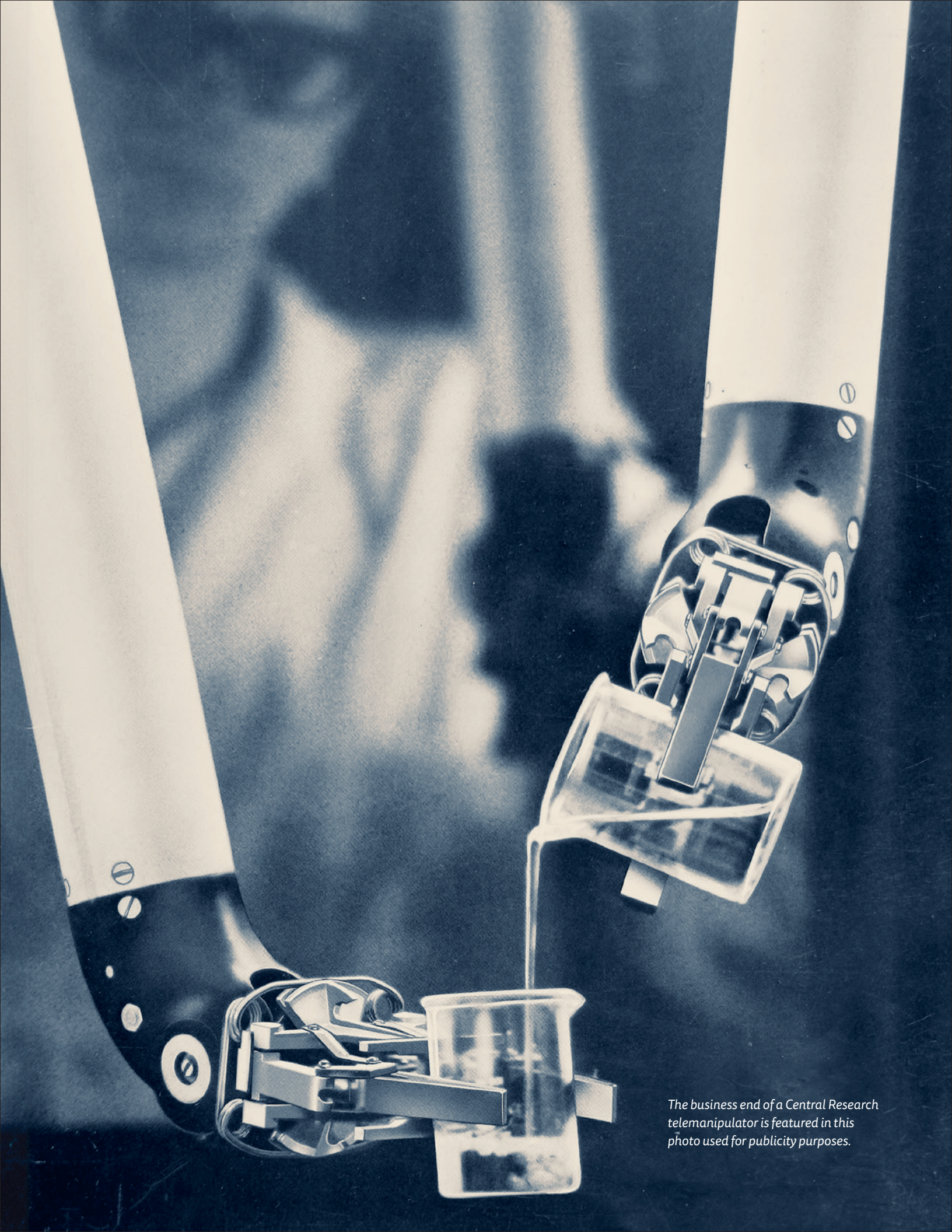


The business end of a Central Research telemanipulator is featured in this photo used for publicity purposes.

CENTRAL RESEARCH LABORATORIES

Precision Instruments for the Atomic Age

Frederick L. Johnson

As war clouds gathered in Europe in the late 1930s, three promising American graduate students studying for their doctorates joined the innocuously named Laboratory for Insulation Research at Massachusetts Institute of Technology (MIT). The lab's high-tech assignment, however, was anything but banal. Led by Professor Arthur von Hippel, a highly regarded German immigrant scientist, these researchers joined with others in MIT's Radiation Laboratory to enhance radar technology for the US military to improve communication and detection capabilities. Among von Hippel's original cadre of 10 scientists were Frank G. Chesley and Gordon M. Lee, from Chicago and Minneapolis, respectively, and Demetrius (Demi) G. Jelatis, who grew up about five miles from MIT's Cambridge campus.

As a German, von Hippel possessed an intimate understanding of the situation in his homeland during the 1930s as the National Socialists (Nazis) grew in power. Brandishing a virulent form of antisemitism, the Nazis and their despotic leader, Adolf Hitler, endangered von Hippel and his family. Von Hippel, who openly opposed Nazism, had married Dagmar Franck, daughter of James Franck, the 1925 Nobel Prize winner for physics, in summer 1930. The Francks were Jewish. Hitler banned Jewish students and professors from universities in spring 1933. Seeing growing danger in Germany, Arthur and Dagmar left the country. Von Hippel accepted a teaching position at the University of Istanbul prior to joining Copenhagen's Niels Bohr Institute in 1935. An invitation from Karl Compton, a prominent American physicist and president of MIT, brought the von Hippels to America in 1936. Arthur von Hippel was a pioneer in the interdisciplinary field of materials science, which studies the microscopic properties of various materials at a molecular level to understand how they perform in the real world.[1]

Von Hippel employed what was at that time a unique philosophy when selecting his MIT Insulation Research Laboratory staff. He opted for specialists from many disciplines—mathematicians, physicists, chemists, biologists, and electrical engineers and technicians with experience in building instruments and devices. Jelatis would later label this group of innovators a "fortunate conglomeration."[2]

MIT DAYS/ROOTS

Gordon Lee, Frank Chesley, and Demi Jelatis met in von Hippel's Insulation Research lab in fall 1939. Lee had earned his undergraduate degree in electrical engineering from the University of Minnesota (1938) and served as a teaching assistant and researcher at the University of Missouri before arriving at MIT. Chesley majored in physics (he also had a talent for chemistry) at Carleton College in Northfield, Minnesota. Upon graduation (1936), he spent time in the industrial sector. In 1938 he married Carleton classmate Jean Anderson, from Burnside Township near Red Wing, Minnesota; that fall they moved to Cambridge and MIT.[3]

Born to immigrant parents from Greece in June 1917, Jelatis experienced an "all Greek" early childhood. His parents spoke their native language at home, attended a Greek Orthodox Church, and sent their son to a Greek-language evening school. As his assimilation into American culture quickened, the intelligent Jelatis excelled in public high school before enrolling at MIT. He graduated with a bachelor of science degree in physics in 1938. Signing up for the school's graduate program was a logical next step.[4]

