# Motor Acceleration Time Report for NEP MV Motors

**for**

## NEP Canada Inc

**Issued: 2016 October 26**

Prepared for:

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**of**

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Ref #: ES03383

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**Results Summary:**

Two motors were tested:

Toshiba 2500 hp 1182RPM
Frame 590-1400
4160 / 3 / 60 Volts 331 Amps FLC
Class F rise, Class H Insulation, Code F
Type TIKE SF 1.0
SN 060011007BH

IEM 1250 hp 1191 RPM
Frame 6808
4160 / 3 / 60 Volts, 155 Amps FLC
Code C
Type HWPI, SF 1.15
SN 8904001

An acceptable acceleration time for the **Toshiba 2500 hp motor is 38 seconds** and for the **IEM 1250 hp, it is 34 seconds** .

**Process:**

The design of an electric motor by North American NEMA standard specifies certain performance requirements in Standard MG1.

Specifically the motor must be able to run at full load current at design voltage and deliver nameplate horsepower without exceeding the temperature rise listed on the nameplate, or insulation class rise if there is no listing on the nameplate.

Further, the motor must be able to accelerate the inertia of the motor rotor, the coupling and load inertia without exceeding the temperature rise limits.

Using the procedure from IEEE Standard 112 Clause 7.3.2 Method 2, measuring the current, voltage rotational speed and time, the power, power factor, torque and rotor moment of inertia are calculated.

$$S=3V_{\phi}I_{\phi}$$
$$P=S\cos(\Theta)$$
$$T=P/\omega$$
$$J_M=T\Delta t/\Delta\omega$$

Where

**S** is the summed product of the phase voltage and the phase current expressed in VA

$\mathbf{V_{\phi}}$ is the phase voltage or $V_{\phi}\sqrt{3}$ if the voltage measured is $V_{LL}$ and is expressed in Volts

$\mathbf{I_{\phi}}$ is the measured phase current expressed in Amps

P is the power expressed in Watts

**cos(Θ)** is the power factor or cosine of the angle (Θ) between the phase current and phase voltage

**T** is torque expressed in N-m

**ω** is the angular velocity expressed in radians/second

$\mathbf{J_M}$ is the moment of inertia for the motor rotor expressed in $kgm^2$

**Δt** is a time difference expressed in seconds

Using these results and adding the design limits specified in NEMA MG1, we can then identify the acceleration time for the total moment of inertia. The temperature rise was then checked to be sure it remains within limits for at least two starts, another requirement of NEMA MG1.

The motor was started at reduced voltage after measuring the cold winding resistance and inductance. The temperature rise was measured and recorded. The three phase voltages, the three phase currents and the rotational velocity were measured and

recorded. The calculations were done according to the preceding formulae and the results recorded. The reduced voltage start was done due to limitations of the starting equipment and to ensure worst case starting conditions.

After the measurements had been taken the motor was shut down and allowed to coast to a stop. The final winding temperature was checked and recorded.

Another start was done and the winding temperature was recorded immediately before the start and upon completion of the start. The voltage was raised to nameplate voltage and held there for the remainder of the test. The losses due to friction, windage, $i^2R$ losses and core losses are measured and the motor was allowed to run with only the losses until the temperature stabilized. The temperature difference between the stabilized temperature and ambient represents the temperature rise from the motors watts lost. This temperature difference is affected by the relative humidity and ambient temperature.

The thermal capacity of the electric motor can be expressed as the energy required to raise the temperature of the motor mass per unit of temperature, or expressed mathematically as

$$C_{TM} = P \times dt/dT$$

or

$$C_{TM} = P \times \Delta t/\Delta T$$

where

**$C_{TM}$** is the thermal capacity of the motor

**P** is the power used by the motor to make heat expressed in watts

**$\Delta t$** is the time difference to reach temperature stability from starting temperature to stabilized temperature expressed in seconds

**$\Delta T$** is the temperature difference between the starting temperature and the final stabilized temperature expressed in °C

The total thermal energy that the motor can absorb for in this case Class H insulation is calculated using $C_{TM}$ and the rise for Class H insulation (185°C).

