NRC Response to Facility Comment on the
March 2017 Generic Fundamentals Examinations

FACILITY: **Monticello**
EXAM: **BWR Form A/B**
QUESTION: **BWR 15/29 (Also applies to PWR 14/28)**

An AC induction motor is operating with the following steady-state conditions:

Motor current	= 20 amps
Stator temperature (average)	= 130°F
Ambient temperature	= 80°F

If a change in motor load causes the motor current to increase to 40 amps, which one of the following will be the new steady-state average stator temperature?

A. 180°F

B. 200°F

C. 260°F

D. 280°F

PRELIMINARY ANSWER: D.

FACILITY COMMENT: See pages 3 and 4.

NRC RESPONSE: The NRC agrees that choice D is not a correct answer to the question as written.

According to Joule's Law of Heating, ***the rate of heat generation in an electrical conductor is proportional to the product of the square of the amount of current flowing through the conductor and the resistance of the conductor***. Joule's Law of Heating applies to any current-carrying conductor, including the stator windings of an AC induction motor. Joule's Law of Heating is the basis for the equation, $P = I^2R$ (provided on the GFE Equation Sheet), where:

P is power, or heat generation
I is current
R is resistance

The original correct answer, 280°F, can be determined by deriving $P \alpha I^2$ from the above equation. According to $P \alpha I^2$, if motor current (I) doubles from 20 amps to 40 amps, then heat generation (P) in the stator will increase by a factor of four. In response to the four-fold increase in P, the motor differential temperature (ΔT) will also increase four-fold from 50°F to 200°F. When 200°F is added to the fixed ambient temperature, 80°F, the result is 280°F (Choice D).

However, the facility comment correctly asserts the answer should be greater than 280°F because R will increase as stator temperature increases, thereby causing a greater increase in P. Using the equation/calculations for a common AC induction motor stator winding material, copper, as provided in the facility comment, and Joule's Law of Heating as described above, R will increase by a factor of 1.38 while I^2 will increase by a factor of 4. In other words, if the changes in both I and R are accounted for, "the correct answer should be some value more than 280°F," as noted by the facility.

The change in R accounts for enough change in P to alter the answer significantly. The question stem does **not** ask the applicant to assume a fixed R value so, as the question is written, the change in R will also contribute to an increase in the stator temperature.

Therefore, the question will be deleted.

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L-MT-17-020

March 15, 2017

Mr. Ivan Kingsley
Sonalysts

Subject: March 2017 Generic Fundamentals Examination Comment

Mr. Kingsley,

The purpose of this letter is to submit a comment to the March 2017 Generic Fundamentals Examination (GFE), question 15 of form A. Specifically, none of the answers appear to be a viable choice, when the temperature coefficient of resistance for the conductor is considered.

The figure below shows the relationship of temperature and the resistance of copper.

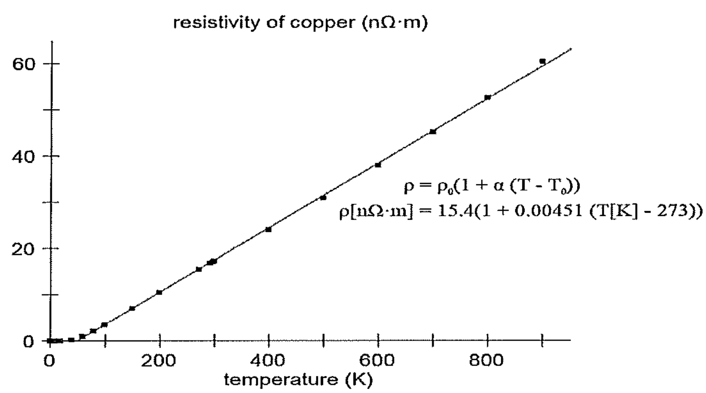

Figure 1-http://physics.info/electric-resistance/

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Mathematically:

Starting with the assumption that heat generation is proportional to I^2R losses:

Heat Generation α I^2R

Then: $(\text{Heat Generation})_{initial}/(\text{Heat Generation})_{final} = (I^2R)_{initial}/(I^2R)_{final}$

X = Heat Generation = the rise above ambient temperature of the stator windings
R_1 is the resistance initially
R_2 is the final resistance of the stator windings.

$(50\ F)/X = ((20\ amps)^2 * R_1)/((40\ amps)^2 * R_2)$

Solving for X:

$X = (200\ F) * R_2/R_1$

Using the above relationship and the values provided for temperature in the question (130 F = 327.6 K and 280 F = 410.9 K):

$R_2 = R_1 * (1 + .00451(410.9K - 327.6K)) = 1.38 * R_1$

Therefore, since $R_2 > R_1$ the correct answer should be some value more than 280 F as the temperature rise would be greater than 200 F.

Your consideration of this comment as part of the final examination grading is appreciated.

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