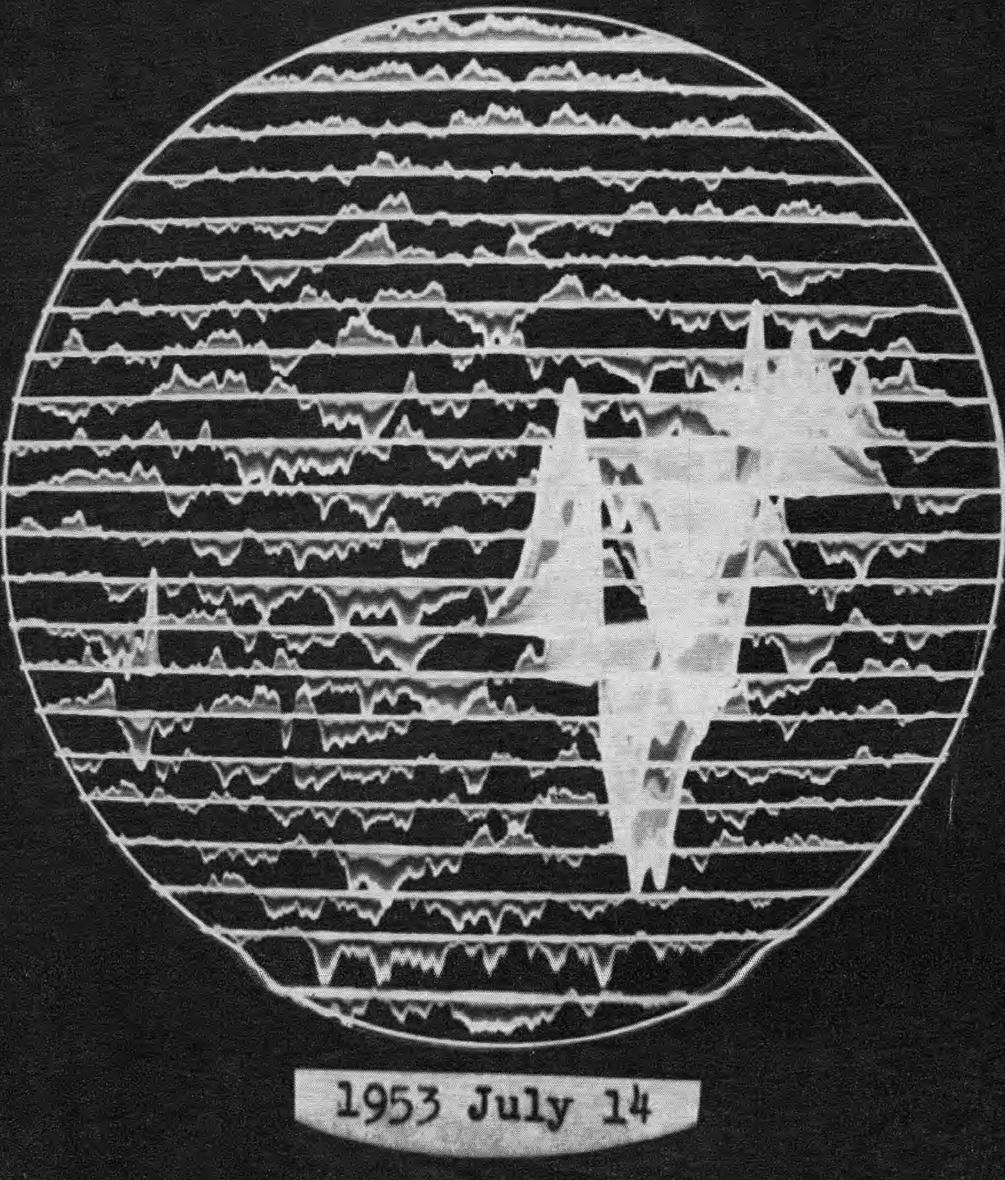
THE
OSCILLOGRAPHER

VOL. 14, No. 4 APRIL-JUNE, 1954



MAGNETIC FIELD OF THE SUN SEE PAGE 2

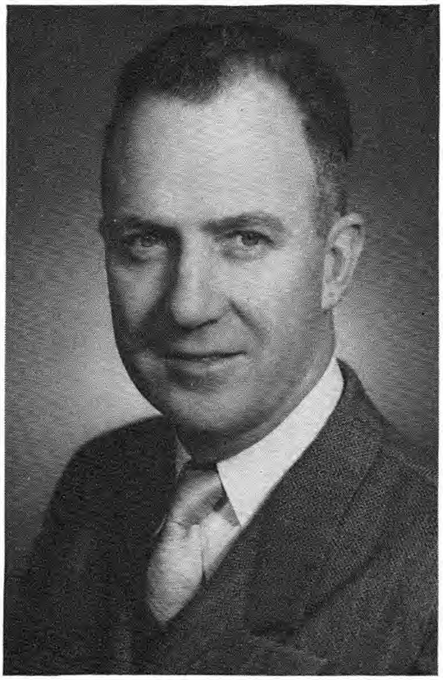
"Who and Why"

Du Mont Selling Agents

Editor's Note: This is the second in a series of articles touching on the highlights in the lives of our Du Mont selling agents throughout the country. No order of selecting reps for subject material has been established. The choice is made at random. During the ensuing issues we hope you will "meet" them all.

Ron Merritt

Ron Merritt got his start in life in Vancouver, Washington, in 1907, making him a native in the territory where he operates. Although Ron's parents lived in many parts of the northwest when he was a lad, they settled in



Ron Merritt

Seattle, Washington in time for him to get most of his schooling in that city.

He finished high school in Seattle, and was well on his way through the University of Washington when he was "persuaded" to leave for Los Angles to assist in setting up a manufacturing operation for a tubetester which he had developed. Ron had been holding down a part-time job while going to the

(*Continued on Page* 15)

THE OSCILLOGRAPHER

A publication devoted exclusively to the cathode-ray oscillograph providing the latest information on developments in equipment, applications, and techniques. Permission for reprinting any material contained herein may be obtained by writing to the Editor at address below.

Published quarterly & Copyright 1954 by
Allen B. Du Mont Laboratories, Inc.
Instrument Division
760 Bloomfield Ave.
Clifton, N. J.
Neil Uptegrove — Editor
Art Hoyt — Asst. Editor

PRINTED IN U.S.A.

On the Cover

The photograph shown is a magnetogram of the sun taken at the Mount Wilson Observatory, Pasadena, California. This magnetogram, recorded on a Du Mont Type 304-H, shows the polarity and intensity of the sun's magnetic field for July 14, 1953. The areas of maximum deflection shown are the result of sun spots. The detector uses two multiplier phototubes, and can be used reliably in measuring magnetic field strengths of 0.5 gauss. The photo was taken with a Du Mont Type 296 Oscillograph-record Camera by H. W. Babcock of the observatory.

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Multiplier Phototubes

Light to Power Converters

FOR YEARS THE CONVERSION OF LIGHT ENERGY INTO ELECTRICAL POWER HAS INTRIGUED MEN, BUT ONLY SINCE EARLY WORLD WAR II YEARS HAS THE MEANS BECOME TRUTHFULLY PRACTICAL COMMERCIALLY. THE MULTIPLIER PHOTOTUBE DEVELOPMENT AND MANUFACTURING FIELD IS STILL YOUNG. FURTHER ADVANCEMENTS WILL DEPEND ON PEOPLE OF VISION.

Today, multiplier phototubes can detect illumination from a match five miles away on a totally dark night. The acute sensitivity of modern phototubes makes them adaptable for innumerable practical uses. Their inception has been an important new addition to the electronic industry.

Even though the commercial development of these devices did not really become important until about 1940, they were not an overnight discovery. Ever since Edmond Becquerel first observed the action of light in generating an electric current in 1839, the field of harnessing light energy and its conversion into an electric curent has intrigued men. Many scientists made notable advances in the ensuing years, but until Elster and Geitel enclosed an electron emitting surface within an evacuated glass envelope in the 1890's, the multiplier phototube was impractical. One of the very first modern-day practical mul-

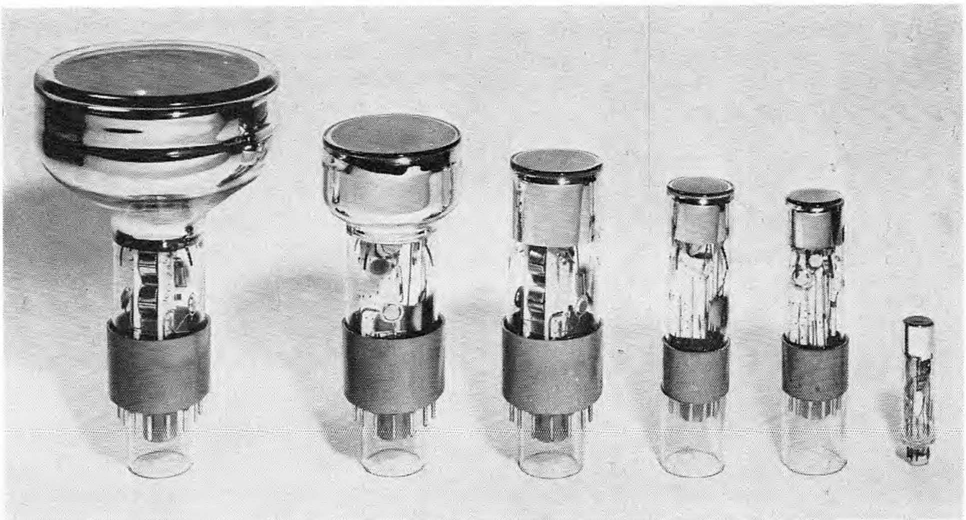

Figure 1. A display of typical modern multiplier phototubes. Shown are Du Mont Types 6364, 6363, 6292, 6291, 6467 and K1211, ranging in diameter from five inches to ¾ inch

tiplier phototubes, designed by Iams and Salsberg, had a then startling amplification factor of six. Those gentlemen laid the foundation for phototube designs of today that have amplification factors up to several million.

