thermometers are used for direct reading of bearing temperatures. The standard dial thermometer is the Trerice Services Model 8500 without alarm contacts, bi-metallic type with back connection, stainless steel case, operating range of 50˚F to 300˚F. Also available is United Electric Series 802 with alarm contacts, armor sleeves, and operating range of -20˚C to +120˚C.

If a particular type or manufacturer of thermometer is required please forward specific requirements to factory for review.

d. Relays

Bearing temperature relays (thermostats) are used to cause an alarm or trip a circuit to alert or guard against bearing failure. Both non-indicating and indicating types of bearing temperature relays are available.

The standard relay is the United Electric Control Co., Model 105 non-indicating relay. The thermal system of this device consists of a remote bulb, capillary and bellows filled with a temperature sensitive liquid. The bulb is sensitive along its full length and is located to sense the bearing temperature. The liquid, and hence the bellows, expands with heat to actuate a snap-action switch at a pre-set temperature. The relay automatically resets when the temperature drops 10°C. The switch is pre-set at the factory to operate at 96°C +3°C.

Indicating type bearing temperature relays are also available. The principle of operation is similar to that of the non-indicating relay except that the expansion of the bellows is used to actuate a direct reading, dial type, temperature indicator as well as the snap-action switch.

Both non-indicating and indicating relays are normally furnished with one set of contacts. Two contact relays (for alarm and shutdown) are also available. Consult factory for pricing or forward specific requirements for review.

Accessories

VIBRATION DETECTION DEVICES

Vibration Measurement Parameters

As an object vibrates, it moves in one direction and then in the opposite direction. The distance it moves is called displacement. The amplitude of displacement is usually measured in thousands of an inch or mils. Vibration may be considered as a sine wave of displacement vs. time. The period of time required to complete one displacement cycle establishes the frequency or period of vibration and is usually expressed in terms of cycles per minute or cycles per second (hertz).The speed at which the object moves through the displacement cycle is velocity. Velocity is zero at the two extremes of the displacement since the object is in the process of reversing direction. Velocity is greatest in the middle of the displacement cycle. Velocity is expressed in terms of inches per second. Acceleration is the rate at which velocity changes. Acceleration is greatest at the extremes of the displacement cycle and is usually expressed in terms of "g's". A particular mode of vibration may be identified in terms of either peak to peak displacement, peak velocity or peak acceleration. At a known frequency, a mathematical relationship exists between the three parameters and a measurement of any one of the three will permit the determination of the other two. Detection devices are available to measure any of the three parameters.

a. Shaft Sensing Transducers

Amplitude sensing devices for measuring vibration at a shaft are called proximity probes, eddy probes, or non-contact pickups. They are eddy-current devices which measure distance and change in distance. The probe is mounted in close proximity to the shaft with a typical gap of 50 mils between probe tip and shaft surface. The probe radiates a magnetic field which varies in strength as the gap varies. By measuring the field strength, the distance between probe tip and shaft surface can be determined.

The signal produced by the probe is quite small; consequently, probes are used with a small electronic package called a proximitor, oscillator-demodulator, driver or signal sensor. The signal produced by the probe and amplified by the proximitor is then transmitted to remotely located monitoring equipment. The probe and proximitor are connected with a coaxial cable having a definite length and impedance. Any change in length of the cable will affect the calibration of the system. An external DC power source is required to drive the probe and proximotor.

Proximity probes are used to measure either radial or axial displacement. In a typical application for the measurement of radial displacement, two probes are mounted near the bearing at a 90° angle to each other (X-Y configuration) to measure shaft movement in both directions. The portion of the shaft observed by the probe must have a smooth, bearing type finish and there can be no plating material on that portion of the shaft. In an axial or thrust monitoring application, proximity probes are used to measure shaft displacement in an axial direction. One or more probes are mounted in such a position as to sense the location of the surface of the shaft end or a thrust collar if available.

Accessories

A single proximitor probe may be used in a keyphasor application to provide a reference in time and position for data acquired by displacement probes mounted elsewhere. In this application a probe is mounted radially to observe the shaft keyway and provide a voltage pulse occurring once every revolution when the shaft is in a known position.

The standard transducer system consists of Bentley Nevada 3300 series probes with aluminmum probe heads, proximitors with aluminum explosion-proof housings, and cable. Stainless steel probe heads and proximitor housing are available as an option. If other manufacturer's types are required, foward specific requirements to factory for review.

b. Bearing Housing Sensing Transducers - Velocity Pickups
A velocity pickup consists of a fixed case which is surface mounted directly to a pad on the motor. Inside the case, the movement of a spring loaded seismic mass and attached coil of wire through a permanent magnet field produces an induced voltage. The high level signal generated by this motion is directly proportional to the absolute vibratory velocity at the point of attachment. Being self-generating, velocity pickups require no external power source. Their relatively high output and low source impedance allow velocity pickups to provide a signal directly to remotely located monitoring equipment without the need for preamplification equipment. Velocity pickups are seismic devices in that they measure total vibration relative to a fixed point in space.

c. Bearing Housing Sensing Transducers -Accelerometers
An accelerometer consists of a fixed case which is surface mounted directly to a pad on the machine. The case contains a seismic mass in contact with a quartz crystal. The output voltage of the crystal is proportional to the force applied by the mass. In operation, the crystal is subjected to a varying force "F" (result of force equals mass times acceleration) and develops a voltage which is proportional to acceleration and the crystal constant. Usually, the output of accelerometers is quite small and they must be used with preamplifiers or "charge" amplifiers in order to provide a signal suitable for transmission to the monitoring equipment. The charge amplifier may be miniaturized and installed within the accelerometer case or furnished separately for external mounting. Usually accelerometers require an external DC power source. Accelerometers are particularly responsive to higher frequency vibration levels. Accelerometers may be considered seismic devices since they measure total vibration relative to a fixed point in space.

Accessories

d.Vibration Detection Switch

The vibration detection switch is an acceleration sensitive device which is pad mounted directly on the motor. The switch measures the total acceleratory shock perpendicular to the base of the switch at the mounting point.

When the entire assembly is subjected to vibration perpendicular to the base, the peak acceleration times the effective mass of the arm produces an inertial force which, aided by the adjustable spring, tends to pull the arm away from the restraining force of the magnet and actuate the switch. When the peak acceleration exceeds the set-point level as determined by the force of the adjusting spring, the arm moves to close the switch contacts and actuate the device. The switch may be reset by depressing a manual reset button or by energizing an electric reset coil. The switch provided is normally furnished with single pole, double throw, load contacts and reset coil. The set-point of the switch is field adjustable. An external AC power source is required.

The vibration switch provides detection of excessive vibration caused by malfunctions such as faulty bearings or a bent shaft. When excessive vibration is present, the destructive forces are a function of both the amplitude of displacement and frequency. An acceleration device is responsive to both amplitude and frequency, and therefore, provides excellent protection for the machine.
The switch may be used to actuate an alarm or cause a shutdown.

Various other vibration switches are available to provide special features, depending upon customer requirements, such as dual switch contacts providing separate alarm and shutdown set-points, startup trip delays, and solid state switches.

Accessories

OIL SUMP HEATERS

Immersion type, oil sump heaters may be used on motors having oil lubricated bearings to heat the bearing oil in applications where the ambient temperature may fall to 10°C (50°F) or below. Oil sump heaters must be specified by the customer.

Oil sump heaters consist of a resistance element (wires) embedded in a high grade refractory material having excellent heat conducting and electrical insulating characteristics. The heater is normally encased in a seamless steel tube or sheath. Oil sump heaters furnished are of the capsule immersion type and are mounted in a 0.5" NPT or .75" NPT hole on the side of the bearing housing.

Thermostatic control of oil sump heater operation is considered essential and is a standard feature with oil sump heaters. The thermostat is wired in series with the heater element and is used to sense the temperature of the oil. This device assures that the oil sump heater is energized when required to maintain oil temperature at the appropriate level. Sump heater leads and thermostat leads are brought to a special terminal box mounted on the bearing housing. Oil sump heaters are available for all enclosures.

Optional stainless steel sheathing and special thread fittings are available. If specific manufacturers or types are required, forward specific requirements to factory for review.

Accessories

SLIDE RAILS

Slide rails are primarily motor bases that are used in the adjustment of the motor position relative to an external load. Slide rails are an option available for motors that are determined to be suitable for belt drive applications.

The rails are of a fabricated structural steel construction with push-pull adjustment. Individual foot pads provide under-rail clearance, accommodate span mounting, and are often more adaptable to uneven surfaces.

Rails are supplied in sets of two per motor. They are not installed on motor at time of shipment but are shipped separate.

Accessories

SHAFT SEALS

When motors are cycled on and off the resultant heating and cooling effect may draw contaminants from the surrounding area into the motor along the shaft extension. The contaminants would then mix with the bearing lubricant changing its properties and resulting in damage to the bearing or significantly reducing the bearing life. A shaft seal can be utilized to minimize this contamination. A shaft seal is sometimes referred to as a shaft slinger or shaft flinger.

All anti-friction bearing motors are supplied with a rubber, V-ring, external shaft seal on all enclosures except explosion-proof. The RGZZ and AZZ explosion-proof enclosure is supplied with a bronze shaft seal. The CGZZ explosion-proof enclosure does not have or require a shaft seal. The following chart indicates the standard and available options for anti-friction bearing shaft seals. Refer to factory for pricing on optional seals.

Anti-Friction Bearings				
	All Except XP	**XP 500 Frame CGZZ**	**XP 500 Frame RGZZ**	**XP 30 Frame AZZ**
Rubber	Std	N/A	N/A	N/A
Bronze	Optional	N/A	Std	Optional
Aluminum	N/A	N/A	N/A	Std
Cast-Iron	N/A	N/A	N/A	Optional
Inpro	Optional	Optional	Optional	Optional
Clipper	Optional	Optional	Optional	Optional

All sleeve bearing motors are supplied with aluminum, labyrinth-type shaft seals. Bronze shaft seals are available as an option. Refer to factory for pricing.

TACHOMETER

A tachometer is an instrument used to measure or determine the rotational speed of a shaft. Their use on Norwood size motors is primarily for adjustable frequency drive applications. The tachometer is an electromechanical device called a rotary pulse generator and is used as a feedback device for the AC adjustable frequency drive control system.

Tachometers are available on all custom enclosures, 500 frame and larger. The standard for anti-friction bearing motors is the Avtron M285 tachometer with dual output and 1024 pulses per revolution (PPR). Depending upon the motor enclosure and bearing arrangement either a throughput type or a coupled, single shaft tachometer is utilized. Refer to factory for tachometer selection, pricing, and availability.

Other types and manufacturers are available but please forward specific requirements to factory for review.

Standards Index

NEMA Standards

National Electrical Manufacturers Association - NEMA

NEMA Standard Publication MG 1-1993

This standard provide information concerning performance, test, construction and manufacturing of alternating-current and direct current motors and generators within the product scopes outlined in the applicable sections.

MG 1 is divided in the following way:

Section I- Standards Applying to all Machines

- Part 1 - Definitions
- Part 2 - Terminal Markings
- Part 3 - High Potential Tests
- Part 4 - Dimensions, Tolerances, and Mounting
- Part 5 - Degree of Protection
- Part 6 - Methods of Cooling
- Part 7 - Mechanical Vibration
  (See Part 3 of this Application Manual for more details)
- Part 10- Ratings - Small and Medium Machines
  The standards in this part cover AC motors up to and including the ratings built in frames corresponding to the continuous open-type rating given below:

Synchronous Speed	HP
3600	500
1800	500
1200	350
900	250
720	200
600	150
514	125

- Part 11 - Dimensions - AC and DC Motors and Generators
  Same ratings as covered in Part 10.
- Part 12 - Tests and Performances - AC and DC Motors and Generators
  Same ratings as covered in Part 10.
- Part 14 - Application Data - AC and DC Motors and Generators
  Same ratings as Covered in Part 10.
- Part 20 - Large Induction Machines
  The standards in this part cover induction motors built in frames larger than those required for ratings listed in Part 10.

NEMA Standard Publication MG 2-1989 (Reaffirmed 1992)

This a safety standard for construction and a guide for selection, installation and use of electric motors and generators.

The motors manufactured at the Norwood Plant of the Industrial Products Division are designed and manufactured using applicable NEMA Standards as a minimum criteria.

ANSI Standards

American National Standards Institute - ANSI

C50.41 - 1982 Polyphase Induction Motors for Power Generating Stations

The requirements in this standard apply to 60 Hertz polyphase induction motors intended for use in power generation stations, including the following:

1. Frame sizes larger than NEMA 440
2. Squirrel-cage type
3. Single speed or multi-speed
4. Horizontal or vertical construction

Excluded from the scope of this standard are:

1. Additional specific features that may be required for application in nuclear-fueled power generation stations.
2. Additional specific features required in motors for use in locations involving hazardous (classified) locations.
3. Starting motors for reversible synchronous generator/motor units for pumped storage installations.
4. Wound-rotor motors.

This standard is listed for reference only. It is not an active ANSI Standard as of this printing of the Application Manual. Many of the technical requirements of this standard have been included in NEMA MG 1 - 1993 (Revision 2) Section 20.

IEEE Standards

The Institute of Electrical and Electronics Engineers - IEEE

The following IEEE Standards may be used in specifying motors manufactured at the Norwood Plant.

IEEE 112-1991 — Test Procedures for Polyphase Induction Motors and Generators.

This standard covers instructions for the conducting and reporting the more generally applicable and acceptable tests to determine the performance characteristics of polyphase induction motors and generators.

IEEE 85-1973 (Reaffirmed 1986) — Test Procedures for Airborne Sound Measurements on Rotating Electric Machinery.

This test procedure defines approved methods for conducting tests and reporting results to affect the uniform determination of rotating electric machine sound under steady-state conditions with an accuracy of +3dB.

IEEE 323-1983 (Reaffirmed 1990) — Standard for Qualifying Class 1 E Equipment for Nuclear Power Generating Stations.

This document describes the basic requirements for qualifying Class 1 E equipment and interfaces that are to be used in nuclear power generating stations. The requirements presented include the principles, procedures, and methods of qualification. These qualification requirements will confirm the adequacy of the equipment design under normal, abnormal, design basis event, post design basis event, and containment test conditions for the performance of Class 1 E functions.

IEEE 334-1994 — Standard for Type Tests of Continuous Duty Class 1 E Motors for Nuclear Power Generation Stations.

This standard provides direction in demonstrating the adequacy of continuous duty Class 1 E electric motors, both inside and outside the containment of nuclear power generating stations, to perform all of their required Class 1 E functions under all required service conditions.

IEEE Standards

IEEE 344-1987 (Reaffirmed 1993) — Recommended Practices for Seismic Qualification of Class 1 E Equipment for Nuclear Power Generating Stations

These recommended practices provide direction for establishing procedures that will yield data which verify that Class 1 E equipment can meet its performance requirements during and following one SSE (safe shutdown earthquake) proceeded by a number of OBE's (operating basis earthquakes).

IEEE 117-1974 (Reaffirmed 1991) — Test Procedure for Evaluation of Systems of Insulating Materials for Random_Wound AC Electric Machinery.

This test procedure has been prepared to outline useful methods for the evaluation of systems of insulation for random wound stators of rotating electric machines. The purpose of this test procedure is to classify insulation systems in accordance with their temperature limits by test, rather than by chemical composition. The intention is to classify according to the recognized, A, B, F and H categories.

IEEE 275-1992 — Recommended Practice for Thermal Evaluation of Insulation Systems for AC Electric Machinery Employing Form Wound Preinsulated Stator Coils

This test procedure has been prepared to outline useful methods for the evaluation of systems of insulation for form-wound stators of rotating electric machines. The purpose is the same as that stated for IEEE-117 above.

IEEE 43-1974 (Reaffirmed 1991) — Recommended Practices for Testing Insulation Resistance of Rotation Machinery

These recommended practices provide direction for procedures to evaluate integrity of insulation system.

(This is currenting being rewritten by an IEEE Standards Working Group).

IEEE 303-1991 — Recommended Practices for Auxiliary Devices for Motors in Class I, Groups A, B, C and D Division2 Location.

ANSI Standards

Recommended practices for the selection and installation auxiliary devices in Division II location.

IEEE 841-1994	Standard for the Petroleum and Chemical Industry - Severe Duty Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors - up to and including 500 hp.

This standard provides information on performance and construction of medium motors for use in the petrochem industry.

API Standards

American Petroleum Institute (API)

API Standard 541, April 1995,Third Edition

This standard, together with required motor data sheets and job specification covers the requirements for form wound, squirrel cage induction motors 250 hp and larger for use in petroleum industry services.

Siemens complies with this specification with comments.

NEC & UL Standards

National Electrical Code — NEC

NFPA 70-1996 NATIONAL ELECTRICAL CODE (NEC)

The National Electrical Code is published by National Fire Protection Association.

The NEC is the major electrical safety standard in the United States and many of the requirements such as terminal box size, grounding, spacing and the like have been incorporatred into the NEMA standards we use.

Chapter 5 of the NEC covers the requirements for electrical equipment and wiring for all voltages in locations where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings. Articles 500 through 503 are those that contain most of the specific information needed for design and application of motors for these areas. Much of the following information is directly from the NEC.

Classification of Locations

500-5. Class I Locations.

Class I locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitible mixtures. Class I locations shall include those specified in (a) and (b) below.

(a) Class I, Division 1. A Class I, Division 1 location is a location (1) in which ignitible concentrations of flammable gases or vapors can exist under normal operating conditions; or (2) in which ignitible concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown or faulty operation of equipment or processes might release ignitible concentrations of flammable gases or vapors, and might also cause simultaneous failure of electric equipment.

(FPN No. 1): This classification usually includes locations where volatile flammable liquids or liquefied flammable gases are transferred from one container to another; interiors of spray booths and areas in the vicinity of spraying and painting operations where volatile flammable solvents are used; locations containing open tanks or vats of volatile flammable liquids; drying rooms or compartments for the evaporation of flammable solvents; locations containing fat and oil extraction equipment using volatile flammable solvents; portions of cleaning and dyeing plants where flammable liquids are used; gas generator rooms and other portions of gas manufacturing plants where flammable gas may escape; inadequately ventilated pump rooms for flammable gas or for volatile flammable liquids; the interiors of refrigerators and freezers in which volatile flammable materials are stored in open, lightly stoppered, or easily ruptured containers; and all other locations where ignitible concentrations of flammable vapors or gases are likely to occur in the course of normal operations.

(FPN No. 2): In some Division 1 locations, ignitible concentrations of flammable gases or vapors may be present continuously or for long periods of time. Examples include the inside of inadequately vented enclosures containing instruments normally venting flammable gases or vapors to the interior of the enclosure, the inside of vented tanks containing volatile flammable liquids, the area between the inner and outer roof sections of a floating roof tank containing volatile flammable fluids, inadequately ventilated areas within spraying or coating operations using volatile flammable fluids, and the interior of an exhaust duct that is used to vent ignitible concentrations of gases or vapors. Experience has demonstrated the prudence of (a) avoiding the installation of instrumentation or other electric equipment in these particular areas altogether or, (b) where it cannot be avoided because it is essential to the process and other locations are not feasible (see Section 500-2, first FPN), using electric equipment or instrumentation approved for the specific application or consisting of intrinsically safe systems as described in Article 504.

(b) Class I, Division 2. A Class I, Division 2 location is a location (1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or (2) in which ignitible concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operation of the ventilating equipment; or (3) that is adjacent to a Class I, Division 1 location, and to which ignitible concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided.

(FPN No. 1): This classification usually includes locations where volatile flammable liquids or flammable gases or vapors are used but that, in the judgment of the authority having jurisdiction, would become hazardous only in case of an accident or of some unusual operating condition. The quantity of flammable material that might escape in case of accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that merit consideration in determining the classification and extent of each location.

(FPN No. 2): Piping without valves, checks, meters, and similar devices would not ordinarily introduce a hazardous condition even though used for flammable liquids or gases. Locations used for the storage of flammable liquids or of liquefied or compressed gases in sealed containers would not normally be considered hazardous unless also subject to other hazardous conditions.

500-6. Class II Locations.

Class II locations are those that are hazardous because of the presence of combustible dust. Class II locations shall include those specified in (a) and (b) below.

(a) Class II, Division 1. A Class II, Division 1 location is a location (1) in which combustible dust is in the air under normal operating conditions in quantities sufficient to produce explosive or ignitible mixtures; or (2) where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitible mixtures to be produced, and might also provide a source of ignition through simultaneous failure of electric equipment, operation of protection devices, or from other causes; or (3) in which combustible dusts of an electrically conductive nature may be present in hazardous quantities.

