1931

Design of a 2 HP Repulsion Start Induction motor

Joseph Worley

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DESIGN OF A 2 HP REPULSION START INDUCTION MOTOR

by

Joseph Worley

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY

OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

DEGREE OF

ELECTRICAL ENGINEER

Rolla, Mo.

1931

Approved by

F. H. Frame

Professor of Electrical Engineering.
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The Repulsion Start Induction motor comprises a wound field or stator of laminated structure and a wound armature or rotor whose coils are connected to a commutator upon which brushes bear and function during the starting period.

This motor operates as a repulsion motor during the starting period and at a predetermined speed the short circuiting device actuates and short circuits the commutator. The motor then operates as an induction or squirrel cage type.

The starting torque of this type motor is exceptionally high, generally 300% to 400% of full load torque. Consequently this type of motor is regarded as having a high efficiency at start. The starting current is low which causes very little line disturbance. Due to this characteristic, this motor is recommended for general use by the Central Stations.

Due to the high starting torque characteristics, this motor is well adapted for applications such as air compressors, baker's machinery, concrete mixers and refrigeration service.
Design of a 2 HP Repulsion Start Induction Motor.

Required -

Quiet Operation
Efficiency 75% at rated load.
Power Factor 77% at rated load.
Starting Torque not less than 350%.
Maximum - 4 HP

40°C Rise by Thermometer on Armature.

Motor Data.

110/220 volt, 60 cycle operation. 1725 R.P.M.
Diameter of stator punchings 9.750"
Stator slots based on spacing of 32.
Connections, 2 circuits, 2 poles in series,
   4 poles series for 220 volt and series-
   parallel for 110 volt operation.
Number of rotor slots - 48
Number of bars in commutator - 48
Axial Width 4.000" over end fibre.
Rotor Twisted 1-1/2 slots.
Single Air Gap .020".


ELECTRICAL DESIGN

STATOR WINDING

The approximate flux per pole for a 2 HP motor which is to have a 4 HP maximum is 390,000 lines.

Then the number of turns required per pole is:

\[ N = \frac{55 \times 10^6 \times .95}{4.44 \times 60 \times .795 \times 390,000} \]

63 turns per pole.

Since the efficiency desired is 75%, the total watts input will be,

\[ \frac{746 \times 2}{.75} = 1990 \text{ watts.} \]

The power factor required is 77% which makes it possible to find the full load current, which is,

\[ \frac{1990}{220 \times .77} = 11.72 \text{ amperes} \]

In order to keep the heating at a minimum an allowance of 550 circular mils per ampere should be made. The proper size of wire for the stator is

\[ 550 \times 11.72 = 6460 \text{ Cir. Mils.} \]

This is approximately #12 Enamel and Cotton wire.
The stator winding is 63 #12 E&C per pole, or distributed properly and using 2 #15 E&C which can be handled with greater ease, the winding becomes - for the inside, middle and outside coils 18-22-23 (2/#15 E&C)

It is necessary at this point to consider the calculation of the stator magnetic circuit.

**MAGNETIC CIRCUIT CALCULATION**

**STATOR YOKE.**

Assume a working density of 68,500 lines per square inch. Then the thickness of the stator yoke will be,

$$\frac{390,000}{2 \times 3.937" \times .95 \times 68,500} = .760"$$

**STATOR TEETH**

Assume a density of 78,500 lines per square inch and since the teeth are to have a taper the minimum thickness of the teeth will be -

$$\frac{390,000 \times 1.57}{8 \times 78,500 \times 3.937" \times .95} = .280"$$

A check should be made at this time to determine if there is space available in stator punching for the winding. However, we find it necessary to determine the diameter of the rotor or bore of the stator. Should an under size armature be
chosen excessive heating will result. In some designs the \( D^2L \) or active material of the rotor is the determining factor. However, it is possible to determine directly the proper size by calculating the flux density in the air gap. By setting a limit to this value, it is possible to quickly determine the bore of the stator. In most designs it is good practice to allow 30,000 lines per square inch as density in the air gap.

Consequently, we get the pole pitch in this case

\[
\frac{390,000 \times 1.57 \times .95}{3.937 \times 30,000} = 4.94''
\]

From this we get the bore of the stator

\[
D = \frac{4.94'' \times 4}{3.1416} = 6.30''
\]

Rather than to use an odd size such as this, we select 6.250" as the bore.

