M3 Design Product Teardown
Low Cost Consumer Product Temperature Control

Why do the product teardowns?
Part of the product development process is to apply knowledge gained from prior experience during the concept development and design phases. Some experience comes from actively designing something in the past while other experience is gleaned from more indirect sources. It is this indirect product development experience that we gain via product teardowns.

Teardowns are different from reverse engineering
Reverse engineering is nothing more than figuring out the design and manufacturing methods of a product, typically for copying. Conversely, M3 Design views product teardowns as ways to gain insight into the design to become better product developers. We focus on "why" questions.

- Why did the designer make the choices they did?
- Why were specific construction techniques chosen?
- Why were certain features included and others left out?
- Why was the particular design approach chosen?

This serves to gain more in depth understanding into the product's design rather than a superficial once-over.

How does M3 Design approach product teardowns?
Our teardown process is a rigorous approach to carefully catalog the product's deconstruction in both pictures and written descriptions. This procedure serves two purposes:

1. It forces the deconstruction team to carefully investigate the product pieces and learn as much about the design details as possible.
2. It provides a detailed record of the process for future reference by other designers.

The end result of this meticulous process is the beneficial expansion of applicable knowledge regarding product designs. We employ the lessons and insights garnered from these teardowns during brainstorming, design, prototype development, and troubleshooting. This method of obtaining indirect product development experience is just one of many important tools that sets M3 Design apart from other product development firms.
Overview
Temperature control on consumer products is all around us. Think about all the devices you use that require temperature to be monitored and controlled: hair dryers, coffee makers, electric stoves, and, of course, hair care products. The product teardown team was curious about how inexpensive products control and regulate temperature, and most importantly, how they do it safely. For this installment, the team investigated a Conair curling iron and a Revlon flat iron. Both perform similar functions – but do they control temperature the same way? Read on...

Outer Appearances
Both products are meant for home use and are relatively attractive. They also feel safe, especially important attributes since users are placing a hot metal object near their heads. We’ll investigate each one a bit further.

Conair Curling Iron
The curling iron consists of a plastic handle that contains the temperature control, connected to a metal barrel with a clamp for transferring heat to the hair. A simple pair of on/off buttons allows the unit to be, well, turned on and off. Temperature is regulated using a simple dial with markings from 1 to 20. There is no indication of how these markings correlate to temperature. The power cord is designed to pivot as the product is used – no tangled cords here! Inside the product, the power cord connection to the curling iron consists of a concentric ring and pin, with the ring connected to the neutral AC wire and the center pin connected to the hot AC wire. This design allows the cord to pivot while maintaining the power connection.
Revlon Flat Iron

The flat iron also has a plastic body that houses the temperature control and heater. A pair of coated flat plates transfers heat to the hair. Each plate “floats” on a compliant item located underneath it, most likely to allow the two plates to mate flat against each other when the flat iron is closed. More on this later. The power cord on this product also pivots to prevent tangled cords and the design and connection method are identical to the curling iron. One thing that appears out of place was the yellow plastic cover over the temperature controller board. The rest of the product looks well done, but this screams “last minute design feature”. Well, this is what happens when engineers ignore the industrial designers.
Heating
The first thing we tested was product heating. The flat iron was non-functional so we set it aside. To measure output temperature on the curling iron, we powered it on and used the clamp to hold a thermocouple against the metal cylinder. After a few minutes the curling iron reached a peak temperature of 290°F before settling at 274°F. That seemed pretty high to the team, but we confirmed it with a regular user of these devices – certain hair types need really hot irons.
Systems
As one might surmise, the minimum content of a heating product consists of a heater and a controller. Moving up in complexity might add temperature feedback to the controller. Finally, there should be some kind of safety system.

Controller – Conair Curling Iron
The Conair controller consists of a PCB with a potentiometer for temperature selection, AC power input, a silicon-controlled rectifier (SCR) for controlling power, and a microcontroller. (The microcontroller was a bit surprising to find, but these days they are so inexpensive that it makes sense to use them in products like this.) As the product heats up, an indicator light blinks then holds steady when it reaches the desired temperature. This feature is implemented by the on-board microcontroller. The other function of the microcontroller is to handle the on/off momentary contact push buttons, since some type of latching feature is needed to keep the unit powered on after the ON button was pushed. Checking the specs for this product, we determined that it also has an automatic shut-off feature – another function easily handled by the microcontroller.
An SCR allows control of an AC voltage source by varying how long the power is ON during each sinusoidal cycle. By design, an SCR acts as a diode and restricts current flow to one direction. This means that only one half of an AC cycle is allowed to pass through an SCR. A signal to the gate of an SCR turns the device on and allows current to pass. By varying when the gate signal is applied, current can flow anywhere from a full 180° of the AC cycle (remember, the SCR will only pass one half, or 180° of a full cycle) all the way to 0° of the cycle, which would conduct no current. Here is a link to a good description of how an SCR works: [http://www.opamp-electronics.com/tutorials/the_silicon_controlled_rectifier_SCR_3_07_05.htm](http://www.opamp-electronics.com/tutorials/the_silicon_controlled_rectifier_SCR_3_07_05.htm)
Controller – Revlon Flat Iron

The Revlon flat iron controller is very similar in function to the curling iron. It also uses a potentiometer and SCR to regulate power to the heater. The on/off switch is a simple mechanical slide switch with an aesthetic cover. There is no microcontroller in this product and no other features that require the use of one.

