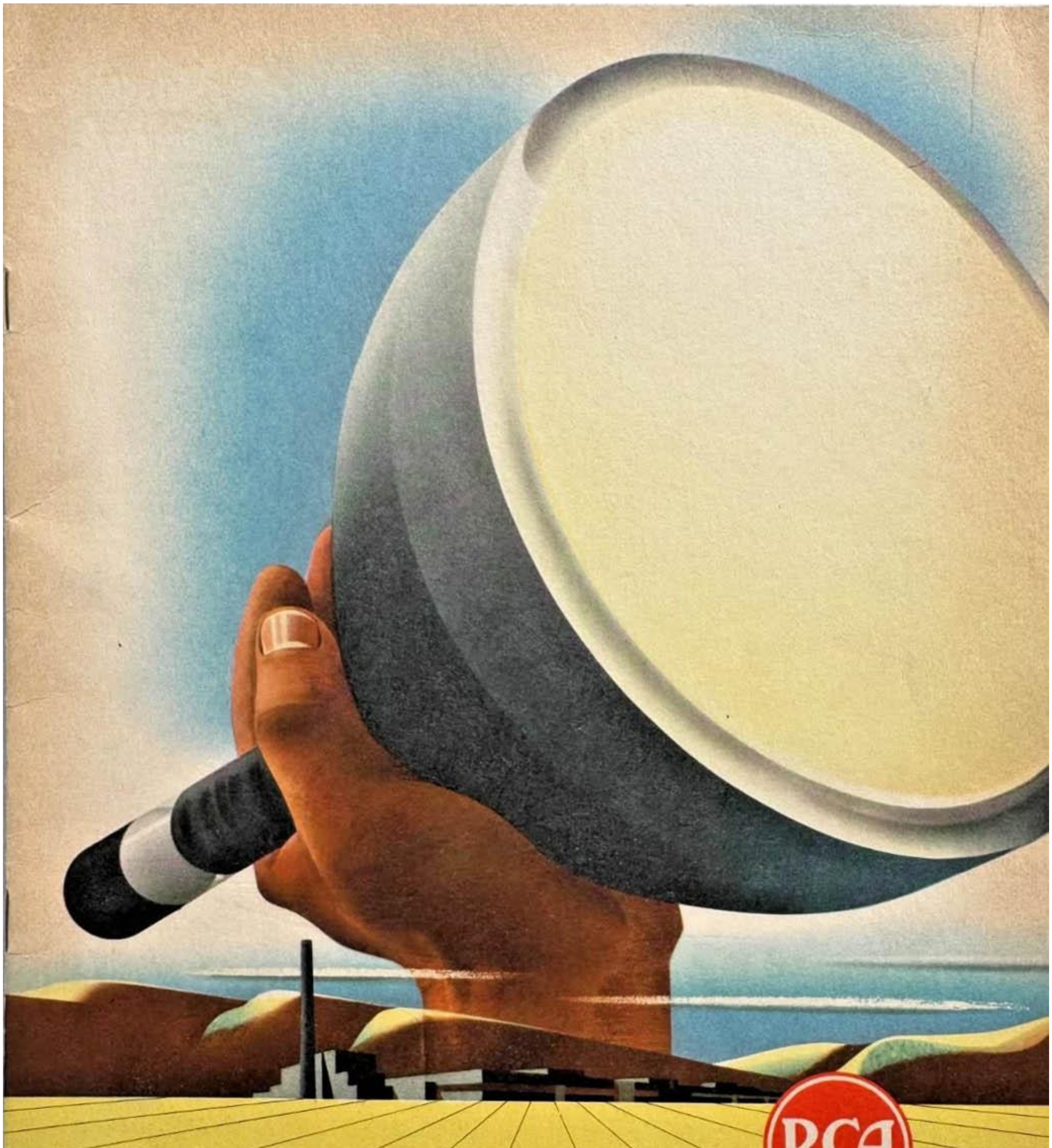
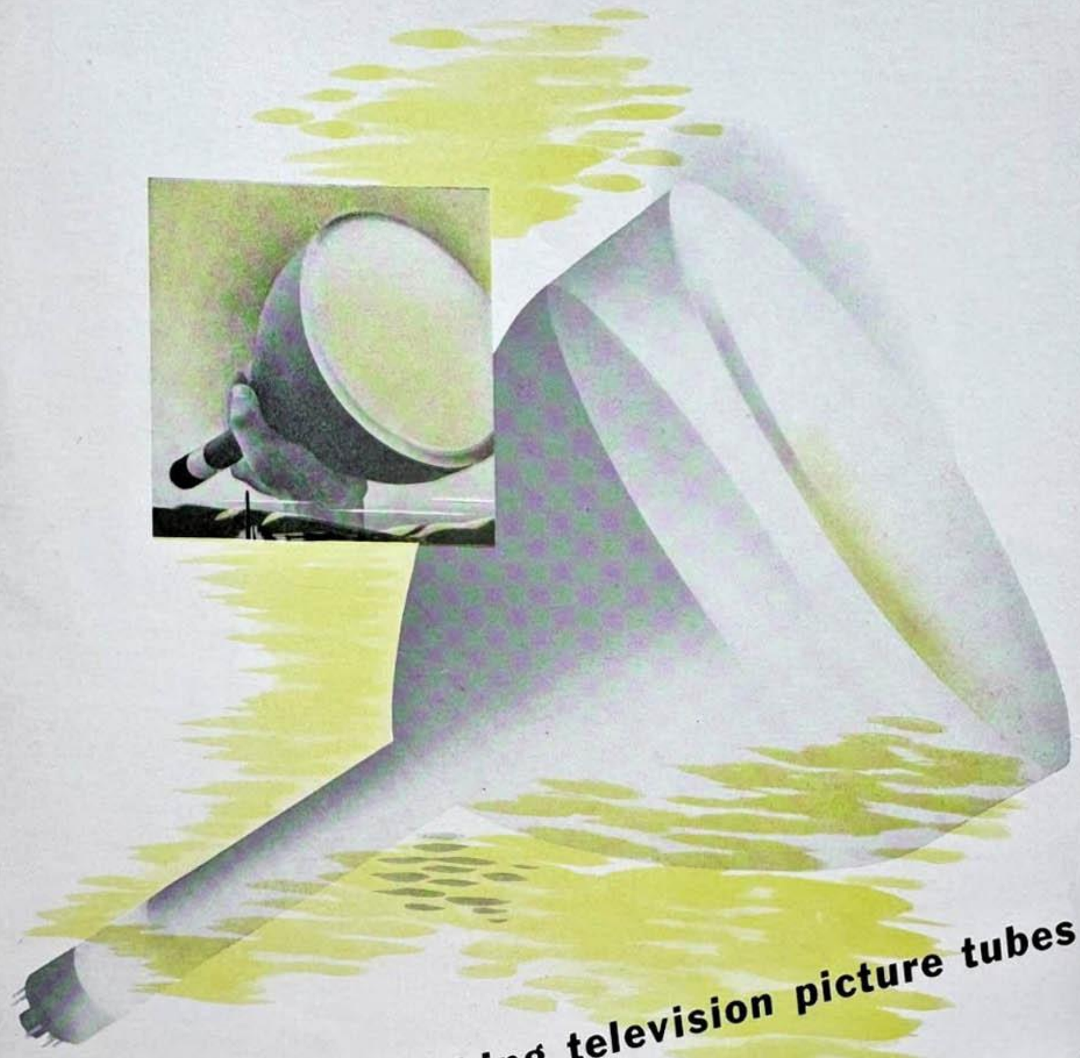


