Gases and getters in color picture tubes

Dr. J. C. Turnbull | Dr. J. J. Moscony | A. Month and J. R. Hale

Picture tubes, like other oxide-cathode electron-tube devices, require a high vacuum for prolonged operating life. Unfortunately, the inside tube surfaces become gas sources and destroy the desired vacuum. This problem results from high-energy electron beams striking the tube screen and the shadow mask, in the case of color picture tubes, and liberating various gases from these surfaces. At the same time, high-energy, back-scattered primary electrons strike and liberate gas from the surface of the conductive funnel coating. The use of a barium getter in picture tubes forms a film on the interior tube surfaces, which reacts chemically with stray gases to form stable, solid, barium compounds and thus maintain the desired vacuum. This paper describes the use of getters and their function in color picture tubes.

J. C. Turnbull
Color TV Chemical and Physical Laboratory
Electronic Components
Lancaster, Pa.
received the BS in Physics from M.I.T. in 1934 and the PhD in physics from Brown University in 1938. Between 1938 and 1942 he worked on glass development and research at the Preston Laboratories. During World War II, he was employed by M.I.T., Princeton, and Harvard to work on high power, high frequency transmitters and modulators. He joined Electronic Components in 1945 and from then through 1954 was involved in glass and ceramic work in the Chemical and Physical Laboratory. Thereafter, he was involved with the development of the metal kinescope and with the development of both the metal bulb and the glass bulb versions of the shadow-mask color kinescopes. Since 1958 he has been leader of the Applied Physics Group of the Chemical and Physical Lab investigating thermionic cathodes, getters and related phenomena which affect performance and life of electron tubes.

Final Manuscript received.

J. J. Moscony
Color TV Chemical and Physical Laboratory
Electronic Components
Lancaster, Pa.
received the BS in Chemistry from St. Joseph's College in 1951. He worked with the Electric Storage Battery Co. as an analytical chemist, served two years in active duty with the U.S. Army and then worked for Waterman Products Co. as a Chemical Engineer in the development of phosphor screening methods for cathode ray tubes. He joined RCA, Defense Electronics Products in 1957, where he assisted in the development of thermoelectric materials for refrigeration purposes. In 1958 he received the MS in Chemistry from St. Joseph's College. In 1959 he joined RCA Industrial Tube Products, Space Components Engineering, where he worked on a variety of topics related to thermionic energy conversion. As a recipient of a David Sarnoff Fellowship, he attended the University of Pennsylvania from 1962 to 1965 where he earned a PhD in Synthetic Inorganic Chemistry. He then joined the Color TV Chemical and Physical Laboratory of EC and has been working on mass spectrometer analysis of residual gases in vacuum and also on getter and cathode developments. Dr. Moscony has had nine papers published and holds one patent. He is a member of the American Chemical, American Physical and American Vacuum Societies.

A. Month
Color TV Chemical and Physical Laboratory
Electronic Components
Lancaster, Pa.
received the BS in Chemistry-Physics in 1950 from the City College of New York and continued graduate studies in Physics at the Polytechnic Institute of Brooklyn and CCNY. Prior to joining RCA he was Engineering Leader of the Spectroscopy Instrument Section of the Process and Instruments Company and then the Manager of the Instrument Model and Glassblowing Shop of Emil Greiner Company. He joined RCA in 1957 as a Spectroscopist for the Microwave Chemical and Physical Laboratory in Harrison, N.J. In 1959 he assumed responsibility for Analytical and Metallurgical Analysis and Physical Testing for the laboratory. He joined the Electron Physics Group in Lancaster Color TV Chemical and Physical Laboratory in 1964. At Lancaster he investigated the factors affecting operating of color TV tubes and was responsible for the use of the first high yield exothermic getters in the color TV tubes. Mr. Month received the EC Engineering Award in 1967 for his work in increasing the reliability and life of color picture tubes. He is presently engaged in the design and development of future color TV picture tubes. He is a member of the American Chemical Society and American Physical Society; has authored technical papers; and has several patents pending.

J. R. Hale
Color TV Chemical and Physical Laboratory
Electronic Components
Lancaster, Pa.
received the BS degree from the New York College of Ceramics at Alfred University in 1961. He was employed as a Development Engineer by the Ferro Company and worked on low temperature glass formulations through 1962. Currently, he is engaged with various glass technology problems, getter design, heater-cathode reliability problems and investigations relative to solder glass technology. Mr. Hale is a member of the American Ceramic Society, The National Institute of Ceramic Engineers, The Society of Glass Technology, and The Society of Rheology.

