THE CATHODE RAY TUBE

SESSION I

INTRODUCTION

The primary purpose of any course of instruction is to convey to the participants a better understanding and knowledge of the subject material.

This course is designed to bring a broader "in-depth" understanding of the cathode ray tube. There are many uses of this type of tube, including the camera tube, radar tracking tubes, oscilloscope tubes and X-Ray tubes, as well as the picture tube which we will study.

We must realize, of course, that each component represents a complete theoretical field of study in itself and through the extensive resources of the Company our design and manufacturing engineering personnel are constantly working to improve the quality and design of our product.

Our facility and equipment is custom designed for its specific function and represents one of the finest manufacturing operations of its type. New and better ways are constantly being sought to improve these capabilities.

Instructions are issued which outline the steps necessary to move the product through each phase of the process and which outline the steps necessary to check out and maintain the facilities.

All of which brings us to the purpose of these classes. It takes the human element -- the mind, the hands, the desire -- to implement fully the theory, the facility and the instructions. With relatively few exceptions,an employee comes to work with the desire to do a good job. If we are capable of communicating to him "why" of his job, he will do better. He will not know, however, if we don't tell him.

This course will follow a step-by-step sequence of each component, its purpose and its relationship to all other components. Each component in the tube, no matter how good, is only as good as the poorest component so far as the end product is concerned.

G. F. Miller
4/6/65

SESSION I

DERIVATION OF NAME - CATHODE RAY

The name is derived from the basic principle of the way the device works.

By using a compatible material, nickel is used in the picture tube, a cathode body is formed. The body is tubular, capped at one end, and an electron emitting material is applied over the closed end. When heat is applied indirectly to the cathode body to raise its temperature to the desired level, electrons are released from the emitting material and by subsequent electrode design, a stream or ray of electrons is produced, which can be controlled to perform a variety of functions.

SESSION II

We will now begin individual component identity and purpose.

A. Bulb or Envelope

1. Material

Glass is chosen for the picture tube because of its transparency, mechanical and thermal strength in compression, low vapor pressure, density, ease of cleaning, generally low cost and ease of working.

This glass is in the "soft" or lead glass category which lends itself to rapid flame working capabilities in the production line.

It has approximately ninety-six percent light transmission in its clear state. This transmission can be controlled down to an acceptable contrast level through additives to darken the color without materially affecting the working properties.

Its density is such that it will not readily absorb atmospheric conditions or processing solutions.

It is readily "de-gassed" and has a relatively low vapor pressure.

2. Fabrication

The bulb is made in three pieces.
The face panel is pressed in a mold.
The funnel is spun against a mold.
The neck is drawn tubing.
The face-to-funnel seal is primarily a lathe operation with the actual seal being made by R.F. and flame.

The funnel-to-neck seal is either vertical or horizontal lathe and flame seal. The flare on the neck tubing is normally put on prior to funnel seal on an automatic flare machine.
Mold lubricants are used by the manufacturer to ensure easy release of the formed parts.

3. Processing
The first step in processing the bulb is preparing the inside surface of the glass for subsequent components. The word "wash" or "clean" is generally used. However, the actual process is quite different. A hydrofluoric acid solution is used, normally in the 7 - 12% concentration. This solution is sprayed into the bulb, which is in a face-up position, on a carefully controlled cycle of time and volume, and is immediately rinsed out with de-ionized water.

The hydrofluoric acid will attack the glass and with the controlled cycle, a very fine or monomolecular layer of glass will be removed, thereby removing any contaminants that may be on the inner surfaces.

The bulb is now ready for the screening operation and passes almost immediately to that station. It has been found that any prolonged delay between cleaning and screening can contribute to screen rejects.

B. Phosphor (Screen)

1. The screen of the picture tube is made up of a luminescent material which when excited will radiate during the excitation period.

Phosphor, which in its pure state, is an organic material, a metal, is the basic source of this luminescent material. In order, however, to achieve the exact color desired, it is necessary to introduce impurities with the base material and then to blend two or more of these phorphors.

Zinc sulfide produces the basic blue and cadmium sulfide the basic yellow. These phosphors are blended in carefully controlled amounts to produce the desired color. In some instances it may be necessary to introduce perhaps a red or green to shift the color to an acceptable condition.

Each tube manufacturer has his own color criteria which, in most cases, differ from ours. The criteria are established by our marketing and engineering personnel in the light of what they feel the public will like the most.

2. Of equal importance to color, is the brightness with which the phosphor radiates under excitation. As noted in the discussion of bulbs, we strive to get an optimum contrast level between blacks and whites. It is important then that with a given light transmission through the bulb glass, the brightness level must be compatible. In most picture tube cases we strive to get the maximum light output from the phosphor.

From the engineering aspect, color is an approach to increased brightness through optimum blending. Another is the use of an activator, usually silver, in the correct amount. Another is the actual structure of the phosphor particle itself to gain the greatest area of surface radiation. These, and other approaches, are constantly being investigated.

C. Screening Process

The screening process is one of the most delicate and exacting processes in the manufacturing operation if good results are to be obtained.

We will first discuss the actual process and then go back to the technical aspects of each step.

The bulb comes to the screening station completely cleaned ready for screening. It is placed on the screen conveyor or tilt table with the face down. Deionized water with an electrolyte (barium acetate in our case) is then introduced into the bulb in the correct volume for that bulb size. This is called the cushion water. Kasil (potassium silicate) in the proper amount for that bulb size and the phosphor in the correct weight, are added to the cushion water.

Now for the purpose of each step: (See bulb sketch)

1. Cushion Water

The cushion water with barium acetate serves a multiple purpose so let's look at each one.

The barium acetate or electrolyte acts somewhat as a wetting agent on the glass surface, making the entire surface in contact with the cushion water completely homogenous.

The barium acetate also reacts with the kasil in such a manner as to speed up the setting time for screen or phosphor adhesion. This time element, however, must be carefully controlled to achieve an optimum balance between "wet" and "dry" adhesion to the bulb face. We will discuss adhesion a little further on.

The cushion water is used also in a dual sense: as we know, the bulb face is curved and, as explained earlier, phosphor particles being basically metal, will settle out when panned into the cushion water and of course would want to go to the lowest point.

It is necessary, therefore, to create a condition which will evenly distribute these particles over the entire inner face of the bulb. The condition we create is called convection currents and can be achieved by using a funnel with holes properly spaced, correct size to control a sort of jet action on the cushion water, and/or by the use of heat on the external face, carefully controlled as to amount and location. Either method is effective and depending on bulb size and configuration, one may do a better job than the other.

The convection currents set up in the cushion will cause the phosphor particles to stay in suspension longer and they will follow the currents as they settle out on the glass surface.

It is particularly worth noting here that temperature differentials play a significant part in the process, i.e. cold bulb, warm cushion or the reverse, a hot or cold atmosphere surrounding the bulb, uneven atmospheric conditions such as a warm or cold air flow on one side of the bulb.

2. Kasil

The actual agent used for "sticking" the phosphor particles to the inner face of the bulb is potassium silicate (Ka Sil). The potassium silicate forms a coating over each phosphor particle. It has a very strong tendency to want to revert back to its original form, sand or glass, and as such forms an excellent bond with the glass bulb. As noted in the barium discussion, a chemical reaction takes place between the barium and Kasil which is controlled by correct concentration of the two in the total volume. The term "reaction rate" is often used in explanation of the process.