the magic of making television picture tubes



the magic of making television picture tubes

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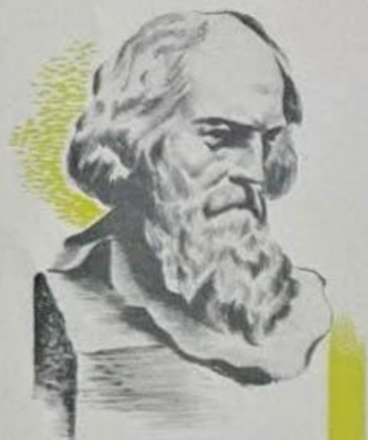


For I dipped into the future,
far as human eye could see,
Saw the Vision of the world,
and all the wonder that would be!

—TENNYSON

Kinescopes—television picture tubes—suspended from conveyor lines hundreds of feet long, are carried from process to process with a minimum of handling.

the magic of making television picture tubes

LORD TENNYSON, were he here today, might well be inspired to write his poetic lines in the fertile valley amidst the hills of Lancaster, Pennsylvania, where the Radio Corporation of America has established the world's foremost center for the development and production of electron tubes for television. A visitor leaves that realm with the poet's words ringing in his mind, for he knows that he has "dipped into the future" in which men will look far beyond the range of the human eye to behold "the Vision of the world" and the wonders all around it.

This modern plant already covers 7½ acres on 99 acres of farm land. It is a productive industrial realm, electronized and mechanized by the ingenuity of scientists and engineers.

Every morning sees eight tons of glass bulbs go down to the production lines. Before the day is ended, the funnel-shaped tubes, with their luminescent faces ready to glow pictorially, have been put together and packed in boxes destined to go into the

After this white-hot block of luminescent material is removed from the furnace, it will be spread on the face of a kinescope to serve as a "screen" on which television pictures will appear.

homes of America so that families, wherever there is television, may watch the world in pictures—news as it happens, politics as practiced, history as it is made, sport events, parades, and dramas by notable players of radio, stage and screen.

Each evening 1,600 employees—two-thirds of them women—homeward bound pass through the gates of this television tube plant, knowing that they have contributed to a product of science that enables their fellow men to see "all the wonder that would be."