In 1939, political tensions and military buildups in Europe and Asia metastasized into the Second World War. The United States, as it had at the onset of the First World War in 1914, announced its neutrality. US political leaders concerned that the nation might become involved in the

Central Research founders Frank Chesley, left; Gordon Lee, center; and Demetrius Jelatis, right, are pictured in 1946 as they confer at their Tower View Farm laboratories.

fighting convinced Congress to pass the controversial Selective Service Act of 1940. The Selective Service law required all men between 21 and 36 to register for possible conscription into military service. Highly trained American scientists whose studies involved them in projects with military applications were qualified for exemption. Chesley, Jelatis, and Lee—their respective fields of doctorate study being chemistry, physics, and electrical engineering—were among those receiving presidential deferments.[5]

An early assignment for the MIT Insulation Lab came from the US Navy Radio Frequency Cable Coordinating Committee. It was looking for improved, durable electrical cables that would safeguard and enhance communication on naval vessels. The highest radio frequencies at the time reached 60 megahertz. Frank Chesley experimented with fireproofing cable using ceramic insulation, a nonconductive insulator. Eventually, these experiments led to the development of coaxial cable for radar and later for commercial use.[6]

Gordon Lee led the Insulation Lab's team effort that developed the fastest oscillograph then on record. The oscillograph could measure and display very high frequency time-varying electrical quantities, including current and voltage. The Institute of Radio Engineers bestowed a high honor to Lee in June 1946 for his research paper, "A Three-Beam Oscillograph for Recording Frequencies up to 10,000 Megacycles." That instrument, Lee recalled, "was used finally to determine the starting characteristics of magnetrons which are at the heart of the radar system . . . which now are in all our microwave ovens." Lee's study received the first Browder J. Thompson Memorial Prize, a coveted recognition that continues today as the Leon K. Kirchmayer Prize.[7]

One major MIT effort involving Jelatis, Lee, and Chesley was testing and measuring dielectric (insulating) properties of cable materials *before* they were made into cable. Measuring a several-hundred-pound batch of the material was difficult and time consuming. Working closely with the Radiation Laboratory team, Demi Jelatis developed a microwave dielectrometer, an instrument that could accurately measure an insulating material's dielectric constant (insulating quality) using a small sample. It was, he noted, "about the size of half your thumb." American companies involved in making insulating materials like those being tested at MIT asked the Insulation Lab to construct microwave dielectrometers for them. The laboratory built about 30 such instruments that were distributed around the nation.[8]

With MIT laboratories developing new instruments at a steady pace, Professor von Hippel asked Chesley,

Lee credited Chesley with an answer: "He's the one who got the idea we ought to go out and try [operating a laboratory and manufacturing center] on our own."

Lee, and Jelatis to form a committee to coordinate all projects directed to the school's very busy precision machine shop. When surgery caused von Hippel to take a medical leave, he placed Frank Chesley in charge of the Insulation Laboratory. By that time, late summer 1944, it appeared the Second World War was moving toward a victorious end for America and her allies. The three friends wondered what they would do when the war ended. Lee credited Chesley with an answer: "He's the one who got the idea we ought to go out and try [operating a laboratory and manufacturing center] on our own."[9]

Chesley also shared the exciting news that a ready-made laboratory for their use might be available. A formidable drawback to this facility, however, was its location in Red Wing, Minnesota—far from their current lives in Massachusetts. Frank's wife, Jean Anderson Chesley, was a daughter of Dr. Alexander P. Anderson (1862–1943), a brilliant botanist and researcher who had discovered the process for "puffing" grain for use as cold cereal. Anderson was offering his Tower View Farm research laboratory to the three MIT scientists.[10]

Despite the distance and wartime travel challenges, the three colleagues decided to investigate the Minnesota laboratory. Lee and Chesley knew the state well, but Jelatis declared he had never been west of the Hudson River. On October 12, 1944, Chesley and Jelatis began a trip by automobile to Minnesota and Tower View. Lee saw the facilities later that fall while traveling to Minnesota to visit his ailing father. After viewing Anderson's laboratories, the trio agreed it fit the partnership's purposes.[11]

Frank Chesley defined the research specialties of the MIT colleagues: "Demi and myself had a flair for instrument design in [our] particular fields. . . . Demi was responsible for designing a microwave dielectrometer [originally the MIT coaxial instrument] and Gordon was involved with the fastest oscillograph that's ever been conceived." The unpretentious Chesley did not mention the X-ray diffraction camera he had developed while working at the Cambridge institution.[12]

BUDDING ENTREPRENEURS MOVE TO MINNESOTA

In late October 1945, the scientists and their families made the move to Red Wing. The wives and children departed by airplane first—Jean Chesley, with four-year-old Gretchen and four-month-old Margaret; Vivienne Jelatis and one-year-old George; and Harriet Lee with one-year-old Theodore. Driving a 1941 Chevrolet, Gordon Lee carried two passengers—his father, who had been staying in Massachusetts with the Lees, and Demi Jelatis. They began a cross-country drive to Minnesota, with Frank Chesley following in his vehicle. Looking to drum up business along the way, the fledgling entrepreneurs detoured to the Naval Research Laboratories in Washington, DC, and then to Wright Air Force Base (today's Wright-Patterson AFB) near Dayton, Ohio. By October 31, everyone had arrived in Minnesota.[13]

Prior to their journey, Chesley had arranged with a Twin Cities legal firm to draw up papers to form a corporation. On November 28, the partners met in Minneapolis at the home of Gordon Lee's in-laws. Using Chesley's auto for a private conference room, they chose officers for their new endeavor: Central Research Laboratories.[14]

Gordon Lee later recalled, "it was obvious that Frank, as the real initiator, would have to be president, and I said I would take care of secretary and treasurer, and we made Demi vice president." With doctorates from MIT and experience as leaders in its radiation and insulation research, all three clearly had the credentials to succeed.[15]

America faced a national shortage of housing following the Second World War and the Great Depression a decade earlier, and the MIT newcomers needed lodging. Tower View Farm included a roomy house and the Anderson Laboratory located five miles from downtown Red Wing. The Chesleys and Jelatises shared the home that Alex and Lydia Anderson had built there in 1915.[16]

The Central Research Laboratories team had access to two Tower View buildings, known by the Anderson family as the Big Lab (an industrial-type structure) and the Little Lab (Alex's original office and lab). Dr. Anderson used both for ongoing research subsidized by the Quaker

Argonne had its origins in the University of Chicago's Metallurgical Laboratory, which played a critically important role in the top-secret Manhattan Project. . . .

