# The History of the Microwave Oven

By Leo R. Reynolds

The microwave oven story is not a stale and sterile tale of technology, patents, or licensing, but a dynamic Walter Mitty, Horatio Alger epic full of interesting characters.

While many people were involved, but for three key men – an inventor, Dr. Percy Spencer; an entrepreneur, Lawrence Marshall; and a marketeer, George Foerstner – there might not have been a microwave oven story today. These unique persons, possessing the right skills needed at just the right time, by some strange process happened to coalesce to form the critical mass needed to make the microwave oven story the success it is today.

But, how did the story start, and what can we learn from it? To set the scene, we must go back in time to 1940. The GNP was $90 billion a year. Hot dogs were 5¢, movies 20¢, and a fifth of scotch was $1.25. Many of the discoveries which were to alter the postwar landscape had been made before Pearl Harbor. NBC had beamed an experimental telecast in April of 1939. Fluorescent lighting was coming along. Just as nylon and dacron foretold a revolution in fabrics, plastics were about to replace steel, aluminum, zinc, and nickel in everything from steering wheels to fountain pens. In the spring of 1940, Igor Sikorsky had made his first helicopter ascent.

In Britain, teams of scientists were working desperately to produce a source of microwave energy to power radar sets being developed for the military. The threat of German invasion added urgency to the British efforts. In February, 1940, Professors Randall and Boot, two scientists working at Birmingham University, devised an electronic tube (the British called it a valve) which they named a cavity magnetron. This device generated large amounts of microwave energy very efficiently.

The unique ability of the magnetron to transmit microwaves at very high power enabled radar equipment to be built that was much smaller, more powerful, and more accurate than anything previously designed. Radar sets could be built into airplanes to "see" other aircraft or targets on the ground. The cavity magnetron gave Britain a big lead in radar, and in 1940, when Britain stood alone, Churchill was persuaded by Dr. Tizard, a preeminent British scientist, to use this priceless knowledge as a lever to persuade the United States, then still neutral, to help Britain by applying some of America's vast production potential.

Tizard, along with Dr. Cockroft, was dispatched by plane to the U.S., carrying with them a single magnetron tube. The distinguished author and scientist, C.P. Snow, later characterized this as "the most important package ever brought across the seas".

Into this setting stepped the first important character in the development of microwave ovens – Percy Spencer. Percy was a "Horatio Alger" character who could aptly be titled "Mr. Microwave". He was the product of a pre-World War II Maine boyhood. To fully appreciate Percy, it is necessary to know a little about his background. He was raised by his Aunt Minnie, an itinerant weaver, when his father was killed in a mill accident and his mother left the family. After elementary school, Percy went to work in a machine shop in Maine. He was introduced to basic electricity when a contractor hired him as a hand to help electrify a pulp and paper mill.

Percy took a poor boy's route to education by enlisting in the Navy. Upon discharge, he worked for a wireless specialty apparatus company making electrical

*This history of the development of the microwave oven is based on a presentation by Leo R. Reynolds given at the 24th Microwave Power Symposium held in Stamford, CT, in August, 1989.*

*Mr. Reynolds is a partner in the law firm of Hamilton, Brook, Smith & Reynolds in Lexington, MA, and was involved in several of the patent applications referenced in this article.*

*Appreciation is also extended to the Raytheon Company of Waltham, MA, for their permission to use information on the microwave oven story from their book entitled, <u>The Creative Ordeal</u>.*

equipment. During World War I, he worked for the Navy as a civilian and was put on loan to the Submarine Signal Company. By coincidence, the Submarine Signal Company was later merged with Raytheon Company.

Submarine Signal was a firm which had developed underwater sound devices for the Navy. It also installed equipment on light ships and shore stations. Percy's skills improved during this employment.

He read widely and assiduously. He devoured technical articles in addition to books of all kinds. Subsig, as it was called, did not hold him long; underwater sound devices seemed far less interesting than electricity.

A brief contact with American Radio and Research Corporation introduced him to the fascinating mysteries of gas and vacuum tubes, and these seemed attractive. Although Subsig offered young Percy Spencer the management of its Norfolk office, he decided to join American Appliance, an early manufacturer of radio tubes, which was the precursor of Raytheon Company.

