RADIO'S LIVEST MAGAZINE

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OVER 175 ILLUSTRATIONS

Radio-Craft

HUGO GERNSBACK EDITOR

December

25 Cents
in United States
and Canada

A NEW
TELEVISION TUBE
IS BORN!
See Page 335

Radio's Golden Jubilee!—Radio Circuits Analyzed—Fun with Radio Parts
Army Plane Lands Without Pilot!—4-Tube Set for "Advanced Beginners"

OVER 50,000 RADIO MEN READ RADIO-CRAFT MONTHLY

TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

Mr. Sanabria—the man who, in 1931, demonstrated 10-ft.-square television images in Loew's State Theatre, New York City!—tells you how the problem of "school-built" television C.-R. tubes is being solved.

PART I

U. A. SANABRIA

Fig. A. Completed 7-in. television C.-R. tube.

A SPECIAL-GLASS "blank," hydrofluoric acid, callux fluorescent powder, ammonium borate binder, high-pressure washer set-up, aspirator, and a drying oven: with these on hand we are "all set" to take the first step in making a laboratory model of television tube!

It is important that a man studying television learn the behavior of a tube from his actual experiments. *Commercial types intended as oscilloscopes do not permit the proper study of characteristics of television tubes;* for instance, in video service, ordinary oscilloscope tubes exhibit bad defocusing of the spot with modulation.

"SCHOOL-BUILT" 'VISION TUBE

As a result of having recently engaged in development work on cathode-ray tubes I came to the conclusion that we here at "A.T.I." could manufacture a big television-receiver tube having desirable characteristics for the money we pay for a commercial tube having undesirable characteries; these "school-built" tubes then would be more suitable for inclusion in the regular home equipment supplied to students taking the television course. Results were so promising that we plan shortly to inaugurate development of the iconoscope or television pick-up type of cathode-ray tube; also with a view to including this in the home equipment.

Some sizes of C.-R. tubes used for television reception in addition to other faults do not permit very satisfactory study of the nature of cathode rays. However by the application of a little ingenuity we found that it is possible to produce a C.-R. tube at very low cost that rivals in efficiency commercial types that sell for about $100. (See Fig. A.) The manner in which a satisfactory 7-in. cathode-ray television receiving tube was developed after numerous experiments, makes a multi-part story that I feel will interest every television enthusiast and dyed-in-the-wool experimenter.

The first problem was to obtain a suitable glass *envelope* or bulb. This problem was quickly solved when it was found that envelopes of suitable size were available in small quantities from a Corning, N. Y., glass works; pyrex glass was found to be the best grade for our purpose.

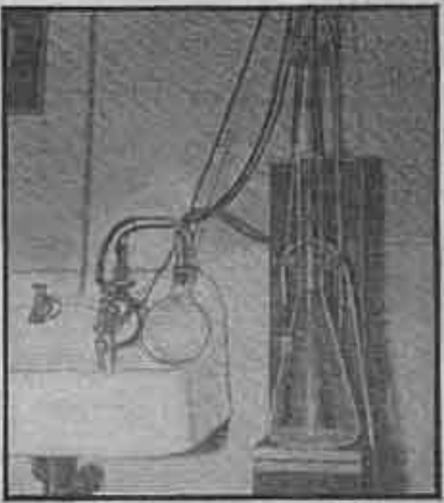

Fig. B. Aspirator sucks water off screen.

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TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

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HOW—AND *WHY*—THE FLUORESCENT SCREEN LUMINESCES

Our next problem was to obtain on the comparatively flat end of the bulb a suitable *fluorescent screen* which would serve as an "image resolution" material or "transducer," that is, converter of electrical energy into some other form of energy—in this instance, light. (In the iconoscope the reverse action takes place.) In the 100 per cent cathode-ray system of television the complete process involves (1) the conversion of light impulses into electrical impulses, (2) the amplification and transmission of these electrical impulses to a distance, and, (3) the amplification and re-conversion of these electrical impulses at the receiver back into light again. In operations 1 and 3 a fluorescent screen is the medium through which the energy is "transduced" or changed from its form as light into electricity and back into light again.

Fluorescent materials depend upon a certain amount of impurity content within the molecules of the substance. When the substances are highly pure they will not appear to fluoresce (or "glow" with a "cold light") when bombarded by electrons. *Fluorescence appears to be a resonance property of the atoms of materials which resonate at the frequency of the light emitted when bombarded by the little electronic particles similar to the manner in which a bell rings when struck by a bullet.*

A fluorescent material called *callux*, readily obtained from a firm in New Jersey, exhibited greater efficiency than any other fluorescent material we were able to obtain.

Since only the crystals that are struck by the electrons *luminesce* ("give off light") a screen thicker than 1 crystal will only obstruct the light. The matter of obtaining on the end of the bulb a smooth, very thin and even layer involved many experiments; and 3 major steps prior to *fusing the screen.*

WASHING THE C.-R. ENVELOPE "CHEMICALLY CLEAN"

(1) A long-necked water faucet with a nozzle turned upside down was arranged over a sink like any bottle washer. Thus a high-pressure water stream was available for washing the inside of the glass flask.

We found that we had to clean the flask with *hydrofluoric acid* in order to wash away any foreign materials inside of the glass bulb. Then we placed the bulb on the high-pressure washer for several minutes to wash out the acid. After that we washed the bulb with a small quantity of distilled water until the water would run out of the flask so perfectly smooth and evenly as to leave no marks whatsoever when it dried out, that is, the water did not run down the glass in streaks, but altogether.

(2) The glass envelope or *blank* then was ready for the next step—that of placing on the inside-end of the blank or flask, the fluorescent powder mixed with a *binder* which would hold the fluorescent material in place until the subsequent fusing process was completed, and which would at the same time readily give up its gas and vapor content so that, like an X-ray tube, the cathode-ray tube could be completely evacuated and made free of any trace of gas.

