Visibility Laboratory
University of California
Scripps Institution of Oceanography
San Diego, California 92152

DEVELOPMENT OF A COLORED TELETYPE TAPE DISCRIMINATION SYSTEM

Final Report

by

R. L. Ensminger

September 1964

SIO Ref. 64-12

Bureau of Ships
Contract NObs-84075
Assignment No. 10
Project SF 01802, Task 0538

Approved:

S. Q. Duntley, Director
Visibility Laboratory

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

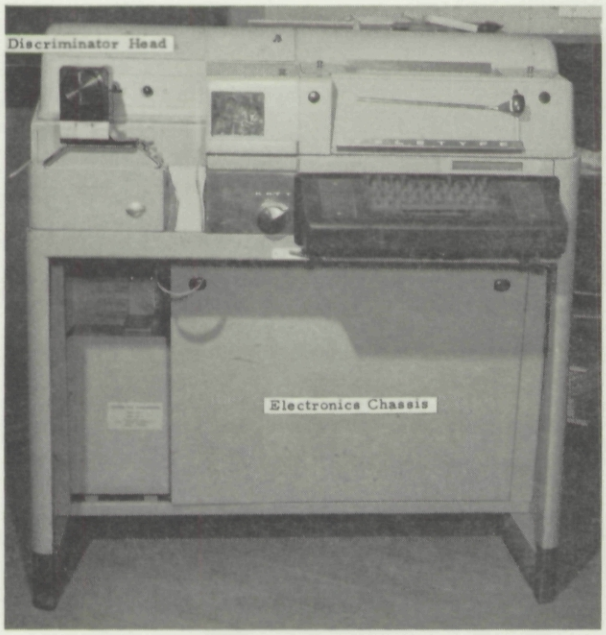
1.0 INTRODUCTION

In some types of Navy teletype communications installations, messages in the form of paper tapes are fed into one tape reader for transmission if unclassified material, and into a separate tape reader for encoding and transmission if classified. The Bureau of Ships is investigating a system of color coding of paper tapes as a technique for safeguarding against unintentional transmission of classified information on the unclassified equipment. The Visibility Laboratory previously constructed a laboratory breadboard of a photoelectric apparatus capable of sensing the color of the paper tape and disabling the tape reader in the presence of tape of the wrong color.[1]

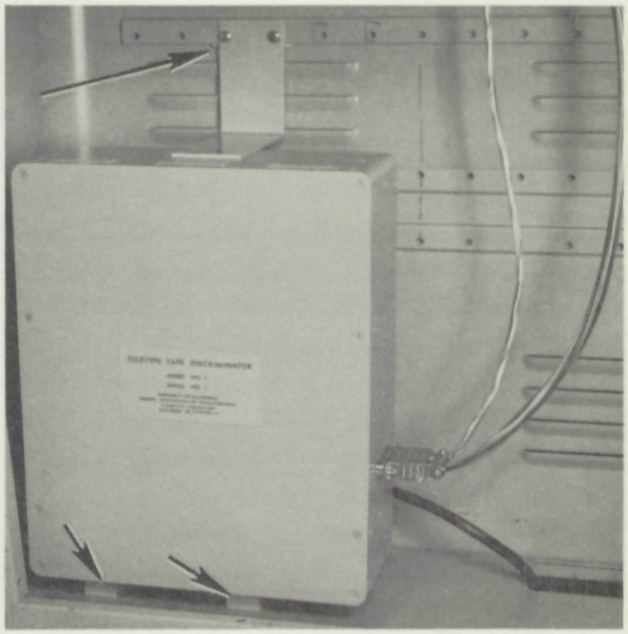
The present report describes the design and construction of an operational breadboard unit for mounting on the AN/UGC-6 teletypewriter. Figure 1 shows the system in operation on a AN/UGC-6 teletypewriter.

To review the design fundamentals, it was found that a significant difference in the reflection spectra of the yellow and red tapes exists in the green portion of the spectrum. Hence it was decided that a reliable decision criterion could be based upon a signal sample between 530 and 570 millimicrons. When the spectrum is limited to such a narrow range by means of an appropriate color filter, solid state light sensors prove to be too insensitive because of their high red response. Hence the choice of detectors is limited to multiplier phototubes.

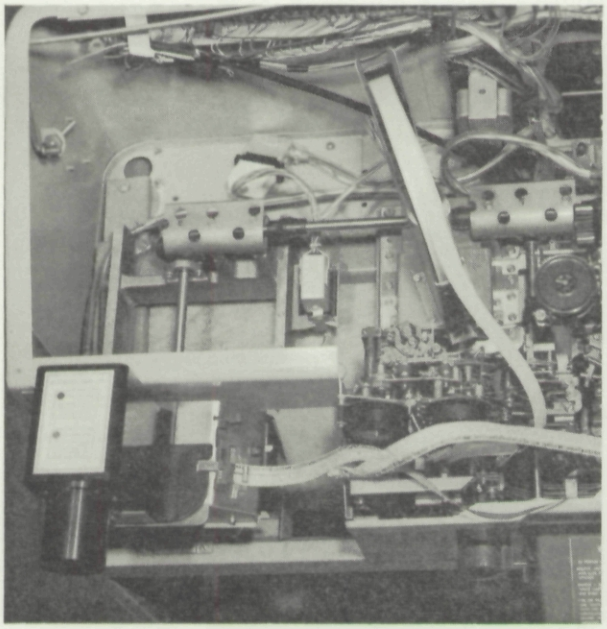
[1] R. L. Ensminger, "Report on the Development of a Colored Teletype Tape Discrimination System," SIO Ref. No. 63-12, March 1963.