Percy quickly progressed from an inspector to head of new tube and engineering production at Raytheon by 1940. His ingenuity was endless. He created photo developer lamps, a line of photocells, and a mercury rectifier tube which served as the basic component in a new welding machine marketed by Raytheon.

In September, 1940, Tizard and Cockroft visited the United States bringing with them the 10-centimeter magnetron which could deliver 1000 times the power of any existing microwave generator. The British planned to have the giant Bell Labs develop radar sets for them. Western Electric would make the magnetrons. Fortunately for the microwave oven story, Tizard and Cockroft were persuaded by people at the radiation lab at MIT to also visit the tiny Raytheon Company in Newton, Massachusetts, ten miles down the road from MIT.

In due course a distinguished British gentleman arrived, bearing the mysterious cavity magnetron in the proverbial black box. Percy Spencer, rising to the occasion, was at his beguiling best.

The Britisher liked Spencer at once. He showed him the magnetron, and the American regarded it thoughtfully. He asked very intelligent questions about how it was produced and was answered at length.

The conversation took place on a Friday afternoon. As the men talked, shadows began to lengthen, and Percy inquired, "Could I take this home with me over the weekend?" The Britisher would have been hard put to explain why he allowed the top secret magnetron out of his hands, but at the moment assent seemed natural. (With all the security red tape nowadays, this could never happen.)

The following Monday they again met in the laboratory. Spencer was smiling and optimistic. He thought Raytheon could produce the magnetron and implied that some improvements might be possible in the manner in which they were manufactured. He discussed some of these, and the visitor, who was himself a notable scientist, grasped their implications immediately. He was surprised and impressed. Raytheon soon received a contract to make copies of the British magnetron.

Spencer immediately set about the task of improving the manufacturability of magnetrons in large production quantities. Within a relatively short time, he had the production of magnetrons up from 12 per month to well over a thousand per day. In the course of these endeavors, he made many noteworthy contributions to the art, two of which stand out. One was the use of stamped laminated copper sheets to form magnetron cavities. This was in place of the time consuming procedure of drilling solid blocks of copper to form cavities. His other innovation was the use of rings, called straps, which were soldered to alternate vanes of the magnetron anode. These straps reduced the tendency of the tube to generate "spurious" oscillations and resulted in a forty percent improvement in the tube performance.

This strapped magnetron invention was conceived in August of 1941 and reduced to practice in October, 1941, about one year from the date Percy first saw the top secret British magnetron. The resultant patent was filed in November, 1942, and was involved in several interferences which kept it pending, which explains why it did not issue until April, 1951, as U.S. Patent No. 2,550,614. To this day, almost all magnetrons used in radars, microwave ovens, and other applications continue to use this strapped anode invention.

In 1945, Percy Spencer's inquisitive

## The Microwave Oven Development History

| | |
|---|---|
| Feb., 1940: | Professors Randall and Boot invent cavity magne-tron in England. |
| Sept., 1940: | Tizard & Cockroft seek U.S. production assistance for magnetron. |
| Aug., 1941: | Strapped magnetron invented. |
| Nov., 1942: | Strapped magnetron patent submitted. |
| ____, 1945: | Percy Spencer discovers radar heating effect. |
| Oct., 1945: | Spencer files first microwave heating patent for "a method of treating foodstuffs." |
| ____, 1946: | Research to develop micro wave oven done at Raytheon Co. |
| Jan., 1947: | Dr. Bill Hall applies for patent on mode stirrer. |
| ____, 1947: | First commercial microwave oven introduced by Raytheon Co. |
| Jan., 1950: | Spencer patent on microwave oven issued (No. 2,495,429). |
| Apr., 1951: | Spencer patent on strappe magnetron issued (No. 2,550,614). |
| Nov., 1952: | Hall patent on mode stirre issued (No. 2,618,735). |
| Dec., 1952: | Raytheon approahces Tap pan Stove Co. to license microwave oven technology. |

