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APPLIED RESEARCH ON HIGH RESOLUTION
SCANNING

Fifth Quarterly Interim Report

By K. F. Wallace/D. Orme

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AMPEX CORPORATION

AMPEX

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✓APPLIED RESEARCH ON HIGH RESOLUTION FILM SCANNING.

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PREFACE

This is the first interim engineering report of the work carried out under Phase II of Contract AF33(657)-11091 (Ampex project No. 7119) for Applied Research on High Resolution Film Scanning.

The objective is the development of a system for obtaining video signals from photographs at 20 Mc bandwidth. The contract is being performed for the Aerial Reconnaissance Laboratory at Wright-Patterson Air Force Base.

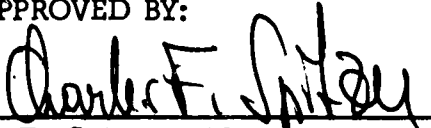
Work on this second phase commenced May 1, 1964, and is devoted to the design and construction of film scanning equipment.

The present report summarizes the work performed through August 1, 1964.

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ABSTRACT

↙ The over-all layout of the film scanner ^{was} ~~has been~~ established and a substantial amount of detailed design work carried out. Construction of several sub-units and ordering of purchased parts ~~is~~ in hand.

✓ The equipment will comprise two self-contained, transportable units for which the only necessary external supply will be electrical power.

✓ An electron gun of improved design ^{was} ~~has been~~ built and tested. It is now possible to achieve a resolution of 100 line pairs per millimeter across a flat test target 4-1/2 inches wide. The use of a flat film carriage (in place of the previous design which had curved guides) will simplify considerably the design of the film transport.

✓ In the area of electronics the main timing unit, deflection waveform generators and amplifiers, and correction waveform synthesizers and amplifiers ^{were} ~~have been~~ designed and tested in breadboard state. Construction has started on the final units.

✓ The main features of the vacuum system are now known ~~and parts for these have been ordered~~. It will be possible to switch from manual to fully automatic operation, and in either mode, the vacuum valves (which are pneumatic) will be actuated by electrical signals. Rough vacuum, compressed air and cooling fluid will be supplied from built-in units.

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1.0 INTRODUCTION

1.1 Purpose of Contract

The second phase of this contract requires the construction of high resolution film scanning equipment for use in an experimental picture transmission system. The other components of the system are a microwave link and reproducing equipment.

The scanner is required to transmit the information contained in a reel of photographic transparencies 4-1/2 inches wide. The resolution specification is 100 line pairs per millimeter and the information is to be transmitted at a 20 megacycles rate.

1.2 Problem in Brief

The principal problem is the construction of an electron gun and film transport in which the exacting electron-optical requirements can be met without the use of impractical adjusting devices. The successful use of a flat film guide has been of particular significance in this respect. It is now felt that the number of adjustments and working tolerances are reasonable for experimental use.

Other problems relate to the size and convenience of operation of the equipment. Some effort is being made to keep the scanner reasonably compact; however, since the equipment will be ground based, ease of operation has been the main consideration.

2.0 TECHNICAL DISCUSSION

2.1 Complete Equipment

The complete scanner will consist of a main unit similar to that illustrated in Fig. 2.1.1 and a smaller unit housed in a standard 19-inch rack. The main unit is expected to be about six feet high, four feet wide and thirty inches deep.

Construction of various sub-units is underway and we are awaiting delivery of some of the principal purchased parts (e.g. the vacuum system and controls).

2.1.1 Main Unit

The layout of the main unit is intended to combine ease of operation with accessibility of principal components, particularly the gun and transport.

Controls which are frequently used, such as those on the high voltage control box, focus unit and shift controls, are placed at a convenient height. Similarly, the waveform and television monitors are at eye level and the important meters (on the high voltage control box) are easily read.

The vacuum system can be operated either manually or automatically and includes several safety features such as automatic closing of the high vacuum valve in case of vacuum failure. It is planned to have an automatic switch in the gun filament supply. This switch will operate also when the vacuum fails. To facilitate automatic operation the vacuum valves are pneumatic and are actuated by solenoids.

