

## DC Motor/Generator Technical Note

### A Practical Use Of The Motor Constant $K_M$ An Aid In The Selection Of DC Motors Or Generators In Power Limited Or Efficiency Sensitive Applications.

#### Introduction

Frequently a dc motor or generator specification will include the value of the motor constant  $K_M$ , which is the torque sensitivity divided by the square root of the winding resistance. Oftentimes even seasoned dc motor applications specialist will view this intrinsic motor property as a somewhat esoteric figure of merit useful only to the motor designer. The feeling is that motor constant  $K_M$  has no real practical value in selecting and dc motors and generators in the real world.

Nothing could be further from the truth! Utilizing this figure of merit properly will substantially reduce the iterative process in selecting a dc motor or generator since it is generally winding independent in a given case or frame size motor or generator from a given vendor.

Even in ironless dc motors, where the  $K_M$  may vary somewhat depending on winding due to variations in the copper fill factor, it remains a solid tool in the selection process. Particularly if there is a listing with Motor Constant in ascending or descending order, like there is in Appendix III at the end of this document.

This methodology limits the "winding hunt" where one winding satisfies the current requirements but not the voltage requirements and vice versa. You "can't get there from here" if the motor does not have the intrinsic electromechanical ability to satisfy the application requirements. This is NOT a thermal issue, but the intrinsic ability of the motor to transform electrical power to mechanical power or the generator to transform mechanical power to electrical power.

Since the  $K_M$  of an electromechanical device does not address the losses in that device in all circumstances the minimum  $K_M$  must be larger than calculated to address those losses. This method may not get you to exactly the correct "house" but it will put you on the correct "street".

This methodology is also a good "sanity check" since it forces the user to compute both the input and output power. This was an omission the author made more than a quarter century ago in attempting to address a requirement from a University PhD's need for a motorized prosthesis device that simply defied the Laws of Physics. It was also the first and last time such an error was ever made!

## Derivation

The Motor Constant addresses the fundamental electromechanical nature of a motor or generator. The selection of a suitable winding is simple after an adequately powerful "case or frame size" is determined.

The motor constant  $K_M$  is defined as:

$$1. \quad K_M = K_T / \sqrt{R}$$

Generators have torque constants too. In fact they are really nothing more than a motor driven backwards!

In a dc motor application with limited power availability and a known torque needed at the motor shaft the minimum  $K_M$  will be set. A derivation is in Appendix II at the end of this document.

For a given motor application the minimum  $K_M$  will be:

$$2. \quad K_M = T / (P_{IN} - P_{OUT})^{0.5}$$

The power into the motor will be positive. For a generator application it would be negative since you are taking power out.  $P_{IN}$  is simply the product of the current and voltage, assuming no phase shift between them.

$$3. \quad P_{IN} = V I$$

The power out of the motor will be positive, since it is supplying mechanical power. For a generator application it would be negative since the generator is taking mechanical power. It is simply the product of the rotational speed and torque.

$$4. \quad P_{OUT} = W T$$

The finesse of performing these calculations in the metric system is that no burdensome conversion factors are needed.

### Example 1-Motor Application:

A battery-powered device needs 300 rad/sec and 5 mNm of torque (2865 rpm and 0.708 oz-in). Power available is 12 Volts and 0.16 Amps. This example actually represents an efficiency of 78.125%.

Using equation 2,

$$K_M = T / (P_{IN} - P_{OUT})^{0.5}$$

$$K_M = 5 \times 10^{-3} \text{ Nm} / (12 \text{ Volts} \times 0.16 \text{ Amps} - 300 \text{ rad/sec} \times 5 \times 10^{-3} \text{ Nm})^{0.5}$$

$$K_M = 5 \times 10^{-3} \text{ Nm} / (1.92 \text{ Watt} - 1.5 \text{ Watt})^{0.5}$$

$$K_M = 7.715 \times 10^{-3} \text{ Nm}/\sqrt{\text{Watt}}$$

Consulting the table in Appendix III we see that the first MicroMo Coreless Motor that at nominal values has sufficient  $K_M$  is the 2842 006C.

It should be noted that the tolerances of the Torque Constant and the Winding Resistance should be accounted for. For example, if the Torque Constant and the Winding Resistance have  $\pm 12\%$  tolerances  $K_M$  worst case will be:

$$5. \quad K_{MWC} = 0.88 K_T / \sqrt{R * 1.12} = 0.832 K_M$$

or almost 17% below nominal values with a cold winding.

