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PROGRESS REPORT ON ELECTRONIC KONIMETER SLIDE COUNTER

by

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MINERAL SCIENCES DIVISION

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SUMMARY OF RESULTS

The feasibility has been studied of designing and building an electronic counter unit for the determination of dust particle concentrations on Konimeter sample slides. Two methods have been used: a) a flying-spot scanner sweeping the illumination to a dark-field microscope and counting of the light flashes emitted by the dust particles when illuminated; and, b) the use of steady microscope illumination and viewing of the magnified image by a T.V. camera tube with subsequent counting of the particles seen. The second approach was found to be practical and circuits are described that have been designed for preliminary test work at fast sweep rates and interlaced scanning. The method looks promising and requires further work to provide slower scanning of the field and fixed-space sweeping.

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INTRODUCTION

One of the standard methods of assessing dust concentrations in mines and mills in connection with safety surveys for silicosis prevention employs a sampling device called the "Konimeter". In this device a constant volume of air is collected and forced to impinge on a sticky glass disk, such that the dust particles in the air sample adhere to the surface of the disk. Each disk is used to preserve up to 40 dust samples. After collection the disk is acid-treated to remove carbonaceous material and heated to bake in the remaining dust particles. Dust concentrations are then estimated by counting a segment of the field visible, when placing the dust sample on the disk under a dark-field microscope (1).

Visual counting of particles through a microscope is fatiguing and necessarily slow and inaccurate, even when a microprojector is used. For this reason attempts have been made in many countries to develop electronic instruments to take over the dust counting function. None of the commercially available instruments appeared to be sufficiently adaptable for this specific purpose. For this reason the Mines Accident Prevention Association of Ontario approached the Mineral Sciences Division of the Mines Branch with a request, that a study be made of the feasibility of a purely electronic approach to this problem, to be undertaken on a short-term contract. This report is a summary of the work done to date, since the start of the work on April 1, 1962. A sum of $5000 was allocated to cover the total cost of the project, including salary, to the end of September 1962.

The desired specifications for the final instrument require the counting of particles in the size range 0.5-5 microns of irregular shape and composition. Viewed in a magnification of 150-250 X, a field would be expected to contain from 50 to 1000 particles in a random distribution, with some concentration around the centre of the field. Valid statistical sampling of the particles is acceptable with a reproducibility of the order of 10%. Very large particles are not expected to be common and it was not considered serious if such a particle might be counted twice. On the other hand, separation of close, contiguous small particles for counting is clearly desirable.

Commercial apparatus, primarily intended for blood cell counting, has been developed in Great Britain and the United States that will count uniform particles, in the order of 1 μ diameter. However, this equipment is either unreasonably expensive or unable to cope with the wide range of particle size and distribution encountered in konimetry. While the scanning microscope systems employed in the British Casella Counter and in Swedish biological studies (2) employ a moving mechanical stage, the studies at the Mines Branch were directed towards an all-electronic system of a type similar to the Perkin-Elmer instrument (3) or the Philco instrument (4). These instruments have a fixed stage and electronically scan the image (or object) being examined. The Perkin-Elmer instrument employs a Vidicon slow-scan television microscope camera and a very complicated electronic computer, which processes the video information. Since this scanner is used for blood cancer research, the computer functions and requirements are many times more complex than those required for konimetry; hence, it was felt that a much simpler data-processing system can be used in the present project. The Philco instrument is primarily intended for visual information and thus is only of interest because of its method of scan. Philco employ a "flying-spot scanner", which moves a spot of light over the field. The transmitted light is detected by a photomultiplier tube, amplified, and sent to a monitor which resembles a television receiver. Since the cathode-ray tube used to generate the flying-spot has a phosphor that emits ultraviolet light, this T.V. microscope is able to convert normally invisible images into a form acceptable to the human eye. It is possible that some adaptation of this system employing scattered light detection could be applied to konimetry; however, due to the relatively short operating life of the flying-spot cathode-ray tube, it is felt that the Vidicon camera provides the most economical and reliable approach to electronic konimetry.

REVIEW OF TEST WORK

The Mines Branch studies were carried out in three phases: a) investigations into the application of flying-spot principles; b) design and construction of an image orthicon camera; and c) tests with a closed-circuit Vidicon television camera system.

The first proposal for detection and counting of konimeter slide particles was that scattered light from a flying-spot scanner could be detected and counted. Figure 1 shows the principle of flying-spot scanning. Essentially it consists of sweeping an illuminating beam of light across the field of view and counting the particles, as the beam passes them in turn, by detecting the light scattered by their surface. The point of light on the face of the cathode-ray tube on the left is projected by the lens onto the illuminated area on the right. With a transparent subject, where transmitted information is sought, the photomultiplier detector is placed behind the object. Where the reflected or scattered light is of interest, the photomultiplier is placed ahead of the object in such a position that direct light from the lens does not strike the photocathode, but reflected light from the object does. Figure 2 shows this principle applied to konimetry. As can be seen, the scattered light detected by the photomultiplier is amplified, then passed to an electronic counter unit and a T.V. monitor. The T.V. monitor is used to adjust the