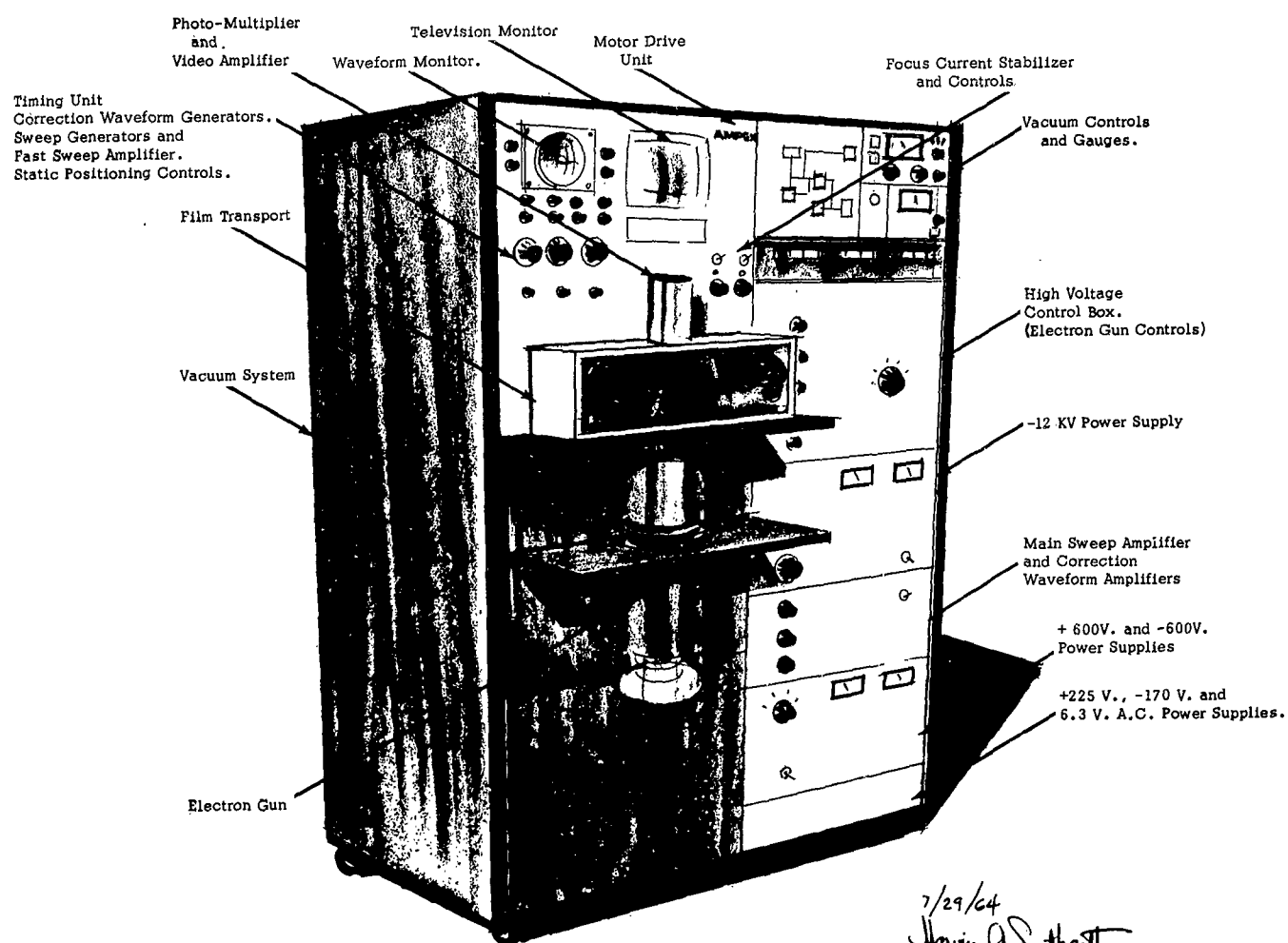


Fig. 2.1.1 Main Unit of Facsimile Scanner

Separate pumping ports are provided for the gun and the tape transport. The two compartments are partially isolated by the sealing action of the film pressing against the guides. This design is intended to alleviate high pressure problems in the transport due to outgassing of the film. It is difficult to estimate the effect of outgassing in terms of pressure rise, and for this reason a manual throttle is placed in the vacuum line to the transport. Thus, a controlled pressure differential can be maintained should the electron gun prove inefficient.

To change film reels it will be necessary to turn off the gun, release the vacuum and remove the front plate of the transport. The fully automatic system should make both this and the subsequent pump-down a relatively simple operation.

2.1.2 Auxiliary Unit

In order to minimize noise and vibration, the roughing pump for the vacuum system and the air compressor for the pneumatic valves will be located in a separate unit.

In addition, a self contained cooling system for the diffusion pump is planned, and part of the equipment necessary for this feature may be housed in the auxiliary rack. Probably several d-c power supplies also will be located in the rack.

There should be no controls on the auxiliary unit which are used frequently and it is expected that it will normally stand close to the main unit, connected by flexible pipes and cables. As with the main unit, it will be transportable.

2.2 Electron Optics

2.2.1 Introduction

During the past quarter of the current contract a new (No. 2 gun) electron optical system has been completed and tested. The No. 2 gun differs from the original, modified Ampex optical system in that all the

adjustments are made between the cathode filament and anode at the lower end of the gun. The complex correction lenses, focus unit, and deflection plate assembly is accurately machined with only a rotational adjustment of the cylindrical lenses. This new electron optical system has been tested and found to work very satisfactorily.

In addition to the new mechanical configuration, a modification has been made to the mode of operation of the dynamic lenses which has now been shown to be capable of maintaining uniform focus over the complete 4-1/2" of the scan by utilizing a flat film instead of the original curved film. A considerable amount of time was spent in making this modification to the electron optical system and its auxiliary electronic support. This time has been extremely well spent, inasmuch as the complexities of the mechanical tape transport have been considerably reduced as a result of allowing the film to remain flat instead of at an exact predetermined curvature.