Oats Company. Combined, the laboratories had the look of a modern test facility.[17]

To properly manage a precision machine shop, Central Research's partners needed to purchase and install equipment and recruit veteran machinists. John R. Trautner, who had established Red Wing Boat Manufacturing Company (later reorganized as Red Wing Motors) in 1903, had a stable of experienced machinists. In late 1945, when Central Research Laboratories (CRL) was searching for technicians, Frank Chesley learned of Elmer Pearson, a lead man for Trautner's reorganized firm, the Red Wing Motor Company. Pearson could handle machine tools and was a skilled welder and parts designer—a "mechanical genius," Chesley was told.[18]

But workers at Red Wing Motors went out on strike several months later. Employees schemed to break the firm's "dollar an hour" wage ceiling, pointing out the multitalented Pearson should surely receive a raise to $1.25 per hour. Tightfisted Trautner slammed his fist on his desk and declared, "Nobody is worth $1.25 an hour." Elmer Pearson opted to move to CRL's operations at Tower View; he would be followed by former Trautner employees Chuck Lindblom and Algot Strom. Pearson proved his worth, emerging as head of the drafting department and as a valued member of the critically important design team.

Other important additions to the CRL team were on board by 1946. Ted Leonard augmented the machine shop team, and Kenneth Kohrt assumed the important roles of bookkeeper and office manager. Electrical engineer Merlin Haugen, a veteran of MIT's Laboratory for Insulation Research and also a University of Minnesota graduate, rejoined Chesley, Lee, and Jelatis. They later lured Argonne National Laboratory's manipulator designers Lester Haaker and Bob Olson to Tower View.[19]

Building and marketing high-tech instruments at CRL was slow going at first. The firm featured Demi Jelatis's microwave dielectrometer and an optical instrument, Gordon Lee's high-speed micro-oscillograph, and Frank Chesley's X-ray diffraction camera. "We were hanging on by the fingernails," recalled secretary-treasurer Lee.[20]

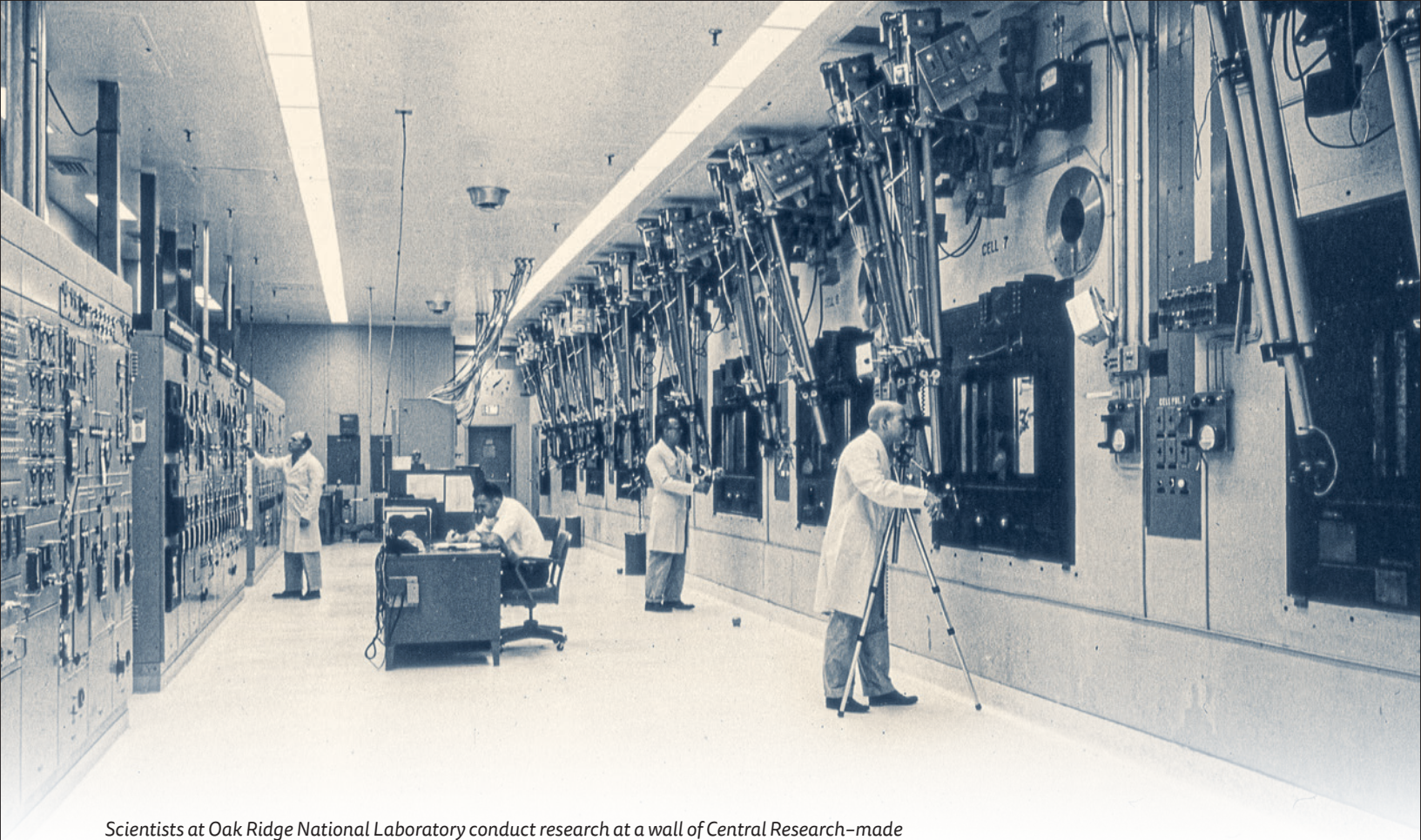
Their original investment in CRL was $100,000—funding that got them through the first two years. "As I recall," said Lee, "the three of us each drew $300 per month for the first couple of years and the first people we hired were paid $1 per hour, which meant they were getting about $2,000 a year and we were getting about $3,600." Once fully established, Lee added, "we grew completely on our own earnings without any additional funds being put in from the outside. . . . I think we were lucky. When you look back, you wonder if you would ever have the courage to try it again."

A fairly large 1947 contract with the US Army Signal Corps to supply test equipment used in advanced radar technology provided work for Central Research. The apparatus would be employed in the early 1950s construction of America's highly publicized Distant Early Warning (DEW) Line. This US–built defense was a string of more than 60 radar stations across northern Canada—and later Alaska, Greenland, and Iceland—ready to warn of an aerial assault (by aircraft and missiles) across the North Pole from the Soviet Union. Said Gordon Lee, "We [CRL] worked like heck for a couple of years [1949–50] fulfilling the Dew Line contract."[21]

EXPANDING THE APPLICATION OF ATOMIC SCIENCE

An August 8, 1948, *Minneapolis Tribune* article, "Trio Probes 'Invisible World,'" breathlessly opened, "A shipment of ray-emitting phosphorus made radioactive in one of the same atomic plant [*sic*] that produce raw materials for A-bombs—will be rushed from Oak Ridge, Tenn. to Red Wing, Minn. soon." Central Research Laboratories and its trio of MIT researchers were to receive the dangerous cargo.[22]

Linking the atomic bomb with CRL was the reporter's device to grab reader attention. Fueled by news reports and movie-theater newsreel film, America's revolutionary, city-destroying A-bombs had captured the world's attention after the bombings of Hiroshima and Nagasaki at the end of the Second World War. Although some readers might have been misled by this account into believing A-bombs were under construction in



Scientists at Oak Ridge National Laboratory conduct research at a wall of Central Research–made telemanipulators. CRL became the international leader in the development of such instruments.