Heater – Conair Curling Iron

The heating element consists of a fine wire wrapped around a mica insulator with sawtooth edges. The sawtooth feature keeps the wire at a constant pitch for even heating and to prevent it from touching any other part of the metal case. Nickel-chromium (NiChrome) wire is used for resistance heater applications as it withstands very high temperatures (up to 2100° F). A mica insulator sheet is placed on either side of the heating wire to isolate it from the rest of the product and provide some protection. A formed D-shaped aluminum sheet metal component is then attached on either side of this sandwich and these are what transfer the heat to the curling iron's outer metal barrel. The design of this component has been well thought out. It is stamped from a flat pattern, and then formed into its final shape. The design leaves a gap on the curved portion of the shape, which provides compliance when inserting into the metal barrel and allows a more uniform contact with the barrel. Better physical contact results in more efficient heat transfer. The heater assembly is then slid into the outer metal curling iron barrel and held in place with a custom wedge washer. The wedge washer is a flat plate that is meant to slide in one way and wedges in place, preventing it from backing out. A secondary function of the wedge washer is to supply a tapped hole for the end cap to thread onto.
Curling iron heater element without insulation plates

- Thermistor temperature feedback
- Heater wire

- Sawtooth grooves to protect heater wire

- Gap to allow compliance when inserting into the curling iron shell

Formed D-shaped heat transfer element
Heater – Revlon Flat Iron

The flat iron heater design is very similar to the curling iron. The main difference is that it is split into two separate heaters, one for each flat plate. It also uses NiChrome wire as the heating element, wound into sawtooth grooves held in place and protected by mica sheets. The flat plates are aluminum extrusions with a non-stick coating applied to the surface, which contacts the hair. The heater sandwich is held against the inner extrusion surface with a curved wire spring. This provides uniform contact pressure, and therefore more efficient heat transfer. Finally, in order to allow the two heated plates to contact each other without a gap when the iron is closed on the user’s hair, two silicone bushings are installed under each heater. These allow the plates to pivot slightly and contact each other when the iron is closed.

The team also discovered why the product no longer functioned. There is a spot where the heater wire had overheated and melted, leaving a scorch mark on the mica and creating an open circuit. Since the two heater assemblies were wired in series, neither plate heated up rendering the product inoperative.
Heater assembly with insulation and flexible bushings:
- Thermal cutoff switch
- Mica insulation
- Flexible bushing

Heater element in extruded plate:
- Curved wire spring
- Extruded aluminum plate
Temperature Feedback

Both products use a negative temperature coefficient (NTC) glass-encapsulated thermistor mounted on the heater element. The flat iron monitors temperature on only one of the heater plates. An NTC thermistor is a resistor that lowers its resistance as its temperature increases. These devices are low-cost, rugged, and have high temperature capability. The thermistor was used in the controller circuit to adjust how much power was delivered to the heater through the SCR and to control temperature overshoot. As heater temperature approaches the set point, the thermistor resistance lowers, causing less current to flow through the SCR. Less current results in less heat.
Heater Safety

The team was curious about what safety systems (if any) these thermal products utilized. The flat iron uses a thermal cutoff switch rated for 216°C (417°F) in line with the heater wiring. This type of switch is a one-time fuse that opens a circuit if it gets above its rated temperature. Therefore a runaway thermal condition will cause the power to be cut off and the product will cease to work. While this is effective, it makes the team wonder how many products are thrown away due to a simple thermal cutoff switch opening up. The curling iron didn’t use any safety switch or other cutoff device that we could find.
Summary and Conclusions

These two products use very similar temperature control and feedback schemes. Since an SCR is a reliable and inexpensive way to vary the amount of power obtained from an AC voltage source, these product similarities make sense. As product designers we are always conscious of product safety and the lack of a safety circuit on the curling iron was disappointing. Perhaps they were using the NiChrome heating elements as a “fuse”. Evidence for this possibility was found in the failure of the flat iron, which failed due to overcurrent in the heater wire, which caused it to melt. This may be an acceptable self-regulating method to prevent over-temperature as long as the components in contact with the wire don't catch fire. NiChrome heater wire can be obtained in grades that limit the maximum temperature (current flow), making this safety cutoff method feasible. Still, we think a safety-specific device would be more appropriate.