STORIES OF ACCIDENTAL OR FORTUITOUS INVENTION HAVE a powerful appeal. Roy Plunkett finds an unfamiliar substance inside a gas canister and turns it into Teflon; Samuel Colt sees a ship's wheel turn and uses the principle to invent his revolver. Alluring as such tales are, they obscure both the insight needed to take advantage of a chance observation and the hard work needed to develop it. In many cases, a simple origin myth like these can overshadow the extensive and detailed research that led to a world-changing invention.

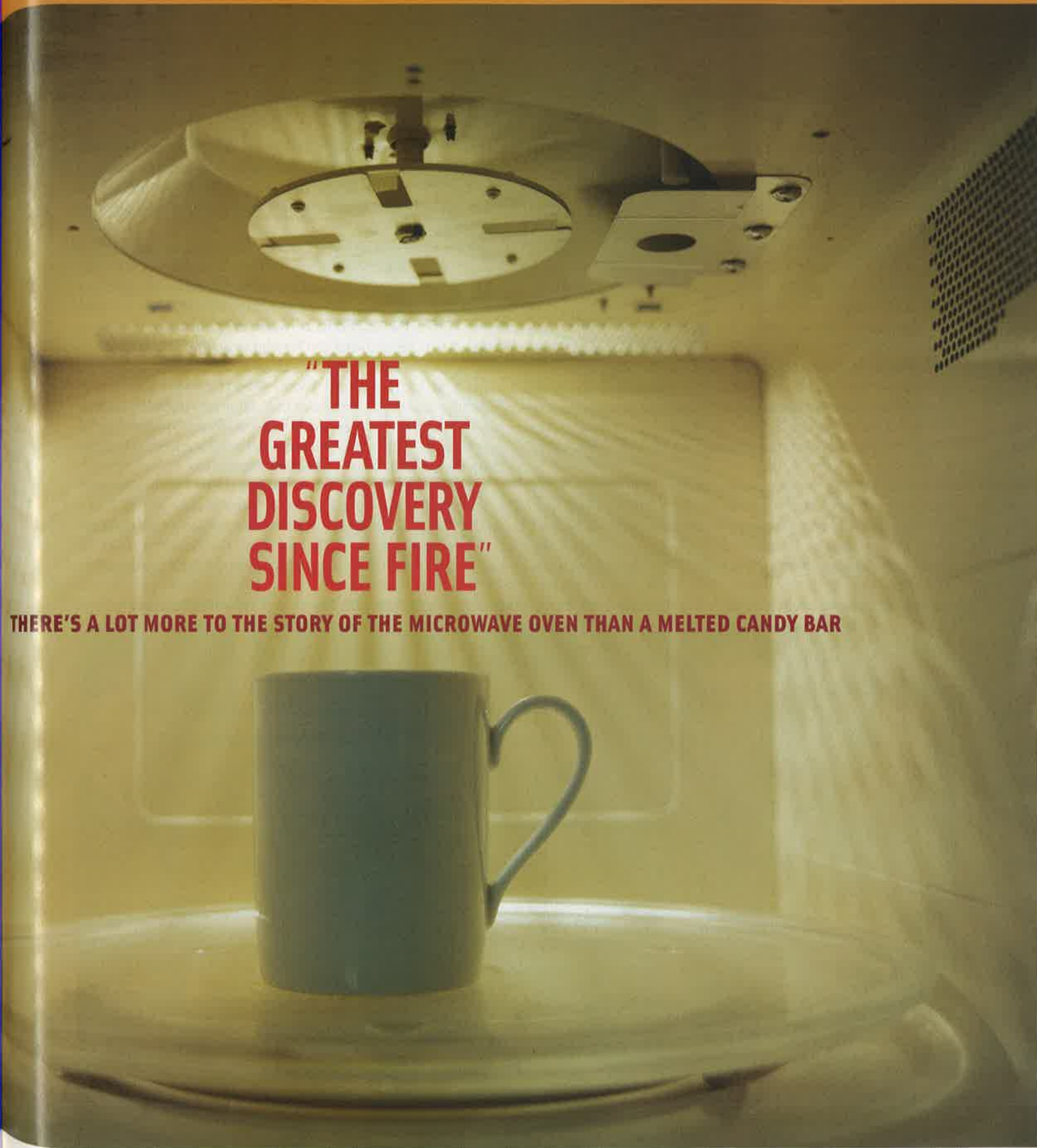
BY WILLIAM HAMMACK

Consider the microwave oven. Many of us have heard how a Raytheon engineer walked past a microwave tube one day, noticed that a candy bar in his pocket had melted, and was struck with the idea of using microwaves to cook food. This incident, or something like it, may have occurred, but there is a lot more to the story than that. The idea of microwave heating was not founded on any single random discovery, and after the initial idea, it took years, even decades, of engineering and marketing to make it work.

