The Wire That Made Cooking Electric

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Modern inventions normally build upon advances in science and engineering that have gone on before. Such was the case in 1859 when George B. Simpson was granted a patent for an 'Improved Electrical Heating Apparatus' (Simpson). (See Figure 1.) The 'electro-heater' consisted of a long coil of 'platina' wire laid in a serpentine groove cut into 'common soapstone'. When electricity was applied from 'any well-known electric or galvanic battery now in use', the wire glowed and radiated heat. The apparatus worked by 'generating heat sufficient to warm rooms, boil water, cook victuals, &c., by passing currents of electricity over the combined arrangement over coils of platina or other metallic wire properly encased in metallic tubes or open vessels insulated with any of the well-known substances non-conducting of electricity'. What Simpson described was a perfect description of the electric hobs in the cooktop I purchased 134 years later.

The heating apparatus depended heavily on resistive heating, at the time also known as Joule heating (Watson, 1904, p.720). Joule's first law states that the power of heating generated by an electrical conductor is proportional to its resistance times the square of the current applied to it. The higher the resistance to the current, the more heat is generated. From the above, it is possible to see that the amount of heat generated can be controlled by controlling the current flowing through the wire (Marsh, 1906).

In Simpson's time, he couldn't just plug his apparatus into a wall socket. He was dependent on a battery. The first battery was demonstrated by Italian physicist Alessandro Volta (Dobson, 1908, p.9). He published his experiments at the turn of the nineteenth century. Others used different materials in the next few years to produce other possible batteries, and workable, homemade systems were well-available by the time Simpson's patent was granted.

The other drawbacks to Simpson's invention were the lack of a means of controlling the amount of current flowing through the system and the reliability of the resistance wire. Simpson's platina is today known as platinum ('Platina', 2020). It is not particularly rugged when used as a resistance wire, but at the time, it possessed a resistivity of about ten times that of copper. Unfortunately, when hot, the surface of the platinum wire oxidizes and the wire becomes brittle (Crompton, 1895, p.512).

It is not known if Simpson ever built a sample of his apparatus, or if he even understood the underlying science. Simpson's device is based on the concept of incandescence, or if you heat an item hot enough it will begin to produce electromagnetic radiation. Incandescence was first demonstrated by Humphrey Davy in 1802 when he passed sufficient

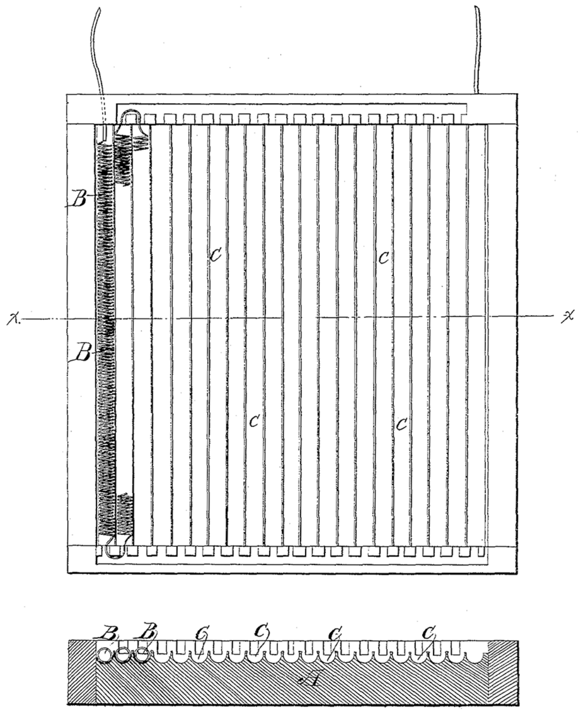

Figure 1. Illustration from George Simpson's 1859 patent of a 'heating apparatus'. Note the coiled resistance wire (B) set into grooves (C) cut into the soapstone base (A).

current through a platinum strip until it glowed (Lardner, 1846, p.189). Although most nineteenth-century inventors studying incandescence were interested in maximizing the amount of visible light, they also recognized that the process could produce significant amounts of infrared radiation—what the non-scientific world refers to as heat. (1)

By the later part of the century when many inventors were concentrating on perfecting a practical filament for an incandescent light bulb, others took advantage of the heat produced by platinum resistance wire to make a better tea kettle. In 1895, a paper presented by R.E. Crompton to the Royal Society for the Encouragement of Arts, Manufactures and Commerce contained illustrations for an electric hot plate, an electric frying pan, an electric saucepan, and an electric grill in addition to an electric kettle (Crompton, 1895, p.513, 515). (See Figure 2.)