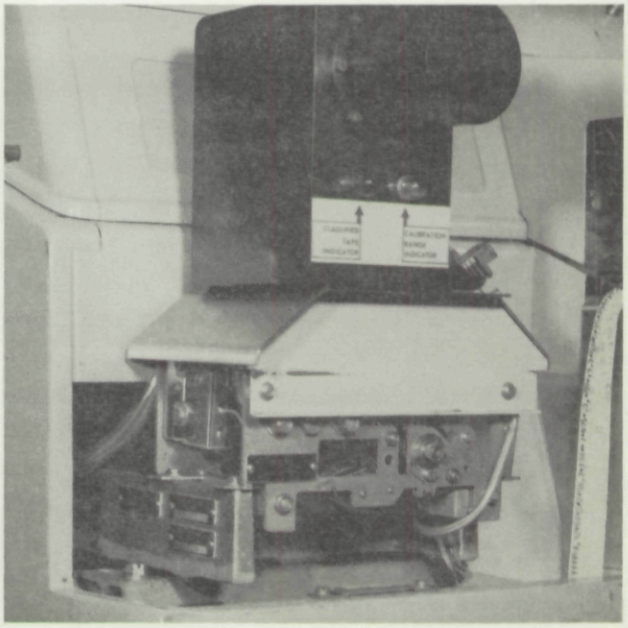
The colored teletype tape discriminator correctly installed on a UGC-6 teletypwriter.



Top bracket is fastened to cabinet flange with number eight machine screws into tapped bar behind flange. 1/4 x 20 screws thread through bottom of cabinet into tapped mounting feet.



The TT-251 connection is unplugged and connected in series with the two discriminator plugs. Cable from discriminator head follows the outside edge of the re-perforator mounting base and goes through hole in bottom of cabinet.



The discriminator head is snapped onto the TT-251 in place of the top cover. The cable is fed through the side of the cabinet as shown. The side cover has been temporarily removed to make this installation.

Figure 1 Complete Color Discrimination System Mounted on a UGC-6 Teletypewriter and Various Installation Details

A basic system consists of a light source, a multiplier phototube with an imaging lens and green filter, and a level detector. This is the type of system that was constructed under the laboratory breadboard phase of the contract.

Two new phases to the problem emerge when the design of an operational breadboard is considered. The first is that of insuring a secure transmission for the message, and the second is that of long-term stability. Since the circuit had to be designed to run for long periods of time, slow aging and drift effects virtually dictated a closed loop system. Otherwise, in a few weeks' time the gain of the system might slowly drift to a point where the system was either perpetually off or perpetually on for all colors of tape.

So that transmission security could not be violated, the system had to be designed so that the equipment could not be simply or inadvertently defeated. Component failures most likely to occur had to result in a permanent off condition rather than a permanent on condition. It was the addition of these features as well as repackaging that led to the present unit. Figures 2 and 3 summarize the operational and fail-safe features of the device.

OPERATIONAL FEATURES

1. In order to start the Transmitter Distributor (TD) two conditions must be satisfied.

   A. The tape must be in correct registration underneath the discriminator.

   B. The tape must be yellow or have a 50% higher reflectance than red tape when viewed through a green filter.

2. Direction of tape insertion in the head is unimportant. Tape can be inserted from the front, side or rear. However, the easiest and most natural way is from the side.

3. Once the TD has started and been running for 8 seconds it will continue to run even though the reflectance of portions of the tape may drop below the acceptance level. This interlock is broken when the tape is removed. If desired, this feature can be simply eliminated by removing a plug-in relay.

4. For normal conditions of component drift the discriminator is self-correcting. Should the correction range of the equipment be exceeded a yellow indicator will light and the TD cannot be started.

5. The equipment is designed for continuous operation.

Figure 2 Operational Features

Fail Safe Features

Failure	Result
Ansco Lamp	The servo motor would increase the voltage on the remaining lamps. If there were not enough range, the yellow indicator would light and the TD could not be operated.
Miniature Lamp (Front or Rear)	Should the tape be inserted from the front or rear, the servo action would not be broken, and the Ansco lamp voltage would automatically be adjusted to the inoperate level as a yellow tape was inserted. For normal insertion of the tape, operation would be as before.
Miniature Lamp (Side)	Servo action would not be broken for normal tape insertion, hence neither the red or yellow tapes could be run.
High Voltage Increase or Decrease	Servo action would compensate for this until the range was exceeded, then the yellow indicator would light and the TD would be inoperative.
Transistor Supply Failure	The TD would be inoperative.
Lamp Supply Failure	The yellow indicator would light and the TD would be inoperative.
Loss of AC Power	The TD would be inoperative.

Figure 3 Fail-Safe Features

2.0 SYSTEM OPERATION

2.1 Discriminator Head

The discriminator head is built onto a cover plate that can be interchanged with the existing top cover plates of the teletype-writer model TT-187 or TT-251. When mounted in this manner and connected to the associated electronics chassis it serves to monitor the color of a tape as it is being inserted into the Transmitter Distributor. Figure 4 shows an exploded view of the discriminator head.

The light from the Ansco lamp is focused onto a .25-inch circular spot of low reflectance paint on the cover. Reflected light from this spot is imaged onto the multiplier phototube after passing through the green filter.

There are three additional light paths formed by the miniature lamp assembly. The light from these lamps passes through the cover plate and impinges upon photodiodes mounted underneath the cover plate. These three sensors serve to detect the passage of any material that is disrupting the light beam. Their principal function is to make the circuitry aware of:

1. The presence of tape
2. The passage of tape
3. The position of tape.

The three light beams are positioned so that a tape in normal running position covers the front and rear beams but does not cover the side beam.