(FPN): Combustible dusts that are electrically nonconductive include dusts produced in the handling and processing of grain and grain products, pulverized sugar and cocoa, dried egg and milk powders, pulverized spices, starch and pastes, potato and woodflour, oil meal from beans and seed, dried hay, and other organic materials that may produce combustible dusts when processed or handled. Only Group E dusts are considered to be electrically conductive for classification purposes. Dusts containing magnesium or aluminum are particularly hazardous, and the use of extreme precaution will be necessary to avoid ignition and explosion.

(b) Class II, Division 2. A Class II, Division 2 location is a location where combustible dust is not normally in the air in quantities sufficient to produce explosive or ignitible mixtures, and dust accumulations are normally insufficient to interfere with the normal operation of electrical equipment or other apparatus, but combustible dust may be in suspension in the air as a result of infrequent malfunctioning of handling or processing equipment and where combustible dust accumulations on, in, or in the vicinity of the electrical equipment may be sufficient to interfere with the safe dissipation of heat from electrical equipment or may be ignitible by abnormal operation or failure of electrical equipment.

(FPN No. 1): The quantity of combustible dust that may be present and the adequacy of dust removal systems are factors that merit consideration in determining the classification and may result in an unclassified area.

(FPN No. 2): Where products such as seed are handled in a manner that produces low quantities of dust, the amount of dust deposited may not warrant classification.

500-7. Class III Locations.

Class III locations are those that are hazardous because of the presence of easily ignitible fibers or flyings, but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitible mixtures. Class III locations shall include those specified in (a) and (b) below.

(a) Class III, Division 1. A Class III, Division 1 location is a location in which easily ignitible fibers or materials producing combustible flyings are handled, manufactured, or used.

(FPN No. 1): Such locations usually include some parts of rayon, cotton, and other textile mills; combustible fiber manufacturing and processing plants; cotton gins and cotton-seed mills; flax-processing plants; clothing manufacturing plants; woodworking plants; and establishments and industries involving similar hazardous processes or conditions.

(FPN No. 2): Easily ignitible fibers and flyings include rayon, cotton (including cotton linters and cotton waste), sisal or henequen, istle, jute, hemp, tow, cocoa fiber, oakum, baled waste kapok, Spanish moss, excelsior, and other materials of similar nature.

(b) Class III, Division 2. A Class III, Division 2 location is a location in which easily ignitible fibers are stored or handled.

Exception: In process of manufacture.

(a) Class I Group Classifications. Class I groups shall be as follows:
(1) Group A. Atmospheres containing acetylene.
(2) Group B. Atmospheres containing hydrogen, fuel and combustible process gases containing more than 30 percent hydrogen by volume, or gases or vapors of equivalent hazard such as butadiene, ethylene oxide, propylene oxide, and acrolein

Exception No. 1: Group D equipment shall be permitted to be used for atmospheres containing butadiene if such equipment is isolated in accordance with Section 501-5(a) by sealing all conduit 1/2-in. size or larger.

Exception No. 2: Group C equipment shall be permitted to be used for atmospheres containing ethylene oxide, propylene oxide, and acrolein if such equipment is isolated in accordance with Section 501-5(a) by sealing all conduit 1/2-in. size or larger.

(3) Group C. Atmospheres such as ethyl ether, ethylene, or gases or vapors of equivalent hazard.

(4) Group D. Atmospheres such as acetone, ammonia, benzene, butane, cyclopropane, ethanol, gasoline, hexane, methanol, methane, natural gas, naphtha, propane, or gases or vapors of equivalent hazard.

(FPN): The explosion characteristics of air mixtures of gases or vapors vary with the specific material involved. For Class I locations, Groups A, B, C, and D, the classification involves determinations of maximum explosion pressure and maximum safe clearance between parts of a clamped joint in an enclosure. It is necessary, therefore, that equipment be approved not only for class but also for the specific group of the gas or vapor that will be present.

(FPN): Certain chemical atmospheres may have characteristics that require safeguards beyond those required for any of the above groups. Carbon disulfide is one of these chemicals because of its low ignition temperature [100°C (212°F)] and the small joint clearance permitted to arrest its flame.

(FPN): For classification of areas involving ammonia atmosphere, see Safety Code for Mechanical Refrigeration, ANSI/ASHRAE 15-1992, and Safety Requirements for the Storage and Handling of Anhydrous Ammonia, ANSI/CGA G2.1-1989.

(b) Class II Group Classifications. Class II groups shall be as follows:

(1)x Group E. Atmospheres containing combustible metal dusts, including aluminum, magnesium, and their commercial alloys, or other combustible dusts whose particle size, abrasiveness, and conductivity present similar hazards in the use of electrical equipment.

(FPN): Certain metal dusts may have characteristics that require safeguards beyond those required for atmospheres containing the dusts of aluminum, magnesium, and their commercial alloys. For example, zirconium, thorium, and uranium dusts have extremely low ignition temperatures [as low as 20°C (68°F)] and minimum ignition energies lower than any material classified in any of the Class I or Class II Groups.

(2)x Group F. Atmospheres containing combustible carbonaceous dusts, including carbon black, charcoal, coal, or dusts that have been sensitized by other materials so that they present an explosion hazard.

(3) Group G. Atmospheres containing combustible dusts not included in Group E or F, including flour, grain, wood, plastic, and chemicals.

(FPN): The explosion characteristics of air mixtures of dust vary with the materials involved. For Class II locations, Groups E, F, and G, the classification involves the tightness of the joints of assembly and shaft openings to prevent the entrance of dust in the dust-ignitionproof enclosure, the blanketing effect of layers of dust on the equipment that may cause overheating, and the ignition temperature of the dust. It is necessary, therefore, that equipment be approved not only for the class, but also for the specific group of dust that will be present.

(FPN): Certain dusts may require additional precautions due to chemical phenomena that can result in the generation of ignitible gases. See National Electrical Safety Code, ANSI C2-1993, Section 127A-Coal Handling Areas.

(c) Approval for Class and Properties. Equipment, regardless of the classification of the location in which it is installed, that depends on a single compression seal, diaphragm, or tube to prevent flammable or combustible fluids from entering the equipment, shall be approved for a Class I, Division 2 location.

Exception: Equipment installed in a Class I, Division 1 location shall be suitable for the Division 1 location.

Equipment shall be approved not only for the class of location but also for the explosive, combustible, or ignitible properties of the specific gas, vapor, dust, fiber, or flyings that will be present. In addition, Class I equipment shall not have any exposed surface that operates at a temperature in excess of the ignition temperature of the specific gas or vapor. Class II equipment shall not have an external temperature higher than that specified in Section 500-3(f). Class III equipment shall not exceed the maximum surface temperatures specified in

Equipment that has been approved for a Division 1 location shall be permitted in a Division 2 location of the same class or group.

Where specifically permitted in Articles 501 through 503, general-purpose equipment or equipment in general-purpose enclosures shall be permitted to be installed in Division 2 locations if the equipment does not constitute a source of ignition under normal operating conditions.

Unless otherwise specified, normal operating conditions for motors shall be assumed to be rated full-load steady conditions.

Where flammable gases or combustible dusts are or may be present at the same time, the simultaneous presence of both shall be considered when determining the safe operating temperature of the electrical equipment.

(d) Marking. Approved equipment shall be marked to show the class, group, and operating temperature or temperature range referenced to a 40°C ambient.

The temperature range, if provided, shall be indicated in identification numbers, as shown in Table 500-3(d). \

Exception: As required in Section 505-10(b).

Identification numbers marked on equipment nameplates shall be in accordance with Table 500-3(d).

Exception: As required in Section 505-10(b).

Equipment that is approved for Class I and Class II shall be marked with the maximum safe operating temperature, as determined by simultaneous exposure to the combinations of Class I and Class II conditions.

(e) Class I Temperature. The temperature marking specified in (d) above shall not exceed the ignition temperature of the specific gas or vapor to be encountered.

(f) Class II Temperature. The temperature marking specified in (d) above shall be less than the ignition temperature of the specific dust to be encountered. For organic dusts that may dehydrate or carbonize, the temperature marking shall not exceed the lower of either the ignition temperature or 165°C (329°F). See

Manual for Classification of Gases, Vapors, and Dusts for Electrical Equipment in Hazardous (Classified) Locations, NFPA 497M-1991, for minimum ignition temperatures of specific dusts.

The ignition temperature for which equipment was approved prior to this requirement shall be assumed to be as shown in Table 500-3(f).

Table 500-3(d). Identification Numbers

Maximum Temperature		Identification Number
Degrees C	**Degrees F**	
50	842	T1
300	572	T2
280	536	T2A
260	500	T2B
230	446	T2C
215	419	T2D
200	392	T3
180	356	T3A
165	329	T3B
160	320	T3C
135	275	T4
120	248	T4A
100	212	T5
85	185	T6

(FPN): Since there is no consistent relationship between explosion properties and ignition temperature, the two are independent requirements.

Table 500-3(f)

Equipment (such as Motors or Power Transformers) that May Be Overloaded						
	Equipment that is not subject to overloading		Normal Operation		Abnormal Operation	
Class II Group	Degrees		Degrees		Degrees	
	C	F	C	F	C	F
E	200	392	200	392	200	392
F	200	392	150	302	200	392
G	165	329	120	248	165	329

501-8. Motors and Generators.

(a) Class I, Division 1. In Class I, Division 1 locations, motors, generators, and other rotating electric machinery shall be (1) approved for Class I, Division 1 locations; or (2) of the totally enclosed type supplied with positive-pressure ventilation from a source of clean air with discharge to a safe area, so arranged to prevent energizing of the machine until ventilation has been established and the enclosure has been purged with at least 10 volumes of air, and also arranged to automatically de-energize the equipment when the air supply fails; or (3) of the totally enclosed inert gas-filled type supplied with a suitable reliable source of inert gas for pressuring the enclosure, with devices provided to ensure a positive pressure in the enclosure and arranged to automatically de-energize the equipment when the gas supply fails; or (4) of a type designed to be submerged in a liquid that is flammable only when vaporized and mixed with air, or in a gas or vapor at a pressure greater than atmospheric and that is flammable only when mixed with air; and the machine is so arranged to prevent energizing it until it has been purged with the liquid or gas to exclude air, and also arranged to automatically de-energize the equipment when the supply of liquid or gas or vapor fails or the pressure is reduced to atmospheric.

Totally enclosed motors of Types (2) or (3) shall have no external surface with an operating temperature in degrees Celsius in excess of 80 percent of the ignition temperature of the gas or vapor involved. Appropriate devices shall be provided to detect and automatically de-energize the motor or provide an adequate alarm if there is any increase in temperature of the motor beyond designed limits. Auxiliary equipment shall be of a type approved for the location in which it is installed.

(b) Class I, Division 2. In Class I, Division 2 locations, motors, generators, and other rotating electric machinery in which are employed sliding contacts, centrifugal or other types of switching mechanism (including motor overcurrent, overloading, and overtemperature devices), or integral resistance devices, either while starting or while running, shall be approved for Class I, Division 1 locations, unless such sliding contacts, switching mechanisms, and resistance devices are provided with enclosures approved for Class I, Division 2 locations in accordance with Section 501-3(b). The exposed surface of space heaters used to prevent condensation of moisture during shutdown periods shall not exceed 80 percent of the ignition temperature in degrees Celsius of the gas or vapor involved when operated at rated voltage, and the maximum surface temperature [based upon a 40°C (104°F) ambient] shall be permanently marked on a visible nameplate mounted on the motor. Otherwise, space heaters shall be approved for Class I, Division 2 locations.

In Class I, Division 2 locations, the installation of open or nonexplosionproof enclosed motors, such as squirrel-cage induction motors without brushes, switching mechanisms, or similar arc-producing devices, shall be permitted.

(FPN No. 1): It is important to consider the temperature of internal and external surfaces that may be exposed to the flammable atmosphere.

(FPN No. 2): It is important to consider the risk of ignition due to currents arcing across discontinuities and overheating of parts in multisection enclosures of large motors and generators. Such motors and generators may need equipotential bonding jumpers across joints in the enclosure and from enclosure to ground. Where the presence of ignitible gases or vapors is suspected, clean-air purging may be needed immediately prior to and during start-up periods.

502-8. Motors and Generators.

(a) Class II, Division 1. In Class II, Division 1 locations, motors, generators, and other rotating electrical machinery shall be:

(1) Approved for Class II, Division 1 locations, or
(2) Totally enclosed pipe-ventilated, meeting temperature limitations in Section 502-1.

(b) Class II, Division 2. In Class II, Division 2 locations, motors, generators, and other rotating electrical equipment shall be totally enclosed nonventilated, totally enclosed pipe-ventilated, totally enclosed water-air cooled, totally enclosed fan-cooled or dust-ignitionproof for which maximum full-load external temperature shall be in accordance with Section 500-3(f) for normal operation when operating in free air (not dust blanketed) and shall have no external openings.

503-6. Motors and Generators, Class III, Division 1 and 2.

In Class III, Division 1 and 2 locations, motors, generators, and other rotating machinery shall be totally enclosed nonventilated, totally enclosed pipe-ventilated, or totally enclosed fan-cooled.

Exception: In locations where, in the judgment of the authority having jurisdiction, only moderate accumulations of lint or flyings will be likely to collect on, in, or in the vicinity of a rotating electric machine and where such machine is readily accessible for routine cleaning and maintenance, one of the following shall be permitted:

a. Self-cleaning textile motors of the squirrel-cage types;

b. Standard open-type machines without sliding contacts, centrifugal or other types of switching mechanism, including motor overload devices; or

c. Standard open-type machines having such contacts, switching mechanisms, or resistance devices enclosed within tight housings without ventilating or other openings.

Underwriters' Laboratories

Underwriters' Laboratories Inc. is an organization established to establish, maintain, and operate laboratories for the examination and testing of devices, systems and materials. Motors are supplied to Underwriters' Laboratories for complete testing in contaminated atmospheres. Underwriters' Laboratory does specify some construction details and the motor as submitted must pass the tests to which they are subjected before approval is obtained to apply the Underwriters' label to the specific motor.

UL prepares standards and conducts tests on materials and equipment based on the requirements of the NEC. Our motors have been examined to see it they meet the necessary strength and clearances and have been tested to see if they meet the temperature and explosion withstand requirements. Some of our explosion -proof motors (those for Class I, Groups C or D, Division 1) are based on designs that were explosion tested years ago while others have just recently been subjected to this test. Likewise, our dust-ignition-proof motors (those for Class II, Groups E, F, and G, Division 1) have been proven by being tests in a grain dust chamber and with complete covering with wet dust paste. Motors that have gone through this process successfully are “approved” motors as described in the NEC. In each of the major categories, approved motors are the first choice for use in and area.

Motors are approved for a specific Class and Group. This may for a single Group within a Class Such as Class I Group D or multiple approvals such as Class I, Group C and Group D or even Class I, Groups C and D and Class II, Groups F and G. This latter arrangement is more common in smaller motors than in large ones.

An approved motor will have a label attached that shows the hazardous areas for which it is approved and the maximum surface temperature that can be expected under any operating condition. This even includes overloading, sustained locked rotor conditions and single phase operation.

NEC & UL Standards

The temperature limits listed in UL 674 to be used for approval testing are:

	Full Load or Service Factor	Under All Operating Conditions
Class II, Group E	200 ˚C (392 ˚F)	200 ˚C (392 ˚F)
Class II, Group F	150 ˚C (302 ˚F)	200 ˚C (392 ˚F)
Class II, Group G	120 ˚C (248 ˚F)	165 ˚C (329 ˚F)

Note that these values for motors are the same as in Table 500-3(f) of the NEC. These temperatures are still generally used for approvals, however, in motor applications with the variations in ignition temperatures of dusts within a Group, it is absolutely necessary to select a motor with a surface temperature below that of the material in the area.

Also note that areas concerning gases and vapors are no longer on this list. The variations in gas and vapor ignition temperatures is even wider than that of dusts and selection by specific gas is the way to apply motors.

The above temperatures are still being used for test and approval purposes by UL. However, it should be noted that the NEC itself no longer includes these numbers as absolute limit for a group containing a gas or vapor. The present NEC follows the more recent procedure of setting requiring that the surface temperature of a motor must not exceed 80 % of the ignition temperature of a gas or vapor to which it will be exposed. Class II motors still follow the old rules and application is based on the values in the above table.

Mechanical Construction

Experience and laboratory tests have proved that gas tight enclosures for motors and generators are not practical. The necessary joints and the openings around the shaft cannot be sealed to prevent gas or vapor entering the enclosure. Gas will get through the joints. Every time a motors is stopped and allowed to cool down, just the cooling down of the air inside the motor will tend to pull outside air and all it contains into the motor. After a few of these “breathing” cycles, the atmosphere inside the motor may be ignitable. If

there is an ignition source present, there will be an explosion within the motor. The motor frame is designed to withstand the explosion and the joints between parts are long enough and small enough to cool the hot gases from the explosion so that when they do get to the outside of the motor, they are not hot enough to ignite the explosive gas around the motor.

Causes of Explosions

Few people realize the dangers connected with the handling of these materials. For example, when the air of a room is contaminated by vapors of the following materials between the limits given, a flammable mixture results and if ignited, will explode:

	Flammable Limits	
	Lower	Upper
Gasoline Vapor	1.4 %	6 %
Ethyl Ether Vapor	1.9 %	22 %
Ethylene	3.3 %	25 %
Methyl Chloride	8.1 %	17.2 %
Illuminating Gas	7.0 %	21 %

Electricity, with proper safeguards, can be used in hazardous locations with a greater degree of safety than any other form of power or lighting. Explosions from electrical ignition usually can be charged to:

1. Normal arcs occurring during operation of switches, circuit breakers, etc.
2. Abnormal conditions due to:
   a. Insulation failure
   b. Faulty connections
   c. Over-heating of conductors, or equipment
   d. Static discharges

The sequence of steps in a gas, or dust explosion area:

1. A flammable gas, vapor, mixture, or dust with air is ignited by an arc, spark, hot wire, or over-heated apparatus or equipment.
2. The flame spreads rapidly in all directions.
3. The flame results in heat.
4. The heat expands the gases; and
5. Causes an explosion, rise in pressure, within an enclosure.
6. If the enclosure is large enough or of proper shape, unignited gas ahead of the rapidly spreading flame may be pre-compressed to such an extent that it will detonate with extremely high pressure and high frequency waves of pressure (Pressure Piling).

As arcs cannot be eliminated in the normal functioning of control and switching apparatus and as ignition is possible from the abnormal causes above enumerated, the problem then is to render harmless the explosion resulting from such ignition.

NEC & UL Standards

Underwriters' Laboratories specifies that only a single label (nameplate) can be mounted on an approved machine. This single label (nameplate) may include approval for multiple hazardous areas. Example: One nameplate listing approval for Class 1, Group D, Class II, Groups F & G areas.

Underwriters' Laboratories Inc. Labels cannot be furnished by a manufacturer to anyone for attachment to a product outside of the factory in which it is manufactured and inspected. See Tables 1 through 4 for Siemens UL listed motors.

Accessories

Any accessories for attachment to an explosion-proof or dust ignition proof motor such as drains, brakes, space heaters, etc. may limit the type of Underwriters' Laboratories label applied to this specific motor. The labeling of the motor cannot be of a higher classification than that of the accessories. See Table 5.

Division 2 Applications

The use of non-approved motors in Class I, Division 2 areas has greatly increased in recent years and the low trouble occurrence rate seems to prove the validity of this approach. The NEC permits this procedure as long as there are no sparking contacts or switches and when the temperatures of the motor and any accessory device is below the ignition temperature of the gas that might be in the area. Generally this temperature must be below 80 per cent of the gas ignition temperature.

Motors of all types are used with the trend toward a weather protected or water cooled motor in the larger sizes and TEFC motors in the small and medium sizes.

NEC & UL Standards

Table 6 summarizes what Siemens will offer for applications in the areas as defined in the NEC.