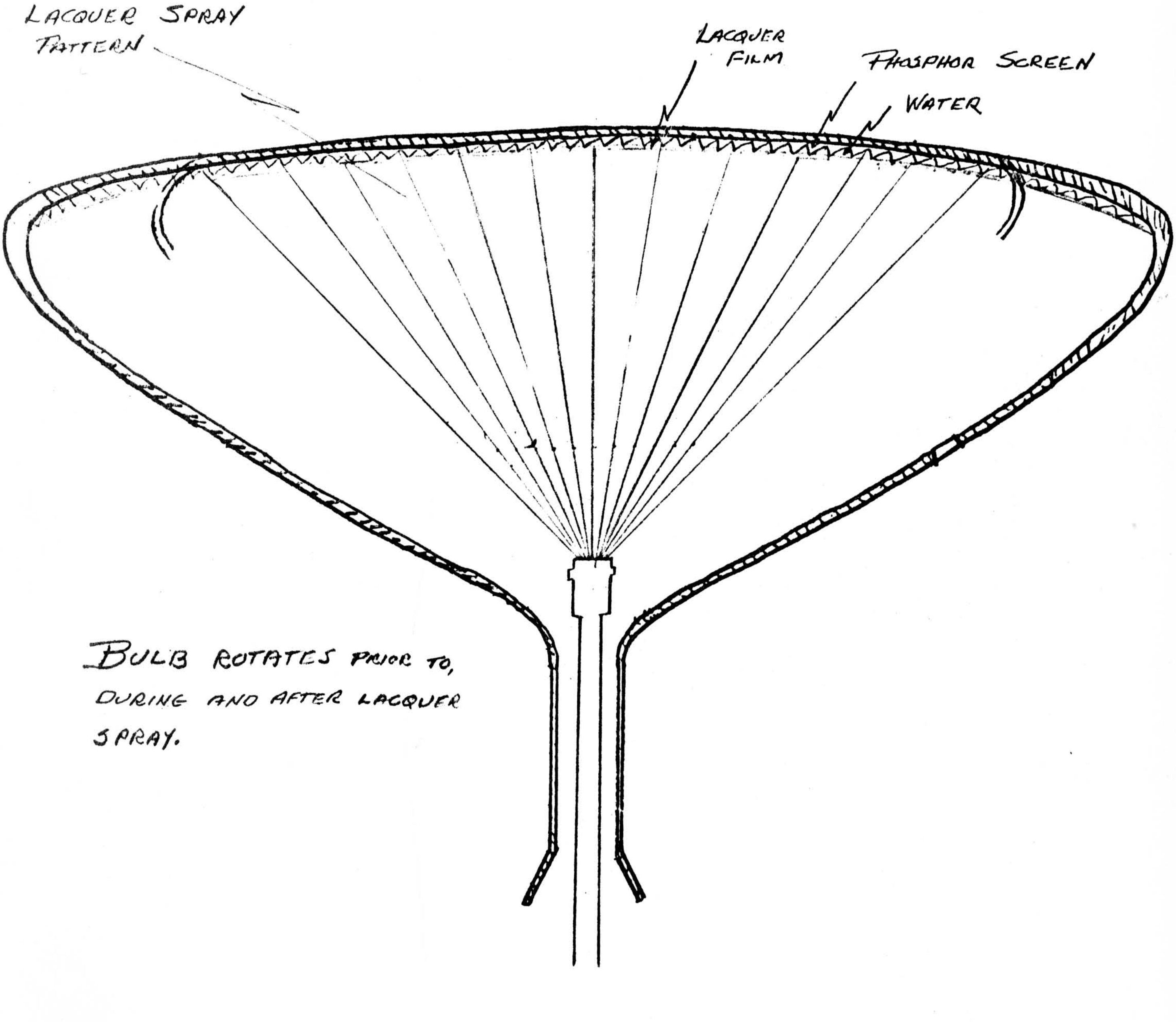
3. Adhesion

When we speak of adhesion we refer to the degree to which the phosphor particles stick to the glass surface and here we must be very careful. Our screening process must meet two criteria and the difference between the two can be very significant.

The two are defined as "wet adhesion" and "dry adhesion." Good wet adhesion is referred to as the ability of the screen to withstand the pour off of the cushion water without coming loose from the surface of the glass. Good dry adhesion is the ability of the screen to withstand subsequent processing without coming loose.

As a rule, if the wet adhesion is allowed to become too good, i.e. the adhesion to the glass is an extremely tight bond, the screen after pour-off and during air dry then becomes "brittle" and is sometimes referred to as "bond." What happens here is a very tight stretching that takes place between the phosphor particles and in subsequent processing they can actually come loose or can cause a piercing of the film.

SESSION #3



BULB ROTATES PRIOR TO, DURING AND AFTER LACQUER SPRAY.

SESSION III

A. Filming

1. The film is not an integral part of a picture tube but it does play a vital part and is a critical step in processing.

   Its purpose is to provide a smooth surface across the phosphor on which to deposit a thin layer of aluminum and prevent the aluminum molecules from penetrating the phosphor.

2. Material
   The film material is basically a plastic in solution. In our present operation we are using approximately a 5.7 Lucite in solution of 47% toluene, 28% ethyl acetate, 20% methyl ethyl ketone and 5% methylisobutyl ketone. This lacquer formula provides the necessary plasticity, quick setting, glass and spray capabilities for our purpose.

3. Process (See sketch)
   The bulb is placed over a low-pressure, deionized water jet and is pre-wet such that the phosphor is saturated and all the valleys are filled in to provide a smooth surface over the phosphor layer. (This is the first test of the dry adhesion discussed last week.)

   The bulb is then transferred to the film spray position, the spray nozzle being inserted in the neck of the bulb as shown. The distance from the face of the bulb to the nozzle is quite critical and is dependent on the spray angle. As our tubes become shorter and shorter it is necessary of course to use nozzles with wider spray angles. The spray is a single plane type, like a fan.

The optimum width of the spray at contact with the screen is such that it will not quite span the narrowest portion of the screen, i.e. across the small axis. The spray cycle consists of:

a) Start bulb spin, the speed of rotation somewhere in the 60 - 120 RPM range, depending on bulb size and shape, viscosity of the film material and temperature. When spin speed is reached, approximately 5 seconds, any excess water is thrown off screen.

b) Film spray is then activated and continues for a pre-established time, depending on bulb size, usually in the 2 to 5 second range. The nozzle size, spray time and pressure determine the volume of film material dispensed.

c) The spin is continued for somewhere in the 30 to 60 second range in order to spread the film material out to the areas not reached by the spray.

This total cycle is extremely important because we must achieve a smooth, constant-thickness film over the entire phosphor surface free from holes, tears, streaks, swirls, build-up in the corners or splash-back. Any of these conditions will be readily visible after aluminizing under either normal or ultraviolet light. It must also be continuous -- once the cycle starts it must not be interrupted.

The spray control itself is both delicate and critical. It must be an instantaneous start and stop. Any erratic start or stop will cause an excess of film material build-up at the point of first or last contact with the screen.

Some excess film material will be spun off and drain down the sides of the bulb. The amount of film material dispensed, however, provides for proper coverage, thickness and excess.

The bulb is then placed on the "trim" position where by means of a small "goose-neck" deionized water jet, the side walls from the face panel-funnel seal are rinsed thoroughly to remove any of the film material from the funnel and neck.

If any of the film material remains on the funnel or neck portions of the bulb, it will cause either the aluminum or paint to come loose from the glass in subsequent processing.

The bulb is then placed on low-volume air flush to dry the screen and film. As in screening, this must be a continuous, uninterrupted drying pattern.

The film after drying can be inspected by looking through the side wall of the bulb on a plane as close to the film surface as possible, with a white light opposite the viewing side. The film should be glossy not dull, and free of spotting. The coarser the film, the coarser the lighted phosphor will look. Any blemish in the film will be passed along to cause the screen to look defective.

B. Inside Paint

1. Inside paint is primarily the electrical connecting link of the bulb components and the electron gun, and although it is relatively quick and easy to go through this process, it cannot be minimized.

2. Material
The inside paint is basically a finely milled graphite, fairly water-soluble, with suitable binder to glass (such as kasil ((potassium silicate)) and a wetting agent ((alcohol))) .

3. Process

With the bulb held in a vertical position on a device that will rotate it when desired, a strip of paint is applied from the anode button down to a point just above the funnel-to-neck seal. The machine then rotates the bulb and the paint is applied around the tube from the lower end of the strip to a predetermined point on the neck.

4. Discussion

Inside paint can be a real trouble-maker in several ways if not handled properly. Let's look at some of the problems:

a) As noted above, the graphite is only fairly soluble in water and unless some agitation is provided, the particles will have a tendency to want to settle out. Therefore, if the paint has been allowed to stand for a prolonged period, an operator could be working off a thinned-out solution, and as the solution gets closer to the bottom it could be thicker. Either a thick or thin condition is poor. If thin, it could lead to poor electrical contact with the anode button or spring clips. If thick, it could lead to blistering, flaking or peeling off, each of which could lead to poor electrical contact and also cause the paint particles to come loose, get into the neck or gun area and cause arcing and leakage.

b) If the paint is used in proper mixture but the operator is applying it too lightly or too heavily, the same poor conditions result.

C. Aluminizing

1. The aluminum which is deposited over the screen and funnel walls of the tube has a threefold purpose:

   a) To provide a highly reflective surface. When the phosphor is excited it radiates light in all directions. Our prime interest is to direct all the light possible through the glass face of the tube. By laying a thin coating of aluminum over the phosphor, we provide a mirror-like reflecting surface which significantly increases the brightness of the tube. Aluminum has a reflectivity of approximately 89%.

   b) To prevent ions from reaching the phosphor. Ions, which came from residual gases in the tube, will cause phosphor deterioration or burning. Because of its size, however, the ion will not pass through the aluminum layer.

   c) Full anode voltage to the screen. Because the aluminum is in contact with both screen and anode, the total anode voltage is applied to the phosphor.

2. Material

   The material is pure aluminum wire or rod.

3. Process (See sketch)

   a) The aluminizing process requires a vacuum pumping station with the port so designed that the bulb will be held in the lower external funnel area, in a vertical position, such that a vacuum-tight seal is made.

   b) Electrodes are so mounted that they will extend up into the neck to a point just above the funnel neck seal. The electrodes are designed so that a tungsten filament can be inserted in each leg to complete an electrical circuit and also provide capability for quick filament change.

   c) The tungsten filament is designed such that it will hold a small aluminum slug or ring. The weight of the aluminum is determined by the size of the bulb to be aluminized.

SESSION IV

A. Bake out

In previous sessions we discussed component drying after the screen, film and inside paint operations. These steps were necessary, of course, only to prepare that component for its next processing operation.