The microwave oven traces its origins to early 1945, when Laurence Marshall faced the financial ruin of his company, Raytheon. World War II seemed likely to end within a year or two, and when it did, Raytheon's lucrative military contracts would vanish, causing the company's revenue to drop by at least 50 percent. Raytheon needed to come up with something it could sell to civilians.

For the tenacious Marshall, once described by *Fortune* magazine as resembling "a friendly and uncommonly intelligent wrestler," this turn of events was nothing new. Since founding Raytheon in 1922, he had seen the company rise and fall several times. Raytheon's fortunes were so chronically touch-and-go that Marshall kept a copy of *The Little Engine That Could* in his office for inspiration. Its simple philosophy of "I think I can" described perfectly Marshall's approach to shep-

One of the microwave oven's mundane indispensabilities: making it easy to reheat coffee.



"THE GREATEST DISCOVERY SINCE FIRE"

THERE'S A LOT MORE TO THE STORY OF THE MICROWAVE OVEN THAN A MELTED CANDY BAR

AFTER THE WAR, RAYTHEON'S LUCRATIVE MILITARY CONTRACTS WOULD VANISH. IT NEEDED SOMETHING IT COULD SELL TO CIVILIANS.

herding Raytheon through every crisis. So as the new year dawned, he gathered a half-dozen of his top employees at his house in Cambridge, Massachusetts, and asked, "What shall we do after the war?"

The men Marshall put his question to were dead tired. They had been working 10 hours a day, seven days a week, assembling and testing radars for the U.S. military. But one of them, Percy Spencer, had an idea. He suggested that Raytheon should build on its expertise in radar by making an oven.

Marshall took the suggestion seriously because Spencer was the technical powerhouse who drove Raytheon. Marshall had depended on him since 1925 to turn his abstract ideas into operable devices. Most often this called for a solution in the form of vacuum tubes. So adept was Spencer in devising these that, a colleague wrote, "given a milk bottle, a tin can, some baling wire, and a bucket of whitewash, he could make any kind of an electronic tube."

Spencer had only a grade-school education, but he had learned the rudiments of vacuum tubes while serving in the Navy during World War I. Inspired, he said, by the heroism of the *Titanic*'s wireless operators, he "got hold of textbooks and taught myself while I was standing watch at night." His brother John was equally enterprising; while stoking a furnace at a clothespin factory in Maine, he got the idea that he later used to co-found Spencer Thermostat. Marshall was another co-founder, and in 1925 John Spencer recommended Percy to him for a position at Raytheon.

There, Spencer continued his self-education, assigning one of his engineers to gather all the new vacuum-tube patents every week. The engineer then reviewed each patent by writing a paragraph-long critique with an emphasis on how it might apply to Raytheon products. Spencer studied these reports with an eye to enhancing the Raytheon line, which desperately needed to be improved. The company was in the red for 10 of its first 19 years until World War II created a bonanza. Raytheon's cardinal successes in its first two decades, including wartime, had depended heavily on Percy Spencer's engineering skill. That's why Marshall was willing to bet the company on his knack for making vacuum tubes.

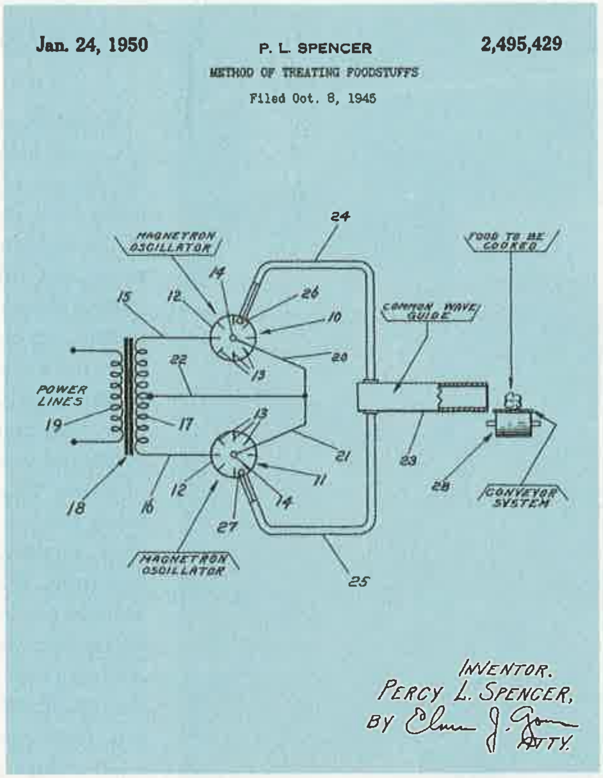
It is not clear how or when Spencer came up with the idea of building a microwave oven, or even that he was the first to think of it. During the war it was common in winter for Raytheon engineers to walk past banks of magnetrons (radar tubes) operating in the open air and warm their hands on the