Valley Forge, where Washington's tattered army camped during the winter of 1777, is but 45 miles to the Northeast; the battleground of Gettysburg is 53 miles to the Southwest. Now, amid those two historic sites in American history, science is writing new history—*Television!* Over the hills from which Washington's soldiers kept eyes on the enemy, now come pictures from Philadelphia and other cities beyond the horizon.

It was war, too—but modern war—that located this great television tube plant at Lancaster, a strategic point on the Lincoln Highway and on the main line of the Pennsylvania Railroad. In March 1942, the U.S. Navy, with the cooperation of the Radio Corporation of America, established Lancaster as a center of specialized electron tube development so that the American soldiers and sailors of World War II would have radar "eyes" to see much farther than the human eye could see. So rapidly did the structure go up and so rapidly was personnel skillfully trained to meet the demands of war, that the first tubes were produced on December 15 of that same year—1942.

The iconoscope, invented by Dr. V. K. Zworykin of RCA Laboratories, and the kinescope, which he developed, gave this great manufacturing enterprise its heritage. The iconoscope was the first sensitive electronic "eye" of the television camera. The kinescope is the electronic picture tube, which serves as the screen of the television receiver. The principles of these devices and the later developed image orthicon camera tube aided the successful conduct of the war. Zworykin, whose original goal was to serve the arts of peace, had given the world "radio sight." But when the trumpets sounded the call to World War II, these electronic "eyes" became a necessity in modern warfare, to keep watch on the enemy, even in fog, or in the blackest night, or above the clouds.

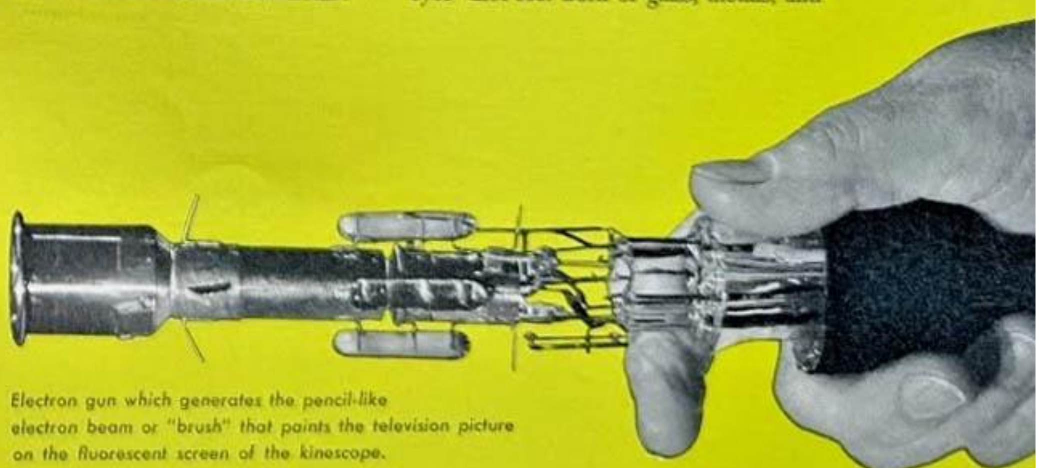
It was radar—a new weapon in war—and the great need for electron tubes which enable man to see by radio, that led to swift construction of the plant. As a result, during the war an average of 42,000 radar tubes came off the production line each month. Most of them had to be made by new processes, because radar itself was new and machines had to be designed in a hurry. As the war went on, scientists, engineers, and production men, working at feverish pace, succeeded in adapting the pre-war kinescope to the exacting demands of radar, producing radarscopes that could spot planes, ships, and other objects hidden in fog or darkness, or lurking below the horizon.

As a result of this wartime research and development, here, when the war ended, was a magnificent plant that offered such great possibilities for the security of the Nation and for the future of television that it could not be left to "cool off," or to be abandoned. It was an attractive place in which to work, and ideal for the production of picture and camera tubes that would start television on its way as a great American industry. Mindful of this, RCA at the end of the war purchased the plant from the U.S. Navy and expended a million dollars for the development of new postwar machinery that converted it to peacetime use.

Here, various types of electron tubes, chiefly known as power tubes, are manufactured, but the kinescope tube comprises the main activity. Its complexity and the magic of its performance add to the wonder that man can take a glass bulb at one end of a factory and bring it out at the other end capable of reproducing a picture that has been electronically scattered through space.

The funnel-shaped kinescope tube has a large face or "screen," coated with fluorescent materials, and an electron gun in its long, glass neck. The electron beam in the kinescope is synchronized precisely with the electron beam in the camera's image orthicon tube. The incoming television signal varies the intensity of the electron beam, which "paints" the picture, and thereby forms the lines of light which make the picture, as the "paint brush" sweeps with incredible speed across the fluorescent screen.

Since Lancaster is the center of such tube production, it is there that the electronic "eyes" first see. Born of glass, metals, and



Electron gun which generates the pencil-like electron beam or "brush" that paints the television picture on the fluorescent screen of the kinescope.

While torch-like fingers of flame shoot out automatically to play upon the glass bulbs, radio-heat is applied to speed the production of television's electronic picture tubes.

chemicals, these tubes come to life through flames and intense heat.