The final step in bulb processing before gun seal and exhaust, is the bake out process which accomplishes several very important subsequent processing needs. Any material, when heated to a given temperature, will break down into a gaseous condition and will not revert back under ordinary atmospheric conditions. Let's look at some of these:

1. Lacquer - As noted in previous discussions, the lacquer film has served its purpose after the aluminum coating has been evaporated over it. The film material, as we learned, is made up of ingredients which break down at different temperatures below the peak 410° to 420° centigrade level that the bulb attains, thereby removing the film completely.
2. Water - In each processing step water is necessary. Although air drying is incorporated in these steps, a great deal of moisture is still retained by the components. At elevated temperature levels this moisture will be released.
3. Gases - Each of the components in the processed bulb, including the glass, has some gas content that would be harmful in subsequent processing. The bake out cycle will free all these gases.
4. Completion of chemical processes - Although each step in our process is completed with respect to the next step, the complete chemical change requires the elevated temperatures of bake out. This can be noted in cases where kasil has been spilled on the outside of the bulb. Normal air drying cycles will cause the interaction of the glass and kasil to start, making it difficult to remove; after bake out at the higher

temperatures it is impossible to remove the spillage except at grind and polish.

The temperature cycle for bake out is established primarily by the capability of the glass to absorb heat. In the discussion of the bulb we learned that the glass is in the "soft" or lead category. Its anneal temperature is approximately 470° C, which means that when the glass has completely absorbed this temperature, the molecules that are under any kind of stress are free to move, such that the molecular structure of the glass is strain-free; i.e., the spacing between each molecule is equal. This applies only when no pressures are exerted on the glass. In the case of bake out, we should remember that some holding device is necessary, and therefore the weight of the bulb is exerting pressure at the point of contact of the holding device. Because the thickness of the glass varies considerably, from about 1/16 to as much as 3/4 of an inch in any one bulb, the thinner sections will get to temperature much faster than the thicker sections, so the rate of rise in temperature of the heat cycle can be critical.

The recommended rate of rise in temperature for lead glass is approximately 10° - 12° centigrade per minute. Our ovens are set at an air temperature somewhat higher throughout the cycle, but as the bulb passes through each zone, the glass temperature will rise at the recommended rate. The same applies to the "soak" time. We must allow the bulb to become heated through its thickest point. Tests have indicated that it takes about 10 - 12 minutes for heat absorption through the thick portion after the outside surface arrives at temperature.

Therefore it is obvious that temperature control must be maintained, otherwise we will either overheat the thin portion if we run too hot, or we will not get to temperature in the thick portion if not hot enough.

The 410^{o} - 420^{o} peak temperature is considered safe. If exceeded to any degree it would be possible to deform the bulb in the area of the holding fixture because of the bulb weight at that point which is also the thinner portion of the glass. It would also contribute to excessive bonding of the inside paint binder, making subsequent rework cleaning of the paint very difficult and expensive.

The recommended rate of cooling for this type of glass is 7^{o} centigrade per minute. If this rate is exceeded it will lead to cracking of the glass during cooling, setting of adverse strain pattern in the bulb, which could lead to breaking and possible implosion on exhaust.

This cycle satisfies the need to break down and release any of the potential gas or gas-producing elements in the bulb or processing materials that would be released in the operation of the tube.

B. Water Preparation

In previous discussions of bulb processing, constant reference is made to the use of deionized water. An extremely high degree of purity is necessary in order to avoid contamination of process materials and to eliminate reject-causing elements.

Water treatment must meet the following conditions:

1. Remove any bacteria, algae and micro-organisms.
2. Remove any oils, grease and slimes.
3. Remove any particles such as sand, lint, dust or dirt.
4. Remove any salts, solubilized metals and non metals.

It might be well to point out here that any one system of water purification will not satisfy all raw water conditions. In choosing a location for a tube manufacturing plant, an attempt is made to locate in an area that has an ample supply of water which can be purified at a rate to meet requirements at a reasonable cost. In our plant we purify water at the rate of some 60 - 75,000 gallons per day, depending on production needs.

The water preparation process consists of passing the raw water through a series of tanks and/or beds, each of which performs its assigned function of removing undesirable elements or changing the chemistry of undesirable elements so that subsequent treatment can complete the removal of the element or transform the element to a satisfactory condition.

Let's look at some for-instances:

1. Live Organisms

   As a rule, acids are used to kill these organisms. Then a filter method is used to remove the dead body. Even though the size of the organism is minute, the decomposed body can cause visible defects, spots in the screen, holes in the film and be a source of contamination as well as a potential breeding ground for other organisms, thereby contaminating the entire D.I. water system, as well as the tube components. Barium acetate is an excellent breeding ground for some micro-organisms.

2. Oils, grease, slimes

   In all raw water there is some presence of oil, grease and slimes, very small quantities that are not necessarily harmful to a human, but in tube processing even the smallest amount will contribute to holes in the screen, poor adhesion, holes in the film and eventually gassy tubes. Sand and carbon filters are normally used to remove these contaminants and any residual dead organisms. Any presence of chlorines can contaminate the phosphor, causing it to have a green cast.

3. Sand, lint, dust or dirt
   Any of these, because they have some mass, will cause holes in screen or film, tears in screen or film, and if they are of an oxidizing nature they will cause discoloration of the phosphor and could cause gassy tubes. Carbon filters, resin beds and micro-filters are used.

4. Salts, solubilized metals and non-metals
   Inorganic materials are normally removed or converted by passing the water through resin beds. The resins used, of course, are entirely dependent on the mineral content of the water as to type and quantity. Particularly harmful to the tube is any presence of iron or copper, whether soluble or solids. Each mineral will evidence its presence in the screen under ultraviolet light or when the phosphor is excited, by its own identifiable color. Iron, for instance, will produce blue spots, copper will produce green spots and so on; therefore the chemistry must be changed to a compatible condition. Other ingredients can cause color spots also, so we have to analyze each of these conditions as they may occur. Toluene, for instance, if splashed on the film, can cause a bluish looking spot.

This, basically, is the water treatment process. Throughout our process, however, it is well to use filters of fine mesh size to remove any possibility of shrinkage that would be caused by particles.

We have now completed the "Bulb Prep" portion of this course.

SESSION V

THE ELECTRON GUN

The electron gun may assume a number of configurations, depending on the end result to be accomplished. It is basic, however, in that it provides a source of electrons, which can be passed through electrical fields, to be focused and deflected to produce a desired result.

The more common nomenclature for the gun used in the picture tube, is magnetic or electrostatic, which refers to the method of focusing. We must be careful, however, in interpretation of these expressions because they are also used in reference to deflection systems. Some of the combinations used in a cathode ray gun are:

1. Magnetic focus - magnetic deflection
2. Magnetic focus - electrostatic deflection
3. Electrostatic focus - electrostatic deflection
4. Electrostatic focus - magnetic deflection

We will study the gun currently used in our picture tube product, which is electrostatic focus, magnetic deflection.

A. Gun Elements (See sketch)

	Element	Material
1.	Stem	Glass (lead)
2.	Stem lead	Nickel, dumet
3.	Eyelet	
4.	Heater	Tungsten (coated)
5.	Cathode	Nickel (4% tungsten)
6.	Retainer	Stainless steel
7.	Insulator	Ceramic
8.	Spacer	Stainless steel
9	Bead	Multiform glass

	Element	Material
10.	$Grid_1$ cup	Stainless steel
11.	$Grid_2$ cup	Stainless steel
12.	Beading strap	Stainless steel
13.	Lens cylinder	Stainless steel
14.	Focus cylinder	stainless steel
15.	Lens electrode	Stainless steel
16.	Spring clip	Stainless steel
17.	Getter	Stainless steel channel Barium-aluminum filled

B. Parts Processing

The need for cleanliness of gun parts is equally as important as for the bulb components.

1. Stainless Steel

   All stainless steel parts, except the spring clips, are thoroughly degreased and then fired in a dry hydrogen atmosphere at approximately 1100^{o} centigrade. Degreasing removes any oils, dirt or other surface contaminants. Hydrogen firing will remove any oxygen or other gasses entrapped in the material.

2. Nickel

   Nickel is degreased and hydrogen fired at approximately 600^{o} centigrade.

3. Stem and Leads

   As part of the stem-making process, the final step is to expose the internal leads and stem surface to a complete hydrogen atmosphere. This atmosphere will de-oxidize the lead wires and remove contamination from the surface of the glass.

4. Beading Glass - Ceramic

   Degreasing followed by any good drying agent to remove oils and oxide particles.

5. Spring Clips

   Degreasing is normally sufficient. The spring clip must retain sufficient temper to provide alignment and good contact. Hydrogen firing would reduce the temper.

C. Assembly

1. a) The G_1, G_2, G_3, G_4, G_5 parts are strapped; i.e. a stainless steel strap, formed in a half circle to the outside diameter of the part with "ears" or "claws" extending out directly opposite each other, is welded to the part.

   b) The parts are then assembled on a beading fixture designed such that it holds the parts in proper alignment and by inserting spacers, the parts will be spaced correctly. The claws must also be in alignment.

   c) The multiform bead is placed on the "beading clock" and the top half is heated by hydrogen-exygen fires to a plastic state. The fires are turned off and the beading fixture is then rotated down so that the lined-up claws penetrate the plastic bead to a depth of about one half to two-thirds the diameter of the bead. This step is repeated for the second bead. In cases where three or four beads may be used on a gun, the strap is replaced by "L" shaped "ears" or "claws." It should be noted here that the insertion of the claws in the molten glass does not provide a glass-to-metal seal. The molten glass will form around the claw to provide a good mechanical bond, but does not "web" the metal. We now have the "beaded assembly."

