…….Brought to you by your Motor & Drive Specialists

Monthly Informative Application Guidelines, with respect to *Motors & Drives* to keep you better INFORMED.

APPLICATION GUIDELINE #17

(Efficiency – Part 1)

Brought to you by your Motor & Drive Specialists……

Part 1 (Application Guideline#17): A. Introduction
B. NEMA MG1 specifications on efficiency
C. Third Party Testing
Part 2: (Application Guideline#18): D. Breakdown of Losses in a motor
E. Losses and Methods of Reductions
F. Important Factors Relating to Efficiency
G. Importance of Quality Control to Efficiency

-A- INTRODUCTION

With the very real potential threat of increased hydro costs due to de-regulation, efficiency issues will again surface to be a very hot topic in the near future. In order to produce high efficiencies, design engineers look at how to reduce losses. At the same time, they must consider the effect loss reduction has on torque reduction, slip and temperature rises. As is often the case, there are compromises and with motor design, efficiency improvements are often gained at the cost of torque, temperature rise and/or increasing the quantity and quality of the materials used. The design engineers have difficult decisions to perform in order to preserve all desired parameters and still maintain competitive costing.

Following is a summary of what NEMA specifies regarding efficiency, summary of a third party (Coordinated Utilities) testing report, and several charts. [Table 12-8 from NEMA indicates acceptable efficiency ranges for a given nominal efficiency, Table 12-10 is a NEMA table indicating the newer required minimum "nominal efficiencies" for a given horsepower rating, and the third table is a comparison of OLD NEMA values, versus the Efficiency Policy ACT (EPACT) levels and Toshiba EQPIII levels.]

-B- NEMA MG1 SPECIFICATION ON EFFICIENCY

A number of terms are used to describe motor efficiency. These include "nominal", and "minimum guaranteed". NEMA MG1-1993, 12.58 describes and specifies these efficiencies as follows:

> "The full load efficiency shall be identified on the nameplate by a nominal efficiency selected from the nominal efficiency column in Table 12-8 (see attached) which shall be not greater than the average efficiency of a large population of motors of the same design. The full load efficiency, when operating at rated voltage and frequency, shall be not less than the minimum value indicated in Column B of Table 12-08 associated with the nominal value in Column A. Variations in materials, manufacturing processes, and test, results in motor to motor efficiency variations for a given motor design; the full-load efficiency for a large population of motors of a single design is not a unique efficiency but rather a band of efficiency. Therefore, Table 12-8 has been established to indicate a logical series of nominal motor efficiencies and the minimum associated with each nominal. The "nominal efficiency" represents a value which should be used to compute the energy consumption of a motor or group of motors."

NEMA also regulates that in order for the motor to be classified as "energy efficient", the nominal full load efficiency shall equal or exceed the values listed in Table 12-10. The values in this table were for a long time considered 'Suggested Standard for Future Design', however when the Efficiency Policy Act of 1997 was introduced these values then became the required industry standards.

The 10% loss Difference column on Table 12-8 is only a 'Suggested Future Standard', which has since been removed because NEMA has decided this would be far too challenging a tolerance band to expect motor manufacturers to meet (based on poor results of third party testing). It should be noted Toshiba uses this more stringent 'loss column' as a standard loss tolerance, and is able to meet it because of strict in house quality standards and use of high quality materials.

-B-THIRD PARTY TESTING

In the recent past, the pressure from provincial demands to increase efficiency levels on motors created an interesting situation in the motor industry. Third party testing by the Canadian Coordinated Utilities, proved that many manufacturers were not following the suggested efficiency guidelines specified by NEMA. The third party testing was initiated by certain provincial hydro companies because if they were going to compensate the industry with a rebate for buying a premium efficiency product they wanted to make sure that manufacturers were indeed supplying a superior product and not just saying it. Note the following excerpts on their key findings.