Multiplier phototubes are now more sensitive to light than the human eye; they can detect light outside of the color range of human perception. They react much faster than the human brain; the time lapse between illumination of the cathode surface and the flow of current is in the order of hundredths of millionths of a second. They are applicable in many instances where inaccessibility or susceptibility to injury prevent direct human contact, such as for radio-active material detection or mining. Because of their high sensitivity and reliability, multiplier phototubes have a use in nearly every field of industry.

Theory of Photo-Emission

There are three types of electron-emission that are of concern to the multiplier phototube manufacturer: photo-electric emission—caused by a visible radiation, secondary emission — caused by impact, and thermionic emision — caused by heat. The first two types of emission are advantageous, while thermionic emission can be detrimental in phototubes and is normally minimized as much as possible. The action of multiplier phototubes is essentially a combination of the photo-emission effect of electrons and secondary emission effects.

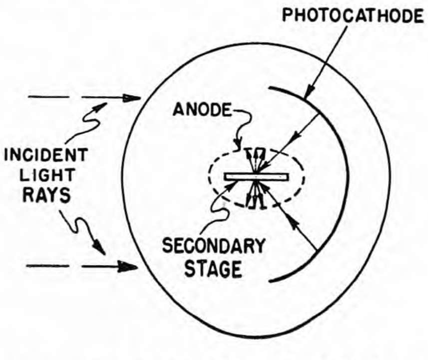

Figure 2. Principle of an Iam-Salzberg phototube, one of the earliest successful multiplier phototubes. The amplification factor of this tube was approximately six

The actual formation, or release of usable electrons for current in a multiplier phototube is the result of *photo-emission,* which is best explained by the quantum, or corpuscular theory, which states that light is energy which occurs in discrete amounts called photons or quanta. The photon energy in any ray or beam of light is directly dependent on the color (frequency) of the light and a factor called Planck's constant.

It has also been theorized that all substances have a certain number of free electrons; that is, electrons that are weakly held, and are restrained only by forces at the surface of the material. Naturally, some materials have more free electrons than others. If enough radiant energy from an outside source falls on the surface of these materials, electrons near the surface can gain enough energy to leave the surface. The amount of energy required to free an electron from a substance is known as the *work function* of the substance. The work functions of some substances are low enough that photons of light falling on their surfaces will cause free electrons to be emitted, much the same as a drop of water is freed from the surface of a pond when a stone is thrown in. Like the drops of water in the splash just mentioned, however, the electrons will return to the surface unless another outside force attracts them away. This is accomplished in phototubes by placing a positively charged electrode near the photo-cathode to draw off the electrons freed by the light.

There are many materials with a work function low enough to permit photo-emission. Some of the more useful are lithium, sodium, potassium, rubidium and cesium, all of which are alkali metals. Surfaces of some metals can be treated by adding an oxide layer, so that their emission potentialities will increase. Even some alloys, such as silver-magnesium and barium-aluminum, have been successfully used for emission surfaces.

The emission of electrons from a surface, due to light impinging on it, is proportional to two factors; the frequency of the light wave, and energy of the light,

$W = hf$, where:

f is frequency
h is Planck's constant
and W = light energy in photons

and the amount of light impinging on the surface.

$$E = \frac{F}{A}, \text{ where:}$$

E = illumination
F is light flux
A is area on which the light is incident

The light standard for determining color (frequency) or sensitivity measurements in the illumination field is that light obtained from a tungsten incandescent lamp operated at 2870°K. A plot of wavelength in Angstrom units vs. relative energy output for this light is shown in figure 3. The arrows enclose the limits of light visible to the human eye, about 4000 to 7000 Angstroms. This curve shows that the greatest radiated energy from such a lamp is not within the visible limits. However, these are not the limits for the multiplier phototubes, since many have a much wider range of sensitivity than the eye.

Sensitivity is the relationship between the number of free electrons, or current, emitted from a surface for a given amount of light flux impinging on it and is usually expresed in microamperes per lumen.

Even at best, the efficiency of the photoelectric effect is poor. Current (electrons) obtained from an emissive surface for low light intensities must be amplified to be of any value. An excellent method of amplifying photoemission currents, the method used in virtually all multiplier phototubes, is to harness the *secondary* emission in some way.

Secondary Emission Theory

When electrons impinge on certain surfaces with sufficient energy, the work function for freeing electrons within the surface may be overcome upon impact. For each primary electron that strikes the surface many secondary electrons may be emitted. The kinetic energy of the electrons hitting the surface will determine the number of secondaries produced.

As with electrons freed by incident light, electrons freed by impact will regroup and return to the emitting surface, or to another nearby electrode at a more positive potential. Therefore, electron ballistics is an important consideration in the design of a multiplier phototube. The velocity of impinging electrons, and their path in an electric or magnetic field are factors as important as the type of secondary surface used. The Du Mont method of utilizing

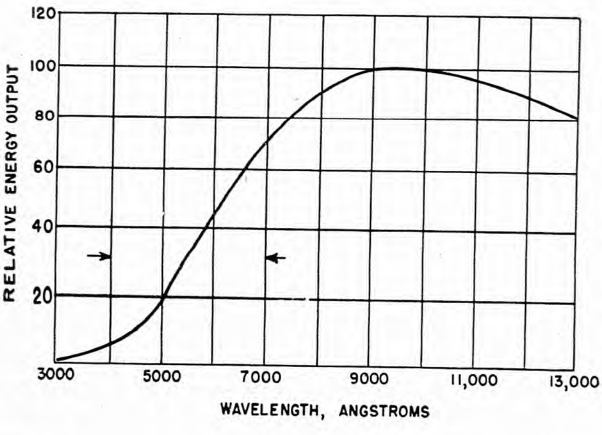

Figure 3. Spectral curve of a light standard tungsten incandescent lamp operated at 2870°K

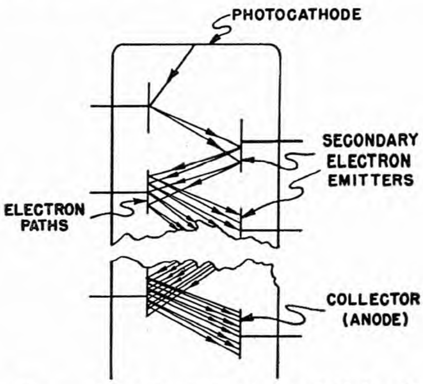

Figure 4. Basic operating principle of multiplier phototubes

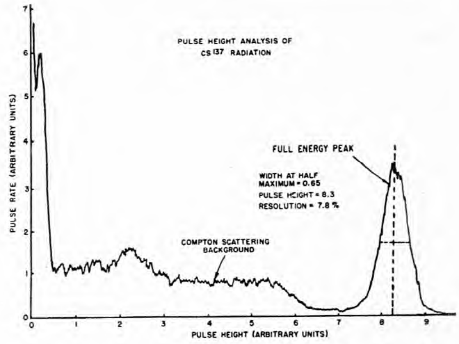

Figure 5. Pulse height analysis of cesium radiation, depicting method of calculating resolution of a typical pulse

the secondary emission effect and harnessing of the resulting current in multiplier phototubes is discussed later in this article.

Du Mont Design of Multiplier Phototubes

The working principle of most modern multiplier phototubes is as follows: light falling on a light sensitive photocathode causes it to emit free electrons, which are drawn away from the photocathode by an electrode having a more positive potential. The collected electrons are then focussed by various means on a secondary emission stage which has an even more positive potential. Each primary electron striking this secondary stage will free more electrons, which are drawn to the next more positive secondary emission stage. The process is continuous, each stage having a more positive potential than the previous one. The electrons emitted from the last secondary stage are collected at an anode and the resulting amplified current is passed to the accompanying circuitry (see figure 4).

Many working designs of phototubes have appeared in the market, each one an attempt to better the preceding one in the method of obtaining a higher rate of photo-emission and in the collection of the resulting electrons. Du Mont enginers concluded that the greatest need in the phototube market was for a tube with stability and long life while remaining a highly sensitive device.

Du Mont designs utilize the end window, semi-transparent type of photoemissive surface—appropriately called a photocathode—rather than the side window type. The primary advantages of the end window are (1) it permits the light to impinge on one side while the emission takes place from the other side, enabling easier mounting in any piece of equipment; (2) light collection efficiency is greater, and (3) manufacturing techniques are simpler. Of all the transparent photoemissive surfaces mentioned previously, the best "all around" surface—the one with the longest stable life, and the one used in these tubes—is cesium-antimony.

Most of the noise in the output of a phototube is the result of statistical fluctuations of the photoelectron current. The result of a constant amount of light impinging on a photocathode does not always give a constant rate of emission, but varies around an average value. Cesium-antimony has been found to give a high average value of photoelectron current which—according to the theory of statistics of random processes—gives a high ratio of average current to deviations from this value. In other words, cesium-antimonv photocathodes in multiplier phototubes give a good signal-to-noise ratio. As observed on a cathode-ray oscillograph or pulse analyzer, the very favorable signal-to-noise ratio permits a low ratio of average pulse heights to pulse widths at half amplitude (see figure 5). This is another way of saying it yields good energy resolution as is desired in scintillation counting. Good resolution in a phototube is a desirable feature in scintillation counting because it allows differentiation of energies of nuclear particles even when these energies are of very similar values.