The energy required to accelerate the motor rotor and the NEMA MG1 design load inertia can then be calculated.

$$E = (((J_M + J_L) \times \Delta\omega / \Delta t_a) \times (V_{\phi R}/V_{\phi T})^2 \times \Delta\omega) \times \Delta t_a$$

where

E is energy expressed in Watt seconds

**$J_M$** is the moment of inertia for the motor rotor expressed in Kg-$m^2$

**$J_L$** is the moment of inertia for the load

$\Delta\omega$ is the change in rotational velocity expressed as radians/sec
$\Delta t_a$ is the acceleration time for the designed inertia
$V_{\phi R}$ is the rated voltage for the motor expressed in Volts
$V_{\phi T}$ is the test voltage used when the motor was tested expressed in volts

This was expressed as percent of the available thermal capacity.

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# MOTOR TORQUE CURRENT/SPEED ANALYSIS REPORT

| | | | |
|---|---|---|---|
| CUSTOMER: | NEP/MAC Engineering | DATE: | 2016 Oct 13 |
| LOCATION: | CEMSN Shop | JOB NUMBER: | ES03383 |
| SUBSTATION: | NA | EQUIPMENT ID: | NA |

## NAMEPLATE INFORMATION

| | | | | | |
|---|---|---|---|---|---|
| MANUFACT.: | Toshiba | HP/KW: | 2500 | / | 1865 |
| MODEL/TYPE: | TIKE | RPM: | 1182 | | |
| STYLE NO.: | NA | VOLTS/PHASES | 4160 | / | 3 |
| SERIAL NO.: | 060011007BH | FREQUENCY: | 60 | | |
| FLA: | 331 | FRAME: | 500-1400 | | |
| S.F.: | 1 | CODE LETTER: | F | | |
| RISE: | F | INS. CLASS: | H | | |

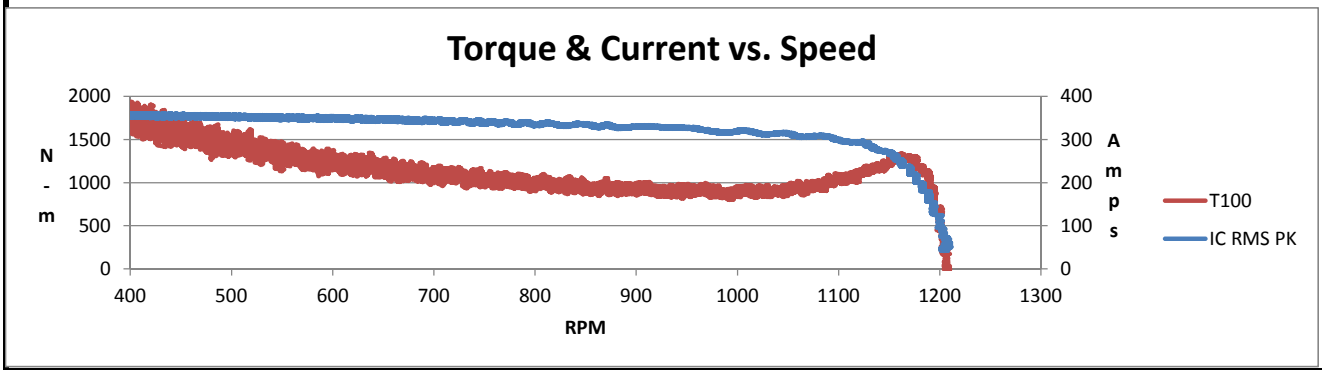
## BASIC MOTOR PARAMETERS

| | | | | | |
|---|---|---|---|---|---|
| Winding Res $R_1$ | 0.0000963 q | Winding Ind $L_1$ | 0.00904 H | Winding Imp $X_{L1}$ | 3 q |
| Ambient Temp $T_a$ | 18.6 °C | Winding Temp $T_c$ | 20.2 °C | | |
| Full Ld Torque $Ü_{FL}$ | 15068 N-m | *1 Des PU Tq $Ü_{PU}$ | 9041 N-m | *1 Des BD Tq $Ü_{BD}$ | 26370 N-m |
| Motor Inertia $J_M$ | 206 $Kgm^2$ | *1 Des Inertia Ld $J_L$ | 844 $Kgm^2$ | | |