Ammonium borate proved best, as a binder, providing the proper proportions were used. We finally found that 5 parts of fluorescent material to 3 parts ammonium borate in 750 parts of water made the best combination. We also found that we could make nearly any temporary binder work reasonably well if we handled it with care.

(3) Four radiant heaters were placed around the top of the bulb and on the sides, while the bottom was allowed to sit on a piece of asbestos. Then the entire device was surrounded with a sheet of metal and the temperature within this *drying oven* was maintained slightly below the boiling point of water. Since glass conducts heat very poorly, the moisture would pass out of the tube leaving it completely dry without the bottom of the glass becoming very warm. Thereafter when the bottom of the glass became very warm, the tube was already dry and free of water vapor.

After settling a very even deposit on the bottom of the tube and, by using an *aspirator* (Fig. B),

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TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

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drying it out successfully, our next task was to make it adhere permanently to the glass. This operation of *fusing* the screen material to the glass is taken up in Part II.

Well, that's about enough for one "lesson," isn't it? It's taken quite a bit of time to tell just this portion—obtaining the envelope, and preparing the fluorescent screen—of the story about "homespun" C.-R. television tubes; however, it's been lots more fun, and it's taken lots longer to acquire the "hard way"—by trial and, too often, failure—the information given here. Are you interested in this story? Or would you rather have an article on how to make an X-tube bloop-a-dyne receiver? Letters, pro and con, may be addressed to the writer in care of *Radio-Craft*.

This article has been prepared from data supplied by courtesy of American Television Institute.

TELEVISION STUDENTS
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CATHODE-RAY TUBES

This description of steps in making a practical television receiving tube experimentally in a school laboratory is believed to be the first newsstand-magazine disclosure.

Fig. D. With screen fused-in, tube is cooled by *slowly* reducing flames.

U. A. SANABRIA

PART II

A BLOWTORCH plays a red-hot flame on the end of a slowly-rotating glass tube—the glass slowly softens—soon a glazed porcelain appearance is obtained and, presto!, the step is finished! A television cathode-ray tube has taken a second step toward completion!

Last month we told you what materials to use for the screen, how the screen fluoresces, how the tube "blank" was obtained, and the preparations necessary prior to the operation, next to be described, of fusing the screen.

FUSING THE SCREEN

We found it best to put the flask on a horizontal rotating machine and apply to it a large blowtorch of the oxy-acetylene type but employing ordinary illuminating gas and oxygen (in order to obtain a large, low-temperature flame), so as to heat the glass to the softening temperature. See Fig. C.

This method worked very well and permitted the glass to get soft while spinning. This allowed the glass to maintain its shape and still become warm enough to be soft and yet not sag. If however the glass was heated too hot so as to melt, it would run and spin away from the center toward the outside and spoil the flask by making it too thin; while at the same time cracking the screen and leaving large streaks. *It was therefore necessary to apply exactly the right amount of heat and spin the bulb* slowly.

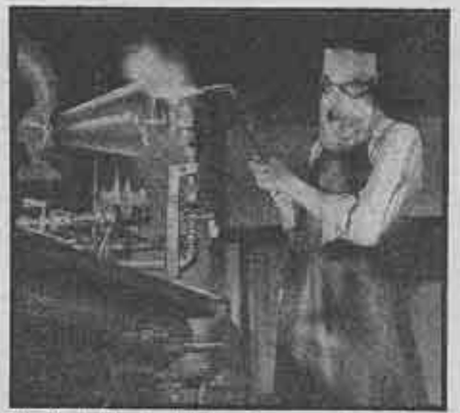

Fig. C. A blowtorch helps fuse screen to slowly-revolving television-tube envelope; while gas flames from all sides maintain glass at even heat. It is this operation which the cover painting depicts in colors.

We were then able to prolong the heating to several minutes. We soon found that it was best to apply a very slight air pressure inside of the spinning vessel through a rubber tube connected to the operator's mouth to press the crust of screen material against the soft glass at the end of the bulb with a gentle enough pressure to make a just-visible distortion and rounding-out of the glass.

After the screen was completely fused with glass, the temperature was gradually reduced over a period of several minutes while the bulb was spinning. This was to allow the partially-soft glass to gradually readjust itself to any new distortions so that, upon complete cooling, all bulb strains would be removed. See Fig. D.

You can readily appreciate that if one part cools and contracts and another part on the opposite side cools and contracts, that a strain will exist between the two parts tending to pull the glass between them toward each other. If this glass is heated warm enough to be bend-

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able and flexible, it will straighten out and adjust itself as it cools down, provided it is allowed to cool slowly. The glass contracts slowly as the temperature falls so it must be allowed to stretch evenly until it solidifies to where it will not stretch any longer. If it continues to cool and the extreme portions of the bulb are very rigid, then the glass will crack because of the tremendous force exerted by the shrinking, therefore, *it is of the utmost importance to soften the entire vicinity of the bulb where the glass is being "worked,"* and then VERY SLOWLY reduce the heat from this "flexible" temperature to that of completely-cold glass.

This process is called *annealing*. The thicker the glass is, the more slowly it must be raised and lowered in temperature. Considerable experience is required to properly handle the heating and "working" of glass vessels.

FINAL INSPECTION OF SCREEN

When the bulb is removed from the spinning machine, the end is examined. We found that this should show a glazed-porcelain appearance where the crust comes in contact with the glass.

If it has the usual white appearance of the screen material, it shows that the material has not fused itself to the glass. If any spots are white, it means that those spots have not adhered to the glass, and the bulb must be again raised in temperature and the flame blown against the soft glass once more. After a little practice, we were able to get the screen properly adhered every time.

The bulb is next placed over a high-pressure washer where the excess screen material is washed off *leaving just a screen 1 crystal thick and very even!* Such a screen has the highest luminous efficiency.