Styles of secondary emitting stages vary even more than styles of photocathodes. The physical arrangement of the secondary surfaces may take many forms, some of which are shown in figure 6. The cascaded box type structure of secondary emission stages, called dynodes, was adopted at Du Mont after careful study and comparison with other successful dynode structures, such as the squirrel cage and linear types. The primary reason for such a decision is found in the fact that electron focussing from dynode to dynode in the cage and linear types is too dependent on proper adjustment of stage voltage, while in the box type it is not. Since Du Mont tubes utilize 10 dynode stages or more, (see figure 7) good focussing without the necessity of a tedious adjustment was a major consideration when the choice was made.

As with photocathodes, there are several good secondary emitting surfaces.

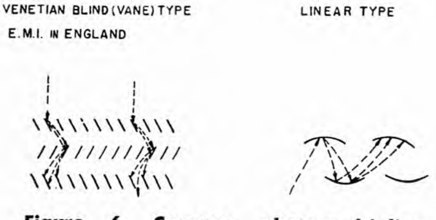

Figure 6. Common photo-multiplier dynode structures

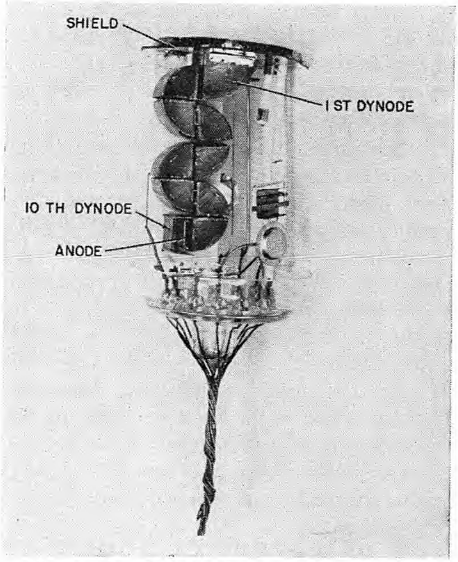

Figure 7. Photo of a partially completed multiplier phototube, highlighting the box dynode structure and electrically separate shield

Secondary emitting surfaces chosen for multiplier phototubes are usually cesium-antimony or silver-magnesium. The latter is used in Du Mont tubes because it has very stable secondary emitting characteristics over long periods of time. The replacement of electrons emitted from the dynodes is accomplished by connecting each dynode electrically to an external source.

The stability of silver-magnesium dynodes has been established in the field. Du Mont Type 6292's equipped with silver-magnesium dynodes have been operated for days in television equipment, such as flying spot scanners, without any adjustments for change in signal output level. In one instance, Du Mont tubes have run for 120 continuous hours at an output of 2 ma without observable change in output.

Research into electrode design and their development has made possible nearly 100% electron collection in Du Mont Multiplier Phototubes. The first dynode has a larger area than that in most tubes in order to enhance the collection of photoelectrons, which are emitted in varying directions owing to electrical fields within the tube. In addition, most Du Mont multiplier phototubes utilize a shield that, contrary to most designs, is electrically separate from other dynodes so that its potential can be varied to obtain optimum focus and collection of the photo-electrons (see figure 7). The shield in the 1-½-inch tube, and in the tubes of smaller diameters, is not electrically separate since the smaller diameters permit easy collection of photo-electrons from all parts of the photocathode. The multiplier structure as employed by Du Mont yields low leakage current, lessening unwanted noise. This results from the fact that the high-voltage dynodes are relatively far from the low-voltage dynodes in the linear cascaded box design.

Circuit Theory of Multiplier Phototubes

Some knowledge of electronic ballistic theory is necessary for an understanding of the dynode focussing principle of multiplier phototubes. In any electrical field there is an equipotential line which is always perpendicular to the intensity lines of a field. Therefore, if one has a plot of either field intensity vectors or equipotential lines, the trajectory of an electron placed in the field may be predicted. By varying the potential field, control of the electron velocity may be achieved; and by varying the field configuration (contour), control of the electron path may be achieved (see figure 8).

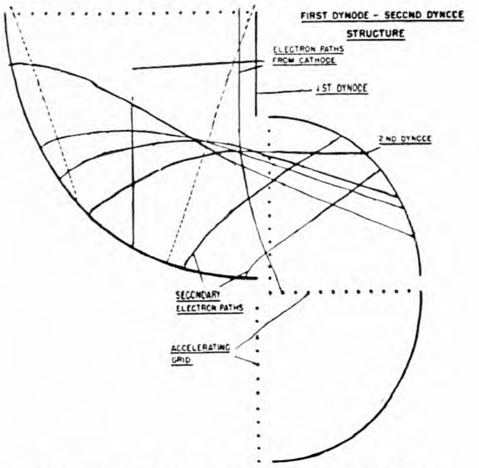

Figure 8. Sketch of field configuration for first three dynodes of a multiplier phototube

The contour of the field in phototubes with box type dynodes is inherently good. The electrons emerging from the photocathode are virtually enclosed in an escape-proof path down the linear structure of dynodes to the collecting anode at the opposite end.

The control of field intensity, thus—the control of electron speed—is accomplished by a separate potential connection from each dynode to an accompanying socket pin. The following applied voltages in Du Mont 10-stage multiplier phototubes over 1-½-inch diameter will yield optimum performance; a minimum of 200 volts between dynode one and the photocathode, although 350 volts may be applied if available; shield voltage close to that of the photocathode (about 30 volts above photocathode); then, starting with voltage between dynode and and dynode two, a voltage ratio of approximately 2-2-1-1-1-1 etc., down to the anode. If the stage voltage is raised too high (in an attempt to obtain higher multiplication), a point of instability could be reached due to the residual gas ions in the tube or breakdown between dynode leads.

Amplification of 150,000 will result from the application of 100 volts between each dynode stage of a typical Du Mont Multiplier Phototube, as can be seen from the graph in figure 9. The maximum average current which this particular tube will deliver at the anode is 5 ma; it can be seen, therefore, that the photocathode current is in the order of millimicroamperes. Total multiplication in a multiplier phototube of n stages may be calculated, if the secondary emission ratio (ratio of current leaving to current entering per stage) is known, by raising the secondary emission ratio to the nth power. If the secondary emission ratio is 3:1 per stage for a 10 stage phototube, the overall multiplcation will be 3^{10}.

The approximate current output of a multiplier phototube can be calculated

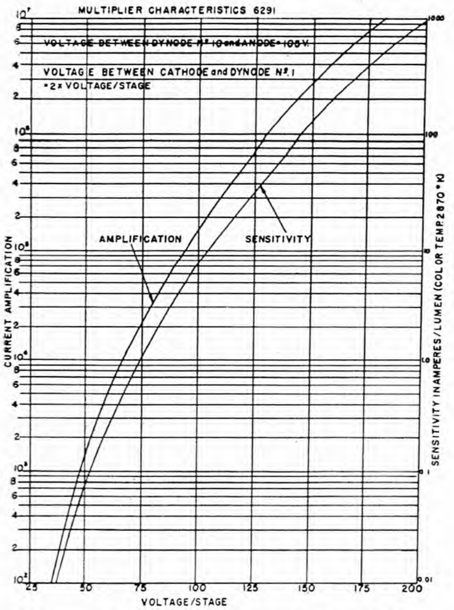

Figure 9. Graph of current amplification at varied stage voltages for a Du Mont Type 6291 multiplier phototube

for operation under any light conditions if the sensitivity of the tube is known. If the light source is steady, the method is as follows: using a curve such as shown in figure 9, determine the current amplication for the particular voltage per stage being used. Determine the strength of the light source with a light meter, then use the formula:

$I_a = SLG$, where:

S = sensitivity in uamp/lumen.
L = light input in lumens,
G = current amplifications,
and I_a = anode (or current) output.

Where the light source is not steady (radio-active pulse counting in the presence of steady light from a window, for example) the formula is:

$I_a = S(L + \triangle L)G$, where $\triangle L$ is the light strength from the unsteady source.

It follows that I_a, steady light component = SLG, and

I_a, variational light component=$S\triangle LG$

Referring to figure 10, it can be seen how the current emitted from the photocathode is built up by secondary emission on the multiplier stages, the multiplication for this case being about thre on each stage. Although the application of the photomultiplier will determine the circuit in which the tube is to be used; the circuit shown in figure 10 is typical, and will serve as an aid in explaining choice of voltages and components.

In this circuit, rather than using a single 1100 volt supply, a more economical circuit with separate positive and negative supplies, and the ground connection at the eighth dynode is utilized. Such a connection is more economical for many reasons:

1. Plate supply voltage of about 300 volts and sufficient capacity is usually available in the associated equipment and can be used as the positive supply.
2. Lower voltage reduce the cost of the required negative supply.
3. Bypassing, if required, may be accomplished with capacitors of lower voltage rating.
4. Smaller current, demanded of the negative supply, simplifies filtering in a-c operated equipment and reduces the cost of the supply.