A check should be made at this time to determine if there is available space in the field for the winding.

\[
\frac{2 \times 24 \times .651^2}{55} = .368 \text{ Square inch area required.}
\]

In order to keep the tooth tip vibration at a minimum, a thickness of .075" is allowed. The thickness of the tooth tip at the side of the slot is .125".

The slot depth is

\[
9.750'' -(2 \times .750'') = 8.230''.
\]

\[
6.250'' + (2 \times .125'') = 6.500''
\]

\[
1.730''
\]
\[ \frac{1.730}{2} = 0.865 \text{" slot depth} \]

\[ \frac{0.368}{0.865} \times 0.427 \text{" average width of slot} \]

\[ 0.427 + 0.050" \]

0.050" is allowed as slot taper.

The maximum tooth width is

\[ \frac{8.230 \times 3.1416}{32} - 0.477" = 0.329" \]

The minimum tooth width is

\[ \frac{6.500 \times 3.1416}{32} - 0.377" = 0.260" \]

The above value of 0.260" agrees with the value as previously calculated. Consequently we have ample slot capacity.

**ROTOR WINDING.**

In designing four pole 60 cycle Repulsion Induction Motors, the writer has always tried to use in the rotor approximately the same slot-turns as in the field and at the same time keeping in mind the cross section of the copper.

In this case we will use #16 E&C wire in the rotor. The number of turns per slot in the rotor are

\[ \frac{21 \times 6 \times 4 \times 3260 \times \frac{2}{48} \times 2580}{2} = 26.6 \]

Since we are using a 48 slot rotor with a 48 bar commutator the rotor winding is 13-25 #16 E&C.
MAGNETIC CIRCUIT CALCULATIONS

ROTOR TEETH

Assuming a density in the rotor teeth of 83,500 lines per square inch, we find the width of the rotor teeth to be

\[
\frac{390,000 \times 1.57 \times .95}{83,500 \times 3.937'' \times .95 \times 12} = .155''
\]

The flux density in the yoke of the rotor is

\[
\frac{390,000 \times .95}{2 \times 1.45'' \times 3.937'' \times .95} = 34,200 \text{ lines per sq. in.}
\]

CALCULATION OF AMPERE TURNS REQUIRED.

STATOR YOKE.

From the magnetization curve

68,500 lines per sq. in. = 4 amp. turns/inch.

\[
\frac{(9.750'' - .760'') \times 3.1416}{4} = 7.82'' \text{ length of path}
\]

7.82'' \times 4 = 31.28 ampere turns.

STATOR TEETH.

From the magnetization curve

78,500 lines per sq. in. = 6.25 amp. turns/inch.

.983'' \times 2 = 1.976'' length of path

1.976'' \times 6.25 = 12.32 ampere turns

AIR GAP.

.15 \times \frac{30,000 \times .020'' \times 2.54 \times 1.210}{6.45}

= 459.00 ampere turns.
ROTOR TEETH

From the magnetization curve
83,500 lines/sq. in. = 8.75 amp. turns/in.

.945" x 2 = 1.890" length of path
8.75 x 1.890 = 16.53 ampere turns

ROTOR YOKE.

From the magnetization curve
34,300 lines/sq. in. = 1.25 amp turns/in.

1.560" + 2.150" = 3.710" length of path.
1.25 x 3.710 = 4.63 ampere turns.

The total ampere turns required for the various parts of the magnetic circuit are:

Stator Yoke = 31.28
Stator Teeth = 12.32
Air Gap = 459.00
Rotor Teeth = 16.53
Rotor Yoke = 4.63

523.76

MAGNETIZING CURRENT

\[ I_{AT} = \frac{2 (523.76)}{1.8 \times .79 \times 252} = 2.92 \text{ amperes} \]

allowing 95% for cross flux current. The magnetizing current is -

2.92 x 1.95 = 5.70 amperes Mag. Current.
CALCULATION OF NO LOAD LOSSES

STATOR IRON LOSSES

STATOR YOKE.

The volume of the yoke expressed in kg is

\[
\frac{(4.875^2 - 4.114^2) \times 3.1416 \times 3.937'' \times .95 \times 16.4 \times 7.9}{1000}
\]

10.43 kilo grams.