Taking worst case  $K_{MWC}$  we find that the first motor that might work is the 3540 024C.

Heating of the winding will further reduce  $K_M$  since copper resistivity rises almost 0.4% per degree °C. Just to exacerbate the problem the magnetic field will attenuate with rising temperatures. Depending on the permanent magnet material utilized this could be as much as 20% for a 100°C rise in temperature. The 20% attenuation for 100°C magnet temperature rise would be for Ferrite Magnets. Neodymium-Boron-Iron has 11% or more, and Samarium Cobalt about 4%.

#### Example 2-Generator Application:

A brushless dc generator must develop 500 Watt at 24 Volts dc. This must be developed at a rotor speed of 30 rad/sec and 20.833 Nm of torque.

To calculate the mechanical power delivered

$$6. P_{IN} = W T$$

Thus:

$$P_{IN} = - 30 \text{ rad/sec} \times 20.833 \text{ Nm} = - 625 \text{ Watt}$$

To determine the efficiency of the generator:

$$6. n = P_{IN} / P_{OUT} = - 500 \text{ Watt} / - 625 \text{ Watt} = 80\%$$

We can utilize equation 2 or

$$K_M = T / (P_{IN} - P_{OUT})^{0.5}$$

$$K_M = 20.833 \text{ Nm} / (- 625 \text{ Watt} + 500 \text{ Watt})^{0.5}$$

$$K_M = 1.863 \text{ Nm} / \sqrt{\text{Watt}} = 1,863 \text{ mNm} / \sqrt{\text{Watt}}$$

Just like in a motor application, this minimum  $K_M$  must be at the winding's steady state worst case operating temperature. Generators have heat losses just like motors do. This approach for a minimum  $K_M$  is only the first step in analysis. Tolerances in torque constant (or back emf constant) and winding resistance must also be accounted for, as well as any attenuation in the torque constant due to a rise in magnet temperature.

A suitable winding must then be selected and a thermal analysis must be performed. Additionally, in the case of a generator it must be clear if the efficiency is before or after losses in rectifying the ac voltage to a dc level.

Interestingly, if for the same mechanical input power if a target of 88% efficiency was desired then the minimum  $K_M$  would skyrocket from 1.863 Nm/√Watt to 2.406 Nm/√Watt. That is equivalent to having the same Winding Resistance but needing the Torque Constant to increase more than 29%. The higher the efficiency desired, the higher the  $K_M$  required. Graph 1 illustrates the sensitivity of  $K_M$  as efficiency requirements.

In Example 2 there is no standard MicroMo product that would satisfy this application at this time. Forthcoming products will be able to satisfy such applications in the near future.

#### Choosing a Winding

Although beyond the scope of this paper to go into detail on a rigorous winding selection and suitability check a hint is in order. If in the case of the motor application you know the maximum current available and the worst-case torque load.

Compute the lowest torque constant that is acceptable.

$$7. K_T = T/I$$

Once you have found a motor family with sufficient  $K_M$  select a winding that has a torque constant that is close to your minimum but exceeds it. Then commence determining if the winding will, in all cases of tolerances and application constraints, perform satisfactorily.