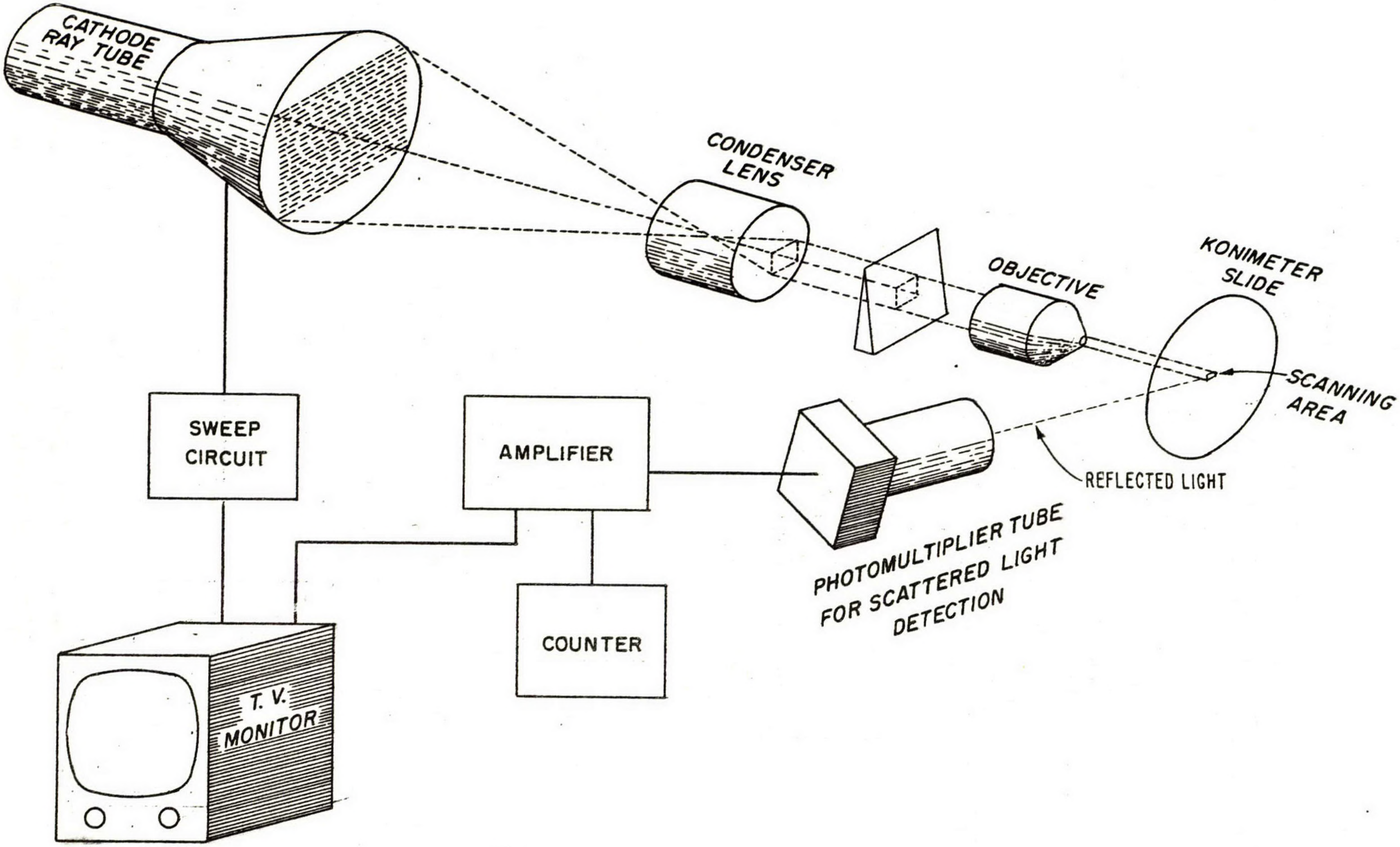

FIGURE I DIAGRAM OF FLYING SPOT SCANNER

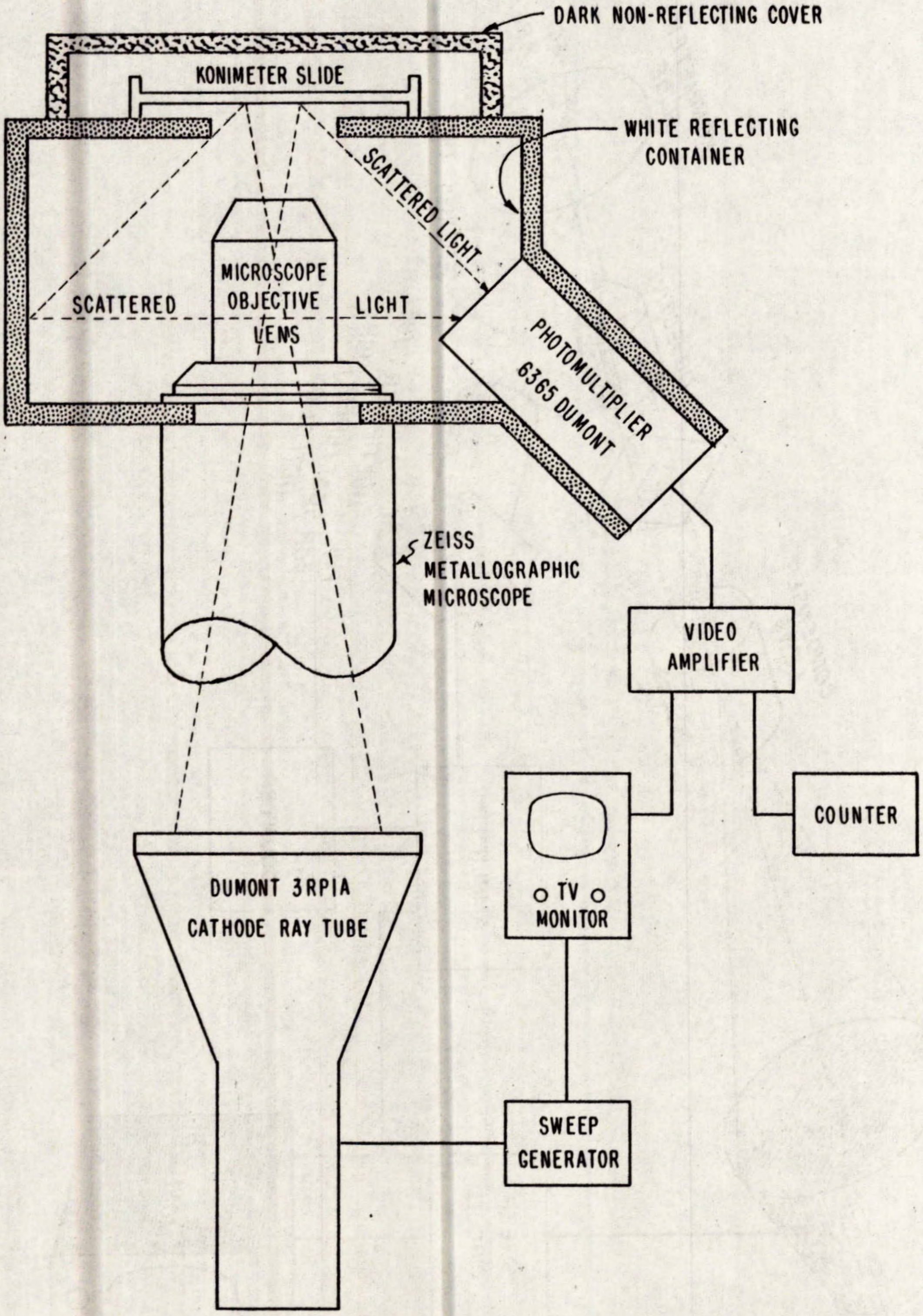

FIGURE 2 DIAGRAM OF FLYING SPOT DETECTOR SYSTEM-
DETAIL OF SLIDE MOUNTING.

electronic image prior to counting in order that the operator can be sure he is counting the correct information.

It was found that light intensities were below practical limits when a 3RP1A (three inch) cathode-ray tube was used. After consultation with RCA Victor Ltd. (5) and Bausch and Lomb (6), it was concluded that due to the poor life of high-intensity small cathode-ray tubes, and the expense of sophisticated optical equipment required to conserve the light emitted from more economical and reliable cathode-ray tubes, the flying-spot scanner would appear to be an impractical way to detect the konimeter slide particles.

Recent publications, particularly the Kemp article (4) on the Philco T.V. microscope, indicate that Philco have produced a two-inch high-intensity flying-spot cathode-ray tube. It remains to be seen, if this tube has adequate life and reliability for it to be practical for this application. In view of the expense of other similar types, it is possible that it may not be very economical in a practical application.

In view of these difficulties, an alternative scanning method employed by Preston and Izzo (3) was investigated by the Mines Branch. This method implies use of a television microscope camera. The dark-field image of the dust colony on the konimeter slide is focussed on the photocathode of a television camera tube, where it is scanned by a low velocity electron beam. The pulses of output current resulting from the image highlights are amplified as electrical pulses, which are counted and recorded on a register. After consideration of the available light from the microscope optics, it was decided to attempt to employ an image orthicon camera tube to convert the optical image into electrical pulses. The image orthicon tube is the most sensitive television camera tube available; however, it costs between $1300 and $1800, and it was fortunate that two used image orthicons could be obtained, free of charge, from the C.B.C.

The design of the camera progressed to a point where a barely discernible image was obtained by mid-July. It was found that the focus and deflection assemblies would require a comprehensive re-design, in order to eliminate the image distortion that occurred. This work was almost completed when a Vidicon camera was obtained on loan from Electronic Associates Ltd. in early August.

Circuits and technical descriptions of the orthicon camera are appended to this report.(Appendix A).