2. The beaded assembly then goes to cathode assembly. A cathode spacer of predetermined height is inserted into the G_1, the cathode and ceramic are inserted and then a cathode retainer ring is inserted with light pressure to ensure correct grid to cathode spacing and is spot-welded in place.

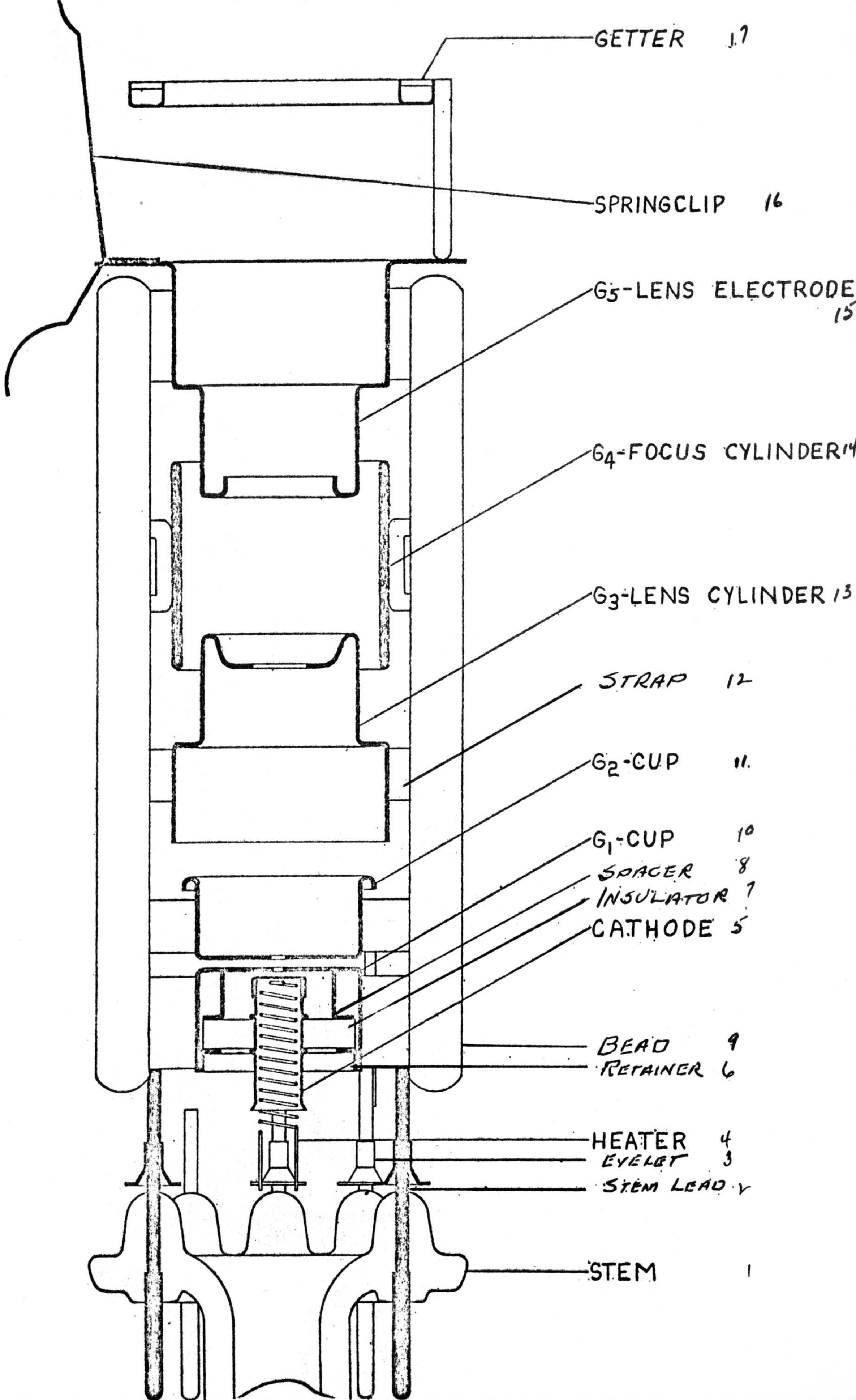
3. Electrical connectors are welded to G_2, G_4 and cathode.

4. The assembly then goes to "stemming." The stem leads have been preformed so that each of the formed leads is properly positioned to weld the electrical connections to G_1, G_2, G_4, cathode and heater legs.

5. The heater is then inserted in the cathode sleeve and the legs welded to the stem leads.

6. The assembly then receives the spring clips and getter.

C.R.T. MOUNT ASSEMBLY



THE GRID 1 - CATHODE ASSEMBLY

The grid one - cathode assembly is the "heart" of a cathode-ray tube and, as such, its fabrication and processing are extremely critical. It is the source of electrons and provides the control of the number of electrons which ultimately produce the picture we see.

Let's look at each part in the assembly, what it does and then how it works as a unit:

1. The heater or filament is tungsten, helically formed, and is coated to provide electrical insulation so that it will not short to the cathode sleeve but will conduct heat. The filament is the source of heat for the cathode.
2. The cathode is normally a four-part assembly consisting of the sleeve which is a nickel alloy, a nickel alloy cap, a ceramic insulator and a coating of emission material on the cathode cap. The ceramic is primarily an electrical insulator. It is swaged on the nickel sleeve and provides a means of mechanically centering the cathode in the grid cup, mechanically holding the spacer in place, provides a means for locking the assembly in place by means of the retainer ring. It also serves as a heat shield by closing off the upper portion of the cathode so that the heat in the emission area can be held more constant. The nickel alloy sleeve is the housing for the filament and conducts heat readily. The cathode cap is also nickel alloy. Both the sleeve and cap are "passive," i.e. they will withstand corrosive effects. Emission material is sprayed on the cathode cap. For our present tubes we are using a "triple carbonate" type consisting of barium, strontium and calcium.

3. The stainless steel spacer provides the means of holding the cathode at the proper distance from the under side of the grid cup.

4. The retainer ring is the locking device for the cathode assembly.
5. The grid, with the proper size aperture, completes the assembly.

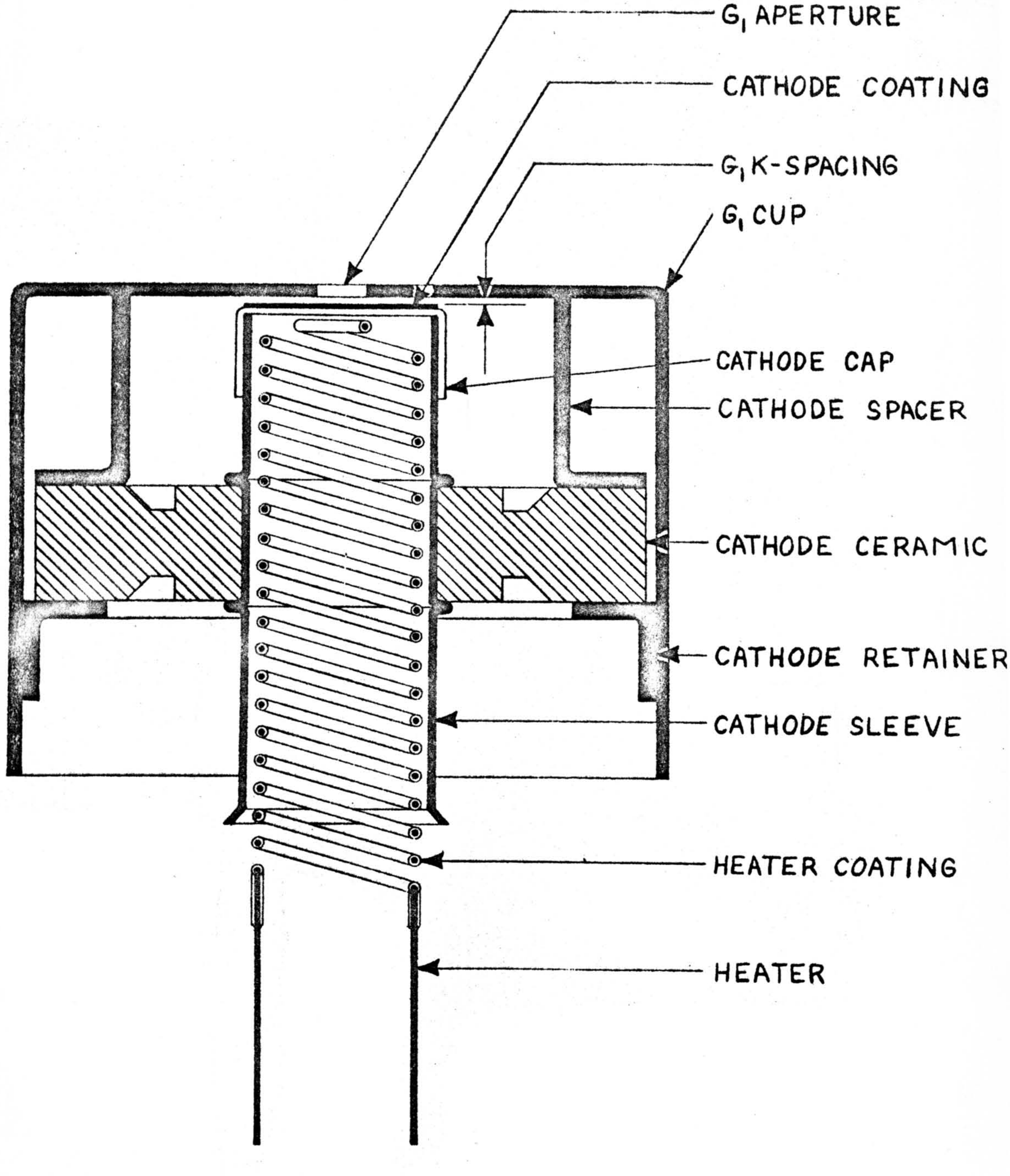
In normal operation the filament is electrically rated to provide a given temperature for optimum cathode emission capability. In most picture tubes this rating is 6.3 volts which produce .6 amps. This heat is transferred to the cathode sleeve and cap. The optimum operating temperature of the cathode is about 750° centigrade.