Class of Location	Motor to be Supplied	Comments
Class I Division 1	1. Approved motor (U.L. Listed and labeled)	Specific Class and Group approval required. Group C and D available in most ratings.
	2. Totally-enclosed Pipe-Ventilated (Purged and Pressurized Enclosures NFPA 496	Possible in some ratings, but no standard line exists. Inlet and exhaust from clean area and other special requirements. Each application must receive individual study. Consult factory.
	3. Totally-enclosed inert-gas filled	No standard line available.
Class I Division 2	1. Approved motor (U.L. Listed and labeled)	Need not have label.
	2. Totally-enclosed Pipe-Ventilated	Possible in some ratings, but no standard line exists. Inlet and exhaust from clean area and other special requirements. Each application must receive individual study.
	3. TEFC	Surface temperature must not exceed 80% of the ignition temperature of gas or vapor
	4. Open	The NEC permits the use of open motor in these locations. Surface temperature must not exceed 80% of the ignition temperature of gas or vapor involved. With no specific data available, Siemens will supply open motors with motor and heater surface temperature of 200˚ C. Lower temperatures can be provided when specifically requested.
Class II Division 1	1. Approved motor (U.L. Listed and labeled)	Specific Class and Group approval required. Group E, F, and G available in many ratings.
		Totally enclosed pipe-ventilated motors are permitted by NEC but no standard line exists. Consult the factory.

NEC & UL Standards

Class of Location	Motor to be Supplied	Comments
Class II Division 2	1. Approved motor (U.L. Listed and labeled)	This is what we recommed for all Class II., Division 2 areas and the only type we will furnish for Group F options.
	2. Totally-enclosed Pipe-Ventilated	Possible in some ratings, but no standard line exists. Each application must receive individual study.
		The NEC permits the use of open or TEFC motors if they are acceptable to the authority having jurisdiction at the end use location. Siemens will not knowingly supply open motors for these applications. Siemens cannot claim that the TEFC motor is suitable for use in these locations. The customer must accept totally the responsibility of obtaining such approval.
Class III Division 1 & 2	1. TEFC	
	2. TENV and Totally-enclosed Pipe-Ventilated	Permitted by the NEC but no standard line available.

Notes:

1. National Electrical Code, NFPA No. 70. The publication provides greater detail on classifications than is summarized in this article. The 1996 edition was used in the preparation of this section.
2. All motors for Class I and II, Division 1 hazardous locations shall be equipped with thermostats.
3. No motors for Class 1, Division 1, Group A and B are available with U.L. Label.
4. No UL labels are possible on ordinary motors for use in Division 2

Table 1

Underwriters Laboratory (UL) Listed Motors

Maximum Horsepower For Various Frame Sizes

Service Factor	Frame Size	3600[a]		1800		1200		900	
		BF or F Insulation 80 C R/R	F Insulation 105 C R/R	BF or F Insulation 80 C R/R	F Insulation 105 C R/R	BF or F Insulation 80 C R/R	F Insulation 105 C R/R	BF or F Insulation 80 C R/R	F Insulation 105 C R/R
1.0	507	250	300	250	300	200	250	125	150
	509	350	400	300	350	250	300	125	150
	5011	-	-	450	500	350	400	150	200
	30	1000	1000	800	800	700	700	b	b
1.15	507	200	250	200	250	150	200	125	150
	509	300	350	250	300	200	250	125	150
	5011	-	-	400	450	300	350	150	200
	30	800	800	700	700	600	600	b	b

Notes:

a: Direct connected only.

b. Motors may have lower speed and horsepower than those shown for 1200 rpm if the temperature rise does not exceed the temperature rise as shown. Lower speed motors are also available on the 500 Frame Series and the same restriction applies. Motors are for continuous duty, 60 hertz,and a maximum of 6600 volts.

NEC & UL Standards

Table 2

Available Motors For Division 1 Hazardous Locations

Type	Frame Series	Winding Rise by Resistance in Degrees Celsius										
		Hazardous Location Class & Group Available										
		80					105					
		I-C[a]	I-D	II-E	II-F	II-G	I-C	I-D	II-E	II-F	II-G	I-D
CGZZ	500	H	H	H	H	No	No	H	H	H	No	No
AZZ	30	No	H,V	H	H	H*	No	H,V	No	No	No	H,V

Notes:

a: Anti-friction bearings only
* 60 degrees Celsius rise over 40 degrees ambient temperature
H: Horizontal motor
V: Vertical motor (Consult Factory for other sizes)

ALL labeled motors are supplied with thermostats which are to be wired into the motor control circuit to provide proper protection.

The UL label attached to the motor indicates the motor is UL-Listed for use in the hazardous location Class(es) and Group(s)identified on the label. The label also shows (a) the maximum external surface temperature that could be attained under all operating conditions, and the corresponding temperature code.

NEC & UL Standards

Table 3

Group Listings Available by Frame Series And Insulation type

<table>
<tr><th rowspan="3">Type</th><th rowspan="3">Frame Series</th><th colspan="5">Random Wound Coils</th><th colspan="3">Form Wound Coils</th></tr>
<tr><th colspan="2">Std Cl B</th><th colspan="2">Std Cl F</th><th rowspan="2">Voltage</th><th colspan="2">MiClad VPI</th><th rowspan="2">Voltage</th></tr>
<tr><th>60</th><th>80</th><th>80</th><th>105</th><th>80</th><th>105</th></tr>
<tr><td>CGZZ</td><td>500</td><td>C
D
E
F
G</td><td>C
D
E
F
G</td><td>C
D
E
F
G</td><td>D
E
F</td><td>600 Volts or less</td><td>C
D
E
F
G</td><td>D
E
F</td><td>460 to 6900 Volts</td></tr>
<tr><td>AZZ</td><td>30</td><td colspan="5">Not Available</td><td>D
E
F
G</td><td>D</td><td>460 to 6900 Volts</td></tr>
</table>

Notes:

All horsepower ratings are not available in all voltages listed.

Numbers shown with the insulation type represent the winding temperature rise limit values in degrees Celsius as measured by the change of resistance method. Motors may be rated at an ambient temperature greater than 40 oC but not more than 60 oC, however, with this elevated ambient, the allowable temperature rise, from the above table, is reduced by an amount equal to the difference between 40oC and the greater ambient.

NEC & UL Standards

Table 4

Available Temperature Ratings

Horizontal Motors							
Frame Series	I-C	I-D	II-E	II-F	II-G	Temperature ˚C	Temperature T No.
500 CGZZ	X	X	X	X	X	160	T3C
		X	X	X	X	165	T3B
		X	X	X		200	T3
		X				215	T2D
30 AZZ	X	X	X	X	X	160	T3C
		X	X	X	X	165	T3B
		X	X	X		200	T3
		X				215	T2D
		X	X	X		165	T3B
		X		X		200	T3
			X	X	X	165	T3B
			X	X		165	T3B
		X				200	T3
			X			200	T3
		X				280+	T2A
Vertical Motors							
30	X	X					T3C
AZZV		X					T2D
HSZZ		X					T2A

Notes

No motors are available from any source for application in class A or Class B, Division 1 hazardous areas.

Consult the factory for details on all motors

NEC & UL Standards

Table 5
Accessories for UL-Labeled Motors

Underwriters Laboratories, Inc. has investigated and declared acceptable for use in Siemens motors the following accessories installed at our factory.

Accessory	Motor		Hazardous Locations				
	Type	Frame	CL.1, GR:		CL.1, GR:		
			C	D	E	F	G
1.Bearing Temperature Detectors (RTD's) -MCGRAW EDISION, Model. Nos. 166, 344, 269 T/R #7/120 ohm 313, 347 T/R #7/120 ohm 534, 569, 986 T/R #15/10 ohm	AZZ	30S6		X		X	X
536 T/R #15/10 ohm	AZZ	30S6		X		X	X
	CGZZ	500	X	X	X	X	X
2. Bearing Temperature Relay - MERCOID No. DA H-35 - 153,With Nol. 26-24 Bulb	AZZ	30S6		X		X	X
3. Bearing Temperature Thermostat -FENWAL 'THERMOSWITCH" No. 18016-4, 115V, A.C. Normally Closed	AZZ	30S6		X		X	X
		30-8		X	X	X	X
4. Stator Winding Thermostats a. Required TEXAS INSTRUMENTS 'KLIXON" No. 1822L, Normally Closed b. Optional TEXAS INSTRUMENTS "KLIXON" No. 1822L, Normally Open	AZZ	30S6		X		X	X
	AZZ	30-8		X	X	X	X
	CGZZ	500	X	X	X	X	X
	AZZ	30S6		X		X	X
	AZZ	30-8		X	X	X	X
	CGZZ	500	X	X	X	X	X

Table 5 (cont'd)
Accessories for UL-Labeled Motors

Underwriters Laboratories, Inc. has investigated and declared acceptable for use in Siemens motors the following accessories installed at our factory.

Accessory	Motor		Hazardous Locations				
	Type	Frame	CL.1, GR:		CL.1, GR:		
			C	D	E	F	G
5. Stator Winding RTD's - MINCO PRODUCTS, Nos. S1220C: Copper element, Class H Teflon Glassbody, AWG #30 lead wire, 10 ohms at 25o Celsius SIC18C: Copper element, Class H, Polyester Glassbody, AWG #22 lead wire, 10 ohm, at 25o Celsius S1420P: Platinum element, Class H Teflon Glassbody, AWG #20 lead wire, 100 ohms at Oo Celsius S13P: Platinum element, Class H Glassbody, AWG #22 lead wire, 100 ohms at 0o Celsius SS142ON: Nickel element, Class H Teflon glassbody, AQWG #30 lead wire, 120 ohms at 0o Celsius S15N: Nickel element, Class H polyester glassbody, AWG #22 lead wire, 120 ohms at 0o Celsius	AZZ	30		X	X	X	X
	CGZZ	500	X	X	X	X	X
6. Stator Winding Thermistors - TEXAS INSTRUMENTS PTC thermal sensors foil type, Model 4BA, with AWG #16 conductor wire leads.	AZZ	30					
	CGZZ	500	X	X	X	X	X
7. Stator Winding Thermocouples - LEEDS & NORTHUP (or others) Type Bimetal E Chromel Constantan J Iron Constantan K Chromel-Alumel T Copper Constantan Only bimetal must be as indicated, and all must be solid wire AWG #20, Teflon insulated	AZZ	30		X	X	X	X
	CGZZ	500	X	X	X	X	X

NEC & UL Standards

Table 5 (cont'd)
Accessories for UL-Labeled Motors

Underwriters Laboratories, Inc. has investigated and declared acceptable for use in Siemens motors the following accessories installed at our factory.

Accessory	Motor		Hazardous Locations				
	Type	Frame	CL.1, GR:		CL.1, GR:		
			C	D	E	F	G
8. Space Heaters Various Manufacturers Htrs/Mtr. Watts/Volts Connection 2 660W/115V Parallel 2 660W/230V Parallel 2 660W/460V Series 2 * 660W/115V Parallel 2 * 660W/230V Parallel	AZZ	30		X	X	X	X
2 * 440W/115V Parallel 2 * 440W/230V Parallel 2 * 440W/460V Series	CGZZ	500	X	X	X	X	X
9. Pilot Light for Space Heaters - CROUSE HINDS Model EFSC 3524 (Single gang enclosure with single pilot light, mounted directly on the yoke through a pipe nipple). Use only with 115V or 230 V space heaters.	AZZ	30		X	X	X	X
	CGZZ	500	X	X	X	X	X
10. Oil Immersion Heater,with Thermostat - INDEECO heater 40-P-1, 40-P-2	AZZ	30-6		X	X	X	X
- FENWAL thermostat Model 18000 (U.L. recognized for same C1 & Gr. H.L.	AZZ	30-6		X	X	X	X
11. Vibration Detector Switches - METRIX NO. 5078	AZZ	30		X	X	X	X
	CGZZ	500	X	X	X	X	X

Table 5 (cont'd)
Accessories for UL-Labeled Motors

Underwriters Laboratories, Inc. has investigated and declared acceptable for use in Siemens motors the following accessories installed at our factory.

Accessory	Motor		Hazardous Locations				
	Type	Frame	CL.1, GR:		CL.1, GR:		
			C	D	E	F	G
12. Lubrication Devices - GITS sights gauge #4285, Style CL	AZZ AZZV	30			X	X	X
- GITS screw top oil gauge,Style STG	AZZ AZZV	30		X	X	X	X
- TRICO OPTOMATIC oiler, constant level	"ZZ"	30		X			
ALEMITE and similar ball check type grease fittings may be provided on any grease lubricated motor.	"ZZ"	All	X	X	X	X	X
13. (Water) Drain and (Air) Fittings -Siemens Combination drain/vent, 0.250" pipe thread: Part #51-485-596-501. (for direct mounting, w/o extensions)	"ZZ"	All	X	X	X	X	X
- CROUSE HINDS Combination drain/vent 0.250" pipe thread. Model ECD 284 (for mounting or with extension on bearing housing and directly only on bottom of stator yoke or on bottom of terminal box). Standard for tube-type motors.	"ZZ"	All	X	X	X	X	X
Combination drain/vent, 0.375" pipe Model ECD 385, NOT STANDARD OUR MOTORS. (Same mounting as for ECD 284, above)	"ZZ"	All	X	X	X	X	X
Drain 0.250" pipe thread Model ECED 281. NOT STANDARD FOR TUBE TYPE MOTORS. (Same mounting as for ECD 284 above.)	"ZZ"	All	X	X	X	X	X

NEC & UL Standards

Table 5 (cont'd)
Accessories for UL-Labeled Motors

Underwriters Laboratories, Inc. has investigated and declared acceptable for use in Siemens motors the following accessories installed at our factory.

Accessory	Motor		Hazardous Location				
	Type	Frame	CL.1, GR:		CL.1, GR:		
			C	D	E	F	G
(Water)Drain and (Air) Fittings (cont'd) Vent, 0.250" pipe thread Model ECD 283. NOT STANDARD FOR TUBE TYPE MOTORS. (For mounting directly on bearing housing, terminal box, or on top of stator yoke.)	"ZZ"	All	X	X	X	X	X
14. Cooling Tubes Although not accessories, cooling tube materials are listed for information. * - Copper No. 19 gauge * - Copper Hard * - Admiralty Metal (70% Cu, 29% Zn 1% Sn) Brass * - Cupro Nickel (70% Cu, 30% Ni) **- Aluminum Alcoa (3003-H14 or H18) * - Aluminum Alcoa (1100-H14 or H18) * - Alclad Alcoa (3003-H14 or H18) * - Finned Aluminum * - Stainless Steel, Seamless, Grades AISI 303, 304 or 316 *UL-approved, but not readily available ** Standard	AZZ AZZV HSZZ	30		X	X	X	X

CSA Standards

Canadian Standards Association (CSA)

Most motors sold and all used in Canada require CSA certification. This involves submitting design details for CSA review and the testing of motors. Below is a tabulation of motors which are presently certified to CSA standards.

Horizontal Motors For Ordinary Locations
CSA Certification File No. LR 15721

Horizontal, three phase, squirrel cage induction motors and/or generators, Class B or F insulation, 50 or 60 hertz.

Table 1 — Maximum Available Ratings

Type	Maximum Horsepower	Maximum kW	Maximum Voltage	Enclosure	Frame Series
RG	4000	3000	6900	ODP, WPI	30, 680
FOD	4000	3000	6900	WPII	30, 680
RG	6000	4500	6600	ODP, WPI	800
FOD	6000	4500	6600	WPII	800
RGG	4000	3000	6900	TEWAC	680
RGG	6000	4500	6600	TEWAC	800
AZ	1250	950	6900	TEFC	30
CG	800	597	6900	ODP, WPI	500
CG	2000	1492	6900	ODP, WPI	580
CGG	800	597	6900	TEWAC	500
CGG	2000	1492	6900	TEWAC	580
CGII	800	597	6900	WPII	500
CGII	2000	1492	6900	WPII	580
IG	700	522	6900	WPI	500
CGZ	500	373	6900	TEFC	500
CGZ	900	672	6900	TEFC	580
CGZ	1500	119	7200	TEFC	708
CGZ	2000	1492	7200	TEFC	788
CGZ	2500	1865	7200	TEFC	880

Notes:

1. The type designation may have the following suffixes: E – High efficiency; F – Flanged housing; H – High torque, high slip; T – High torque, low slip.
2. The frame size number may have the suffix F, C, D, P, JM, T, U, S, R, Y, or Z indicating flange mounting, short shaft, special mounting, etc.
3. This table lists maximum values. It is not possible to obtain the maxmum output at all voltages and at all speeds. Refer to the frame assignment charts presented elsewhere in this manual. Consult the factory for specific information.

Vertical Motors For Ordinary Locations

CSA Certification File No. LR 15721

Vertical, three phase, squirrel cage induction motors and/or generators, Class B or F insulation, 50 or 60 hertz.

Table 1 — Maximum Available Ratings

Type	Maximum Horsepower	Maximum kW	Maximum Voltage	Enclosure	Frame Series
GV HSHG	4000	3000	6900	ODP, WPI	30
FODV FOD-HS	4000	3000	6900	WPII	30
AZ	1250	950	6900	TEFC	30

Notes:

1. The type designation may have the following suffixes: E - High efficiency; F - Flanged housing; H - High torque, high slip; T - High torque, low slip.
2 Type prefix or suffix HS means hollow shaft.
3. The frame size number may have the suffix F, C, D, P, JM, T, U, S, R, Y, or Z indicating flange mounting, short shaft, special mounting, etc.
4. This table lists maximum values. It is not possible to obtain the maximum output at all voltages and at all speeds. Refer to the frame assignment charts presented elsewhere in this manual. Consult the factory for specific information.

The following notes apply to horizontal and vertical motors.

Accessories:

Auxiliary devices such as current transformers, surge arrestors, surge capacitors, power factor correction capacitors, space heaters, pressure differential switches, filters, stator thermal detectors or protective devices, zero speed switches and plugging switches, bearing thermal detectors and protective devices, vibration detection devices, and oil sump heaters are available on CSA certified motors. Consult the factory if specific brands or types of such instruments are required.

Special Markings:

The CSA symbol will appear on the nameplate of all CSA certified motors. The month and year of manufacture will also appear. Any required warning labels will required warning labels will

Hazardous Location Motors

Motors are also available for application in Areas of various Classes, Groups and Divisions. Consult the factory for availability of specific units.

Testing Index

Standard Commercial Test
(Siemens Routine Test)

Each motor is given a routine test in accordance with ANSI C50.41-1982, NEMA Standard MG1-20.47 and IEEE-112 to assure that it is free from electrical and mechanical defects.

The following tests are performed:

1. Inspection Before Test:
   A. Turn rotor to make sure of no obstruction.
   B. Check bearing lubrication.
   C. Assure all items are secure to motor frame.

2. Stator Protective Devices Test:
   - Thermostats (Klixons) - Checked for continuity of circuit.
   - Resistance Type (RTD's) - Cold resistance value of detector is measured.
   - Thermocouples - Checked for cold temperature output and continuity of circuit.

3. No Load Readings: (At rated voltage and frequency)
   - Current
   - Voltage
   - Power
   - Speed

4. Mechanical Vibration per NEMA MG1-20.53
   (Bearing Noise Noted) No load readings on housing and record unfiltered readings.

5. Dielectric Test (Hipot) per NEMA 1-20.48
   A.C voltage applied at twice rated voltage plus 1000 volts.

6. If required:
   A. Space Heater _ Wattage measured into heater terminal at rated voltage.
   B. Differential Pressure Switch _ Checked to make sure of set points.
   C. End Play:
      Sleeve bearings only
      Limit scribed and center checked
   D. Manometer
      Sleeve bearings only
      Measure bearing cavity pressure

7. Measure of Winding Resistance:
   This is done using Kelvin bridge at ambient temperature.

Standard Commercial Test
(Siemens Routine Test)

8. * Locked Rotor Current Point:
   Lock rotor and apply reduced voltage. Record voltage, current, power.

9. Rotor Test (Die Cast Only)
   Apply 25% rated voltage to two terminals. Rotate rotor and observe current readings.

10. Shaft Voltage/Current Test:
    Record voltages between:
    1. Shaft end to shaft end
    2. Drive end to frame
    3. Non drive end to frame

11. Insulation Resistance:
    Connect all leads together and measure resistance to motor frame.

12. Bearing Insulation:
    Pretest before final test.
    Record resistance measurement when both bearings are insulated.

13. Air Gap Measurement:
    All motors have stator I.D. and rotor O.D. measured to determine air gap.
    Sleeve bearings two pole motors:
    Record air gap at "Air Gap Holes" both ends of motor.

14. Rotation:
    Proper rotation verified.

*Only recorded for test reports.

Complete Tests

A complete test is not normally performed on motors manufactured at the Norwood Plant. If required, a complete test must be specified.

A. A complete test may be performed with efficiency determination in accordance with either IEEE STD 112-1991, Method E1 (E) or F1 (F) as indicated in the following table:

Description	Method F1 (F)	Method E1 (E)
1000 HP and Below	0	X
1001 HP-3000 HP	X	0
Above 3000 HP	N/A	X
All Vertical	X	N/A

X= Probable Method
0 = Alternate method

Unless a particular test method is specified, either Method E1 (E) or F1 (F) may be selected.

