APPENDIX: Alternative Designs

["Dissection of a Hair Dryer," Stan Eisenstein and Jeff Simpson, **46**, 532-537 (Dec. 2008)]

The "Cool Shot": The "Cool Shot" is a fairly common feature on hair dryers. When the "Cool Shot" button is pushed, the current to the heating coil is either cut or significantly reduced, but the fan motor is still active. Keeping the motor running without current going through the coil is a significant challenge. Figures 10(a) and 10(b) show the complete circuit diagrams for the "high" settings of a hair dryer with a "Cool Shot" switch not depressed and then depressed, respectively. Parts of the circuit that are crossed out have no current running through them.

As long as the "Cool Shot" button is not depressed, the hair dryer acts just like the hair dryer without a "Cool Shot" button [Fig. 6(b)]. The current starts in the center of a long coil and passes through the coil in two different directions. The motor attaches to the coil in two places, causing the coil to act as a voltage divider. AC rectification is done using two diodes (A and B). Because the branch consisting of diode C and the 28-Ω resistive coil are in parallel with a branch of wires and switches with essentially no resistance, current bypasses the 28-Ω coil, and this coil has no effect on the circuit. In this case, the power is 1400 W and the voltage drop over the motor is approximately 36 V (29 V if the resistance of the motor is taken into account).

When the "Cool Shot" button *is* depressed, the circuit becomes very different. When current goes from left to right along the 21.6-Ω section of the heating coil (and right to left along the 19.5-Ω section), the current flow is blocked by the open switch at the "Cool Shot" button and by diode C. When current flows in the reverse direction, the current flows through the fuse, is blocked from passing through the circuit breaker because of the open cool switch, passes through the 28-Ω resistive coil, through the 26.4-Ω motor, and through a 15.1-Ω section of the heating coil before passing through the switch and back to the wall outlet.

The power dissipated in the heating coil is now greatly reduced to about 100 W. The power is reduced for two reasons. First, the resistance is now increased to 69.5 Ω including the motor, the 28-Ω resistive coil, and the 15.1-Ω section of the heating coil in series. Power and resistance are inversely proportional, so the power is reduced. Secondly, the coil receives current for only one-half a cycle.

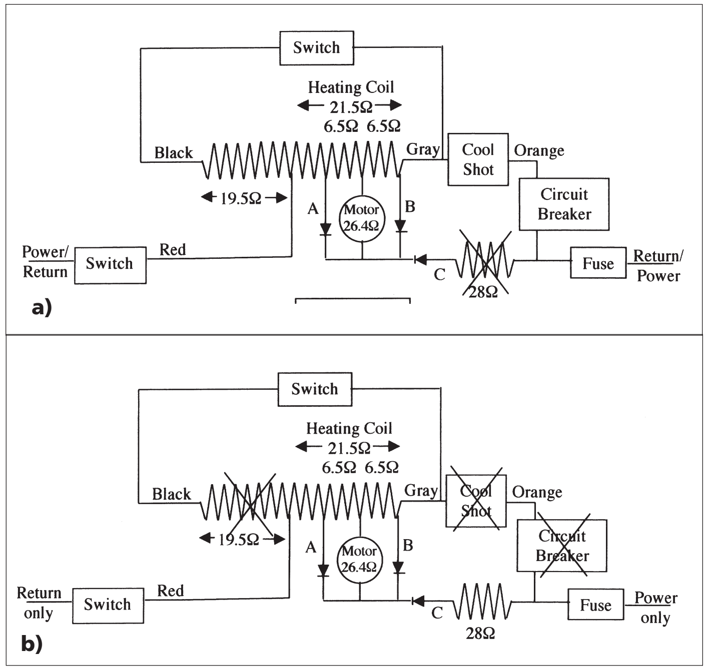

Fig. 10. Schematic for the "high" setting of the basic design with a "Cool Shot" feature. (a) The "Cool Shot" feature is off. The switch acts as a conductor and short circuits the 28-Ω resistor so the hair dryer functions just like the basic model (Fig. 7). (b) The "Cool Shot" is on. The switch is opened and current will only flow from right to left, through the fuse, the 28-Ω resistor, the 26.4-Ω motor, a 15-Ω portion of the heating coil, and the switch. This half cycle of current and added resistance greatly reduces the power in the coil but hardly affects the voltage acoss the motor. Note that the circuit breaker is also bypassed in the "Cool Shot" mode.

