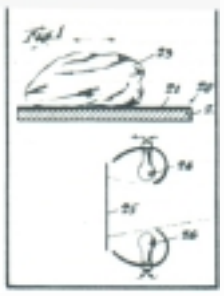
The Development of Xerography

Designated an International Historic Landmark
The American Society of Mechanical Engineers
October 20, 1983

Chester Carlson memorabilia, including a photograph of the inventor as a high school senior and a page from his scrapbook with a xerographic portrait made at Battelle in 1950.



The story of xerography is really three stories.

One is of a visionary man who recognized a need, then devoted his life to seeking technical solutions and financial support to fulfill it.

Another is of an innovative research organization that had the foresight to invest in an idea and the technical talents to engineer its basic concept into a viable working process.

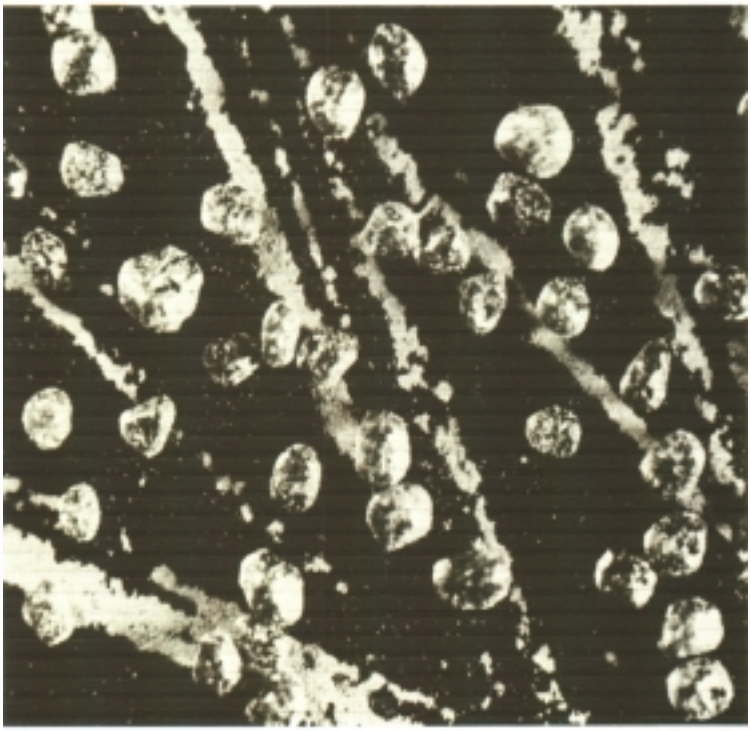
And the third is of a small, entrepreneuring company with the courage to defy the conventional and to risk its assets in successfully bringing a new concept and pioneering technology to the marketplace.

This classic three-in-one tale stretches over two-and-a-half decades and it illustrates the best in American innovation, in individual initiative, and in team spirit.

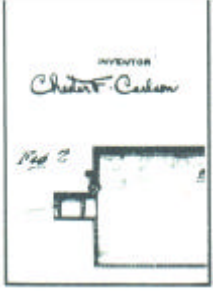
Despite early hardships and repeated predictions of failure, the effort culminated with the highly successful introduction and marketing of one of the twentieth century's most novel products: an easy-to-use copying process that rapidly and inexpensively produces copies through electrical and mechanical means. With the advent of the Xerox machine, the whole world suddenly possessed the ability to generate copies at the push of a button.

The process has imparted to this and future generations a new way to manage information. Its universal acceptance by business and government has improved the flow of communication.

Most importantly, like few other developments before it, xerography has filled an American technology dream—creating a multinational, multibillion dollar industry employing hundreds of thousands of people.



Taken during 1947 research on xerography, this photo depicts electrostatic imaging.



The Dream

The year was 1935 and America was in the midst of the Great Depression when 29-year-old Chester Carlson, a patent attorney with a physics background, conceived the idea for an office copier and began his personal crusade to create a new era in the printing industry.

An inquisitive and thoughtful man, Carlson always had been fascinated by the graphic arts. Even as a teenager, he ran the press for a small printer and started his own newspaper for amateur chemists.

Although his newspaper "folded" after its second edition, Carlson later recalled: "I was impressed with the tremendous amount of labor involved in getting something into print." That started him thinking about easier duplicating methods.