Red Wing, the small quantity of hazardous materials was to be used for research only.

CRL, in fact, made its focus the creation of precision instruments to be used for the most part by those experimenting with dangerous nuclear/radioactive materials, in order to develop peaceful uses for the new science, the study of the atomic world. The aforementioned *Tribune* report noted Red Wing physicians at the new Interstate Clinic were researching medical applications "in the invisible world of atoms."[23]

A tip from Alfred O. C. Nier, chairman of the University of Minnesota's Physics and Astronomy School, provided a meaningful change in Central Research's corporate outlook. Nier suggested a CRL sales visit to Argonne National Laboratory near Chicago. Argonne had its origins in the University of Chicago's Metallurgical Laboratory, which played a critically important role in the top-secret Manhattan Project, the wartime effort to build the first nuclear weapons. Such experiments also held potential for the development of commercial nuclear power.[24]

Jelatis and Lee already had scheduled a fall 1949 sales trip to Argonne Laboratory to discuss Jelatis's optical instruments and, perhaps, other business opportunities. Once there, a staff member said the laboratory had something new that should interest Central Research. He handed the visitors a news release scheduled to be made public in a few days. It announced that Raymond Goertz, from Argonne's Remote-Control Division, had found a way to protect workers from dangerous radiation while handling radioactive materials. It was an experimental device called a master-slave manipulator that, to a remarkable extent, could duplicate the sensitivity and motion of a human hand. (Original developers of remote-control systems used the terms *master* and *slave* to describe the controlling and following parts of any remote-control system. Such controversial terms have been discontinued and devices are now known as telemanipulators and teleoperators.)[25]

Jelatis and Lee were invited to check out Goertz's device; the visitors from Red Wing asked for more information. The Argonne representative handed them the device's assembly drawing—"a lot different than a detailed drawing," Lee noted, "but helpful." Jelatis asked his hosts, "Do you mind if we make one [master-slave manipulator]?" They didn't.[26]

Returning to Tower View, Demi Jelatis and Elmer Pearson got together and, with a few modifications of the Goertz model, made CRL's first master-slave manipulator. Argonne's Remote-Control team, meanwhile, continued refining the device and

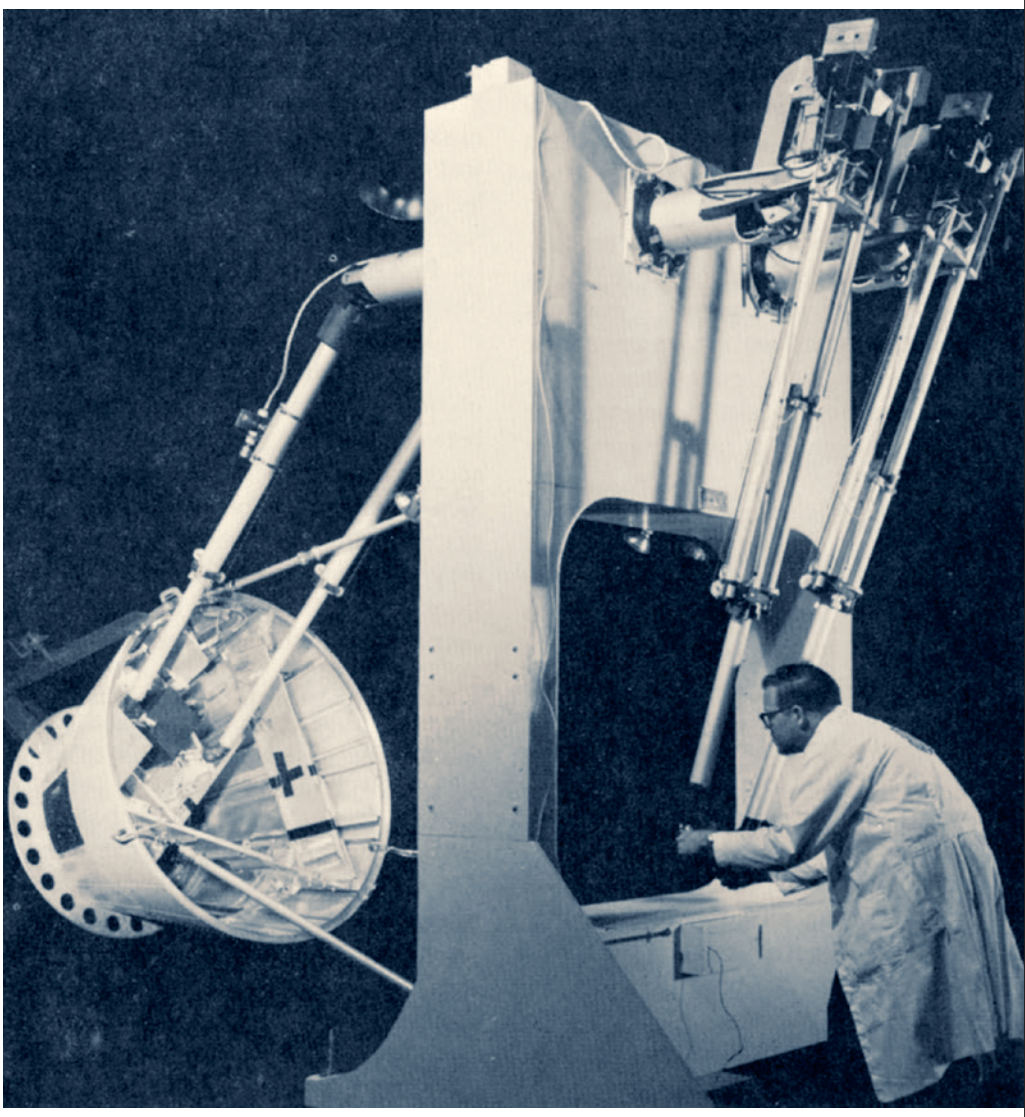
issued the first contract for commercial production of those devices. Central Research and about a dozen other firms submitted bids to construct 12 Model 4 manipulators. At $3,600 apiece, CRL's offer was near the bottom of the bidding ladder (submissions ranged from $3,000 to $20,000) and CRL got the job. "They came to us," Lee theorized, "because we were the only one that had any experience" making such a machine.[27]