Five or six of the latest television receiving sets lined up alongside each other in a laboratory—all connected to an electronic camera scanning the countryside—prove that television is all-seeing. On the screens of these receivers, automobiles on the roadway, people on the street, and trees blowing in the wind, provide a natural picture which aids the engineers in testing and developing electronic eyes to distinguish every detail and to detect every movement.

It is remarkable what machines can do and what man can do with machines in "ever reaping something new."

"All the machines you see here," remarked an engineer, "were conceived, designed and built by RCA for automatic, mass production of television tubes of the finest quality and at the lowest possible cost. New since the war, these machines reveal the importance of electronic, mechanical and design engineers in this modern age of mass production and speed. If it were not for this machinery, which is uncanny in its operation, television tubes would be produced by a slow, uncertain and costlier process. But these giant machines pick up glass bulbs, move them around, wash them, subject them to terrific heat, exhaust them of air, and give them a luminescent face, or screen."

The magic of the production engineers' handiwork is demonstrated as torch-like fingers of flame shoot out automatically to play upon the glass bulb while radio-heat is applied to speed the process. Every advantage is taken of the opportunities which radio provides for the electronization of industry. For instance, in a preliminary operation, a blue flame beats upon the glass at 250 degrees centigrade to prepare the tube for the processes that are to come. While this is going on, advantage is taken of time to insert a tiny metal button into the side of the tube. Mechanical fingers hold the button in place while intense radio-heat welds it to the glass at 700 degrees. At that spot, the glass and button glow red.

After passing through such a torrid process, the glass must be handled with great care to prevent sudden cooling and, therefore, it is automatically routed through a machine known as an annealer, which, by gradually lowering the temperature, "cures" the glass for more than an hour before it again comes into the open air.

Giving Vision to Eyes of Glass

Now let us watch these glass bulbs gain their sight; it is really the creation of electronic vision. The empty glass bulbs which form the envelope of the "eye" begin a "parade" into the plant along moving belts that carry hundreds of cradles, each of which holds a bulb. In this way, there is no piling up of bulbs to occupy valuable floor space. Throughout most of the journey, the belts move along just under the ceiling, dipping only here and there as various processes are applied to give the bulbs electronic life. So proficient are the conveyors in handling the big glass envelopes that throughout the entire operation only 1 per cent is lost because of breakage or damage.

There was a time not long ago when these big glass bulbs had to be washed slowly and dried by hand. Now all that is done as quickly as a tea cup is cleansed under a faucet. On an automatic washing machine, hot chemicals and water at high pressure

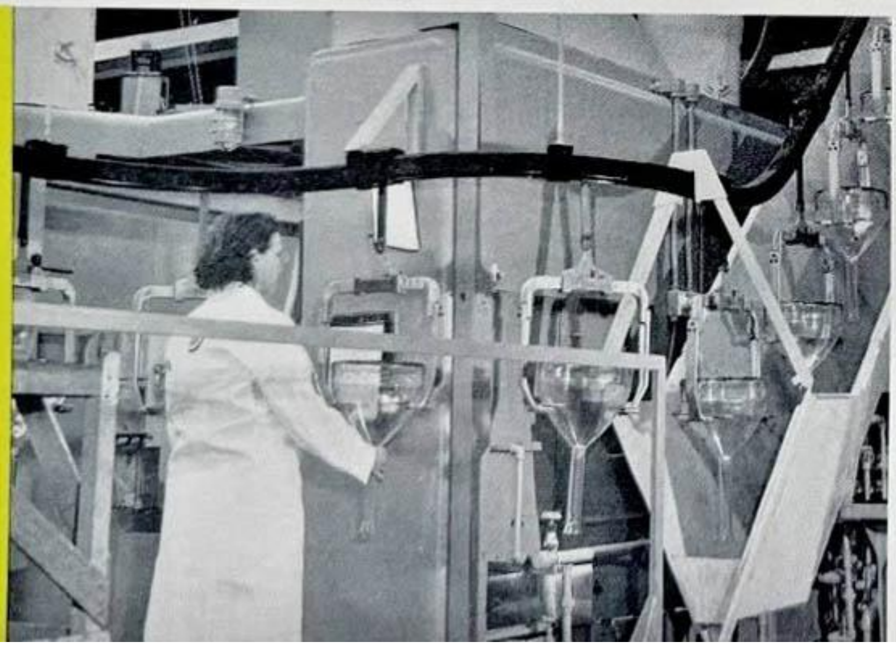
After kinescopes are subjected to a heat of 250° to 700° centigrade, they are routed through this machine which "cures" the glass by lowering its temperature gradually.

are sprayed throughout the inside of the bulb, which is quickly dried by warm air so that no lint or other foreign particles contaminate the "eye." Each machine washes 60 bulbs an hour—one a minute!