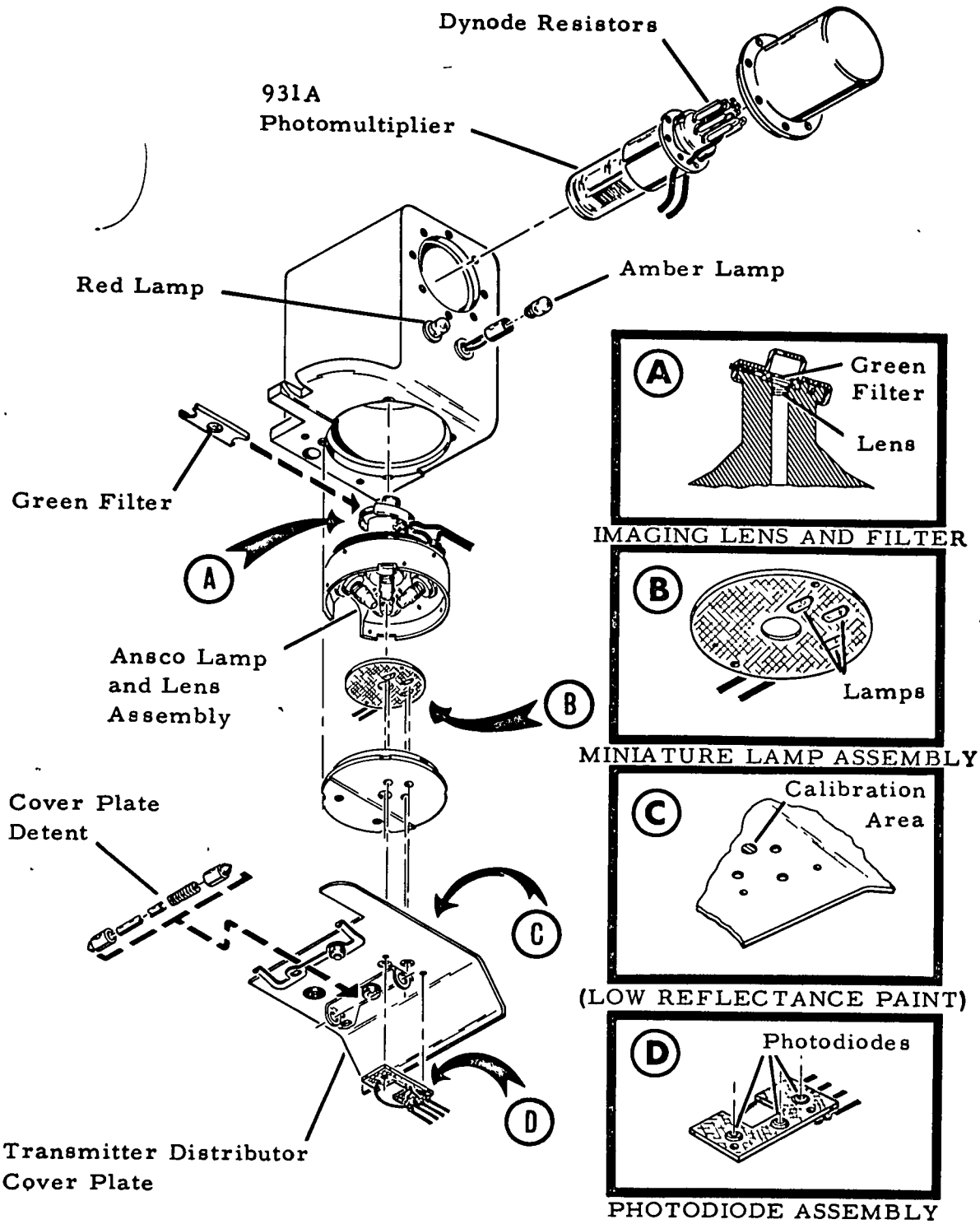


Figure 4 Exploded View of Discriminator Head

2.2 Modes of Operation

2.2.1 Auto Calibration

The operation of the device can best be understood by reference to Figs. 5 through 8. When no tape is present the system is said to be in auto calibration. In this condition the multiplier phototube output is referenced against a standard voltage. The difference signal serves to operate a motor which is geared to a potentiometer that adjusts the ansco lamp voltage if the error exceeds a certain amount in either direction. The system has a certain dead band so that the motor does not run continually. The advantage to the system is that there is no constant mechanical motion of a shutter or optical chopper. The system has memory, and once correction takes place there is no further mechanical motion. Since regulated voltages are employed throughout, it is only slow drifts, heating, and aging effects that need to be corrected for.

In this mode the TD cannot be operated since the return flux from the low reflectance spot is insufficient to operate the level circuit and the proper combination of presence detectors is not energized.