Argonne's Remote-Control researchers soon came up with a smaller unit, the Model 6. Instead of extending a telemanipulator over a wall into another room, the Model 6 was designed to go through a wall into a space with a sealed ceiling. This arrangement gave operators more protection from hazardous materials. "It was kind of a dog [the Model 6] that had to be disassembled to insert through the wall, but it was expensive, and we [Central Research] made money [building] it," said CRL treasurer Lee.[28]

During this Central Research growth period, Gordon Lee was secretly summoned to the Los Alamos National Laboratory in New Mexico, the top-secret site where nuclear weapons research in the post–World War II era continued. It was a memorable and mysterious event for the Lee family, because for security reasons Dr. Lee could not tell them where he was going. Most work at CRL, however, was not classified as secret, with the exception of the frequency used for one or two of their dielectrometers.[29]

The market for "mechanical arms" in the United States grew as research in atomic energy mushroomed. Scientists at work in national laboratories—Los Alamos, Oak Ridge, Brookhaven, University of California—needed such instruments to avoid exposure to workplace radiation levels. Argonne's well-staffed Remote-Control Lab led the way with their Model 4 and 6 manipulators, improved and manufactured by Central Research Laboratories. Chesley asserted that, ironically, the Red Wing firm "came up with more convincing improvements and models than [Argonne] did with its government budget of two to three million dollars a year."[30]

In the case of the popular Model 8, a "through the wall" instrument, Argonne Laboratory asked CRL to create a small number of instruments made to their specifications. Jelatis looked over the plans and suggested improvements. The contract with CRL was then adapted to include those modifications. "Well, it got pretty complicated," Jelatis recalled, "because there were two patents issued on that [Model 8] design—one to Ray Goertz at Argonne and one to me at Central Research." CRL had signed a development contract giving the rights of their Model 8 conception to the federal government. Although Argonne would not mass manufacture telemanipulators, the firm claimed to be their principal inventor. Gordon Lee



CRL telemanipulators proved useful in other fields of science. This researcher is using a Model 8 manipulator to simulate a docking maneuver required by America's National Aeronautics and Space Administration (NASA). Spacecraft of the future would need to safely connect with other space vehicles.

Niels Bohr, the brilliant Danish Nobel Prize–winning physicist, made a December 1957 visit to Central Research's Tower View laboratories to see its innovative manipulators, the Model 8, and other variations.

stated, "Demi Jelatis was the real brains behind all the development of all the manipulators," and was soon to become a nationally known authority and author regarding these devices. When word of what many would call "mechanical arms" became public, the manipulators would be in demand. Moreover, any major American manufacturer would be eligible to compete for construction contracts. These corporate powers would wield a formidable competitive edge over Central Research. But CRL had a head start building these remarkably versatile creations. And they also had Demi Jelatis.[31]

A 1958 newspaper report described the mechanical arm of the Model 8 in action:

> [A] pair of light-weight metal arms reach from the operator's position into the room containing the "hot material." At the "master" end of the manipulator are a set of finger grips. The operator can duplicate his natural finger movements at the "slave" end, consisting of mechanical fingers. He watches the operation through a thick glass window and is shielded from radiation by a high-density concrete barrier.

Chesley further explained, "The motions are duplicated so precisely that a needle can be threaded with the device."[32]

Gordon Lee's son Ted explained how the devices were made:

> It should be noted that the manipulators were entirely mechanical—no motors or solenoids or anything like that. Not even any gears! They involved an assemblage of pulleys and wheels and thin pipes or tubes, but instead of cables they used thin ribbons of stainless steel. . . . I don't know if the original design started with cables with the ribbons being later, but [after some early] design improvements, I don't ever remember seeing one that didn't use ribbons.[33]

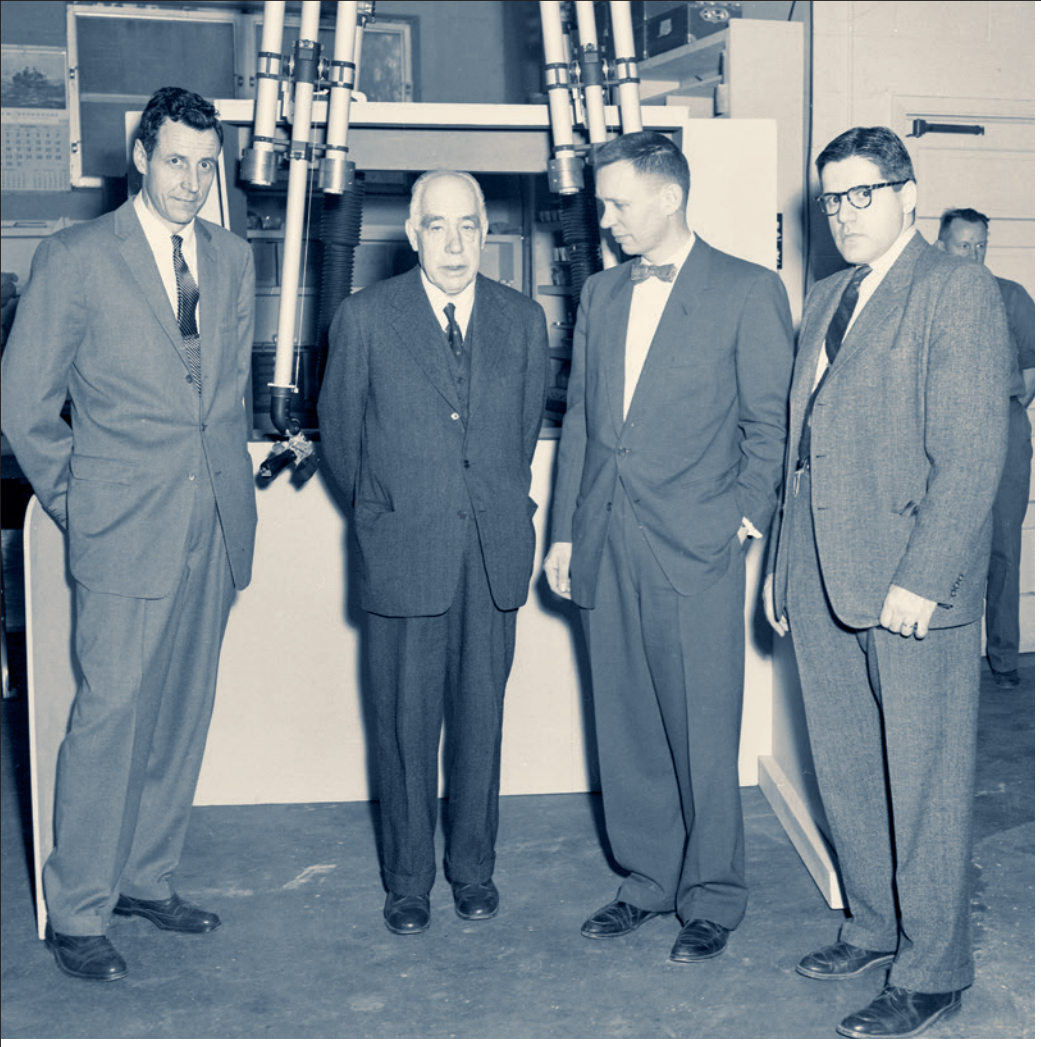
Years later, Demi Jelatis supplied background on the development and success of the Model 8 telemanipulator during a conference in Annapolis, Maryland, in 1975: "Some six to seven thousand of these devices are currently in use throughout the world. Most of them are used in shielded 'hot cells' for handling radioactive materials." He asserted that these instruments are "indispensable in the nuclear field, serving as effective extensions of a human operator's hands and arms into a hostile environment."[34]