Rather than use the resistance wire to emit radiant energy, Crompton described the great lengths he went to to attach a nickel-steel wire to a metal plate so the energy created would be transferred by conduction. The wire was formed into 'a waved or crimped ribbon'. The ribbon was

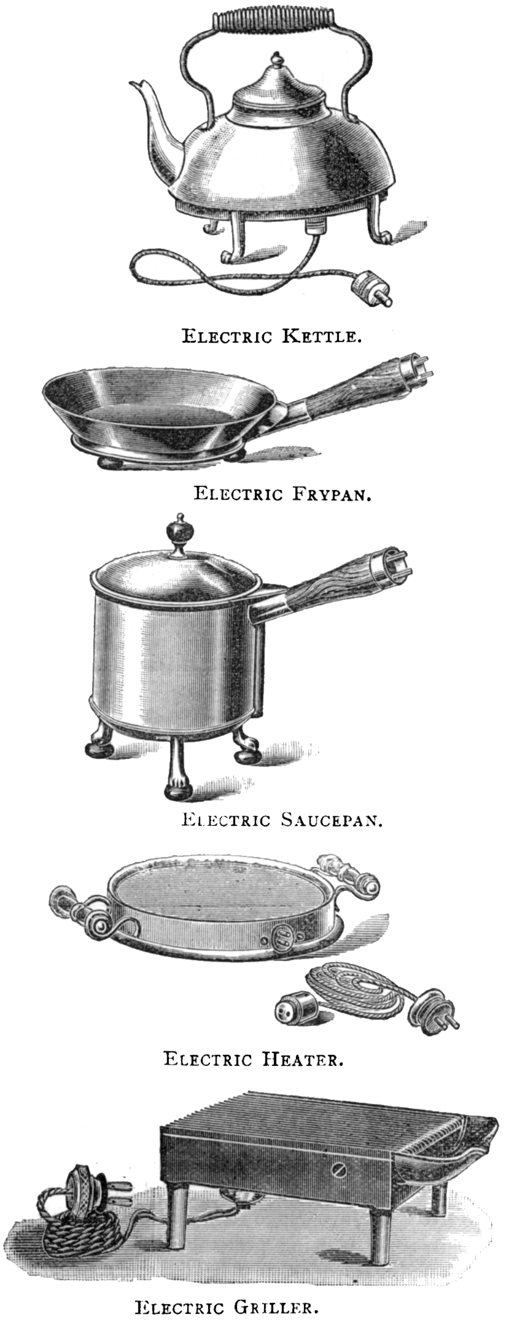

Figure 2. Five electric cooking appliances from Crompton's 1895 paper on using electricity for cooking.

attached to a metal plate with softened enamel. 'We then cover the first enamel and the wire with powdered enamel of a more easily fusible nature, and we then raise the temperature of the whole to a sufficient degree to enable the second enamel to melt down and incorporate itself with the upper surface of the first coat of enamel, at the time completely covering and insulating our wires' (Crompton, 1895, p.513). This method of attachment also sealed the wire surface to prevent oxidation.

The small electric appliances suffered from a number of shortcomings that prevented them from becoming true marketing successes. Large-scale generation of direct-current electricity in London started in 1882 and generation of alternating-current electricity in 1889. Although produced in large generating plants, the distribution was limited to commercial and public buildings and the homes of the well-off (Wilson, 1988, p.35).

Even if you were fortunate enough to live in an electrified dwelling, the distribution within your house was most likely done by abandoning the gas lighting, removing the elbows from the pipes and running the wires through the now unused pipes. Although the first, practical wall plug was proposed in 1890, it would not be until after the Great War until wall outlets would be routinely installed (Schroeder, 1986, p.533). Accordingly, most electric appliances came with the ability to screw into an overhead light socket.

Then there was the issue with longevity of the appliance. Crompton's enamel coating and attachment of the resistance wire would eventually crack, allowing the wire to oxidize and break. The cracks would occur because of the dissimilar thermal expansion of the metals and the enamel.