Part III will continue this interesting discussion.

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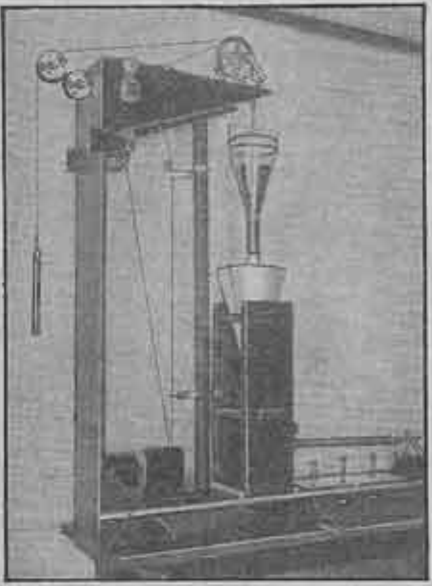

Fig. F. The complicated-looking (but simple) laboratory set-up for applying the internal graphite coating to the cathode-ray tube blank.

U. A. SANABRIA

PART III

LAST MONTH WE DESCRIBED the mechanics of fusing the fluorescent screen to the glass of the cathode-ray tube. Now let's continue with the story.

After the screen is properly coated upon the inner-glass surface, the next step is to provide a thin graphite coating over the conical inner-surface.

THE GRAPHITE FUNNEL

The purpose of this graphite coating is to act as a *focusing electrode* in the cathode-ray tube and as a means of discharging the accumulated electrons on the surface of the screen. The electron beam would otherwise store, after a few seconds, so large an accumulation of electrons on the screen surface, that the beam thereafter would be repelled from striking the screen at all. The graphite coating is normally deposited in the position shown in Fig. E.

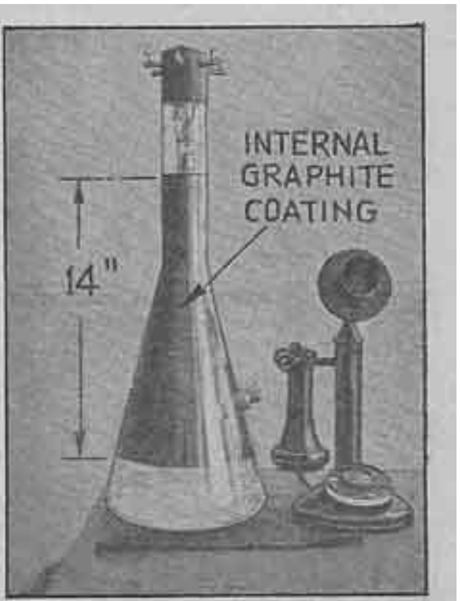

Fig. E. The telephone affords an excellent idea of the size of the completed C.-R. tube. Note the extent and position of the internal graphite coating.

It almost touches the screen, but is not actually connected to it. It also runs down the entire sloping surface and partway down the neck. It must be smooth and have a sharp, even edge. The graphite coating must be thick enough to provide a uniform electrical conductor or metallic funnel distributed throughout the entire inner surface with the exception of the screen front

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(Continued from page 403)

and the lower neck. The graphite is obtained in colloidal form (that is, fine particles of graphite suspended in water) and is known commercially as "Aquadag."

In cathode-ray tube manufacture, aquadag is usually mixed with two or three times its volume of distilled water and the resulting solution carefully worked and agitated to effect a homogeneous dispersion of the graphite. In simpler words, there must be no lumps, no matter how small, in the solution.

Numerous methods for applying the graphite coating were tried until the ultimate one, to be described, was evolved. Although these experiments were numerous, time-consuming and ofttimes disastrous to our clothes, we obtained a considerable amount of valuable information from them.

HEATING THE AIR INSIDE THE C.-R. TUBE

We found, for instance, that the air inside the cathode-ray tube had to be heated before the graphite would adhere to the sides of the tube. Experimentation with the proper method for heating this air eventually resulted in the method shown diagrammatically in Fig. 1, and photographically in Fig. F.

The early experiments were so disappointing that at one time we were almost tempted to use an internal coating of metal like potassium and magnesium instead of graphite. These metals, however, have a tendency of combining only with the active gases which remain in a tube after it is evacuated and not with the inert gases which, therefore, tend to reduce the high vacuum necessary for proper operation of the cathode-ray tube.

Graphite, on the other hand, possesses the highly desirable power of *adsorption*; that is, it has an affinity for all types of gas molecules, which adhere to its surface but do not combine with the graphite chemically. Thus, any gases remaining in the tube after evacuation are adsorbed by the graphite, thereby maintaining the high vacuum within the tube.

With this and other points in its favor, we determined to find a solution for the method of applying the graphite coating. Figure F shows the apparatus which we used and with which we were finally successful.

APPLYING THE GRAPHITE

As shown (diagrammatically in Fig. 1), the aquadag solution is contained in a metal funnel, through the center of which extend 2 concentric glass tubes, one being the hot-air intake and the other the exhaust tube. Then we lowered the cathode-ray "blank" into the liquid by means of the pulley system shown. It was necessary to place a fingered guide over the exhaust tube since otherwise the cathode-ray blank would be apt to lean to one side or the other and not become evenly coated on the inside of the narrow neck. Of course the outside of the bulb became coated, too, and had to be washed. Each bulb required 2 or 3 coatings.

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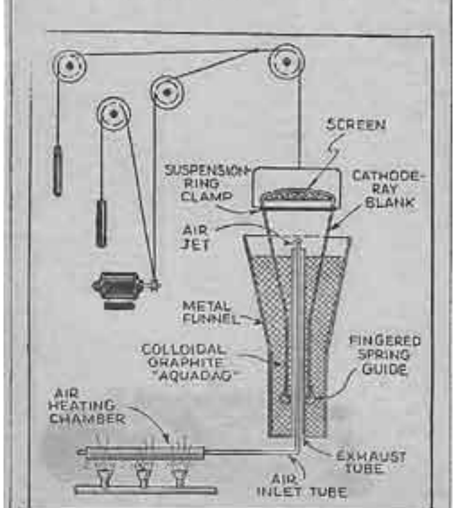

Fig. 1. Diagrammatic view of the set-up for graphite-coating the inner surface of the tube.