2.2.2 Electron Gun Structure

Figure 2.2.1 shows the main electron gun structure mounted on the vacuum system. At the lower end of the electron gun is the filament and cathode assembly which will be shielded to avoid accidental shock. The lower adjusting knob controls the X and Y motion of the filament and cathode relative to the remaining part of the electron gun. Just above the lower three position knobs, is a single knob which controls the height of the anode aperture. Above this single control are four more adjustments which control the X-axis and Y-axis motion of the main electron gun structure relative to the remaining optical elements. A single control in about the center of the electron gun structure provides rotational adjustment on the cylindrical electron optical elements.

2.2.3 Anode Assembly

Figure 2.2.2 shows a closeup view of the anode assembly with its adjustments. The single control on the right is used to adjust the height of the anode aperture which cannot be seen but is mounted directly below the clearly visible anode cap in the center of the picture. The other four control knobs govern the X-Y position of the complete assembly. It should be noted that the anode assembly itself is made of highly polished material to reduce the risk of field emission or Corona breakdown.

2.2.4 Focus Structure

Figure 2.2.3 shows the assembly of the focus unit. Directly below the main focus cylinder mounted on a rotatable base are the 11 cylindrical and circular dynamic lens elements. These lens elements and the main focus units are all machined very accurately. The only adjustment is rotation which is made by rotating the geartooth assembly shown in the center of the picture.

2.2.5 Deflection and Focusing Assembly

Figure 2.2.4 shows a closeup of the deflection plate assembly mounted on top of the focus and dynamic lens assembly. The Y-deflection plates (a pair of small plates) can be seen at the very top of the picture. They are used for checking the focus of the electron gun. Below the Y-deflection plates are mounted the X-deflection plates. These plates are very accurately machined and jugged to fractions of a thousandth of an inch to maintain uniform focus. The over-all assembly is very accurately aligned so that no adjustments are made once the various elements have been positioned in the vacuum system. The main focus assembly is located just below the deflection plate assembly and was shown in the previous figure (Fig. 2.2.3).