Spencer (right) shows magnetrons to (left to right) Marshall, Gen. Omar Bradley, Adams, Edward L. Bowles, and Col. Willis Matthews in 1948.

OVERLEAF: TIM FLACH/STONE/GETTY IMAGES. LEFT: COURTESY OF RAYTHEON.

heat they emitted. The magnetrons hung on "aging racks," where they were run continuously to seal the vacuums and increase their reliability.

Spencer took note of these racks and envisioned hundreds of uses for microwave heating. "Goodness knows," he told *Fortune* in 1946, "eventually the field will be tremendous. We can't begin to think of all the uses—ink drying, soda straws, tobacco curing . . . there's so much to be done it drives you frantic." He was most intrigued by the idea of cooking with microwave radiation, so in the early 1940s he and other Raytheon engineers began to play around with using the radar tubes to heat food. The oft-reported candy-bar incident may perhaps have spurred Spencer to experiment with food, but the possibilities of using microwave tubes for heating were already quite well known.



Percy Spencer's first patent for the microwave oven, which envisioned moving food through the waves on a conveyor.

There's nothing new about heating with radiation: That's what sunlight is. Visible and infrared radiation have always been used for cooking, from the glowing coals of ancient times to today's electric broilers, heat lamps, and Easy Bake ovens. These types of radiation cannot penetrate the surface of most foods, so they work only on the outside, with heat diffusing from there to the interior. But microwaves, which are a type of radio wave, can pass through the outer layer of food (just as they pass through the walls of a house) and heat the interior directly.

THEY DO THIS BY SETTING MOLECULES OF WATER, FATS, sugars, and other food components into rapid motion. Since a molecule in the middle of a piece of food can receive this energy as readily as one on the exterior, microwaves are sometimes said to cook food from the inside out. In practice, however, they are generally absorbed in the outer inch or so of a piece of food, which is why thick items that are cooked in a microwave oven can still be raw inside.

With Marshall's blessing, Spencer and the Raytheon staff started building prototype ovens. One began as a garbage bin lying on its side with a radar tube sticking through a hole in its back. They used the nascent technology to pop corn and found that eggs would explode when heated rapidly, since the yolk absorbs heat faster than the white. Most important, though, whatever they cooked was always finished in a hurry—much faster than with conventional methods. Marshall was impressed enough by this progress to authorize funding for further development.

To design and build the new oven, Spencer turned to Marvin Bock, a young Raytheon engineer. Making a device for sale to the general public was something new for Raytheon; most of its equipment was built to be run by trained specialists, like military officers, who could be trusted to read the manual and handle an instrument carefully. But the oven would have to be much more foolproof than any military device if it was going to be put to work in restaurants, which were seen as its main market. Operation had to be as automatic as possible, for many users would be short-order cooks, and Bock also had to anticipate that most of them would experiment with it.

Bock and Raytheon didn't create the oven in complete isolation; other companies were investigating microwave heating. General Electric, Westinghouse, and RCA were interested in using it for processing everything from plastics and rubber to textiles to wood. In fact, General Electric was working on its own version of a microwave oven. Electronics-industry trade journal articles described the prospect of "sterilization, blanching, and cooking of food stuffs" by microwave radiation. One article described the essential problems Bock faced in designing his oven: finding "a suitable frequency, cavity size, food stuffs, and proper orientation of the food" to get uniform heating. Bock was up against the classic dilemma of any design engineer, balancing requirements that are only partly compatible.