B. All complete tests include those tests and inspections made during a standard commercial routine test.

C. Complete test with efficiency determination by Method E or E1 (Electrical power measurement under load with loss segregation).

In this test method, power input is measured and output is determined by subtracting total losses from the input. Total losses are equal to the sum of the stator and rotor I^2R losses corrected to the specified temperature, core loss, windage and friction losses and stray-load loss.

A complete test per Method E (E1) consists of the following tests:

1. No Load Tests: Voltage, current and power input at rated frequency and at voltages ranging from 125% to approximately 25% of rated voltage are measured. This test determines the no load losses of the motor.

2. Load Curve: In this test, the machine is coupled to a variable load and measurements of power, current, voltage, slip, stator temperature, and ambient temperature are made at 25, 50, 75, 100, 125 and 150% of rated full load current.

Complete Tests

3. Static Torque and Current Test: With the rotor in a locked position and with reduced test voltages applied, measurement of voltage, current, power, frequency and temperature are made at a minimum of five test points between 25% and approximately 50% of rated voltage.

4. Temperature Test (Direct Load Heat Run): This test is made with the machine directly connected to a loading device. With the correct voltage and frequency applied, the test is performed at required load. During the performance of this test, measurements are made every fifteen minutes for the first hour and every thirty minutes thereafter. The test is continued until the winding temperature stabilizes; that is, the temperature change between readings is one degree C or less. The following measurements are made and recorded:

   Time
   Voltage
   Current
   Power
   Slip and Speed
   Vibration
   Temperature of:
      Air in and out of machine
      Yoke
      Stator coil surface
      Stator core (where possible)
      Bearings Housing
      Stator RTD's or Thermocouples (when so equipped)
      Bearing RTD's or Thermocouples (when so equipped)
      Ambient Air

5. Stray Load Loss (Reverse Rotation) Test:

   Stray-load loss is that portion of the total losses in a machine not accounted for by the sum of the stator and rotor I^2R losses, core loss, and windage and friction losses. The direct measurement test of stray-load loss is the reverse rotation test and is included in the Method E test. If a reverse rotation test is not performed and it is acceptable by applicable standards and/or contract specifications, a value for stray-load loss at rated load is assumed in accordance with the following table (per IEEE 112-1991):

Complete Tests

HP Range	% of Rated Output
126-500	1.5 %
501-2499	1.2 %
2500 and Greater	.9 %

If a value for stray load loss is assumed, the test is designated Method E1. Unless specified otherwise, Norwood will assume a value for stray load loss.

D. Complete test with efficiency determination by Method F or F1 (equivalent circuit)

When tests under load are not made, the operating characteristics (efficiency power factor, torque, etc.) are calculated based upon the equivalent circuit. The machine parameters in the equivalent circuit are derived from data recorded during a no-load test and an impedance test (low frequency locked rotor test).

A complete test per Method F (F1) consists of the following tests:

1. No Load Tests: Voltage, current and power input at rated frequency and at voltages ranging from 125% to approximately 25% of rated voltage are measured. This test determines the no load losses of the motor.

2. Impedance Test (Low Frequency Locked Rotor Test): With the rotor locked, the motor is energized with a fifteen hertz power source at approximately 25, 50, 75, 100, 125 and 155% of motor rated full load current. Measurements of voltage, current, power input, frequency and temperatures are made at each test point.

3. Static Torque & Current Test: With the rotor in a locked position and with reduced test voltages applied, measurements of voltage, current, power, frequency, and temperatures are made at a minimum of five test points between 25% and approximately 50% of rated voltage.

4. Temperature Test (Dual Frequency Heat Run): Simulated loading of large induction motors can be performed by simultaneously introducing two frequencies into the power supply. With this type of power supply the motor attempts to alternately speed up and slow down to seek the synchronous speeds associated with the frequencies involved. The test apparatus is arranged to supply a combination of 60 hertz and 50 hertz to the motor. The 50 hertz supply is connected in series with the 60 hertz supply and adjusted so that the RMS voltage and current at the motor are at rated values and the average power consumed is approximately equal to

the full load losses of the machine. During the performance of this test, measurements are made every fifteen minutes for the first hour and every thirty minutes thereafter. The test is continued until the winding temperature stabilizes, that is, the temperature change between readings is one degree C or less. The following measurements are made and recorded:

- Time
- Voltage
- Current
- Power
- Frequencies
- Speed
- Temperature
  - Air in and out of the machine
  - Yoke
  - Stator coil surface
  - Stator core (where possible)
  - Bearings Housing
  - Stator RTD's or Thermocouples (when so equipped)
  - Bearing RTD's or Thermocouples (when so equipped)
  - Ambient Air

5. Stray-Load (Reverse Rotation) Test:

Stray-load loss is that portion of the total losses in a machine not accounted for by the sum of the stator and rotor I^2R losses, core loss and windage and friction losses. The direct measurement test of stray-load loss is the reverse rotation test and is included in the Method F test. If a reverse rotation test is not performed and it is acceptable by applicable standards and/or contract specifications, a value for stray-load loss at rated load is assumed in accordance with the following table (per IEEE 112-1991):

HP Range	% of Rated Output
126-500	1.5 %
501-2499	1.2 %
2500 and Greater	.9 %

If a value for stray-load loss is assumed, the test is designated Method F1. Unless specified otherwise, Norwood will assume a value for stray load loss.

Noise Test

Noise tests on 680 and smaller motors with a maximum of 4000 volts are conducted per IEEE No. 85 -"Test Procedure for Airborne Noise Measurements on Rotating Electrical Equipment" using a traversing microphone in a reverberant room. Refer to Noise, Section 3.

Test measurements recorded are:

1. Full octave of motor noise.
2. Full octave of reference sound source.

Sound power and free field sound pressure are computed from data recorded.

On larger machines and voltages over 4000 volts, the machine is run in the normal factory test area, uncoupled. without load and at the rated voltage. Test procedures will be generally in accordance with IEEE No. 85, except the measurements will be limited to five key microphone positions and corrections for free field conditions will be per NEMA MG-3.

Underwater High-Potential Test

Sealed Insulation Systems, NEMA Test MG-1-20.49

Stators are completely submerged in a water solution containing a non-ionic wetting agent which reduces the surface tension to less than 31 dynes/cm. A ten-minute insulation test is made at 500 volts DC with the resistance values recorded. The stator is then subjected to the high potential test with 60 Hz AC voltage of 115% rated voltage for one minute. After the high potential test, the insulation resistance is again measured using 500 volts DC.

When the wound stator, because of its size or for some other reason, cannot be submerged, the tests may be performed by spraying the windings with treated water. This alternative method is in accordance with Paragraph B of MG-20.49.2.

Special Applications and Formulae

Power Factor Correction

This section deals with power factor correction of three-phase AC squirrel-cage induction motors.

Terms:

Apparent Power - The total kilovolt=amperes (KVA) a motor is demanding from the power supply.
Actual Power - The real power being used by a motor to drive the connected load. Expressed as watts or kilowatts (KW).
Reactive power - The reactive component drawn by the motor due to the magnetic fields and leakage reactances. Expressed as kilovolt-amperes reactive (KVAR).

Power factor is the ratio of the actual power to the apparent power. It is generally expressed in percentage. When apparent power (KVA) exceeds the actual power (KW) a component known as reactive power (KVAR) is present. The apparent power consists of two parts: actual power which results in useful work, and reactive power which merely bounces energy back and forth. Both generate heat in the wires or conductors. The reactive power is always present in inductive load devices and is actually part of the total current indicated by ammeter reading. However, it does not register on a kilowatt hour meter.

The inductive reactance of the A.C. induction motor causes the motor current to lag behind the motor voltage, and thereby causes the power factor to drop below unity. This can be offset by the addition of capacitors preferably connected in such a manner that they are automatically removed from the system as the power source is removed from the motor (See Figures 10.1.1 and 10.1.2).

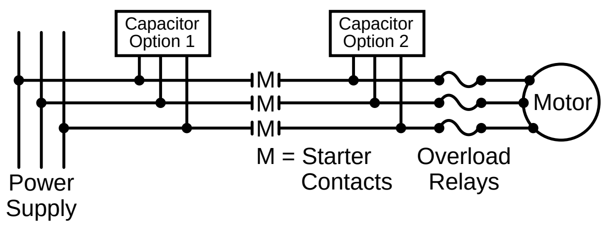


Figure 10.1.1

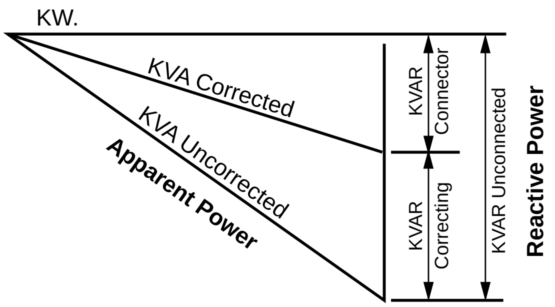


Figure 10.1.2

The capacitors can be connected in one of two ways:

A) Capacitor Option 1 should be considered for multi-speed motors, motors connected to high inertia loads, or motors that are repeatedly started, multi-jogged, or plugging duty (plug-reversed).

B) Capacitor Option 2 could be considered if none of the applications mentioned above apply. NOTE: THE OPEN CIRCUIT TIME CONSTANT OF THE MOTOR WILL INCREASE CONSIDERABLY DUE TO CAPACITOR ADDITION.

Power Factor Correction

The capacitor causes the current to lead the voltage which tends to offset the lagging current caused by the motor reactance, thereby improving the system power factor. The capacitive current in the capacitors opposes the inductive current in the induction motor.

Low power factor increases the power company's cost of supplying actual power because more current must be transmitted than is actually used to perform useful work. This additional transmitted current increases the cost incurred by the power company and is directly billed to the consumer by means of power factor clauses in the rate schedules. Low power factor reduces the load handling capability of the industrial plants electrical system as well as the load handling capabilities of the power company's generators, transmissions lines, and transformers.

Over correction of power factor by the addition of excessive capacitance is dangerous to the motor and driven equipment; therefore, it is undesirable. Over correction of power factor by the addition of excessive capacitance must be avoided because:

1. Over correction of power factor may cause damage to the A.C. induction motor as well as to the driven equipment. The power factor correction capacitors are electrical energy storage devices. When the motor is de-energized, the capacitor which remains connected in parallel to the motor can maintain the motor voltage. If the motor is re-energized after a short time, the motor voltage and the line voltage may be additive, and dangerously high currents and torques may result. This condition, if present for only a short time, can result in dangerously high transient currents and torques which in turn can cause physical damage to the motor's power transmission devices and the driven load. The important consideration is time. The motor voltage will normally decay in five seconds or less, therefore, the motor should not be re-energized before five seconds have elapsed.

2. Regenerative effect on A.C. induction motors. The motor power factor should not be corrected on A.C. induction motors connected to loads which are capable of causing the motor to rotate at speeds above synchronous motor speed when the motor is de-energized. The addition of power factor correction capacitors to motors connected to overhauling loads must be done with extreme care. Although the motor and its connected capacitors are de-energized, continued rotation of the rotor combined with the stored energy in the capacitor causes the motor to act as an alternator (A.C. generator). The voltage thus generated in the A.C. motor severely strains the capacitors and may be sufficient to cause destruction of the capacitors. When power factor correction is required on A.C. motors connected to overhauling loads, contact the factory for technical assistance.

Power Factor Correction

3. Excessive capacitance applied to an A.C. induction motor will correct the power factor of other inductive loads connected to the same power supply source. Since the same power supply system is used to supply power to many inductive loads, over correction at one load point will correct the power factor at another load point. The user that over corrects the power factor of this inductive load does not receive additional financial benefits from the power company even though he is aiding the power company by allowing it to supply power having a leading current (current leads the voltage) to other customers on the same supply system.

For these reasons, the power factor of an A.C. induction motor should not be corrected above 95%. The amount of capacitance expressed as KVAR required for power factor correction can be determined by use of the formula below. This value will probably fall between standard sizes available from manufacturers. The next lower standard size is usually selected.

The added KVAR should never exceed the no load magnetizing KVAR of the motor. If the selected correcting value of KVAR exceeds the no load magnetizing KVAR, it must be reduced to avoid overexcitation of the motor. The magnetizing KVAR can be calculated using the following formula:

$$\frac{\text{Motor Voltage} \times \sqrt{3} \times \text{Motor No-Load Amperes}}{1000} = \text{Magnetizing KVAR}$$

Power Factor Correction

Uncorrected Motor Power Factor and Constant			
%PF	K_1	%PF	K_1
60.0	1.333	77.0	0.829
60.5	1.316	77.5	0.815
61.0	1.299	78.0	0.802
61.5	1.282	78.5	0.789
62.0	1.266	79.0	0.776
62.5	1.249	79.5	0.763
63.0	1.233	80.0	0.750
63.5	1.217	80.5	0.737
64.0	1.201	81.0	0.724
64.5	1.183	81.5	0.711
65.0	1.169	82.0	0.698
65.5	1.154	82.5	0.685
66.0	1.138	83.0	0.672
66.5	1.123	83.5	0.659
67.0	1.108	84.0	0.646
67.5	1.093	84.5	0.633
68.0	1.078	85.0	0.620
68.5	1.064	85.5	0.607
69.0	1.049	86.0	0.593
69.5	1.035	86.5	0.580
70.0	1.020	87.0	0.567
70.5	1.006	87.5	0.553
71.0	0.992	88.0	0.540
71.5	0.978	88.5	0.526
472.0	0.964	89.0	0.512
72.5	0.950	89.5	0.498
73.0	0.936	90.0	0.484
73.5	0.923	90.5	0.470
74.0	0.909	91.0	0.456
74.5	0.896	91.5	0.441
75.0	0.882	92.0	0.426
75.5	0.868	92.5	0.411
76.0	0.855	93.0	0.395
95.5	0.842	93.5	0.379
		94.0	0.363
		94.5	0.346
		95.0	0.329

Desired Motor Power Factor and Constant	
% PF	K2
90.0	0.484
90.5	0.470
91.0	0.456
91.5	0.441
92.0	0.426
92.5	0.411
93.0	0.395
93.5	0.379
94.0	0.363
94.5	0.346
95.0	0.329

Figure 10.1.3

$$\text{KVAR} = \frac{\text{HP x .746}}{\text{EFF}} (K_1 - K_2)$$

Where KVAR = Kilovolt amperes reactive required to be added to circuit for Power Factor Correction (capacitor rating)

HP = Nameplate motor horespower

EFF = Motor full load effciency expressed as a decimal (example, .95).

Methods of Starting Three Phase A.C. Induction Motors

The purpose of all motor starters is to provide a means of connecting the motor to the power supply thereby accelerating the motor and connected load from standstill to the normal operating speed.

The following items should be considered when selecting a motor started for a specific three phase A.C. induction motor and motor load.

1. The power source (phase, voltage, frequency).
2 The starting torque requirements of the load.
3. Power source restrictions concerning amperage draw.

Three phase A.C. induction motor starters can be classified into three basic categories.

A. Full Voltage Type
The full voltage type of across-the-line started simply connects the motor directly to the power source.

B. Reduced Voltage Type
Reduced voltage starters cause a voltage, lower than that of the power source, to be impressed on the motor terminals in order to reduce motor inrush current and starting torque.
Example:
a. Autotransformer
b. Series Resistor or Reactor
c. Solid State Starters
d. Adjustable Frequency Drives

C. Increment Type
Increment starters use various motor reconnecting techniques to reduce motor inrush current and starting torque. Normal line voltage is maintained at the motor terminals.
Example:
a. Part Winding
b. Wye-Delta

Starting Methods

A. Full Voltage Start

General
Across-the-line starting is the most basic and widely used method of starting squirrel cage induction motors and is, therefore, used as a basis for comparing other starting methods.

Operation
A pilot device (such as a start push button) closes the line contactor to connect the motor directly to the line.

Advantages:

1. The across-the-line starter is the most simple A.C. motor starting device and, therefore, the least expensive. It provides reliable trouble free operation with low maintenance costs.
2. The across-the-line starter allows the A.C. motor to develop its maximum starting torque.

Caution:

1. The high inrush current (approximately 6.0 to 6.5 times the nameplate full load current) may be in excess of that allowed by the power company.
2. The high motor starting torque may cause excessive shock loading to the driven equipment.
3. The high starting current may cause a temporary reduction in motor terminal voltage. This voltage drop will reduce the motor starting torque by the square of the voltage ratio. An excessive voltage drop may cause dimming of lights or cause magnetic relays to “trip out”.

B. Reduced Voltage Start

a. Autotransformer Type

General
The autotransformer starter is classified as a reduced voltage starter. It is a device with which the applied motor voltage can be reduced below that of the line voltage. Both motor starting current and torque, therefore will be reduced below those values obtained with across-the-line starting.

Any standard three phase induction motor may be used with an autotransformer starter. The starter portion of the autotransformer start connects the motor leads to the reduced voltage output winding of the autotransformer. After a pre-set time delay (normally 10 to 20 seconds) the started connects the motor leads to the full line voltage.

Operation
Two autotransformer started designs are used, the open-circuit transition and the closed-circuit (Korndorfer) transition types. Both manual and magnetic open or closed circuit transition autotransformers are available. During switching from reduced voltage starting to full applied line

voltage operation, the motor is disconnected from voltage supply in the case of the open circuit transition. For closed circuit operation, however, a voltage is continuously applied to the motor terminals from the moment of reduced voltage starting and during the switching to full line voltage operation.

Advantages:

1. Starting torque per starting amp ration equal to that of the across-the-line starter.
2 The most desirable starting current and starting torque can be selected by means of reconnecting the motor leads to the 50%, 65%, or 80% output taps of the autotransformer. The characteristics of the motor load and allowable accelerating times establish the best tap connection.

%Tap	%LT	%LRA
50	25	27
65	42	45
80	64	66

Where:

%LT = Starting torque expressed as a percentage of the value encountered during across-the-line starting.

%LRA = Starting current drawn from the power lines expressed as percentage of the value encountered during across-the-line starting. This value includes the approximate required autotransformer magnetiziation current.

Note: Both % locked torque and % locked rotor current vary approximately as the square of the voltage applied to the motor.

3. Limited motor noise and vibration during starting.
4. On the closed circuit transition type started, voltage transients during the transition period are minimized which reduces the possibility of unacceptable performance of other electrical components within the same plant.

Caution:

1. The autotransformer output tap may have to be changed to a higher percentage voltage value if the load torque and/or inertia exceeds the motor can accelerate within the required starting period.
2. The transfer from reduced voltage to full voltage operation should be delayed until the motor speed is high enough to ensure that the current change during switching will not exceed power company requirements.

3. The starter as well as the motor should be evaluated for application requiring frequent starting. For autotransformer starters, NEMA states that one 15 second starting period every four minutes for a total of four per hour is acceptable. The majority of standard induction motors are capable of four 15 second starting periods per hour.
4. On the open-circuit transition type, line voltage transients can result during the transition period due to sudden current changes.

b. Primary Resistor or Reactor Starting

Operation
Resistor type starters introduce a resistor bank in series with the motor windings.

The initial current surge through the motor is limited by the resistors. Simultaneously, a voltage drop develops across the resistors, reducing the voltage applied to the motor. At reduced voltage, the motor torque capability is reduced.

As the motor begins to accelerate, it produces a counter emf, opposing the applied voltage and further reducing the initial current surge. As the current surge is reduced, the voltage drop across the resistor bank diminishes while that of the motor is increased. This increases motor torque while current inrush is diminishing. The net result is a smooth and gradual accelerating cycle without open transients in the motor windings.

An adjustable timing device on the starter is pre-set to initiate a run contactor at the proper time during the accelerating period. This function closes a run contactor, shorting across the resistors. The start contactor then drops open, removing the resistors from the circuit.

Reactor type starters follow the same sequence of starting, with the exception that the reactors remain shorted after the final stage of acceleration. As implied, the reactors are core wound devices, having adjustable voltage taps. These devices limit the initial motor current surge by an inherent tendency to oppose a sudden changing condition of current and voltage.

Advantages:
The resistor or reactor controllers are of the close-transition type since the lines to the motor are not opened during transfer to the run condition.

Resistors supplied provide 65% voltage but have taps at 80% to allow for adjustment. Reactors have 50%, 65%, and 80% taps. All controllers are connected for 65% voltage as standard.

Current drawn from the line upon starting is reduced to approximately the value of the tap used.