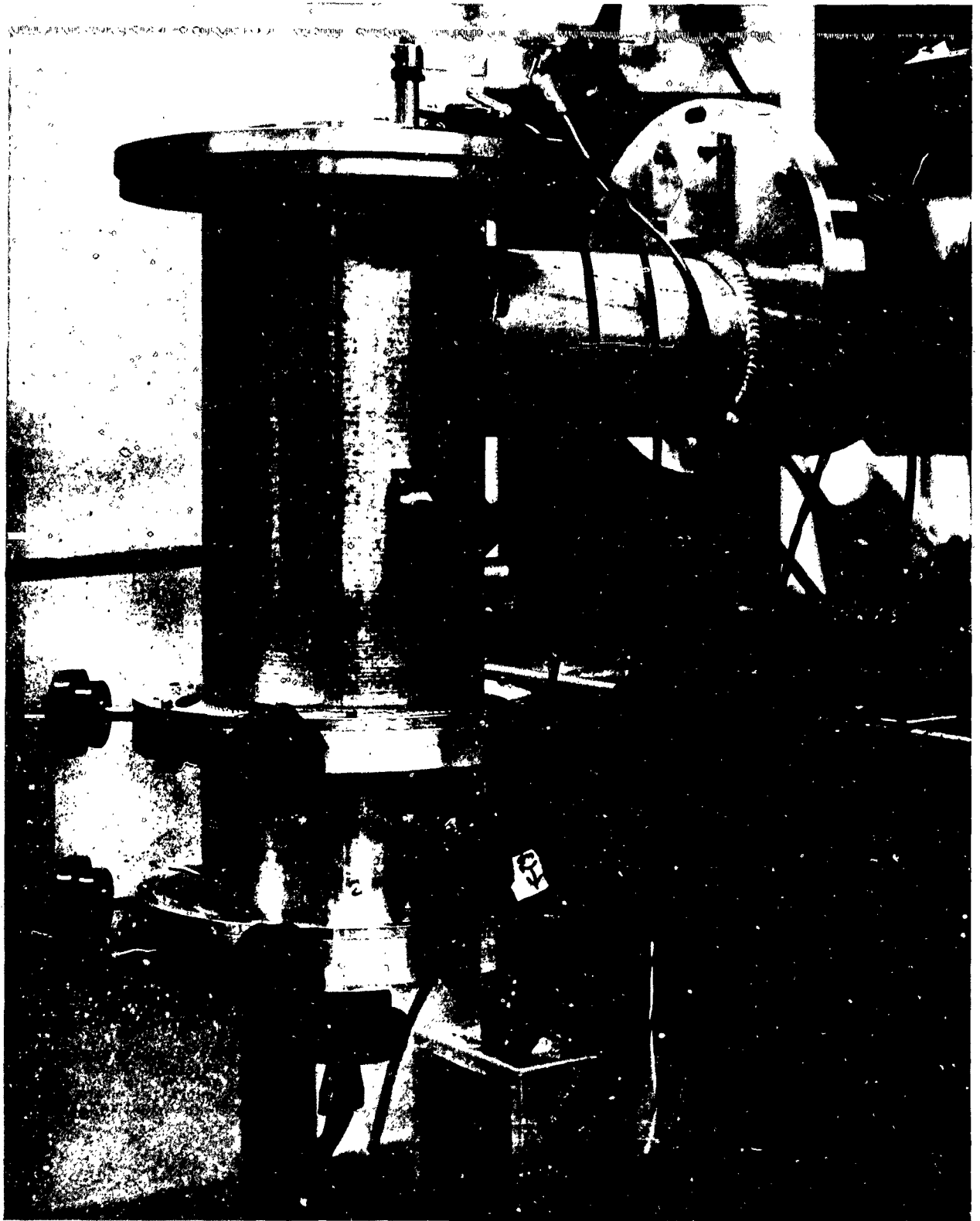


Fig. 2.2.1 Electron Gun Structure

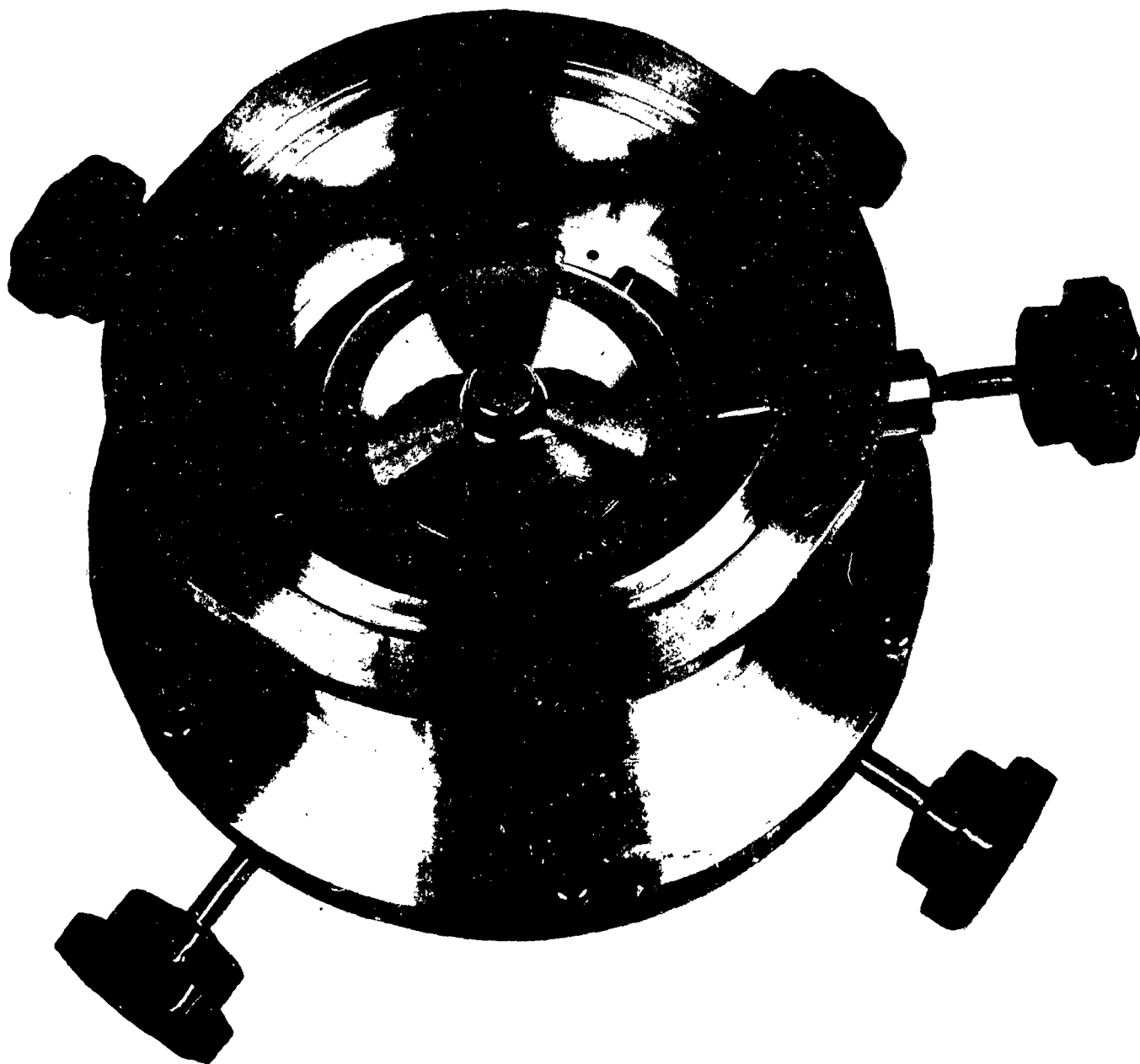


Fig. 2.2.2 Anode Assembly

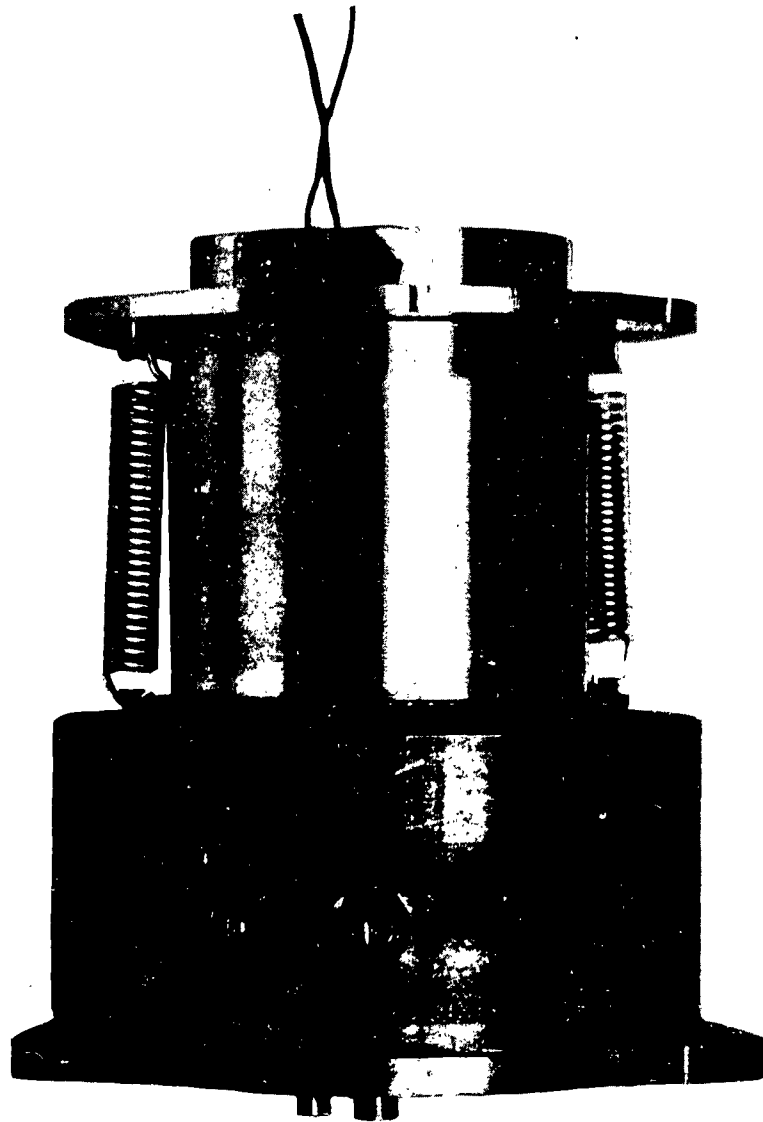


Fig. 2.2.3 Focus Unit Assembly

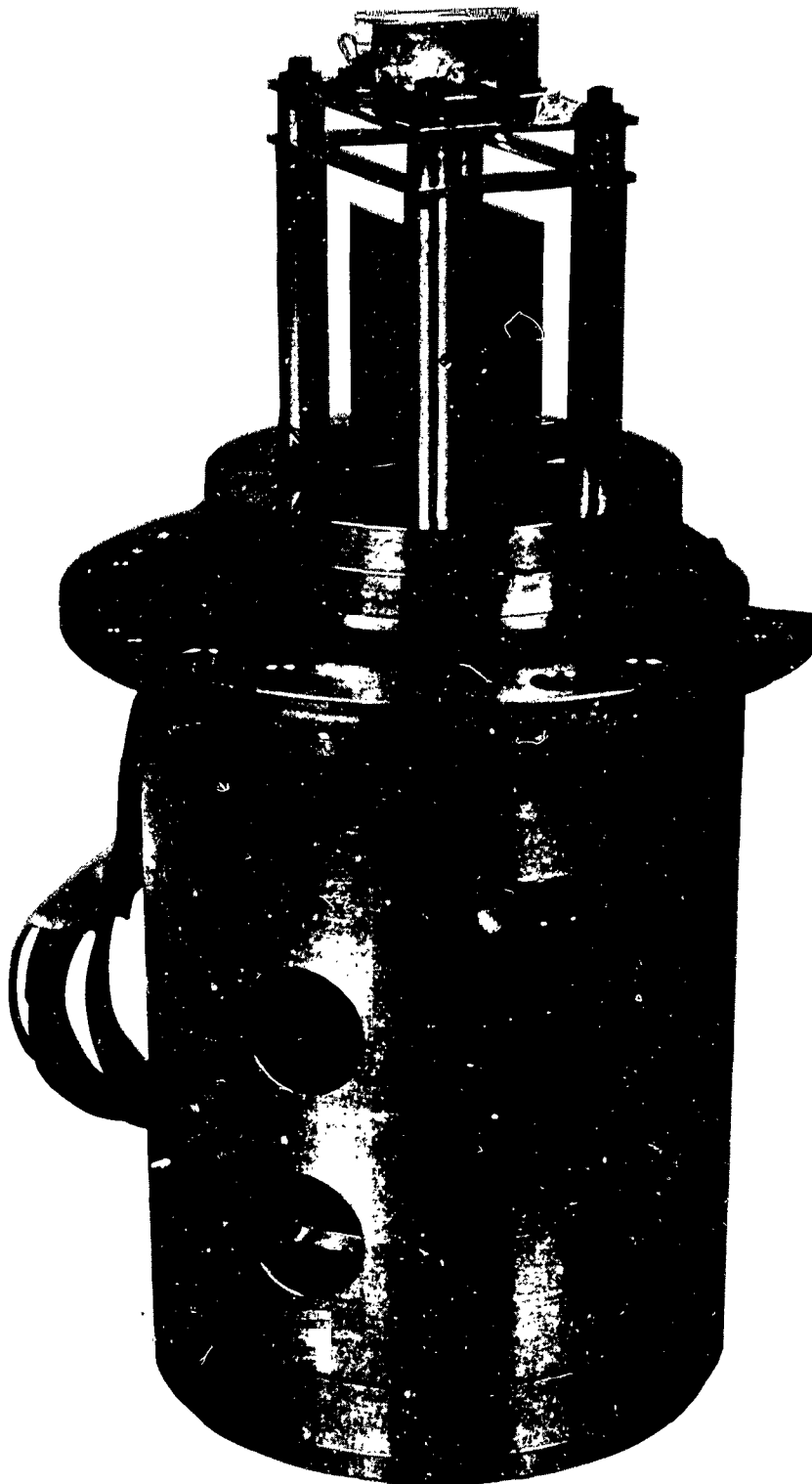


Fig. 2.2.4 Deflection Plate Assembly

2.3 Deflection and Spot Correction System

Generation of sweep waveforms for deflection of the electron beam and correction waveforms for the maintenance of proper spot shape and size is to be carried out as shown in Fig. 2.3.1.

Most of the necessary equipment has been designed and tested in breadboard state.

2.3.1 Deflection

In normal operation of the equipment a photographic film is scanned at a 1.5 kc/sec rate, and the slow sweep amplifier shown in the figure is capable of providing a sawtooth waveform of about 600 volts peak-to-peak amplitude for this purpose. The 1.5 kc/sec sweep generator is a transistor circuit which produces a sawtooth (approximately 5 volts peak-to-peak) in synchronism with pulses received from the timing unit. When running at 1.5 kc/sec the switches are in the "operate" position and the subsidiary deflection plates (Y-plates) are grounded.