The main difficulty was the frequency of the radiation. The magnetron that Bock started with produced radiation with a wavelength of about 12 centimeters (5 inches). This was convenient, because Spencer said in his 1945 patent application that radiation heating works best when the wavelength is comparable to the size of the food being cooked. But that meant the wavelength was also comparable to the size of the oven cavity, which in turn meant the microwaves could easily set up a standing wave inside it, causing uneven heating. As one engineer said, "If you put a hot dog in that, it would be cooked in

The original Radarange looks clunky today, but in 1947 it seemed like a miracle.

ROY STEVENS/TIME LIFE PICTURES/GETTY IMAGES

the middle and raw on the ends." Putting the food on a rotating turntable could reduce this problem but not eliminate it.

Why not just change the frequency of the radiation or make the oven a different size? The market set the size of the oven: It had to be compact enough to fit in a restaurant kitchen. This meant a cubic oven capacity no bigger than about 12 inches on a side. As for the wavelength, a federal regulation forced Bock to use a frequency of either 915 or 2450 megahertz, which meant a wavelength of 12.9 or 4.8 inches respectively. This regulation came about because even before World War II ended, microwave devices were being developed for such uses as FM radio, long-distance telephone relays, aircraft guidance systems, and even facsimile transmission. The Federal Communications Commission realized that it needed to allocate specific bands of wavelengths for specific uses, and the two frequencies mentioned above were set aside for "industrial, scientific, and medical" purposes, including microwave heating. Bock chose 2450 megahertz because its shorter wavelength would create smaller standing waves, and thus smaller (though more numerous) hot and cold zones.

To tackle the design of his oven, Bock divided his work into two areas, technical and culinary. He began with the magnetron. He needed to learn how to build and use one that would be stable and long-lived, so he took several Raytheon tubes and subjected them to stringent tests. He varied the voltage and measured their power output, recording how long each one lasted before it burned out. He also studied how best to carry off the tube's copious output of waste heat, eventually settling on water cooling. He measured how fast each tube heated a container of water. "Seven ounces of water with a 60 degree start, was put into a glass container and it boiled in 45 seconds," he recorded in his notebook for one tube. When he finished his studies, he had in hand the best magnetron, the best transformer and power supply to run it, and the best way to cool it. Now he could concentrate on designing the oven itself, especially the tricky task of getting it to cook evenly.

To reduce the problem of uneven heating, he needed to continually modulate the standing waves within the oven, a trick that in technical parlance was called "mixing the modes." The most promising solution was to vary the size of the oven cavity while the food was being heated. First he tried using a small motor to move one wall of the oven back and forth, but this proved to be too complex and expensive for mass manufacturing, partly because of the motor and partly because radiation leaked out of the joint between the moving wall and the body of the oven. So Bock implemented a solution developed by another engineer: Instead of changing the actual size of the cavity, he changed it in a virtual way.

From the upper wall of the oven he hung rotating rods. A motor turned them at about two to three revolutions per second. As the radiation bounced from top to bottom of the oven, this "mode stirrer" alternately blocked and let pass certain parts of the waves, creating a constantly shifting set of standing waves. While the solution was not perfect — even today no microwave oven warms food completely evenly— it distributed the microwave energy through the cavity well enough.

Now, with all these elements in place—the tube, its power supply, and the mode stirrer—Bock turned to the second part of the problem: cooking food. First he tried popcorn. "Refreshing corn popped takes 20 seconds is good," with 80 percent of the kernels popped, he recorded. Next he looked at vegetables. For potatoes he noted that "the flavor was good but the potato was not crisp. The time required was 1 minute."

THE FIRST PRODUCTION OVEN WEIGHED 670 POUNDS, STOOD MORE THAN FIVE FEET TALL, AND WAS NEARLY TWO FEET DEEP AND WIDE.

Other notebook entries: "Brussels Sprouts, 1 minute 15 seconds, no water was used. The flavor was dry and not good. Brussels Sprouts frozen, the flavor was good.... Mashed frozen potatoes, the taste was good but they did not brown. Time required: 1 minute." Then came the ultimate test: meat. "Noted that chicken Fricassee took a minute and tasted good; steak doesn't brown and a thin steak works better for browning. Thick steak tastes good, retained juices and flavor."

THE FIRST PRODUCTION MICROWAVE OVEN WEIGHED IN at 670 pounds, stood 62 inches tall, and measured nearly 2 feet deep and wide. To install it, an electrician had to put in a 220-volt line and a plumber had to install a water pipe to cool the oven's radar tube. This first oven sold shortly after the war ended for more than $2,000, the equivalent of about $20,000 today. Obviously, this was not an appliance for home use.