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A time-driven device to slowly raise the blank out of the aquadag was necessary to insure a uniform coating. A series of pulleys and a motor with a speed reducer were used in combination with a string and weight. A switch attached to the string was employed to automatically shut off the motor at the proper time.

Making an electrical contact through the glass wall of the vessel was another problem, since a large surface and a good contact were necessary for the thin coating of graphite. A piece of platinum foil fastened to a little tungsten and nickel hook was employed. When the glass was heated and the platinum pressed against it, it adhered to the "wet" glass. Since the platinum was so thin, it did not have strength enough to crack the glass due to the different coefficients of expansion between the pyrex glass and the platinum. This operation, naturally, had to be done before the graphite coating was applied.

In a cathode-ray tube, any 2 electrodes of different size with a difference of potential between them act as focusing electrodes. It is possible with certain types of electron guns to make the last electrode in the gun the same potential as the aquadag coating, with the result that the aquadag produces a negative focusing effect, and in that case, would act as a means of discharging the accumulated electrons. The aquadag coating may be used as a focusing electrode discharger or as a discharger only, depending upon its relation to the other gun design and assembly, and the potentials thereon. *In our cathode-ray tube, it is used as a combination discharger and focusing electrode.*

Part IV will continue this enlightening discussion with details on the design of the "electron gun" of the cathode-ray tube.

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PART IV

U. A. SANABRIA

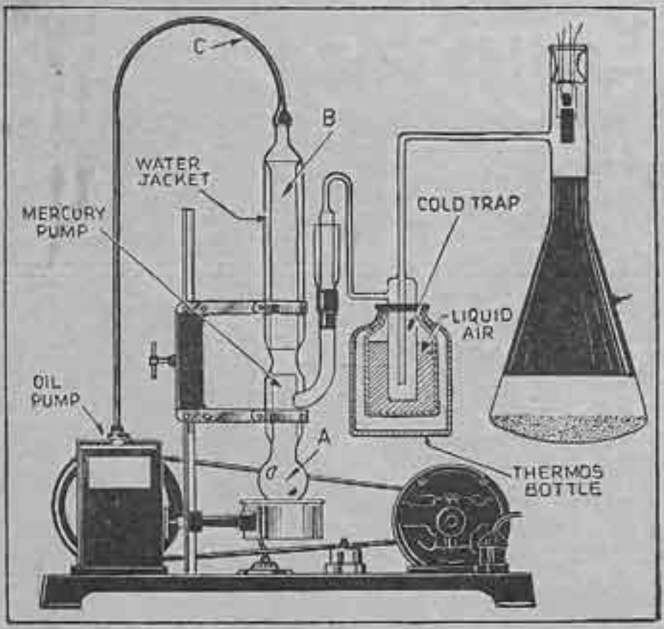

Fig. 2. The set-up used to evacuate the cathode-ray tube. An oil pump, mercury pump, electric heater, and cold trap are utilized.

IN THE PRECEDING installments we described the mechanics of fusing the fluorescent screen to the inside surface of our cathode-ray tube as well as applying an internal graphite coating. We now come to the description of the *electron gun* construction as well as the procedure for evacuating the tube.

(The final design of the electron gun will be discussed in another installment. The one described here is one of many designs with which we experimented before evolving the final one.)

CONSTRUCTION OF THE ELECTRON GUN

A *nickel sleeve* is tipped with a mixture of *barium* and *strontium carbonate* (made by a well-known chemical firm and called "Radio Mixture No. 1"). *Amylacetate* is used as a *binder* material together with a very small amount of *collodion.*

Only the end of this cylinder, which is short, is coated with this mixture. When the sleeve is heated to a bright red heat the mixture combines with the nickel to form what is known as an *oxide filament.* This combination constitutes a very copious emitter of electrons and is far better for this purpose than either tungsten or thoriated tungsten.

In the center of this sleeve is placed a tungsten heater element (A, in Fig. 3). The tungsten heater is the filament which heats up the nickel sleeve (B) or cathode. Over this

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TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

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cathode now is placed another cylinder (C), the end of which has a hole which is smaller than the emitter-end of the cathode. Again, in front of this second cylinder is placed the first anode (D) which has a hole in its center smaller than that in the second cylinder. The other electrode is of course the graphite coating (described in a preceding installment) on the inside surface of the tube.

It is very important that the holes in these electrodes be properly aligned with respect to the cathode if any suitable spot of good intensity is to be obtained upon completion of the tube. Furthermore, unless the electrodes are very rigidly mounted they will be warped out of alignment during the subsequent "bombarding" procedure in the process of evacuation later on. The insulating material used to properly align the electrodes and hold them firmly in place is *isolantite*. Although this material has considerable gas combined in its structure it was found that, by prolonging the heating process when degassing the tube later on, all gas could be driven off. Glass supports are used wherever possible and the design of the electrodes so arranged that the metal wires require a minimum amount of insulating structural material to help keep the parts of the gun in line.

EVACUATING THE TUBE

We found that the cathode-ray tube had to be exhausted more carefully than nearly any other tube with which we ever worked. The magnitude of this problem was surprising.

The metals comprising the electron gun had to be heated close to their melting point if they were to be made to give up their gases readily. The same was true of the gas envelope as well as the insulating material supporting the structure of the gun. The process required simultaneous sustained heating and pumping; and the use of mercury vapor and liquid air to remove all traces of air and other gases. The entire set-up is shown diagrammatically in Fig. 2.