## Conclusion

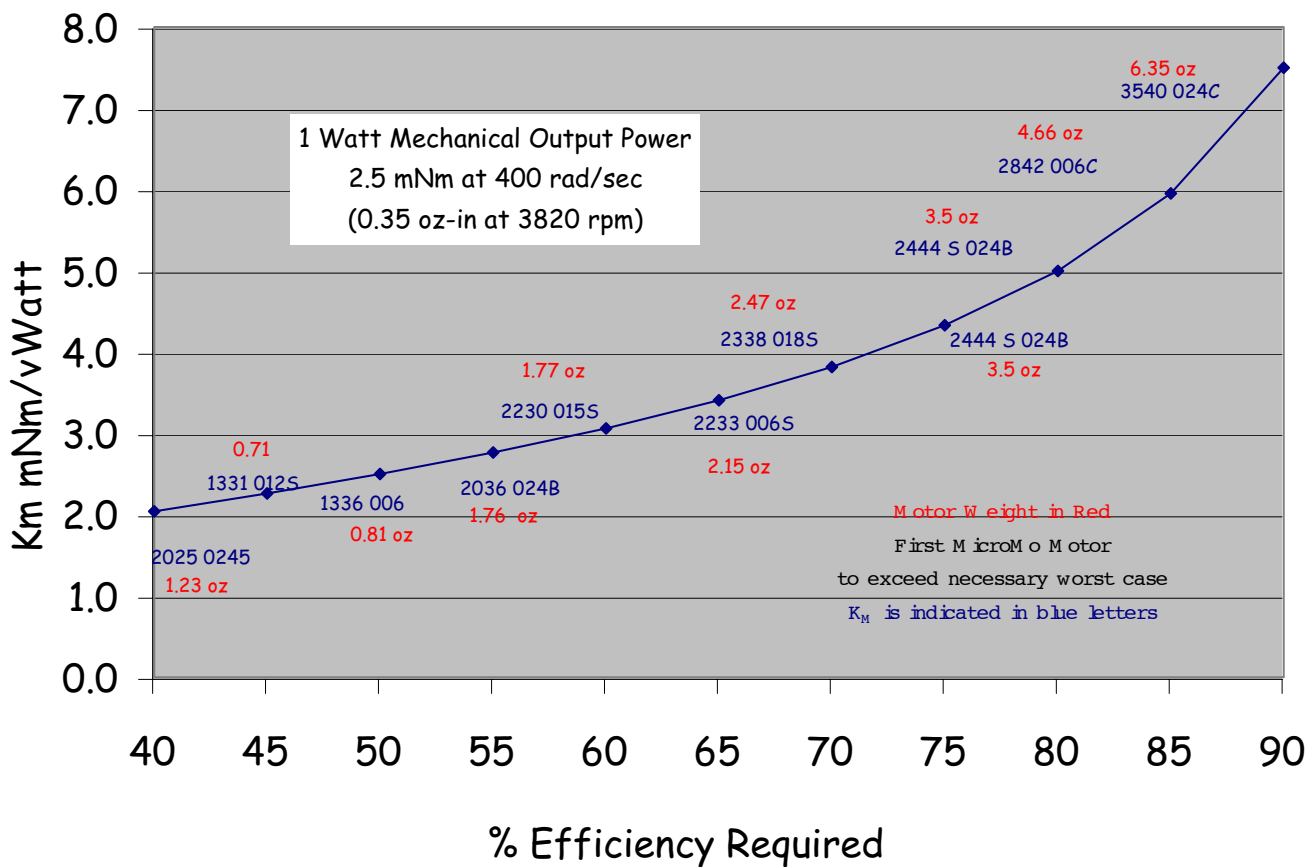
Clearly, choosing a motor or generator by first determining the minimum  $K_M$  in power sensitive motor and efficiency challenging generator applications can speed the selection process. The next step will then be to select a suitable winding and insure that all application parameters and motor/generator limitations are acceptable, including consideration due to winding tolerances.

Because of the manufacturing tolerances, thermal effects, and internal losses one should ALWAYS choose a  $K_M$  somewhat larger than what the application requires. Indeed, a certain amount of latitude is needed since there are not an infinite number of winding variations available from a practical point of view.

The larger the  $K_M$ , the more forgiving it is in satisfying a given application's requirements.

Graph 1

### Minimum Motor Constant vs. Efficiency



As Graph 1 illustrates, demanding higher efficiency power generation or motor efficiency will come at a price. The price will be larger motors and generators. That translates generally to more expensive motors and generators.

In general, practical efficiencies above 85 - 90% may be virtually unobtainable. Larger motors and generators have larger mechanical losses. This is due to bearing, windage, and electromechanical losses like hysteresis and eddy currents. Brush type motors also have losses from the mechanical commutation system. In the case of precious metal commutation, popular with coreless motors, these commutation losses can be extremely small, less than the bearing losses.

Ironless dc motors and generators have virtually no hysteresis and eddy current losses in the brush variant of this design.

In the brushless versions these losses, although low, do exist. This is because the magnet is usually rotating relative to the back iron of the magnetic circuit. This induces eddy current and hysteresis losses. However, there are brushless dc versions that have the magnet and back iron moving in unison. In these cases losses are usually very low.

Be it generating electrical power efficiently or pumping out mechanical power with a miser's attention to power consumption, brush and brushless dc ironless motors and generators are an excellent consideration in power sensitive or efficiency craving applications.