The Vidicon camera, a Dage 60A closed-circuit television camera, employs a much faster scan than would be anticipated for efficient data processing, since it is intended to produce information acceptable to a normal television receiver. It has been possible, however, to obtain good qualitative results, which indicate that this is a practical method of detecting the particles in a countable form. Video information from the camera is simultaneously passed to the video amplifier and the television receiver. The television receiver is used merely to adjust the camera and microscope until a properly focussed image is obtained. The counter is then read. With a Hewlett-Packard 5243L fast counter, which was obtained briefly on loan from the manufacturer, and with a scale of 1000 ratemeter counter (Figure 3), it was possible to obtain qualitative results with typical konimeter slides. With the system depicted in Figure 3 the results shown in Table 1 and Figure 4 were obtained. The microscope was defocussed before each sample was read and a "background" counter reading was taken; then the image was refocussed and the counter was re-read. The difference between focussed and defocussed counts is proportional to the particle count on the slide. Figure 4 shows reasonable correlation between the estimated visual counts and the electronic counts.

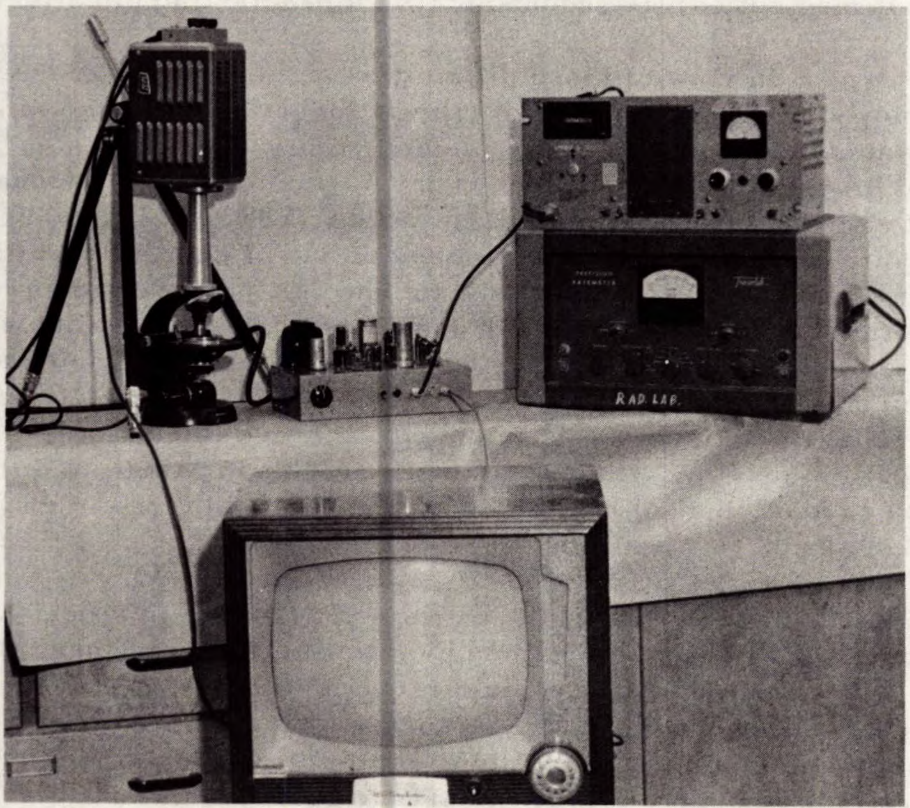

Figure 3. View of Assembled Equipment (Microscope with Dage camera at left, scaler and ratemeter at right).

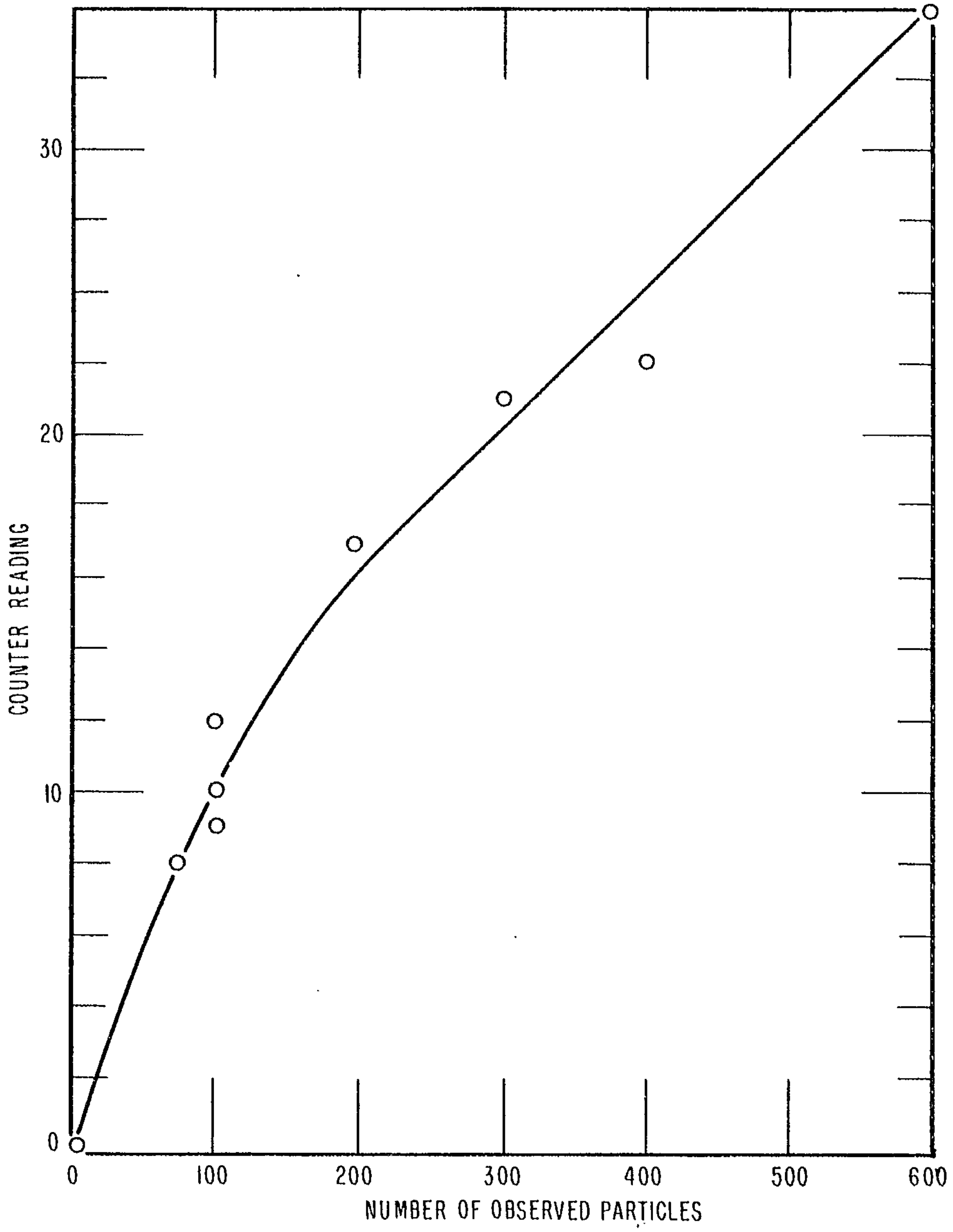

FIGURE 4 COUNTER SENSITIVITY CURVE

TABLE 1

Konimeter Slide Tests

Area	Defocussed	Focussed	Difference	Visually Estimated Count
1	44	44	0	3
2	50	58	8	+ 70
3	56	64	8	+ 70
4	56	66	10	+100
5	56	65	9	+100
6	59	80	21	+300
7	59	76	17	+200
8	60	82	22	+400
9	58	70	12	+150
10	58	90	32	+600

The technical details of the video amplifier designed and used are appended to this report (Appendix B).