The evacuating system, which after considerable experimentation we found to be suitable, consists of an *oil pump* "in series" with a mercury-vapor pump or *aspirator* as it is called. The operation of the system is as follows:

The oil pump, by means of suction, draws as much air as possible out of the cathode-ray tube. Yet, by its best possible action, it cannot create a vacuum sufficiently good for television work. Therefore, to aid the oil pump the mercury aspirator is used. *Both pumps work simultaneously.*

The mercury (which in its natural state is a liquid metal) in chamber A (Fig. 2) is heated by an *electric heater* until it boils-off into a vapor. The mercury molecules in their gaseous state are in a state of vigorous vibration due to the heat which they have absorbed from the electric heater. By virtue of their intense vibration, they collide with the air molecules, carrying them along up towards the *suction tube* (C) of the oil pump.

As both gases (mercury vapor and air) ri into chamber B, the mercury vapor is condensed by means of the cold water circulatin in the *water jacket*. The air molecules, howeve due to the tremendous momentum, imparted them by the action of the mercury vapor mol cules, are carried up into the suction tube the oil pump and hence removed from th system—and from the cathode-ray tube.

The overall effect of the mercury aspirato therefore, is to aid the work of the oil pump b increasing the velocity of the air molecule thereby permitting a more complete evacuatio of the cathode-ray tube.

THE LIQUID AIR "COLD-TRAP"

During the operation of the mercury aspirato it is inevitable that some of the mercury vapo should "kick back" or diffuse through the syste and eventually find their way into the cathode ray tube . . . unless it is caught in some manne To prevent such a condition, a *cold-trap* i incorporated in the set-up to ensnare the mercury vapor by condensing it into liquid form The cooling medium used for this purpose i *liquid air*.

THE HIGH-FREQUENCY OVEN

While this pump action is in progress, bot the glass envelope of the cathode-ray and th electron gun are being heated to close to thei respective melting points, the object being t drive off any gas which may be imbedded i their structures. While it is easy enough t heat the tube by means of a flame, the problem of heating the internal metals constituting th electron gun was solved by using *high-frequenc currents*.

A coil of wire carrying these currents i placed around the neck of the tube immediatel surrounding the electron gun. Due to eddy currents and hysteresis in the metal, they becom heated. All gases thus liberated are drawn of by the vacuum pumps.

After the tube had been pumped for the fir half-hour, the filament (and hence the cathode) was heated, both giving off large volumes o gas. The barium and strontium carbonat together with the binding material also give o large quantities of gas, specifically *carbo dioxide*.

After another half-hour, the first cylinder wa charged with a small positive potential so tha electrons emitted by the cathode were attracte to it, developing a thermionic or electron current The positive potential on this electrode wa gradually increased until the filament curren started to show an increase without furthe increasing the positive potential on the anode It was then allowed to remain at this potentia until no further increase in current was evident over a period of several minutes.

The next cylinder or *anode* was then charge positively and a stream of cathode-rays projected on the screen, yielding a bright gree fluorescent spot. At this stage, the walls of glass rapidly collected a negative charge which was disbursed by charging the graphite coating with a positive potential. Continued bombardment of the screen freed additional gas which was drained by the pumping system. After several hours, all trace of gas disappeared, *even when the anode voltages were raised to several thousand volts.*

FOCUSING THE CATHODE RAYS

We then proceeded to investigate how we could *focus* these cathode rays and vary their intensity.

It was apparent that here we had a tool which was similar to the combination of a (1) "projection system," (2) "scanning system," and (3) "light valve," speaking in mechanical-television language. We could place a *focusing magnetic coil* in front of the electron gun and focus the divergent stream of electrons down to a point, or by raising the potential of the aquadag coating over that of the first anode, we could also focus the cathode ray to a point. We could deflect the electron stream considerably with either the smallest *magnetic* force held near it, or an *electrostatic* charge.

From this point on, it then remained for us to increase the intensity of the cathode ray, and to vary the intensity of the spot without varying the spot size and also, to learn the factors governing the size of the aperture, and cathode, and the ratio of these various sizes, distances and potentials.

How we obtained the desired results, and the type of gun finally decided upon (which is practically identical in *function* with a good optical projection system), will be the subject of our next article.

This article has been prepared from data supplied by courtesy of American Television Institute.

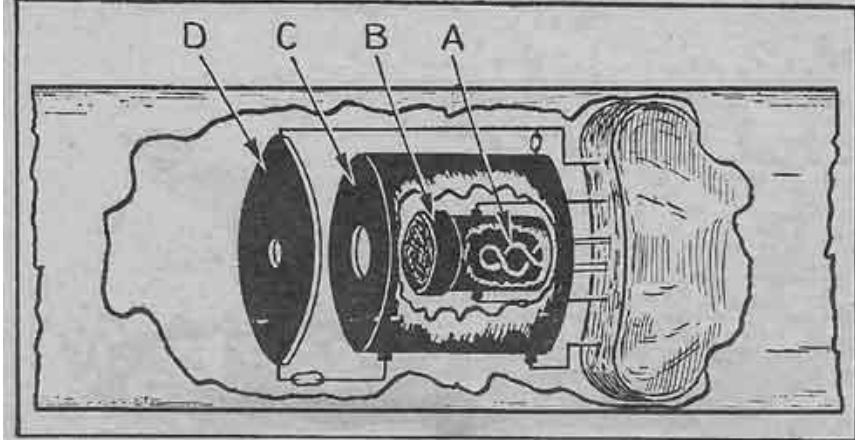

Fig. 3. Showing construction of the electron "gun". A is the tungsten filament; B is the electron emitter; C and D, focusing electrodes. The graphite coating (see text) is also an electrode.