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## Appendix I

### SYMBOLS AND UNITS

Symbol	Definition	Unit(s)
I	Current to motor Or delivered from generator	Amp
$K_{ER}$	Back emf constant	Volt-sec*
$K_M$	Motor Constant	Nm/ $\sqrt{\text{Watt}}$
$K_{MWC}$	Motor Constant-Worst Case With tolerances considered	Nm/ $\sqrt{\text{Watt}}$
$K_T$	Torque Sensitivity	Nm/Amp**
n	efficiency of electrical to mechanical or mechanical to electrical conversion	%
$P_{IN}$	Input Power	Watt
$P_{OUT}$	Output Power	Watt
R	Cold Winding Resistance specified by manufacturer	Ohm
T	Load Torque or Driving Torque	Nm
W	Motor or Generator Rotational Speed	rad/sec
V	Voltage Applied to Motor or Load Voltage of Generator	Volt
*	"Volts-sec" is equivalent to "Volt/(rad/sec)"	
**	"Nm/Amp" is Newton-meters/Amp	

## Appendix II

### Determination of Minimum Motor Constant $K_M$ .

The dynamic equation of a dc motor is:

$$A. \quad V = I R + K \omega$$

The Motor constant  $K_M$  is defined as:

$$B. \quad K_M = K_T / \sqrt{R}$$

In the MKS system

$$K_T = K_{ER} = K$$

Therefore:

$$C. \quad K_M = K / \sqrt{R}$$

If we solve Equation C for R we have, after squaring both sides:

$$D. \quad R = K^2 / K_M^2$$

We further know that the torque generated is:

$$E. \quad T = I K$$

Or, solving for I:

$$F. \quad I = T / K$$

If we then subtract  $(K \times \omega)$  from both sides in Equation A, and substitute values of R in Equation D and I in Equation F:

$$V - K \times \omega = I \times R = (T/K) K^2 / K_M^2 = T K / K_M^2$$

Solving for  $K_M$ :

$$G. \quad K_M^2 = T K / (V - K \times \omega)$$

If we solve Equation E for K we have:

$$H. \quad K = T / I$$

Continuing to solve Equation G for  $K_M$  by substituting K of Equation H.

$$I. \quad K_M^2 = T (T/I) / (V - (T/I) \times \omega) = T^2 / (V I - T \omega)$$

Taking the square root we have:

$$J. \quad K_M = T / (V I - T \omega)^{0.5}$$

Note that the mechanical power is defined as the product of speed and torque or:

$$K. \quad P_{OUT} = T \omega$$

The electrical power is the product of Voltage and Current or:

$$L. \quad P_{IN} = V I$$

Therefore, putting Equations K and L into J we have:

$$M. \quad K_M = T / (P_{IN} - P_{OUT})^{0.5}$$

Just remember that in a generator application  $P_{IN}$  and  $P_{OUT}$  will have negative values.

### Appendix III

#### Motor Constant of MicroMo DC Motor Products Descending by Nominal Motor Constant Data from Spread Sheet Supplied By Clyde Hancock