| | |
|---|---|
| Jul., 1953: | Tappan and Raytheon sign license agreement. |
| 1953-1961: | Similar license agreements signed with Hotpoint, Westinghouse, and Litton. |
| 1961: | Litton acquires license from Raytheon to manufacture and sell magnetrons and power supplies for microwave ovens. |
| 1962: | Ironfield patents quarter-wave choke (No. 3,182,164). |
| 1965: | Litton introduces its first microwave oven. |
| 1965: | Raytheon acquires Amana. Projected sales estimates for microwave ovens given at 50,000 units per year. |
| 1967: | Amana introduces first counter-top microwave oven. |
| 1972: | 885,000 microwave ovens installed with sales of 525,000/yr. |
| 1975: | Annual sales 2.7 million units. |
| 1980: | Annual sales 3.6 million units. |
| 1983: | Annual sales 5.9 million units. |
| 1984: | Annual sales 9.1 million units. |
| 1987: | Annual sales 12.8 million units. |
| 1989: | Annual sales 10.6 million units (est.) Projected market penetration rate = 75% to 80% of all U.S. households. |

mind was applied to the next major step in the microwave oven story, and this was indeed "a giant step". Percy was intrigued by his observation that microwave energy could generate heat in various substances when in use. Allegedly, he became aware of this phenomena when passing a radiating antenna he felt his body go warm.

One day he took a bag of popcorn kernels and placed it in front of a waveguide horn and watched in fascination as the kernels popped as though before a fire. Legend has it that the next day he brought a raw egg and placed that before the waveguide horn. The story goes that one of the engineers became so engrossed he leaned too close and was splattered when the egg suddenly exploded.

It is at this juncture that another fascinating character should be introduced. At that time, Lawrence Marshall was the president of Raytheon Company and one of the original founders in 1922. Mr. Marshall was an engineer, a business man, and an entrepreneur in the best sense of the word. At the time of Percy Spencer's discovery, Marshall was in the midst of converting Raytheon to a peacetime economy. During the war, Raytheon sales had leaped from $3 million in 1939 to $173 million in 1945. Marshall immediately perceived the potential of Spencer's discovery to revolutionize the cooking process and, at the same time, provide a vast commercial market for the magnetrons produced by Raytheon in such large quantities during the war years.

In the evening, after almost everybody else had gone home, Lawrence Marshall would leave his president's office and appear in the laboratories. There he was transformed into an engineer once again.

Not long after Spencer's discovery, Marshall sponsored an employee contest to come up with an appropriate trademark for this new device, and the term "radarange", combining the words radar and range, was coined.

Next, a cabinet for the Radarange® oven had to be created. The first design leaked radiation. Also, it was too large and cooked too slowly. Marshall and his engineers would create a new, better model. They began with the idea that the energy should be radiated into a closed cavity containing the food. Casting about for such a container, they left the building. The nature of their search is not difficult to imagine because they brought back a large, galvanized garbage can.

Marshall wanted to experiment with real food and selected gingerbread mix. They cooked this in batches, varying the magnetron coupling and the amounts of mix. First they would cook, then munch the results; then cook some more. Gradually the scent of gingerbread permeated the premises, seeped into their clothing, and surrounded them. It was a smell they grew to hate as they worked away night after night.

Although this was a private, intense, after-hours effort conducted at the end of busy and complex days, they succeeded in establishing the principles of a functioning microwave oven with the cooking speeds that Marshall considered the best attainable. He then turned the project over to a regular engineering group.

This group created larger ovens, control circuits, and a special cooking magnetron.

This approach to microwave cooking was a Marshall classic in the art of developing new technology. He had realized the potential of Spencer's discovery immediately, had rushed to improve it, and had pulled together the elements of manufacturing it in volume with miraculous speed. The swiftness with which he moved and his uncanny ability to evoke special efforts from his engineers was impressive. Although he was in his late fifties, the pace at which he worked was that of a young and tireless person. It was the same sort of perception and drive that had pushed Raytheon into a huge national resource during the war. But during the war, a huge and anxious customer had been waiting impatiently, order forms at the ready.

In microwave cooking, no such customer was either at hand or visible on the horizon. And in the crush of his effort, Marshall had overlooked some key commercial elements inherent in peacetime markets. Who would sell the radarange oven? How would salesmen be selected and organized? How would the radarange oven be distributed? Finally, to whom would it be sold?

In October, 1945, Percy Spencer's patent application, entitled merely "method of treating foodstuffs" was filed. The patent U.S. No. 2,495,429 issued on January 24, 1950, with broad claims which society which settled in America in 1842. Despite their belief in holding all goods in common, the Colony moved from a socialist business system to a mixed economy during the depression. To make a long story short, by 1964 George Foerstner's refrigeration company was selling refrigerators and air conditioners at a pace of $25 million per year. Foerstner knew the home market; he had built an excellent distribution system and a quality reputation for Amana products.