The cathode which we noted as being a nickel alloy is of extremely critical composition. We hear the designation N96 which identifies the make-up. Without getting too theoretical, the cathode comprises some thirteen base metals, not counting the emission materials, with the nickel being about 95%, tungsten 4%. The balance are sort of additions to enhance the conversion and long life characteristics. Some minute percentages of unwelcome materials are present which must be removed on the exhaust activation cycle.

The barium (57%), strontium (39%) and calcium (4%) carbonates which are sprayed on the cathode cap are broken down during the exhaust activation cycle, the oxygen and binders removed and the oxides unite with agents in the cathode to form a substantial mechanical bond. After activation and aging the emission material is essentially in its pure form and will readily release electrons when properly heated.

The grid which operates on a negative potential is the controlling factor in passing electrons emitted from the cathode. If we remember that electrically opposite potentials attract and like potentials repel, the electron being a negative charge, will be repelled by the grid by the degree to which the grid is operated, i.e. if no negative voltage is applied (we call this zero bias), all electrons emitted from the cathode will pass through the aperture. By any degree the grid is run negative up to about 70 volts, fewer and fewer electrons will pass through the aperture, so that at about 70 volts all electrons are repelled by the grid. This is how the blacks, whites and grays are produced on the screen. We will discuss this further in subsequent sessions.

G_1 K-ASSEMBLY



SESSION VI

In our last session we discussed electron emission and control of the number of electrons emitted. We will now look at the control of these electrons after leaving the G_1 aperture.

A. Grid #2

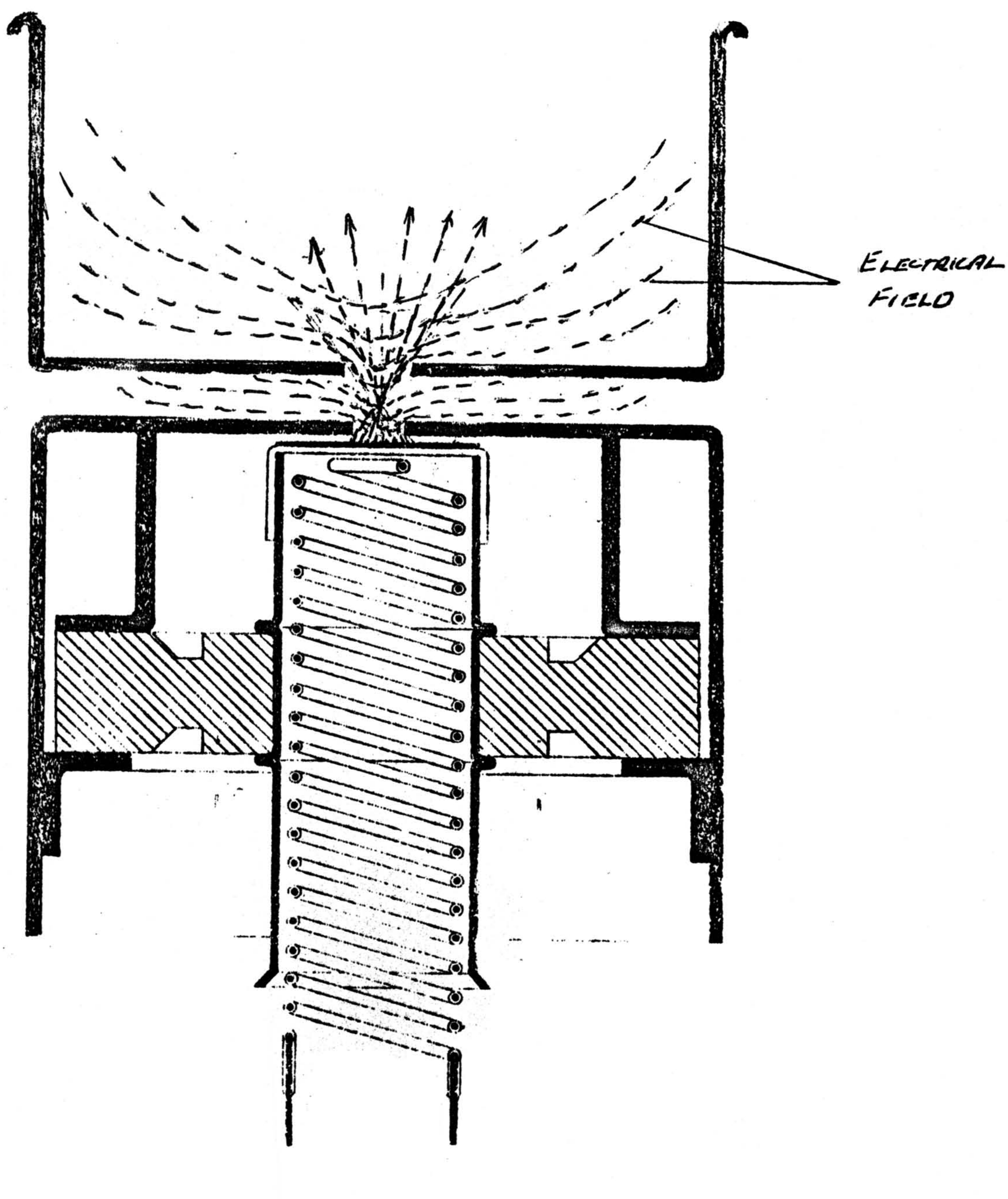
The second grid is sometimes called an accelerator or screen grid. It serves both functions. As an accelerator grid its field exerts an accelerating or speeding up force to the electron, projecting it into the high voltage anode field. As a screen grid it acts as a low voltage accelerator, which is required in this area, and as such, shields the cathode and grid from high voltage effects.

Let's look at how the second grid operates: (See sketch). This grid works in close association with the first grid-cathode. Its operation potential is positive and in the order of 200 volts D.C. As previously noted, an electrical field is created in the general configuration of the part. Being a positive potential vs. the negative charge of the electron, it will attract the electron and impart a velocity in direct relation to the voltage applied to the grid. Its field effect is such that it has a direct pulling effect on the cathode surface.

As its influence is exerted, all electrons that are seen by this field are passed through the first and second grid apertures and of course, as shown, emerge in the second grid cavity in somewhat of a spray pattern. Because the field is of low voltage nature, this pattern is somewhat wide and must be condensed and controlled by subsequent electrode configuration and potentials.

If we look closely at the pattern produced, we can see the effects of any misalignment. The two apertures must line up because of the field configuration that will develop by any degree of poor alignment. The electron beam will assume the shape of the field, i.e. if the apertures

HEATER - CATHODE - GRID 1 - GRID 2



are not in line, the field could be of elliptical shape and the resultant projection of this shape can be readily seen at test. The picture quality is dependent on the beam shape being round and of proper size.

If there is any tilt, i.e. if the spacing between first and second grid is not equal across the surfaces, the field will be distorted and also produce an elliptical beam shape.

If we change the spacing between these grids you can see the effect of the beam size. Closer spacing will broaden the beam, wider spacing will narrow the beam.

It might be well to note here that all the elements are so designed that when assembled correctly we will have the beam striking the phosphor at the correct speed, in the correct quantity and in the correct shape. By any degree that this assembly varies from design, it puts a greater burden on other components to perform their functions.