Some Data May Have Minor Revisions Since The Spread Sheet Was Created

Part Number	Motor Constant-Nominal	Motor Constant-Worst Case
GNM 70130 80V	464.8 mNm/√Watt	386.5 mNm/√Watt
GNM 70130 24V 1.5K	448.1 mNm/√Watt	372.6 mNm/√Watt
GNM 70130 180V 3K	444.2 mNm/√Watt	369.3 mNm/√Watt
GNM 70130 24V 3K	424.3 mNm/√Watt	352.8 mNm/√Watt
GNM 70130 180V 1.5K	422.9 mNm/√Watt	351.6 mNm/√Watt
GNM 8070/4	386.8 mNm/√Watt	321.7 mNm/√Watt
GNM 7085 180V 1.5K	365.1 mNm/√Watt	303.6 mNm/√Watt
GNM 7085 24V 1.5K	354.6 mNm/√Watt	294.8 mNm/√Watt
GNM 7085 180V 3K	352.8 mNm/√Watt	293.4 mNm/√Watt
GNM 7085 80V	336.4 mNm/√Watt	279.7 mNm/√Watt
GNM 7085 24V 3K	319.2 mNm/√Watt	265.4 mNm/√Watt
GNM 62100 180V 1.5K	295.9 mNm/√Watt	246.1 mNm/√Watt
GNM 62100 24V 1.5K	286.2 mNm/√Watt	238.0 mNm/√Watt
GNM 8035/4	272.2 mNm/√Watt	226.3 mNm/√Watt
GNM 62100 180V 3K	270.0 mNm/√Watt	224.5 mNm/√Watt
GNM 62100 80V	237.4 mNm/√Watt	197.4 mNm/√Watt
GNM 62100 24V 3K	236.7 mNm/√Watt	196.9 mNm/√Watt
GNM 7045 24V 1.5K	230.7 mNm/√Watt	191.8 mNm/√Watt
GNM 7045 180V 3K	226.0 mNm/√Watt	187.9 mNm/√Watt
GNM 5480 180V 3K	221.9 mNm/√Watt	184.5 mNm/√Watt
GNM 7045 24V 3K	219.9 mNm/√Watt	182.8 mNm/√Watt
GNM 5480 180V 1.5K	219.9 mNm/√Watt	182.8 mNm/√Watt
GNM 7045 180V 1.5K	216.1 mNm/√Watt	179.7 mNm/√Watt
GNM 5480 24V 3K	214.0 mNm/√Watt	178.0 mNm/√Watt
GNM 5480 34V	213.5 mNm/√Watt	177.5 mNm/√Watt
GNM 5480 24V 1.5K	208.9 mNm/√Watt	173.7 mNm/√Watt
GNM 5480 42V	208.9 mNm/√Watt	173.7 mNm/√Watt
GNM 7045 80V	205.7 mNm/√Watt	171.0 mNm/√Watt
GNM 5440 180V 3K	136.3 mNm/√Watt	113.4 mNm/√Watt
GNM 5440 24V 1.5K	136.3 mNm/√Watt	113.3 mNm/√Watt
GNM 5440 42V	136.3 mNm/√Watt	113.3 mNm/√Watt
GNM 4175 24V 1.5K	136.2 mNm/√Watt	113.2 mNm/√Watt
GNM 4175 42V	136.2 mNm/√Watt	113.2 mNm/√Watt
GNM 4175 180V 1.5K	135.7 mNm/√Watt	112.8 mNm/√Watt
GNM 4175 180V 3K	133.8 mNm/√Watt	111.2 mNm/√Watt
GNM 5440 34V	132.5 mNm/√Watt	110.2 mNm/√Watt
GNM 5440 180V 1.5K	131.2 mNm/√Watt	109.1 mNm/√Watt
GNM 4175 34V	125.7 mNm/√Watt	104.5 mNm/√Watt
GNM 5440 24V 3K	124.4 mNm/√Watt	103.5 mNm/√Watt
GNM 4175 24V 3K	115.5 mNm/√Watt	96.1 mNm/√Watt
GNM 4150 24V 1.5K	111.9 mNm/√Watt	93.1 mNm/√Watt
GNM 4150 42V	111.9 mNm/√Watt	93.1 mNm/√Watt
GNM 4150 180V 3K	111.4 mNm/√Watt	92.6 mNm/√Watt
GNM 4150 34V	109.5 mNm/√Watt	91.0 mNm/√Watt
GNM 4150 180V 1.5K	108.3 mNm/√Watt	90.1 mNm/√Watt
GNM 4150 24V 3K	107.2 mNm/√Watt	89.1 mNm/√Watt
GNM 3175 3K	80.7 mNm/√Watt	67.1 mNm/√Watt
GNM 3175 4K	80.3 mNm/√Watt	66.8 mNm/√Watt
GNM 4125 24V 3K	69.4 mNm/√Watt	57.7 mNm/√Watt
GNM 4125 24V 2K	69.3 mNm/√Watt	57.6 mNm/√Watt