Carlson went on to study physics at the California Institute of Technology and eventually law at the New York Law School. It was in 1935, in his job as a patent attorney at the New York office of the P.R. Mallory & Co., when he again began thinking of easier ways to duplicate material.

"We had constant need for extra copies of patent specifications," he recalled. "They were sent to associates in foreign countries, to companies, to inventors, and others. We would need a dozen or more copies of every specification. To make 12 copies with carbon paper is pretty difficult. Often it involved two typing operations."

Additionally, there was no quick or easy method of getting copies of drawings, other than by enlisting the aid of a photocopy firm. The wait was as long as 24 hours.

"I recognized a very great need then for a machine that could be right in an office where you could bring a document to it, push it in a slot, push a button, and get a copy out," he said. "I set for myself a spare-time project of trying to fill that need."

The Concept

The starting point was the New York Public Library, where Carlson spent evenings and weekends reading everything he could find on imaging processes.

Quickly he determined he wanted a copying—not a duplicating—process. And he realized that the process would need to involve some unconventional photograpy.

He became engrossed in the then little-known field of photoconductivity and his ideas began to take shape. He was determined to create a visible image using an electrostatic charge.

His concept called for providing an electrical charge on a plate coated with a photoconductive material. This plate would be exposed to the image of a document to be copied. Light would discharge the surface of the plate in all but the image area, which being unexposed, would remain charged.

A black powder then would be dusted onto the surface. The powder would electrostatically adhere to the charged image area, making a visible image. Finally, the powder image would be transferred to a sheet of paper, where it would be fixed to produce a permanent copy.

"It was so clear to me at the very beginning that here was a wonderful idea," he later remembered. "I was convinced, even before testing it, that it was pretty sure to work and that if it did it would be a tremendous thing."

Worried that other inventors were on his trail, Carlson first took steps to forestall the competition by filing a patent application. He did so on October 18, 1937, calling the process electrophotography. Since his work was so innovative, he was awarded broad patent protection.

Early Research

Next he tackled the problem of reducing theory to practice. He started by experimenting, after work, in the kitchen of his apartment in Long Island. But soon, frustrated by lack of time and hindered by arthritis, Carlson decided he needed help. He hired a young Austrian physicist, Otto Kornei, to help him and they set up a lab in a second-floor room over a bar and grill in nearby Astoria.

It was here that Carlson first succeeded in producing a powder image. He did it on a photoconductive layer of sulfur coated on a metal plate.

The story goes like this: Carlson and Kornei first charged the coated plate electrically by rubbing it with a cotton handkerchief. Next, they placed over that plate a glass plate with the date-and-place legend, "10-22-38 Astoria". They then exposed this sandwich to a flood lamp for three seconds.