Typical counter input signals are shown in Figure 5(b) of a pattern shown in Figure 5(a). The dust particle pattern would occupy the same portion of the picture as the dash pattern,which was used because of its known character.

Figure 5(a)
Small Test Pattern

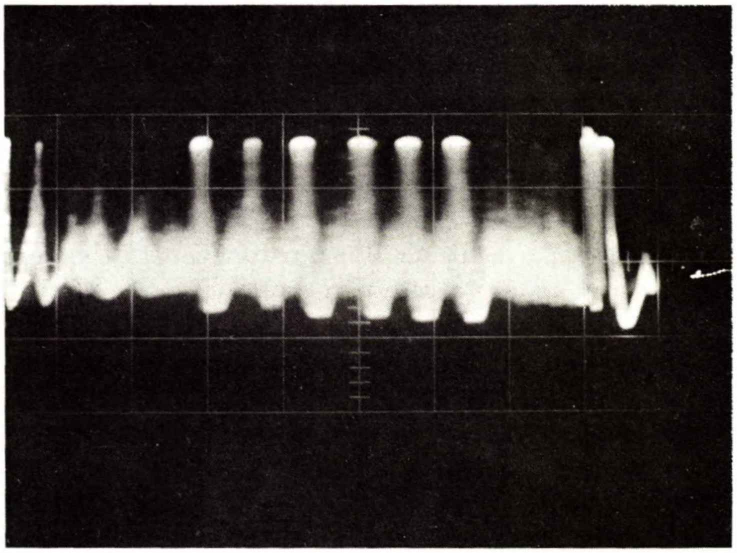

Figure 5(b)
Typical Camera Scan for this Test Pattern

CONCLUSIONS AND PROPOSALS

It is felt that the Vidicon camera method of counting is highly practical and with a modern Vidicon camera, which scans at a more suitable rate for counting operations, a practical prototype counter can be built at reasonable cost. The Dage 60A camera is a relatively poor-quality camera of early design;however, it proved useful for exploratory tests. Modern Vidicon tubes and improved design features available in a more advanced Vidicon camera would overcome many of the technical problems introduced by the $262\frac{1}{2}$ line,60 frame/sec scan of the camera used in these tests. The fast scan rates encountered introduced similar problems to those experienced when one observes the rotating blades of an aeroplane propeller. The simple counters useable with slow scan methods become overloaded when information arrives faster than it can be resolved. It is, therefore, recommended that a 900 line, 1 frame/sec scan be used in the prototype apparatus. It is further recommended, in order to avoid double counts of large particles, that the counter be gated, so that only a fixed percentage of the scanned field reaches the counter. If, for instance, every twenty-fifth line were counted by the counter, particles 5 μ in diameter would not be counted twice in a 200 μ x 250 μ field.

If the scanned area of the slide were rotated after one scan through 90° and the area recounted, the average count so obtained would bear a good statistical relationship to the actual count on the slide, since particles missed the first time would probably be the same proportion as those missed on the second scan. However, even such a repeat count would rarely be required to obtain a statistically valid count value.

A block design of a suitable camera and monitor for particle counting is described in Appendix C. This proposed apparatus would employ a long-persistence monitor tube, which would simplify the adjustment of the camera and microscope. A minimum of adjustments will be required to set the instrument into operation. It is envisaged that, once initial adjustment is carried out, the operator will merely have to focus the microscope for each area scanned. (This was the case with the experimental set-up and there is no valid reason to suppose that the prototype would be very different).

The normal count period will be about 1 second, which will allow low-cost glow register counters to be used in the system.

The other electronics will be of a design familiar to a T.V. service technician of average calibre, so that normal maintenance would present no insuperable problem.

It is felt that, if the project were continued as a summer project in 1963, the construction of a working prototype counter would be possible. In view of the recent advances in Vidicon camera design with the emphasis on slow scan systems used in space efforts, it is possible that most of the design would be available as "off' the shelf" items. The basic block diagram of the counter is shown in Figure 6 as an indication of typical design; however, it is probable that many of the functions shown could be filled by commercially available items rather than specially designed circuits.

It is suggested, therefore, that a comparable development contract at about the same level of expenditure could reasonably be expected to lead to a usable prototype counter, for trials in the field, after 3-4 months' work. The cost of such further development work would not be expected to exceed $5000.

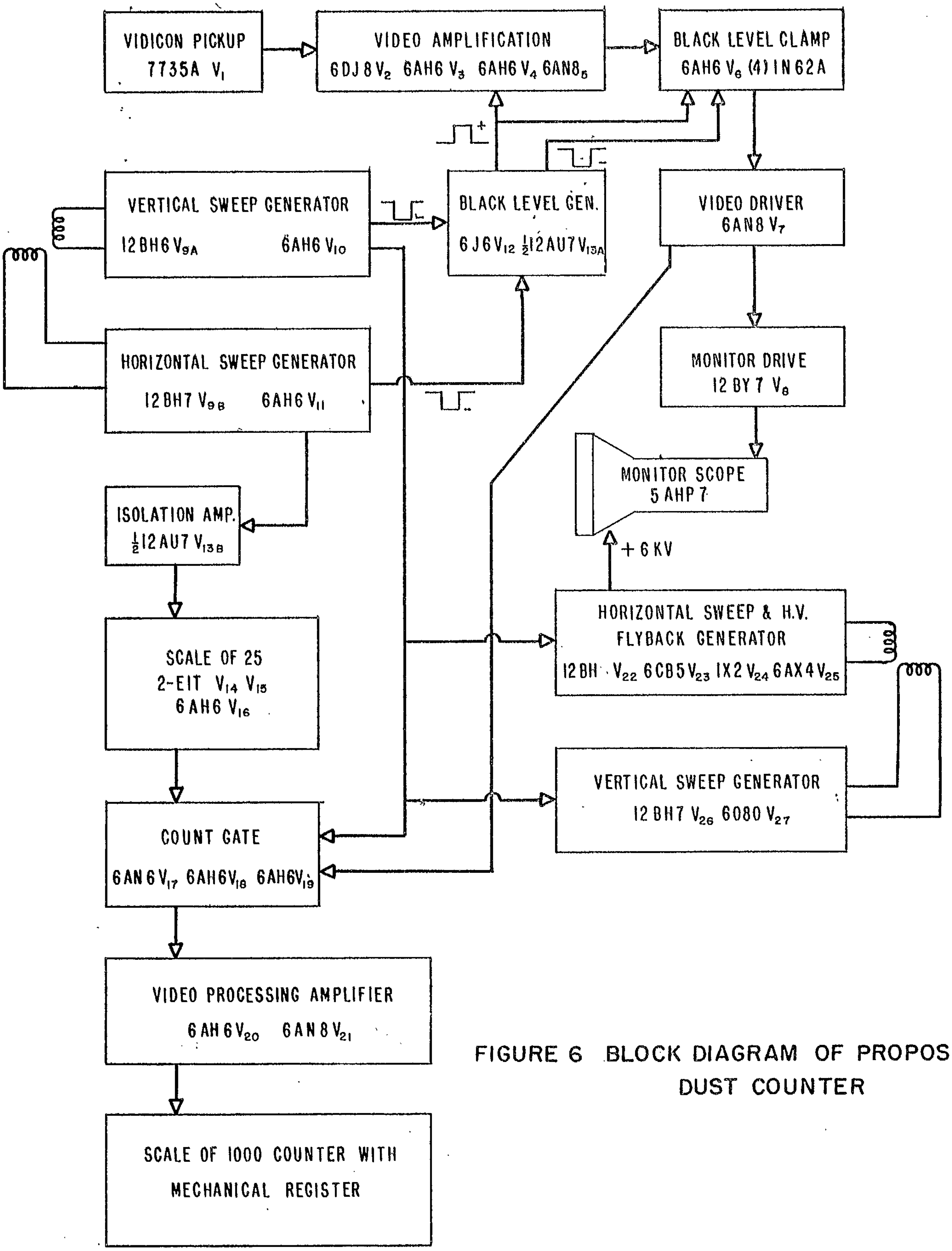

FIGURE 6 BLOCK DIAGRAM OF PROPOSED DUST COUNTER

ACKNOWLEDGEMENTS

This work was done under the direction of Dr. G.G. Eichholz. The author wishes to acknowledge gratefully the advice and assistance of the following persons:

Mr. W.A. Cameron, National Research Council, for his advice on the design of the orthicon camera and loan of various pieces of equipment used in that phase of the project.

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Mr. C.H. Williams, Hewlett-Packard Co. Ltd., Ottawa, for the kind loan of his 4253 L high-speed counter.

Mr. H.A. Johnston, Bausch and Lomb, for his helpful advice on the design of the flying-spot scanner.

The Engineering staff of CBOT for their kind assistance in testing the image orthicon tubes and Mr. Richards of the C.B.C. for the actual acquisition of these tubes.

APPENDIX A

ORTHICON CAMERA DESIGN DETAILS

Refer to block diagram, Figure 7.

Initial development of the orthicon camera closely follows the "Mimo" camera designed by RCA (7); however, it was decided to employ a Lissajous scan pattern developed by an x-frequency of 2500 cps and a y-frequency of 2540 cps.

This unusual scan was selected to eliminate the bothersome blanking and synchronization problems inherent in linear raster scan. (Blanking pulses have also caused trouble in the Vidicon camera used in the final system). A further advantage of this form of scan is the significant reduction in video bandwidth. 625 kc is required for 40 frame/sec with 504 equivalent lines, as compared with 4.5 Mc bandwidth required for the 30 frame/sec, 525 lines, 2:1 interlaced television (US Standard) pattern.

The sweep generator for this unusual scan is shown in Figure 8. V_1 is a standard grounded-grid multivibrator, and V_2 is a class-A buffer stage. V_3 is a standard class-B phase-inverting power amplifier. Adjustment of the multivibrator is quite critical; if the resistance of the purity (harmonic content) control is reduced excessively, the oscillator ceases to function. The frequency is adjusted by variation of both frequency and purity controls, with the frequency control maintained near mid-range. Proper adjustment of both x and y generators produces a stable pattern of a 250 x 254 Lissajous figure. It is mandatory that a phase-shift network be introduced between the monitor and the sweep generator, because the deflection voltage at point "A" is about 10-15° out of phase with the current through the deflection coils. Since a commercial oscilloscope was used as a monitor, this phase-shift network was a simple pi-network between point A and the deflection amplifiers of the oscilloscope. The values of components forming the pi-network were arrived at the following way. The approximate phase-shift of the scanning coils was computed, then the same phase-shift was produced with an RC pi-network.

The video amplifier shown in Figure 9 follows common practice, V_1 is a low noise cascode stage. It has a moderate input impedance, 47 kΩ (which is the output resistor of the image orthicon (Figure 10); thus it has low input noise. The anode load of the second stage is very low, $1000\Omega + j\omega \cdot 10^{-4}$. The second stage, V_2, is a high-gain stage. It has a plate load of 10 kΩ and thus has a gain of 80-90. The last stage, V_3, is a low-gain, low-impedance output stage. The gain of this stage is low;