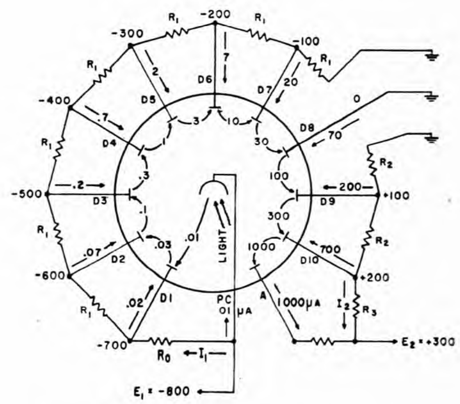

Figure 10. Schematic of a typical multiplier phototube circuit, showing currents, where stage multiplication is assumed to be three

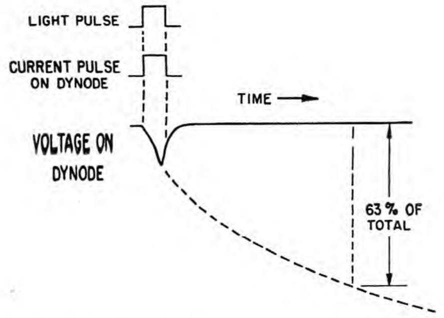

Figure 11. Illustration of principle behind selection of bypass capacitors. At 63% of total, time constant of selected capacitor combined with an individual resistor in the circuit should be 10 times longer than the time of the average light pulse encountered

The current flowing through the bleeder resistors will determine the voltage between any two stages. In any application, therefore, the individual stage currents should be computed and corrections to the divider made. As a "rule of thumb," however, the divider is usually composed of equal resistors selected to provide a bleeder current of 5 to 10 times the greatest current taken from any tap on the divider. For the case shown in figure 10, the largest current taken from the negative divider is 20 microamperes flowing to the seventh dynode. Accordingly, a typical bleeder current in the negative divider would be 200 microamperes, and for the indicated voltage of 100 volts per stage, each resistor R_1 of this divider would have a value of 500,000 ohms. In the case where the photocathode-to-first-dynode potential is twice the potential per stage, the resistor R_0 would be twice the value of the other divider resistors, and the negative supply potential increased accordingly.

The greatest current taken from the positive divider, represented by the two resistors designated R_2 and R_3, is 700 microamperes — flowing to the tenth dynode. The bleeder current in the positive divider, for this case, would be typically 7 milliamperes. Note that if the tube were operated from a single 1100 volt supply, the current being 7 milliamperes, the resulting power demand would be 7.7 watts. This is in comparison to approximately 1/6 watt from an 800 volt negative supply plus 2.1 watts from the 300 volt positive supply, resulting in a total power demand of about 2.3 watts.

Frequently the light-input is in the form of short pulses which have a low average value. When such is the case, the bleeder current in the divider may be assumed to be 5 to 10 times the greatest average current demanded from any tap, and bypass capacitors can be used to supply the peak currents to the dynodes. The capacitors used should be of a size adequate to maintain response to the lowest frequencies encountered in the light-input variation. As another rule of thumb, a capacitor is selected which, together with an individual resistor in the divider, has a time constant of ten times the pulse time (width) ; see figure 11. If the overall voltage is divided between positive and negative supplies, electrolytic capacitors can be advantageously used in bypassing the taps of the positive divider.

Stray capacitance is usually adequate for bypassing the first three or four dynodes since the change in potential due to current from any pulse of light would not be large enough to necessitate bypassing. This can be seen by

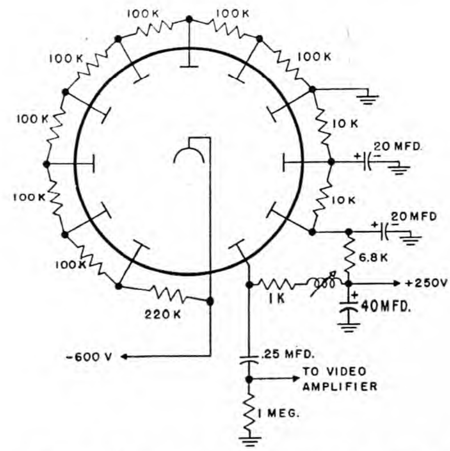

Figure 12. Typical phototube circuit used in a flying spot scanner

calculating with the values of the typical circuit in figure 10, and assuming the bleeder resistor R_1 to be a typical 100,000 ohms.

Where $\triangle E$ is the change in voltage, and I_{d1} is current to the first dynode, change of voltage at the first dynode would be:

$$\begin{aligned} E_1 &= I_{d1} \times R_1 \\ &= I_{d1} \times \text{source resistance} \\ &= (.02\ \text{ua})\ (100\text{K}) \\ &= 2 \times 10^{-8} \times 10^5 \\ &= .002\ \text{volts} \end{aligned}$$

Change in voltage at the eighth dynode, however, would be appreciable and require bypassing.

$$\begin{aligned} E_8 &= I_{d8} \times R_1 \\ &= 70\ \text{ua} \times 100\text{K} \\ &= 7 \times 10^{-5} \times 10^5 \\ &= 7\ \text{volts} \end{aligned}$$

Figure 12 shows a complete circuit as might be used for a flying spot scanner. In this circuit no bypass capacitors are used on the negative side of the divider since the impedance is so low that dynode current loading causes in insignificant change in dynode potential. Simple shunt peaking is used in the anode load circuit to permit use of higher load resistor without loss of bandwith.

Power Supplies

The design of power supplies for use with multiplier phototube circuits will in some cases require special consideration, but some general recommendations can be made. The simple resistance divider will be found adequate for most applications since it permits control of overall gain through a simple adjustment of voltage. As an example, performances of the Du Mont Types 6291 and 6292 Multiplier Phototubes are not adversely affected by unequal stage potentials. Therefore, an adjustment of the negative supply potential provides the most convenient means of gain control. Regulation of power supplies is not generally necessary if bypassing is used, and if the bleeder current is large enough. Where stability of gain is important for critical applications, regu-

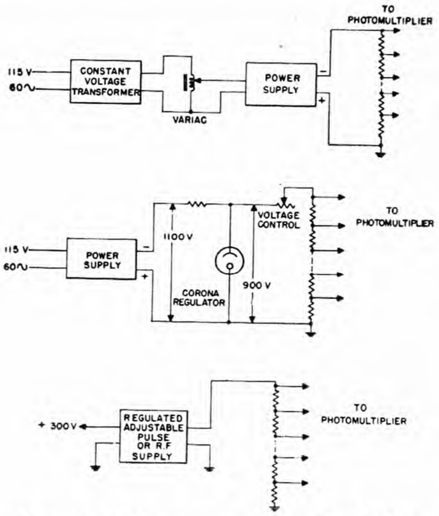

Figure 13. Some power supply circuits for obtaining necessary voltage to operate multiplier phototubes

lation of power supplies is a necessity because gain varies directly with stage potential. Using voltage regulator tubes in place of the voltage divider will give such regulation.

Figure 13 shows three typical methods of obtaining the required negative potential. Since multiplier gain varies from tube to tube, a range of supply potential of not less than 1-½ to 1 should be provided.

In those applications where the photomultiplier may be subjected to more than normal light input, protection against excessive anode current is recommended. A method which has been usd with success employs a circuit as shown in figure 14. An overload relay in the anode circuit of the photomultiplier removes power from the divider when an anode current exceeds the maximum average rating. When the overloading conditions have been corrected, power is reapplied by operating the reset button.

A signal of reverse polarity may be required in some applications. Referring to figure 10 again, it can be seen that the direction of current in the tenth dynode lead is opposite to that in the anode. If some loss in output can be tolerated, a signal of reverse polarity

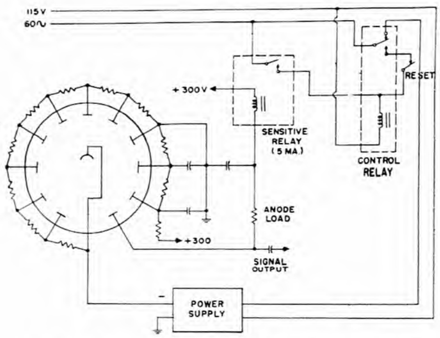

Figure 14. An overload protection circuit for multiplier phototubes. Maxi mum current allowed by this particular circuit is 5 ma

may be obtained from the tenth dynode (or whichever dynode comprises the last multiplier stage) while using the output from the anode at the same time.

What Constitutes A Good Design

Concentrated research by multiplier phototube development engineers, seeking goals of high sensitivity and high signal-to-noise ratio with the best in stability and long life, has made possible photomultipliers that surpass the fondest expectations.

One of the greatest contributions made by the Du Mont multiplier phototube development engineers is the high signal-to-noise ratio tube; probably the most difficult problem encountered by any company in the design and manufacture of phototubes. This high signal-to-noise ratio is possible because leakage is insignificant, being in the order of .01 ua at 106 volts per stage and less than .003 ua between the cathode and the whole multiplier structure. These phototubes are exceptional in their ability to collect a very high percentage of the electrons emited from the photocathode. Except in the smaller tubes, electron collection is enhanced by the electrically separate shield and the large area of the first dynode. The chance of losing electrons in the multiplier structure, owing to spurious deflection, is practically impossible because of the box type dynode structure.

Excess light will not damage the photosensitive surface of a good tube, but heat from excessive light possibly could. Even if the tube has been badly affected as a result of exposure to the heat of direct sunlight, often the tube can be rejuvenated by placing it in a cool; dark place for several days.

Of course there are still a few inherent problems in multiplier phototubes that engineers are striving to eliminate. Being able to alter the voltage on an electrically free shield, thus permitting partial compensating adjustment for misalignment of dynodes (virtually impossible to eliminate) is an example. A further look into the problems of phototubes and corrective design features used may establish the difficulties encountered by multiplier phototube engineers.