The Y-plates are utilized when the scanner is being set up and tested. A 525 line television raster, formed by sweeping the spot at a 15.75 kc/sec rate in the Y-direction and a 60 cps rate in the X-direction, is used to scan the film. On the television monitor the Y scan will be displayed horizontally and the X scan vertically. The 15.75 kc/sec and 60 cps sweep generators are transistor circuits whose output waveforms are synchronized by pulses received from the timing unit. Since only a small area is scanned when running at TV rates, the amplitude of the deflection waveforms is about 100 volts peak-to-peak, allowing the use of transistors in the fast sweep amplifier.

To inspect the whole width of the film using the small TV raster, static shift is provided by the application of a steady, but variable voltage

to the X-deflection plates. This voltage is supplied by the static positioning control and is added to the 60 cps sweep waveform in the adder.

2.3.2 Spot Correction

To maintain the correct size and shape of spot as it is swept across the width of the film, correction voltages which vary with deflection angle are applied to the circular and cylindrical lenses.

The voltages required for each lens are different and maximum voltage is applied at zero deflection for the circular lens and maximum deflection for the cylindrical lens. Hence, the need for separate channels and a voltage inverter before the cylindrical lens amplifier. Because of the high peak voltages (about two thousand volts positive), it is necessary to use vacuum tubes in the drive amplifiers.

Since the correction voltages are a function of deflection angle, and therefore deflection voltage, it is advantageous to use the latter as directly as possible in generating the correction voltages. After passing through buffer stages (to prevent distortion of the sweep waveforms), the more negative of the complementary deflection voltages from the slow sweep amplifier is selected by a gating circuit (the triangular wave synthesizer). It is then modified by the correction waveform synthesizers. When running at 1.5 kc/sec the effect is to convert the two sawtooth waveforms into a symmetrical triangular wave of half the sawtooth amplitude. The correction waveform synthesizers then attenuate and reshape the triangle in 16 discrete steps, producing a rounded wave-shape of about 40 volts amplitude.

2.4 Timing Unit

Synchronizing pulses generated in the timing unit will be used to trigger the main sweep generator (1.5 kc/sec rate) and the sweep generators (operating at television rates) used for setting up and testing the equipment.