The clean bulbs are then conveyed on an automatic belt to a special vibration-free room, literally an "island," its floor suspended and separated from the rest of the plant. This room, as well as the entire plant, is air-conditioned, the humidity and the temperature evenly controlled. Here, under these ideal conditions, a solution of fluorescent material is put in the bulb. As the material settles, it forms a delicate film-like covering on the interior of the face of the bulb—a flawless fluorescent surface, smooth and uniform. That is why the floor has to "float," to guard against the slightest vibrations that might ripple the fluorescent material like sand on a beach.

Each bulb, therefore, must be handled with imperceptible motion. As the fluorescent material settles, the water in the flourescent solution must be drained off. This delicate task challenged the ingenuity and patience of the engineers. At first they tried a long and tedious process in which the tubes were placed on tables suspended on springs in the vibration-free room. But there could be no mass production as long as such a slow method prevailed. The mechanical engineers were given the problem of circumventing this bottleneck. They solved it by designing a vibration-free machine that would assure a uniform result in mass production. It was a radically new machine, as gigantic as a dinosaur, yet handling the glass bulbs with a touch so gentle that they scarcely seem to move as they are conveyed across the top of this machine at the rate of about three inches a minute for more than an hour. As the bulbs, held face down in suction cups, approach the end of

Kinescopes emerge from the "laundry" where cleansing solutions remove all impurities from the bulbs which are then taken by conveyor belt to the next process.



the conveyor belt, they slowly pass over the brink as if going over a waterfall, with their long glass necks projected outward. This permits the solution to drain off gradually, during a period of about ten or fifteen minutes, while the particles of fluorescent material dry and adhere to the face.

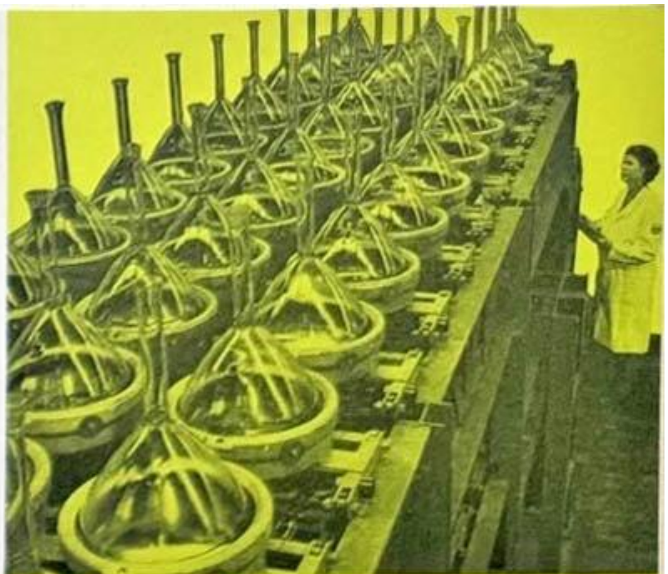
"Why does the material cling to the inside of the tube's face so uniformly, when the water runs off?" an engineer was asked.

"We don't know," he confessed. "The scientists tell us that the trick is accomplished by molecular attraction. Whatever it is, it's lucky for us!"

This big machine "moves but slowly, slowly creeping on from point to point." Nevertheless, it speeds production compared with the old table-drying method. The engineers themselves marvel at the fact that a small one-quarter horsepower motor is all that is necessary to run this massive but finely-balanced mechanism. The little motor keeps 2½ tons of machine and materials in motion.

All the machines along the production line are so different in shape, size and performance, and yet so exactly synchronized that an observer is moved to inquire where they came from. They handle the bulbs with a tender care that is almost human. The answer is that they were "dreamed up" by mechanical engineers with an aptitude for robots. So uncanny is the vision of these engineers that they design machines to prevent epidemics of trouble on the production line. Warning devices and alarms, electronic and otherwise, keep the machines running smoothly, and should any symptom of trouble develop, it is quickly detected before the bulbs can pile up in a "log jam."

Now, to resume the trip along the line:



Tubes move at a snail's pace along this "settling belt" while the luminescent coating settles evenly on the face of the bulb.

At the "spillway" end of the settling belt, the tubes containing the luminescent solution slowly pass over the brink. This permits the liquid to drain off leaving the phosphor particles adhering to the tube face thus forming a flawless fluorescent surface.

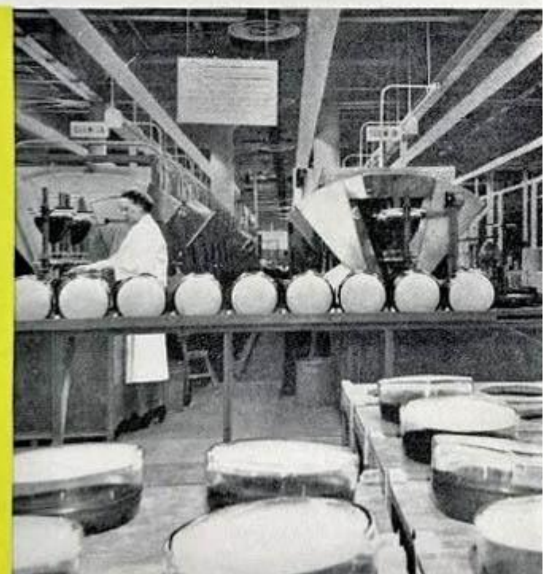
The inside of the kinescope is given a black coating on a machine that whirls the tube to permit graphite paint to be applied evenly.