To market the oven, Marshall turned to Raytheon's supersalesman, Art Welch, who focused his pitch on its cooking speed. If a restaurant was serving ribs to a large group, for example, and found itself short a rib or two, the kitchen staff could quickly roast a few in the microwave oven. Chefs could even develop special microwave dishes that were cooked on demand, using the oven to eliminate waste. And since the food could be heated in serving dishes, dishwashing costs would diminish.

Welch prepared elaborate stage spectaculars to introduce the microwave oven to restaurant-equipment dealers. Hanging above the stage was a clock three feet in diameter with only a second hand. Three chefs prepared the food, and two waitresses served it to an onstage group of industry leaders. Welch, a rotund man who wore a highly visible diamond ring and a tie with a big embroidered duck, orchestrated the show. He would dip a sponge in water, put it in the oven, and bring it out steaming hot within seconds. He would zap a cob of popcorn and then wave it around moments later, fully popped. He cooked a six-pound roast in two minutes, a hamburger in 25 seconds, and a flat slab of gingerbread batter into a springy dome in 29 seconds.

Even today these figures are startling. In keeping with the company's military background, Raytheon made the first Radarange as rugged and powerful as possible. Yet while the feats of speed cooking were impressive, few at the company stopped to consider whether those extra seconds were worth the added cost they made necessary. Another problem was that ultrafast cooking tended to accentuate the problem of uneven heating.

Betting on Welch's sales prowess, Marshall launched a major marketing campaign in 15 cities in the East and Midwest. Besides restaurants, the company also sold a few units to railroads and ocean liners. But at the end of 1948, seeing that the market had dried up, Raytheon stopped making Radaranges. By then the board of directors had already replaced the oven's biggest advocate.

The board had tired of Laurence Marshall's eccentric management. Members complained that he kept starting new projects, which drew time, money, and personnel from other areas and spread the company's resources too thin (for example, buying hilltops for microwave relay towers). In 1946 *Fortune* quoted Marshall spelling out in one breath all that he thought Raytheon could do—a list covering no fewer than 16 areas, from precipitation of soot and smoke to night photography to the dehydration of food.

Marshall's omnivorous ambitions had worked to build the company and paid off big in the crucible of wartime. But to sustain its growth in a consumer economy, Raytheon needed someone with a business or banking background, so the board sought a professional manager. In mid-1947 it had hired Charles Francis Adams, Jr., the great-great-grandson and great-great-great-grandson of U.S. Presidents, as executive vice president. Adams had been a partner in the investment firm of Paine, Webber, Jackson & Curtis, and the Raytheon board (of which Adams had been a member since 1938) hoped he would bring some financial sense to the company. Early in 1948, as matters continued to deteriorate, Marshall was kicked upstairs to become board chairman and Adams was named president.

The contrast between Marshall and Adams could not have been more extreme. Marshall had always been in motion, his eyes blinking rapidly as he discussed a new direction for Raytheon. With his prominent eyebrows and full head of white hair, he would ceaselessly roam the hallways, dabbling his way through the company. By contrast, employees rarely saw the austere Adams's bald pate. With the innovative Marshall gone and a cost accountant, albeit a very skilled and high-level one, in his place, what would happen to the failed microwave oven?

Surprisingly, in Adams the Radarange had found its great protector, for underneath his quiet exterior lay the soul of a true technophile. He loved to ask Percy Spencer, whom he greatly admired, to build microwave devices—ovens and medical apparatus to warm aching muscles—which he would quietly take home and test. Moreover, he had vowed to avoid Marshall's error of depending exclusively on military contracts. Instead of letting the microwave-oven program die, he reopened it with vigor, ordering a redesign and creating a food laboratory where a chef developed recipes for it.