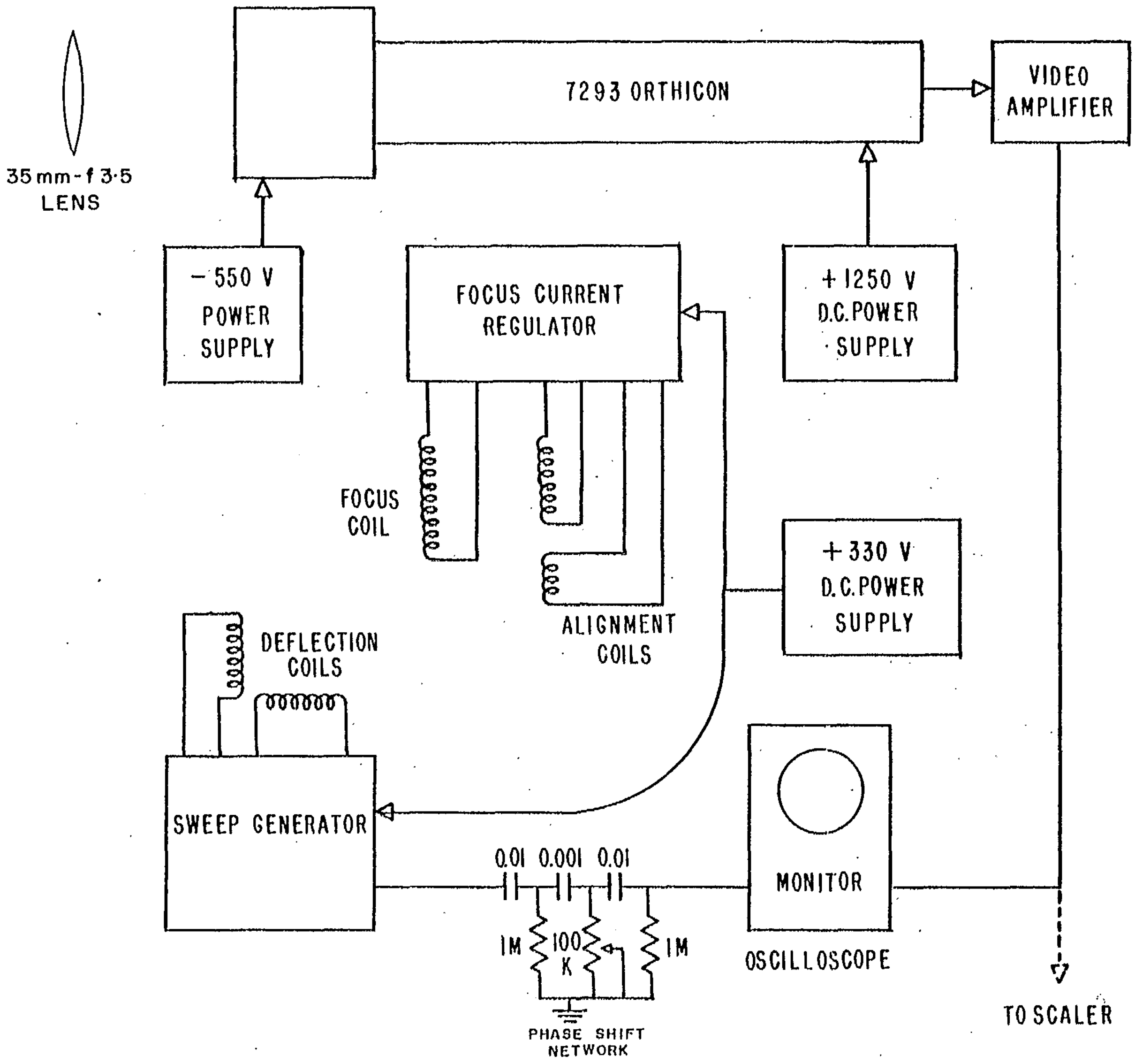


FIGURE 7 BLOCK DIAGRAM OF ORTHICON CAMERA

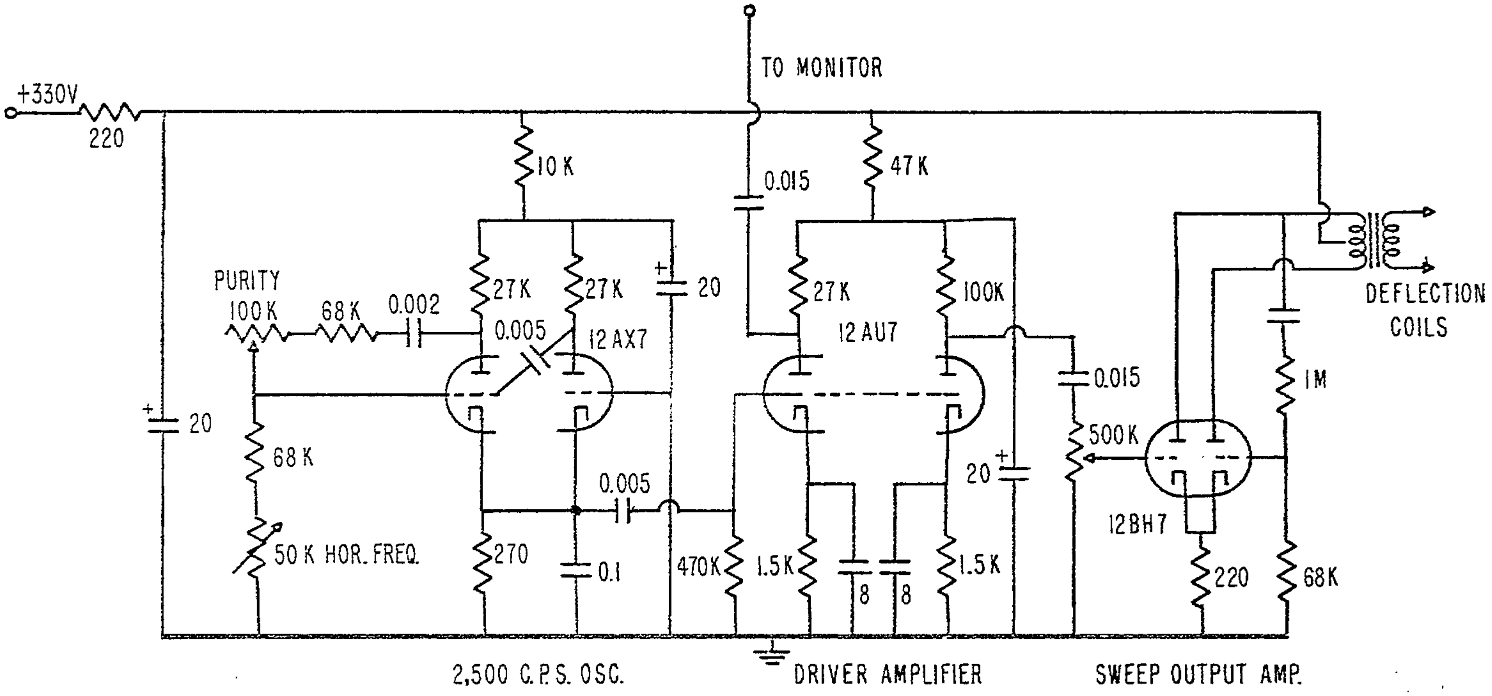


FIGURE 8 SWEEP GENERATOR FOR ORTHICON CAMERA

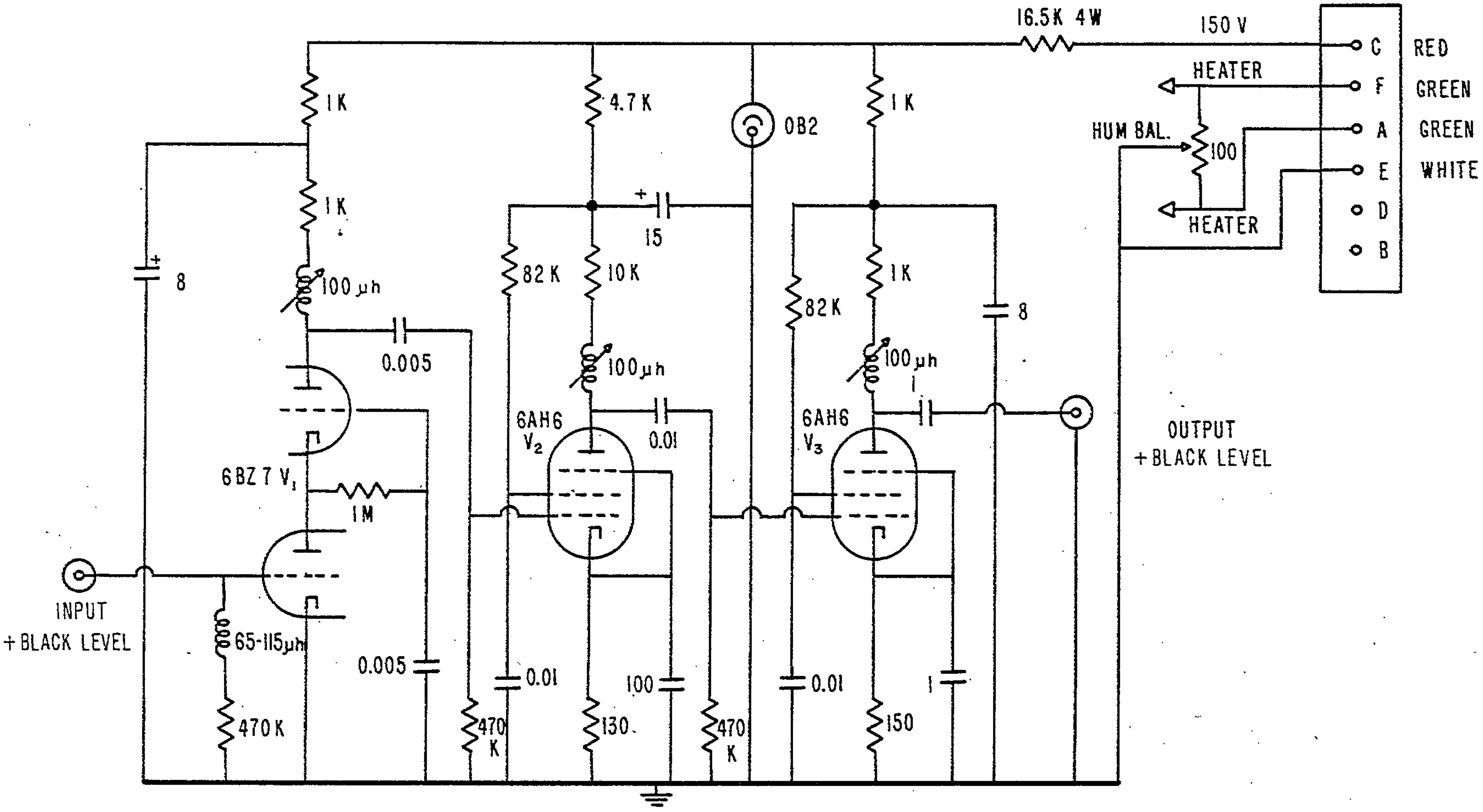


FIGURE 9 WIDEBAND VIDEO AMPLIFIER, GAIN ~2500.