The density of the yoke expressed in lines per sq. cm is -

\[
\frac{68,500}{6.45} = 10620 \text{ lines/sq. cm.}
\]

From the core loss curve we find the corresponding loss to be 3.25 watts per kg. The loss in the yoke is

\[
10.43 \times 3.25 = 33.9 \text{ watts.}
\]

STATOR TEETH

The volume of the stator teeth expressed in kilograms is -

\[
\frac{4 \times 6 \times .284 \times 3.937'' \times 16.4 \times 7.9 \times .989'' \times .95}{1000} + \frac{3.1416 \times (4.114^2 - 3.125^2) \times 3.937'' \times 16.4 \times 7.9 \times .95}{4 \times 1000}
\]

6.00 kilo grams.

The density of the teeth expressed in lines per sq. cm is -

\[
\frac{78500}{6.45} = 12180 \text{ lines/sq. cm.}
\]

From the core loss curve we find the corresponding loss to be 4.68 watts per kilogram. The loss in the teeth is -

\[
4.68 \times 6 = 28.08 \text{ watts.}
\]
COPPER LOSSES

STATOR WINDING RESISTANCE.

\[
R_F = \frac{1.20 \times 1.16 \times 8.00'' \times 2.54 \times 2 \times 252}{5700 \times 3.304} = 0.753 \text{ Ohms at } 40^\circ \text{ C.}
\]

ROTOR WINDING RESISTANCE.

\[
R_A = \frac{17'' \times 48 \times 4.48 \times 13}{12'' \times 1000} = 3.97 \text{ Ohms.}
\]

\[
R_A' = \frac{3.97 \times 252^2}{0.845^2 \times 624^2} = 0.908 \text{ Ohms.}
\]

The copper loss in the stator is -

\[
5.70^2 \times 0.753 = 24.5 \text{ Watts.}
\]

The copper loss in the rotor is -

\[
2 \left(\frac{5.70}{2}\right)^2 \times 0.908 = 14.7 \text{ Watts.}
\]

FRIC TIONAL LOSSES

BEARING LOSSES.

The commutator cover bearing loss in watts is -

\[
1.20 \left(0.875'' \times 2.125''\right) \left(\frac{1750 \times 3.1416 \times 0.875^{3/2}}{12 \times 1000}\right) = 17.9 \text{ watts.}
\]

The pulley cover bearing loss in watts is -

\[
1.20 \left(1.062'' \times 2.125''\right) \left(\frac{1750 \times 3.1416 \times 1.062^{3/2}}{12 \times 1000}\right) = 28.7
\]

The total bearing loss in watts is 46.6.

As it is difficult to determine the windage losses, 10% is added to the bearing loss which makes total frictional and windage loss 51.2 watts.
The brush friction loss may be expressed in the following:

\[
1.25 \times 4 (1 \times 0.281) \times 3.1416 \times 4.062'' \times 1750 \\
\frac{100}{12}
\]

= 26.2 Watts.

**SUMMARY OF LOSSES AT NO LOAD.**

Since the rotor runs a practically synchronous speed it is assumed that the rotor iron losses are negligible. There are additional losses which occur at the surface of the stator teeth and further losses due to eddy currents. It is generally assumed that these are approximately 75% of the stator iron losses.

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<tr>
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<td>Losses in Stator Teeth</td>
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<td><strong>Total No Load Watts</strong></td>
<td><strong>224.88</strong></td>
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**NO LOAD CURRENT.**

The component of the current due to the losses is:

\[
\frac{224.88}{220} = 1.02 \text{ Amperes.}
\]
This current should be added vectorially to the magnetizing current in order to determine the no load current.

\[ I = \sqrt{5.70^2 + 1.02^2} = 5.78 \text{ Amperes,} \]

No Load Power Factor = \( \frac{225 \times 100}{220 \times 5.78} = 17.68\% \)

**Calculation of Reactance.**

**Stator**

The permeance of the path of the stator slot leakage flux per cm. of the slot is -

\[ P_S = 1.25 \left( \frac{0.318'' - 0.047''}{3 \times 0.410''} + \frac{2 \times 0.050''}{0.377''} + \frac{0.075''}{0.110''} \right) = 2.095 \text{ Cms.} \]

The leakage flux per cm. length of end wire is -

\[ P_W = 0.46 \times 3 \left( \log \left( \frac{1.5 \times 4.50''}{3.97''} \right) \right) \times 2 \times 1.30 = 0.825 \text{ Cms.} \]

Expressed in terms of motor width it is -

\[ P_W^1 = \frac{0.825 \times 4.50''}{3.937''} = 0.945 \text{ Cms.} \]

The permeance due to the slot opening is -

\[ P_0 = 1.25 \left( \frac{0.316'' - 0.110''}{6 \times 0.200''} \right) = 2.245 \text{ Cms.} \]

The total permeance is 5.285 cms for the stator.