B. Lens and Focus Assembly (See sketch)

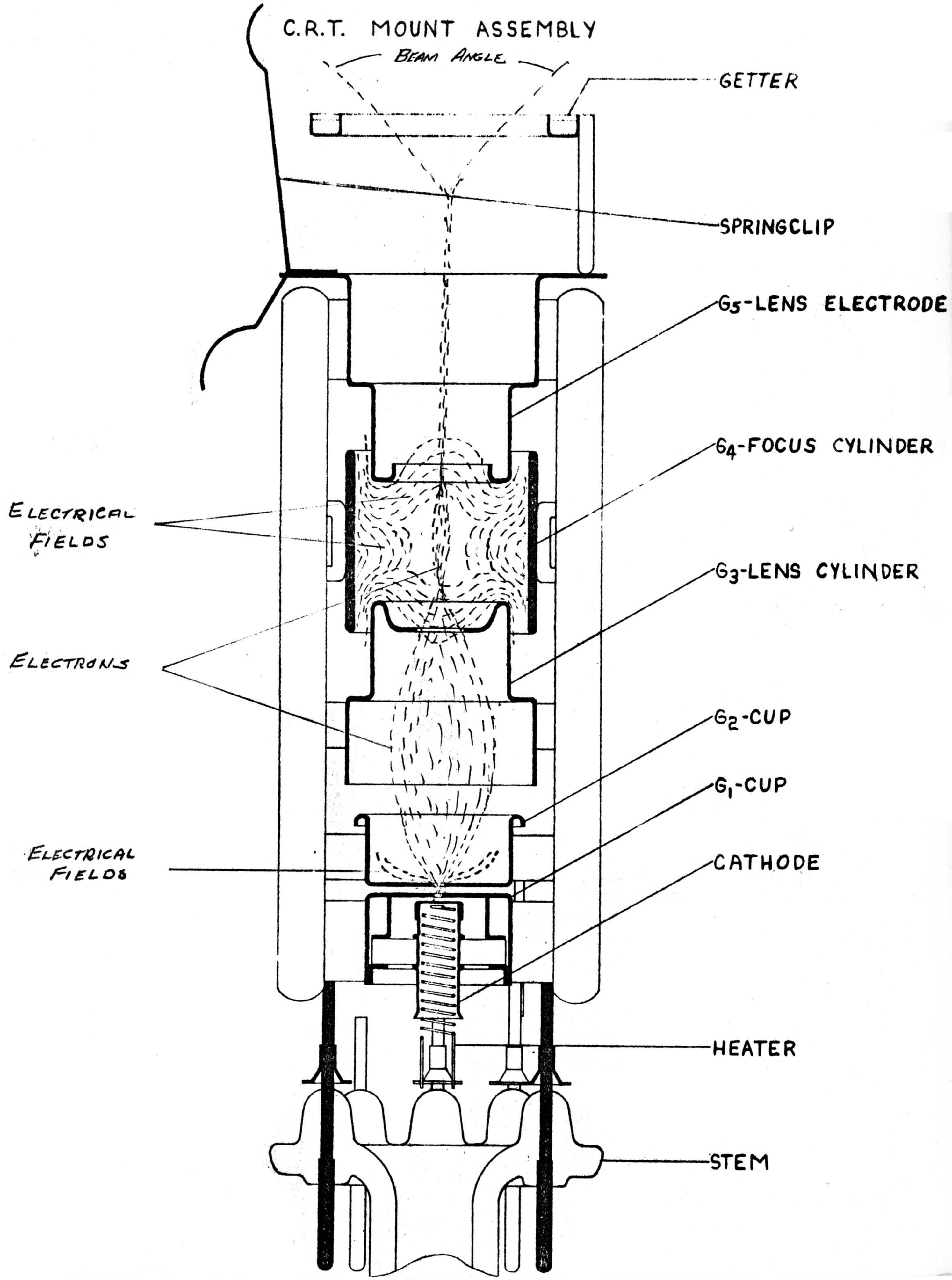
Now that we have the electrons started on their way through the second grid area at low velocity, it is necessary to speed them on their way to the screen and condense them into a compact pattern.

In order to accomplish this we go through a combined lens and focus structure. We will look at it more as a single unit because it is so interrelated as the fields affect the beam.

Here again the electron is attracted by the positive voltage applied to lens electrodes which in turn are connected to the inside bulb coatings operating in the range of 12 - 18 thousand volts D.C. Bulb size, as well as economics, dictates these ratings.

As shown on the sketch, the electrons in the second grid area are

C.R.T. MOUNT ASSEMBLY



attracted and accelerated by the intense fields created in the lens structure. In order to condense the beam into straight flow configuration, it is necessary to further compress the flow through the creation of an additional field to overcome the "cross-over" effect that would prevail by simply using the lens structure. A focusing cylinder is incorporated in this high voltage area but its potential is not electrically tied into the lens structure. The focus cylinder, according to design, may operate best on either positive or negative charge or no charge at all. The fields created by the lens structure are of course affected by the focus cylinder which by design can have an influence on the lens field configuration.

If we keep in mind that the fields created assume the configuration of the part, we can see that any change in size, shape, misalignment or location of any part, will have a pronounced effect on the shape of, or direction of, the beam. By the same token, any variation in design specification of voltages will be obvious.

C. Spring Clips - Getter

The spring clips have a twofold purpose. They provide the electrical connection of the lens structure to the inside coating. As we can see, it is of extreme importance that the spring clips have the strength to make good contact with the paint. The clips also hold the gun in alignment with the neck of the bulb. Any misalignment, we will see in another session, can have serious consequences.

The getter provides a means of absorbing residual gases left in the tube after evacuation and gases possibly generated in subsequent operation of the tube.

SESSION VII

Now that we have the bulb through processing and the gun built, we will start the tube finishing process.

A. Gun Seal

1. The gun seal operation is primarily mechanical. The stem is preheated to a temperature that will allow it to be inserted into the mount pin on the sealer without cracking from thermal shock. The bulb is placed in position on the gun seal head with the neck down, directly over the gun. The sealer may be so constructed that the fires rotate around the neck, or in the case of our factory, the entire head and mount spindle rotates. The entire assembly passes through a series of preheat positions to bring both the neck of the bulb and the stem of the gun to a temperature that will accept the intense heat of the sealing fires. The preheat fires are usually gas-air mixtures, the sealing fires gas-oxygen. During the preheat period the mount spindle rises on a gradual basis so that by the time the head reaches the first of two sealing fires, the gun is in the correct location in the neck of the tube.

   The first of the two sealing fires is normally a two-burner gas-oxygen flame, long and sharp, each hitting opposite sides of the neck of the bulb, tangentially, at a point approximately on a plane with the upper half of the disk of the stem. The neck glass softens and the weight of the flare causes the softened portion of the glass to stretch and "neck-in" to make contact with the disk. The second set of sealing fires is made up of three gas-oxygen burners, long and sharp, with the two outside burners striking opposite sides of the seal area, tangentially, on a plane with the lower half of the disk and the third or middle burner hitting the seal directly at the center of the disk glass.

2. The positioning of the gun in the neck of the bulb is extremely critical for optimum tube operation (See sketch). The yoke reference line is shown for the first time. This is the reference line from which all positioning dimensions are taken. The gun is so engineered that its position in the neck determines whether the beam will properly cover the entire screen area.

   Some of the problems if not positioned properly:

   a) Too high -- beam will strike getter and/or spring clips.

   b) Too low -- tube will not fit cabinet.

   c) Tilted -- beam will strike getter or bulb in yoke area.