GNM 4125 42V	69.3 mNm/√Watt	57.6 mNm/√Watt
GNM 4125 180V 3K	67.9 mNm/√Watt	56.4 mNm/√Watt
GNM 4125 180V 2K	65.3 mNm/√Watt	54.3 mNm/√Watt
GNM 4125 34V	65.3 mNm/√Watt	54.3 mNm/√Watt
GNM 3150 3K	62.5 mNm/√Watt	52.0 mNm/√Watt
GNM 3150 4K	61.8 mNm/√Watt	51.4 mNm/√Watt
4490 H 036 B	49.0 mNm/√Watt	40.7 mNm/√Watt
4490 H 024 B	48.9 mNm/√Watt	40.6 mNm/√Watt
4490 H 048 B	48.8 mNm/√Watt	40.5 mNm/√Watt
GNM 2670A 4K	48.0 mNm/√Watt	39.9 mNm/√Watt
GNM 2670A 3K	46.6 mNm/√Watt	38.8 mNm/√Watt
3863 048C	42.6 mNm/√Watt	35.4 mNm/√Watt
3863 024C	42.5 mNm/√Watt	35.3 mNm/√Watt
3863 012C	41.8 mNm/√Watt	34.8 mNm/√Watt
GNM 3125 4K	38.4 mNm/√Watt	31.9 mNm/√Watt
GNM 3125 3K	37.2 mNm/√Watt	30.9 mNm/√Watt
GNM 2636A 4K	34.1 mNm/√Watt	28.3 mNm/√Watt
GNM 2636A 3K	32.9 mNm/√Watt	27.4 mNm/√Watt
3557 048CR	30.7 mNm/√Watt	25.5 mNm/√Watt
3557 012CR	30.4 mNm/√Watt	25.2 mNm/√Watt
3557 024CR	30.3 mNm/√Watt	25.2 mNm/√Watt
1331 006S	27.3 mNm/√Watt	22.7 mNm/√Watt
3564 012B	18.8 mNm/√Watt	15.6 mNm/√Watt
3557 012CS	18.1 mNm/√Watt	15.0 mNm/√Watt
3557 009CS	17.8 mNm/√Watt	14.8 mNm/√Watt
3564 024B	17.6 mNm/√Watt	14.7 mNm/√Watt
3564 048B	17.6 mNm/√Watt	14.7 mNm/√Watt
3564 036B	17.6 mNm/√Watt	14.7 mNm/√Watt
3557 048CS	17.6 mNm/√Watt	14.6 mNm/√Watt
3557 024CS	17.5 mNm/√Watt	14.6 mNm/√Watt
3557 020CS	17.1 mNm/√Watt	14.2 mNm/√Watt
3042 036C	16.5 mNm/√Watt	13.7 mNm/√Watt
3042 012C	16.0 mNm/√Watt	13.3 mNm/√Watt
3557 020C	15.9 mNm/√Watt	13.2 mNm/√Watt
3042 018C	15.5 mNm/√Watt	12.9 mNm/√Watt
3557 006C	15.5 mNm/√Watt	12.9 mNm/√Watt
3042 024C	15.2 mNm/√Watt	12.6 mNm/√Watt
3557 012C	15.1 mNm/√Watt	12.6 mNm/√Watt
3557 032C	15.0 mNm/√Watt	12.5 mNm/√Watt
3557 009C	14.8 mNm/√Watt	12.3 mNm/√Watt
3557 024C	14.4 mNm/√Watt	12.0 mNm/√Watt
3042 006C	14.2 mNm/√Watt	11.8 mNm/√Watt
GNM 2145 24V	12.2 mNm/√Watt	10.1 mNm/√Watt
GNM 2145 12V	11.9 mNm/√Watt	9.9 mNm/√Watt
3056 048B	10.4 mNm/√Watt	8.6 mNm/√Watt
3056 024B	10.3 mNm/√Watt	8.6 mNm/√Watt
3056 036B	10.3 mNm/√Watt	8.5 mNm/√Watt
3056 012B	10.1 mNm/√Watt	8.4 mNm/√Watt
2342 024 CR	10.0 mNm/√Watt	8.3 mNm/√Watt
2842 024C	9.8 mNm/√Watt	8.1 mNm/√Watt
3540 015C	9.7 mNm/√Watt	8.1 mNm/√Watt
2342 012 CR	9.6 mNm/√Watt	8.0 mNm/√Watt
2342 006 CR	9.6 mNm/√Watt	8.0 mNm/√Watt
2842 028C	9.6 mNm/√Watt	8.0 mNm/√Watt
GNM 2130 12V	9.6 mNm/√Watt	8.0 mNm/√Watt
GNM 2130 24V	9.6 mNm/√Watt	8.0 mNm/√Watt
3540 006C	9.6 mNm/√Watt	7.9 mNm/√Watt
2842 012C	9.5 mNm/√Watt	7.9 mNm/√Watt
2842 036C	9.5 mNm/√Watt	7.9 mNm/√Watt
3540 012C	9.5 mNm/√Watt	7.9 mNm/√Watt