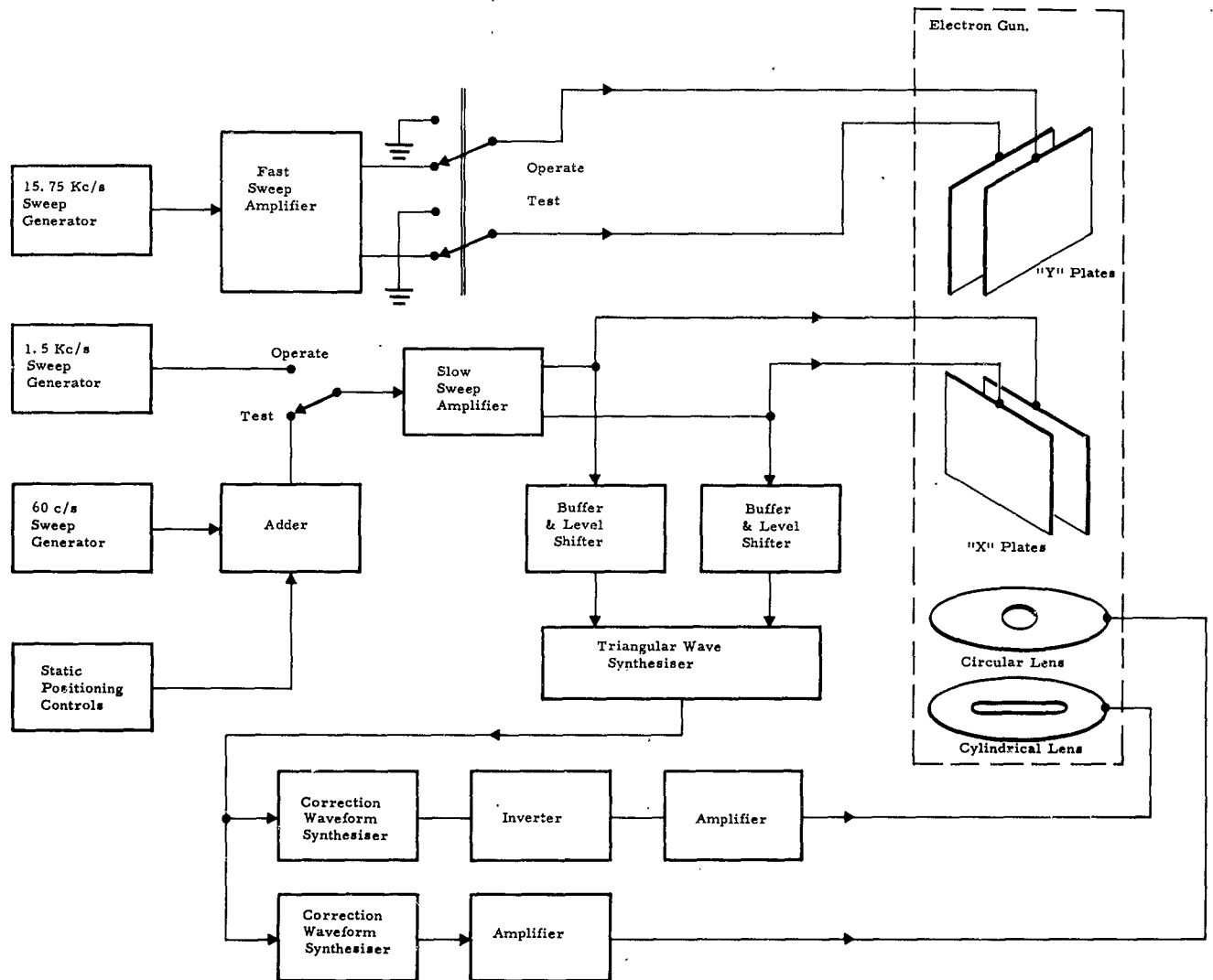


Fig. 2.3.1 Deflection Spot Correction System

The timing unit will also provide horizontal and vertical blanking pulses for flyback suppression in the television monitor.

The unit, which uses transistors throughout, has been designed and a breadboard model tested. A description, together with the block diagram (Fig. 2.4.1), is given below.

In normal operation of the scanner, photographs are swept by the electron beam at a 1.5 kc/sec rate. For setting up the equipment an interlaced television raster, requiring horizontal and vertical sweeps, is used. Trigger pulses for the three sweep waveforms are derived from one of two primary sources in the timing unit. The first is a crystal controlled oscillator and the second a free running multivibrator whose frequency can be either controlled manually or locked to the 60-cps supply frequency. The last alternative provides a way of avoiding uncoordinated interference patterns.

Since a standard 525 line TV monitor is used for setting up, the frame repetition rate is nominally a thirtieth of a second and in this period two interlaced rasters are written. Hence, the horizontal repetition frequency is 525×30 or 15.75 kc/sec. For correct interlace, vertical synchronizing pulses must occur every $262\frac{1}{2}$ line periods, and a primary frequency of $2 \times 262\frac{1}{2} \times$ (field repetition rate) is used to accurately define the half period. Since the field repetition rate is the supply frequency, the primary frequency is nominally $2 \times 262\frac{1}{2} \times 60$, or 31.5 kc/sec. This is the frequency of the crystal oscillator and the rate at which the master multivibrator runs when under the control of the phase comparator.

Horizontal sync and blanking pulses are obtained by dividing the primary frequency by two in the binary counter and forming suitably shaped pulses in pulseformers 2 and 3.