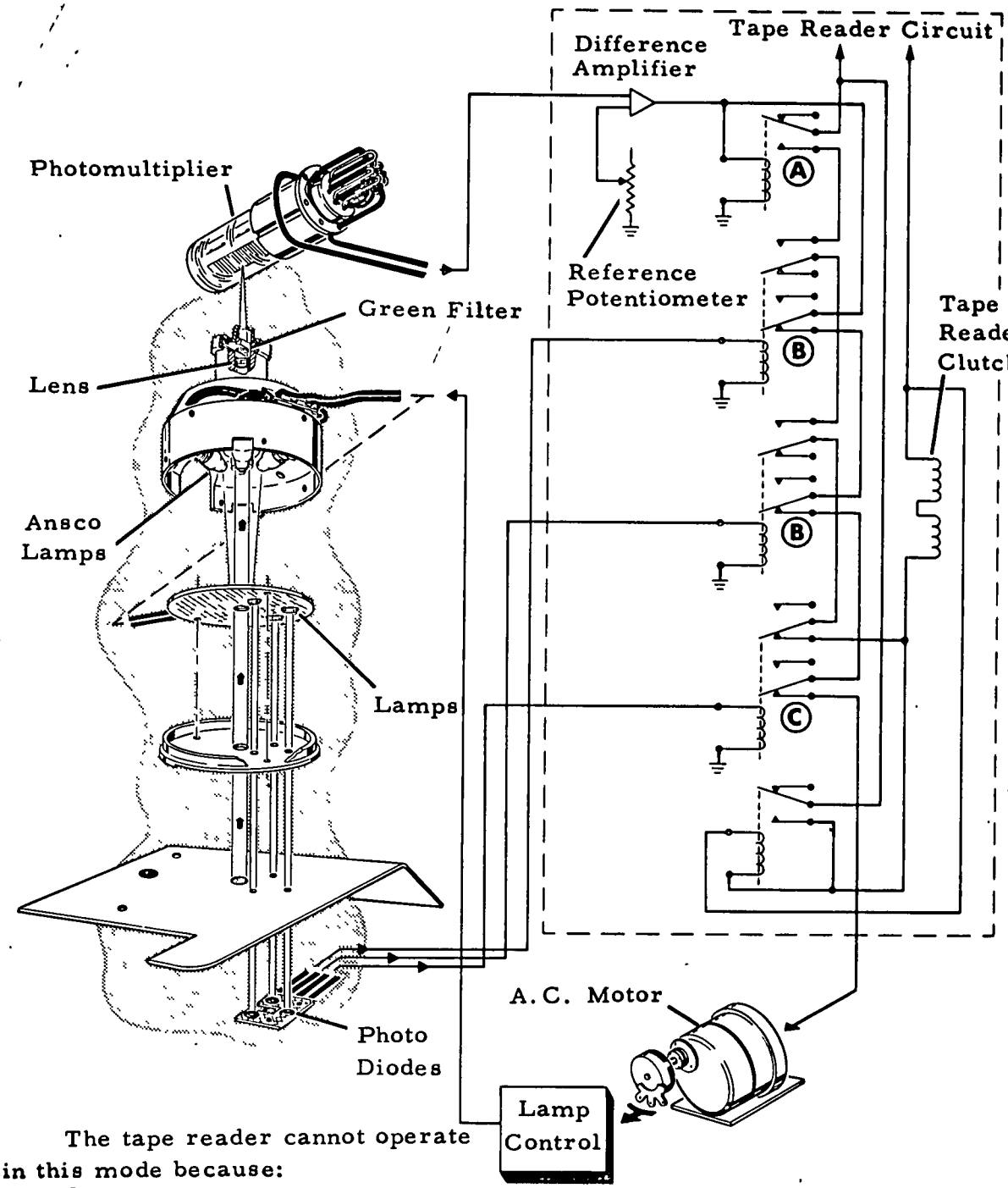
The logic condition necessary for TD operation is the "and" condition between the following set of events.

(1) Sufficient level -- which means a yellow tape and not a red tape.

(2) No tape under the side presence detector.

(3) Tape under the front and rear presence detectors.

This condition can be met only by a piece of material of the same reflectance or higher than a yellow tape and of the same width.



The tape reader cannot operate in this mode because:

Ⓐ There is insufficient flux level to operate the level relay.

Ⓑ A tape has not been correctly positioned under the presence indicators.

Ⓒ In the absence of a tape the motor circuit is closed and the multiplier phototube current is maintained at a constant value by changing the Ansco lamp voltage as required.

Figure 5 Block Diagram: Auto Calibration Mode

2.2.2 Start of Tape Insertion

As a tape is inserted from any direction the servo action is broken since the logic condition necessary for servoing is not to have tape under any presence detector.

Normally tape will be inserted from the side, but should tape be inserted from the front or rear these respective presence detectors will respond. The geometric layout of the three detectors is such that tape cannot get in the spot illuminated by the Ansco lamps without first being detected by a presence detector.