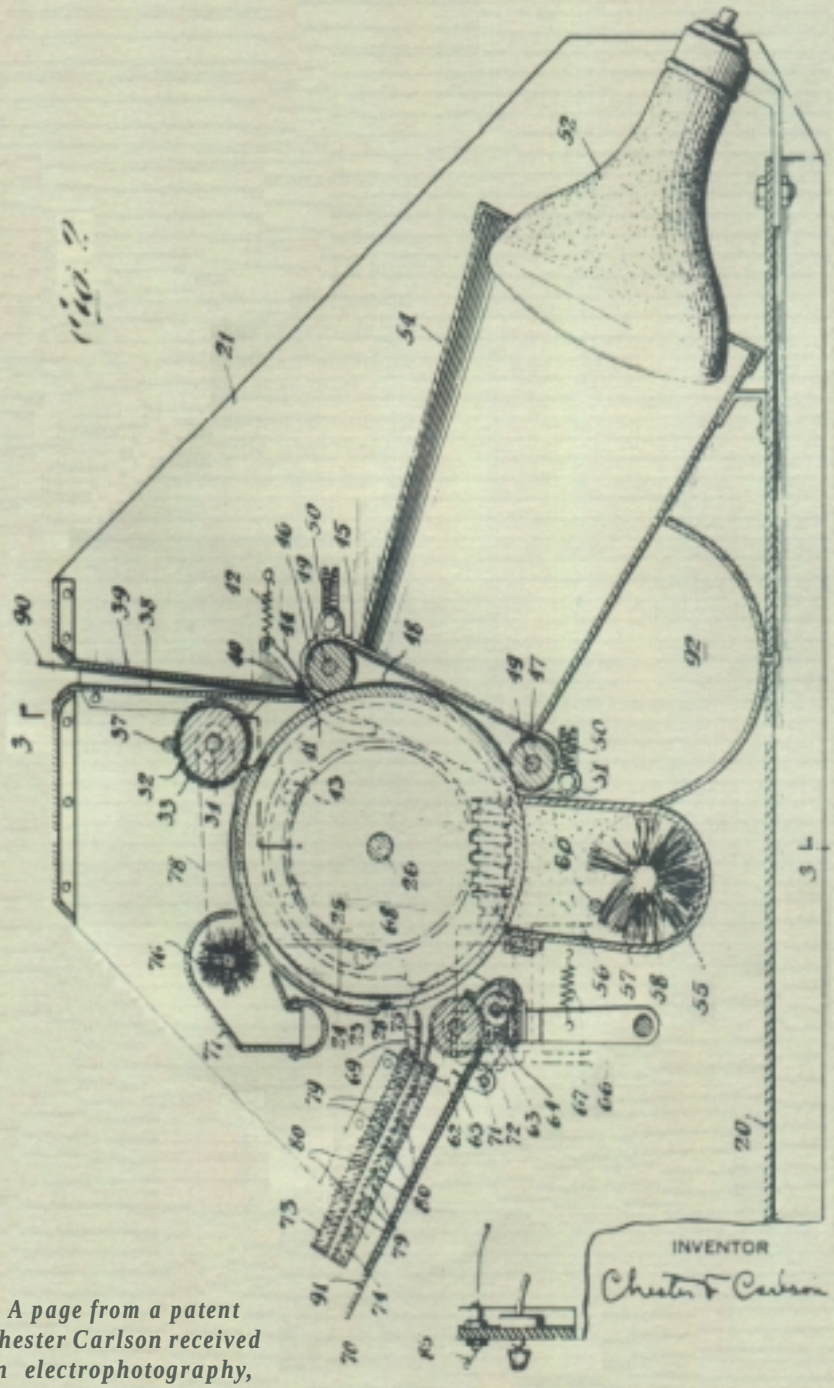
At this point they dusted across the exposed plate some dyed lycopodium powder—the spores of a creeping evergreen plant. Lycopodium particles adhered to the charged portions of the plate that had been protected from exposure to light. Next, Carlson pressed waxed paper against the sulfur coating, and the powder particles transferred to the surface of the paper.

The result: a transferred image of "10-22-38 Astoria"—and history in the making.

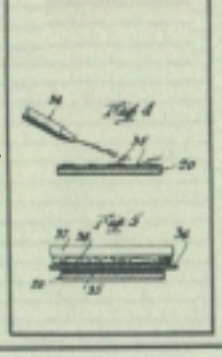
Sept. 12, 1944. C. F. CARLSON 2,357,809

ELECTRO-PHOTOGRAPHIC APPARATUS

Filed Nov. 16, 1940 5 Sheets–Sheet 2



A page from a patent Chester Carlson received on electrophotography, later called xerography.



Search for Support

For the next several years, Carlson tried to develop his invention and to obtain outside help in perfecting and marketing it. He contacted more than twenty organizations, including several major corporations. Each turned him down. Electrophotography was an idea whose time had not yet arrived.

"After talking to a number of people in industry, I found that my little crude demonstration did not impress them," Carlson said later. "A technical person could usually understand it, but few of them saw the potential in it. Businessmen were not very impressed with it. It was hard to find anyone who could visualize what could be done toward the engineering development of the process."

Finally, though, the pendulum began to swing. In 1944, scientists at Battelle Memorial Institute, the worlds foremost contract research and development organization, saw value in Carlson's crude invention.

Enter Battelle

The union between Carlson and Battelle was by fortuitous happenstance. Battelle's Dr. Russell W. Dayton was meeting with patent attorney Carlson to discuss some business between Battelle and P.R. Mallory and Company.

After their business discussion, Carlson told Dayton about his invention. Dayton recognized that it might be of interest to Battelle Development Corporation, a subsidiary that developed new inventions.