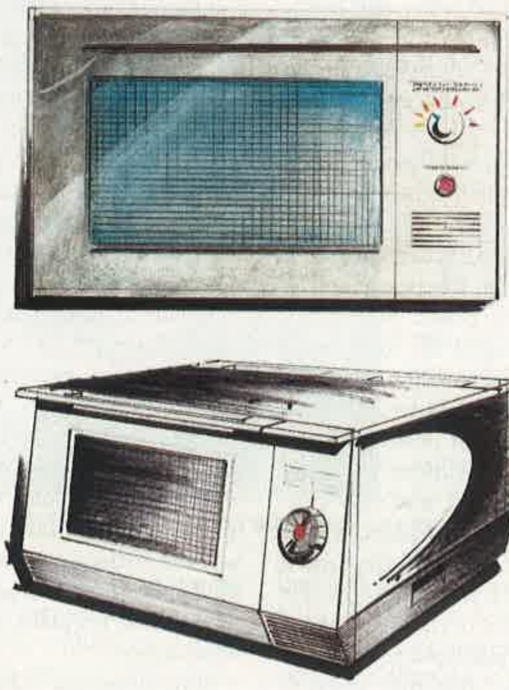
In 1953 Raytheon relaunched the Radarange, with a somewhat streamlined appearance and a sheaf of tasty recipes. The new oven featured a sleek sheet-metal exterior, vertical sliding doors, and an additional magnetron to increase heating precision. It was more successful than its predecessor, selling 10,000 units between 1953 and 1967, but it remained a money loser. Still believing in its ultimate success, Raytheon decided in the

FOERSTNER'S INITIAL MOVE FILLED THE RAYTHEON TEAM WITH TREPIDATION: HE SENT HIS SON TO DESIGN THE NEW MODEL.

mid-1960s that the microwave oven would sell better if salesmen could offer a whole line of related items, so it acquired the high-end refrigerator maker Amana.

While the company was going after Amana, a Raytheon engineering team was struggling with the third generation of the microwave oven. This time it would be a consumer product. Tom Phillips, the new president of Raytheon (Adams had moved up to chairman), had a proposal for George Foerstner, the founder and president of Amana: Now that they were in business together, Amana could take its expertise in building, distributing, and marketing consumer appliances and apply it to Raytheon's microwave-oven project.

Raytheon had tried making compact ovens for consumers before. As early as 1945 it had built a small prototype meant for reheating meals on airplanes. In 1952 it licensed its oven technology to Tappan, which three years later came out with the first home microwave oven, a built-in wall unit. Its magnetron was air-cooled, eliminating the need for a water line, but it still required 220 volts and took 75 seconds to warm up. At around $1,200, it was a bit cheaper than the Radarange, but not cheap enough. The Tappan microwave oven sold poorly, as did those from other manufacturers. A dozen years later, however, technology had changed to the point where a cheap, compact home unit seemed possible.



Except for the lack of digital displays, a pair of 1964 designs for a countertop model appear surprisingly modern.

Unfortunately, Foerstner only wanted to make refrigerators. Associates described him as "a very, very tough man to work for," "a kind of dictator," "a pretty aggressive guy," and "a curmudgeon." By sheer willpower he had turned a beer-cooler business into Amana Refrigeration, which, by 1964, had sales of $25 million. The challenge for Raytheon was to take this stubborn and successful force of nature and aim him toward the microwave oven.

Charles Adams didn't have the patience to deal with Foerstner, whom he called "an arrogant eccentric" who thought he "knew all the answers to everything whether they were political or appliance business or what." But Tom Phillips was a patient man, and he kept planting and replanting the seed of a microwave oven. One day Foerstner began showing interest. Adams recalled that the microwave oven "was really forced down his throat till it took hold." Yet once Foerstner bought into the idea, he moved in his usual fashion—full steam ahead. His first step filled the Raytheon engineering team with trepidation: He sent his son to design the new model.

In 1964, just before acquiring Amana, Raytheon had hired an industrial-design firm to create a new microwave oven that would be attractive to housewives. The designers gave it an elegant overall look and components such as knobs shaped to fit a woman's hand. Still the project stagnated, partly because most Raytheon engineers saw it as a dead end. One of them stuck with it; Richard Ironfield had his laboratory moved to the cafeteria and recalls wondering how much longer he would have a job. His savior showed up in the form of George Foerstner's son.

When Ironfield heard that Richard Foerstner was traveling from Amana headquarters in Iowa to Boston to supervise the oven's final engineering, he and his colleagues "had visions of this goof-off showing up, who had a job only because he was the boss's son." At first engineers complained about him. "I don't understand that Foerstner guy," said one, "he's always nickel-and-diming everything." Yet that was Foerstner's key contribution—a deep knowledge of how to design an appliance so that it could be manufactured cheaply. To engineers accustomed to making military equipment, where reliability was paramount and price was not, such an approach was alien. But the complaints turned to admiration as the engineers marveled at how Foerstner simplified a bracket that would hold the same weight as its complex predecessor yet could be stamped out of a single piece of metal instead of being welded together from four separate elements.