## FIRST RUN

| | | | | | |
|---|---|---|---|---|---|
| Volts $V_{LL}$ | 899 V | Current $I_{ü}$ | 246 A | Speed qpn | 1200 rpm |
| Avg VA S | 382900 VA | Avg Watts P | 77000 W | Avg Vars Q | 375077.8719 Var |
| Avg Tq $Ü_M$ | 1011 N-m | Inertia $J_M$ | 206 $Kgm^2$ | | |
| Ambient Temp $T_a$ | 18.6 ºC | Wdg Temp Start $T_C$ | 20.2 ºC | Wdg Temp Pk $T_H$ | 21.2 ºC |
| Time Acc q$t_{acc}$ | s | | | | |

## τ/n I /n Curves




## COMMENTS

*1 NEMA MG1 Std.

| INSPECTED BY: | TEST DEVICE(S): |
|---|---|
| (PRINT NAME) | |
| (SIGNATURE) | |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## NAMEPLATE INFORMATION

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|---|---|---|---|---|---|
| MANUFACT.: | Toshiba | HP/KW: | 2500 | / | 1865 |
| MODEL/TYPE: | TIKE | RPM: | 1182 | | |
| STYLE NO.: | NA | VOLTS/PHASES | 4160 | / | 3 |
| SERIAL NO.: | 060011007BH | FREQUENCY: | 60 | | |
| FLA: | 331 | FRAME: | 500-1400 | | |
| S.F.: | 1 | CODE LETTER: | F | | |
| RISE: | F | INS. CLASS: | H | | |

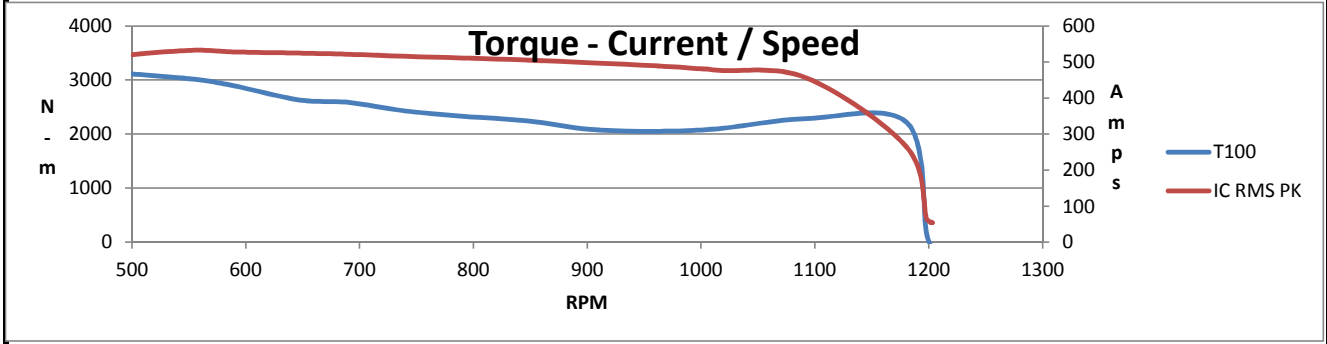
## SECOND RUN

| | | | | | |
|---|---|---|---|---|---|
| Volts $V_{LL}$ | 808 V | Current $I_{ü}$ | 230 A | Speed qpn | 1200 rpm |
| Avg VA S | 401000 VA | Avg Watts P | 80300 W | Avg Vars Q | 392878 Var |
| Avg Tq $Ü_M$ | 3400 N-m | Inertia $J_M$ | 204 $Kgm^2$ | | |
| Ambient Temp $T_a$ | 19.1 ºC | Wdg Temp Start $T_C$ | 21.4 ºC | Wdg Temp Pk $T_H$ | 23.1 ºC |
| Time Acc qpt$_{acc}$ | 24.8 s | | | | |

## SECOND RUN STEADY STATE

| | | | | | |
|---|---|---|---|---|---|
| Volts $V_{LL}$ | 1050 V | Current $I_{ü}$ | 30 A | Speed qpn | 0 rpm |
| Avg VA S | 51500 VA | Avg Watts P | 24500 W | Avg Vars Q | 45299 Var |
| Avg Tq $Ü_M$ | 160 N-m | Inertia $J_M$ | 204 $Kgm^2$ | | |
| Ambient Temp $T_a$ | 21.2 ºC | Wdg Temp Start $T_c$ | 27.8 ºC | Wdg Temp Pk $T_H$ | 45.5 ºC |