The biggest problem, dark current, or noise, seems to come from two primary sources; leakage from dynode to dynode caused by photo-emission from cesium deposits on the ceramic structure of the multipliers — deposited there when coating the dynodes; and thermionic emission from the various low-work-function metals found on surfaces of the tube. Leakage due to cesium deposits is something that must be contended with, since no method of avoiding these deposits has been found to date. As mentioned previously however, the leakage is insignificant. The following formula shows that by using metals with higher work function, and/or by refrigerating tubes, thermionic emission is minimized.

$$\text{Illum} = AT^2e^{-\frac{b}{T}}, \text{ where:}$$

A = a constant
T = temperature, and
b = a constant dependent on work function

Sensitivity of phototubes is not the same for every color over the visual spectrum range. Figure 15 illustrates the spectral response of some surfaces used on multiplier phototubes. It has

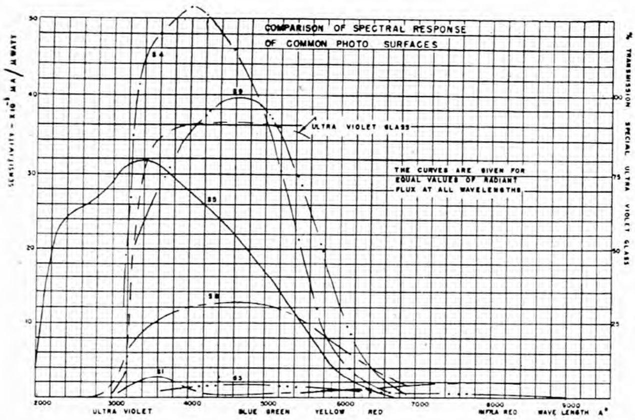

Figure 15. Spectral response curves for various types of common photo-emission surfaces. Dotted line depicts spectral response for special ultra-violet-light sensitive tube made by Du Mont

been found that the introduction of certain complex oxides in photocathodes will increase the emissivity and shift the emission threshold toward the red end of the spectrum, but the practice is not common. Not shown in this figure is the spectral response of an infra-red sensitive surface which Du Mont produces. Further information on the surface can be obtained by contacting the Laboratories directly.

So far as ultra-violet light is concerned, it is necessary to use special glass in the tube to pass the signal. While many glasses are available, such as quartz or special types of silica glass, they are expensive and difficult to work with. Du Mont has a glass available which is relatively inexpensive and can be used for these special tubes. The spectral transmission curve for this special glass is shown as a dotted line in figure 15.

Applications of Phototubes

Applications for multiplier phototubes are many, and probably many uses will be unveiled in the future. Applications, so far, seem to fall into three main classes: television, nuclear physics, and industrial devices.

The photomultiplier is utilized in the television industry primarily in the television flying spot scanners. The principle of the flying spot scanner is shown in figure 16. A moving beam of light, emanating from a cathode-ray tube, is focused on either a transparent or opaque material. The light reflection from or transmitted through the material, containing the picture information, is picked up by a multiplier phototube and converted into an electrical signal. The electrical signal is amplified and used to modulate a carrier for transmission of the television picture information. This operation is especially suitable for taking information from a movie film for transmission. The advantages of flying spot scanner equipment over television cameras, which are attributed to multiplier phototubes, are several. Some of these are: (1) the phototube costs about 1/30 the price of an image orthicon, and is useful for years while the orthicon's life is seldom more than 1000 hours; (2) the output of the multiplier phototube generally contains no spurious picture information, therefore no special circuitry for eliminating it is required; (3) the output level of the multiplier phototube is

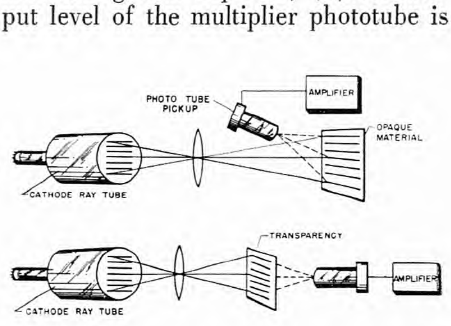

Figure 16. Illustration of the principle of a flying spot scanner

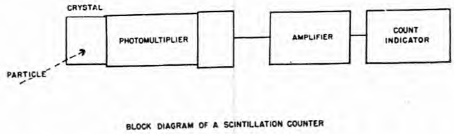

Figure 17. A sketch depicting the physical layout of a scintillation counter

very high and requires fewer stages of amplification. The circuit in figure 12 is that of a flying spot scanner.

The chief use of the multiplier photocell in the nuclear physics field is in the scintillation counter. For a physical layout refer to figure 17. The radiation from a radioactive source is converted into small light pulses of short duration by a scintillation crystal cemented directly to the flat end-window of a multiplier phototube. These light pulses are converted into electrical pulses by the phototube and fed into a pulse analyzer. The output of the analyzer will be a pulse height spectrum—i.e., a plot of the number of pulses per given time versus height.

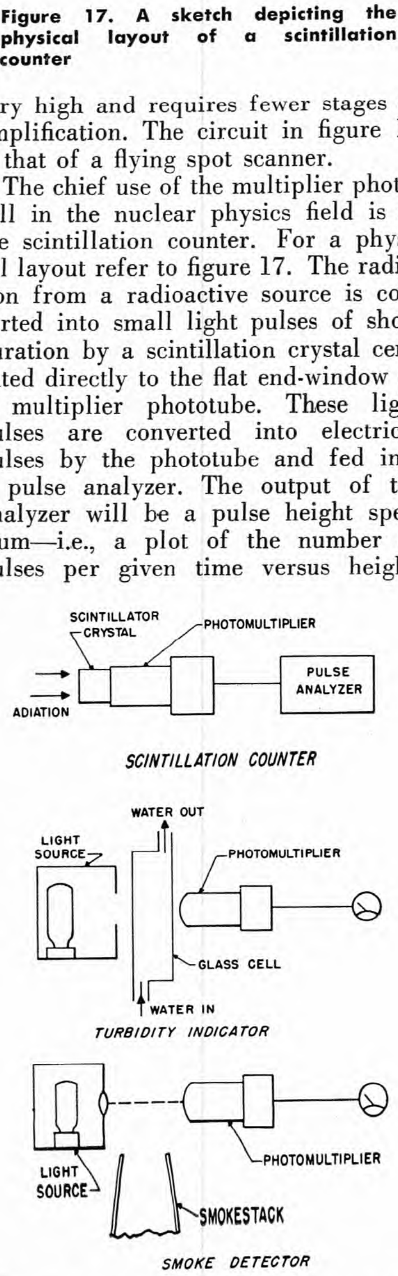

Figure 18. Examples of the wide range of applications for multiplier phototubes

Since each radioactive material has its own distinct spectrum, identification of unknown substances can be made by this method. This operation is useful in prospecting for certain ores. If a detector probe is lowered into a small hole drilled in the earth, it can pick up information for a pulse analyzer on the surface which will reveal the presence and type of radio-active material. Larger multiplier phototubes will be especially suitable for scintillation counting because larger crystals can be used to permit the conversion of a larger percentage of radiation into light pulses, thus obtaining a better statistical average of radiation levels.

Industrial applications of the multiplier phototube are legion. A few of these are outlined in figure 18. Some applications, not shown, include, colorimeters, sorting devices, reading punched cards, and an important one—an automatic light dimmer for automobiles. Small multiplier phototubes, the ¾″ tube for example, are finding wide use in small probes such as may be used for prospecting of radio-active ores, and in radioactive tracing in medicine and surgery.

At present, Du Mont is manufacturing a 5-inch multiplier phototube—the Type 6364, a 3-inch tube—Type 6363, a 2-inch tube—Type 6292, a 1½ inch—Type 6291, a 1¼ inch—Type 6467, and a ¾ inch—Type K1211 Multiplier Phototube.

Phototube engineers are continuing their program of concentrated research and development of multiplier phototubes in order to increase the range of uses. As an example, a tube containing 12 dynode stages, producing better amplification with a higher signal-to-noise ratio for the same stage voltages has just been developed by Du Mont. Tubes with efficiency improvement are now practical and will soon be marketed.

For information on price, delivery and specifications of any of the tubes mentioned, write to the Technical Sales Department, Allen B. Du Mont Laboratories, Inc., 760 Bloomfield Avenue, Clifton, New Jersey.

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Acknowledgment

Information obtained from various technical papers by Dr. Bernard Linden, Mr. R. C. Palmer and Mr. Robert W. Deichert, all of the Tube Development Laboratory staff of Allen B. Du Mont Laboratories, Inc., was used in this article.

"WHO AND WHY"

(*Continued from Page* 2)

university, and in 1931, in addition to doing experimental work on wire recording, he had developed the new tube-tester which turned out to be quite acceptable to the electronic equipment distributors all over the country. After getting to Los Angeles and setting up the tester manufacturing operation, his plans to return to Seattle and finish his formal education somehow became delayed—about twelve years.

During his stay in California, Ron worked his way up from an electronic parts and equipment distributor, while a sales engineering representative, to Sales Manager and subsequently Branch Manager for one of the larger southern California electronic parts and equipment distributors. It was here that he became acquainted with the sale and distribution of Du Mont products.

He returned to native Washington soil in 1943, and worked closely with Boeing on various types of electrical aircraft equipment during the latter stages of World War II. In 1947 Ron decided to hang out his own shingle and stay in the Northwest.

In the seven years that the Ron Merritt Company has been in business, it has progressed from desk space and a part-time stenographer to the point where it now employs four sales engineers, an office manager, and five other employees. They also operate a complete branch office headquarters in Portland, Oregon.

The Ron Merritt Company's formal affiliation with Du Mont started about four years ago, although Ron had sold Du Mont oscillographs during his days in California. Since then, several other manufacturers have appointed Ron Merritt Co. as their Selling Agent. At the present time, according to Ron, his company is almost certainly the principal group of electronic testing equipment specialists in the Washington-Oregon-Montana area.

Ron says he likes the business, and likes his association with Du Mont. The only thing he wishes for is more customers per square mile.

Our Error

In the "Who and Why" story, last issue, we had Walt Knoop graduating from Rensselaer Polytechnical Institute in Schenectady. Actually, we do know that the esteemed institute is in Troy, N. Y., and we apologize for moving it on such short notice.