Niels Bohr, the brilliant Danish Nobel Prize–winning physicist, made a December 1957 visit to Central Research's Tower View laboratories to see its innovative manipulators, the Model 8, and other variations. Bohr's revolutionary theories on atomic structures had speeded the dawn of the atomic age, and he was widely considered the world's greatest living theoretical physicist. In 1955 President Dwight Eisenhower called for international efforts to develop nuclear energy for peaceful purposes, bringing about the Atoms for Peace program. Two years later, Niels Bohr became the first winner of that organization's Atoms for Peace award.[35]

Eugenie Moore Anderson became the nation's first woman ambassador when appointed to serve in Denmark in 1949, and she was the link between Tower View and Bohr. She had married John Anderson, Alex Anderson's son, and they lived on Tower View farm. While in Denmark, the Andersons had become good friends with Niels and his wife, Margrethe; thus, during their Minnesota visit, the Bohrs came to Tower View and the Andersons' home for a weekend stay. During that interlude, Chesley, Lee, and Jelatis presented their visitor with a set of manipulators for Bohr's Institute of Advanced Physics in Copenhagen.[36]

CRL WIDENS ITS REACH

With specifications for the Model 8 manipulator now in the public domain, it was open season for other American manufacturers when US research laboratories called for bids to purchase the devices. General Electric, American Machine and Foundry (AMF), or whatever outfit that wanted to could take a shot at securing an order. The deep pockets of AMF allowed that Brooklyn, New York, company to bid low in order to get in on this new and important product line. Gordon Lee acknowledged that



Known as the "father of modern atomic theory," Danish physicist Dr. Niels Bohr (second from left) visits Central Research's laboratory in 1957. Bohr is flanked by Lee and Jelatis to his right, Chesley left. The Nobel Prize winner and his wife, Margrethe, stayed for the weekend as guests of US ambassador to Denmark Eugenie Anderson and her husband, John.

established firms could afford to lose money during these early days and freeze out competition. "We simply couldn't," he said. Central Research battled AMF for a share of the market for a number of years. "Happily, we actually out-competed them," Lee declared, "and finally they went out of the business while we stayed in."[37]

Frank Chesley expanded on Lee's comment regarding competition with AMF: "[It] took a couple of years [for word] to get around in the trade [equipment for nuclear research] until the products that we made, *and the improvement and the development in their performance* [emphasis added], eventually [reduced our price] to where we essentially had a lock on the market."[38]

In 1956 Demi Jelatis and Gordon Lee traveled to Europe to meet with sales representatives and CRL licensees from England's H. M. Hobson Ltd. (specialists in aircraft instrumentation) and West Germany's Leybold Hochvakuum Anlagen (industrial vacuum equipment). Two years later, CRL began a long relationship with LaCalhene, a French firm commencing production of remote-manipulation devices. The Minnesota firm's presence in Europe would continue to expand.[39]

Business boomed with the credit going to Central Research's growing domination of the telemanipulator market. Frank Chesley credited Jelatis's talents. Although all three CRL founders had patents issued to them, Chesley declared, "Demi is the king." Jelatis couldn't recall exactly how many patents he had acquired, but his knack for modifying manipulators and other products resulted in 30 to 40 patents when those granted in foreign countries were included. CRL had strong patent protection in most industrialized countries.[40]

Central Research's sales in manipulators grew. Instead of the devices being mass-produced, they were customized to meet the needs of their clientele. "[W]e would talk to people before they ordered . . . they would visit us and see what we had and go over their application drawings, so we did a lot of free application work," Demi Jelatis said. He recalled prospective customers coming in wanting a Model 8 manipulator, and after reviewing their request, the team would often say, "You don't want that. You want one that costs a third as much, the Model 4." Such openness established good rapport with customers and engineers who specified the equipment.[41]

CRL capitalized on the unique appeal of their manipulators, using it as an advertising tool. America's young nuclear industry hosted one or two major exhibitions each year. CRL's exhibits featured demonstrations of their products. Lee recalled crowds gathering around the booth to watch operators using the remote-control device lighting matches, piling up blocks, pouring liquids. A female volunteer from the audience was often recruited for a popular demo. Using a manipulator, the CRL person at the controls used the subject's own lipstick and applied it to her lips from the other side of a wall representing the protective barrier of a hot cell.[42]

Gordon Lee was in New York City for a convention in 1965 and had set up a Model 7 manipulator in Manhattan's Union Carbide Building lobby. A representative from America's most

The forward-looking firm introduced additional manipulators developed over this period that included Models B, D, E, F, G, H, J, K, L, M, and System 50. Sales reached $6 million in 1978.

popular late-night TV program of that era, the *Tonight Show* with Johnny Carson, observed the device in action and asked Lee to bring it to the TV studio. With a few tips from Lee, Carson employed the Model 7 to apply lipstick to a young model. The studio audience roared their approval.[43]

By the 1950s, master-slave manipulators made up 80 to 90 percent of CRL's business. Forty-five employees worked in the Tower View laboratories, divided into office, machine shop, design room, and assembly rooms. In 1954 an enclosure was built to connect the two laboratory buildings, expanding the plant to about 14,000 square feet. Costing about $8,000 per pair, CRL's manipulators were in use in the United States, Canada, France, England, Australia, and Japan. Orders for the devices ranged from a single pair to 30 pairs.[44]

Lee estimated that Central Research shipped as many as 200 telemanipulators a year. CRL had to anticipate demand to reduce downtime on the production line. "When we had orders for say 10 manipulators, we might start a lot of 20, figuring we would sell them, and generally we did." When the firm concentrated principally on Models 4 and 8 and, later, on Model A, they typically built from 10 to 30 for each product.[45]

Although Tower View's labs had served them well, by the late 1950s Central Research founders could see they were outgrowing A. P. Anderson's facilities. They decided to purchase land south of Tower View, directly across US Highway 61, and built a production facility/laboratory. Their business had prospered during the decade, allowing them to construct the entire plant without borrowing any money.[46]

A newspaper report of the 1961 grand opening asserted that the 32,000-square-foot facility, designed by Minneapolis architect David J. Griswold, was "built to be beautiful as well as useful and economical." Concrete columns on 24-foot centers—24 columns each way—supported the roof; thus neither interior nor exterior walls would be load-bearing. Embedded steel reinforced each column, which, according to the news story, "made the building truly fireproof." Floor tunnels running under the manufacturing area carried heating, power, compressed air, water, and other services.[47]

From the beginning, Central Research's employees opted not to unionize. "We told them if they wanted to form a union or get affiliation, we would not stand in their way," remembered CRL secretary-treasurer Lee. They said, "We will wait and see." Employee wages were competitive with Twin Cities rates, which were used as a model. Very popular benefits were offered: fully paid health care, sick leave, and a profit-sharing program (checks were handed out at the annual Christmas party), making for a positive work environment. The firm also offered employees opportunities for further training. "We would pay for it whether it was Dunwoody [College of Technology in Minneapolis], the U [University of Minnesota], or any place or program" that improved their capabilities, Lee stated.[48]

Business remained strong at CRL as its thirtieth anniversary approached in 1975, but the workload of the company founders remained heavy. Other entrepreneurs took note of Central Research's success: "[W]e were getting inquiries about acquisition or merger or buyout and so forth from many sources," said Chesley, the firm's president.