## τ/n I /n Curves




## COMMENTS

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| (SIGNATURE) | |


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| SUBSTATION: | NA | EQUIPMENT ID: | NA |

## NAMEPLATE INFORMATION

| | | | |
|---|---|---|---|
| MANUFACT.: | Toshiba | HP/KW: | 2500 / 1865 |
| MODEL/TYPE: | TIKE | RPM: | 1182 |
| STYLE NO.: | NA | VOLTS/PHASES | 4160 / 3 |
| SERIAL NO.: | 060011007BH | FREQUENCY: | 60 |
| FLA: | 331 | FRAME: | 500-1400 |
| S.F.: | 1 | CODE LETTER: | F |
| RISE: | F | INS. CLASS: | H |

## ACCELERATION FIRST RUN

| | | | | | |
|---|---|---|---|---|---|
| Volts $V_{LL}$ | 899 V | Current $I_{ü}$ | 246 A | Speed qpn | 1200 rpm |
| Avg VA S | 382900 VA | Avg Power P | 77000 W | Avg Vars Q | 375078 Var |
| Avg Tq $Ü_M$ | 6700 N.m | Avg Inertia $J_M$ | 206 $Kgm^2$ | | |
| Ambient Temp $T_a$ | 18.6 ºC | Wdg Temp Start $T_C$ | 20.2 ºC | Wdg Temp Pk $T_H$ | 21.2 ºC |
| | | | | Wdg Res $R_{1H}$ | 9.66781E-05 q |

## STEADY STATE FIRST RUN

| | | | | | |
|---|---|---|---|---|---|
| Volts $V_{LL}$ | 899 V | Current $I_{ü}$ | 107 A | Speed qpn | 1200 rpm |
| Avg VA S | 777000 VA | Avg Watts SS $P_{fw}$ | 91000 W | Avg Vars Q | 771653 Var |
| Avg Tq $Ü_M$ | 760 N-m | Inertia $J_M$ | 206 $Kgm^2$ | MG1 Des Inertia $J_L$ | 844 $Kgm^2$ |
| Ambient Temp $T_a$ | 18.7 ºC | Wdg Temp Start $T_H$ | 27.8 ºC | Wdg Temp Pk $T_{H1}$ | 45.5 ºC |
| | | | | Wdg Res $R_{1H1}$ | 9.05667E-05 q |

## ACCELERATION TIME

| | | | | | |
|---|---|---|---|---|---|
| Full Ld Tq $Ü_{FL}$ | 15068 N.m | Breakdown Tq $Ü_{BD}$ | 1236 N.m | Pull-up Tq $Ü_{PU}$ | 921 N.m |
| Frict Wind Tq $Ü_{fw}$ | 760 N.m | BD Tq @ Full Volts | 26466 N-m | PU Tq @ Full Volts | 19721 N-m |
| FW Tq @FV $Ü_{fw}$ | 16273 N-m | Accel Tq $Ü_{acc}$ | 3436 N.m | | |
| | | Accel Tq @ Full V | 73582 N-m | | |
| | | Motor & Load Acc $t_a$ | 38 s | | |
| | | Accel $t_a$ @FV | 2 s | | |

## COMMENTS

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| SUBSTATION: | NA | EQUIPMENT ID: | NA |

## NAMEPLATE INFORMATION

| | | | | | |
|---|---|---|---|---|---|
| MANUFACT.: | Toshiba | HP/KW: | 2500 | / | 1865 |
| MODEL/TYPE: | TIKE | RPM: | 1182 | | |
| STYLE NO.: | NA | VOLTS/PHASES | 4160 | / | 3 |
| SERIAL NO.: | 060011007BH | FREQUENCY: | 60 | | |
| FLA: | 331 | FRAME: | 500-1400 | | |
| S.F.: | 1 | CODE LETTER: | F | | |
| RISE: | F | INS. CLASS: | H | | |