The acquisition of Amana provided a splendid opportunity for reevaluating the microwave oven business. Foerstner, when shown the Radarange® ovens, was impressed and optimistic. He overflowed with suggestions and observations, and soon a constant interchange occurred between Raytheon microwave engineers and Amana home appliance specialists.

After extensive testing and market surveys in 1967, Amana introduced the first countertop domestic microwave oven at a press conference in Chicago. It had a retail price of less than $500. Foerstner's marketing flair was evident, and the results were so successful that Foerstner forecast an astonishing sales figure of 50,000 units a year. Subsequent events proved this prediction to be grossly understated.

Commencing in 1967, when Spencer's basic patent expired, the microwave oven domestic market took off. By 1972, total U.S. unit sales were 525,000 with 885,000 ovens already installed. Today, U.S. microwave oven sales are over 10,000,000 units a year and have been in excess of 12,000,000 units a year previously. The joint efforts of Amana and Raytheon produced a synergistic effect. The Amana Radarange® oven was vastly superior to earlier microwave oven models in cost, reliability, and safety.

The microwave ovens of the late 50's and early 60's were priced from $1000-$1200. Today, prices range from less than $100, for small portable models, to $300, for full-featured countertop models.

Much attention has been given to safety seal design. It was discovered at an early date that metal-contact door seals were inadequate for long term leakage suppression. In 1962, the first effective choke seal was invented and patented, again at Raytheon, by Richard Ironfield (U.S. Patent No. 3,182,164). This design proved to be a major advance in door-seal technology, resulting in choke designs that are free of arcing phenomena. But, the main feature of this design is the intentional avoidance of metal-to-metal contact at the door seal and reliance, instead, on the electrical phenomena of reflecting a short circuit (or low impedance) across the gap between door and oven by means of a quarter wavelength choke.

The advantage of this type of seal is the insignificant increase of leakage when gaps form between the door and the body of the oven. With a metal-gasket seal, if a gap forms (whether caused by loose hinges, warpage, food build-up, or trapped objects such as paper towels), leakage increases very rapidly as the gap grows larger.

Amana also brought to bear effective promotion emphasizing the energy saving features of microwave ovens. Extensive advertising was placed on television, in magazines, and in newspapers to promote the concept of microwave ovens. In-store demonstrations were given to actively show the concept of microwave cooking.

The concept promoted was one of convenience and speed in meal preparation, of freeing the cook from long hours in the kitchen, of quickly reheating meals for members of the family who eat at odd times, and of quick meal preparation for working wives.

What can be learned from this success story? From a patent perspective, persons not knowledgeable in the patent field should learn to doubt the old maxim "build a better mousetrap and the world will beat a path to your door". Much of the old rugged individualistic pioneer spirit is still needed to nurture a concept through its formative stages to its mature growth period. Patents alone are not enough.

One might observe that, with Spencer's basic oven patent, Raytheon had in its power the right to exclude all others from the microwave heating market through 1967. It chose not to do so in the interest of obtaining broader acceptance of the product in a shorter period of time. As events proved, this was a wise decision.

It should also be noted that a number of "improvement" patents evolved in the story. The strapped magnetron patent and Hall stirrer patent were not what would be called basic patents, but they proved to be of considerable value.

From the technology transfer point of view, the message is clear. Without such transfer, technology withers and dies. With transfer, the technology blossoms and flourishes. In each step of development, transfer of old technology led to development of new technology. Transfer of the British cavity magnetron technology begot the strapped magnetron development, which led to development of microwave ovens, which required cheaper and longer lived tubes. Licensing of technology to competitors by Raytheon led to improvements in oven design in terms of cost, safety, and reliability. Acquisition of Amana resulted in a transfer of Amana's knowledge of the consumer market, in one direction, and a transfer of Raytheon's technical knowledge of ovens, in the other direction.

Unfortunately, this transfer process has not kept pace with global developments and has mutated into a one-way street. Cook magnetrons are no longer made in the U.S. American companies interested in short term profits have abandoned the market: just as we have given up competing in TV sets and VCR's.

The microwave industry needs another microwave oven story. I challenge today's dreamers , researchers, and inventors to create that story, for the saga of human triumph through technological advancements in this field has not yet ended. In fact, it has only begun.