Starting Methods

Starting torque is reduced to approximately the value of the tap squared. For example, with connection to the 65% taps, current inrush will be approximately 65% of full-voltage, locked-rotor current, and starting torque will be about 42% of that developed under full-voltage starting.

Any standard motor may be used. (No special windings or connection are needed.)

Caution:
The motor will not start if the break away torque required of the load exceeds that which the motor can develop on the starting connection.

Full impact of inrush current and torque are then experienced at transfer from the short to run connection.

c. Solid State Starters
Solid state starters provide reduced voltage during starting by controlling the firing angle of Silicon Controlled Rectifiers (SCR's) during the starting cycle. The firing angle allows conduction of voltage and current during only a portion of the A-C sine wave.

The most commonly used type of solid state starting is Current Limit Starting. A current limit, as a percentage of full load current, is selected at the started controller. Voltage is ramped up until the line current reaches the value selected (typically 175 to 500 percent of full load current). This current is maintained as the motor accelerates, until the motor has reached a speed at which its current draw is less than the current limit selected. The torque delivered by the motor will be approximately:

$$\left(\frac{\text{Current Limit, Percent}}{\text{Current at Full Voltage, Percent}}\right)^2 \times \text{Full Voltage Motor Torque}$$

For example, a motor which delivers 100 percent of full load torque at locked rotor, with 650 percent locked rotor amps at full voltage, being started with a solid state started set at 300 percent current limit will deliver $(300/650)^2 \times 100$, or 21.3 percent of full load torque at start.

Solid state starters can also be used in conjunction with shaft driven tachometers to provide controlled acceleration times (up to 30 seconds, maximum). Voltage output is adjusted as required by the starter controller to provide a constant rate of acceleration.

It should be noted that the starter output voltage frequency is not changed from the incoming line frequency.

Solid state starters are usually limited to applications to motors below 1000 horsepower and below 575 volts.

d. Adjustable Frequency Drives
Adjustable Frequency Drives (AFD's) are solid state devices which control both the voltage amplitude and frequency seen at the motor's terminals. When used with motors driving high inertia centrifugal loads, such as fans, AFD's can be controlled to greatly reduce the power required to start the load and to greatly reduce the thermal stresses on the motor during acceleration.

With normal ATL or autotransformer starting, most of the power drawn by the motor as it accelerates is dissipated as heat in the stator or rotor windings. AFD's can be controlled to allow the motor and load to reach near synchronous speed of a reduced frequency terminal voltage. The power drawn by the motor will be slightly greater than the brake horsepower required by the load at the speed at which the motor and load are rotating. Losses in the motor an motor windings will be minimal in comparison with their losses occuring in an ATL start at the same speed. Drive output voltage and frequency are gradually ramped up until the motor reaches its final desired speed. AFD application often allows a smaller frame motor to be used than would otherwise be required to start inertia loads.

For additional information on AFD see Part 6.

C. Increment Starting

a. Part Winding Start - 1/2 Winding Method

General
Part winding starting, 1/2 winding type, is the most commonly used method of increment starting of A.C. induction motors. The 1/2 winding method of part winding starting is used to reduce the initial value of motor starting current and/or to reduce the value of motor starting torque. The 1/2 winding method of part winding starting requires the use of a specific motor starter with an A.C. induction motor having two parallel stator windings suitably connected internally for part winding starting.

The starter must be capable of energizing, with full line voltage, 1/2 of the motor winding, then after a slight time delay (not to exceed three seconds) energizing the complete winding.

Operation

A pilot device (push button) closes contactor 1, connects 1/2 of the motor winding across the line, and energizes a timer. After a predetermined time interval, the timer closes contactor 2, connecting the second half of the motor winding in parallel with the first half of the motor winding.

Advantages:

1. Starting current is reduce 60 to 65% of the value encountered if the motor were started across-the-line.
2. Starting torque is approximately 45 to 50% of the value encountered if the motor were started across-the-line.
3. Continuous connection of motor to line during transition periods minimizes voltage fluctation during the transition period.
4. Can be applied to most 4, 6 and 8 pole motors.

Motor Starters and Schematic Diagrams

Many standard (stock) dual voltage motors are designed and built to be suitable for operation on part winding start on the lower voltage. The standard motor may be a star or delta connected unit and the type of motor connection employed must be considered when selecting the starter type.

There are two types of starters which may be used for part winding starting, the 4-2 and 3-3 types. Both starter types have two contactors, however, the 4-2 has one 4 pole and on 2 pole contactor; whereas the 3-3 type has two 3 pole contactors. It is possible to use either starter type regardless of motor connection (Star or Delta) or whether it is built for single or dual voltage operation. The 4-2 type starter characteristics makes it the most flexible of the two starter types; however, the 3-3 type starter is presently the most popular since it is a NEMA defined starter.

External connection diagram 51-676-394 shows a typical dual voltage (230/460) motor connection. Diagram 51-688-230 shows how this motor con be used with part winding start on the low voltage (230) volt rating. For part winding start on 460 volt, or other than 230 volt, the motor must be wound specifically for the intended voltage. It would have a six lead connection and 51-406-529 is typical (see Section 5).

Caution:

1. Motor to be part winding started must be designed and built properly to ensure that two parallel stator windings are provided.
2. The motor will not start if the torque demanded by the load exceeds that developed by the motor on the first step or when 1/2 of the motor winding is energized. When the second half of

the winding is energized, the normal starting torque (same as across-the-line starting) is available to accelerate the load.

3. By use of two step part winding starting, the inrush current is divided into two steps thus providing the power source’s line voltage regulators sufficient time to compensate for the voltage drop caused by motor starting.
4. Motor heating on first step operation is greater than that normally encountered on across-the-line start. Therefore, elapsed time on the first step of the part winding start should not exceed three seconds.
5. When the first half of the winding is energized, a slight increase in electrical noise and vibration may be encountered.

b. Wye-Delta Starting

General

Wye-Delta starting is a method of increment starting used with a three phase A.C. induction motor to reduce the initial values of motor starting current and torque compared to those values obtained with across-the-line starting.

Both ends of each phase winding are brought into the motor conduit box. The starter is designed to connect these windings in Wye on the first step. After a preset time delay, the starter will disconnect from the Wye configuration and reconnect in Delta for continuous operation.

The voltage impressed across each phase of the motor winding during the first step (Wye connection) of a Wye-start Delta-run motor is lower than the voltage which would be impressed across each phase of the motor if across-the-line starting were used. This lower voltage results in lower starting current and torque (Refer to Figure 1).

Three phase A.C. induction motors having Wye-Delta winding connections are popular in Europe because supply voltages of 220 and 380 are used. Motors wound for 220/380 volts may be started across-the-line on either 220 or 380 volts or may be operated at Wye-start Delta-run on 220 volts.

Operation

Two types of Wye-Delta starters are used, the open-circuit transition and the closed-circuit transition types. Both types connect the motor windings in Wye on the first step. After a predetermined time interval, the timer causes the starter contactors to reconnect the motor windings in the Delta or “run” connection.

Starting Methods

Advantages:

1. Starting torque per starting amp ratio equal to that of the across-the-line starter.
2. Starting current is reduced to approximately 33% of the values encountered if the motor were started across-the-line.
3. Soft start - Starting torque is approximately 33% of the value encountered if the motor were started across-the-line. This low starting torque is often desirable to softly accelerate loads having high inertia and low retarding torque (Example - centrifuges and unloaded compressors). The low starting current during the starting period allows the motor to withstand a longer acceleration time than an equivalent sized across-the-line start motor. The Wye-Delta motor, however, will accelerate only slightly more inertia than the across-the-line motor since the thermal capacity of both motors is the same. To accelerate a specific inertia, the Wye-Delta motor will produce a lower temperature rise within the motor than an equivalent size across-the-line start motor because the longer acceleration time allows the heat in the motor to be efficiently dissipated to the housings and surrounding atmosphere.
4. Can be adapted to most 2, 4, 6 and 8 pole motors.
5. May be started as frequently as an across-the-line start motor if the retarding torque of the load is negligible.
6. Limited motor noise and vibration during starting.
7. On the open-circuit transition type, no resistors are required.
8. On the closed-circuit transition type, voltage fluctuation during the transition period is minimized.

Caution:

1. Motor started on Wye connection and operated on the Delta connection must be specifically designed for Wye-Delta. Motors rated 4000 volts and higher are usually not suitable for Wye-Delta starting.
2. The motor will not start if the torque demanded by the load exceeds that developed by the motor on the Wye connection. When the motor is connected in Delta, normal starting torque is available to start the load.
3. The transfer from Wye to Delta should be delayed until the motor speed is high enough to ensure that the current change during switching will not exceed power source requirements. Generally, the starter time should be set so that switching from Wye to Delta occurs at 80-90% of full load speed.
4. On the open-circuit transition type, line voltage fluctuation can result during the transition period due to sudden current changes.

Summary

Figure (2) summarizes in chart from the motor starting performance with these various starting methods.

Starting Methods

To this point, we have reviewed these various starting methods and their effect on inrush current, line current and starting torque. Our major concern is the motor; to get it started and up to speed as rapidly as the load permits. Figure (3) shows why this is necessary . This is a typical speed current curve, and illustrates that inrush current remains high throughout most of the accelerating period.

If the power system on which this motor is to operate cannot stand this inrush at full voltage, and a means of reduced voltage or increment start is elected, then we must be aware of the effect on current and torque as displayed in Figure (2).

Bear in mind also, the motor does not recognize the type of starter being used. It interprets what is received at the motor terminals as applied voltage, and that which appears at the shaft as a torque to be overcome. It is recognizing two factors; voltage and load torque.

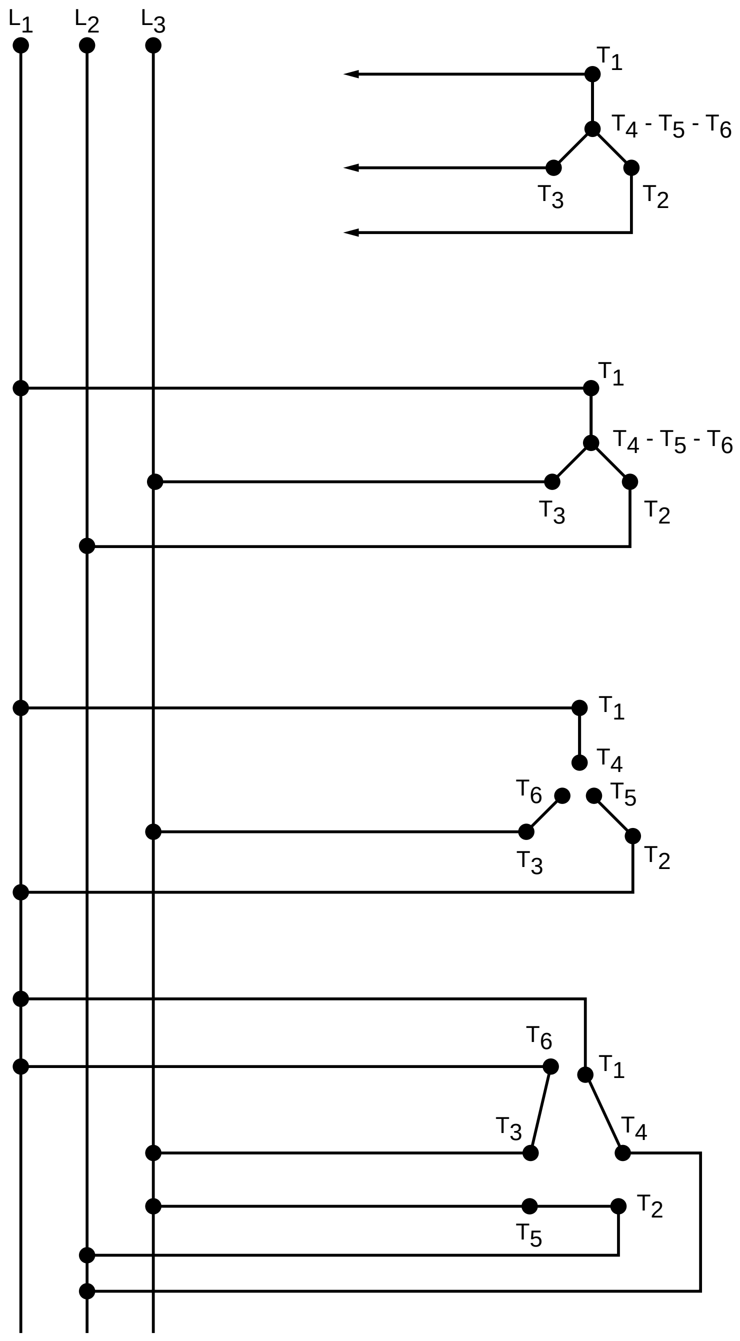
An increasing number of specifications are being written which state that the motor must be capable of starting with 90%, 80% or 70% voltage, and must also be capable of momentary operation with a voltage dip to 90%, 80%, or 70% voltage. This introduces three points for consideration.

1. Will the motor develop enough torque at start to initiate rotation of the load?
2. Will the motor be capable of maintaining rotation during the accelerating period?
3. Will the motor have sufficient torque to sustain rotation during periodic voltage dips?

Figure (4) displays a family of motor speed torques for terminal voltages of 100%, 90%, 80% and 70% rated voltage. The speed torque requirement of a centrifugal pump is also shown as a typical load curve.

1. The motor will break away and begin rotating as long as more torque is generated at locked rotor than the load requires. In this example the motor will start under any one of the four voltage conditions.
2. As long as the motor is generating more torque than required by the load the motor will continue to accelerate. This will continue until the torque developed by the motor is equal to the torque required by the load. Acceleration will stop and the motor will attempt to operate the driven device at this speed. If the speed is too low for the driven device the torque condition of either the motor or the driven device must be changed to increase the speed to acceptable value.
3. When the voltage dip occurs the motor performance will be in accordance with the speed torque curve for this reduced value. The motor will continue to operate as long as the intersection of the load curve and the motor speed torque curve occurs above the breakdown torque point of the motor. The closer this operating point approaches the breakdown point, the quicker the motor will overheat, and therefore, the shorter the time the motor can successfully withstand the voltage dip.

Starting Methods



Step #1
Contractor(s) Closes, Connecting Motor Windings in Wye.

Step#2
Contactor (IM) Closes, Connecting the Wye Connected Motor to the Line (Wye Starting).

Step #3
Contactor(s) Opens, Breaking Wye Point Connection. Contactor (IM) Remains Closed.

Step #4
Contactor (2M) Closes Connecting Motor Windings in Delta to the Line (Delta Running).

Sequence of Operation
Open Circuit Transition
Figure 1

Starting Methods

General Comparison of Characteristics of Various Methods of Motor Starting

	Reduced-Voltage Starting				
	Autotransformer*	**Primary Resistance**	**Reactor**	**Part Winding**	**Wye (Star)-Delta**
	50% Tap 65% Tap 80% Tap	65% Tap 80% Tap	50% 65% 80%	2-Step 3-Step	
Starting current drawn from line as % of that which would be drawn upon full-voltage starting.	25% 42% 64%	65% 80%	50% 65% 80%	50%** 25%**	33-1/3%
Starting torque developed as % of that which would be developed on full-voltage starting.	25% 42% 64% Increase slightly with speed.	42% 64% Increase greatly with speed.	25% 42% 64%	50%** 12-1/2%**	33-1/3%
Smoothness of acceleration	Second in order of smoothness.	Smoothest of reduced-voltage types. As motor gains speed, current decreases. Voltage drop across resistor or reactor decreases and motor terminal voltage increases.		Fourth in order of smoothness.	Third in order of smoothness.
Allowable accelerating times (typical).	30 seconds Based on NEMA medium duty transformers.	5 seconds Based on NEMA Class 116 Resistors	15 seconds Based on medium duty reactors	2-3 seconds Limited by motor design	45-60 seconds Limited by motor design.
Starting current and torque adjustment.	Adjustable within limits of various taps.			Fixed	
Equipment	Three contactors, timer and starting element.	Two contactors, timer and starting element.		Two contactors and timer. Starting element inherent in motor design.	Three contactors and timer on open transition. Four contactors, timer and resistor on closed transition. Starting element inherent in motor design.

* Full-voltage start usually draws between 500% and 600% of full-load current.
* Closed transition
** Approximate values only. Exact values can be obtained from motor manufacturer.

Figure 2

Starting Methods

Typical Speed vs. Current Squirrel Cage Induction Motor

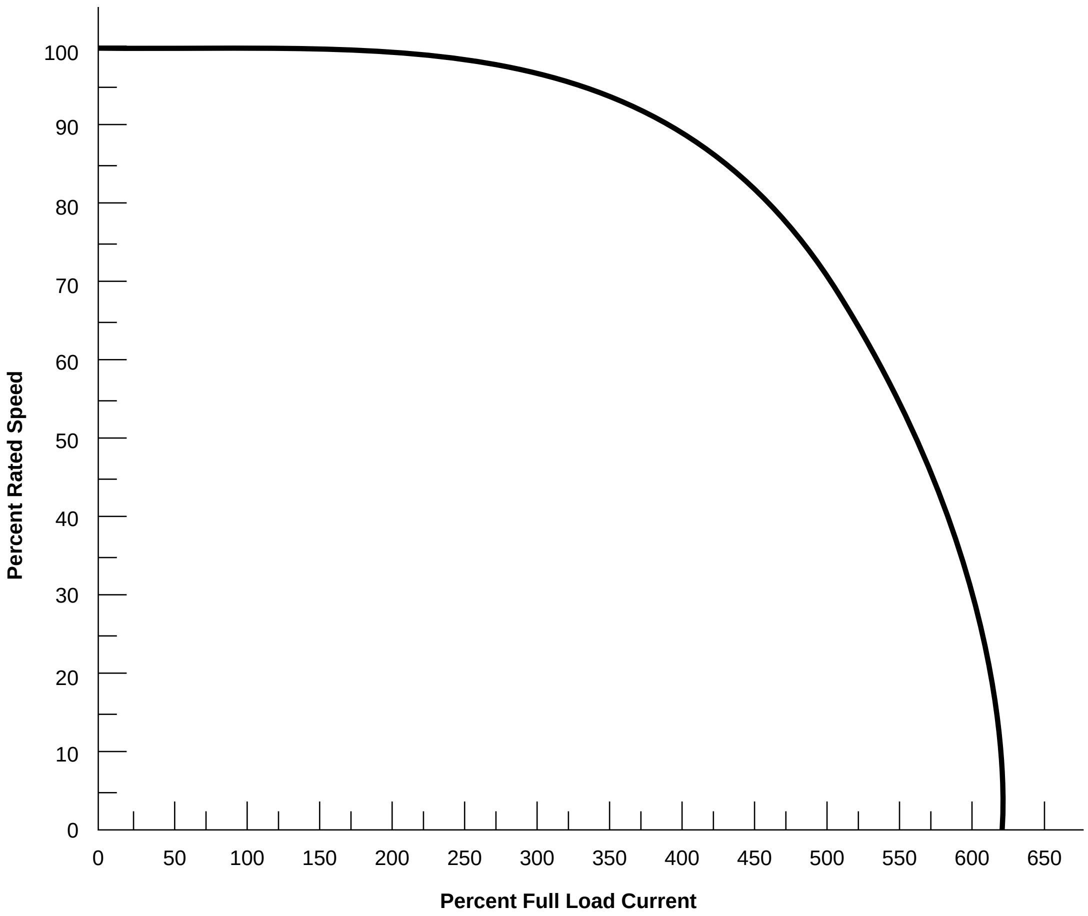


Figure 3

Starting Methods

Typical Speed Torque Curves, Low Terminal Voltage Squirrel Cage Induction Motor

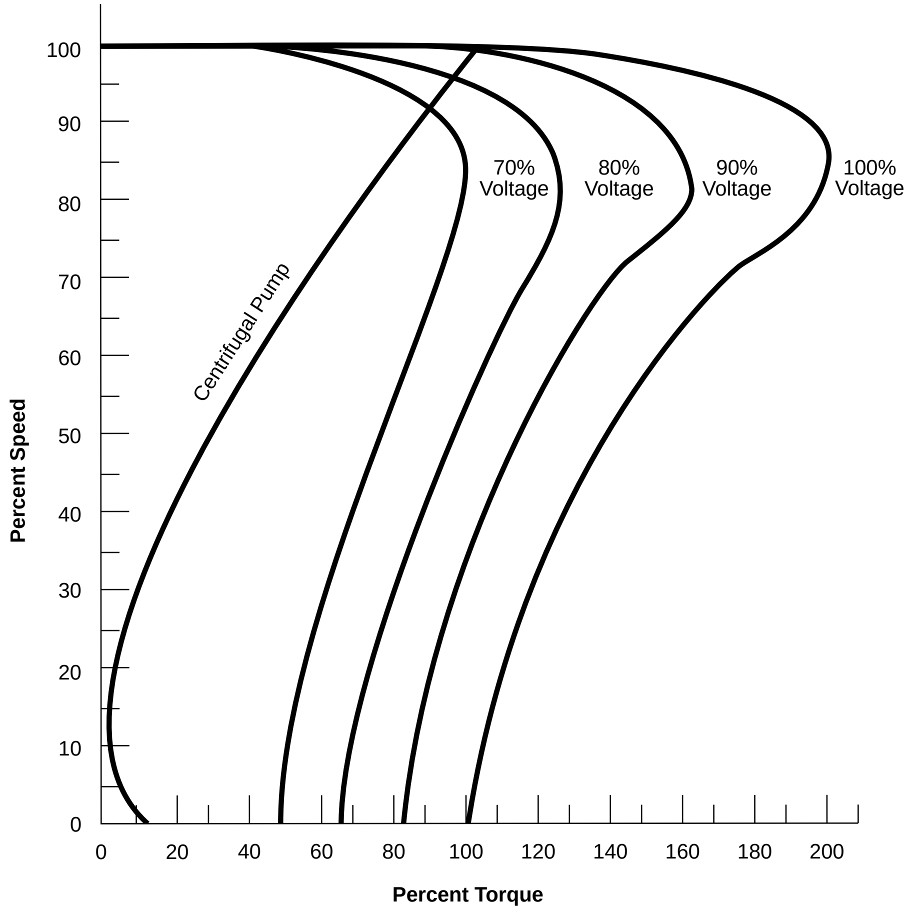


Figure 4

Duty Cycles and Inertia

Horsepower Variations

Many machines work on a definate duty cycle that repeats at regular intervals. If the values of power required during the cycle, and the length of thier durations are known, then the rating of the motor required can be calculated by the root-mean-square (RMS) method.

