

Service Factor: What is it and what does it do?



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There are many misconceptions about Service Factor (SF) in the industry. Some feel it is meant for temporary excursions into overload conditions; others consider it to be an allowance for permanent overload. The truth is that it is neither. As defined in the EASA *Technical Manual* and NEMA MG1, the definition of service factor is:

A multiplier which, when applied to rated power, indicates a permissible power loading that may be carried under the conditions specified for the service factor.

The NEMA MG1-2011 theory of SF says that a motor is thermally capable of overload to that point within the insulation class at normal service conditions.

Since any increase in load increases the current, this overload will increase the operating temperature of the motor. For every increase of 10° C, the motor winding expected life is reduced by one-half. It does not matter what the source of that increase in temperature is; overload, poor ventilation, low voltage or high ambient temperature are just a few.

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Source of heat

First, we will examine the source of the heat being produced in the motor. Electric motors, like all electromechanical devices, are not totally efficient. Much has been discussed about this efficiency since the inefficiency results in wasted power. This costs money and requires more power to be produced than is required to do the work. The efficiency of the motor can be expressed as:

$$\%Eff = P_{out} / P_{in}$$

$$\text{or} = (P_{in} - L) / P_{in}$$

Where P_{in} = Power In
 P_{out} = Power out
 L = Losses

So the losses constitute the inefficiency. Some of these losses are friction and windage, but most of the inefficiency is the result of winding and core losses. The largest contributor is the winding loss that can be expressed as:

$$P_{losses} = I^2R$$

Where: P_{losses} = Power lost
 I = Motor load current
 R = Motor winding resistance

The winding resistance remains relatively constant and is a smaller factor than the load current. We can determine from this equation that the heat producing losses increase by the square of the increase in load current. The increase in current compared to load is nearly linear over short changes so if we have a SF of 1.15, the load current will increase by $\approx 15\%$. The additional watts produced will be 1.15^2 or 1.32, a 32% increase, which will result in a similar increase in temperature. **Table 1** shows this increase for several examples of Totally Enclosed Fan

Table 1. Temperature Rise (° C) vs Percent Loading.

Size/load	50%	100%	115%	125%
20 hp				
Avg. winding temp.	23	56	75	91
Max. rotor temp.	28	79	100	126
Max. bearing housing temp.	15	37	49	62
50 hp				
Avg. winding temp.	28	75	102	128
Max. rotor temp.	33	93	126	139
Max. bearing housing temp.	20	50	70	80
100 hp				
Avg. winding temp.	32	64	80	94
Max. rotor temp.	39	84	107	127
Max. bearing housing temp.	21	41	51	60
200 hp				
Avg. winding temp.	31	69	80	108
Max. rotor temp.	39	98	130	160
Max. bearing housing temp.	17	37	48	58

IEEE 841 TEFC, 4 pole, 460V

Notes: Bearing housing temperature is the drive end bearing. Maximum rotor temperature is in the rotor bar. These temperatures are the rise above ambient.

Cooled (TEFC) motors. TEFC motors will also have a greater increase in bearing temperatures than open motors because of the way they are cooled.

Effects of heat

Figure 1 shows that for every 10° C (18° F) increase in winding temperature, the thermal life of the insulation system is reduced by one-half. Looking at the 50 hp (37.5 kW) motor in **Table 1** as an example, at full load the temperature rise is 75° C (135° F). If the load is increased to the SF of 1.15 or 57.5 hp (43 kW), the temperature rise is increased to 102° C (184° F), an increase of 27° C (49° F). The reduction in life expectancy is calculated by:

$$Life_{1.15} = Life_{1.0} \times 0.5^{(\Delta T/10)}$$

$$= 1 \times 0.5^{27/10} = 0.154$$

The life has been reduced to 15.4% of the original expected life. Of course

Continued on Page 2

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Continued From Page 1

these are theoretical numbers and in real situations many factors contribute to the life (or lack thereof) of the motor. This example is meant to illustrate how important temperature considerations are in the proper application of the equipment. According to this example, if we expected a theoretical life of 10 years for our motor, by operating at SF that would be reduced to 1.5 years. A motor with Class F insulation can be rewound with Class H to help accommodate the higher temperature. This step will improve the overall life but will not lessen the impact of the overload condition. The theoretical expected life might be increased to 15 years, for instance, and the life at SF would be 2.3 years.