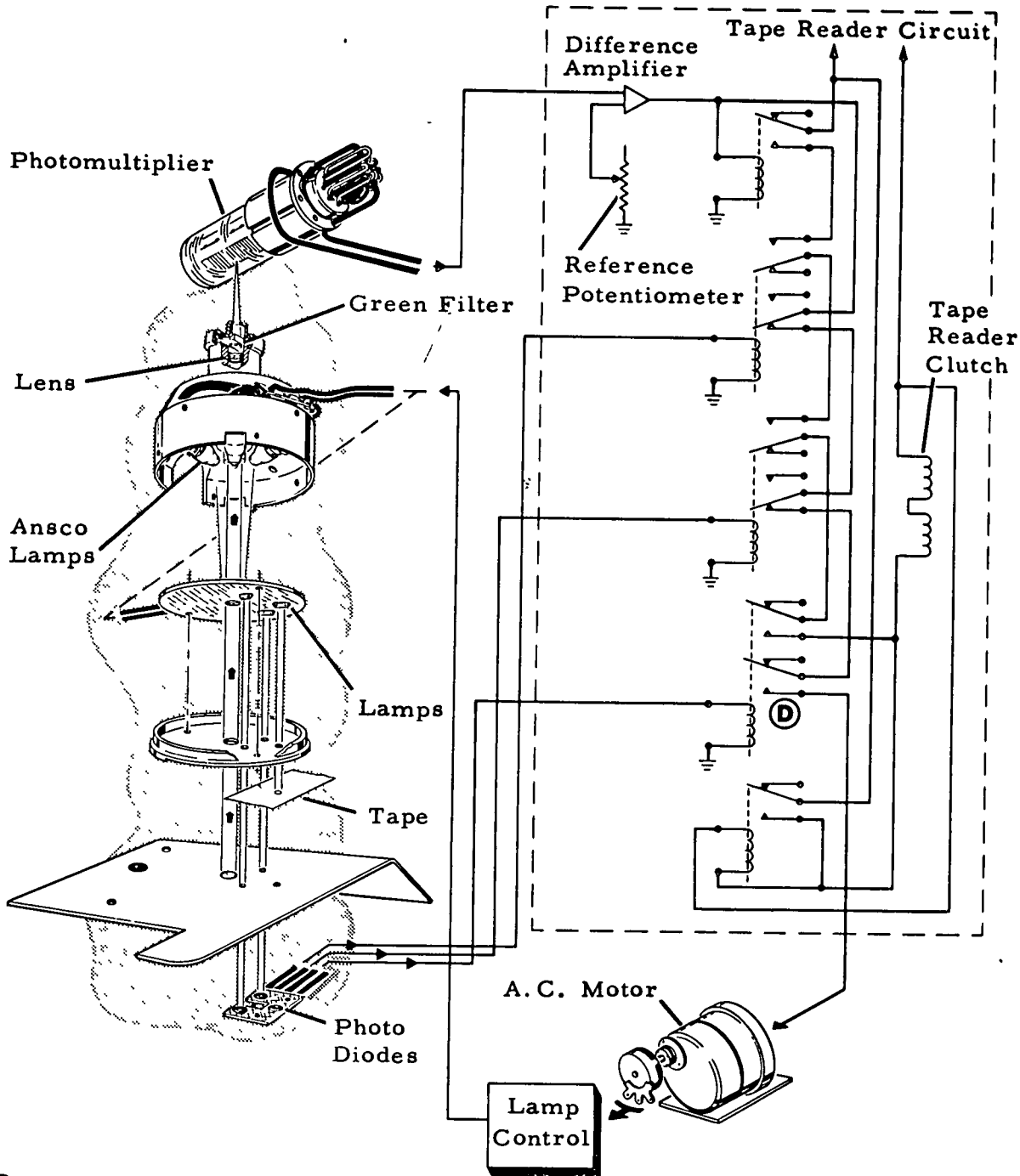
2.2.3 Registration Position

In this position tape covers the front and rear presence detectors but does not cover the side detector. If this condition is met and the level is high enough the TD can be started. The servo action remains broken since the tape is over at least one of the presence detectors.

2.2.4 The TD is Started

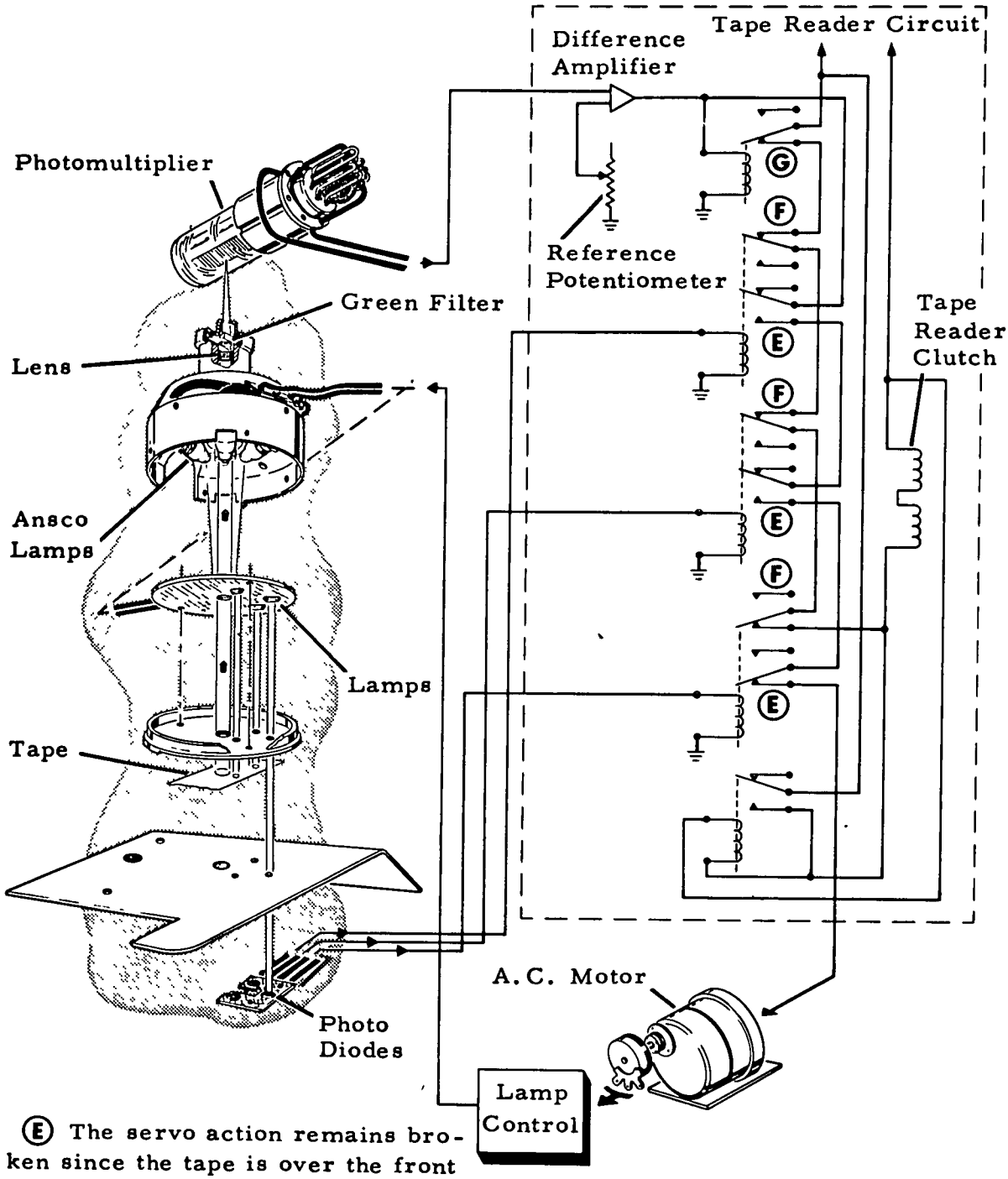
Eight seconds after the TD is started a relay picks up which bridges the start circuit. This has been done so that once the decision to start has been made the TD will continue to run until the tape has been completely read. It was felt that this was a necessary precaution since a dark area on the tape might cause the level circuit to drop out. Tests made at the Visibility Laboratory have indicated that there is considerable variability in response from a given tape.