The getters used in black-and-white picture tubes evolved from the early loop getters which were mounted and flashed onto the neck area of the tube above the electron gun. These getters were stable in air and used a barium-aluminum alloy which contained approximately 50% of each metal.

The alloy was in the form of a wire clad with nickel or stainless steel; the wire was ground down on one side to expose the alloy for easy flashing. The getter wire was welded to a metal loop (see Fig. 1) to facilitate heating by a high-frequency source. This heating causes the barium metal to be flashed from the alloy by evaporation. The ring getter shown in Fig. 1 is an improved version which allows a larger quantity of barium to be flashed with a minimum expenditure of RF energy. This getter has a stainless-steel channel to which the barium-aluminum alloy material is pressed.

Ring getters can be exothermic or endothermic. The exothermic ring getter is made by mixing nickel powder with the barium-aluminum alloy powder. When heating of the getter starts, the nickel and aluminum form an alloy and release heat to help to bring the getter quickly to the flash temperature. The endothermic getter does not include the nickel-powder addition.

Getters in shadow-mask picture tubes

Getters used for shadow-mask color picture tubes evolved along the same lines as the black-and-white tube versions. The first color picture tubes (type 21AP22, 70° deflection, large neck tubes) were produced with six loop getters mounted above the gun in a circle. These getters had a total maximum yield of 90 mg of barium and were flashed radially outward with a high-frequency coil onto a limited area of the neck. Later, a number of different types of getters were used in this tube as part of a transition that led to a ring getter 36 mm in diameter, located above the gun mount and flashed upward and away from it. This getter provided a large area of flash on the 2-inch (diameter) neck of the tube. Barium fill was 150 mg and actual yield was maintained above 100 mg. By observation of the disappearance of metallic barium, it was estimated that 50 mg of barium were typically consumed during the first few thousand hours of tube operation. The good performance of this single getter system has been demonstrated by the excellent life of the 70° deflection color picture tubes.

Two-getter systems

A greatly increased flash area was achieved by using a getter system mounted in the funnel and directed to flash across the bulb onto the funnel and mask areas. Two 130 mg endothermic getters were used in this system. As shown in Fig. 2, one was mounted in the tube neck, and the other in tube funnel. The system had adequate getter-capacity on the oxygen capacity test (described later), however, experience showed it to be more difficult to control the flash of two getters and that the flashing produced higher methane pressure[1,2] than with a single getter. Although the methane disappeared during tube scanning, it caused short-term emission instability after cathode aging.

Large exothermic funnel getters

RCA's getter-vendors were asked to develop, to RCA specifications, a single, large getter for the 90° deflection tubes. An exothermic getter was preferred because it is easier to flash than a large endothermic getter. (Large endothermic getters can present the problem of liquid aluminum spilling from the channel during flash. This problem is not present with endothermic getters because a solid nickel-aluminum matrix is formed during flash.) A goal of a minimum of 135 mg of barium-flash yield was set to achieve the same performance as the two-getter system. Experience with factory flash capabilities indicated that the getter fill would have to be in the range of 175 to 185 mg, about twice the amount as in the largest exothermic getter of 25-mm size.

Based on RCA's specifications, one vendor developed an exothermic getter with 185 mg of fill. The antenna mounting system needed no changes to position this getter in the funnel. This getter flashed better than the 127-mg endothermic getter that it replaced. The starting time (time from the application of RF to initiation of the flash) was 7 ± 1s with a total RF application time of 30 seconds, and the average yields in production exceeded 150 mg. This getter is now being used in the smaller color picture tubes.

Another vendor produced a large getter having 240 mg of barium fill. This getter, also shown in Fig. 3, has a number of features which departed from the conventional ring-type getters. First, it used a greater exposed area, relative to the weight of fill, than other getters. This was achieved by forming a solid ring of getter material and pressing the ring into a separate external retainer ring. This external ring also aided the RF heating of the getter material. Second, a reflector was incorporated which became hot during flash and re-radiated the barium that normally deposited on the glass surface as back flash. Third, a ceramic substrate was substituted in place of metallic supports in the glass funnel around the getter support to minimize locallized over-heating and cracking. This substrate eliminated glass problems and reduced the distance that the getter extended above the surface of the glass, resulting in more efficient coupling to the RF unit. Fourth, the getter used gas doping with nitrogen. This allowed the getter to release nitrogen just before flashing and, thereby, to momentarily increase the pressure and confine the flash area.