The Institute invited Carlson to its headquarters in Columbus, Ohio, to demonstrate his invention. When Carlson presented his findings, Dayton remarked: "However crude this may seem, this is the first time any of you have seen a reproduction made without any chemical reaction and by a dry process."

Battelle management and graphic arts specialists agreed. The process, they felt, looked "like a good research gamble." They envisioned many applications in addition to office copying. Some even thought it would find a place in the printing industry alongside lithography and photoengraving.

So in October of 1944—six years after Carlson made his first image—Battelle signed a contract with Carlson to develop the process. Under the agreement, Battelle would financially support the development as well as conduct research in exchange for royalties once electrophotography was commercialized.

Battelle Development Work Begins

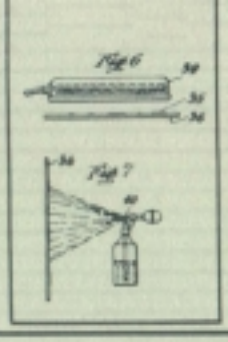
The graphic arts research group at Battelle was assigned the project. Although at the time World War II was still going on and most Battelle work focused on the war effort, a small group of staff enthusiastically embarked on the new project. Yet, the scientists did so sensing that many technical difficulties lay ahead of them.

They began work on improving the process and on learning its basic principles. They obtained a better understanding of what worked, what didn't, and why.

As a result, the Battelle staff significantly advanced Carlson's technology. A major step was the discovery that one form of pure selenium was a particularly good photoconductive insulator, sensitive enough to make a copying process practical.

Equally important, improvements were made in ways to develop the powder image. The powder became a pigmented resin that could be fused to the paper. A mixture of that fine powder with

Early Battelle demonstrations of the xerographic process. Here, researchers used heat to fuse the powder and fix the image on the paper to create a permanent print.



coarser particles chosen to control the charge on the powder made it possible to develop clean, sharp images.

Other significant early improvements included developing techniques for charging the plate by means of a corona discharge, and for electrostatically transferring the powder image to paper using a corona discharge.

Enter Haloid

As the months went by and with many technical questions still remaining, Battelle decided it needed a partner to support further research costs and to eventually produce and market the product. By a set of happy circumstances, such a partner appeared—The Haloid Company, a small Rochester-based manufacturer of photographic and photocopy papers

Shortly after the end of World War II, Haloid President Joseph C. Wilson recognized that the company needed to improve its profit position by finding other products. About this time, Dr. John Dessauer, Haloid's research chief, read a description of the new process in *Radio News*. He and Wilson agreed the process merited a closer examination. They eventually came to Battelle to discuss how The Haloid Company could enter this field.

After the visit Wilson acknowledged: "Of course, it's got a million miles to go before it will be marketable. But when it does become marketable, we've got to be in the picture."

Following months of negotiations, in December of 1946 Battelle and Haloid agreed that Haloid would sponsor part of Battelle's continuing research. In exchange, Haloid would receive a license to develop machines that would print up to 20 copies.

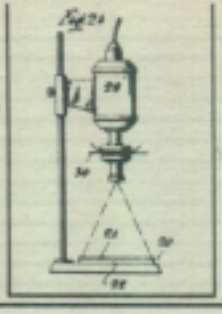
This basic agreement was revised several times, because of the large investments required to finally bring the process to commercial profitability. Eventually, exclusive and permanent rights for Carlson's and Battelle's patents were assigned to Haloid and both Battelle and Carlson received royalties, and later, Haloid stock.

The two parties also agreed that electrophotography, the word Carlson had coined to describe his process, was too cumbersome. Instead, they desired "a crisp, startling name, as new as the invention itself."

A classical language professor was consulted and the name xerography was selected. It stems from the Greek *xeros*, for dry, and *graphos*, for writing.

Aluminum plates were coated with selenium at Battelle using this vacuum system.

Battelle used a mixture of fine powder and coarser particles to develop images on xerographic plates.



The First Product

On October 22, 1948—ten years to the day after Carlson created the first xerographic image—the process had its first public demonstration. It was in Detroit at a meeting of the American Optical Society.

Like so many times before, the process was greeted with little interest. Many of the Society members just could not see the advantages of xerography.