The eight-second delay was incorporated in the event that the operator tried to place a red tape just in the TD feed latch but not under the reader and at the same time place a yellow "trick tape" under the discriminator. Under these circumstances the reader would start but stop when the red tape reached the



Ⓓ As soon as a tape is inserted over any photodiode the servo action is broken leaving the circuit free to respond to the color of the tape.

Figure 6 Block Diagram: Start of Tape Insertion

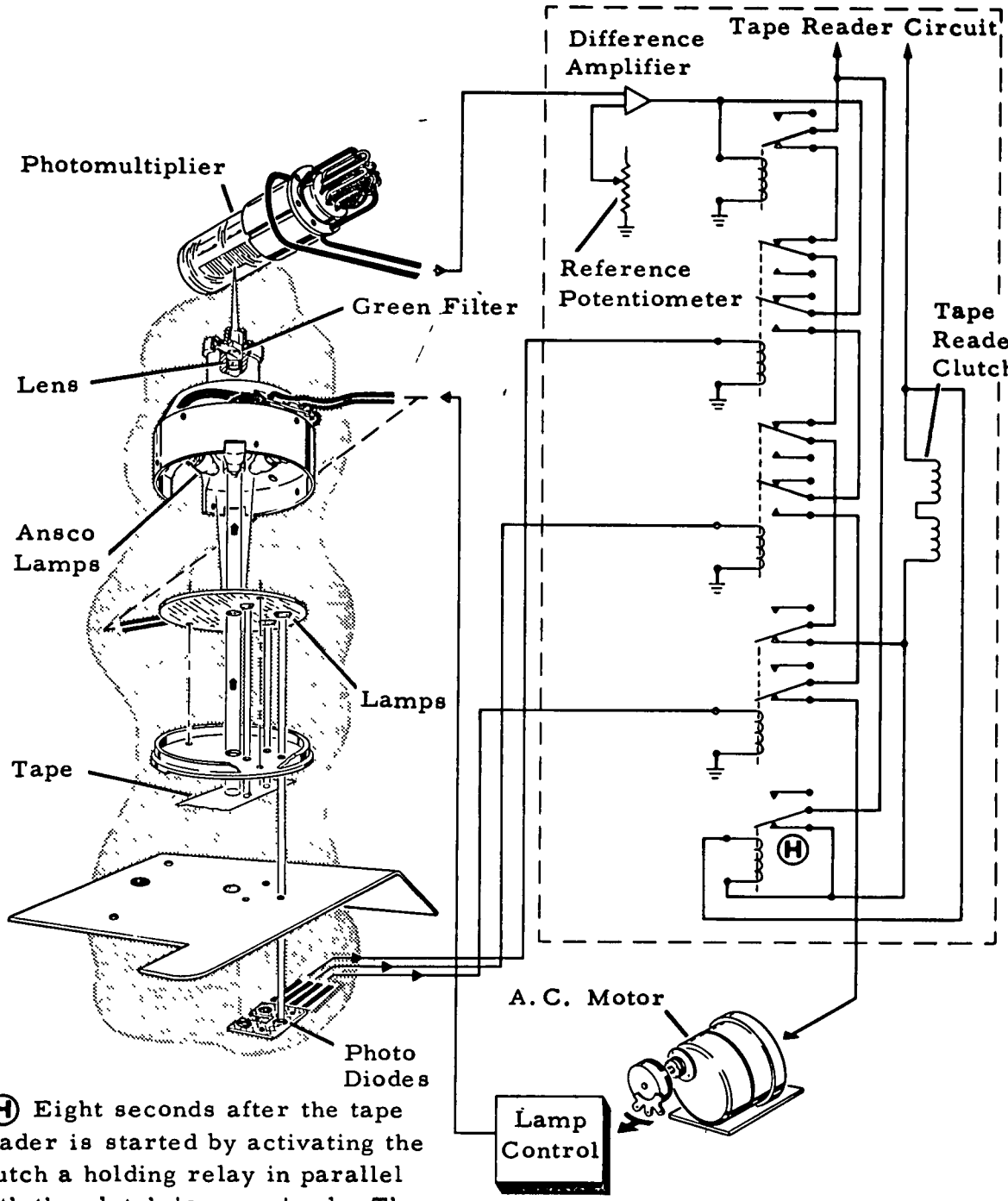


(E) The servo action remains broken since the tape is over the front and rear photodiode.

(F) Closing of the tape reader circuit depends only upon the color of the tape since the tape is registered.

(G) If the tape is yellow the level will be sufficient to activate the level relay and the reader can be started.

Figure 7 Block Diagram: The Tape is Registered in Position



Ⓗ Eight seconds after the tape reader is started by activating the clutch a holding relay in parallel with the clutch is energized. The contacts of this relay bridge the decision making contacts to insure that nothing will interfere with running the tape once a decision has been made.

Figure 8 Block Diagram: The Tape Reader is Started

recognition area, since the bridging relay would not yet have picked up because of the delay. Admittedly this is an overt act of trying to use the device incorrectly, but it was felt such a possibility should be guarded against.

3.0 CIRCUIT DESCRIPTION

With the exception of the multiplier phototube, all solid state circuitry has been utilized throughout. The circuitry has been packaged in the form of two sub-chassis and two circuit boards. The functions performed by these sub-units are as follows:

Terminal Board A	1. Motor control 2. Multiplier phototube impedance changer and level detector
Terminal Board B	1. Presence detectors
Sub-Chassis A	1. Ansco and miniature lamp power supplies 2. Motor 3. Time delay relay
Sub-Chassis B	1. ± Low voltage supplies 2. High voltage supplies

The system schematics are shown in Figs. 9 and 10.