By the mid-1970s, early digital computers were entering the market, meaning changes at CRL. "Computers had very limited capabilities," recalled Jelatis, who investigated the new technology. The PDP8 minicomputer made by Digital Equipment Corporation (DEC) was used for the first digitally controlled manipulator. "The input/output system [for programming] was a teletype with a paper tape, and I remember spending endless hours on that [computer], and it had only 4K memory." But remarkably, by 1974, Jelatis had CRL's first digital manipulator on exhibit in Washington, DC.[49]

By the late 1970s, CRL reached its peak employment of just under 100 employees. The forward-looking firm introduced additional manipulators developed over this period that included Models B, D, E, F, G, H, J, K, L, M, and System 50. Sales reached $6 million in 1978. Sargent Industries, a Los Angeles firm, bought Central Research a year later. Frank Chesley

retired in 1979, followed by Gordon Lee in 1982. Demi Jelatis, who had also gained prominence locally as Red Wing's long-serving mayor (1961–77), left the firm in 1987.[50]

As they sat together being interviewed after their retirement, the warm regard the partners held for each other was unmistakable. Gordon Lee offered a statement unsolicited by their interviewer: "Something else about us which was unique is that Frank, Demi, and I started out as partners in 1945—and we stayed together all of our working lives—and I can't remember that we ever had a serious fight. We probably had a few arguments, but we never had serious conflicts, and many a committee meeting was held out in the hall. That's the quickest way to get rid of [animosity]."

These demonstrably brilliant but modest American scientists built a world-class research laboratory and manufacturing facility that, at the dawn of the Atomic Age, dominated international production of master-slave telemanipulators. It was an extraordinary achievement. ⊡

Notes

The author wishes to thank Gretchen Chesley Lang, George Jelatis, and Ted Lee for their contributions to the Central Research Laboratories story.

1. Arthur von Hippel, *Life in Times of Turbulent Transitions: The* Autobiography *of Arthur Robert von Hippel*, 63–70, Materials Research Society, https://www.mrs.org/careers-advancement/awards/fall-awards/von-hippel-award/arthur-von-hippel-memorial-website/autobiography; "Central Research Laboratories: Ken Peterson's interview with Frank G. Chesley, Demetrius Jelatis, and Gordon Lee" (unpublished manuscript, Feb. 4, 1991), 4–5, Goodhue County Historical Society's Oral History Collection (hereafter Central Research Laboratories interview). See also Ken Peterson, "An Interview with Dr. Demetrius Jelatis" (unpublished manuscript, Jan. 27, 1979), 1–2 (hereafter Jelatis interview with Ken Peterson).

Von Hippel and his colleagues were in the vanguard in studying the forerunners of solid state physics, a branch of condensed matter physics emerging during the 1940s. Jelatis characterized von Hippel's work in the Central Research Laboratories interview. For background on solid state physics and its applications, see Joseph D. Martin, "What's in a Name Change? Solid State Physics, Condensed Matter Physics, and Materials Science," *Physics in Perspective* 17, no. 1 (2015): 3–32.

2. Central Research Laboratories interview, 1–4.

3. Ann Barsness and Ruth Nerhaugen, "Three of Red Wing's Finest," and Jim Pumarlo, "A Man for All Times," *Red Wing Republican Eagle*, Mar. 14, 1997, 1–2, 4.

4. George Jelatis, interview with the author, Red Wing, MN, Oct. 18, 2022, notes in author's possession. George Jelatis, Demetrius's son, used the term "all Greek" to define his father's upbringing. Demetrius Jelatis spoke only Greek until his cousin enrolled him in first grade at their local public school.

5. Gordon Lee, "Historical Highlights: CRL incorporates, sets up shop at Tower View," 2004, Gretchen Chesley Lang personal collection, copy in author's collection; George Jelatis interview.

6. Jelatis and Chesley discussed Chesley's experiment in Central Research Laboratories interview, 6–7.

7. "Browder J. Thompson Memorial Prize for 1946," *Proceedings of the I.R.E. [Institute of Radio Engineers] and Waves and Electrons* (July 1946), 466.

8. For development of the microwave dielectrometer and purposes for its use, see comments of Jelatis and Lee in Central Research Laboratories interview, 6–10. See also p. 10 for von Hippel's decision to place Chesley in charge of the Insulation Laboratory.

9. Central Research Laboratories interview, 11.

10. Central Research Laboratories interview, 10. For background on the life and career of Alexander Pierce Anderson, see Frederick L. Johnson, "Professor Anderson's 'Food Shot from Guns,'" *Minnesota History* 59, no. 1 (Spring 2004): 4–16. Anderson was born to Swedish immigrants John and Britta Anderson on a small farm in Spring Creek valley, 10 miles from Red Wing and even closer to the eventual site of Tower View Farm, built by Anderson and his wife, Lydia, in 1915.

11. Central Research Laboratories interview, 11–12; Lee, "Historical Highlights."

12. Central Research Laboratories interview, 8; Lee, "Historical Highlights."

13. Central Research Laboratories interview, 14–15.

14. Central Research Laboratories interview, 15; Lee, "Historical Highlights."

15. Central Research Laboratories interview, 15.

16. Gretchen Chesley Lang, Aug. 18, 2023, and Ted Lee, Aug. 19, 2023, emails to author, both in the author's collection. The oldest of the children, Gretchen Chesley Lang, was allowed to "hang around the shop" and in the barn with its animals. While exploring Tower View's underground tunnels, Gordon Lee's son Ted remembered, "One of them was filled with batteries and some puffed wheat experiments," likely from Alex P. Anderson's work. The author of this article was a future Red Wing Central High School classmate of two of the toddlers making the 1945 Red Wing trip with the Jelatis and Lee families: George Jelatis, who was interviewed for this piece, son of Demetrius and Vivienne (Vi) Jelatis, and Ted Lee, son of Gordon and Harriet Lee.