But, Carlson, Battelle, and Haloid continued to be believers. On the day of the first public introduction, Battelle's staff publication described xerography as a "word that may eventually become an integral part of our language, rating in significance with such words as photography, radar, and television."

In 1949 Haloid introduced its first commercial product, the Model A. It was still a crude machine, unsuited for use as an office copier because it required a series of hand operations three to four minutes in length before a good single copy was produced.

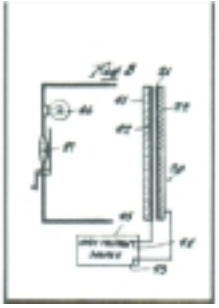
Fortunately, though, the Model A had a ready-made market. Slow as it was for office use, it proved successful in making good lithographic paper plates.

Arriving in 1955 was Copyflo, the first completely automated xerographic machine. Thanks to many mechanical engineering developments, it produced enlarged prints on a continuous roll from microfilm originals.

This machine was the first to use a rotating drum, instead of a plate, as the photoconductive surface. The drum solved the problem of how to make copies quickly.

Inspired by Copyflo's success in the market, Haloid changed its name to Haloid Xerox in 1958. A year later, the company also was ready to begin manufacturing the fast, low-cost convenient copier that had been so long in development. Yet, one last challenge remained.

The Xeroprinter demonstrated in the late 1940s by Dr. John Dessauer (left) Haloid's research chief; Chester Carlson; and Haloid President Joseph C. Wilson. This early xerographic device, which printed on a roll of paper, commanded public attention, but was never marketed as a product.



The Last Challenge

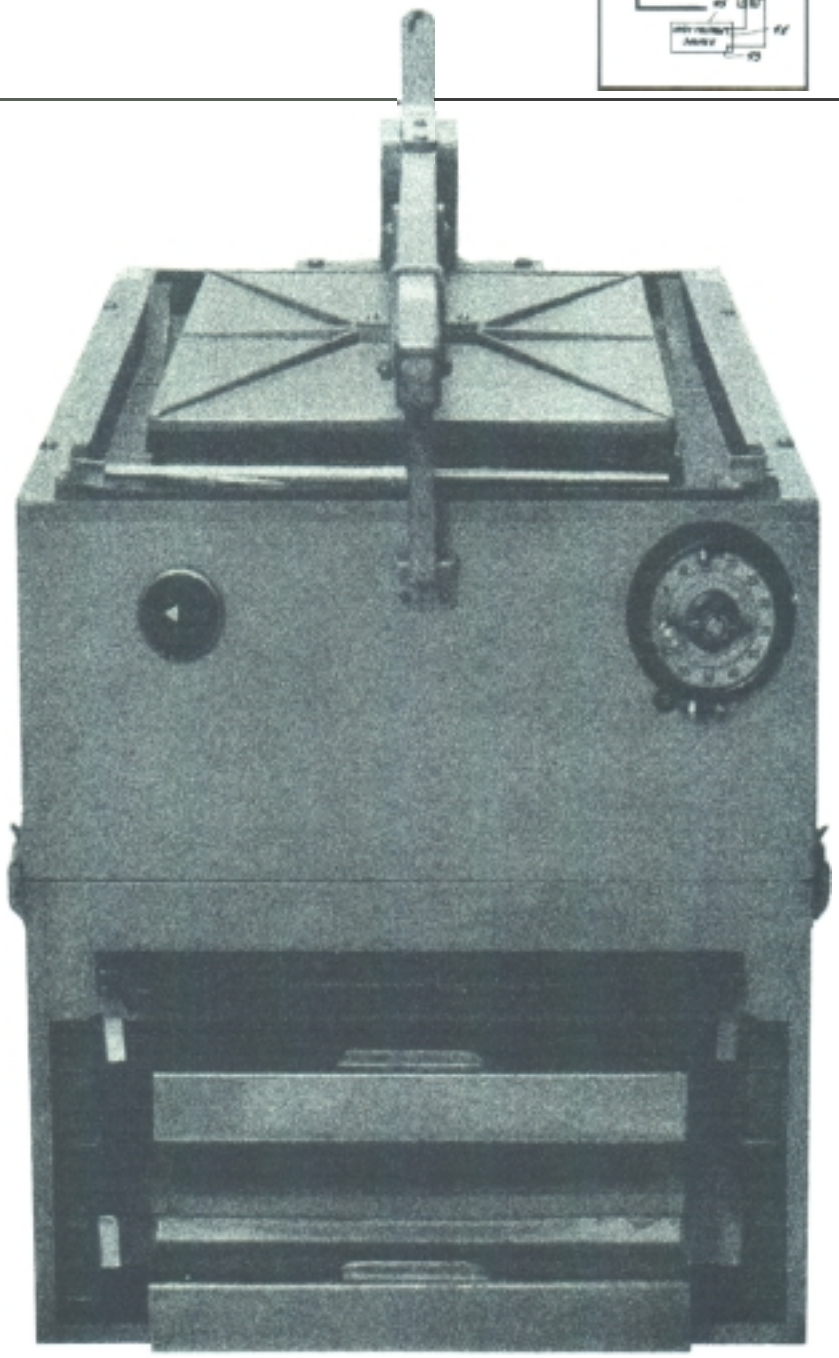
The Haloid Xerox Company, though starting to generate healthy revenues from its xerographic products, feared it lacked the financial resources to bring out the office copier model. The company was low on cash because it had invested $12.5 million in development—more than the company's total earnings from 1950 through 1959.