3.1 Motor Control and Level Detector

A Siliconix field effect transistor is used in conjunction with an emitter follower as an impedance changer to couple the multiplier phototube to the level detector stage, Q11. When the voltage from the emitter of Q10 is sufficient to break down the zener diode, Q11 saturates, picking up the L relay.

Q5, Q6 and Q7 comprise a difference amplifier whose outputs are connected to Q8 and Q9 through zener diodes. The dead band control is adjusted so that the collectors of Q5 and Q7 are low enough at balance so as not to pick up either of the motor control relays ML or MR. Insufficient dead band may cause the

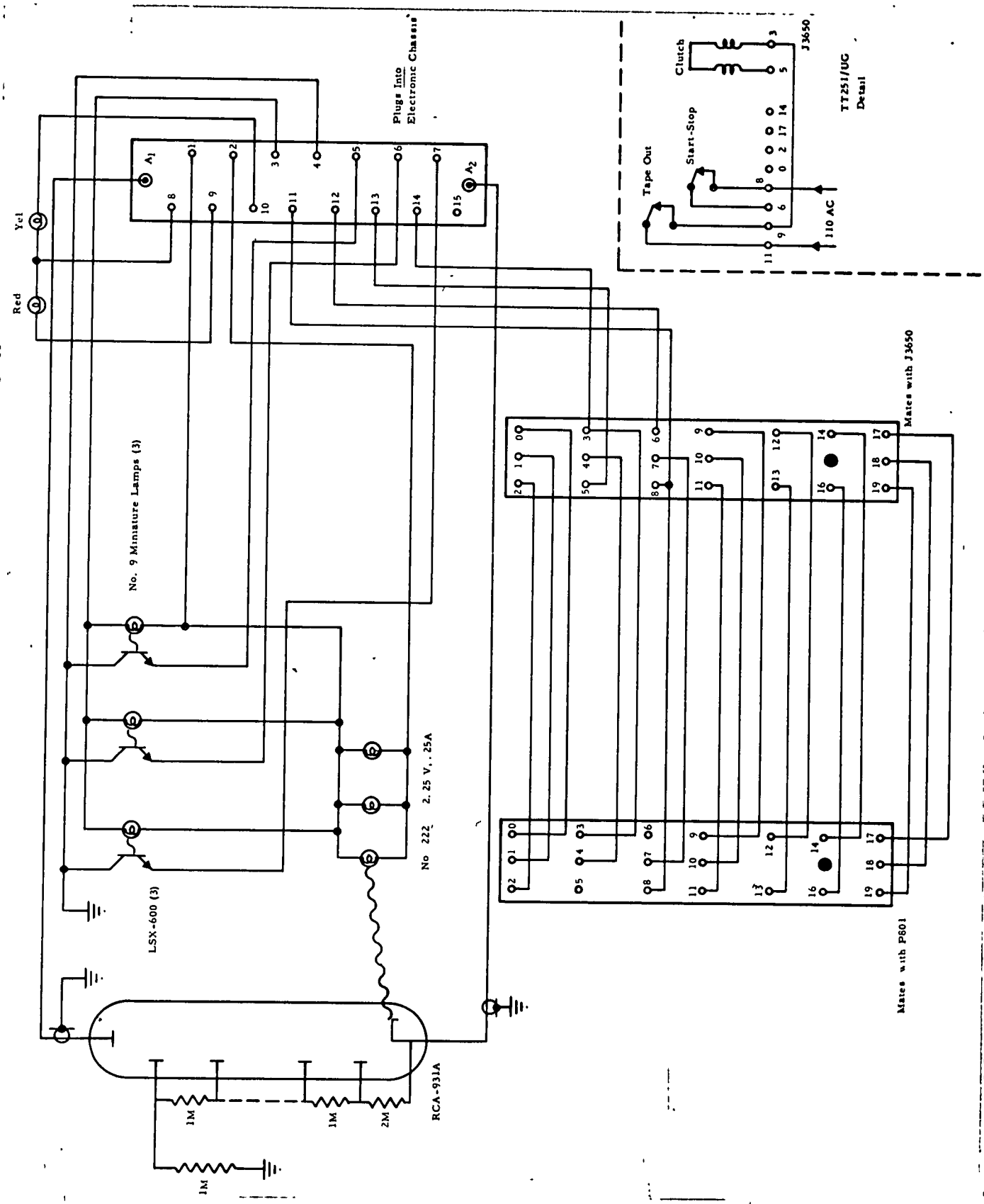


Figure 9 Schematic of Tape Head

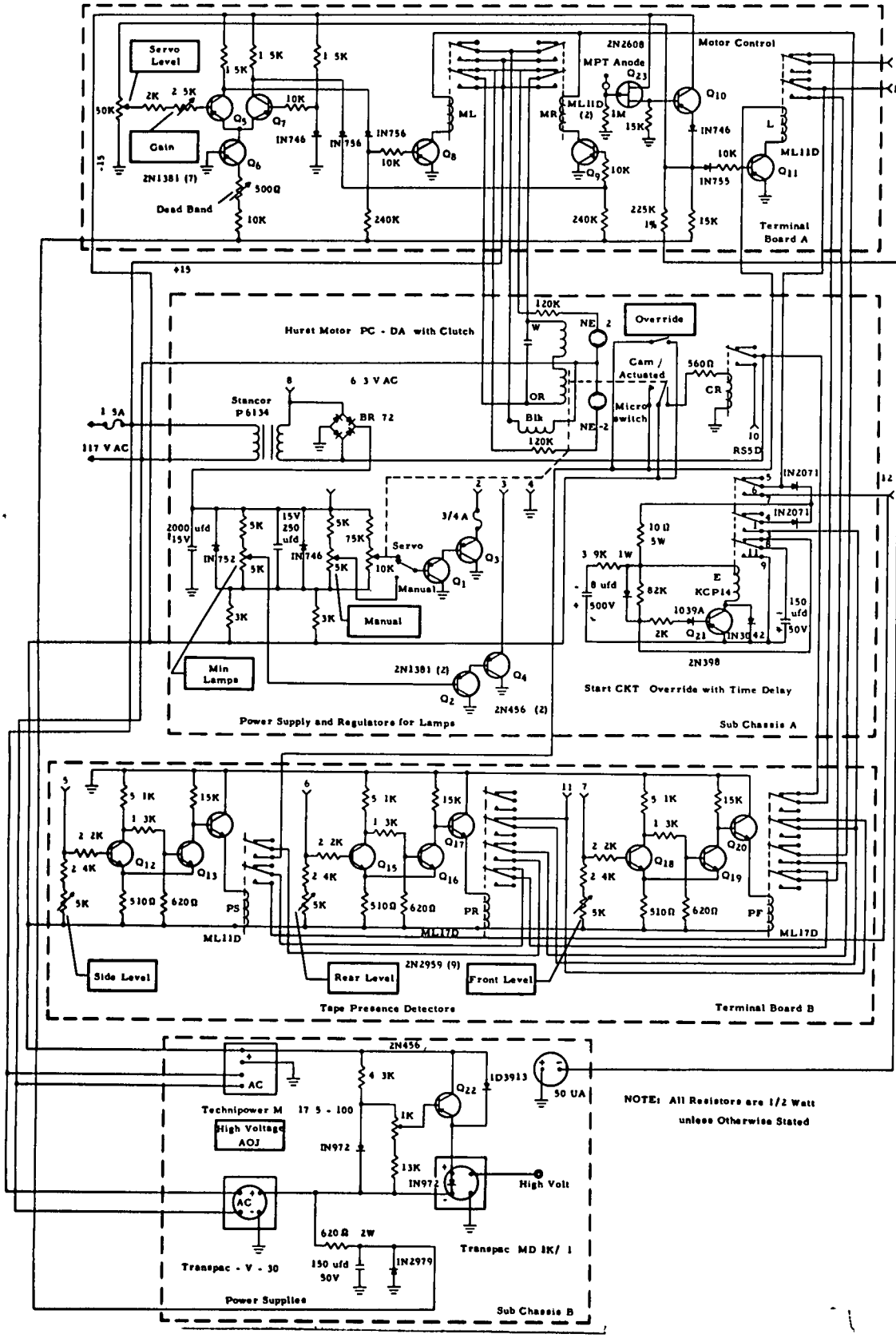


Figure 10 Schematic of Electronics Chassis

control circuit to oscillate. The gain control should be set for as high a gain as possible without instability. The motor control relays pick up the motor clutch and energize the motor for either left or right rotation, depending upon the polarity of the unbalance.

3.2 Tape Presence Detectors

Each of the three tape presence detectors is identical except that the side detector has a two-pole instead of a four-pole relay. The detectors are named front, rear, and side to correspond to the position of the photoconductor to which they are connected. The load resistor for the photoconductor consists of a 2.4K resistor in series with a 5K variable resistance. For a typical detector the first two transistors, say Q12 and Q13, comprise a Schmitt trigger. The third transistor, Q14, is the relay driver. The trigger level controls are adjusted together with the miniature lamp control so that all three circuits trigger at about the center of the flux change between the tape-in and tape-out conditions.

The number one set of relay contacts on all three detectors are wired with the normally open contacts in series as part of the circuit which furnishes the collector supply voltage to the motor control relays. Hence a tape over any photoconductor will disable the motor control circuit.

The series wiring of the number one set of contacts is such that a closed circuit through all three sets of contacts is presented when a tape is correctly positioned in the discriminator head. These contacts in conjunction with the level relay contacts comprise the start circuit for the TD clutch.