After the fluorescent material is dry on the face of the bulb, it is nearly time to create the vacuum so that electrons can be put to work under ideal conditions. First, each bulb must be inspected under a strong light to make sure that the fluorescent coating is uniform and free from scratches, ripples, or holes. Even a mere speck—a pinpoint—causes the inspector to reject the bulb, yet only a small percentage is turned back for reprocessing. The next step is to apply a graphite paint to the sides of the inner wall of the bulb and dry it in an oven for twenty minutes. Then for the first time the bulb's ability to glow is electrically tested.

With automatic precision, an electron gun which generates the electron beam, or "television paint brush," is inserted in the neck of the bulb. This gun consists of an electrically heated surface which releases electrons, and a combination of little cylinders and disks, the latter perforated with tiny holes all machined to an accuracy of .001 inch. The jigs and fixtures used in assembling the gun are the envy of watchmakers.

Production of the electron gun is an interesting study in contrasts. Unlike the massive machinery of the bulb assembly line, the construction of an electron gun requires an extreme delicacy of touch and hair-splitting accuracy.

All this care is essential to insure that the electrons from the heated surface will be compressed by the cylinders and disks into a pencil-like beam that will "paint" a clear picture on the fluorescent screen as the beam moves back and forth faster than the eye can preceive.



Bulbs move into long, oven-like exhaust machines where they are evacuated of air and become vacuum tubes.

With the gun inserted and sealed in place so that it points directly at the center of the screen, the bulb next passes into a straight-line exhaust machine which removes the air. This machine looks like a long oven. Through it moves a series of carts, each equipped with a vacuum pump, and each carrying a bulb. There are eighty-four bulbs in two parallel "ovens" at a time, and a cart comes out of each machine alternately every two minutes with an evacuated tube.

If there should be any appreciable air left in the finished tube, the "painting" of the picture would be imperfect. The vacuum in a kinescope picture tube must be ten times better than the vacuum in a standard radio tube or in an electric lamp.

The tubes are then cleaned on the outside in a soap-and-water bath, and quickly dried so that a metallic, conductive paint can be sprayed on the outer surface. This outside coating, in conjunction with the graphite coating inside, forms the electrical condenser needed to complete the television circuit. After this final step, the tube is taken off the line, boxed, and sent to the warehouse. From there it goes into service to give an American family television entertainment and to take them sightseeing by radio!

As television picture tubes near the end of the production line, they are sprayed with an outer coating of graphite paint, the final process before shipment.

Every morning sees eight tons of glass bulbs start down the production lines. Before the end of the day they are ready for shipment, with their luminescent faces prepared to glow with television pictures.

This block of luminescent material, energized by ultraviolet light, provided illumination for this photograph which was taken in a darkened room.

Fluorescence

A visitor watching the production line is certain to be fascinated by the magic of fluorescence. He realizes that the brilliance of television is found in the wondrous fluorescent materials, which can be selected to glow in any color. These gleaming phosphors are to television what the retina is to the human eye.

Where do these phosphors come from? For centuries Nature held the secret—even sugar, salt, quartz, diamonds and many other substances have luminescent properties. Some materials have the amazing property of absorbing daylight and then emitting a faint blue light in the night. Such phosphors have attracted man's attention for centuries. As far back as 1603, an alchemist noticed light emanating from white barite rocks which had been accidentally heated.

But it was not until scientists began to think of television that their curiosity resulted in intensive research. They wondered whether these glowing materials might be useful in an electron tube that would serve as the screen of a television receiver.

One of the first to develop the fundamentals of a process to make luminescent materials for television was Dr. H. W. Leverenz of RCA Laboratories. He set up a dust-proof chamber and over the doorway hung a sign, "SPECPURE LABORATORY", that admonished visitors: "Please Do Not Enter—Dust is Our No. 1 Troublemaker." Moistened rugs were used to trap shoe-borne dust, and the laboratory technicians were required to change to clean white clothing before entering the dust-free rooms that looked more like the operating room in a hospital than a chemico-physics laboratory.

Long years of research led to success. Even the preparation of a cupful of fluorescent crystals was considered to be an outstanding achievement not many years ago. But before mass production could be applied to television tubes, fluorescent materials would have to be synthesized and produced in bulk, while still maintaining the highest quality and purity. When Dr. Leverenz and his staff achieved their goal, it was possible to make tankfuls of fluorescent materials rather than cupfuls.

Today, as one approaches a new building alongside the tube plant at Lancaster, the faint scent of hydrogen sulphide gives evidence that this is a chemical laboratory.

Here fluorescent materials are made in what appears to be a distilling plant, with glass pipes woven through vats and tanks from roof to basement.