## THERMAL CAPACITY DATA

| | | | | | |
|---|---|---|---|---|---|
| Volts $V_{LL}$ | 4160 V | Current $I_{ü}$ | 107 A | Speed qpn | 1200 rpm |
| Avg VA S | 777000 VA | Avg Power P | 91000 W | Avg Vars Q | 771653 Var |
| Avg Tq Ü$_M$ | 760 N.m | Time to Stab sec | 8400 s | Speed qpr | 191 rad/s |
| Ambient Temp $T_a$ | 18.7 ºC | Wdg Temp Start $T_C$ | 27.8 ºC | Wdg Temp Pk $T_H$ | 45.5 ºC |
| | | | | Wdg Res $R_{1H}$ | 0.000102798 q |

## THERMAL CAPACITY DATA 2

| | | | | | |
|---|---|---|---|---|---|
| Inertia $J_M$ | 206 $Kgm^2$ | MG1 Des Inertia $J_L$ | 844 $Kgm^2$ | Design Ambient | 40 °C |
| Motor & Load Acc $t_a$ | 38 s | Test Voltage | 521 V | Insulation Class | 185 °C |
| M&L Tq | 5223 N-m | Rated Voltage | 2400 V | Damage Temp | 225 °C |
| M&L Tq FV | 110826 N-m | | | | |
| M&L Power @FV | 21166150 W | | | | |

## THERMAL CAPACITY CALCULATION

| | | | | | |
|---|---|---|---|---|---|
| Thermal Capacity | 43,186,441 Ws/°C | Start Energy @ FV | 812,716,527 Ws | | |
| TC Class H Ins | 7,989,491,525 Ws | | | | |
| | | % TC Used @ FV | 10 % | | |

## COMMENTS

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| CUSTOMER: | NEP | DATE: | 2016 Oct 13 |
| LOCATION: | CEMSN Shop | JOB NUMBER: | ES03383 |
| SUBSTATION: | NA | EQUIPMENT ID: | NA |

## NAMEPLATE INFORMATION

| | | | | | |
|---|---|---|---|---|---|
| MANUFACT.: | IEM | HP/KW: | 1250 | / | 932.5 |
| MODEL/TYPE: | 765621 | RPM: | 1191 | | |
| STYLE NO.: | NA | VOLTS/PHASES | 4160 | / | 3 |
| SERIAL NO.: | 8904001 | FREQUENCY: | 60 | | |
| FLA: | 155 | FRAME: | 6808 | | |
| S.F.: | 1.15 | CODE LETTER: | C | | |
| RISE: | B | INS. CLASS: | F | | |

## THERMAL CAPACITY DATA

| | | | | | |
|---|---|---|---|---|---|
| Volts $V_{LL}$ | 4177 V | Current $I_{ü}$ | 37 A | Speed qpn | 1200 rpm |
| Avg VA S | 268000 VA | Avg Power P | 95400 W | Avg Vars Q | 250445 Var |
| Avg Tq Ü$_M$ | 800 N.m | Time to Stab sec | 8400 s | Speed qpr | 191 rad/s |
| Ambient Temp $T_a$ | 18.7 ºC | Wdg Temp Start $T_C$ | 27.8 ºC | Wdg Temp Pk $T_H$ | 45.5 ºC |
| | | | | Wdg Res $R_{1H}$ | 0.000287152 q |

## THERMAL CAPACITY DATA 2

| | | | | | |
|---|---|---|---|---|---|
| Inertia $J_M$ | 83 $Kgm^2$ | MG1 Des Inertia $J_L$ | 480 $Kgm^2$ | Design Ambient | 40 °C |
| Motor & Load Acc $t_a$ | 34 s | Test Voltage | 400 V | Insulation Class | 155 °C |
| M&L Tq | 3198 N-m | Rated Voltage | 2400 V | Damage Temp | 195 °C |
| M&L Tq FV | 115119 N-m | | | | |
| M&L Power @FV | 21986134 W | | | | |

## THERMAL CAPACITY CALCULATION

| | | | | | |
|---|---|---|---|---|---|
| Thermal Capacity | 45,274,576 Ws/°C | Start Energy @ FV | 739,287,990 Ws | | |
| TC Class H Ins | 7,017,559,322 Ws | | | | |
| | | % TC Used @ FV | 11 % | | |

## COMMENTS

| INSPECTED BY: | TEST DEVICE(S): |
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| (PRINT NAME) | |
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