The New Du Mont Type 323

A Precision Cathode-Ray Oscillograph

IF YOUR DEMANDS ARE BEYOND THE CAPABILITIES OF THE ORDINARY OSCILLOGRAPH, WE INVITE YOUR EXAMINATION OF THIS SUPERB NEW INSTRUMENT.

At the 1954 I.R.E. show in New York, Du Mont unveiled a brand new addition to the field of precision cathode-ray oscillography, the Du Mont Type 323. This new oscillograph is a precision instrument designed to more than satisfy the most critical user. The complete range of laboratory requirements for low-frequency, medium-frequency and especially high-frequency oscillography are fulfilled at the same time with the new Type 323. Throughout the entire design of the Type 323, the goal remained constant, precision measurement over a wide range. Every feature of the instrument has been engineered to complement every other, making it a completely integrated instrument. There has been no compromise with quality.

The new Du Mont Type 323 embodies a number of unique, modern features designed specifically for the exacting problems of today. All power supplies, including the high-voltage power supply and filament supplies, are electronically regulated to give a stable operation and calibrated accuracy over a long period of time. This is the first cathode-ray oscillograph to incorporate one of the newly developed Du Mont mono-accelerator cathode-ray tubes, which offer high-precision tolerances, uniform focus and virtually no field distortion. Another notable feature is the single-time-constant sweep which is applied directly at high level to the deflection plates to assure linearity. Because of the highly linear sweep, precision sweep controls and virtually distortion-free cathode-ray tube, accurate time measurements can be obtained directly from calibrated dials on the front panel.

In keeping with the exceptionally accurate time base is the newly developed Du Mont "notch" sweep. The "notch" is a new concept in signal expansion on the time axis. It permits a two-inch segment of the sweep to be instantaneously and accurately increased in speed by a factor of ten to provide expansion of that trace segment. The "notch" segment is movable so that any expanded portion of the normal four-inch signal can be observed in proper relation to the unexpanded portion.

An accurate standardizing potential for full scale Y-sensitivity adjustment, a direct-reading calibrated scale, and eleven precision voltmeter ranges from 0.2 volts full scale to 400 volts full scale make the Type 323 an accurate and versatile amplitude determining device—essentially a cathode-ray tube voltmeter.

Finally, to make the most uniform product possible, and to provide a rugged yet accessible instrument, printed wiring has been used extensively throughout the Type 323.

Calibrated Sweeps

Previous efforts to design truly accurate, directly calibrated sweeps have been limited by the difficulty of eliminating non-linearities created by non-linear devices in the instrument. Sweep amplifiers could not be made linear on all ranges. Previously available cathode-ray tubes, particularly high-voltage cathode-ray tubes, introduced further deflection distortion. Sweep-tube characteristics were changing with age, over even a relatively short time, which causes changes in calibration; this necessitated frequent readjustment of each range. Recognizing these deficiences, Du Mont in the past has used a timing wave substituted for the Y-signal, or has added blanking markers to assure accurate readings along increments of the sweep. This system had the advantage of guaranteeing calibration accuracy over small portions of the sweep, despite sweep non-linearity, tube aging or deflection distortions in the cathode-ray tube.

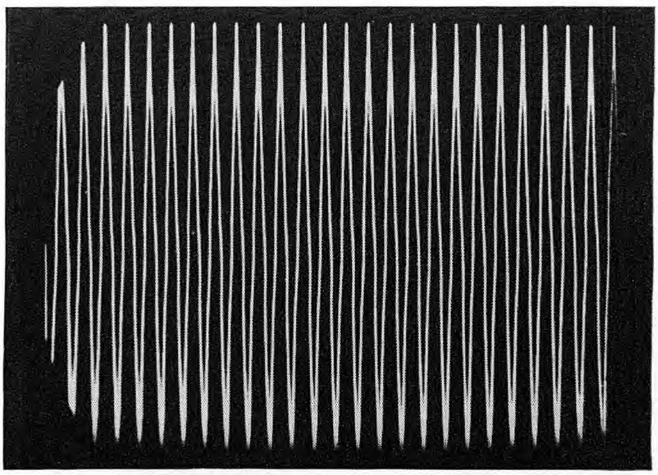


Figure 2. A very low-frequency triangular wave, showing the excellent spot size, resolution and freedom from distortion over the entire scanned area. Cut off portions on each end of the wave were caused by the bezel

Now, in the Du Mont Type 323—with the newly developed single-time-constant sweep, the new "notch" sweep expansion and the Du Mont mono-accelerator—a precise and direct front-panel reading calibrated sweep with long lasting accuracy has been made an accomplished fact.

The single-time-constant sweep used in the Type 323 is a Du Mont innovation to provide the most linear, and the most easily calibrated sweep known. This sweep relies on a single precision resistor to assure exact sweep duration. The sweep is developed at high voltage level necessary to directly drive the deflection plates of the cathode-ray tube. In this way, sweep linearizing can be accomplished directly within the sweep generator without an intervening amplifier to introduce possible non-linearities. Since d-c potentials are completely regulated, the sweep is extremely stable over long periods of time.

Because the Type 323 has such linear, distortion-free sweeps, it has been possible to utilize direct-reading sweep controls on the front panel. The vernier sweep control is a large precision potentiometer which provides a continuously variable multiplying factor from 1:10. This factor multiplies the sweep-range steps; the steps being determined and controlled by fixed resistors. With both sweep multipliers (designated as MULTIPLIER A and MULTIPLIER B on the front panel), the total sweep-speed range extends in seven steps, from one second to 0.1 microsecond per major scale division, in continuous calibration.

The single-time-constant sweep enables the use of a single control at the side of the instrument for completely recalibrating the entire range of sweeps simultaneously with one simple adjustment. Though seldom necessary, this simple calibration could be performed every time the instrument is used to assure maximum accuracy of sweep calibration. The instructions for making this calibration are fixed to the side of

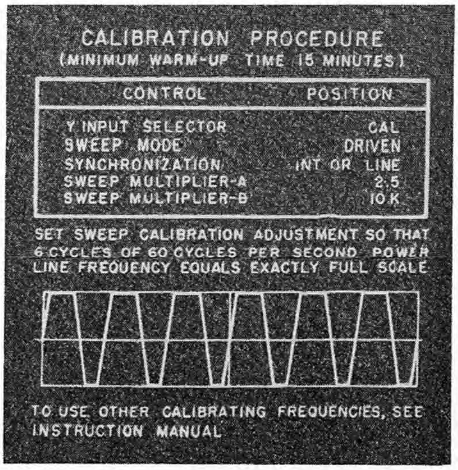


Figure 3. Directions for completely recalibrating the entire range of sweeps simultaneously, with one adjustment, are fixed to the side of the instrument

the Type 323, adjacent to the calibration adjustment (see figure 3). For most purposes, the 60-cycle power line frequency, available as the calibration frequency in the Type 323, is sufficiently accurate (usually within 0.5%) for setting up the calibration. For greater accuracy in recalibrating all ranges another more precise signal may be inserted. For even greater accuracy of time calibration on a given range, a highly accurate frequency standard may be substituted at a desired point of the MULTIPLIER A dial, and the calibration accuracy at nearby points will be better than 1%. This corresponds to a maximum error of approximately one spot diameter. The calibration process is a simple matter. The one control used insures that, as tubes in the sweep generator age, the complete range of sweeps can be kept in accurate calibration at all times although the calibration should seldom be necessary even under constant use. Overall calibration accuracy is better than 5%.

"Notch" Sweep

Complementing the highly accurate calibrated sweep is the new Du Mont

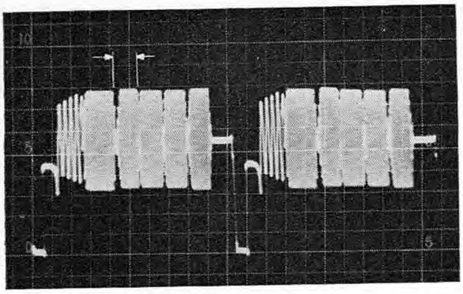


Figure 4. Waveform of a series of frequency bursts for checking frequency response characteristics in color television systems; shown in a conventional presentation

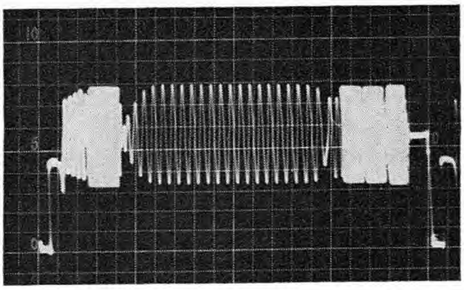


Figure 5. The portion of the waveform between the arrows in figure 4 is shown here with the "notch" expanding that portion 10 times. The rest of the waveform remains conventional

"notch" sweep. With this new concept of sweep expansion, a segment two major scale divisions wide (two inches), of the four covered by the sweep, is instantaneously speeded up by a factor of ten on all ranges but the two highest. On the highest range it is speeded by a factor of five. The notch is switched in or out at will. The notch is an integral part of the sweep, thus any signal that is stably presented on the calibrated sweep will be stably expanded in the calibrated notch. By use of this notch expansion, the true relationship of the expanded portion of the signal to the remainder of the signal is never lost.