At the present time, more than 1400 pounds of fluorescent materials are produced in a month for television tubes, and at lower cost than the experts of research once produced a cupful. The pioneers had to guard against contamination, because even a speck of foreign material in a cupful would be disastrous. One part of copper in 10 million parts of fluorescent material would cause green spots on the television screen. In bulk, however, a speck of extraneous matter has less chance to play havoc because it is lost like a raindrop in a lake. Nevertheless, purity is still vital; every guard is posted against contamination.

Each batch of material must have the same characteristics. That fact necessitates careful tests to insure uniformity of the fluorescent material with respect to color. A white screen, which is standard in home television, is a mixture of blue and yellow materials which, when combined in the proper proportions and acted upon by an electron beam, produces white light, or black-and-white television pictures.

The development of fluorescent materials provides an excellent illustration of the relation of the laboratory to manufacturing. When the research man has reached his objective, the development engineer and the production engineer are handed the problem of making practical application of the research man's discoveries and at a reasonable cost. This calls for close cooperation between research and production. There may be a five-year gap between completion of research and factory development. Sometimes development actually begins before research is completed, in an effort to reduce the time gap between the two.

Tubes Lead to Tubes

All this reveals that television is not the essence of simplicity; the new science calls upon all the complexities of radio, physics, chemistry and optics and, to an extraordinary degree, upon Nature.

Reception of television is only half the magic; first there must be transmission. Every video transmitter, as well as each receiver, requires specialized electron tubes. The specifications in each instance are com-

So precise is the design of the RCA 5-kilowatt television transmitter tube that the finely separated parts must be aligned under a microscope.

pletely different. The transmitter tube takes the electronic pictures, converts them into radio waves and broadcasts them into space. All sounds associated with the picture leave the antenna at the same instant as the pictorial wave, and both signals arrive together at the receiving set. Thus, the voice or music that enlivened the original scene is reproduced with perfect timing.

The picture tubes that make this miracle of television possible are aided throughout the circuits by many other smaller tubes, which amplify and perform numerous electronic tricks, each in a split second. Since transmission and reception are a tandem operation, each dependent upon the other, the RCA tube plant at Lancaster specializes in tubes for transmitters as well as for receivers.

As soon as research is completed at RCA Laboratories, Princeton, N. J., development work is instituted at the Lancaster plant to pave the way for tube production. One result of this team-play in industry was a new and unique 5-kilowatt transmitter tube. So precise is the design that the finely separated parts of the tube are aligned under a microscope. Every element except the filament is water-cooled through an intricate system of silver-plated copper channels. This tube combines, in the smallest glass envelope, the greatest continuous power output at the highest frequency of any transmitting tube so far produced. Jewel-like in construction, it is a masterpiece in engineering and provides television with power and a clear picture signal over a greater area than was believed possible only a few years ago.

Electronic Keys to Progress

Tubes are the master keys to progress in radio communication. Radio and television men know that no tube, no matter how impressive in performance, ever represents the ultimate; the tube designer and engineer never reach Utopia. Every new radio tube leads to a newer one. For instance, early in 1948, RCA announced a 16-inch metal kinescope. Development and production of this tube was brought about by the perfection of a process to vacuum-seal large areas of metal to glass. The cone of this tube is metal, only the neck and face are glass.

The industrialist asks the development engineer, "What next?" And he is likely to get the answer when the engineer asks the research man the same question, for the latter is usually five or ten years ahead.

In all-electronic television the tube men introduced what they describe as "a fourth important element"—a new deflection tube, which ranks in importance alongside the image orthicon, kinescope and transmitter tube. The function of this tube is to generate the power that moves the electron beam across the face or screen of the kine-

The RCA 5-kilowatt television transmitter tube is water-cooled through a system of silver-plated copper channels.

Jewel-like in its construction, the 5-kilowatt television transmitter tube is a masterpiece in engineering—a miracle of precision.

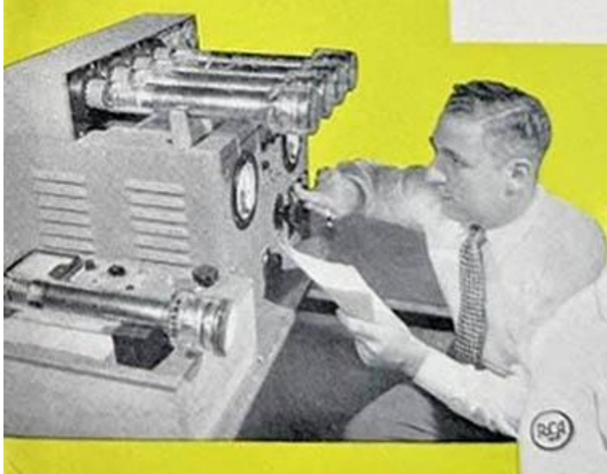
Final tests of the RCA image orthicon camera tube check its perfection as an "eye" that can see anything the human eye can see, even in candlelight.

scope. In other words, it acts like the movement of a painter's hand as he wields the brush. It looks like a conventional radio tube, but the engineers explain that it has the ability to perform "some little tricks" that make it quite different. They describe it as a modification of a power tube, but in popular terms it is the electronic painter's "wrist."