Objectives:

To summarize the Canadian Coordinated Utilities Motor Efficiency Verification Testing Program and demonstrate the range and scope of variation between tested data and motor nameplate or manufacturer published performance data. The comparison is presented in three parts:

1. Adherence to the nameplate requirements of NEMA MG1
2. Quality and accuracy of manufacturer published performance data
3. Variation from multiple motor testing

Testing to Date:

- 403 motors between 1 to 500Hp were dynamometer tested during the six year testing program (340 motors with unique model numbers)
- Products from 21 different motor manufacturers were tested
- Tests conducted in 3 laboratories according to IEEE std 112 Method B (CSA C390)

Key findings for Part 1: Adherence to the nameplate requirements of NEMA MG1:

1. To date, the motor efficiency verification testing program has tested 340 new motors with unique model numbers and found that the nominal nameplate efficiency does not represent the statistical mean for a large population of motors as required by the NEMA MG1 motor performance standard.
2. There is a correlation between motor manufacturer and test results. The test results for certain manufacturers were consistently below the minimum efficiency (20% Variation of Losses), while a few manufacturers showed results that were normally distributed about the nominal efficiency (0% Variation).
3. There is no correlation between motor horsepower and test results. The variation of losses between measured and nameplate efficiency is equally scattered for small motors as it is for larger motors.
4. The test results indicate that 48(16%) motors failed to meet the minimum guaranteed efficiency levels as per Column B(20% Loss Difference) of NEMA MG1 Table 12-8.
5. The pass/fail rates were fairly constant over the six years of utility testing, as summarized below.
6. Nameplate efficiency data was unavailable for 39(11%) of the motors tested. Furthermore, the efficiency rating of 77(26%) of the motors tested that did have a nameplate efficiency was not in accordance with the efficiency levels as described in NEMA MG1 Table 12-8.
7. Manufacturers who consistently fail to meet the minimum efficiency requirements have their motors de-rated in the Canadian Motors Database as a result of the motor efficiency verification program.

Key findings of Part 2: Quality and accuracy of manufacturer published performance data

1. Published motor efficiency best describes the tested efficiency at 50% load, where an almost equal number of motors tested above and below the published efficiency. The largest variation in loss difference is at full load, where the tested efficiency was found to be 9% lower than the published data, on average. Performance data at 25% of rated load is rarely published by the manufacturer.
2. The power factor of over 90% of the motors tested was within +/- 10% of the published power factor above half load. More motors fall outside the allowable tolerance at low loads because of the rapid drop in power factor with decreasing load.

Key findings of Part 3: Variation in Efficiency from Multiple Motor Testing:

1. The results from multiple motor testing show that the range of variation in loss difference from the nominal efficiency is much greater than the variation in loss difference from the average efficiency of motors of the same rating and manufacturer.
2. The variation in losses at full load due to testing accuracy, manufacturing process and material tolerance is within 10% loss difference, while the efficiency tested up to 40% loss difference from the motor's nominal efficiency. (This emphasizes that the loss tolerance guidelines are reasonable to allow for variations in manufacturing, however some have used it as a chance to increase their nameplated nominal efficiency levels.)

NEMA MG-1 Table 12-8 Efficiency Levels		
Column A Nominal Efficiency	Column B Minimum Guaranteed (20% Loss Difference)	Column C Minimum Guaranteed (10% Loss Difference) Suggested STD. For FUTURE DESIGN
99.0	98.8	98.9
98.9	98.7	98.8
98.8	98.6	98.7
98.7	98.5	98.6
98.6	98.4	98.5
98.5	98.2	98.4
98.4	98.0	98.2
98.2	97.8	98.0
98.0	97.6	97.8
97.8	97.4	97.6
97.6	97.1	97.4
97.4	96.8	97.1
97.1	96.5	96.8
96.8	96.2	96.5
96.5	95.8	96.2
96.2	95.4	95.8
95.8	95.0	95.4
95.4	94.5	95.0
95.0	94.1	94.5
94.5	93.6	94.1
94.1	93.0	93.6
93.6	92.4	93.0
93.0	91.7	92.4
92.4	91.0	91.7
91.7	90.2	91.0
91.0	89.5	90.2
90.2	88.5	89.5
89.5	87.5	88.5
88.5	86.5	87.5
87.5	85.5	86.5
86.5	84.0	85.5
85.5	82.5	84.0
84.0	81.5	82.5
82.5	80.0	81.5
81.5	78.5	80.0
80.0	77.0	78.5
78.5	75.5	77.0
77.0	74.0	75.5
75.5	72.0	74.0
74.0	70.0	72.0
72.0	68.0	70.0
70.0	66.0	68.0
68.0	64.0	66.0
66.0	62.0	64.0