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TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

PART V

U. A. SANABRIA

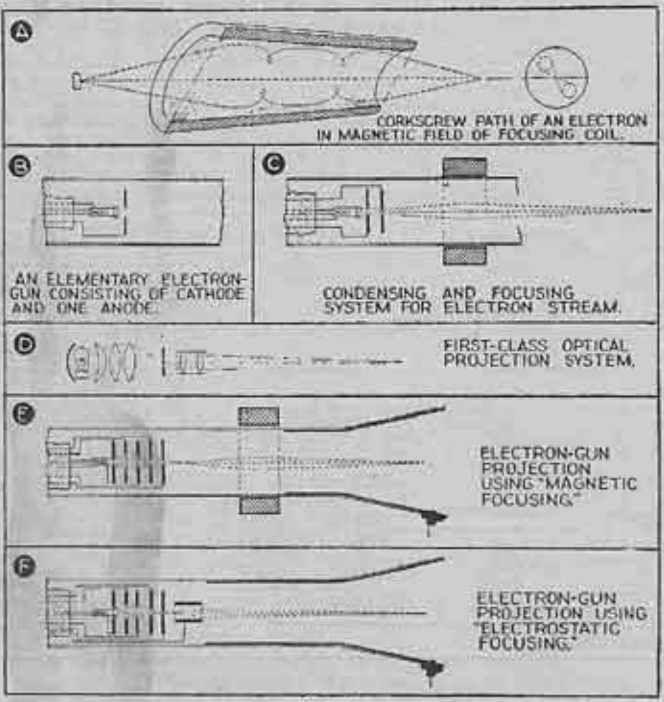

Fig. 4.

LAST month we described our early experiments on the construction of the electron gun and the process for the evacuation of the cathode-ray tube. This month we continue with our experiments with an improved type of gun.

The design of the electron gun was not a pleasant type of task, because the elements were not adjustable during experimentation due to the fact that the elements of the gun were inside of a vacuum tube where they could not be physically reached for adjustment. An ordinary light optical system using lenses can be set up on an optical bench, and the best conditions can be readily found. When the electron optical system is inside an evacuated vessel, obstacles in experimenting occur. *For example, you can readily see that a shift of a few thousandths of an inch for one of the electrodes will produce the desired results; yet, you are unable to change the position of an element without rebuilding the whole tube.*

Since every part of the tube affects the operation of all the other parts in final performance, it is sometimes difficult to locate the exact source of trouble. At first, this has to be accomplished with a combination of intuition and plodding isolation. It did not take long to find that it was much better to make every part so good in the first place that trouble was unlikely to occur with the exception of those points where you were making your investigations. Learning dimensions and adjustments in cathode-ray tubes consists of making a number of them having different adjustments while taking great care to keep other parts constant in dimensions

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TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

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and performance. *(While it would be ideal to have adjustable elements in the electron gun, no good solution which can be joined with present vacuum technique has been forthcoming.)*

ELECTRON EMISSION

Our experiments on obtaining the most suitable electron emitter included a simple, pure-nickel filament coated with *barium* and *strontium carbonate* mixture. This coating was applied with a spray or by dipping in a solution. The solution consisted of 90 parts *amyl acetate* and 10 parts of *collodion* with enough powder to form a fast-drying "white paint." When the coating was thick and pebbly, like the snow on a refrigerator pipe, the best results were obtained. If the coating was too thin, which we found was recommended by some workers, it would wear away in spots very quickly when in use; on the other hand, if the coating was too thick, it would chip off during formation when first heated up. We were unable to measure the thickness of a good coating and simply resorted to using 3 spray coatings with a uniform mixture, letting the coating dry between each coat. The thickness of the coating affected the life more than the original emission. Very thin coatings emitted as well as the thick ones during the first few hours. (Emission, in this case, means the current between cathode and plate.)

We found no difference in performance between the direct-heater type of coated filament and the indirect type (described in the preceding installment), but the heater-type emitter was far more durable and less subject to burn-out. The emitter end was flat while in the case of the direct-heater filament, the shape was not quite so satisfactory. The heater type also has the advantage of having a smaller alternating current magnetic field to distort the cathode ray or electrons leaving the surface. When electrons move from the surface of the heated filament toward a positively-charged anode and move through a magnetic field, they will follow the 3-fingered "motor rule" for the motion of a conductor passing a current through a magnetic field (only, of course, using the right hand for electron direction instead of the left). If the magnetic field is properly shaped, the electrons will describe a cork-screw type of path and converge at one point called the *focus*, provided the magnetic field encircles the electron beam coaxially as shown in Fig. 4A. Here, the electron assumes a path of least work and any work done by it is returned to the system. That is, the magnetic field simply alters the motion of the electron, and both the magnetic field and the electron work so that no energy is taken away from either the moving electron or the magnetic field in order to bring about the focusing action. The electron spirals around any line of force which it approaches at an angle when it enters the magnetic field and continues to show this corkscrew motion through it. When it leaves the magnetic field, it travels in a straight path like a ball thrown from a whirling wheel. Obviously, if the magnetic field is not adjusted so as to focus all of the electrons at one point in their corkscrew motion, then, several sections of the corkscrew will be visible on the screen as shown beyond the focus point.

Thus, a magnetic coil may be used to focus the electron stream, but any stray magnetic field not properly shaped will distort the path of the electrons, and if an alternating current through the heater cathode element is permitted to develop a magnetic field it will distort the path of the electrons at the start. A directly-heated filament is more difficult to properly design than the heater type so that the magnetic field does not interfere with the electron path. We were, therefore, very pleased to observe that we obtained as much emission from the heater-type emitter as from the directly-heated type of filament.

FORMING THE FILAMENT (EMITTER)

The process of "forming the filament," is important. The gas must be totally exhausted from the vessel as well as possible before forming is started. When the emitter is formed, it is brought up to a temperature higher than normal and then a potential difference of 20 volts is applied between the emitter and the nearest anode which is, of course, charged positively to develop a small electron current. This electron current increases steadily starting from zero, and chemical combination between the mixture and the nickel appears to take place. If any gas is present in the tube, or the voltage is raised high enough to ionize the small remaining gas which is usually present until the pumping operation has been entirely completed, then, the positive molecules will bombard the filament surface and tear away large pieces of the emitter materials.