Multiply the square of the horsepower required for each part of the cycle by the duration in seconds. Divide the sum of these results by the effective time in seconds to complete the whole cycle. Extract the square root of this result. This gives the RMS horsepower. If the motor is stopped for part of the cycle, only 1/3 of the rest period should be used in determining the effective time for open motors (enclosed motors use 1/2 of the rest period). This is due to the reduction in cooling effect when motor is at rest.

Example:
Assume a machine operation, where an open motor operates at an 8 HP load for 4 minutes, 6 HP load for 50 seconds, 10 HP load for 3 minutes, and the motor is at rest for 6 minutes.

Calculation

$$\text{RMS HP} = \sqrt{\frac{(8^2 \times 240) + (6^2 \times 50) + (10^2 \times 180)}{240 + 50 + \frac{360}{3} + 180}} =$$

$$\sqrt{50.5} = 7.7 \text{ HP}$$

Use 7.5 HP motor

For fast repeating cycles involving reversals and deceleration by plugging, the additional heating due to reversing and external WK^2 must be considered. Consequently, a more elaborate duty cycle analysis than devised is required. It is necessary to know the torque, time, and motor speed for each portion of the cycle, such as acceleration, running with load, running without load, deceleration, and the rest.

For such detailed duty cycles it is sometimes more convenient to calculate on the basis of torque required rather than on the horsepower basis.

Duty Cycles and Inertia

Accelerating Time

$$\text{time, sec.} = \frac{WK^2 \times (\text{change in rpm})}{308 \times \text{torque (lb-ft) average from motor}}$$

The above formula can be used when the accelerating torque is substantially constant. If the accelerating torque varies considerably, the accelerating time should be calculated in increments: the average accelerating torque during th increment should be used and the size of the increment used depends on the accuracy required. The following equation should be used for each increment:

$$\text{time, sec.} = \frac{WK^2 \times \text{rpm}}{308 \times (T - T_L)}$$

WK^2 = moment of inertia, lb-ft^2 of system (motor + load)
RPM = motor speed
TL = motor torque, lb-ft at a given speed
T = load torque, lb-ft at the same speed

Moment of Inertia (WK^2)

The moment of inertia is used for calculating the accelerating time of the motor and its load. The moment of inertia of a rotating body is the weight of the body time the radius of gyration squared. The mass of the body as actually distributed around the center of rotation is equivalent to the whole mass concentrated at a certain radius “K”, called the radius of gyration, from the axis of rotation. The radius of gyration “K” depends upon the shape of the object and the axis of rotation. An unsymmetrical object will have a different “K” depending upon the orientation of the axis of rotation. In the formula for calculating “accelerating time” the WK^2 product of weight W and the square of the radius of gyratio K^2 appears. This will hold true in any formula whenever the moment of inertia is of concern.

Formulas for the moment of inertia (WK^2) based on specific weights of metals can be found in Table 1. In Table 2, WK^2 of solid cylinders per inch of length is provided.

Duty Cycles and Inertia

Calculation of Inertia of Shafts

To determine the WK^2 of a solid shaft, use the following formula:

$$WK^2 = 170.4\ WLD^4$$

Where WK^2 = inertia in $lb\text{-}ft^2$
W = specific weight of shaft material in $lb\text{-}in^3$
L = length of shaft in feet
D = diameter of shaft in feet

For solid seel shaft with specific weight of .282 lb/in^3

$$WK^2 = 48LD^4$$

For hollow shaft with the same specific weight

$$WK^2 = 48L\ (D_1^4 - D_1^4)$$

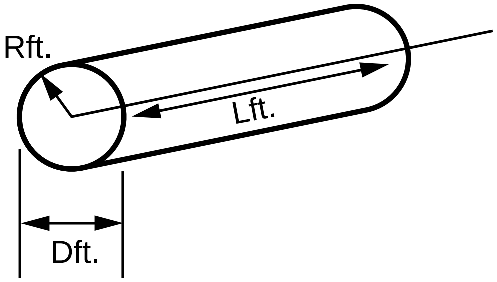
Where D_2 = outside shaft diameter in feet

D_1 = inside shaft diameter in feet

For other materials, simply use the ratio of specific weights to adjust the above formulas.

Duty Cycles and Inertia (Calculations)

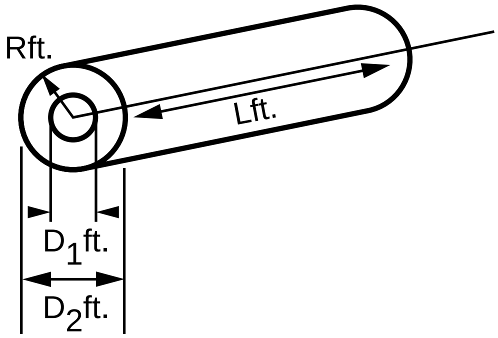
(a) Circular Cylinder



$WK^2 = 170.4\ w\ LD^4$

w = weight of material

(b) Hollow Circular Cylinder



$WK^2 = 170.4\ w\ LD^4$

$(D_2^4 - D_1^4)$

Weights of Metals
lbs./cu.In.

1.	Magnesium	0.0628
2.	Aluminum	0.0924
3.	Cast Iron	0.260
4.	Steel	0.282
5.	Copper	0.318
6.	Bronze	0.320
7.	Lead	0.411

Table 1

Duty Cycles and Inertia

WK^2 of Steel Shafting and Disc

To determine the WK^2 of a given shaft or disc, multiply the WK^2 given below, by the length of the shaft, or thickness of disc, in inches. To determine inertias of solids of greater diameter than shown below, multiply the nearest tenth of the diameter by 10^4 or move decimal point four places to the right and multiply by length as above. For hollow shafts, subtract WK^2 of inside diameter from WK^2 of outside diameter and again multiply by length.

Per Inch of Length or Thickness					
Diameter (Inches)	WK^2 (Lb. Ft.^{2})	Diameter (Inches)	WK^2 (Lb. Ft.^{2})	Diameter (Inches)	WK^2 (Lb. Ft.^{2})
3/4	.00006	10-1/2	2.35	32	201.8
1	.0002	10-3/4	2.58	33	228.2
1-1/4	.0005	11	2.83	34	257.2
1-1/2	.001	11-1/4	3.09	35	288.8
1-3/4	.002	11-1/2	3.38	36	323.2
2	.003	11-3/4	3.68	37	360.7
2-1/4	.005	12	4.0	38	401.3
2-1/2	.008	12-1/4	4.35	39	445.3
2-3/4	.011	12/1-2	4.72	40	492.8
3	.016	12-3/4	5.11	41	543.9
3-1/2	.029	13	5.58	42	598.8
3-3/4	.038	13-1/4	5.96	43	658.1
4	.049	13-1/2	6.42	44	721.4
4-1/4	.063	13-3/4	6.91	45	789.3
4-1/2	.079	14	7.42	46	861.8
5	.120	14-1/4	7.97	47	939.3
5-1/2	.177	14-1/2	8.54	48	1021.8
6	.250	14-3/4	9.15	49	1109.6
6-1/4	.296	15	9.75	50	1203.1
6-1/2	.345	16	12.61	51	1302.2
6-3/4	.402	17	16.07	52	1407.4
7	.464	18	20.21	53	1518.8
7-1/4	.535	19	25.08	54	1636.7
7-1/2	.611	20	30.79	55	1761.4
7-3/4	.699	21	37.43	56	1898.1
8	.791	22	45.09	57	2031.9
8-1/4	.895	23	53.87	58	2178.3
8-1/2	1.000	24	63.86	59	2332.5
8-3/4	1.13	25	75.19	60	2494.7
9	1.27	26	87.96	66	3652.5
9-1/4	1.141	27	102.30	72	5172.0
9-1/2	1.35	28	118.31	78	7125.0
9-3/4	1.75	29	136.14	84	9384.0
10	1.93	30	135.92	90	12629.0
10-1/4	2.13	31	177.77	96	16349.0

Table 2

Duty Cycles and Inertia

High WK^2 Acceleration

When starting a high WK^2 load, step-starting may be required to maintain the torque necessary to accelerate the mass. Care must be taken in choosing resistor capacity to dissipate the heat resulting from the starting current.

Data Required

To determine the correct motor for a high WK^2 load:

1. WK^2 of load
2. Torque required
3. Duty cycle

Example

200 lbs-ft for 5 seconds accelerates load to 1150 rpm; 50 lb-ft for 10 seconds does work required; 200 lbs-ft for 5 seconds decelerates load to standstill; 12 seconds at rest (1/3 of off-time is used for open motors).

$$\text{total cycles time} = 5 + 10 + 5 + \frac{12}{3} = 24 \text{ seconds}$$

$$\text{RMS torque} = \sqrt{\frac{(200^2 \times 5) + (50^2 \times 10) + (200^2 \times 5)}{24}}$$

$$\text{RMS torque} = 133.1 \text{ lbs-ft}$$

$$\text{HP} = \frac{\text{RMS torque} \times 1150}{5250}$$

$$\text{HP} = \frac{133.1 \times 1150}{5250} = 29.15$$

Therefore, use motor rated 30 HP, 1150 rpm.

Note: The above example is calculated on the basis of rms torque rather than rms HP.
The additional heating due to the nature of the duty cycle has been taken into consideration.

Duty Cycles and Inertia

Information Required for Proper Selection

It is recommended that the factory be supplied with the following information:

1. Load WK^2 motor shaft.
2. Number of starts, stops or reversal per unit of time.
3. HP load and length of each operating period.
4. Length of standing idle periods.
5. Method of stopping.
6. Special torque requirements of motor, such as need to break away heavy friction load from rest; need to bring heavy inertia load up to speed (or down to stop) in specified period of time; need to have high pull-out torque to carry momentary overloads.

Special Applications

Accelerating Rotary Compressors and Vacuum Pumps

This type machine is unique in that it usually requires full load torque at 25 to 30% speed when started under full load conditions. This poses serious acceleration problems for electric motors as this high torque demand of the load occurs at the point where a motor has the least available accelerating torque - the pull-up point in the motor speed/torque curve. Normal torque motors will not accelerate load. These motors are available at Custom Built pricing and should be used for these applications.

Data Needed for Fan or Blower Drive

HP

RPM

Phase/Hz/Volts

Enclosure

Temperature Rise

Service Factor

WK^2 at motor speed or WK^2 at fan speed

Dampers closed at start?
  If yes, what % HP at full speed?

Across the line (full voltage) start?

Reduced voltage start?
  If yes, % voltage tap
    inrush KVA specified?
    Max. accel. time specified?

Note - We do not recommend Part Winding or Wye Delta starting for fans or blowers.

Motors for Cutting Water Pumps for Decokers

This application requires two pole motors generally in the range of 1500 HP to 2500 HP driving multi-stage horizontal high pressure pumps. The only difficult aspect of this application is the fairly frequent requirement for repetitive starts in excess of NEMA standards, particularly during start-up of the system. For this application we find that in most cases our standard designs can meet the application requirements. The system is set up with a bypass for starting, reducing the torque requirement during acceleration to approximately 1/4 the design load which is an important consideration in motor sizing and should be defined in the quite stage.

The limiting factor for two pole motors in applications requiring frequent starting is the heat dissipation capability of the rotor; most of the energy required to accelerate the pump must pass through the rotor, and, since a two pole rotor of necessity is much smaller than lower speed rotors, heat dissipation is a serious consideration. We have standard rotor designs, with die cast aluminum or silver brazed copper alloy cage construction which allow starting frequency at least double NEMA standards with normal pump WK2. With complete application information we can furnish designs to meet all requirements for driving cutting water pumps.

Formulae and General Data

Determination of HP Requirements

The horsepower required can be determined from the factual information or power requirements for specific operations. Where the force or torque required is known, one of the equations below may be used to calculate the horsepower required by constant load characteristics.

Power for Translation

$$HP = \frac{\text{Force (lbs.)} \times \text{ft. per min.}}{33{,}000}$$

Power for Rotation

$$HP = \frac{\text{Force (lbs.)} \times \text{RPM}}{5250}$$

Power to Drive Pumps

$$HP = \frac{\text{Gal. per min.} \times \text{total head (inc. friction)} \times \text{specific gravity}}{3960 \times \text{eff. of pump}}$$

Where friction head (ft.) = pipe length (ft.) x velocity of flow

$$\frac{(\text{fps})^2 \times 0.02}{5.367 \times \text{diameter (in.)}}$$

Power to Hoist a Load

$$HP = \frac{\text{Weight (lbs.)} \times \text{feet per min.} \times \sin\theta}{33{,}000}$$

θ = Angle of hoist with horizontal

Power to Hoist a Load

$$HP = \frac{\text{Cu. ft. gas per min.} \times \text{water gauge pressure (in.)}}{6350 \times \text{efficiency}}$$

Efficiencies for fans range between 50 and 80 percent

Formulae and General Data

To Find	Three Phase
Amperes when HP is known	$I = \frac{746 \times HP}{1.73 \times E \times Eff. \times PF}$
Amperes when KW is known	$I = \frac{1000 \times KW}{1.73 \times E \times PF}$
Amperes when KVA is known	$I = \frac{1000 \times KVA}{1.73 \times E}$
Kilowatts Input	$KW = \frac{1.73 \times E \times I \times PF}{1000}$
Kilovolt Amperes	$KVA = \frac{1.73 \times E \times I}{1000}$
Horsepower Output	$HP = \frac{1.73 \times E \times I \times Eff. \times PF}{746}$

NEMA Code Letters

Letter Designation	kVA per Horsepower*	Letter Designation	kVA per Horsepower*
A	0 - 3.15	K	8.0 - 9.0
B	3.15 - 3.55	L	9.0 - 10.0
C	3.55 - 4.0	M	10.0 - 11.2
D	4.0 - 4.0	N	11.2 - 12.5
E	4.5 - 5.0	P	12.5 - 14.0
F	5.0 - 5.6	R	14.0 - 16.0
G	5.6 - 6.3	S	16.0 - 18.0
H	6.3 - 7.1	T	18.0 - 20.0
J	7.1 - 8.0	U	20.0 - 22.4
		V	22.4 - and up

* Locked kVA per horsepower range includes the lower figure up to, but not including, the higher figure. For example, 3.14 is designated by letter A and 3.15 by letter B

Formulae and General Data

Synchronous Speed Frequency and Number of Poles of AC Motor and Generators

$$HP = \frac{120 \times f}{p} \qquad f = \frac{p \times n_S}{p} \qquad P = \frac{120 \times f}{n_S}$$

Relationship Between Horsepower, Torque, and Speed

$$HP = \frac{T \times n}{5250} \qquad T = \frac{5250\ HP}{n} \qquad P = \frac{5250\ HP}{T}$$

Motor Slip

$$\%\ Slip = \frac{n_S - n}{n_S} \times 100$$

Locked Rotor Current (I_L) From Nameplate Data

Three Phase: $$I_L = \frac{577 \times HP \times KVA/HP}{E}$$

Example: Motor nameplate indicated 100 HP,
3 Phase, 460 Volts, Code F.

$$I_L = \frac{577 \times 100 \times (5 \text{ to } 5.59)}{460}$$

I_L = 627 to 703 ASmperes (possible range)

Effect of Line Voltage on Locked Rotor Current (I_L) (Approx.)

$$I_L \propto E_{LINE}$$

or I_L at E_{LINE} = I_L at $E_{N.P.}$ x $\frac{E_{LINE}}{E_{N.P.}}$

Symbols

PF = power factor as a decimal
EFF = efficiency as a decimal
T = torque in pound-feet
f = frequency in cycles per second (HZ)
I = current in amperes
E = voltage in volts
KW = power in kilowatts
KVA = apparent power in kilovolt-amperes
HP = output power in horsepower
n = motor speed in revolutions per minute (RPM)
ns = synchronous speed in revolutions per minute (RPM)
p = number of poles

Formulae and General Data

Rules of Thumb (Approx.)

- At 3600 RPM a motor develops 1.5 lb.ft. per HP of torque at Rated HP Output.
- At 1800 RPM a motor develops 3 lb.ft. per HP of torque at Rated HP Output.
- At 1200 RPM a motor develops 4.5 lb.ft. per HP of torque at Rated HP Output.
- At 900 RPM a motor develops 6 lb.ft. per HP of torque at Rated HP Output.
- At 575 RPM a 3 phase motor draws 1 amp per HP at Rated HP Output.
- At 460 RPM a 3 phase motor draws 1.25 amp per HP at Rated HP Output.
- At 230 RPM a 3 phase motor draws 2.5 amp per HP at Rated HP Output.

Temperature Conversion Table
Centigrade - Fahrenheit

Fahrenheit to Centigrade				Centigrade to Fahrenheit			
°F ◄──► °C		°F ◄──► °C		°C ◄──► °F		°C ◄──► °F	
0	-17.8	105	40.6	0	32	105	221
5	-15	110	43.3	5	41	110	230
10	-12.2	115	45.8	10	50	115	239
15	- 9.44	120	49	15	59	120	248
20	- 6.67	125	51.8	20	68	125	257
25	- 3.89	130	54	25	77	130	266
30	- 1.11	135	56.8	30	86	135	275
32	0	140	60	35	95	140	284
35	1.67	145	62.8	40	104	145	293
40	4.44	150	66	45	113	150	302
45	7.22	155	68.8	50	122	155	311
50	10	160	71	55	131	160	320
55	12.8	165	73.8	60	140	165	329
60	15.6	170	77	65	149	170	338
65	18.3	175	79.8	70	158	175	347
70	21.1	180	82	75	167	180	356
75	23.9	185	84.8	80	176	185	365
80	26.7	190	88	85	185	190	374
85	29.4	195	90.8	90	194	195	383
90	32.2	200	93	95	203	200	392
95	35	205	95.8	100	212	–	–
100	38	212	100				

Formulae:

Fahrenheit to Centigrade

$$(°F - 32)\,\frac{5}{9} = °C$$

Centigrade to Fahrenheit

$$\left(°C \times \frac{5}{9}\right) + 32 = °F$$

Adjustable Frequency Drive

And AC adjustable frequency drive (AFD) is an electronic device that delivers a combination of voltage and amperage at a selected frequency to an AC squirrel cage induction motor in order to develop a desired torque at a certain speed to drive the connected load effectively. There are several types of AFD's currently marketed and the most common types are pulse-width modulated (PWM), voltage-source inverter (VSI), current-source inverter (CSI), variable-voltage inverter (VVI), and gate-turnoff thyristor (GTO).

An AC squirrel-cage induction motor is designed to be energized by a symmetrical sine wave power source which is commonly encountered on constant frequency sources such as that which local power companies supply.