The performance of the 240-mg getter has been favorable. With gas doping, it was found that RF generators with frequencies above 450 kHz caused ionization of the gas released during flash and that getter yield was below normal. However, when the frequency was reduced to 300 kHz, ionization was not visible. This getter is used in the larger color picture tubes, and has provided an average yield of 210 mg.

Control criteria for getters and getter flash

Getters delivered to RCA are checked for barium fill, barium yield under controlled flash conditions, and gas content. During the inspection for barium fill, the getter material is

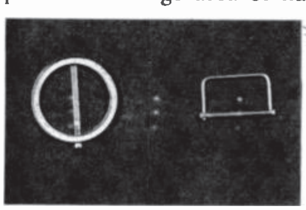

Fig. 1—Endothermic getters: loop getter (left), ring getter (right).

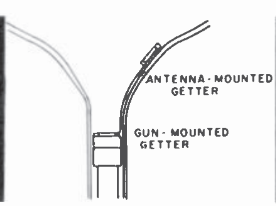

Fig. 2—Two-getter system used on the 90° deflection color picture tube.

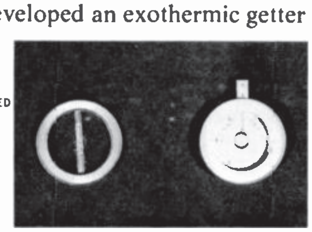

Fig. 3—Exothermic getters: 185-mg getter (left), 240-mg getter (right).

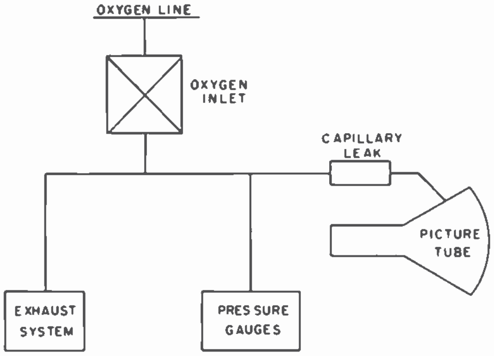

Fig. 4—Oxygen capacity test system.

Table I. Efficiencies of Various Getter Types

Getter Tube	*Barium fill (mg)*	*Getter Efficiency (l-μ/mg Ba)*	*Average Oxygen Capacity (l-μ)*
70° Tube			
Endothermic Neck Getter	150	20	2400
90° Tube			
Endothermic Neck Getter*	127	10	4500
Endothermic Funnel Getter*	127	40	
Exothermic Funnel Getter	185	40	6200
Exothermic Funnel Getter (nitrogen gas doped)	240	35	7350

*Used in combination.

broken out of its channel and inspected for barium content by chemical analysis. Barium yield is determined by the weight-loss method in which longer than average flashing is used so that most of the barium is removed from the channel. Gas content is determined by an ASTM test,[3] in which the pressure peak during flash is recorded in a system of known volume.

In production, barium yield must be controlled and conveniently evaluated. The weight-loss method is not wholly suitable because the initial weight of the getter, in an arbitrarily selected production tube, cannot be accurately determined. However, because the manufacturer maintains control over the amount of barium fill in each new getter, the approximate yield can be determined. This method of checking yield is used for endothermic getters. For exothermic getters a less time consuming approach is used, namely, X-rays are used to perform a residual barium analysis. This is achieved as follows: when a primary X-ray beam impinges on the face of a getter and its ring, the excited elements in the fill (barium, aluminum, and nickel) emit secondary or fluorescense X-radiation of discrete wavelengths. Quantitative analysis by X-ray fluorescence-emission spectroscopy is possible because the intensity of the wavelengths emitted is proportional to the concentration of that element in the sample. In this analysis, the barium $K\alpha$ emission line is used to determine the amount of remaining barium in a flashed getter. Each determination is the average of two readings, with the getter rotated 90° between readings. This X-ray technique gives the amount of barium to within ±3 milligrams and has been very useful in determining the best flashing techniques and in the discovery of faulty or poor flashing stations.