The life of the filament is greatly reduced and affected if this is permitted. The longest life can be obtained by forming the filament at low potentials and with an absence of gas according to our brief and incomplete observations. However, these same cathodes, once well formed, can emit powerful electronic currents in the presence of gas up to 20 millimeters or more in pressure and such emitters are used in our powerful *glow-discharge lamps*. The filament is most badly taxed when the gas is at those extremely low pressures which are low enough to permit cathode rays to be formed and still high enough to form a "glow discharge" where the velocity of the positive molecules is very high. Therefore, small traces of gas in a cathode-ray tube shorten the filament life tremendously.

TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

This Part concludes the series of articles—published here for the first time in any popular radio magazine—on constructing experimental C.-R. tubes for television.

U. A. SANABRIA

PART VI

IN preceding installments we described the construction of the electron gun and various tests applied regarding the brilliancy of the cathode-ray "spot" and methods of focusing same. We found that the spot could be focussed fine enough for television purposes and that the intensity of the beam could be varied to give sufficient contrast for a television picture without changing the focus appreciably. We now approach the final test (which will conclude this series of articles), namely, that of obtaining an elementary trace on the screen. If a satisfactory trace is obtained then we know that the tube will be suitable for television purposes.

OBTAINING HORIZONTAL BEAM-SWEEP

First, we must have a horizontal sweep circuit which will swing the spot of light from one end of the tube to the other and back again.

The first circuit with which we experimented was that shown in Fig. 5. The glow lamp, G, had a striking potential of 150 volts. That is, when the potential between the electrodes becomes strong enough to ionize the gas within the tube, an arc would form between the electrodes and current would continue to flow until the voltage dropped to such a value that ionization within the tube ceased and the arc

(Continued on page 757)

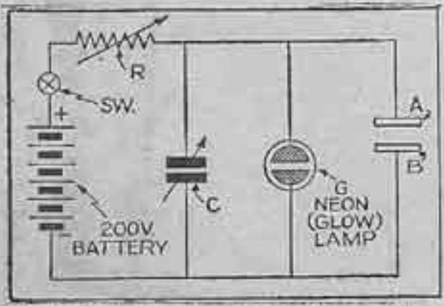
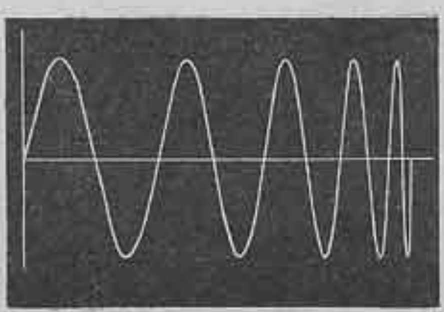


Fig. 5. The horizontal sweep circuit first used to test the C.-R. tube. Condenser C charges up to 150V. and then discharges through the neon tube.



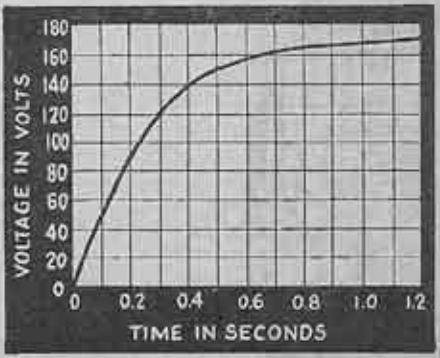


Fig. 6. Above—trace of the familiar sine wave, using the horizontal sweep circuit diagrammed at left. Fig. 7. Right—voltage build-up of C in Fig. 5.

TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

(Continued from page 759)

bias, however, must not be reduced too much or a constant flow of current will no longer exist.

The frequency of the sweep circuit is further dependent upon the grid bias of the 58, the output voltage of the power pack across the circuit, the grid bias of the thyratron, and the capacity of the charging condenser.

Figure 9A shows the waveform set up by a sweep circuit such as produced by the combination shown in Fig. 5. Figure 9B shows the waveform produced by a circuit using a constant-current device. Notice how the upper parts of the waveforms in Fig. 9A depart from true linearity and curve to the right. The waveforms of Fig. 9B show desired linear or sawtooth waveform.

The deflector plates charge up and deflect the electron beam with the rise in voltage developed by the sweep circuit. When the gas in the thyratron or glow discharge tube arcs, the output of the sweep circuit is discharged very rapidly which in turn produces a very rapid voltage decrease across the deflector plates and the beam is very rapidly returned to its starting point as shown by the steepness of the discharge part of the waveforms shown in Fig. 9. The speed with which this discharge takes place determines the rate at which the electron beam will snap back to the starting point, and hence, determines whether this return-trace is made with sufficient rapidity to prevent it registering on the screen sufficiently long to come within the observer's persistence-of-vision response.

This concludes our series of practical articles on how the *television-type* cathode-ray tube is made. Schools or individuals wishing to obtain back copies may secure them, for a limited time, at the regular price per issue. No radio man who has read this series of highly informative articles—believed to be the first in any popular radio magazine—need be stumped by any questions concerning the bases of cathode-ray tube design and construction as they apply to television.

This article has been prepared from data supplied by courtesy of American Television Institute.

TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

(Continued from page 757)

charged to a value equal to that of the source. Due to the rapid rise in voltage during the first few instances, the beam would move rapidly from left to right across the first few divisions on the screen. As the rise in voltage becomes less, we find that the rate with which the beam is moving to the right is likewise becoming less, until between 1.0 and 1.1 seconds there is practically no movement of the beam to the right.