Even with these obstacles, there was good reason to at least electrify your kettle. As early as 1744, the surface of a hot metal stove—the term heater was less common then—was recognized as a useful way of heating a kettle or keeping a plate of food warm (Franklin, 1905, p.267). One-hundred-and-fifty years later, using the stove that heats your room as a means of heating your kettle was still described as a salient benefit in stove advertisements. 'The top of [the] heater cylinder has an ornamental dome, which can be removed and any ordinary boiling or cooking done in kettle, basin or pan' (The Rochester Lamp Company, 1893). Since most of these stoves used solid fuel, the time required to heat a kettle may also have included the time required to build a fire. During winter months, the stove may already be warm, but what if you wanted your tea during a warmer season? Here, an electric kettle could have the advantage of instant turn on and rapid heating.

According to Crompton, his state-of-the-art electric tea kettle could heat a pound of water (one pint or enough for two to three teacups) in eighteen minutes for a cost of about a third of a penny loaf. Today, that seems like a long time to wait—my modern electric kettle takes 90 seconds and costs less than a slice of bread—but it was much quicker than firing up the coal grate. (2)

Another alternative to firing up a stove was using a liquid fuel burner. Alcohol stoves were patented as early as 1856, although their popularity seemed to not extend past expeditions and camping trips (Anon., 1857). The effectiveness of alcohol stoves increased with the introduction of the single burner, table-top Primus stove, where the wick was replaced by an air-injection gas burner. (3) With the Primus stove, the liquid fuel is pressurized with a manual pump causing the liquid to flow into the burner as vapor. The liquid-fuel was called paraffin, which today is called kerosene (Wm. Whitely, Ltd., 1913, sec.2, p.842). (I assume the smell was not the most pleasant.) This same principle was used in modern camp stoves before the common availability of small pressurized gas canisters, although the fuel smell was less of an issue (The Coleman Company, 1978, p.56). S. Sternau & Co. of Brooklyn, New York, produced numerous appliances heated by alcohol, and eventually, their signature product, Sterno or jellied alcohol, would become synonymous with chafing dishes (S. Sternau & Co., 1918).

The small electric appliances of the turn of the twentieth century—kettles, saucepans, frying pans, and grills—all relied on enclosing the resistance wire for durability and thus transferred energy from the electric current to the item being cooked by means of conduction. The only appliance relying on radiant energy was the electric toaster, and at the time, only one had been introduced, the Eclipse Electric Toaster designed by Alan MacMasters for Crompton & Co in 1893 (Winn, 2018, p.77). Due to the limited availability of electricity in the home, no small electric appliance achieved universal use.

Toast was almost as important to the English and their overseas descendants as tea. During the eighteenth and nineteenth centuries, tea and toast consumption expanded from that served by servants to that prepared by the consumer. The non-enzymatic browning that produces toast must be created by exposing the surface of a slice of bread to radiant energy. Initially this process was performed by stabbing the bread with a toasting fork in order to hold the bread surface exposed to the radiant energy produced by a wood or coal fire in a hearth or a grate. The fork was later supplemented by various designs of racks and grilling baskets that could be held over or in front of the fire. A glowing coal fire set in a fire grate was thought to be ideal for the task of making toast for tea.

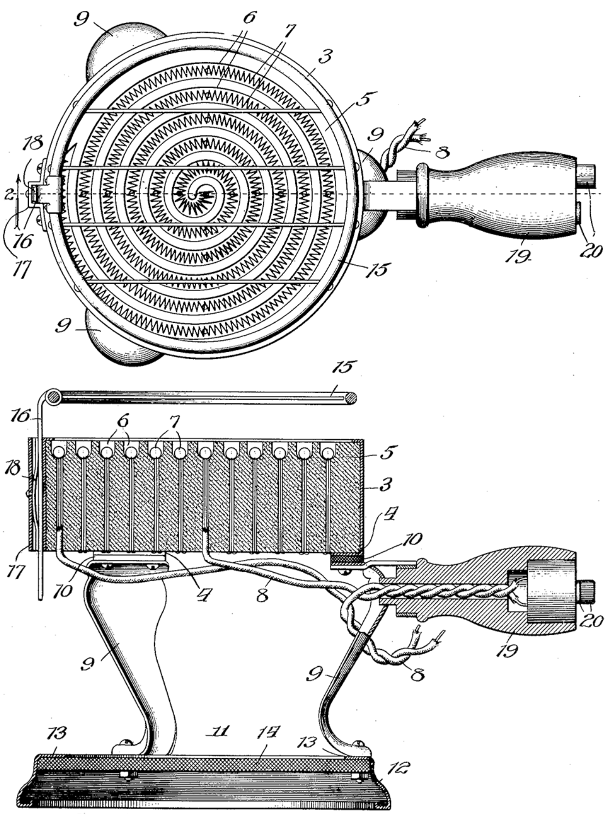

Figure 3. Illustration from Albert Marsh's 1907 patent of an 'electric stove'. Note the lack of any form of protection from burns and no control of heat other than on or off (20).