The notch is movable, its position on the sweep being governed by a calibrated control designated NOTCH DELAY on the front panel. By use of the NOTCH DELAY control the notch can be moved as a strobe on all sweeps except the fastest, to cover the entire four major scale divisions. The NOTCH DELAY dial can be set to zero relative time, and a concentric notch ZERO control used to start the notch at the beginning of the trace, regardless of the range. Then the NOTCH DELAY is

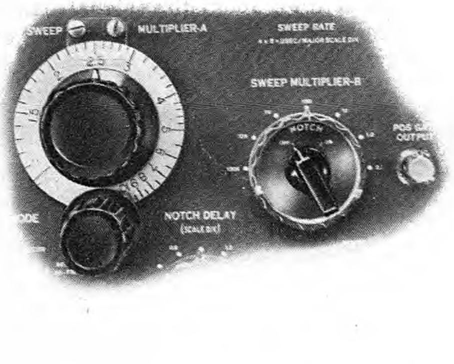


Figure 6. By multiplying two readings, from vernier dial MULTIPLIER A, and the stepped switch MULTIPLIER B, the time between major scale divisions is precisely determined. To measure the duration of a pulse, merely adjust the vernier until the pulse occupies a major scale division, then read the pulse width as the product of A x B. The multiplication is easy since MULTIPLIER B reads in decade steps

operated to move the notch any desired distance along the trace, and the number of divisions moved read directly from zero on the scale. Time in microseconds of the notch movement can then be obtained by multiplying the NOTCH DELAY reading by the product of the MULTIPLIER A and MULTIPLIER B readings. This feature may be useful in making such time measurements as pulse rise time, time between pulses, pulse width, etc. The extremely long total notch delay available is 2,200,000 microseconds on the slowest sweep.

Since the notch is always an accurate multiple of sweep speed, signals within the notch may be measured with high accuracy. To find the time between major scale divisions in the notch, it is only necessary to multiply the MULTIPLIER A and MULTIPLIER B product by 0.1 for the lower ranges, and by 0.2 for the second fastest range. Accuracy of the notch multiplication is 5%.

Amplitude Calibration

The Du Mont Type 323 has all the attributes required to be an absolute amplitude measuring cathode-ray voltmeter with an accuracy of better than 5%. Eleven ranges of voltages may be selected to deflect the spot full scale (or two major scale divisions). The ranges extend from 0.2 to 400 volts full scale, and range selection is made by a front panel VOLTS FULL SCALE switch. All eleven of the VOLTS FULL SCALE ranges are calibrated by inserting an accurate 60-cycle voltage standard into the vertical amplifier, by means of a Y INPUT SELECTOR switch on the front panel, and adjusting this signal to full scale.

A-c voltages, d-c voltages, or a-c voltages with d-c components may be measured using the direct reading, edge-lighted scale that is on the instrument. Since the vertical scale is divided into 10 minor scale divisions, reading from 0 to 10, each minor scale division represents 1/10 of the VOLTS FULL SCALE reading. For example, on the 0.2 volt range, each scale division represents 0.02 volts and the number of divisions read is simply multiplied by 0.02 to give the true voltage reading.

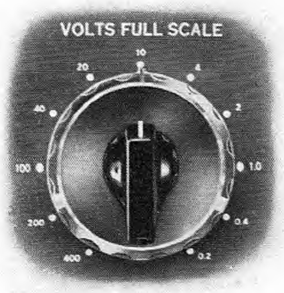


Figure 7. The VOLTS FULL SCALE switch is basically a voltmeter-range switch which determines the voltage necessary to deflect the spot full scale. All 11 ranges of the VOLTS FULL SCALE range are calibrated by inserting an accurate 60-cycle voltage standard into the vertical amplifier by means of the Y INPUT SELECTOR and adjusting this signal to full scale

Because so many ranges of volts full scale so closely spaced together are available, there is virtually no commonly encountered signal that cannot be conveniently scaled on this instrument.

Stabilized Sync

To complement the precision measuring circuits of the Type 323, up-to-date synchronizing circuits to lock all types of signals stably have been incorporated. These sync circuits are of the utmost flexibility to lock the signal stably whether the signal happens to be occurring once, or repeating at near 20 mc.

To handle the very wide range of recurrent signal frequencies and amplitudes likely to be encountered, two controls have been provided. Rather than compromise on a single sync amplifier to handle the wide range of frequencies, the front panel SWEEP MODE switch (see figure 8) has two sync amplifier band-switch positions labeled RECUR and RECUR HI-FREQ. The RECUR position permits signals of medium to low frequencies to be locked in while the RECUR HI-FREQ

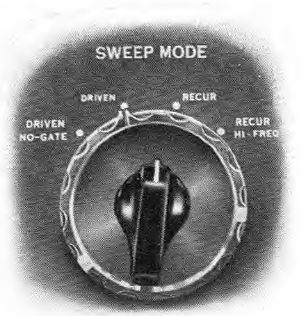


Figure 8. The SWEEP MODE switch selects proper sweep operation for the signal input. DRIVEN NO-GATE for viewing the start of a trace; DRIVEN for transient signals; RECUR for repetitive phenomena to about 10 mc; and RECUR HI-FREQ to 20 mc and higher

permits signals up to 20 mc and higher to be synchronized. For the very large range of amplitudes which the Type 323 is capable of handling, the SYNCHRONIZATION switch (front panel) includes an input attenuator for external sync connections with a 1:1 position for low level signals and a 10:1 position for high-level signals. Other positions of the SYNCHRONIZATION switch permit locking the signal to line frequency or locking the input signal internally.

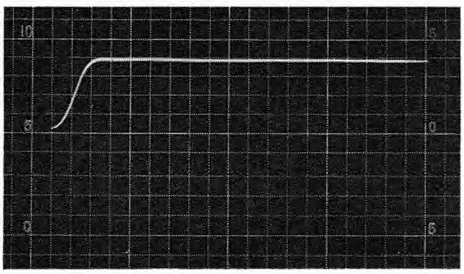
Two additional positions of the SWEEP MODE switch are the DRIVEN and DRIVEN NO-GATE positions. In the DRIVEN position the gate circuit is operative and no spot is seen until the trigger causes the sweep to operate. In the DRIVEN-NO GATE position the gate circuit is disabled and the spot rests at the left of screen. This is very useful with low-level, relatively slow rise time pulses where it is difficult to see the start of the sweep. In addition, with the same amount of sync signal, the DRIVEN NO-GATE position will offer somewhat more base line prior to a fast rising pulse since the gate starting time is not a factor.

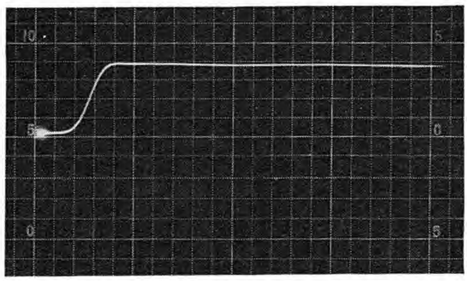
Mono-Accelerator Cathode-Ray Tube

It is only natural that the first instrument to incorporate the newly developed Du Mont Type 5AMP Mono-Accelerator Cathode-ray Tube would be the Type 323. Without the mono-accelerator, the Type 323 could not be the high-precision instrument that it is. On the other hand, without the advanced circuitry of the Type 323, the inherent capabilities of the mono-accelerator could hardly have been realized.

The now well known glass-rod construction developed by Du Mont has been utilized in the mono-accelerator to accomplish the critical tolerances required for this design. Such tolerances as angular alignment between deflection plates are reduced to 1°; deflection factors are held to 10%; while grid cutoff bias is maintained within 25%. All of these represent a 50% increase in tolerance tightening.

All acceleration of the electron beam takes place within the electron gun in these tubes. The screen is at the same





Figures 9 and 10. At left, a very low-level pulse seen with the SWEEP MODE switch in the *driven* position. At right, the same pulse with the switch in the *driven no-gate* position. Note the spot at the left, clearly showing the start of the trace and the additional base line gained by disabling the gate.

potential as the accelerator (A_2) which is behind the deflection plates in the electron gun. Since the electron gun produces a highly resolved, high-current beam, the tube suffers no loss in sensitivity, spot size or brightness at lower accelerating voltages. The uniform field between the deflection plates and screen virtually eliminates field distortion from consideration. The mono-accelerator cathode-ray tubes also incorporate a low-voltage electrostatic focus lens which essentially provides automatic focus over wide variations in accelerator voltage.

The uniform field in the post-deflection region of these tubes prevents the tendency of secondary electrons emitted from the tube walls to migrate to the screen; thus, glow from overscanning is all but eliminated. This feature is of particular value when oscillograms are recorded since there is little or no glow to fog film. In addition, better contrast for recordings is achieved.

All mono-accelerator cathode-ray tubes have flat face plates to reduce measurement error due to parallax.

Regulated Supplies

All power supplies in the Type 323 are electronically regulated to provide maximum stability in all circuits and to assure that calibration remains precise over long periods of operation, and at various power-line potentials.

The low-voltage power supply utilizes selenium rectifiers for good reliability. Also, the low output impedance of the regulated supply minimizes the change of cross coupling between circuits.

The high-voltage rf supply is also regulated. No effect on the amplitude or sweep calibration can be detected regardless of power-line voltage variations within the ± 10% limits specified. Nor is stability affected by variations in duty cycle, as for example between a single transient and a high-frequency sine-wave.

Filaments of the Y-axis d-c amplifier, and two tubes in the sync circuits are placed in series with the cathodes of the balanced power output tube in the Y-axis. This design feature provides very excellent d-c regulation and eliminates hum.

Mechanical Layout

To assure that every Type 323 has uniform high quality and performance, the printed-wiring technique has been used throughout. Du Mont printed wiring has been perfected after much research and extensive field testing in commercial instruments. The Type 323 is the first commercial cathode-ray oscillograph to incorporate printed wiring exclusively.

Since all circuits are carefully laid out experimentally long before production and since the production is essentially a dip-soldering operation with all circuits preformed, an absolutely uniform product results. Printed boards also offer high strength and ruggedness to the instrument design since tube sockets are an integral part of the board and component connections are soldered inside pins.