Table 12-10 NEMA MG-1 1993
(Suggested Standard for Future Design = EPACT LEVELS)
FULL LOAD EFFICIENCIES OF ENERGY EFFICIENT MOTORS (ENCLOSED MOTORS)

HP	2-Pole		4-Pole		6-Pole	
	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency	Nominal Efficiency	Minimum Efficiency
1	75.5	72.0	82.5	80.0	80.0	77.0
1.5	82.5	80.0	84.0	81.5	85.5	82.5
2	84.0	81.5	84.0	81.5	86.5	84.0
3	85.5	82.5	87.5	85.5	87.5	85.5
5	87.5	85.5	87.5	85.5	87.5	85.5
7.5	88.5	86.5	89.5	87.5	89.5	87.5
10	89.5	87.5	89.5	87.5	89.5	87.5
15	90.2	88.5	91.0	89.5	90.2	88.5
20	90.2	88.5	91.0	89.5	90.2	88.5
25	91.0	89.5	92.4	91.0	91.7	90.2
30	91.0	89.5	92.4	91.0	91.7	90.2
40	91.7	90.2	93.0	91.7	93.0	91.7
50	92.4	91.0	93.0	91.7	93.0	91.7
60	93.0	91.7	93.6	92.4	93.6	92.4
75	93.0	91.7	94.1	93.0	93.6	92.4
100	93.6	92.4	94.5	93.6	94.1	93.0
125	94.5	93.6	94.5	93.6	94.1	93.0
150	94.5	93.6	95.0	94.1	95.0	94.1
200	95.0	94.1	95.0	94.1	95.0	94.1

'COMPARE' NEMA/EPACT/TOSHIBA EQP

4-POLE (1800RPM) COMPARISON TABLE

HP	NEMA Standard MG1-1993		EPACT LEVELS of 1997		TOSHIBA EQPIII	
	Nominal Efficiency	Minimum Efficiency (20% loss)	Nominal Efficiency	Minimum Efficiency (20% loss)	Nominal Efficiency	Minimum Efficiency (10% loss)
1	80.0	77.0	82.5	80.0	85.7	84.5
1.5	81.5	78.5	84.0	81.5	86.9	85.8
2	82.5	80.0	84.0	81.5	86.4	85.7
3	84.0	81.5	87.5	85.5	89.5	88.6
5	85.5	82.5	87.5	85.5	88.4	87.5
7.5	87.5	85.5	89.5	87.5	90.9	90.1
10	87.5	85.5	89.5	87.5	90.9	90.1
15	88.5	86.5	91.0	89.5	92.4	91.7
20	90.2	88.5	91.0	89.5	93.1	92.5
25	91.0	89.5	92.4	91.0	93.5	92.9
30	91.0	89.5	92.4	91.0	93.4	92.8
40	91.7	90.2	93.0	91.7	94.0	93.4
50	92.4	91.0	93.0	91.7	94.0	93.4
60	93.0	91.7	93.6	92.4	95.1	94.6
75	93.0	91.7	94.1	93.0	95.3	94.9
100	93.6	92.4	94.5	93.6	95.4	95
125	93.6	92.4	94.5	93.6	95.7	95.3
150	94.1	93.0	95.0	94.1	95.7	95.3
200	94.5	93.6	95.0	94.1	96.1	95.7

***On average Toshiba EQP Nominals are 1.6% greater efficiency than what is demanded of NEMA or EPACT.**