This cuts the power in half since electric energy is being provided for only half the time.

The voltage drop over the motor stays about the same as before the "Cool Shot" switch was pushed. If both halves of the current cycle were to pass through the motor, the voltage drop (V) across the motor would be given by the equation

$$V = R_{\text{motor}} \cdot E/R_{\text{equivalent}}, \tag{6}$$

where $R_{\text{equivalent}}$ is the sum of the resistances of the 28-Ω resistor, the motor, and a 15.1-Ω section of the heating coil in series with each other. Using Eq. (6) yields a voltage drop over the motor of 46 V. However, only half the cycle of current passes through the motor. Power is proportional to the square of voltage, and voltage is proportional to the square root of power. Since the power is divided by two when only one-half the current cycle is experienced, the average voltage is divided by √2. This yields a potential drop over the motor of approximately 32 V, not significantly different than before the "Cool Shot" button was depressed.

Separate Fan and Temperature Switches: Figure 11 shows schematics for a hair dryer that has separate switches for the fan and heating coil. The fan has its own "high," "low," and "off" settings, as does the coil. The wiring of the switches is designed so that the heating coil can only be powered if the fan is on, and the coil can only be on the "high" setting if the motor is on "high" as well.

As can be seen from Fig. 11, the fan has its own circuit. Even when the temperature switch is "off," the motor is in a complete circuit. Only the high-speed motor circuit is shown in Fig. 11, but low speed can be achieved by adding a diode in series with the 72.3-Ω resistor. This diode causes current to only pass through the circuit in one direction, thereby dividing the average voltage over the motor by √2.

Figures 11(a) and 11(b) show the difference between the high and low temperature settings. Since the speed of the motor no longer is dependent on the heating coil, higher power can simply be achieved by adding more coils in parallel. In the case shown, the power is essentially doubled by providing current to a second 22.8-Ω coil.

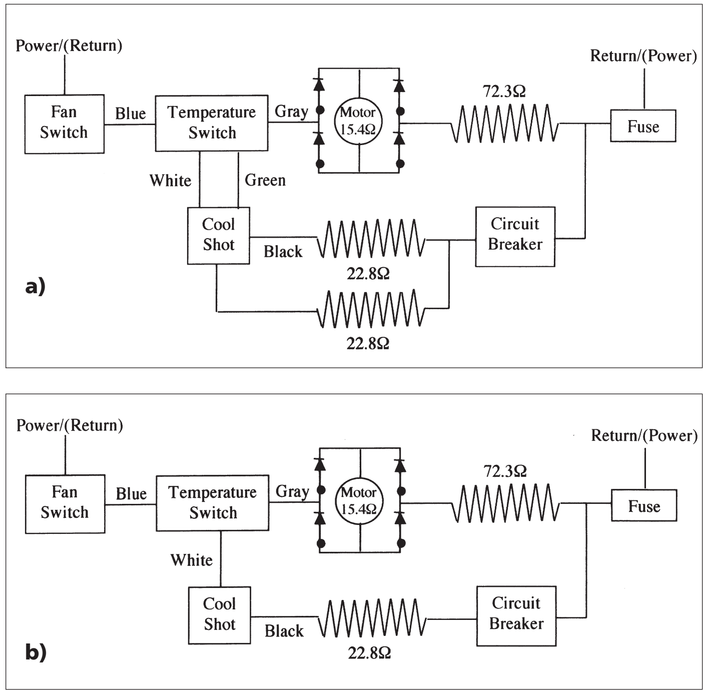

Fig. 11. Schematic for a hair dryer with separate switches controlling the fan and the temperature. (a) High fan/low heat setting. (b) High fan/high heat setting. Notice that the fan will run without the heating coil (22.8 Ω) receiving current, but the heating coil cannot receive current if the fan is not running. Also, to switch from low to high temperature, voltage is applied to a second coil, doubling the power. a)