Foerstner and Ironfield worked as a team to create the first Amana oven. Like Marvin Bock on the original model, they began with the magnetron tube. By this time a new player had appeared in electronics: Japan. Before the Japanese tube, the magnetron and its power supply accounted for much of the cost of the oven. Foerstner and Ironfield began designing the Amana oven, intending to use a Raytheon tube costing $300—in an oven that George Foerstner planned to sell for $500. The new Japanese tube cost less than $25.

Raytheon worried that this was *too* cheap. But the New Japan Radio Company (NJRC) had aimed for just good enough. The

LEFT: DRAWINGS BY ROY BRADBURY, COURTESY OF SYRACUSE UNIVERSITY LIBRARY, DEPARTMENT OF SPECIAL COLLECTIONS; RIGHT: COURTESY OF RUSSEL CREEL

Raytheon tube had 13 separate metal parts, including 10 cooling fins, which had to be carefully put together. The Japanese made their tube body in a single unit, punching a big slug of metal in a die and shaping it into finished form complete with cooling fins.

The Japanese further reduced the cost by using a cheap ceramic magnet instead of the alnico magnet used by Raytheon, which was 10 times as expensive. The ceramic magnet didn't work as well; its properties changed with temperature, so that after the first minute or two of operation, the magnetic field dropped and the tube's power output to the oven decreased. But it was good enough for kitchen use.

Ladylike Amana demonstrators prepare to introduce housewives to the wonders of microwave cooking.

Finally, the NJRC tube brought a critical benefit to the oven. As Ironfield recalls, it had "a very modest heater power, 65 watts.... And it was about 65 percent efficient, which made it fit into a 15-amp household circuit." No special wiring had to be installed; a consumer could bring the oven home, plug it in, and use it right away. The reduced power meant, of course, that the oven wouldn't be able to cook nearly as fast as Raytheon's original model, but Richard Foerstner had a clear sense of how fast was fast enough. Amana did not start putting Japanese tubes in its ovens until the 1970s, but even before that, the company modified its own tube designs to resemble the Japanese version.

WITH THE FIRST AMANA MODEL, THE MICROWAVE oven entered a new era, the age of microelectronics. The special transformer used to regulate the voltage required a solid-state diode to control the flow of electricity. Foerstner called a major supplier and asked for a quote on 20,000 diodes. The maker promptly told him, "You'll never use 20,000 and we won't quote you 20,000." Foerstner ran into the same problem with other electronic components. "When you're putting something into production like a microwave oven," he said, "you have high-voltage diodes, high-voltage capacitors... none of which had ever been produced in volume." For one component, Foerstner reports that the vendor "was actually working out of the garage" and kept changing the materials he used. As a result, quality control was nonexistent, and "every time he sent me samples, it was a little bit different."

As Richard Foerstner redesigned the oven and prepared it for mass production, his father concentrated on getting ready to sell it. George Foerstner had pitched Amana refrigerators in newspapers and magazines since the 1940s, and later on television, using celebrities as endorsers (Groucho Marx was one). Although the media would play a significant role in the oven's success, Foerstner knew from the start that the best way to sell it was by demonstrations. To organize them, he hired the 26-year-old JoAnne Anderson, who had recently been discharged from the Air Force.

Anderson groomed a team of 42 carefully chosen women to show off the oven. Taking a cue from her drill instructor, who had said, "You're a lady first and an airman second," Anderson substituted "Amana demonstrator" as the secondary obligation for her recruits: "You must always dress, look, and act like a lady." She issued guidelines on what to wear, what to say, and especially what to cook. She advocated Lazy Maple bacon, recalls Anderson, because it had "a marvelous odor, and it traveled from one department to another department, and it went down the escalators, and it went up the escalators. Customers followed the smell and ended up in the appliance department." She warned against demonstrating cakes, which were "iffy," but told her sales force to "always bring baked potatoes." Anderson's most important advice was: "Never ever lie or exaggerate about this machine. You don't have to. It's a marvel."

She taught her demonstrators how to explain the marvel. "It's a simple thing," she would say, "there's nothing unusual here. There is energy, that is radio-wave energy, that basically attacks water molecules in your food... it activates those molecules." Then she would put her hand out and shake it as she explained how the water molecules were rotating at a very high speed, more

DEMONSTRATORS WERE TOLD: "NEVER EVER LIE OR EXAGGERATE ABOUT THIS MACHINE. YOU DON'T HAVE TO. IT'S A MARVEL."

than two billion times per second. "That causes friction, and friction, we know, is heat. Therefore, your food is cooking itself."