3540 024C	9.4 mNm/√Watt	7.8 mNm/√Watt
2842 006C	8.7 mNm/√Watt	7.2 mNm/√Watt
2444 048B	7.0 mNm/√Watt	5.8 mNm/√Watt
2444 S 048 B	7.0 mNm/√Watt	5.8 mNm/√Watt
2444 024B	6.8 mNm/√Watt	5.6 mNm/√Watt
2444 S 024 B	6.8 mNm/√Watt	5.6 mNm/√Watt
2224 006S R	5.0 mNm/√Watt	4.2 mNm/√Watt
2224 012S R	5.0 mNm/√Watt	4.1 mNm/√Watt
2338 4.5S	4.9 mNm/√Watt	4.1 mNm/√Watt
2224 024S R	4.8 mNm/√Watt	4.0 mNm/√Watt
2338 006S	4.8 mNm/√Watt	4.0 mNm/√Watt
2230 040S	4.8 mNm/√Watt	4.0 mNm/√Watt
2338 024S	4.7 mNm/√Watt	3.9 mNm/√Watt
2233 04.5S	4.7 mNm/√Watt	3.9 mNm/√Watt
2338 009S	4.7 mNm/√Watt	3.9 mNm/√Watt
2338 018S	4.6 mNm/√Watt	3.8 mNm/√Watt
2338 012S	4.5 mNm/√Watt	3.7 mNm/√Watt
2233 012S	4.3 mNm/√Watt	3.6 mNm/√Watt
2233 006S	4.2 mNm/√Watt	3.5 mNm/√Watt
2233 018S	3.9 mNm/√Watt	3.3 mNm/√Watt
2230 003S	3.8 mNm/√Watt	3.2 mNm/√Watt
1727 006C	3.7 mNm/√Watt	3.1 mNm/√Watt
2230 015S	3.7 mNm/√Watt	3.1 mNm/√Watt
2230 012S	3.6 mNm/√Watt	3.0 mNm/√Watt
1727 012C	3.6 mNm/√Watt	3.0 mNm/√Watt
2230 024S	3.6 mNm/√Watt	3.0 mNm/√Watt
1724 012S	3.5 mNm/√Watt	2.9 mNm/√Watt
1724 006S	3.5 mNm/√Watt	2.9 mNm/√Watt
2230 006S	3.5 mNm/√Watt	2.9 mNm/√Watt
1724 024S	3.5 mNm/√Watt	2.9 mNm/√Watt
1724 018S	3.4 mNm/√Watt	2.9 mNm/√Watt
2036 012B	3.4 mNm/√Watt	2.9 mNm/√Watt
2233 024S	3.4 mNm/√Watt	2.8 mNm/√Watt
1724 003S	3.4 mNm/√Watt	2.8 mNm/√Watt
2036 036B	3.3 mNm/√Watt	2.8 mNm/√Watt
2036 024B	3.3 mNm/√Watt	2.8 mNm/√Watt
2036 048B	3.2 mNm/√Watt	2.7 mNm/√Watt
1727 024C	3.1 mNm/√Watt	2.6 mNm/√Watt
2225 003S	3.1 mNm/√Watt	2.6 mNm/√Watt
2225 006S	3.0 mNm/√Watt	2.5 mNm/√Watt
1336 012C	3.0 mNm/√Watt	2.5 mNm/√Watt
1336 024C	3.0 mNm/√Watt	2.5 mNm/√Watt
2233 030S	3.0 mNm/√Watt	2.5 mNm/√Watt
1336 006	3.0 mNm/√Watt	2.5 mNm/√Watt
2025 003S	2.9 mNm/√Watt	2.4 mNm/√Watt
1331 012S	2.7 mNm/√Watt	2.3 mNm/√Watt
1331 024S	2.7 mNm/√Watt	2.2 mNm/√Watt
1331 4.5S	2.6 mNm/√Watt	2.2 mNm/√Watt
1331 015S	2.6 mNm/√Watt	2.2 mNm/√Watt
2225 009S	2.6 mNm/√Watt	2.2 mNm/√Watt
1524 006S R	2.6 mNm/√Watt	2.1 mNm/√Watt
2225 012S	2.6 mNm/√Watt	2.1 mNm/√Watt
1524 012S R	2.5 mNm/√Watt	2.1 mNm/√Watt
1524 024S R	2.5 mNm/√Watt	2.1 mNm/√Watt
2025 006S	2.5 mNm/√Watt	2.1 mNm/√Watt
2025 012S	2.4 mNm/√Watt	2.0 mNm/√Watt
2225 024S	2.3 mNm/√Watt	2.0 mNm/√Watt
2025 009S	2.3 mNm/√Watt	1.9 mNm/√Watt
2025 024S	1.9 mNm/√Watt	1.6 mNm/√Watt
1624 009S	1.9 mNm/√Watt	1.6 mNm/√Watt