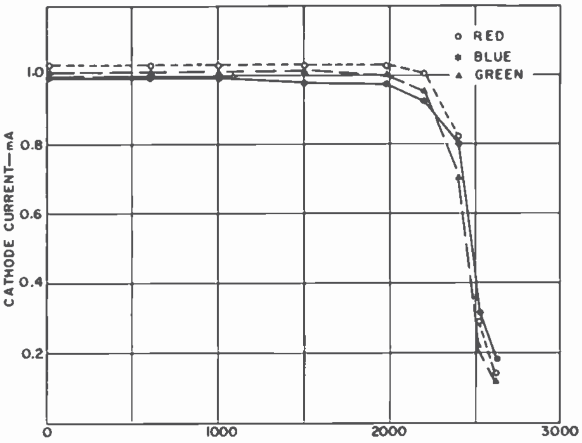

Fig. 5—Oxygen capacity test on a 70° tube.

Evaluation of getter performance

Getter performance is best evaluated in an operating picture tube. The detrimental effect of oxygen on the oxide cathode and the high degree of activity of barium for oxygen led to a test method in which oxygen is introduced into a finished tube. (Oxygen is known to be present in picture tubes during scanning as is carbon dioxide[4,5]; the effects of these gases can sometimes be seen by oxidation of grid surfaces in tubes which are operated with insufficient getter yield.) When oxygen is admitted, cathode current is constant as long as the barium film is active and absorbs oxygen. When the film is depleted, the oxygen pressure rises and cathode current slumps.

For the purpose of this test method, a procedure was developed to break into the tube and admit oxygen gas. In this procedure, see Fig. 4, the funnel of a tube is partially drilled with a hollow, diamond-impregnated tool. Glass tubing from a vacuum station is sealed to the funnel with epoxy resin and the hole is broken through by impact with a magnetically controlled rod. Oxygen is let into the funnel from the manifold through a fixed leak. The latter is a section of capillary tube 1 mm in diameter and ¼ inch long having a conductance (at room temperature) of 0.017 liters of oxygen per second. A second leak from an oxygen line keeps oxygen pressure in the manifold constant, usually at 4 microns — a convenient value to be checked with McLeod gauge. The rate of gas admission into the tube is normally 250 liter-microns per hour. The quantity of oxygen that causes the cathode current to decrease to 80% of its initial value is taken as the oxygen absorption capacity (in liter-microns) of the getter. Fig. 5 shows a plot of cathode current as a function of oxygen quantity let into a new RCA-21FBP22 (70°-deflection) color picture tube. The current for all cathodes (red, blue, green) is constant up to 2000 liter-microns where it starts to slump. The 80% end point is about 2070 liter-microns for all three cathodes. A slower than normal rate of oxygen admission, 34 liter-microns per hour for 60 hours, was used to provide sharper end-points on the curves. The amount of barium flashed into the tube was 109 mg; therefore, the efficiency of the getter in the neck position of the tube was 19 liter-microns per mg of barium.

Oxygen capacity and getter efficiency

In a single getter system, oxygen capacity is a linear function of barium yield. The getter efficiency (liter-microns of capacity per mg of barium yield) depends on getter location and design and is sensitive to the distribution of the flash.

For a two-getter system, consisting of a neck getter plus a funnel getter attached to an antenna spring, oxygen capacity can be expressed by the following linear relation:

$$Q = aN + bF$$

where Q is getter capacity (liter-microns), N and F barium quantities (in mg), and a and b are constants. The chemical equivalent of oxygen reacting with barium to form barium oxide, BaO, is 67.7 liter-microns per mg of barium. This value is the maximum expected for the constants, a and b, for a getter film which reacts completely with oxygen to form BaO (assuming this happens before the cathode emission is affected). With this relationship, a least-squares fit of the data taken on many new 25-inch (90° deflection) color picture tubes gave actual values of a equal to 10 and b equal to 40 liter-microns per mg of barium. Results show that the funnel getter with its large area of flash approaches the theoretical value, while the neck getter with its restricted area is less than ¼ as efficient as the funnel getter.

Getter efficiencies for the various types of getters used in color picture tubes are listed in Table I. These values are a function of flash area. The 70° neck getter has a large area of flash and greater efficiency than the 90° neck getter. The 90° endothermic and exothermic funnel getters have the same flash areas. The 90° exothermic gas-doped getter, also located in the funnel, has a more restricted area of flash and somewhat lower efficiency in terms of this test than the other 90° getters.

Getter depletion during tube operation

The oxygen capacity test can also be used for evaluation of getter depletion in tubes that have been operated. By use of this procedure, getter depletion is taken as the difference between the getter capacity of a used tube and that calculated for a new tube. Through the use of this test method, it has been found that oxygen absorption capacity of the 2-getter system in 25-inch tubes was depleted at the average rate of 3 liter-microns per hour during the first 300 hours of normal operation, and at the average rate of 1.5 liter-microns per hour during the first 1000 hours.