Early in the twentieth century, both tea and toast would become significantly more convenient to enjoy because of Albert Marsh's patent for a robust electrical resistance wire, published in early 1906, yet it provides no mention of tea or toast or anything else culinary (Marsh, 1906). The accompanying illustration is of an electric resistance element. Nonetheless, the invention would have a profound effect on both small and large electrical cooking appliances as well as many other devices in industry and the home.

Marsh recognized the culinary importance of nickel-chromium wire in a follow-up patent he filed about a year after receiving the initial patent (Marsh, 1907). The patent is titled 'Electric Stove', but to most observers, it appears to be nothing more than what today is referred to as a hot plate. It does appear to be a direct competitor to the alcohol stoves mentioned previously. Marsh describes his stove in the patent as 'a novel construction of portable electric stove or heater, which shall adapt it, more particularly, for table use in preparing food to be served, and which peculiarly adapt it for use as a toaster'. (See Figure 3.)

As illustrated and described in the patent, the 'electric stove' had many features that would be unacceptable to a modern user as well as to government safety agencies. The stove came with 'a flexible conductor carrying [on] its free end the usual plug (not shown) adapted to be inserted into the socket of an incandescent electric lamp for furnishing the current' (Marsh, 1907). Wall outlets were still not available when this patent was issued. (4) The resistance wire lay coiled in its spiral groove, exposed to all that needs heating. There is no way to clean the wire or its bed should a pot of coffee boil over or some pancake batter splash on the burner some Sunday morning. If the user is not careful, all hot portions of the stove are easy to inadvertently touch. To control the stove, there's only an on-off switch. It's all or nothing when it comes to the amount of power delivered to the resistance wire.

At this time, it was known that '4 kilowatt-hours are about the equivalent of one pound of coal, which, at present commercial rates, places a very onerous burden on the use of electricity for such purposes. On the other hand it is highly serviceable for some uses on account of its great convenience, cleanliness and adaptability' (Koester, 1913, p.194). Two appliances that benefited from the advent of nichrome wire important to the average users were toasters and kettles, even though the cost of electrical energy was higher than that produced by coal.

In 1910, Frank E. Shailor (1910) was granted a patent for an 'Electric Heater'. The patent was assigned to the

General Electric Company and was similar to another filed by a co-worker, Leon Parkhurst. Both were for an electric toaster and together became the Model D-12 Toaster, possibly the first practical electric toaster. Features that allowed toasting both sides of a slice of bread at the same time, others that timed the toasting, and all the ways toast could now travel in front of the heating elements would all come later. Today, just as with that early twentieth-century appliance, a basic toaster still relies on radiation emitted by nichrome resistance wire to toast bread for our breakfast.

I assume that once a superior resistance wire became available, manufacturers substituted the new material for whatever they previously used. A 1910 catalogue from the Glasgow Electric Department states that 'Electric kettles are at present more generally used than any other electrical cooking apparatus. Manufacturers are producing kettles of every description suitable for all purposes' (Electricity Department, 1910, p.16).

Toasters differ from kettles in that they use resistance wire to directly radiate energy into the bread to toast it, whereas with kettles, the resistance wire is used to conduct energy directly into a secondary material, usually a metallic solid, to provide a hot surface for heating the water. Whether bonded to the metal with enamel, as Crompton did, or simply held adjacent to the metal with clips or clamps, the resistance wire still could eventually break.

This issue was solved in 1915 when the first 'calrod' heating element was invented. (5) A calrod heating element consists of a soft metal tube in which a long coil of resistance wire is inserted. The space between the coil and the tube wall is filled with a powder that is both an electrical insulator and highly conductive to heat. After filling, the tube is swaged into a smaller diameter to tightly pack the powder around the wire for full contact. It would be more than a decade until the term calrod was used in marketing materials. It was initially termed 'sheathed wire' (Edison Electric Appliance Co., 1918, p.15).