The reactance for the stator expressed in ohms is -

\[ 12.5 \times 60 \times 252^2 \times 3.937'' \times 2.54 \times 5.285 \times \frac{1}{2 \times 6 \times 10^6} = 2.125 \text{ Ohms.} \]

**Rotor**

The permeance of the path of the rotor slot leakage flux per cm of the slot is -
The permeance due to the end wire of an armature is generally .8 Cms for this case we get -

\[ P_E = \frac{.8 \times 4.50''}{3.937''} = .92 \text{ Cms.} \]

The permeance due to connections at the commutator is so small that it can be neglected.

The leakage flux due to the slot opening in the rotor expressed in Cms is -

\[ P_\text{leak} = 1.25 \left( \frac{.504'' - .090''}{6 \times .025''} \right) = 3.45 \text{ Cms.} \]

The total permeance for the rotor is 11.81 Cms. The reactance of the rotor expressed in terms of the stator is -

\[ 12.56 \times 60 \times 252^2 \times 3.937'' \times 2.54 \times 8.09 \times .79^2 \times .95^2 \]

\[ \frac{2 \times 12 \times 10^8 \times .845^2}{2} \]

\[ = 1.84 \text{ Ohms.} \]

The total reactance is 2.125 + 1.84 = 3.965 Ohms. The total impedance when the commutator is short-circuited and the rotor is at a stand-still is -

\[ Z = \sqrt{2.661^2 \times 3.965^2} = 4.30 \text{ Ohms.} \]

The blocked current for the above conditions will be -

\[ \frac{220}{4.30} = 51.2 \text{ Amperes} \]
The power factor blocked will be -

\[ \frac{1.661}{4.30} \times 100 = 38.8\% \]

The watts input to the motor for the locked and shorted commutator condition are

\[ 51.2^2 \times 1.661 = 4320 \text{ Watts}. \]

Having determined the no load current and power factor and the blocked current and power factor, it is possible to construct the circle diagram and check the maximum HP which the motor will develop. From this diagram it is possible to determine the power factor and efficiency for full load.

The writer has found that it is possible to approximate the maximum HP which the motor is capable of developing by using the values heretofore calculated in the following manner.

\[ \text{Max. HP} = \frac{220 \times (51.2 - 5.78) \times .85}{2 \times (1 + .388) \times 746} = 4.11 \text{ HP} \]

**C I R C L E D I A G R A M**

The circle diagram is constructed in the usual manner. Using the angle whose cosine is the no load power factor, the angle AOC is laid off and the no load current AC is measured according to a suitable scale. The angle COB corresponds to the power factor angle for blocked condition. The blocked current is measured on the line OB.
Through point A and parallel to the horizontal, the line AD is drawn. The line AE represents the no load watts. Through points A and B and using a point on the line AD, the circle is drawn. Since we know the resistance of the rotor and stator it is possible to separate the losses for blocked condition. The losses corresponding to any load can then be determined for the stator and rotor. The maximum HP which the motor will develop occurs where a line parallel to AB is tangent to the circle. The maximum power factor which the motor will have can be found by drawing a tangent to the circle through point O. By locating the point corresponding to the rated load, it is possible to determine the efficiency and power factor.

It was found that the circle diagram varies with the frame construction and the amount of twist either in the rotor or stator. Consequently, for the larger frames such as has been used in the design of recent motors, an approximate calculation has been used. Since the results are within 2% of actual test value, the writer chooses to use the following:

\[
\text{Max. HP} = \frac{16.3 (1 - .1992) 225}{746} = 3.950 \text{ HP}
\]

It is realized that this is not absolutely correct and further work and tests are continuing to determine if it is possible to construct the circle diagram so that the results will agree with the test data.
The writer has designed during recent years, Repulsion Start Induction and Polyphase motors ranging from 1/8 HP to 2 HP., for frequencies ranging from 25 to 60 cycles.