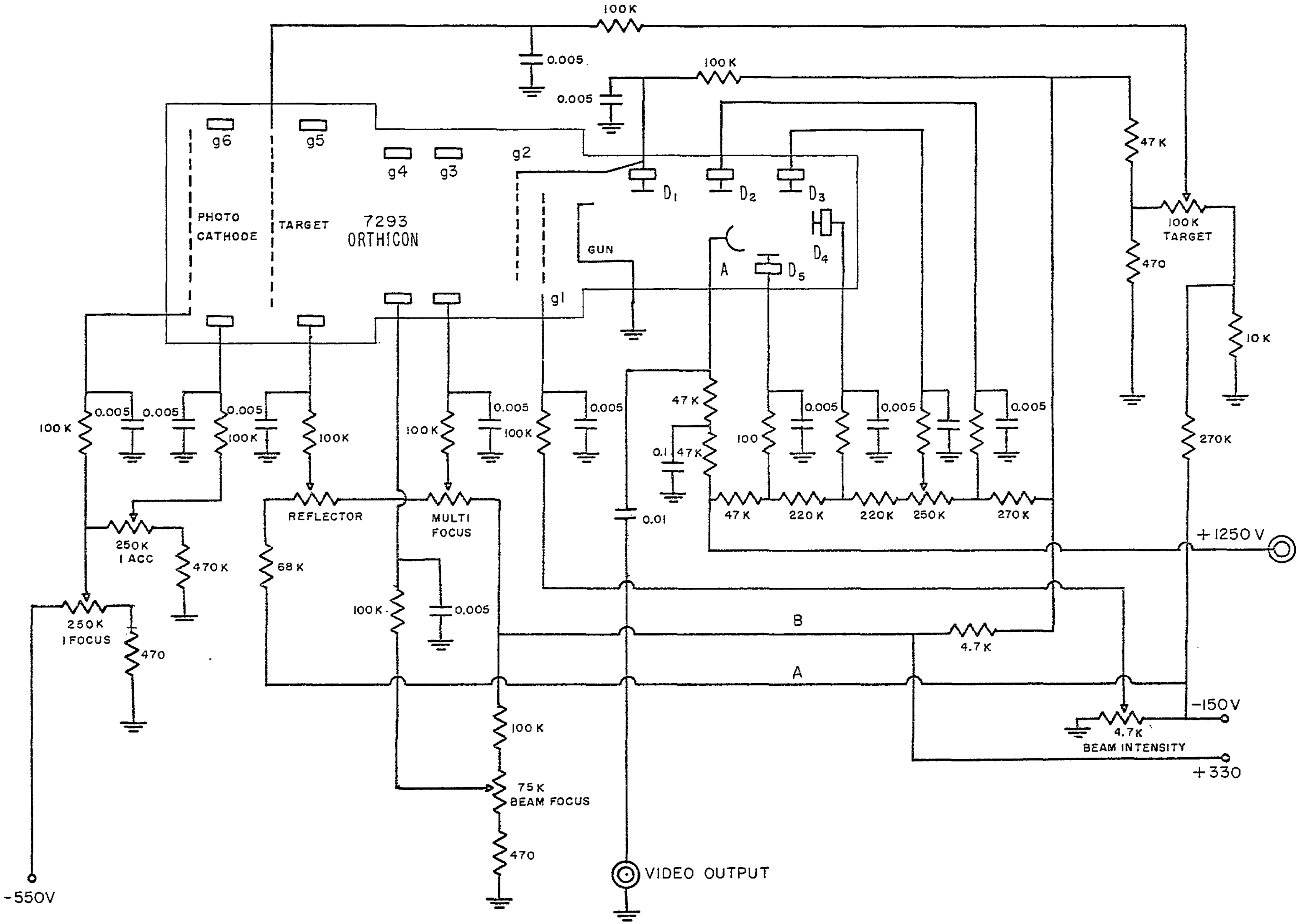
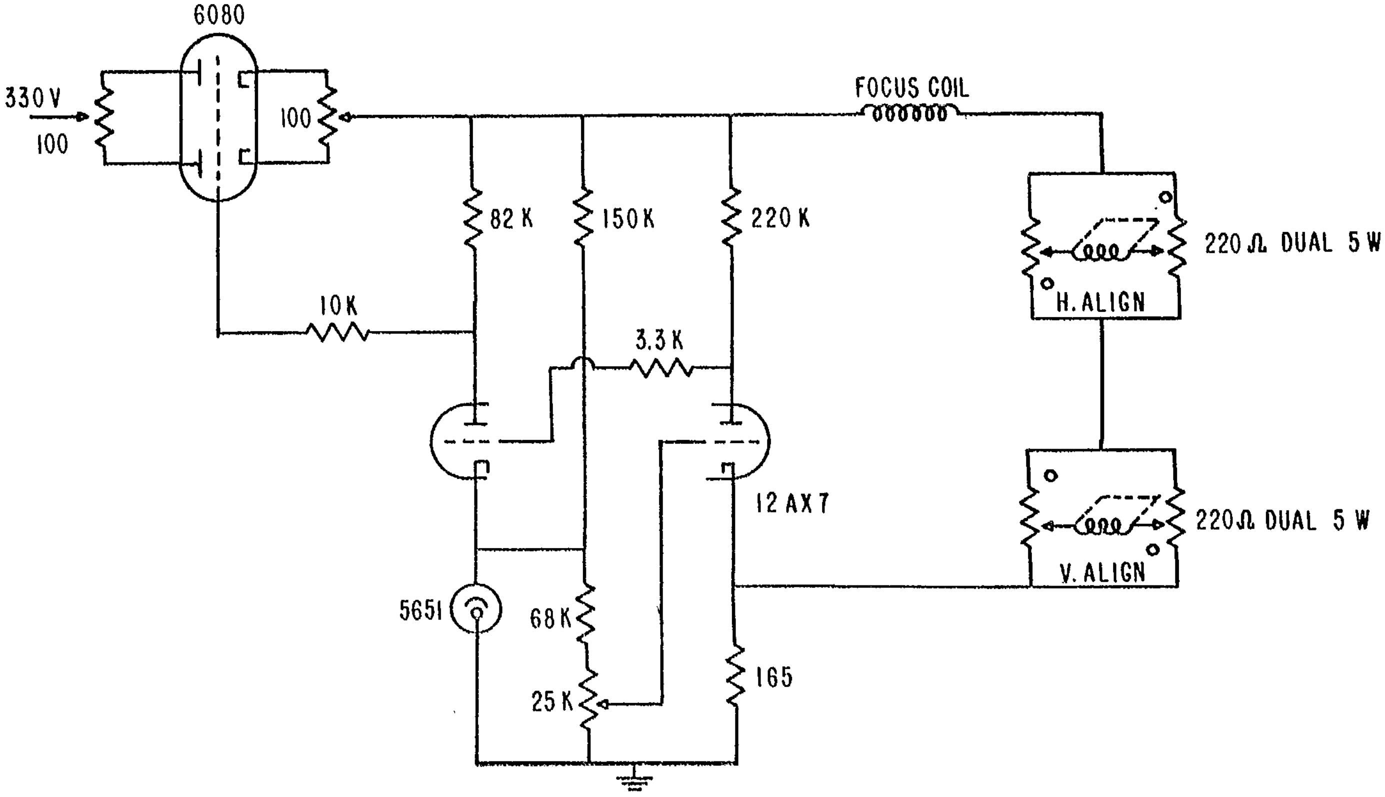


FIGURE 10 ORTHICON TUBE CIRCUIT

however, it must have low impedance, since it is intended for cathode drive of the 511 A Tektronix oscilloscope. This amplifier is in a closed shielded chassis to prevent stray pickup.