When an AFD is the main power source to the motor it subjects the motor to wave shapes other than true sinusoidal. Output from the AFD consists of small segments of square waves combined in an attempt to approach the sine wave. The most common are 6-step or 6-pulse and PWM inverters. A 6-step drive creates a wave with six equally spaced parts (one positive/one negative on each of the three phases) to form a cycle. A PWM drive creates a wave with several positive and negative segments of varying widths on each of the three phases to form a cycle. These nonsinusoidal waves contain numerous harmonics that could be detrimental to a motor. The harmonics cause additional heating of the motor windings and in some cases result in reduced torque capability of the motor. Operating the motor continuously below its design speed may not sufficiently dissipate the increased heat. Additionally, operating the motor continuously above its design speed, consideration must be given to torque capability as well as mechanical capability of the motor due to the increased centrifugal forces.

Many of our standard AC squirrel-cage induction motors operate successfully with adjustable frequency drive systems. In order to properly design and/or size a motor, the following must be defines:

1) Application – Variable torque or constant torque.
2) Operating Range – Expressed in RPM, frequency or both. This assuming constant volts per hertz up to base motor design frequency and constant voltage, constant horsepower above base motor design frequency. Consult factory on all 2-pole applications. Consult factory on all 4-pole applications above 75 Hz.
3) Torque Requirement – Expressed as the torque value or values required at a particular speed or throughout the operating speed range. Usually expressed as the base (sinusoidal) HP and RPM of motor required.

It is recommended that the size of the motor base rating not exceed 80°C by resistance at full load on a 60 Hz sinsusoidal input and utilize the class F insulation for the additional heating caused by the AFD application. Depending upon the application and motor enclosure required, dissipation of this excess heat must be considered.

Adjustable Frequency Drive

Note: Explosion-proof/dust ignition-proof enclosures are currently not U/L listed for use on AFD applications.

For a variable torque application, where the torque varies as the square of the speed, a standard 80°C rise unit in any enclosure could be utilized for operation from 6 to 75 Hz.

For a constant torque application, where the torque is required throughout the speed range, sizing and enclosure options are more restrictive. Depending on the enclosure construction, compensation for and dissipation of the additional heat can be accomplished by derating (oversizing) the motor, addition of an auxiliary blower, or both. In addition, a special rotor design may be necessary. Consult factory for availability and price.

Other Considerations

Voltage Spikes

A motor driven by an adjustable frequency drive is subjected to significantly larger peak voltage rates of rise. Modern power semiconductor devices such as insulted gate bipolar transistors (IGBT) feature faster switching cycles and steep edges of the width-modulated voltage pulses. The switching times are now commonly less than 1 microsecond with voltage rate of changes up to extremes of 10 KV/microsecond after the end of the diode current. This is very stressful to the insulation system. In particular, on our random wound, 600 volt insulation system the maximum peak voltage (voltage spike) must not exceed 1300 volts line to line. If this is exceeded, then a greater insulation system would need to be supplied resulting in higher cost and possible change in motor frame size.

Cable Length

Inverters produce peak voltages approximately 1.5 times the nominal voltage of the nominal supply voltage compared to 1.4 for a sinsusoidal power supply. In reality, the amplitude of voltage peaks can be even greater. This is due to the impedance mismatch between the cable and motor combined with long cables connecting the motor and drive. The AFD pulses can act like impulse waves on the motor cables resulting in reflection phenomena. This causes the peak voltage at the motor to be increased up to a theoretical limit of two times. Therefore, it is recommended that the cable length between the motor and drive be limited to fifty (50) meters.

Insulated Bearings

The AFD can induce voltages greater than 0.5 volts into the motor shaft and bearings. This results in many tiny pits forming in the bearing or shaft surfaces, ultimately causing failure. These shaft currents may not show up on a sinusoidal system. Therefore, when a motor is to be used in conjunction with an AFD, it is recommended that the non-drive end bearing be insulated to break the circuit.

Adjustable Frequency Drive

Other Types of Drive Applications:

A) 12-Pulse AFD – This type of drive uses twelve parts to form the three voltage waves. To accomplish this requires a 30 degree phase displacement. In some instances, the drive manufacturer accomplishes this in the drive. Otherwise, the drive manufacturer will request that the motor be designed for this by having two sets of windings, 30 degrees phase displaced. Consult factory for availability and pricing.

B) Two PWM Drives on One Motor – This would involve utilizing two PWM drives firing in phase and connected to a single motor. To accomplish this, the motor would have to be designed with two sets of windings, but they will not be phase-displaced. This is known as parallel circuit. Consult factory for availability and pricing.

Vertical Motors – Index

Vertical Motors

General Comments

Vertical motors are used to drive pumps when there is a space limitation or when it is necessary to adjust the impeller setting without disturbing the motor mounting. Siemens builds vertical motors with the following enclosures for both solid and hollow shafts:

ODP & WPI	WPII	TEFC
500	500	500
580	580	580
30	30	30
36	36	-

Hollow shaft motors are generally used in conjunction with vertical turbine pumps and when it is desired to be able to do impeller setting from the top of the motor. Hollowshaft motors are not available for 2 pole ratings. Self-release or rigid coupling are available with an option for a non-reverse device with a rigid coupling.

Siemens builds vertical motors with a P-Base. BD dimensions are shown on the motor outline. BD is the NEMA designation for width of the base, bolt hole pattern, and rabbett fit. BD options are as follows:

FRAME	BD
500	24 1/2” or 30 1/2”
580	24 1/2” or 30 1/2”
30	30 1/2”
36	Refer to factory

On vertical turbine pump motors, a non-reverse backstop is usually specified to prevent the falling water column from causing the pump and motor to rotate in the reverse direction. When the pump setting is deeper than 300 feet, consult factory before quoting non-reverse backstops. Non-reverse backstops are available on hollow and solid shaft machines.
NON-REVERSE BACKSTOPS ARE NOT AVAILABLE ON 2 POLE MOTORS.

Vertical motors are designed with a thrust bearing and guide bearing system. Thrust bearings are always located in the upper bearing housing. Bearings used are deep groove ball bearings, single, tandem, or back to back angular contact ball, spherical roller bearing (water cooling required for 4 pole machines), or Kingsbury plate type (water cooling always required). The lower guide ball bearing is grease lubricated and locked to withstand momentary upthrust. Refer to factory for availability of oil lubricated lower guide bearings 30 frame only.

Vertical Motors

General Comments

NOTES:

1. In order to quote a vertical motor, we must know what thrust is applied by the pump. The bearing system is usually designed based on the continuous down thrust condition + required bearing life, so as a minimum we must have this information in order to quote (momentary down also known as shut-off condition and momentary up thrust should also be provided, if they exist). If the momentary down thrust exceeds 200% of the continuous condition, we will need duration of such thrust condition (typically 2 to 15 sec). If the customer cannot specify required thrust values, the bearing type and size will be selected to give a calculated 1 year B-10 (L-10) life and standard high thrust condition. We cannot guarantee the bearing design will support the actual thrust condition unless the actual thrust condition is defined.

FOR 3600 RPM MOTORS – REFER TO COMPANY FOR AVAILABILITY.

2. If we propose water cooled bearings, the bearings are based on a maximum “water in” temperature of 85˚F. If the actual job site water temperature is higher, a larger cooler may be required and must be specified on the order.

3. When a plate type thrust bearing, such a Kingsbury, is used, water cooling is always required and Siemens will specify maximum water pressure, pressure drop through the bearing oil cooler, and required water flow rate based upon the maximum “water in” temperature specified by the customer.

4. Any time we quote a pump motor or accept an order for a pump motor with as low as 80% voltage start (for 2 pole motors, consult factory before quoting less than 90% voltage start), we assume that the pump will be started with closed discharge valve since the torque requirement under this condition is considerably lower than for starting a pump on open valve (see Figure #2). If the customer requires an open valve start, the speed torque curve of the pump is needed in order to quote.

5. Efficiencies of vertical motors are specified without including the bearing losses due to the external thrust. This method of specifying efficiency is acceptable per NEMA Standards MG1-20.51 and IEEE-112 Method F with assigned stray*. The standard reads:
   In the case of motors furnished with thrust bearings, only that portion of the thrust bearing loss produced by the motor itself shall be included in the efficiency calculation.”

If a calculated efficiency value including bearing loss due to external thrust load is requested, refer to factory.

Vertical Motors

General Comments

NOTES: (Cont'd)

6. When ordering a hollow shaft motor, we must know the “BX” dimension. “BX” is the NEMA designation for coupling bore.

7. Non-reverse backstops are suitable for a maximum run-back torque equivalent to the motor’s torque at service factor and rated speed.

8. When ordering, base diameter (BD) must be specified.

*Per ANSI C50.41.

General Comments

Typical Speed-Torque Curve
(Centrifugal Pump)

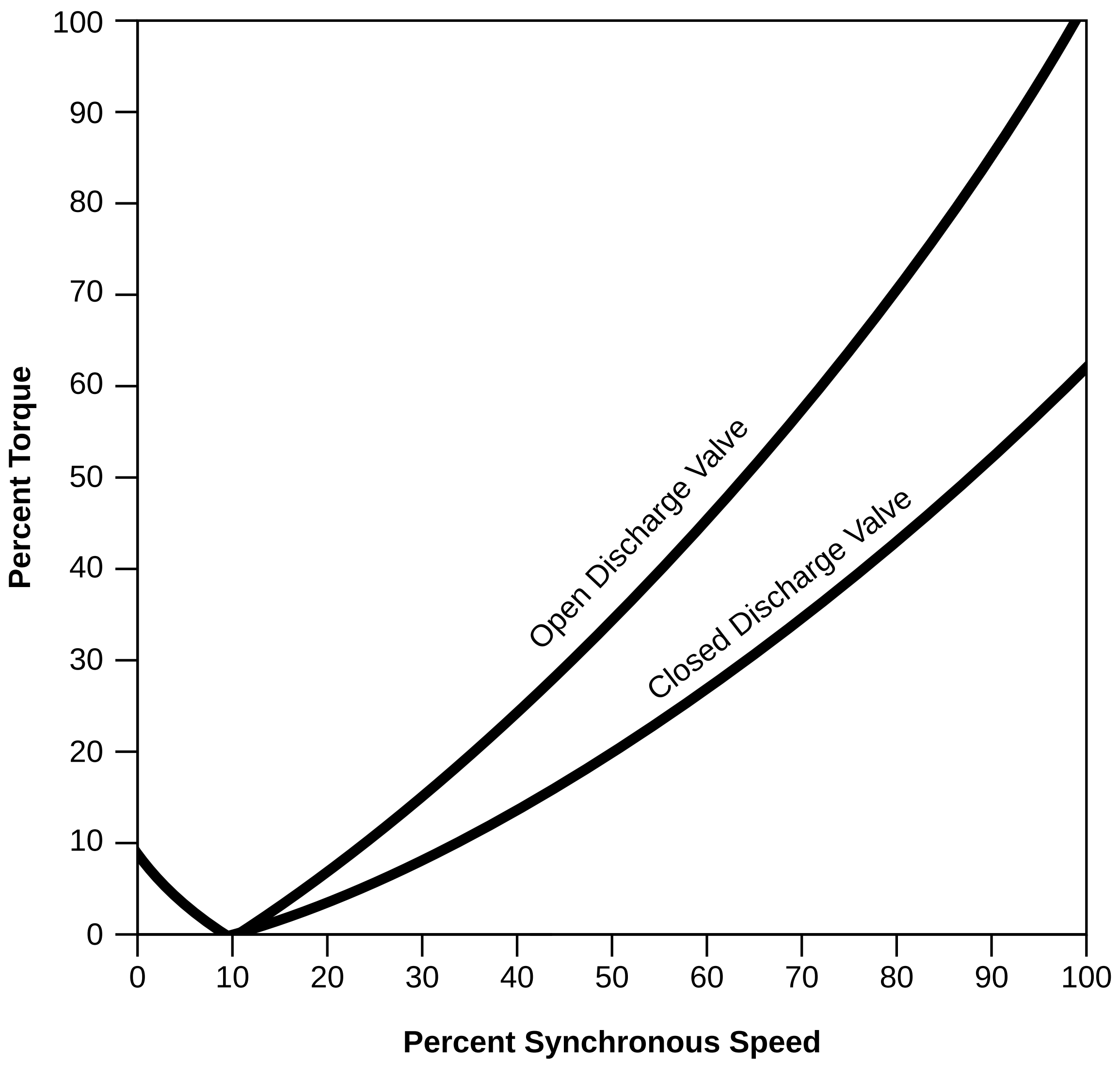


Figure 2

Vertical Frame Assignments

OPEN Enclosures

		Speed															
HP	**SF**	**3600 RPM – 2 Pole**				**1800 RPM – 4 Pole**				**1200 RPM – 6 Pole**				**900 RPM – 8 Pole**			
		Voltage															
		Low	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**
150	1.0		507				507				507				507		
	1.15		507				507				507				507		
200	1.0		507	507			507	507			507				507	507	
	1.15		507	507			507	507			507				507	507	
250	1.0		507	507			507	507			507	507		507	509	509	
	1.15		507	507			507	507			507	507		507	509	509	
300	1.0		507	507			507	507		507	507	507		509	509	509	
	1.15		507	507			507	507		507	507	507		509	509	588	
350	1.0		507	507	588		507	507	588	509	509	509	588	509	588	588	588
	1.15		507	507	588	505	505	507	588	509	509	509	588	509	588	588	588
400	1.0		507	507	588	505	507	509	588	509	509	509	588	588	588	588	588
	1.15		507	507	588	507	509	509	588	509	509	509	588	588	588	588	5810
450	1.0		507	507	588	507	509	509	588	509	509	588	588	588	588	588	5810
	1.15		507	507	588	507	509	509	588	509	588	588	588	588	588	588	30KK
500	1.0		509	509	588	509	509	509	588	588	588	588	588	588	588	588	30KK
	1.15	507	509	509	588	509	509	509	588	588	588	588	588	588	588	588	3020
600	1.0	507	509	509	588	509	509	509	588	588	588	588	5810	588	5810	5810	3020
	1.15	507	509	509	588	509	509	509	588	588	588	588	5810	5810	5810	5810	3020

Class B Temperature Rise by Resistance

Vertical Frame Assignments

OPEN Enclosures

HP	SF	Speed															
		3600 RPM – 2 Pole				1800 RPM – 4 Pole				1200 RPM – 6 Pole				900 RPM – 8 Pole			
		Voltage															
		Low	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**
700	1.0	509	509	509	588	509	588	588	5810	588	588	588	5810	5810	5810	5810	3020
	1.15	509	509	588	588	509	588	588	5810	588	588	588	30KK	5810	5810	5810	3023
800	1.0	588	588	588	5810	588	588	588	5810	588	588	5810	3020	5810	5810	5810	3023
	1.15	588	588	588	5810	588	588	588	5810	588	588	5810	3020	3020	3020	3020	3023
900	1.0		588	588	5810		5810	5810	5810		5810	5810	3020		3020	3020	
	1.15		588	588			5810	5810	3020		5810	5810	3020		3020	3020	
1000	1.0		5810	5810			5810	5810	3020		5810	5810	3020		3023	3023	
	1.15		5810	5810			5810	5810	3020		5820	3020	3023		3023	3023	
1250	1.0		5810	5810			5810	5810	3020		3020	3020	3023		3023	3620	
	1.15		5810	5810			5810	5810	3020		3020	3020	3023		3620	3620	
1500	1.0						5810	5810	3023		3023	3023			3625	3625	
	1.15						3020	3020			3023	3023			3625	3625	
1750	1.0						3023	3023			3620	3620			3630	3630	
	1.15						3023	3023			3625	3625			3630	3630	
2000	1.0						3620	3620			3625	3625			3630	3630	
	1.15						3620	3620			3630	3630			3633	3633	
2250	1.0						3620	3620			3630	3630			3633	3633	
	1.15						3625	3625			3630	3630					
2500	1.0						3625	3625			3630	3630					
	1.15						3625	3625									
3000	1.0						3630	3630									
	1.15						3630	3630									
3500	1.0						3630	3630									
	1.15																

Class B Temperature Rise by Resistance

Vertical Frame Assignments

TEFC Enclosure

		Speed															
HP	**SF**	**3600 RPM – 2 Pole**				**1800 RPM – 4 Pole**				**1200 RPM – 6 Pole**				**900 RPM – 8 Pole**			
		Voltage															
		Low	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**
150	1.0		507				507				507				507		
	1.15		507				507				507				507		
200	1.0		507	507			507	507			507	507		509	509	509	
	1.15		507	507			507	507			507	509		509	509	509	
250	1.0		507	507		507	507	507		509	509	509		588	588	588	
	1.15		507	507		507	507	507		509	509	509		588	588	588	
300	1.0	509	509	509		507	507	507		509	509	509		588	588	588	
	1.15	509	509	509		509	509	509		509	588	588		588	588	588	
350	1.0	509	509	509		509	509	509	588	588	588	588	5810	588	5810	5810	5810
	1.15	509	509	509		509	509	509	588	588	588	588	5810	588	5810	5810	5810
400	1.0	509	509	509		509	588	588	588	588	588	588	5810	588	5810	5810	5810
	1.15	509	509	509		588	588	588	5810	588	588	588	5810	5810	5810	5810	30L
450	1.0	509	509	509	5810	588	588	588	5810	588	588	588	5810	5810	5810	5810	30L
	1.15	588	588	588	5810	588	588	588	5810	588	588	5810	5810	5810	5810	30KK	30L
500	1.0	588	588	588	5810	588	588	588	5810	588	5810	5810	5810	30KK	30KK	30KK	30L
	1.15	588	588	588	5810	588	588	588	5810	588	5810	5810	30LL	30L	30L	30L	30LL
600	1.0	588	5810	5810	5810	588	588	588	5810	5810	5810	5810	30LL	30L	30L	30L	30LL
	1.15	5810	5810	5810	5810	588	588	5810	5810	5810	30KK	30KK	30LL	30L	30L	30L	
700	1.0	5810	5810	5810	5810	5810	5810	5810	5810	30L	30KK	30KK	30LL	30L	30L	30L	
	1.15	5810	5810	5810		5810	5810	5810	3020	30L	30L	30L		30LL	30LL	30LL	
800	1.0	5810	5810	5810		5810	5810	5810	3020	30L	30L	30L		30LL	30LL		
	1.15	5810	5810	5810		5810	30JJ	30JJ	3023	30LL	30L	30LL					
900	1.0		5810	5810			30JJ	30JJ	3023		30L	30LL					
	1.15						3020	3020			30LL	30LL					
1000	1.0						30JJ	3020			30LL						
	1.15						3020	3023									
1250	1.0						3023	3023									
	1.15						3023	3023									

Vertical Frame Assignments

Explosion-Proof Enclosure

		Speed															
HP	**SF**	**3600 RPM – 2 Pole**				**1800 RPM – 4 Pole**				**1200 RPM – 6 Pole**				**900 RPM – 8 Pole**			
		Voltage															
		Low	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**	**Low**	**2300**	**4000**	**6600**
100	1.0		507				507										
125	1.0		507				507				507				507		
150	1.0		507				507				507				507		
200	1.0		507	507			507	507			507	507		509	509	509	
250	1.0		507	507			507	507		509	509	509		509	509	509	
300	1.0	509	509	509			509	509		509	509	509		30E	30E	30E	
350	1.0	509	509	509		509	509	509	30B	509	30E	30E	30E	30E	30E	30E	30KK
400	1.0					509	30B	30B	30B	30E	30E	30E	30KK	30E	30E	30E	30L
450	1.0					509	30B	30B	30B	30E	30E	30E	30KK	30E	30KK	30KK	30L
500	1.0					30B	30B	30B	30JJ	30E	30KK	30KK	30L	30KK	30KK	30KK	30L
600	1.0					30B	30B	30B	30JJ	30KK	30KK	30KK	30LL	30L	30L	30L	30LL
700	1.0					30JJ	30JJ	30JJ	30JJ	30L	30KK	30KK	30LL	30L	30L	30L	3030
800	1.0					30JJ	30JJ	30JJ	3020	30L	30L	30L	3030	30LL	30LL	3030	
900	1.0						30JJ	30JJ	3023		30L	30LL	3030		3030	3030	
1000	1.0						30JJ	3020	3030		30LL	3030					
1250	1.0						3023	3023			3030	3030					
1500	1.0						3030	3030									
1750	1.0						3030	3030									

Class B Temperature Rise by Resistance

Vertical Motor Construction Features
Open Dripproof and Weather-Protected Types I & II Enclosures
Type CGV & CGIIV 500 and 580 Frame

AIR DEFLECTORS – Fiberglass.