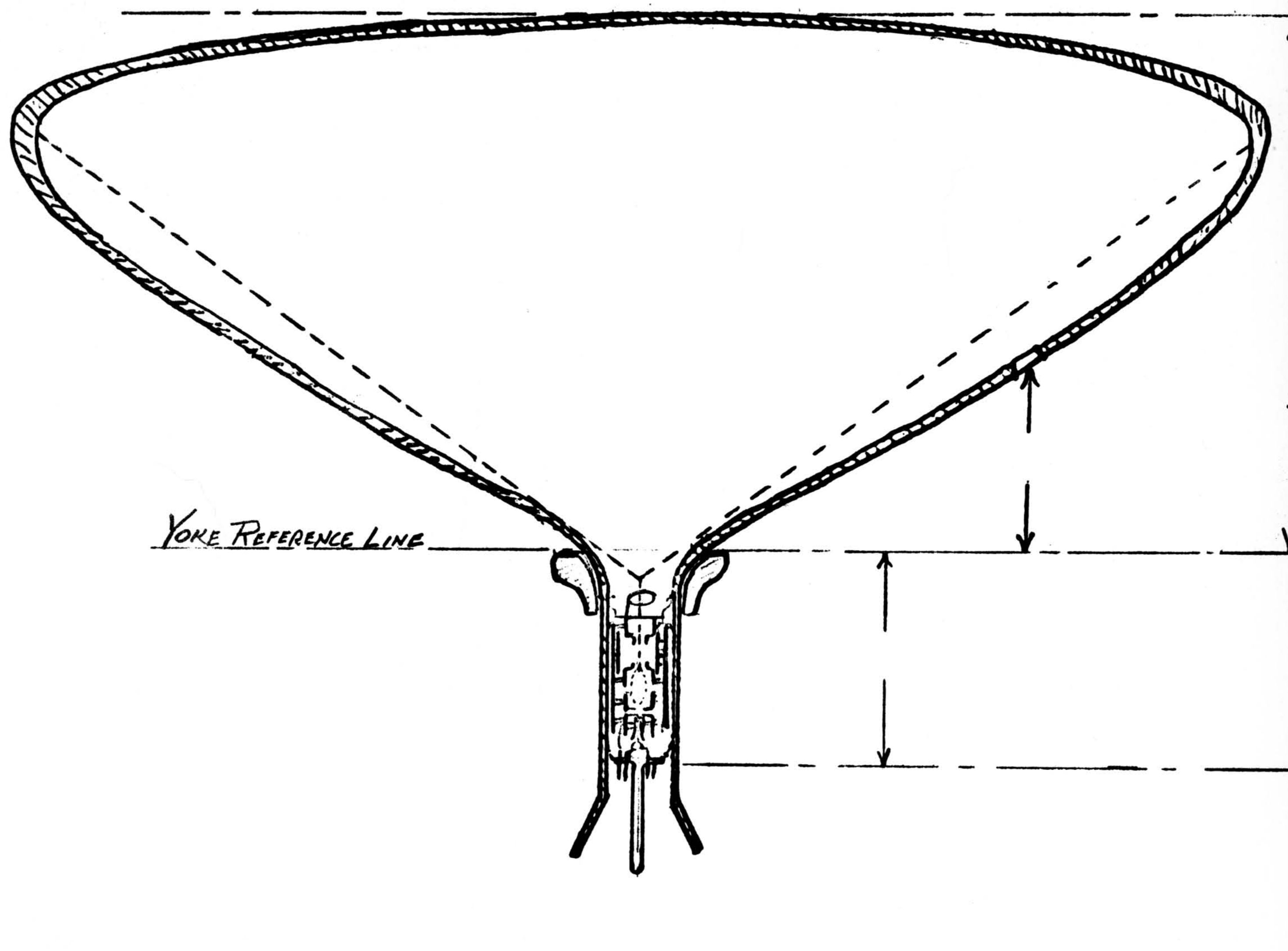
B. Exhaust

The exhaust operation performs several functions which we will discuss separately.

1. As part of the exhaust cycle, we essentially repeat the bake out cycle and for the most part for the same reasons -- to bring the bulb up to an approximate 410° C or the recommended rate of rise, soak and rate of cool to release gases, gas producing elements that will break down in these heat ranges and to remove such gases from the tube envelope by means of the "pumps."

2. The gun sealed tube is placed on the exhaust system, which is designed such that the bulb is supported in the funnel area with the neck in a down position and the stem tubulation inserted in the exhaust part which consists of a compression rubber "doughnut" which accepts the tubulation and when tightened down (hand pressure) by means of mechanically exerting pressure on the rubber "doughnut", it in turn squeezes around the tubulation creating a vacuum tight seal.

   The neck portion of the bulb is at the same time inserted through an R.F. coil which is located such that when operating, the field


YOKE REFERENCE LINE

is concentrated in the grid one-cathode area.

The tubulation is also inserted through a tip-off oven which serves two purposes: the oven is so constructed that the stem leads are inserted into the oven and one electrically connected to supplier that will activate the heater. If necessary or advisable, other connections may be made. At the center portion of the oven, a radiant coil is incorporated which is exposed to, but not touching the tubulation. When the exhaust cycle is completed, the coil is energized, heats the tubulation to a plastic condition, and the pressure of the evacuated tube causes the glass to close off the tubulation, sealing off the tubulation. We now have the evacuated tube.

At the start of the cycle the "rough" or "hacker" pump is started and most of the atmospheric conditions in the tube envelope are removed. The heat cycle is then started and the "diffusion" pump activated. As the bulb temperature increases, gases are released and removed by the pumps.

After the heat cycle has performed its function and the pressure in the bulb has optimized at a sufficiently low level, we start the activation cycle. The question of what an optimum pressure level is, is entirely dependent on economics of pump costs, speed and acceptable quality conditions of tube operation. I know this sounds evasive and requires considerable discussion. To "broad-brush" however, the pressure must be such that the gas molecules left in the tube will be few enough in number to be absorbed by gettering and not be allowed to react with the cathode or heater to shorten their lives. These pressure levels must be reached within a time element that makes it economically sound from a manufacturing aspect.

3. At the proper time in the cycle we start activation. This process consists of converting the triple carbonates to their basic metallic composition by releasing the binders and creating the mechanical and chemical bonding of the emission materials to the cathode cap.

Primarily, the process is to heat the cathode to a sufficient level, somewhere in the order of 1200° C at a carefully set rate of heating to cause the release of oxygen, binders and other gases, giving the chemistry of cathode and emission materials time to combine to form the pure mechanical bond.

Let's refer to the sketch in Session #5, Page 29, for further exploration of this process.

It is necessary that the R.F. coil be positioned such that the maximum intensity of its field be focused on the first grid-cathode. The R.F. is turned on first and the grid-cathode brought up to temperature to start the degasing of the assembly -- temperature-wise the grid should get to about 800°C -- just visibly red. Then the heater or filament is brought on and increased gradually so that the cathode gets to approximately 1200° C. If these temperatures are arrived at too quickly, the chemical reaction will not take place, and little or no bonding is achieved. If the temperatures are not reached, i.e. the process is too cool, the chemical bonding will not be complete. If gas pressures are too high, i.e. too many foreign elements are present, the correct chemistry is not achieved and bonding is weak and contaminated.

It is necessary also to keep the grid at sufficient temperature that when the carbonates of the emission material are breaking down the molecules released do not form on the underside of the grid and in the aperture area. If they do collect here on subsequent operation of the cathode, these molecules or ions will find their way back into the emission material and cause burning, thereby shortening the cathode life and also cause low emission.

SESSION VIII

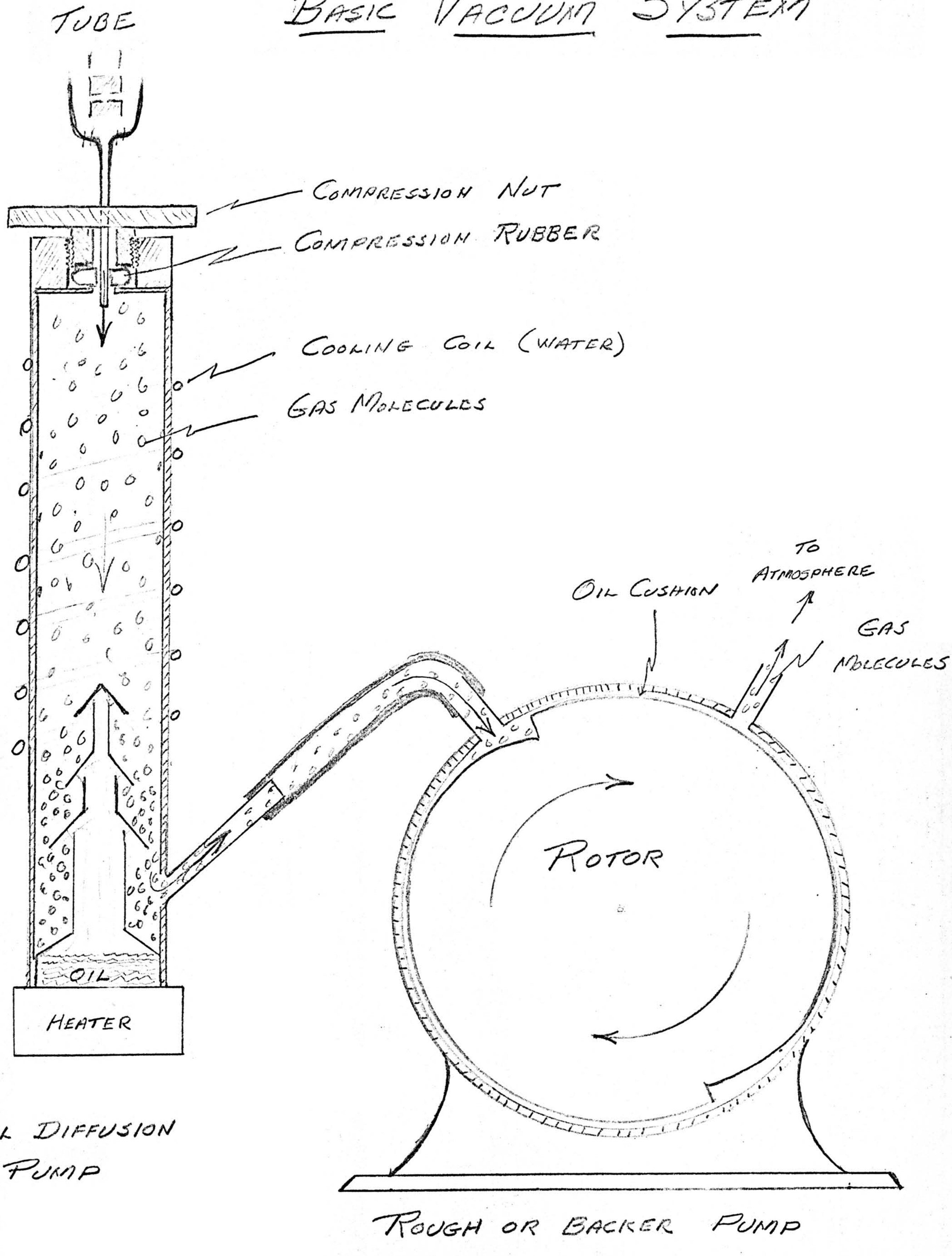
Before leaving exhaust we should spend some time on the evacuating equipment.

