Heat and power reduction in small shaded-pole fan motors when operated at reduced voltage

A study by Energy Control Equipment, Inc.

In order to verify the theory that small shaded-pole fan motors would demonstrate a reduction in both power usage and heat production when operated at lowered voltage, a series of tests were conducted at Energy Control Equipment's motor laboratory in Watsonville, CA.

Measuring the electrical use by the motor is a comparatively trivial matter, using modern instrumentation. Measuring the heat produced, however, is a much more complicated process. The heat must be retained in an insulated chamber, which will cause the chamber's temperature to rise. This rise in temperature can then be used to calculate the amount of heat produced.

To this end, a special insulated chamber was constructed, using thick styrofoam panels. The chamber had a small hole for the motor shaft, so that the fan blades were outside the chamber. Power wiring was run into the chamber in a manner to minimize heat transfer, and accurate thermocouple temperature sensors were installed.

Various test motors were installed in the chamber, and measurements taken to determine the heat output under full-speed conditions and under reduced-voltage conditions.

For each test, the starting temperature of the chamber was taken, the motor was operated for 15 minutes (there were some exceptions - see the individual reports), the power was turned off and the temperature in the chamber allowed to stabilize, and the final temperature measurement was taken.

Heat production is normally calculated by multiplying the weight of the motor times the specific heat of the motor times the temperature rise in the chamber. However, the calculation as it appears in the test sheets needs a little more explanation.

The specific heat of the motors is stated as ".115". This is our calculation of the combined specific heat of the copper and steel which is used in the motor.

The "1.15" factor is used to account for absorption and transmission of heat by the walls of the test chamber.

The factor of "4" is used because the motors were operated for 15 minutes (1/4 of an hour). Again, there were some exceptions - see the individual reports.

The low speed operating voltage for the tests was chosen to be 40 volts - the same low-voltage setting used in the Single-Phase Frigitek. This normally results in a low speed of approximately 20% of the full-voltage speed. But, for the GE 1/20Hp motor, the low speed was lower than expected. This was probably due to the fact that it was a used motor, and had bad bearings. This is a common condition, often seen in older motors which have been in operation for some time.

The result of the tests bore out the theory - under reduced-voltage operation, small shaded-pole fan motors demonstrate dramatic reduction in both electrical usage and heat production. These reductions are the sources of the savings provided by the Frigitek, with the electrical power reduction directly affecting the cost of operation, and the heat reduction indirectly affecting the cost of operation, through reduced refrigeration compressor operation.

One final observation - note that the GE 16 watts motor uses 81 watts at normal voltage. So what is the "16 Watt" rating? This is the power actually applied to the fan. Thus, for 81 watts of input power, only 16 watts actually does any useful work - the rest converts directly to heat. This 20% efficiency is typical of small shaded-pole motors.

GE 1/20 Hp Fan Motor Test

Normally we would run a motor for 15 minutes. But this motor heated up so quickly at full speed that we had to run it for 10 minutes to prevent its overheating.

Because we could only run the motor for 10 minutes, the "4" factor which we use for 15 minute runs (1/4 of an hour) had to be changed to "6".

The Specific Heat calculation factors include .115 as the combined specific heat of the copper and steel in the motor, and 1.15 as a factor to account for absorption and transmission losses in the test chamber.

Evaporator Fan Motor Test

Test #: 8 Date: 12-2-98 By: Al

Motor Specifications Mfr: GE Model: 5KSM59ES2001ES

Volts: 115 Hp: 1/20 Amp: ______ RPM: 1550

Wgt: 2.58 Fan Diameter: 10" # Blades: 4 Other: ______

First Test (compressor running)

Volts: 120 CONTROLLED Amp: 2.04 Watts: 146

Kw/hr meter rate: 0.88 RPM: 1,576

Starting time: 10:45 End of test: 11:00 (~~15~~ 10 minutes)

Starting Temp: 74.1 °F Ending Temp: 202.2 °F Diff: 128.1 °F

Motor Wgt: 2.58 X Temp: 128.1 X SpHt .115 X 1.15 X ~~4~~ 6 = 262.25 Btu/hr

Second Test (compressor not running)

Volts: 40.2 Amp: .56 Watts: 21

Kw/hr meter rate: 0.18 RPM: 233

Starting time: 1:25 End of test: 1:40 (15 minutes)

Starting Temp: 73.6 °F Ending Temp: 111.8 °F Diff: 38.2 °F

Motor Wgt: 2.58 X Temp: 38.2 X SpHt .115 X 1.15 X 4: = 52.1 Btu/hr

Reduction from normal: (1st test minus 2nd test °F)

Btu / hr: 210.2 = 80.1 % Kw/hr: ______ = 79.5 %

For this motor, the heat was reduced by 80.1% at the low speed, and the electricity use was reduced by 79.5%.

GE 16 Watt Fan Motor Test

Evaporator Fan Motor Test

Test #: 5 Date: 11-24-98 By: Al

Motor Specifications Mfr: GE Model: 5KSP51GL-583JT

Volts: 115 Hp: 16W Amp: 1.1 RPM: 1550

Wgt: 3.89 Fan Diameter: 10" # Blades: 5 Other:

First Test (compressor running)

Volts: 120 SET Amp: 1.12 Watts: 81

Kw/hr meter rate: 0.48 RPM: 1523

Starting time: 2:20 End of test: 2:35 (15 minutes)

Starting Temp: 79.8 °F Ending Temp: 155.1 °F Diff: 75.3 °F

Motor Wgt: 3.89 X Temp: 75.3 X SpHt .115 X 1.15 X 4: = 154.95 Btu/hr

Second Test (compressor not running)

Volts: 40 Amp: .42 Watts: 13

Kw/hr meter rate: 0.105 RPM: 371

Starting time: 3:30 End of test: 3:45 (15 minutes)

Starting Temp: 88.1 °F Ending Temp: 103.9 °F Diff: 15.8 °F

Motor Wgt: 3.89 X Temp: 15.8 X SpHt .115 X 1.15 X 4: = 32.51 Btu/hr

Reduction from normal: (1st test minus 2nd test °F)

Btu / hr: 122.44 = 79 % Kw/hr: = 78 %

Because we only run the motor for 15 minutes, the "4" factor is used to convert the measurement to hourly for the BTU/Hr number.

The Specific Heat calculation factors include .115 as the combined specific heat of the copper and steel in the motor, and 1.15 as a factor to account for absorption and transmission losses in the test chamber.

For this motor, the heat was reduced by 79% at the low speed, and the electricity use was reduced by 78%.