In the design of single-phase induction motors rated from 1/30 HP to 1/2 HP, the problem of sound condition has resulted in extensive noise tests. The writer remembers particularly an instance where it was found that 32 slots in the stator and 41 slots in the rotor resulted in an excellent sound condition. This combination was tried in a smaller and a larger motor in an effort to improve the noise condition. It was found that noisy operation resulted. Therefore sound not only is dependent upon the combination but also upon the size and shape of the frame. Of course in making the above statement, it is assumed that the various portions of the magnetic circuit are approximately the proper size and shape.
Performance Data Comparison
Predetermined - Actual Brake Test

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<th>No Load</th>
<th>Predetermined</th>
<th>Actual</th>
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</thead>
<tbody>
<tr>
<td>Current</td>
<td>5.78</td>
<td>5.75</td>
</tr>
<tr>
<td>Watts</td>
<td>225</td>
<td>236</td>
</tr>
<tr>
<td>Power Factor %</td>
<td>17.68</td>
<td>18.65</td>
</tr>
<tr>
<td>Full Load</td>
<td>2.00</td>
<td>2.025</td>
</tr>
<tr>
<td>Amperes</td>
<td>11.60</td>
<td>11.20</td>
</tr>
<tr>
<td>Watts</td>
<td>1965</td>
<td>2000</td>
</tr>
<tr>
<td>Efficiency %</td>
<td>76.0</td>
<td>75.5</td>
</tr>
<tr>
<td>Power Factor %</td>
<td>77.0</td>
<td>81.1</td>
</tr>
<tr>
<td>Maximum Pf. %</td>
<td>81.9</td>
<td>32.7</td>
</tr>
<tr>
<td>Maximum H.P.</td>
<td>3.95 &amp; 4.11</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Locked Rotor With
Commutator Shorted

| Watts                        | 4320          | 4120   |
| Amperes                      | 51.20         | 49.6   |
| Power Factor %               | 33.80         | 37.7   |

The starting torque of the final motor is 40% of the full load torque which should be ample starting torque for almost any condition.
Brake Test

Type IK9 AB-130-7440   E.P. 2   Date 8-5-30.
Volts 110/220   Phase 1   Cycles 60
Field Winding 18-21-23   (2 # 15) E&C
Field Iron 9724 A   Field Bore 6.252"
Arm. Winding 13 - 26   #16 E&C
Arm. Iron 6248-A   Diameter 6.211"
Arm. Twist 1-1/2 Slots   Commutator 48 Bars.

INDUCTION TEST

<table>
<thead>
<tr>
<th>Watts</th>
<th>Volts</th>
<th>Amps</th>
<th>RPM</th>
<th>Wt.</th>
<th>Arm.</th>
<th>H.P.</th>
<th>Eff.%</th>
<th>Pf.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>4700</td>
<td>220</td>
<td>29.5</td>
<td>1625</td>
<td>10</td>
<td>15(\frac{1}{2})</td>
<td>3.99</td>
<td>63.5</td>
<td>72.4</td>
</tr>
<tr>
<td>4100</td>
<td>220</td>
<td>24.0</td>
<td>1675</td>
<td>10</td>
<td>14(\frac{1}{2})</td>
<td>3.55</td>
<td>70.0</td>
<td>77.8</td>
</tr>
<tr>
<td>3275</td>
<td>220</td>
<td>18.0</td>
<td>1730</td>
<td>8</td>
<td>15</td>
<td>3.30</td>
<td>75.1</td>
<td>82.7</td>
</tr>
<tr>
<td>2000</td>
<td>220</td>
<td>11.2</td>
<td>1760</td>
<td>5</td>
<td>14(\frac{1}{2})</td>
<td>2.03</td>
<td>75.5</td>
<td>81.2</td>
</tr>
<tr>
<td>1560</td>
<td>220</td>
<td>9.45</td>
<td>1775</td>
<td>4</td>
<td>14</td>
<td>1.58</td>
<td>75.5</td>
<td>75.0</td>
</tr>
<tr>
<td>1100</td>
<td>220</td>
<td>7.65</td>
<td>1785</td>
<td>4</td>
<td>9</td>
<td>1.04</td>
<td>69.0</td>
<td>65.0</td>
</tr>
<tr>
<td>660</td>
<td>220</td>
<td>6.45</td>
<td>1790</td>
<td>2</td>
<td>9</td>
<td>.512</td>
<td>57.7</td>
<td>46.6</td>
</tr>
<tr>
<td>236</td>
<td>220</td>
<td>5.75</td>
<td>1795</td>
<td>No Load</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3400</td>
<td>220</td>
<td>32.8</td>
<td>Lift 16</td>
<td>18(\frac{1}{2})</td>
<td></td>
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</tbody>
</table>