In previous sessions we discussed the need for cleanliness of all components and an internal bulb atmosphere relatively free of migrating gas molecules. In order to achieve this, our process is designed to release the contaminating elements and then remove these by means of an exhaust or pumping system. Although we refer to the equipment as "pumps" the process is based on the theory of molecular displacement. In other words, in a totally enclosed area, such as the tube and pumping system, there are millions of molecules that make up the atmosphere of the enclosure. These molecules are evenly distributed and will always seek to stay in this state. If we remove some or add some, the total number will adjust so that the even distribution is maintained.

So, in our evacuating process, as we remove molecules from the enclosure, the remaining molecules will tend to redistribute themselves to maintain the even distribution. The process, as we shall see, is accelerated by our pumping system which is made up of a "backer" or "rough" pump and an oil diffusion pump. (See sketch).

The rough pump is, as its name implies, designed to do a rapid job of removing large quantities of molecules but is relatively ineffectual when only a small quantity are present. It is fairly simple in principle and construction. A precision rotor revolving in a precision housing with a low vapor pressure oil cushion performing the dual function of lubrication and sealing off molecular gas flow except as desired. The rotor as it revolves will entrap some gas molecules on the intake side and discharge them as it passes the exhaust port. This pump is self-sufficient, with capacity to reach, under optimum conditions, pressure levels in the order of one or two microns. Lower pressures can be reached, however, with variations on the basic design.

TYPICAL BASIC VACUUM SYSTEM



The oil diffusion pump, working with the rough pump, can achieve pressures in the range of .003 - .004 microns under optimum conditions. Here, as with the rough pump, design changes can enable lower pressures to be reached. As shown in the sketch, the oil is heated so that it vaporizes, rises in the stack and is essentially sprayed in an umbrella pattern, down toward the bottom of the pump. As it hits the walls of the pump it condenses and runs back into the reservoir. Its working characteristic is to cause the oil molecule, which is much larger and heavier, to strike the lighter gas molecule, driving it down to the exhaust port area where, through compressive action and the molecular displacement theory, it will be picked up by the rough pump. The oil molecule being larger, heavier and not compatible with the gas molecule, returns to the oil reservoir. When extremes have been reached, however, in the pump's capability, there is possibility that some oil molecules will migrate to other areas of the enclosure. Cooling coils (water) are wound around the outside of the pump housing, above the heated oil area, to cool the housing, thereby creating a trapping condition to attract the gas molecule.

SESSION IX

The final processing step in building the tube is the outside paint -- a conductive graphite-based paint which serves to provide the correct capacitance for that tube size. It is applied, in a carefully engineered pattern, to the funnel area such that it will not cause any electrical interaction with the yoke or bands around the face panel.

Test

1. From a production standpoint, electrical testing of the tube is just another area for inspection. It is not, generally speaking, a part of the production process. If we were able to make perfect tubes the testing function could be eliminated.

2. From a quality standpoint the series of tests is much more complete and designed to tell us just how good we are making them. Spot tests and sometimes small lot tests are made. If tubes are marginal or evidence says that something is out of control, all production may be restricted until the trouble is corrected. We will discuss these tests in more detail.

3. From the engineering and development viewpoint, testing is the most important tool for design analysis that we have. The engineer can only theorize in his research and development studies and in most instances his calculations are only approximations. He needs test data to confirm or explode his theories.

4. From the sales and marketing standpoint, testing is the means by which we compare our competitors' products with ours. We constantly strive to provide our customers with a product which is fully competitive in quality and price.

Let's look at some of the more important tests that our tubes are subjected to:

1. <u>Emission</u>:

The emission of electrons from the cathode is the heart of the cathode ray tube. Everything else is used to give the electrons additional energy, to shape the beam, to deflect the beam, to focus or to change the electron energy to light energy.

a) Zero bias emission and cut-off:
This test will indicate how well the cathode will emit electrons.

b) Emission build-up:
The rapidity with which the cathode reaches full emission is an indication of its condition -- and possibly how well it will hold up on life test.

c) Cathode image:
This is essentially a technique for looking at the cathode surface. This can indicate poor cathode activation or excessive bombardment by gas ions.

d) Stray emission:
This indicates electrons being emitted by other elements besides the cathode. Strong fields may cause electrons to be pulled from the gun parts. Also, poor processing may cause cathode material to be settled on the grid aperture. Emission will occur here in the same manner as that of the cathode.

2. <u>Leakages (also shorts) and Breakdown</u>:

Undesirable current flow and arcing are turned up with this series of tests. Primarily due to cost considerations, television receivers are not made to deliver high power voltage sources to the picture tube and excessive leakage could upset the operation of the receiver.

3. <u>Screen Condition</u>:

a) Lighting up the screen electronically may turn up screen defects which are not obvious otherwise.

b) Color:

Use of a colorimeter or spectroradiometer is required to determine the actual color of the screen.

c) Brightness:

This test is an indication of how hard the picture tube must be driven electrically to produce a given amount of illumination.

4. Focus Quality (These tests are all related to one thing -- how does the picture look?)

a) Focus voltage:

Set manufacturers build TV receivers with ranges of variation governed by our tube specifications. These tests indicate whether the tubes also follow the requirements.

b) Resolution:

This is a qualitative test for focus. It presents a way of comparing one tube with another as far as focus is concerned.

c) Spot Distortion or Astigmatism:

The ideal cathode ray tube would have a beam of electrons focused at the screen which is very small and perfectly round. Unfortunately, because of the distortions produced by misalignments, the spot in many cases is elliptical. A distorted spot will reduce the definition that is possible.

d) Blooming:

This is the tendency of the spot to enlarge at greater beam currents.

5. Miscellaneous Tests

a) Gas:

Excessive gas in a tube could shorten the life of the cathode and burn the phosphor screen.

b) Filament current:

Receiver designers must be certain of the range of currents required for the selection of transformers and in particular for series string filament sets.

c) Heater warm-up:

If the tubes in a series string filament do not warm up at nearly the same rate, excessive strain may be placed on the fast warm-up ones resulting in filament burn-outs.

d) Neck shadow:

If neck shadow results when a standard yoke is used, then either the glass companies are not staying within specs or the reworked bulbs are rejects.

SESSION X

Getter Flash

After the tube has completed the exhaust cycle, it goes to the getter flash operation. The tube neck is inserted through an R.F. coil and is positioned such that the coil, when energized, will heat the getter material, at a preset rate, to the proper temperature for a relatively constant conversion of the solids to free molecular state. The molecules react very similar to the aluminum evaporation in that they will go to the inside surfaces of the tube in a fairly even distribution. The getter material is of the exothermic type and as such, when heated at the proper rate, the release of molecules is uniform. Caution must be used not to heat too rapidly. If this type getter gets to temperature too quickly, the molecular release is of an explosive nature and will result in a heavy deposit of getter material in the center face area of the tube, thus cutting down brightness and seriously affecting color distribution as seen by the viewer. It could also cause evaporation of the stainless steel channel which contains the getter material.

Spark and Age

From getter flash the tube goes to spark and age.

1. The sparking process is designed to eliminate or minimize the effects of small particles of paint, aluminum, phosphor or other contaminants or their oxides from the gun elements and the neck or funnel of the tube. It could well be interpreted as saying that if the tube components were not properly processed, we could possibly correct the condition by sparking. The process consists of tying all gun elements together as one side of an electrical circuit and using the anode button as the other side and pass a high voltage, relatively low current charge in a reverse direction to normal operation. If there are any contaminant particles or peaks of paint, or possibly aluminum, that could cause shorting or leakage between elements, they would be subjected to the

influence of the charge and would essentially be burned out or transformed to a gaseous condition and absorbed by the getter. A simple spark coil can in most instances be sufficient. It is possible to observe the degree of gas release by watching the color of the internal atmosphere of the bulb during this process. The internal atmosphere will be clear or a very pale blue under good conditions. If much contamination is present, the atmosphere will be anywhere from a pale pink to a deep-to-purplish pink.

2. The aging process is the final step in the conversion of the cathode emitting material to its base metallic form, bonded to the cathode cap, to achieve an optimum emission condition. The process in general consists of:

   a) Filament voltage is turned on and brought to a value of somewhere in the order of double the normal operating voltage. This value, of course, is dependent on the cathode material, filament rating and gun design. The elevated voltage is held for only a short time, perhaps a couple of minutes. Extreme care should be used to make sure the first grid remains at zero potential. There are few exceptional conditions where it might be advisable to apply some controlled voltage to the grid.

   b) The filament voltage is then reduced to a value somewhat above the normal operating potential, perhaps ten to fifteen percent. A positive voltage is then applied to the second grid. This voltage is normally somewhat higher than its operating value. This portion of the process is run for some thirty to forty-five minutes. The desired emission level of the tube should now be achieved.

As presented, the explanation of the aging process may sound very evasive, and it is. However, if we keep in mind that as the tube comes off exhaust the emission material is only partially converted, harmful gases released,