Anderson called the microwave oven a "woman's appliance." Refrigerators were a "couple" purchase, but a microwave oven was "bought by a woman—alone." She also saw how it fitted into a woman's role as a mother. "Women liked to teach their kids to cook but were put off because of the danger," says Anderson. The safety of using a microwave oven made it easy for "a relatively young child to use to reheat, to warm up, or just put a hot dog in a bun and have a snack when they come home from school."

This was quite a change from the 1940s, when Percy Spencer had seen the oven as an industrial item built to military specifications. One of Spencer's early patents shows the oven cooking a lobster and a huge beef roast. The 1953 cookbook contains 40 recipes for meats of every type: steak, poultry, seafood, chicken livers, game birds, bacon, sausages, even "canned luncheon meat." Yet the oven would thrive mainly as a reheater. The spread of households with two working parents, or with only one parent, created a demand for more packaged food, and the microwave oven cut heating time from as much as half an hour down to a few minutes.

In a merging of old and new technologies, an innovative microwave oven from the Korean manufacturer LG Appliances comes equipped with a built-in toaster.

To make the machine's debut, George Foerstner had brought in Russel Creel, who represented a new breed of advertising professional. Unlike an earlier generation, which had learned the business only by experience, Creel had taken advertising courses as part of his college curriculum. He had learned the general principles of marketing anything; over his career he sold cherry pickers, ditch diggers, and politicians. To introduce the microwave oven, he took a page from politics: the whistle-stop train from Harry Truman's 1948 campaign (a model Creel had already used for Sen. Chuck Percy of Illinois and Gov. Spiro Agnew of Maryland).

In the fall of 1967 Creel hired a train to travel from downtown Chicago through the city's suburbs, making nine stops before ending up in Aurora, Illinois. He publicized the train in local papers and contacted women's groups and church groups, paying them $25 if they would provide an audience of 30 or so people. All were invited to "come down and see this space-age wonder." At each stop, JoAnne Anderson's demonstrators guided the visitors through the car. They baked potatoes, cooking them in two and a half minutes, then broke them open to let their scent fill the air. They cooked hamburgers in 60 seconds and gave out samples of a five-pound roast, which had been cooking for 37 minutes. Anderson recalls "feeling just like we were Santa Claus."

Month after month Amana's tireless sales force put on 65 to 70 demonstrations a week. Each buyer of a microwave oven got a certificate on "parchment" offering her a two-hour cooking lesson at the local Amana branch office. As word of mouth spread, Amana marketed the oven across the nation, advertising on television and in newspapers and magazines, often using the headline THE GREATEST DISCOVERY SINCE FIRE.

Yet all this marketing hoopla may simply have helped the competition. In 1970 Raytheon and other U.S. manufacturers sold 40,000 ovens at $300 to $400 apiece, but by 1971 the Japanese had begun exporting low-cost models priced $100 to $200 less. Sales increased rapidly over the next 15 years, rising to a million by 1975 and 10 million by 1985, nearly all of them Japanese.

In the decades since 1970 the microwave oven has followed the familiar path from high-priced wonder to cheap, ubiquitous necessity. It has been incorporated in popular culture, with apocryphal stories of kittens or babies being dried off in microwaves. It even shows up in sports nicknames, such as Vinnie ("Microwave") Johnson of the 1980s Detroit Pistons, so dubbed because he would get hot in a hurry after entering the game from the bench.

The microwave oven has achieved the status of a primary technology, meaning that other technologies adapt to it instead of vice versa. TV dinners no longer have metal trays, and pizzas and other frozen foods are designed specifically to make a quick microwave blast mimic the results of slow cooking in a conventional oven. Browned exteriors and crisp crusts or skins had long been unattainable with microwave ovens, but now carefully designed cooking dishes and shields with layers of metal foil can be used to concentrate the microwaves.

The development of the microwave oven encapsulates much of the story of technology in the second half of the twentieth century. It reveals the great influence of World War II technology in our lives; it charts the rise of electronics as the greatest force in technological change; it reflects the growing sophistication of advertising and marketing; and lastly, it exemplifies the great change in women's roles due to the industrialization of the household. ★

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