BRUP 10   12
### REPULSION TEST

<table>
<thead>
<tr>
<th>Watts</th>
<th>Volts</th>
<th>Amp.</th>
<th>RPM</th>
<th>Wt.</th>
<th>Arm.</th>
<th>H.P.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2680</td>
<td>220</td>
<td>14.6</td>
<td>1030</td>
<td>10</td>
<td>16</td>
<td>2.61</td>
</tr>
<tr>
<td>3040</td>
<td>220</td>
<td>16.7</td>
<td>955</td>
<td>10</td>
<td>18.5</td>
<td>2.81</td>
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<tr>
<td>3280</td>
<td>220</td>
<td>18.0</td>
<td>900</td>
<td>10</td>
<td>20</td>
<td>2.86</td>
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<tr>
<td>3680</td>
<td>220</td>
<td>19.8</td>
<td>850</td>
<td>12</td>
<td>19</td>
<td>3.07</td>
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</table>

### MAGNETIZATION TEST

<table>
<thead>
<tr>
<th>Watts</th>
<th>Volts</th>
<th>Amp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>300</td>
<td>9.19</td>
</tr>
<tr>
<td>320</td>
<td>260</td>
<td>7.10</td>
</tr>
<tr>
<td>240</td>
<td>220</td>
<td>5.78</td>
</tr>
<tr>
<td>200</td>
<td>180</td>
<td>4.57</td>
</tr>
<tr>
<td>155</td>
<td>140</td>
<td>3.51</td>
</tr>
<tr>
<td>120</td>
<td>100</td>
<td>2.68</td>
</tr>
<tr>
<td>110</td>
<td>70</td>
<td>2.30</td>
</tr>
</tbody>
</table>

### HEAT RUN

<table>
<thead>
<tr>
<th></th>
<th>Rise ° C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>27.5</td>
</tr>
<tr>
<td>Field Iron</td>
<td>31.5</td>
</tr>
<tr>
<td>Arm. Iron</td>
<td>40.0</td>
</tr>
</tbody>
</table>

Joseph Worley/Louise Beiser.
IR-S-AB-130-7440

Worley-Harsley

2HP/10/220V 60Cy/1725RPM
F: 18-21-23 (2#/15E+C)
A: 13-26 #16E+C

Curve Sheet No. 2534
The Emerson Electric Mfg. Co.
St. Louis, Mo.

---

RPM

Torque Oz. Ft

Watts

Amps

Eff

P.F

RPM

On 220V

Blocked Torque 393 Oz. Ft
Blocked Amps 32.8
Temp Rise°C
Frame 2.75 50 50 800
Fl. Iron 31.5
Arm. Iron 40.0

H.P. Output
PLACEMENT IDENTIFICATION:

HOLE HERE MUST NOT BE LARGER THAN 5/32 IN. DIAM.
4 Poles - 24 Slot Field
48 Slot Arm. - 48 Bar Comm.
Arm. Lam. Shown Is On Comm. End
Slot #4 Is In Line With Mica Between
Bars #14 & 2 First Coil Is Wound In
Slots #14 & 11, Connect Start Of First
Coil To Bar #14, Finish To Bar #2.

IR 97-4 Pole
Winding Diagram.
The Emerson Electric Mfg. Co.,
St. Louis, U.S.A.
Scale Full Size No. 52969-A
Commutator Cover

Pattern # G218

IR9 AB-130 Bearing For

Bronze Casting

Fig. 8 Groove wide and deep crossing at Wick opening of each end of bearing.

Emerson Electric Mfg. Co.
St. Louis, U.S.A.

Scale: 1/4″ = 1 ft.

Ream 8.757" + 0002" in Mach Shop
Finish Ream 8.757" + 0002" in Mach Shop

IR9 AB-130-7440
**Bronze Casting**

(Fig. 8 Groove 8" wide 1/8" deep crossing at wick opening. Groove to extend to 1/2" of each end of bearing.)

**IR9 AB-130**

*Beading For Pulley Cover.*

The Emerson Electric Mfg. Co.,
St. Louis, U.S.A.

Scale full size. No. 50326-A
ASSEMBLED BRUSH

DR 94440 DG

Cemented shunt of approximately 105 strands of 36 wire to be twisted or braided.

MINIMUM: 990"
MAXIMUM: 1,000"

MINIMUM: 276"
MAXIMUM: 291"

3/8"

1/8"

3/2 Diameter