Because the wiring is in planes, it is relatively simple to lay out parts for a very clean and accessible design. With this open layout, ventilation is good and temperature rise in components is minimized. Trouble shooting is greatly simplified because open pin connections and the wiring are readily accessible to test probe.

The power transformers are premium with high quality Hypersil cores. The transformers are potted to permit operation under adverse climatic conditions.

The metal frames and all metal chassis are of aluminum to reduce weight. The aluminum is chemically treated to resist corrosion and moisture.

The new Du Mont Type 323—for the first time—enables the accurate observation and measurement required for present day applications. From every aspect, beginning with the new Type 5AMP Mono-Accelerator Cathode-ray Tube—through all of the electronic circuitry—down to the finest detail of mechanical design, the emphasis has been on precision. The Type 323 yields precise operation over the entire range of general laboratory applications, from long-duration mechanical phenomena to high-speed pulses and single transients. Every feature of the Type 323 has been engineered toward these goals.

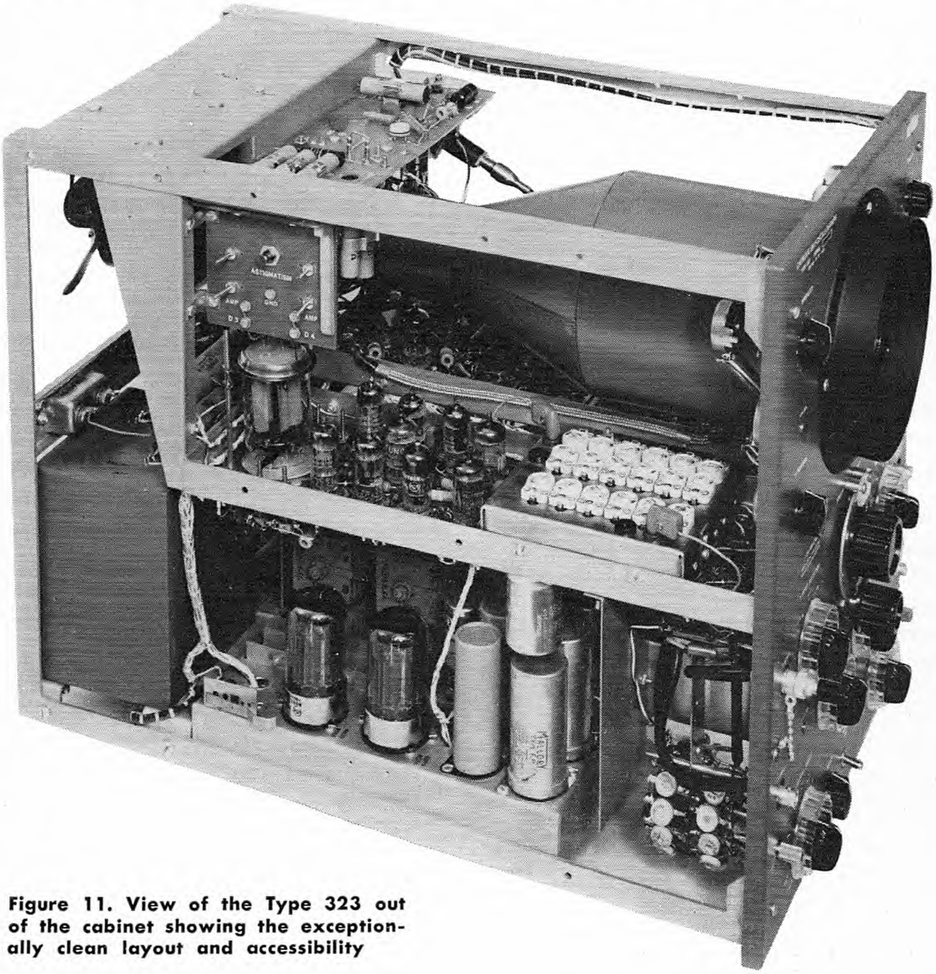


Figure 11. View of the Type 323 out of the cabinet showing the exceptionally clean layout and accessibility

SPECIFICATIONS, DU MONT TYPE 323

(The major scale division of the Type 323 is 1 inch)

CATHODE-RAY TUBE—Type: 5 AMP. mono-accelerator.
Accelerating Potential: 2500 V Equivalent to a post-accelerator tube operating at 1.5KV on the accelerator and 3KV on the post accelerator.

VERTICAL DEFLECTION—Frequency Response: (for any setting of gain or attenuator controls): Sinusoidal Response: Direct coupling, flat from zero to down not more than 30% at 10 MC, down not more than 75% at 20 MC; capacitive coupling down not more than 10% at 10 cps.
Pulse response: Rise time, 0.035 usec; overshoot, 2% max.; decay flat topped pulse, no more than 10% in 8 milliseconds for capacitive coupling; no decay for direct coupling.
Deflection Factor: Through Amplifier (full gain): a-c or d-c input, 0.1 peak-to-peak volt per major scale division (0.2 p-p v full scale); 0.5 p-p volt/major scale division at 20 MC.
Direct to Deflection Plates: 22.5 to 27.5 peak-to-peak volts per inch.

Specifications, Type 323

(Continued from Page 23)

Undistorted Deflection: with d-c positioning the equivalent of two times full scale may be positioned on screen and seen without distortion.

Signal Delay: 0.15 usec lumped constant line permits sweep to start and beam to brighten before amplified signal is applied to deflection plates.

Input Impedance: Through amplifier, 2 megohms 60 uuf; direct (unbalanced) 6.5 uuf max.; direct (balanced) 5 uuf max.; no return resistor provided.

Maximum Allowable Input Potential: 600 volts d-c plus peak a-c.

CALIBRATED SWEEPS—Sweep Writing Rates: (driven or recurrent) continuously variable in seven steps from 1 second to 0.1 usec per major scale division; maximum writing rate, 10 inches per usec. Calibration: By means of 7 position switch and vernier control; reads in usec per major scale division; accuracy within 5%.

Sweep Expansion: Type: Movable notch which may be switched in or out.
Length: 2 major scale divisions ± 10%. Notch Start: Movable over first two major scale divisions. Notch rate: 0.2 times the sweep rate on 1.0 step, 0.1 times the sweep rate on other steps; no notch on the 0.1 step of MULT. B. multiplier accuracy 5%.

Sweep Amplitude: At least 4 major scale divisions of undistorted sweep; positioning, ± 3 divisions.

Sweep Gating: Beam on during forward sweep only; spot not visible prior to driven sweep triggering, except in driven-no-gate operation.

Gate Output: Availability: Direct coupled to front-panel terminal.
Polarity: Positive. Voltage: Open circuit, more than 15 volts peak; loaded by 150 uuf, 5000 ohm, 9 volts peak.
Rise time: Less than 0.2 usec (open circuit); 1.5 usec with specified loading.

Synchronization and Triggering: (instrument set for voltage calibration). Internal Sync: For a vertical sinewave deflection of 2, 5 or 10 divisions the frequency range of driven sweep extends from 40 cps to 2 mc, 20 cps to 3 mc or 10 cps to 4 mc; of recurrent sweep 40 cps to 5 mc, 20 cps to 20 mc or 10 cps to 30 mc. Driven sweep will trigger on a sawtooth having a slope of greater than 1 div/millisecond (20 volts/second).
External Sync: For an rms sinewave amplitude of 0.1, 0.2 or 1.0 volt the frequency range of driven sweep extends from 50 cps to 2 mc, 40 cps to 3 mc or 20 cps to 5 mc; of recurrent from 50 cps to 10 mc, 40 cps to 20 mc or 20 cps to 30 mc. Driven sweep will trigger on a sawtooth having a slope of greater than 50 volts/second and duration of more than 0.025 usec.

AMPLITUDE MEASUREMENT—Calibrating Voltage: Squarewave 0.2 volts peak-to-peak ±2% regulated, at power-line frequency. **VOLTS FULL SCALE—Range:** 11 full scale ranges of 0.2, 0.4, 1, 2, 4, 10, 20, 40, 100, 200, and 400 volts full scale. **Calibrated Scale:** Reads directly in volts or percent of full scale. **Frequency Range:** See "Frequency Response" above. **Overall Accuracy: 5%.**

INTENSITY MODULATION—Availability: Front-panel connector. **Polarity:** Positive signals decrease intensity; 15 volts peak will blank beam at normal intensity settings. **Input Impedance:** 12000 ohms, 70 uuf. **Direct:** Link at top rear of instrument disconnects input cable to reduce input capacity to 25 uuf on direct input.

MAXIMUM PHOTOGRAPHIC WRITING RATES—Type 296 (f/2.8 lens): 0.8 inch/usec. **Types 295 and 321 (f/1.5 lens):** 2.8 inches usec.

POWER SOURCE—Voltage: 115/230 volts ± 10%. **Frequency:** 50-60 cycles. **Power Consumption:** 440 watts.

PHYSICAL CHARACTERISTICS—Style: housed in blue-gray wrinkle metal cabinet with smooth blue-gray panel; direct-etched, white-filled numerals on panel; two leather carrying handles. **Size:** Height: 16⅞"; width: 12⅜"; depth: 22½"; weight 70 lbs. **Accessories:** Illuminated scale and color filter; the scale illumination is variable from zero to more than sufficient for photographic recording; scale is numbered to facilitate direct readings in volts; two BNC to binding post adapters supplied for low-frequency applications. Other useful accessories such as oscillograph record cameras, movable laboratory tables, a variety of probes, etc. are available from Du-Mont.

CAT. NO.	DESCRIPTION
1682-K	Cathode-ray oscillograph with Type 5AMP1 cathode-ray tube for 115/230 volts, 50-60 cycles.
1686-K	Same as above but with Type 5AMP11 cathode-ray tube.