1717 012S	1.9 mNm/√Watt	1.6 mNm/√Watt
1628 024B	1.9 mNm/√Watt	1.6 mNm/√Watt
1624 018S	1.9 mNm/√Watt	1.6 mNm/√Watt
1717 006S	1.9 mNm/√Watt	1.6 mNm/√Watt
1628 012B	1.9 mNm/√Watt	1.5 mNm/√Watt
1624 003S	1.9 mNm/√Watt	1.5 mNm/√Watt
1624 024S	1.8 mNm/√Watt	1.5 mNm/√Watt
1624 006S	1.8 mNm/√Watt	1.5 mNm/√Watt
1624 012S	1.8 mNm/√Watt	1.5 mNm/√Watt
1717 003S	1.7 mNm/√Watt	1.4 mNm/√Watt
1319 015	1.5 mNm/√Watt	1.2 mNm/√Watt
1524 018S	1.4 mNm/√Watt	1.2 mNm/√Watt
1319 003	1.4 mNm/√Watt	1.2 mNm/√Watt
1319 006	1.4 mNm/√Watt	1.2 mNm/√Watt
1319 012	1.4 mNm/√Watt	1.2 mNm/√Watt
1319 024	1.3 mNm/√Watt	1.1 mNm/√Watt
1524 012S	1.3 mNm/√Watt	1.1 mNm/√Watt
1524 009S	1.3 mNm/√Watt	1.1 mNm/√Watt
2017 1.5S	1.3 mNm/√Watt	1.1 mNm/√Watt
1524 006S	1.3 mNm/√Watt	1.0 mNm/√Watt
1516 009SR	1.1 mNm/√Watt	0.9 mNm/√Watt
1516 012R	1.1 mNm/√Watt	0.9 mNm/√Watt
1516 006SR	1.1 mNm/√Watt	0.9 mNm/√Watt
2017 006S	1.0 mNm/√Watt	0.9 mNm/√Watt
2017 012S	0.9 mNm/√Watt	0.7 mNm/√Watt
1219 4.5G	0.9 mNm/√Watt	0.7 mNm/√Watt
2017 009S	0.9 mNm/√Watt	0.7 mNm/√Watt
1219 012G	0.8 mNm/√Watt	0.7 mNm/√Watt
1219 006G	0.8 mNm/√Watt	0.7 mNm/√Watt
2017 003S	0.8 mNm/√Watt	0.7 mNm/√Watt
1616 003S	0.8 mNm/√Watt	0.7 mNm/√Watt
1616 004S	0.8 mNm/√Watt	0.7 mNm/√Watt
1516 1.5S	0.8 mNm/√Watt	0.6 mNm/√Watt
1016 012G	0.8 mNm/√Watt	0.6 mNm/√Watt
1016 006G	0.8 mNm/√Watt	0.6 mNm/√Watt
1219 015G	0.8 mNm/√Watt	0.6 mNm/√Watt
1616 006S	0.7 mNm/√Watt	0.6 mNm/√Watt
1616 018S	0.7 mNm/√Watt	0.6 mNm/√Watt
1616 012S	0.7 mNm/√Watt	0.6 mNm/√Watt
1016 003G	0.7 mNm/√Watt	0.6 mNm/√Watt
1516 4.5S	0.7 mNm/√Watt	0.6 mNm/√Watt
1516 002S	0.6 mNm/√Watt	0.5 mNm/√Watt
1516 012S	0.6 mNm/√Watt	0.5 mNm/√Watt
1516 006S	0.6 mNm/√Watt	0.5 mNm/√Watt
0816 003S	0.5 mNm/√Watt	0.4 mNm/√Watt
0816 006S	0.5 mNm/√Watt	0.4 mNm/√Watt
0816 008S	0.4 mNm/√Watt	0.4 mNm/√Watt
1212 2.7G	0.4 mNm/√Watt	0.3 mNm/√Watt
1212 1.8G	0.4 mNm/√Watt	0.3 mNm/√Watt
1212 004G	0.4 mNm/√Watt	0.3 mNm/√Watt
1212 006G	0.3 mNm/√Watt	0.3 mNm/√Watt
0206 H	0.0 mNm/√Watt	0.0 mNm/√Watt