Figure 10 shows the orthicon connections. This circuit closely follows the recommended circuit (8); however, the reflector (g 5) is allowed to go negative with respect to the cathode, instead of just to 0 volts as in the standard design. This provision was made to reduce beam velocity to precisely zero at the target.

Figure 11 is the focus-current regulator, which is intended to maintain focus and alignment fields at a constant value. This is a standard-design current regulator that employs a high-gain d.c. difference amplifier, which is referred to a glow reference tube.



FOCUS COIL — 30,000 TURNS NO. 26 WIRE, WOUND ON A FORM 3½" DIA. AND 11½" LONG
ALIGNMENT COILS — 2 ORTHOGONAL PAIRS, 250 TURNS HONEYCOMB NO. 36
FOCUS CURRENT — 75 mA

FIGURE 11 FOCUS AND ALIGNMENT CURRENT REGULATOR

APPENDIX B

VIDEO PROCESSING AMPLIFIER

The video processing amplifier used in the Vidicon camera system is shown in Figure 12. This is a video amplifier with a low cut-off of 30 kc and a high cut-off of about 8 Mc. Coupling capacitor values have been selected so that the unwanted video information of the Dage 60 camera is rejected, while the sharp edges of the dust particle pulses are amplified. This system is not very efficient, but it makes the camera information compatible with the available counters.

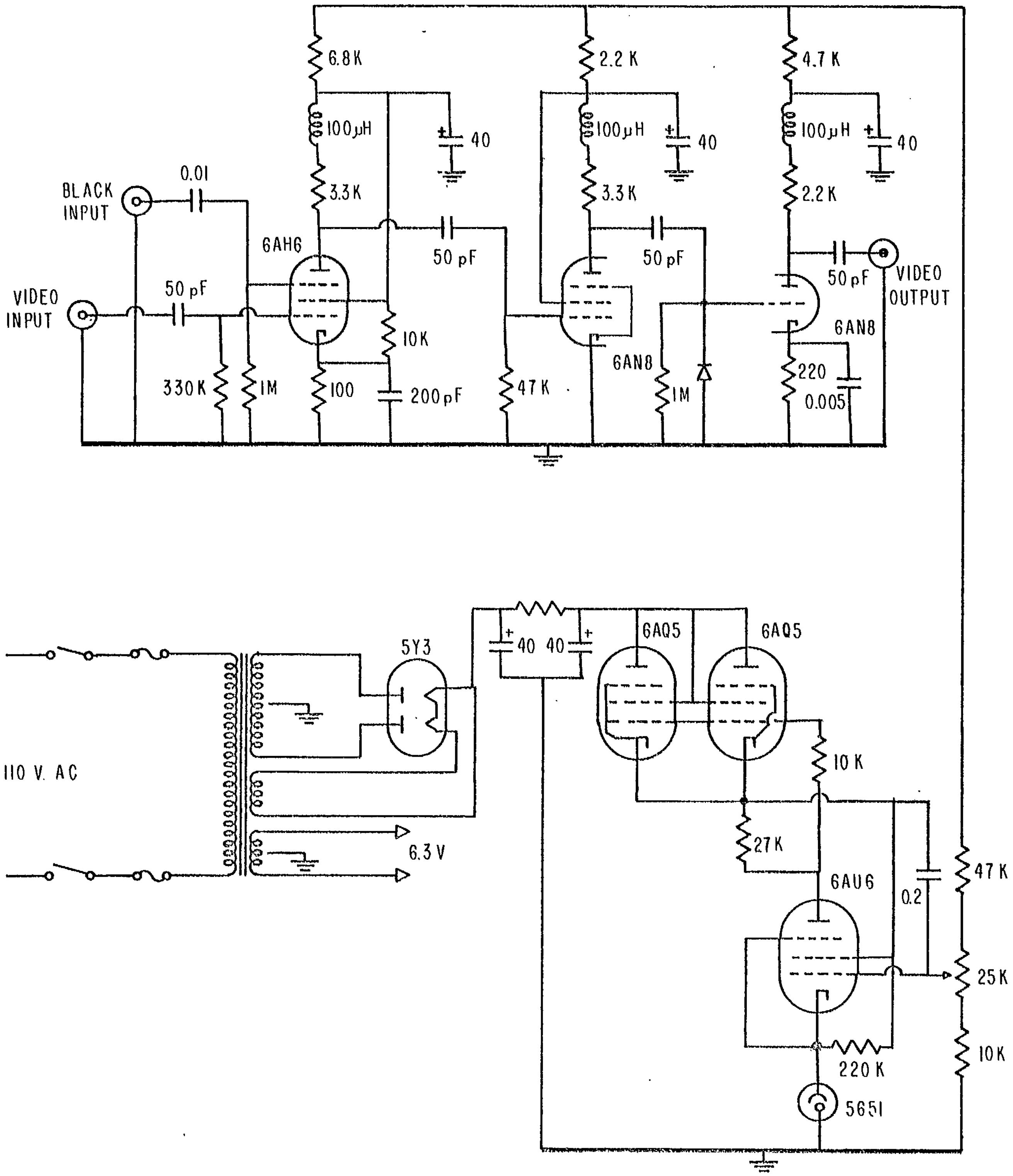


FIGURE 12 VIDEO AMPLIFIER FOR VIDICON CAMERA

APPENDIX C

PROPOSED CAMERA DESIGN FOR PROTOTYPE COUNTER

Figure 6 shows the block diagram of the camera, monitor and video processing unit. The operation of this unit is as follows: video information from V_1 is amplified in the normal manner by the video amplifier V_2--------V_5. The phase-corrected video information is then clamped and clipped by the black-level clamp (9). This establishes firmly the black level as a function of known voltages generated in V_{12} and V_{13a}. The video information which has been thus processed is passed to the monitor and the count gate V_{17}, V_{18}, V_{19}. The count gate is controlled by the scale of 25 counter (which can be made to count any integral number from 1 to 99). The count gate allows only every 25th horizontal scan to be passed to the counter through the video processing amplifier, V_{20} and V_{21}. This amplifier is very similar to the amplifier shown in Figure 12; however, it will not require the high-frequency response of the former system. This amplifier should pass information from 1800 cps to 1 Mc in order that the smallest particles can be counted. It will be noted that selection of the low cut-off of the amplifier above the line frequency reduces the effects of poor scanning and focus in the Vidicon.

It is strongly urged that the following precautions be taken in construction of this or any other similar camera:

1) Employ only the best quality Vidicon deflection components. The yoke and focus/alignment assembly must be of equivalent calibre to the specifications of Cleveland Electronics model VYFA-231.

2) Mount the power supplies and other large bodies well away from the Vidicon assembly.

3) Use d.c. heaters and a well-regulated HT supply for the camera and video processing circuits. The monitor can have poorer regulation, since the information is purely of a qualitative nature.

4) Mount the Vidicon in such a manner that the face-plate temperature will be in the range between 25°C and 35°C. Cold operation will result in a sticking picture and carry-over of signal from one scan to the next, while hot operation results in low resolution due to charge migration in the photoconductive layer.

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