Of course, the television camera also must have an eye, and that, too, as previously mentioned, is an electron tube—the RCA image orthicon. It will see anything the human eye can see, even in candlelight or in the light of a match.

The complexity of the image orthicon is found in the fact that it is actually a combination of three tubes—a phototube, a cathode-ray tube, and an electron multiplier. Each of these must work at maximum efficiency at the same time and within the small glass envelope which comprises this magic camera eye.

The phototube converts the light image into an electron image which is instantly transferred by electrical means to a glass



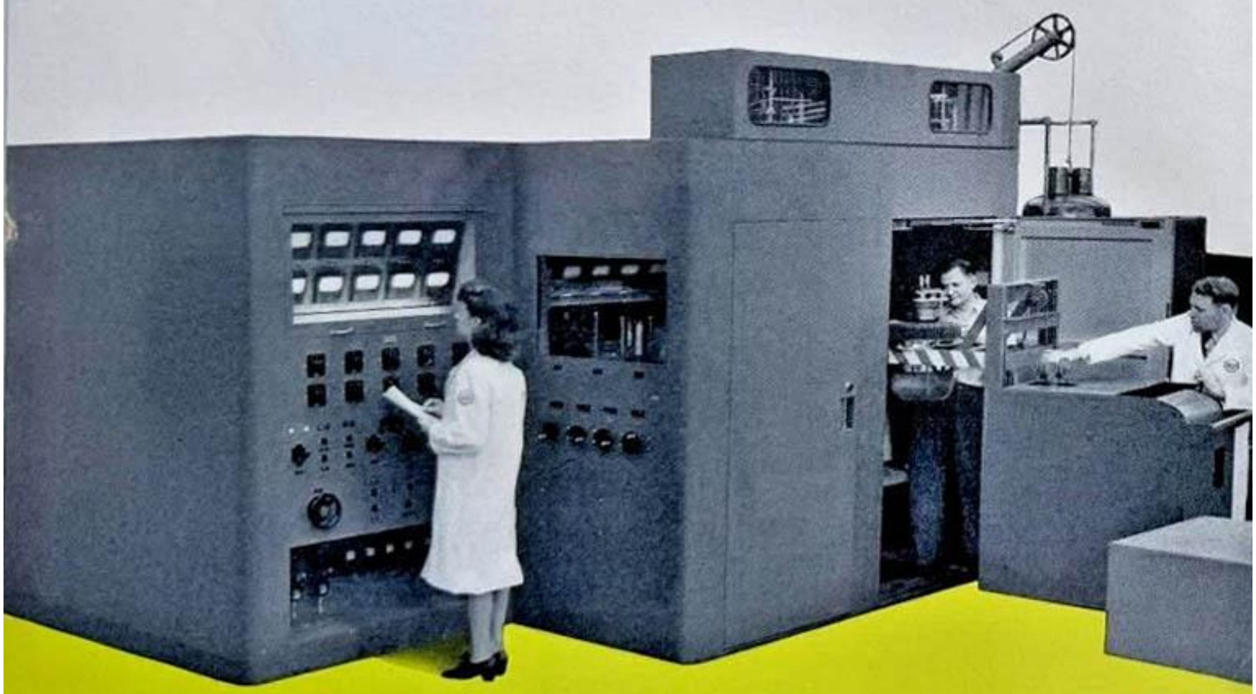
Skilled workers prepare the fine copper mesh, with 250,000 holes to a square inch, which is one of the essential elements that make the image orthicon so complex, intricate and delicate.

target where it is scanned by the electron beam from the gun, thereby creating the radio signal. Then the electron multiplier, as its name implies, takes the signal and greatly multiplies its strength, so that it can travel over the circuits that lead to the broadcast transmitter.

So complex, so intricate, and so delicate are these sensitive "eyes" that the assembly of the more than 200 parts requires the precision of a watchmaker. For example, one tiny part is a polished piece of nickel about the size of a dime with a hole .0005 of an inch in diameter—one tenth the thickness of a hair. Another element is a small copper mesh with 250,000 holes to a square inch, which means that more area is devoted to holes than to the material that holds it together.

"When you put all of these tube elements together and make each work in harmony," said an engineer, "you have a device which I really believe would tax the ability of the best of watchmakers in their task of keeping up with time!

"So you see, television is not merely transmitting and receiving a picture. When you get behind the scenes of research and manufacturing into the intricacies of the art, and study the wonders of science coupled with the craftsmanship of production, you begin to realize what a wondrous development television is and how it has challenged the ingenuity of man—not only to make it work, but to put it into quality mass production in the factory and into practical service in the home."



A giant 300-kilowatt transmitter is employed in the final test of power tubes used for broadcasting.

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Courtesy of Harry Moore