While this sweep variation is sufficient, to a certain degree, for wave analysis its non-linearity would make it completely useless for television. Hence, it was necessary to devise a circuit which would give a *linear* variation. The striking potential of the neon glow lamp being comparatively constant caused the deflection of the beam to traverse only a limited, definite distance across the tube. It was desirable, therefore, to have in addition to linear sweep a means for varying the deflection of the beam *completely across the screen.*

THYRATRON OR "GRID GLOW" SWEEP

A *thyratron* or, as it is more popularly known, "grid glow," tube, was employed, at first without an amplifier, in an effort to accomplish linear and complete sweep. The thyratron is similar in operation to the above-mentioned neon tube, but in addition to the latter it has a grid. By changing the bias on the grid, the striking potential between the cathode and the plate is likewise changed. This made it possible to more closely approach linearity as we were then able to cause the thyratron to strike at a lower voltage on the curve in Fig. 7.

However, operating on this lower voltage reduced the total deflection of the beam considerably and it was necessary to amplify this signal with a stage of amplification. (True linearity cannot be attained unless the rate of the charging current remains constant.) We had achieved linearity but lacked sufficient width of sweep.

It was necessary, therefore, to develop a horizontal sweep circuit which would produce a constant current flowing into the condenser even though the voltage across the system was varying. See Fig. 8. A type 58 vacuum tube was used since it was capable of producing only little variation in plate current for wide voltage variations on the plate.

The rate with which the current flows into condenser C (Fig. 8) can be controlled by varying the grid bias on the 58 tube. The negative

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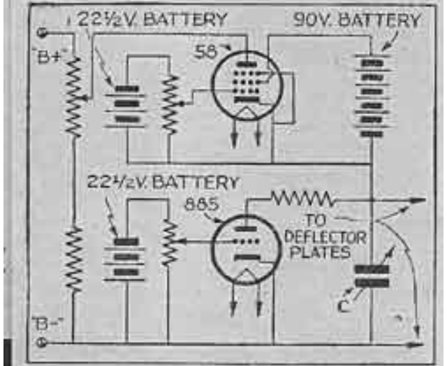

Fig. 8. The horizontal sweep circuit used.

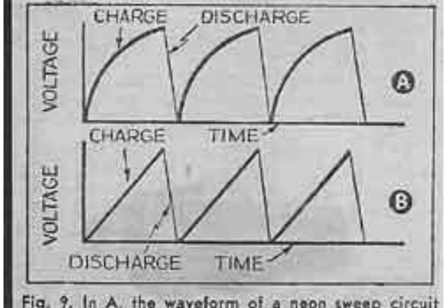

Fig. 9. In A, the waveform of a neon sweep circuit and in B, that of a constant-current sweep circuit.

TELEVISION STUDENTS LEARN BY MAKING CATHODE-RAY TUBES

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would disappear. Therefore, with this in mind, let us proceed to analyze the operation of the circuit shown in Fig. 5.

THE "HOW" OF NEON OSCILLATORS

As switch S is closed, placing 200 volts across the circuit, current starts to flow through resistor R into condenser C in its attempt to charge condenser C to the same potential as the battery. However, when condenser C has charged up to 150 volts, the gas in the glow lamp, G, becomes sufficiently ionized and an arc forms within the tube; which acts essentially the same as placing a short circuit across C causing discharge.

If we couple the variations of voltage across C to the deflector plates of our cathode-ray tube, we will then have a simple method of causing the electron beam to be deflected, because as C is charged, deflector plate B of the cathode-ray tube becomes more negatively charged with electrons with the result that these electrons in turn repel the electrons of the electron beam away from them. The electron beam is repelled more and more as the voltage across C increases until the arc forms in the neon glow lamp, discharging the condenser and likewise relieving the stress across the deflector plates and thereby allowing the electron beam to return to its original position.

As the resistor, R, is varied, it varies the charging rate or amount of current flowing into the condenser. In other words, when the value of R is high, only a small amount of current can flow into C, and consequently, it takes a comparatively long time for the condenser to charge up to a voltage sufficient to cause the neon bulb to strike. As the resistance is lowered, more current can flow into the condenser, and thereby, charge it faster.

SOURCE OF DEFLECTION VOLTAGE

The neon bulb continues to discharge C until the voltage drops to 60 volts (for this particular glow lamp) where the stress across the electrodes is no longer sufficient to maintain ionization of the gas. When ionization ceases within the tube, it then becomes a non-conductor and C again starts to charge.

The building up and discharge of condenser C produces a similar build up and discharge of voltage across deflector plates AB at a rate which is dependent upon the rate at which C charges up to the striking potential of the neon glow lamp. This rate can be varied by varying the resistance of R, or by changing the capacity of C. That is, the smaller we make C, the more rapidly it will charge up.

This, then, gives us 2 methods for varying the rate of frequency with which the electron beam may be caused to sweep across the end of the cathode-ray tube when a sine wave is impressed upon the vertical deflector plate and the resistance in the previously described sweep circuit is adjusted until the beam sweeps across the screen at a rate which produces several complete cycles upon the screen.

NEON SWEEP VOLTAGE IS NON-LINEAR

When a sine wave variation is applied to the vertical deflector plates, the result, however, is that shown in Fig. 6 which clearly shows how the beam is moving at a comparatively rapid and given rate on the left, and decreases in speed as it approaches the right side thereby causing the cycles in that section to become cramped or pushed together. This indicates that the speed with which the electron beam is deflected horizontally across the screen is not constant. This is technically spoken of as *non-linearity* of the sweep circuit. It is a result of the nature with which a condenser charges when placed across a D.C. potential.

CAUSE OF NON-LINEARITY

The voltage rise across the condenser in Fig. 5 is plotted graphically in Fig. 7. Between 0 and 0.2-second, the rise in voltage is very rapid. As the time increases, the rise becomes less and less until between 1.1 and 1.2 seconds there is no further rise in voltage and the condenser is

(Continued on page 759)

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