The definition of SF includes the phrase “normal service conditions.” These conditions include that the motor be operated at rated voltage and frequency, at a maximum of 40°C (104°F) ambient, and a maximum altitude of 3300 feet (1000 meters). Only when these conditions are met is the motor capable of the full SF overload. NEMA also allows that the motor perform successfully at ±10% of rated voltage, but it also states that at other than rated voltage, the motor’s performance may be affected. Service factor is included in the performance that is affected.

Another way to consider it is that the SF accommodates these excursions into other than normal conditions to protect the motor’s performance and life expectancy. If you have a SF of 1.15, for instance, but are operating at rated load, a voltage lower than rated voltage will not have as much negative impact on the performance. Since the motor rarely operates at rated voltage, it therefore seems to be a poor design choice to have the motor operate continually in the service factor.

Other parts of the motor’s performance are also affected. Part of NEMA MG1-2011 14.37.1 says:

“When the motor is operated at any service factor greater than 1, it may have efficiency, power factor, and speed different from those at rated

load, but the locked rotor torque and current and breakdown torque will remain unchanged.

A motor operating continuously at any service factor greater than 1 will have a reduced life expectancy compared to operating at rated nameplate horsepower. Insulation life and bearing life are reduced by the service factor load.”

If the application requires 110 brake horsepower (82 kW), it is tempting to use a 100 hp (75 kW) motor and operate it in service factor. Of course this will reduce the initial cost of the project. Installing a 125 hp (93 kW) motor will not only improve the reliability, but the improved efficiency will result in lower cost of operation. Much has been published concerning the return on investment resulting from improved efficiency so it is not necessary to review that here. Further, many motor manufacturers design their motors to have a peak efficiency near 80% of rated load. It is then best practice to increase the rating of the motor rather than operate continuously in service factor.

While many service centers are not involved in the design and specification of motor applications, it is good to be aware of these situations in the event of motor failures due to less than optimum applications. If you have the opportunity to influence the application design, you can provide a valuable service to your customer by applying this information.

The EASA *Technical Manual* refers to a practice followed by some in an attempt to increase the hp (kW) rating by increasing the wire size in older motors, many of which had ample room in the winding slot for an increase. It is not true that this will increase the

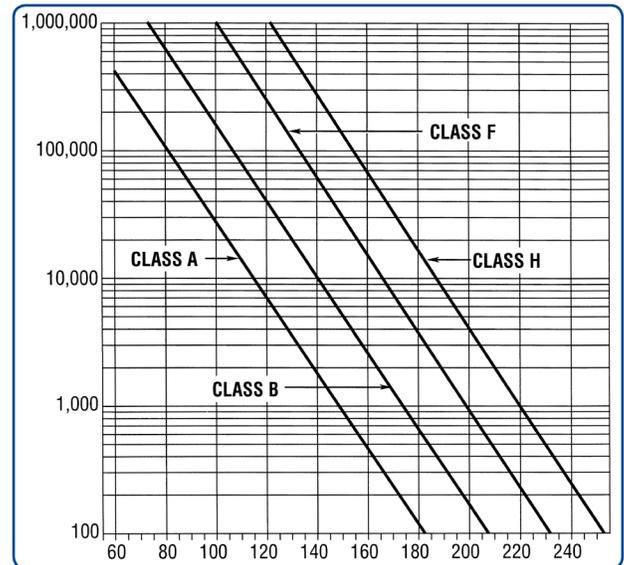


Figure 1. Temperature vs Life Curves for Insulation Systems.

hp (kW); other factors such as winding turn count and coil pitch must be changed to do so. It is a way to affect the temperature rise, however, as shown in the paragraph from the EASA *Technical Manual* below:

“Using larger wire or improving the temperature rating of the insulation will not increase the torque. Consequently, such measures will NOT increase the rated hp or kW. Increasing wire size, however, does reduce the winding loss and temperature rise under a given load, so the motor can be operated at a higher overload or service factor.”

Conclusion

By misunderstanding the proper application of service factor, the system designer will often reduce reliability and increase operating cost for the sake of a lower initial project cost. This is one time that you truly get what you pay for; a little foresight and a small increase in the investment will pay dividends for the life of the application. ●



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