Once a straight calrod element is fabricated and the metal sleeve annealed, it can be formed into the shape required for the heating application ('Anneal', 2020). The familiar single or double spiral form became commonplace as electric stove surface burners for close to a century. The spiral heating element could additionally have a metal case moulded around it to produce a disk-shaped heating element that later would be marketed as a 'European-style burner'.

Within three years of the development, General Electric was marketing ranges with both ovens and burners that incorporated calrod-type heating elements. The oven heating element consisted of two serpentine runs of sheathed wires mounted to a metal frame that supported the wires and allowed the arrangement to be removed from the oven as a single unit. The surface burners were metal plates with a dual-spiral arrangement of sheathed wire clamped to the underside of a flat, metal disk. A sheet metal enclosure protected the wire from the bottom side.

Three other types of surface burners were easily found on electric ranges of this period (Piper, 1919, p.22-24). The first type has heating coils inset into deep grooves in the top surface of a round, flat porcelain plate. Although the coils are directly exposed to the pot or pan above, most of the energy first goes to heating the ceramic disk. The heat transfer is mostly by conduction rather than radiation.

The next type of surface burner has an array of open coils mounted in a steel frame. The coils are supported and insulated by a series of ceramic bushings. Below the burner is a bright reflector to direct more heat up to the cooking utensil. The heat is transferred mostly by radiation although in time there is also conduction from the heated steel frame. (6)

The last type consisted of a cast steel grating that both supported the cooking vessel and a moulded porcelain disk that, in turn, supported the heating coils. The bottom of the assembly forms an enclosure so that heat radiates upward from the package. Much of the heat goes to heating the metal grating which, in turn, conducts heat into the vessel.

These three previous surface burners all suffer from the same defect as Marsh's stove, which the literature of the period seemed oblivious to: There was no way to clean the burner if food got into it. I wonder how many burners met their maker when a pot boiled over or a bit of batter missed its mark? The metal plate burner suffered less cleaning issues, but it took longer to come to heat and was slower to react to changes in current. In tests, this type of burner was less efficient than the others (Piper, 1919, p.25).

The electric range of this period was considerably under powered when compared to modern ranges. A four-burner range would have three burners rated at 1000 watts and the fourth at 1500 watts. By comparison, a century later, the typical six-inch burner was rated at 1500 watts and the typical eight-inch burner at 2600 to 3200 watts. In addition, modern ranges allow the cook to choose six to eight intermediate power levels. The controls of the early ranges allowed for three discrete levels: 100%, 50%, and 25% (Edison Electric Appliance Co., 1918, pp.16–20). Electric ovens were controlled in the same manner, and had cavities, typically 18 inches wide, 18 deep, and 14 inches high, significantly smaller than modern ovens. It would not be until the late 1920s that thermostatically controlled ovens became commonplace.

In 1929, General Electric moved the 'sheathed wire', or the calrod as it is now known, out from under the cast metal disk and placed it in direct contact with the cooking vessel. (See Figure 4.) The single or double spiral of heating element was supported on a sheet metal frame and backed by a reflector pan. This calrod burner became the 'killer app' of electric ranges, and the manufacturer started to refer to the heating element as the 'hi-speed calrod' (Edison Electric Appliance Co., 1929). Later tests showed a significant efficiency increase was achieved in modern versions of the calrod burner (DOE, 1998, v.2, pp.1–21; Edison General Electric Appliance Co., 1930).

In the twenty-first century, the calrod is all but gone in the world of cooking appliances, having been replaced by alternative means of holding the resistance wire for improved