Gas sources within the picture tube can be evaluated by similar measurements on picture tubes which are modified by omission of tube components. In one test, the mask, phosphor screen, and graphite-silicate funnel coating were omitted from a tube, and an operating tube made by aluminizing the funnel and face of the bulb, and by providing small-area patches to allow set up of the picture tube in a receiver. This tube showed no appreciable depletion of the neck flashed getter during hundreds of hours of tube operation, thus demonstrating that the omitted components were the important sources of gas.

Gas measurement in picture tubes

Mass spectrometer analysis of partial pressures of gas in tubes during their operating life can define conditions that limit cathode performance. A mass spectrometer developed for use in color picture tubes has the ionization source incorporated into the electron-gun mount structure, making the partial pressure measurement refer to the same gaseous ambient to which the cathode is exposed. The analyser sector is attached directly to the neck of the tube; therefore, gas measurement can be made during scanning operation since one of the three guns in the mount is operable.

The picture tube mass spectrometer is used in a normally processed, sealed-off color tube which can then be operated and tested for gas pressures throughout a life test. These tests have shown the following: Prior to getter flash, the residual pressure in the tube is approximately 5 x 10^{-8} Torr, and consists mainly of nitrogen, carbon monoxide, and hydrogen. Several minutes after getter flash a significant drop in pressure occurs; the predominant gases are then methane, hydrogen and argon at a total pressure of 5 x 10^{-7} Torr. Upon subsequent processing, e.g., cathode aging, the total pressure continues to fall.

Results from initial scanning of the picture tube show an increase in nitrogen and carbon dioxide pressure; with a well flashed getter, however, the combined pressure of these gases does not exceed 5 x 10^{-9} Torr. With continued operation, the pressure in the tube is further reduced until after several hundred hours the total and partial pressures do not appear to change appreciably. At this point, the total pressure, caused chiefly by nitrogen and carbon monoxide, is 5 x 10^{-10} Torr. Thus, the total pressure in the tube decreased by a factor of about 10^5 Torr from immediately following exhaust (before getter flash) until after several hundred hours of operation.

The picture-tube mass spectrometer can also define getter performance. In this procedure gas is admitted into the funnel at a constant rate, simulating the gas sources from bulb surfaces. The steady-state change in pressure of the gettered gas is determined with the mass spectrometer.

Gettering action is described by the ratio between the gas inlet rate and the pressure change at the cathode. This ratio has the same units as pumping speed (liters per second), but it is not equal to the pumping speed of the getter for the gas under test, unless this quantity is very small. The ratio measures directly the ability of the getter

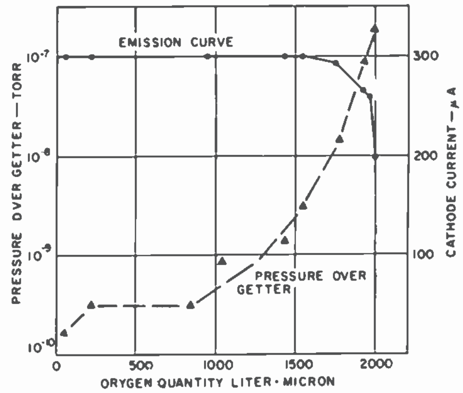

Fig. 6—Oxygen pressure over getter and cathode current as a function of quantity of oxygen absorbed.

to protect the cathode from the test gas and, therefore, its ability to protect the cathode during normal tube operation.

When the mass spectrometer is used to measure change in oxygen pressure as a function of a constant oxygen-inlet rate, and the resulting data is compared to the drop in cathode emission, the results are similar to those shown in Fig. 6. The color picture tube used for this test was a newly processed RCA-19EYP22 tube in which 50 mg of barium fill had been evaporated. From Fig. 6, it can be seen that the cathode emission current decreases to 80% of the initial value at a pressure of about 2 x 10^{-7} Torr. At this point the oxygen capacity is 2000 liter-microns. Many similar tests carried out on new 19EYP22 tubes and tubes which have been operated for thousands of hours indicate that the 80% emission level occurs when the pressure rises to the range 5 x 10^{-8} to 5 x 10^{-7} Torr.

Concluding remarks

Large barium getters have been developed to satisly gas absorption requirements in color picture tubes. Tests evolved to assess gettering ability in production tubes can show whether a getter system is adequate throughout life operation of the tube, and can thus be used to define the getter system.

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