The last challenge was how to financially move the product to market. Haloid Xerox offered to share the project with larger companies, but once again xerography met disinterest and rejection.

Forced either to quit or to go for it all, Haloid Xerox chose the latter course. It risked all of its assets on a product whose need and advantages were foreseen only by one visionary man, one research organization, and one daring company.

The result: in 1959 the world saw the first fast, low cost, and convenient office copier. Called the 914 copier (since it could copy sheets as large as 9 by 14 inches), it proved to be one of the most successful single products ever marketed.

In 1961, Haloid Xerox changed its named again—this time to the Xerox Corporation. And it found itself in the happy position of trying to keep pace with the vast demand for its new line. It built huge research complexes, hired and trained sales and service forces, and tooled up budding manufacturing operations.



A laboratory version of the first commercial xerographic copier. Introduced in 1948, it met with only modest success, but paved the way for bigger things.

At Long Last: Success

For Chester Carlson, xerography's commercial success turned a fantasy into a reality. His early identification of a need and his personal crusade to fill that need ultimately resulted in an improved flow of communication and revolutionized an industry.

But the story of xerography is unending for Battelle Memorial Institute, for the Xerox Corporation, and for the world.

Battelle, the research institute that likes to tackle difficult problems and find practical solutions, was able to grow and diversify with earnings from xerography's success. As a result, today Battelle is the world's largest independent R&D organization, annually solving research problems for more than 3,000 companies or government agencies.

For the Xerox Corporation, xerographic and related products have enabled the company to grow to be a billion dollar corporate giant and leader in the office information industry. In 1980, it produced its one-millionth xerographic copier.

For the world, xerography offered a new and better way to make copies—and the innovations keep coming. Xerography also proved once again that success in the corporate world comes to those risk-taking individuals and organizations who identify real needs, who develop technology bases to fill those needs, and who nurture the end-product through innovative and long-term commitments.

Several of the Battelle staff involved with the development of xerography in 1951.

An historical montage of xerography: nameplates from various models, pellets of selenium, a machine drum, an early sales brochure, Xerox copiers, the first 914 off the line, and Xerox President Joseph C. Wilson (right) with Sales Vice President C. Peter McColough in 1960.

The ASME Central Ohio Section gratefully acknowledges the efforts of all who cooperated on the landmark designation of the development of xerography as an International Historic Mechanical Engineering Landmark, particularly the staff at Battelle Memorial Institute and the Xerox Corporation.

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The development of xerography is the fifteenth International Historic Mechanical Engineering Landmark to be designated since the program began in 1973. Since then, sixty-six National and seven Regional Landmarks have been recognized by the Society. Each represents a progressive step in the evolution of mechanical engineering and each reflects its influence on society.

The Landmarks program illuminates our technological heritage and serves to encourage the preservation of physical remains of historically important works. It provides an annotated roster for engineers, students, educators, historians and travelers, and helps establish persistent reminders of where we have been, where we are, and where we are going along the divergent paths of discovery.

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