BEARINGS:

Thrust (top housing)
- Angular contact ball bearings, oil lubricated and air cooled.
- For higher thrust loads, spherical roller bearings are available, water cooling is required at 4 pole speeds.
- Kingsbury bearings, oil lube and water cooled are available. The Kingsbury bearing is furnished with a solid sleeve upper guide bearing.
- Grease lube deep groove ball bearings available for very low thrust conditions

Guide (bottom housing) – Ball Bearing, grease lubricated.

BEARING HOUSING: Cast iron. Multiple drain holes provided in lower housing.

BEARING SEALS: Cast iron, steel, or aluminum

CONDUIT BOX: Cast iron or wrought steel with gasketed cover which will meet or exceed the minimum requirements of the National Electrical Code and NEMA Standards MG1 and MG2.

FLANGE HOUSING: P-Base Standard

HARDWARE: Zinc plated Grade 5 steel hex head bolts and cap screws.

RATCHET: – Non-Reverse, if specified, is ball type located in the lower end of motor. (Available as option on 4 pole and slower motors)

ROTOR:
- Die cast aluminum rotors are standard.
- Copper is an available option. Copper bars are induction brazed to end connector. Steel slot liners are sized to ensure rotor bars are tight in slots.
- Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotatingelement. Unidirectional fans on 2-pole motors.

SCREENS: – Included in standard construction.

Vertical Motor Construction Features
Open Dripproof and Weather-Protected Types I & II Enclosures
Type CGV & CGIIV 500 and 580 Frame (Cont'd)

SHAFT:	–	Hot rolled carbon steel.
STATOR CORE:	–	Laminations made from high grade silicon steel stacked and compressed with unitized core construction keyed to yoke.
STATOR WINDING:	–	Form wound stators are vacuum pressure impregnated and dipped in epoxy varnish.
	–	Random wound coils are dipped in polyester varnish.
YOKE	–	Cast iron with flange mounting.
VENTILATION	–	The air intakes are on the upper and lower bearing brackets with discharges through openings located in the middle of yoke.

Vertical Motor Construction Features
Open Dripproof and Weather-Protected Types I & II Enclosures
Type GV and FODV – 30 & 36 Frames

AIR DEFLECTORS: – Fiberglass used on most motors. Steel is used on some 30 frames.

BEARINGS:

Thrust (top housing)
- Angular contact ball bearings, oil lubricated and air cooled.
- For higher thrust loads, spherical roller bearings are available, water cooling is required at 4 pole speeds.
- Kingsbury bearings, oil lube and water cooled are available. The Kingsbury bearing is furnished with a solid sleeve upper guide bearing.

Guide
(bottom housing)
- Ball Bearing, grease lubricated are standard.
- Oil lubricated ball bearings are available
- Oil lube split sleeve bearings available ONLY WHEN KINGSBURY THRUST BEARING IS SUPPLIED

BEARING HOUSING: Cast iron or fabricated steel.

BEARING SEALS: Cast iron, steel, or aluminum.

CONDUIT BOX: Cast iron or wrought steel with gasketed cover which will meet or exceed the minimum requirements of the National Eletrical Code and NEMA Standards MG1 and MG2.

DRIP COVER: – Sheet Steel.

FLANGE HOUSING: – P-Base Standard.

HARDWARE: – Zinc plated Grade 5 steel hex head bolts and cap screws.

RATCHET: – Non-Reverse device is available as option, if specified. Refer to factory for location of device.

Vertical Motor Construction Features
Open Dripproof and Weather-Protected Types I & II Enclosures
Type GV and FODV – 30 & 36 Frames (Cont'd)

ROTOR:	–	Copper bar rotors are standard on most 30 frames and all 36 frames. Copper bars are induction brazed to end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots.
	–	Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element.
SCREENS:	–	Included in standard construction.
SHAFT:	–	Hot rolled carbon steel.
STATOR CORE:	–	Laminations made from high grade silicon steel stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring.
STATOR WINDING:	–	Form wound stators are vacuum pressure impregnated and dipped in epoxy varnish.
YOKE	–	Cast iron with flange mounting. Drain hole provided.

Vertical Motor Construction Features
TEFC Enclosure
Type CGZV – 500 and 580 Frame

BEARINGS:

Thrust (top housing)
- Angular contact ball bearings, oil lubricated and air cooled.
- For higher thrust loads, spherical roller bearings are available, water cooling is required at 4 pole speeds.
- Kingsbury bearings, oil lube and water cooled are available. The Kingsbury bearing is furnished with a solid sleeve upper guide bearing.
- Grease lube deep groove ball bearings available for very low thrust conditions

Guide (bottom housing) – Ball Bearing, grease lubricated.

BEARING HOUSING: Cast iron.

BEARING SEALS: Cast iron, steel, or aluminum.

CONDUIT BOX: Cast iron or wrought steel with gasketed cover which will meet or exceed the minimum requirements of the National Electrical Code and NEMA Standards MG1 or MG2.

DRIP COVER: Cast iron.

FAN HOUSING: Fiberglass is standard. Cast iron is available as special.

FLANGE HOUSING: – P-Base Standard.

HARDWARE: – Zinc plated Grade 5 steel hex head bolts and cap screws.

RATCHET: – Non-Reverse, if specified, is ball type located in the lower end of motor. (Available as option on 4 pole and slower motors.)

Vertical Motor Construction Features
TEFC Enclosure
Type CGZV – 500 and 580 Frame (Cont'd)

ROTOR:
- Die cast aluminum rotors are standard on all 500 frame and most 580 frames.
- Copper is an available option. Copper bars are induction brazed to end connector. Steel slot liners are sized to ensure rotor bars are tight in slots.
- Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element.
- Unidirectional fans on 2-pole motors.

SHAFT:
- Hot rolled carbon steel.

STATOR CORE:
- Laminations made from high grade silicon steel stacked and compressed with unitized core construction keyed to yoke.

STATOR WINDING:
- Form wound stators are vacuum pressure impregnated and dipped in epoxy varnish.
- Random wound coils are dipped in polyester varnish.

YOKE
- Cast iron with flange mounting.

Vertical Motor Construction Features
TEFC Enclosure
Type AZV – 30 Frame

BEARINGS:

Thrust (top housing)
- Angular contact ball bearings, oil lubricated and air cooled.
- For higher thrust loads, spherical roller bearings are available, water cooling is required at 4 pole speeds.
- Kingsbury bearings, oil lube and water cooled are available. The Kingsbury bearing is furnished with a solid sleeve upper guide bearing.

Guide (bottom housing)
- Ball Bearings, grease lubricated are standard. Oil lube ball bearings are available.

BEARING HOUSING: Fabricated Steel.

BEARING SEALS: Cast iron, steel, or aluminum.

CONDUIT BOX: Cast iron or wrought steel with gasketed cover which will meet or exceed the minimum requirements of the National Electrical Code and NEMA Standards MG1 or MG2.

DRIP COVER: Sheet Steel.

FAN HOUSING: Fabricated Steel.

FLANGE HOUSING: – P-Base Standard.

HARDWARE: Zinc plated Grade 5 steel hex head bolts and cap screws.

RATCHET: – Non-Reverse device is available as option, if specified. Refer to factory for location of device.

ROTOR:
- Copper bars are standard on most 30 frames. Copper bars are induction brazed to end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots.
- Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element.

SHAFT: – Hot rolled carbon steel.

Vertical Motor Construction Features
TEFC Enclosure
Type AZV – 30 Frame (Cont'd)

STATOR CORE: – Laminations made from high grade silicon steel stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring.

STATOR WINDING: – Form wound stators are vacuum pressure impregnated and dipped in epoxy varnish.

– Random wound coils are dipped in polyester varnish.

YOKE: – Fabricated Steel.

Vertical Motor Construction Features
Explosion-Proof Enclosure
RGZZV – 500 Frames and AZZV – 30 Frames

BEARINGS:

Thrust (top housing)
- Angular contact ball bearings, oil lubricated and air cooled.
- For higher thrust loads, spherical roller bearings are available, water cooling is required at 4 pole speeds.
  *30 Frame Only – Consult factory on the availability of Kingsbury thrust bearing.

Guide (bottom housing)
- Ball Bearing grease lubricated is standard. Oil lubricated bottom bearing available on 30 frame only.

BEARING HOUSING: Cast iron.

BEARING SEALS: Meets Underwriters Laboratories requirements.

CONDUIT BOX: Cast iron or wrought steel which meets UL requirements.

DRIP COVER: Sheet Steel.

FAN HOUSING: Cast iron or fabricated steel.

FLANGE HOUSING: P-Base Standard.

HARDWARE: Zinc plated Grade 5 or stronger steel hex head bolts and cap screws.

RATCHET: Consult Factory for availability.

ROTOR:
- Die cast aluminum rotors are standard on most 500 frames.
  Copper bar is an option. Uni-directional fans on 2 pole machines.
- Copper bars are standard on most 30 frames. Copper bars are induction brazed to end connectors. Steel slot liners are sized to ensure rotor bars are tight in slots.
- Special corrosion resistant epoxy coating on rotor and shaft for added protection of rotating element.

SHAFT: Hot rolled carbon steel.

Vertical Motor Construction Features
Explosion-Proof Enclosure
RGZZV – 500 Frames and AZZV – 30 Frames (Cont'd)

STATOR CORE: – Laminations made from high grade silicon steel stacked, compressed and keyed in yoke. Secured in place by heavy retaining ring and welded snap ring.

STATOR WINDING:
- – Form wound stators are vacuum pressure impregnated and dipped in epoxy varnish.
- – Random wound coils are dipped in polyester varnish.

YOKE: Cast iron on 500 Frame; fabricated steel on 30 Frames

NOTE: MOTORS WILL CARRY THE UL LABEL.

Vertical Motor Construction Features
Hollow Shaft

Construction is comparable to solid shaft motors except for the hollow shaft and either a self-release or rigid coupling that is mounted on the upper end of the motor shaft. The type of coupling and coupling bore must be specified.

The self-release coupling is a two-part coupling that is pinned together. If phase reversal or other occurrences cause reversal in direction of rotation of the motor, the pump line shaft will start to unscrew itself. This will lift the upper half of the coupling from the lower half, disengaging pump shaft from motor, preventing the pump from reversal.

A rigid coupling can be furnished without or with an optional non-reverse device. The type of non-reverse device available depends on the torque requirements and motor frame size. The non-reverse

device may be a ball type located in the lower end of the motor (typical on 500 & 580 frames) or it may be a Formsprag clutch located on the top of the motor (typical on 30 frames). The non-reverse device prevents reversal rotation of the motor and pump line shaft.

Hollow shaft construction allows adjustment of pump shaft so impeller clearance tolerance can be maintained.

Hollow shaft motors are not available for 2 pole speeds.

Hollow shaft motors are available in all enclosures except Explosion-proof.

Hollow Shaft Type Designations			
Frame	**WPI**	**WPII**	**TEFC**
500/580	CGHS	CGIIHS	CGZHS
30	HSHG	HSFOD	HSZ
36	HSHG	HSFOD	-

Vertical Motor Bearings

When considering the application of vertical motors, perhaps one of the most important characteristics is the selection of proper bearings to facilitate the application. Unlike horizontal motors, vertical motors are subjected to external thrust. This thrust is in the form of downthrust. Please note the following data is for informational purposes. Because of the complexity of the vertical motor application and corresponding sizing of bearing types, all vertical motor inquiries should be sent to the Norwood plant for review and quotation.

The thrust is typically in the form of the following components: continuous (design) downthrust, momentary downthrust, and momentary upthrust. The continuous downthrust that the motor bearing is subjected to is the component that is utilized to size the upper (thrust) bearing. The lower (guide) bearing is normally a grease lubricated deep groove anti-friction bearing. Below is a chart with the various bearing options that can be applied to each frame. No one bearing can be considered standard and not all bearings can be used on each application since the selection is often contingent upon the thrust and life requirements. Following the chart you will find a description of the most common bearing types.

FRAME SIZE	**500**	**580**	**30**	**36**
Deep Groove Ball	A	A	N/A	N/A
Angular Contact	A	A	A	A
Back To Back Angular Contact	A	A	A	A
Tandem Angular Contact	A	A	A	A
Spherical Roller	A1	A1	A1	A1
Kingsbury Type	A2	A2	A2	A2

N/A = Not Available
A = Available
A1 = Available but 4 pole motors must have water cooling for bearings
A2 = Available but water cooling is required for all speeds

Due to the especially harsh application of vertical thrust bearings at very high rotational speeds, all 3600 RPM applications must be referred to the factory for quotation and application.

Vertical Motor Bearings

Angular Contact Bearing:

Angular contact bearings can accommodate load in one direction only. This bearing has one high and one low shoulder on each ring enabling a 40 degree contact angle (see figure 1) and therefore the bearing is capable of moderate load carrying capabilities.

Tandem Angular Contact Bearing:

A tandem angular contact bearing is in reality two angular contact bearings mounted so that the thrust carrying capabilities are in the same direction. It has been determined by the bearing manufacturers that this arrangement has approximately 60% more capacity than a single bearing.

Spherical Roller Bearing:

When thrust loads are very high and exceed the capacity of practical multiple mounting of angular contact bearings, spherical roller bearings are used. Spherical roller thrust bearings transmit the load from one raceway to the other at an angle to the bearing axis. They are self-aligning and are insensitive to shaft deflections. Spherical roller bearings incorporate a large number of asymmetrical rollers and are suitable for very heavy axial loads and relatively high speed operations.

Kingsbury Thrust Bearing:

The highest thrust compatible bearing is the Kingsbury thrust bearing. The Kingsbury thrust bearing transmits thrust loads through a self renewing film of oil during operations. The load is distributed among the shoes of the bearing through a force balancing system. Working surface only touches during starting and stopping of the machine, otherwise, the surfaces are separated by the fluid film. The basic elements of the bearing are as follows:

A thrust collar is attached to the shaft and transmits the load from the rotating shaft to the bearing shoes. Stationary pivoted shoes contain a body of carbon steel, a shoes support of hardened steel, and a babbitt face. The shoe is loosely constrained so free pivoting can occur. Under hydrodynamic forces the shoe inclines and forms a wedge channel for the oil film to ride in. Pressure is generated as the fluid is carried through this channel and the thrust collar rides on a film of fluid, thus supporting the entire thrust load.

Vertical Motors
External Thrust Capacities

Maximum Continuous Down Thrust

Down thrust load for each bearing typed is based upon the following:
1. One year L10 minimum life (8760 hours)
2. Five year average life (43,800 hours)
3. Oil lubricated thrust bearing

	Bearing Type		
Speed	**Single Angular Contact Pump Thrust (Lbs.)**	**Tandem Angular Contact Pump Thrust (Lbs.)**	**Spherical Roller Thrust Pump Thrust (Lbs.)**
500 Frame			
1800	8400	14,000	30,000*
1200	9800	16,000	35,000
900	10,900	18,000	40,000
580 Frame			
1800	7500	13,700	30,000*
1200	8700	15,000	35,000
900	9900	17,000	...40,000
30 Frame			
1800	11,900	20,800	35,000
1200	14,000	24,500	40,000
900	15,600	27,300	45,000

1. *Water cooling is required
2. Lower guide bearings are locked for momentary upthrust of 30% of rated pump thrust.

Maximum continuous down thrust plate type (Kingsbury) thrust bearings**

	500 Frame	**580 Frame**		**30 Frame**
Speed	**Pump Thrust**			
	WPI/II (Lbs.)	**WPI/II (Lbs.)**	**TEFC (Lbs.)**	**WPI/II (Lbs.)**
1800	21,200	29,000	20,700	31,100
1200	19,700	35,000	18,900	29,250
900	18,700	33,000	18,000	27,500
720	17,900	32,000	17,200	26,500
600	17,200	31,000	16,500	25,900
514	16,700	30,000	16,000	25,500

**Based on a vertical solid shaft machine. For vertical hollow shaft with Kingsbury bearings refer to factory.
All Kingsbury bearings require water cooling.

Vertical Motor

Bearing Life Multipliers

In order to obtain increased anti-friction bearing life, it is necessary to reduce the thrust load on the bearings. To obtain the thrust load for a given L10 life, determine the multiplier using the bearing type and motor speed. Multiply the one-year L10 pump thrust by the correct multipliers to obtain the equivalent thrust for the longer minimum L10 life. Values shown below are approximate.

Angular Contact Thrust Bearing				
Hours	**Years**	**1800**	**1200**	**900**
17500	2	.75	.75	.76
26000	3	.59	.60	.61
44000	5	.46	.48	.49
100000	11	.32	.35	.36
SPHERICAL ROLLER THRUST BEARING				
17500	2	.80	.80	.80
26000	3	.67	.67	.67
44000	5	.57	.57	.57
100000	11	.45	.45	.44

Typical Electrical Performance Data

Due to the vertical bearing system losses, efficiencies will be lower than a horizontal motor. Use the following chart and formula for the specific project bearing system and deduct from horizontal data found in Section 5.

Bearing	**Single Angular Contact**		**Tandem Angular Contact**		**Spherical Roller**	
Frame	500 / 580	30	500 / 580	30	500 / 580	30
1800 RPM	.78 HP	1.7 HP	1.56 HP	3.4 HP	1.88 HP	2.68 HP
1200 RPM	.42HP	.89 HP	.84 HP	1.78 HP	.98 HP	1.37 HP
900 RPM	.27 HP	.59 HP	.54 HP	1.18 HP	.62 HP	.91 HP

Examples:

1. 200 HP, 1800 RPM, WPI 500 frame with single angular contact thrust bearing.

Efficiency Reduction: .78 / 200 = .004 or 0.4% at full load
.78 / 150 = .005 or 0.5% at 3/4 load
.78 / 100 = .008 or 0.8% at 1/2 load

	Full Load	3/4 Load	1/2 Load
Horizontal Typical Efficiency Data	92.5%	92.3%	91.0%
Reduction:	- 0.4%	- 0.5%	- 0.8%
Vertical Typical Efficiency Data	92.1%	91.8%	90.2%

2. 800 HP, 1200 RPM, WPI 580 frame with tandem angular contact thrust bearing.

Efficiency Reduction: .84 / 800 = .001 or 0.1% at full load
.84 / 600 = .002 or 0.2% at 3/4 load
.84 / 400 = .002 or 0.2% at 1/2 load

	Full Load	3/4 Load	1/2 Load
Horizontal Typical Efficiency Data	94.8%	95.4%	95.6%
Reduction:	- 0.1%	- 0.2%	- 0.2%
Vertical Typical Efficiency Data	94.7%	95.2%	95.4%

3. 700 HP, 1800 RPM, TEFC 500 frame with spherical roller thrust bearing.

Efficiency Reduction: 1.88 / 700 = .003 at full load
1.88 / 525 = .004 at 3/4 load
1.88 / 350 = .006 at 1/2 load

	Full Load	3/4 Load	1/2 Load
Horizontal Typical Efficiency Data	95.2%	95.1%	94.5%
Reduction:	- 0.3%	- 0.4%	- 0.6%
Vertical Typical Efficiency Data	94.9%	94.7%	93.9%

Vertical Motor Weights

Approximate Total Motor Weight

Frame	WPI	WPII	TEFC
507	4200	4500	4700
509	4900	5300	4900
588	6500	6800	-
5810	7600	7900	-
30KK	-	-	8200
30JJ	-	-	8200
30L	-	-	9500
30LL	-	-	10300
3020	6200	8200	-
3023	6800	8900	-
3620	13000	13000	-
3625	13200	13200	-
3630	13500	13500	-
3636	15500	15500	-

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Our mission is to achieve total customer satisfaction by exceeding the requirements of our external and internal customers in all products, processes and services every time.

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The TÜV-Zertifizierungsgemeinschaft e.V.
hereby certifies that

Siemens Energy & Automation, Inc.
Industrial Products Division
4620 Forest Avenue
Norwood, OH 45212, USA

has established and applies
a quality system for

Design and Manufacture of Large Electric Motors to meet Standard and Special Applications.

An audit was performed, Report No. **6592**

Proof has been furnished that the requirements according to

ISO 9001 / ANSI/ASQC Q9001-1994 / EN ISO 9001

are fulfilled

The certificate is valid until

August 1999

Certificate Registration No.

74 100 6592

Bonn, Germany, October 8, 1996
TÜV CERT Executive Board

TUV Rheinland
of North America, Inc.

Newtown, CT, October 8, 1996
TÜV CERT Certification Body of
TUV Rheinland of North America, Inc.