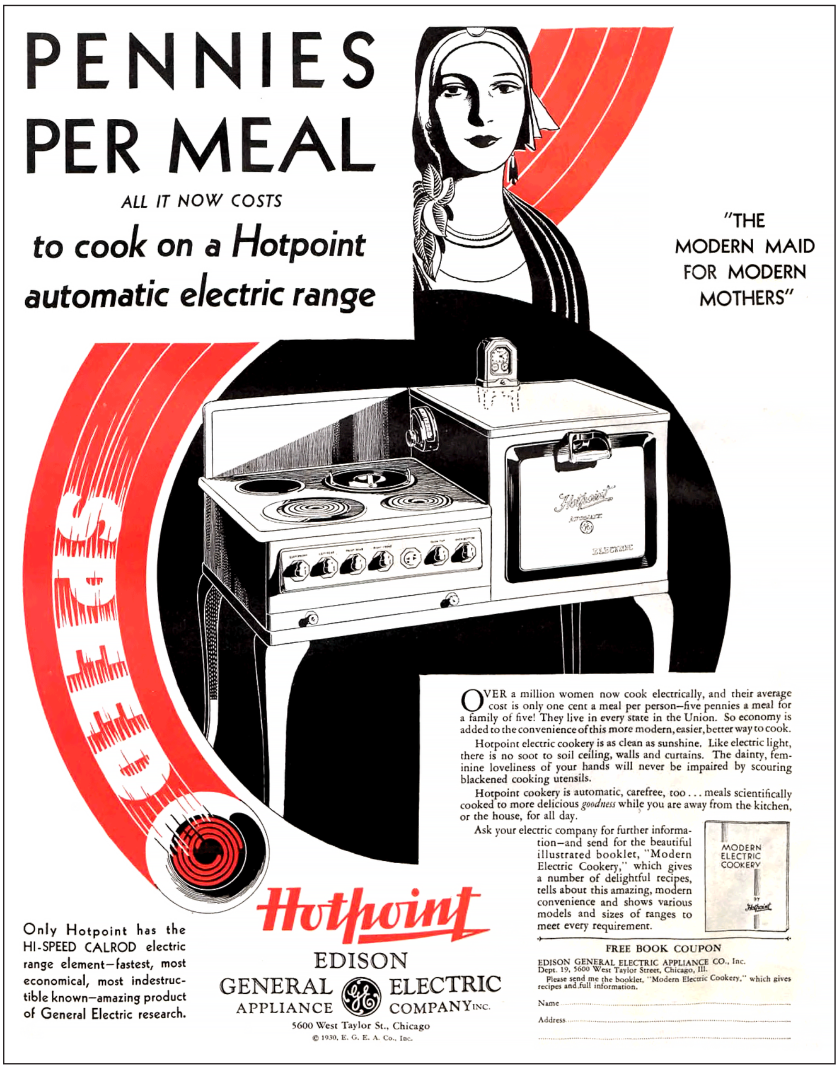

Figure 4. Early advertisement for a Hotpoint electric range featuring calrod surface burners. Note that only the front burners appear to be the new style. The right rear burner is a cooking well used with an accompanying pot. The left rear burner appears to be the older style of disk burner (Piper, 1919, p.28).

radiant efficiency. Yet, improvements on Marsh's original wire are minimal. The ratio of chrome to nickel is varied to produce variations in the wire's features, and other alloyed wires have been developed for specific heating uses. Still, the resistance wire most used today is the same as developed over a century ago. That wire became the basis of so many cooking devices, large and small, that would not have been as successful as they've become if the wire didn't exist. Other elements of toasters, kettles, hotplates, and stoves have changed, but Marsh's nichrome wire remains the same.

Notes

1. 'The intensity of the heat is determined by the length and thickness of the wire or foil. Platinum is well suited to the purpose, but iron will answer. For heating water, the wire or foil is wound or otherwise arranged at the bottom of the receptacle in which the water is contained, such receptacle being made of earthenware or other suitable material; the water becomes heated by contact with the wire or foil.' (Lane Fox, 1878).
2. Crompton used 0.075 kWh of electricity at a cost of 0.32 pence to heat 1 pound of water from 50°F to 212°F in 18 minutes. In comparison, I used 0.040 kWh of electricity at a cost 0.003 cents to heat the same amount of water to boiling in 90 seconds (Crompton, 1895, p.514).
3. The Primus Stove would reportedly boil two litres of water in five minutes consuming one-half a litre of petroleum oil per hour (Davis, 1893).
4. Although published 10 years after Marsh's (1907) patent, this catalog (Sears, Roebuck, & Co., 1917) contains no electric receptacles, and there are many appliances shown with a plug designed for screwing into a light socket, including a washing machine illustration (p.33) depicting a woman plugging the unit into such a socket with the caption: 'Starts as easily as turning on an electric light'.
5. Calrod is a trademark of the General Electric Company, but the term has become the generic term used for tubular heating elements consisting of resistance wire packed in an electrically insulative powder. The calrod design was apparently never patented. The design appears to rely heavily on a patent by Carpenter (1890).
6. Piper gives equal weight to radiation and convection for this type of burner, but a century later it is known that convection plays a very small role in electric surface-burner heat transfer.

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