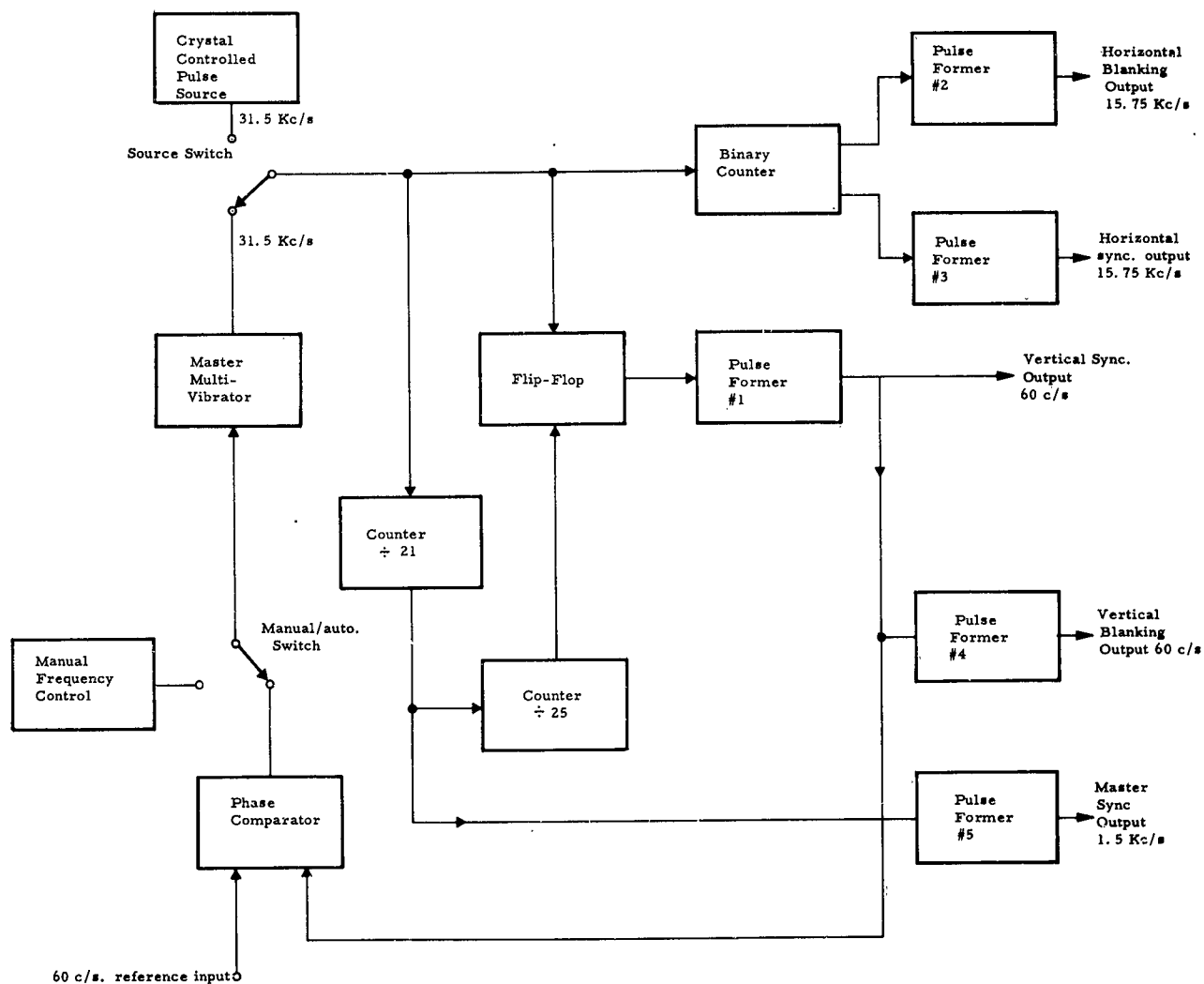


Fig. 2.4.1 Timing Unit

Two monostable multivibrators set for counts of 3 and 7 (the $\div 21$ counter in Fig. 2.2.1) reduce the 31.5 kc/sec primary frequency to 1.5 kc/sec and provide, via pulseformer 5, the master sync pulses for the equipment when in normal operation.

Another two monostable multivibrators, each set for a count of 5, (the $\div 25$ counter) reduce the 1.5 kc/sec pulse train to a 60 cps signal.

To maintain precise timing between vertical and horizontal synchronizing (sync) pulses, and so obtain good interlacing, the primary pulse train is used directly to generate vertical sync in pulseformer 1. This is accomplished by setting the flip-flop with the 60 cps output of the counters and allowing the next primary pulse to reset it. Pulseformer 1 is actuated only upon reset of the flip-flop.

Pulseformer 4 provides a pulse of variable width for blanking the vertical retrace lines.

The phase comparator is actually a step generator in which the 60 cps input sine wave is sampled during each relatively short vertical sync pulse. At the output of the comparator the voltage encountered at each sampling is maintained between sync pulses. Therefore, when phase lock is accomplished (i.e. the sync pulse samples the same portion of the sine wave in every cycle) the comparator output is a steady voltage which changes only in very small step to correct for drift of the master multivibrator. A feature of the step generator is an output voltage which does not droop between samples. Droop would cause frequency modulation of the master multivibrator and hence modulation of the horizontal repetition rate. In the manually controlled mode of operation the frequency of the master multivibrator is determined by a steady voltage derived from a potentiometer.

3.0 CONCLUSIONS

A. Design and construction of the scanner is on schedule and no major difficulties can be foreseen at this time.

B. The resolution and bandwidth specifications can be met with existing equipment. However, it is hoped that current development work will result in improved cathode stability and easier alignment of the electron gun.

C. The time required to pump down the electron gun and film transport will not be known until the appropriate parts have been assembled and tested. It may prove necessary to operate the gun at a pressure lower than that in the transport, due to outgassing of film in the latter.

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