17. Elizabeth Hedin and Jean Chesley (Alex Anderson's daughters), interview with the author, Red Wing, MN, July 21, 2002, notes in author's possession; Johnson, "Food Shot from Guns," 15. In researching this article, the author was allowed access to Anderson's collected papers by his daughter Elizabeth Hedin. Alexander P. Anderson's Papers and Research Notebooks (1855–2003, bulk 1890–1943) are now in MNHS collections. It took Anderson nearly a decade of effort to engineer machinery for the "continuous puffing process" of cereal production. He followed his nationally popular Quaker Puffed Rice and Wheat creations with a new cereal, Quaker Cracklers.

18. Here and below, Central Research Laboratories interview, 11–13. Lee, "Historical Highlights," 2004. John Trautner moved his firm to Red Wing from his native Winona, MN, in 1903. Red Wing Marine Museum details the colorful history of Red Wing Motors through its displays and events. Trautner's machinists created the Thorobred, the renowned small boat motor. For an illustrated history of Red Wing boat and motor manufacturing, including information about Trautner and his company, see https://redwingmarinemuseum.com/history.

19. Lee, "Historical Highlights."

20. Central Research Laboratories interview, 18–19.

21. Central Research Laboratories interview, 18–19.

22. Victor Cohn, "Trio Probes 'Invisible World,'" *Minneapolis Sunday Tribune*, Aug. 8, 1948, 30. In fact, Chesley, Jelatis, and Lee would witness construction of a large electricity-producing nuclear generating plant on nearby Prairie Island in 1968.

23. Cohn, "Trio Probes 'Invisible World.'" Raymond F. Hedin and Dr. Edward H. Juers started a Red Wing medical practice together in 1932. In 1936, Hedin left temporarily for postgraduate work in surgery while Juers and Dr. Grant F. Hartnagel worked together in his absence. By 1940, with Dr. R. V. Sherman on board, the new Interstate Clinic was in operation. These were the physicians referred to in Cohn's *Tribune* article. Madeline Angell, *Red Wing, Minnesota: Saga of a River Town* (Minneapolis: Dillon Press, 1977), 320–21.

24. Argonne National Laboratory, "Our History," https://www.anl.gov/our-history.

25. Argonne National Laboratory, "Our History"; Lee, "Historical Highlights"; Central

Research Laboratories interview, 17–18 (Goertz's name is misspelled "Gerts"), 30–31 (note the change in terminology from master-slave manipulator to teleoperator); Raymond C. Goertz, "Remote-control Manipulator," US2632574A, 1949–12–16. The US patent application included 18 drawings detailing the manipulator and its workings. Following the war, the federal government formally chartered the facility as Argonne National Laboratory, charging it, on July 1, 1946, with conducting "cooperative research in nucleonics." It became the nation's first such *national* lab.

26. Central Research Laboratories interview, 17–18.

27. Central Research Laboratories interview, 20–21; R. C. Goertz, "Master–Slave Manipulator," 3–8, Remote Control Engineering Division, Mar. 7, 1949, Argonne National Laboratory, Chicago.

28. Central Research Laboratories interview, 23.

29. Ted Lee, email to author, Aug. 19, 2023. Lee believed his father made more than one journey to Los Alamos National Laboratory.

30. Central Research Laboratories interview, 23–24.

31. Central Research Laboratories interview, 23–24. Among Jelatis's research papers and presentations: "Design Criteria for Heavy-Duty Master-Slave Manipulator" (Apr. 1959); "A Rugged-Duty Man-Capacity Master-Slave Manipulator" (Nov. 1962); "Where Do We Go from Here with Master-Slave Manipulators" (1970); "Characteristics and Evaluation of Master-Slave Manipulators" (Oct. 1975)—all in Roy E. Clark and Candace L. Roat, *Metrication and Dimensional Coordination: A Selected Bibliography* (Washington, DC: Center for Building Technology, Institute for Applied Technology, National Bureau of Standards, 1977), 146.

32. Russell Hurst, "Atom Research Pops from Puffed Cereal," *Minneapolis Tribune*, Aug. 3, 1958, 41. In 1960, a compilation of American industrial research laboratories reported Central Research's staff included one chemist, three engineers (one electrical, two mechanical), one physicist, eight technicians, and four auxiliaries. CRL was described as doing research on "remote handling of radioactive and other hazardous materials, dielectric measurements, high speed oscillography, x-ray diffraction": see John H. Gribbin and Sue Singer Krogfus, comp., *Industrial Research Laboratories of the United States*, 11th ed. (Washington, DC: National Academy of Sciences–National Research Council, 1960).

33. Ted Lee, email to author, Aug. 19, 2023.

34. Jelatis, "Characteristics and Evaluation of Master-Slave Manipulators," in *Performance Evaluation of Programmable Robots and Manipulators*, NBS Special Publication 459, ed. T. B. Sheridan (Washington, DC: National Bureau of Standards, 1975), 141.

35. Peter R. Lavoy, "The Enduring Effects of Atoms for Peace," Arms Control Association, Dec. 2003, https://core.ac.uk/download/pdf/36731195.pdf.

36. Lydia E. Hedin, et al., *Alexander P. Anderson: A Biography of His Life* (West St. Paul, MN: Sexton Printing, Inc., 1997).

37. Central Research Laboratories interview, 24.

38. Central Research Laboratories interview, 25. George Jelatis, email to author, Aug. 16, 2023, reported his father's account of the CRL and AMF sales competition and manipulator quality issues. Demi Jelatis told his son, George, that AMF manipulators proved less reliable and lacked the features of Central Research devices, so that despite the price disadvantage, the Red Wing firm's manipulators became the preferred purchase.

39. Lee, "Historical Highlights."

40. Central Research Laboratories interview, 32.

41. Central Research Laboratories interview, 32, 34.

42. Central Research Laboratories interview, 36–37.

43. Lee reported convincing Johnny Carson's producer to pay for the dismantling of the Model 7 and the reconstruction of it in the studio. In his introduction to the audience, Carson said, "We've got a young fellow out here from Red Wing, Minnesota, with an interesting apparatus."

44. Hurst, "Atom Research Pops from Puffed Cereal."

45. Central Research Laboratories interview, 33.

46. Central Research Laboratories interview, 25–26.

47. "Open House at Central Research Plant Saturday," undated *Red Wing Daily Republican Eagle* newspaper clipping c. 1961, courtesy of George Jelatis. The new building's telephone and electrical power lines also ran underground. A bank of transformers adapted the 12,000-volt service to a level appropriate for the manufacturing of machinery and other needs. Architectural records regarding the new Central Research Laboratories building are found in Griswold, Rauma, Egge & Olson Architectural Commission Records (1958–66), B567v.4.2, box 1, folder 20, Hennepin County Museum, Minneapolis, MN.

48. Central Research Laboratories interview, 26–28.

49. Central Research Laboratories interview, 42–45.

50. Lee, "Historical Highlights."

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