The number three contacts comprise part of the holding circuit for the time delay relay so that this relay will drop out after a tape is removed from underneath the discriminator head. The

number four contact on the PF relay prevents the red indicator from lighting unless there is a tape present.

3.3 Lamp Supplies and Time Delay Relay

Both lamp supplies consist of a series regulator powered by a 6-volt bridge rectifier. The Ansco lamp supply is either controlled by the motor-driven potentiometer in the servo position or set by the manual control in the manual position. This is a test condition only and not normally used.

The time delay relay is energized by the AC supply in the TD. The time delay is obtained by means of an RC charging circuit connected to the base of Q 21. Once the relay energizes it holds through the normally closed contacts of the front and rear presence relays.

3.4 Power Supplies

A -15 v, 100 ma regulated supply furnishes the supply voltage for most of the transistors. A +15 volt potential is obtained from a zener diode regulator connected to a +30-volt supply. The input to the high voltage supply floats between the -15 and the +30 supplies. Q 22 furnishes a regulated input voltage to the high voltage dc to dc converter.

For future re-design considerations a 110 v input for the high voltage supply might be more satisfactory. Such a supply meeting the size and weight requirements could not be procured in the allotted time.

4.0 FUTURE MODELS

Several improvements have suggested themselves in the course of designing the present model.

The design philosophy employed in designing the present model was that of incorporating all of the important features without giving too much consideration to the least expensive method. It was felt that the important goal to keep in mind was that of constructing a highly reliable working model. Hence a redesign giving greater consideration to the cost factor would undoubtedly effect a lowering of the expense of future models.

If a future redesign is attempted, a number of improvements have occurred to us as being worthy of consideration.

(1) A smaller motor would help to reduce the size of the unit. The present motor has a higher than necessary capacity.

(2) A multiturn potentiometer could be substituted for the motor driven, conventional potentiometer now employed. To obtain a sufficiently low volts-per-degree of motor shaft rotation, the range of the potentiometer had to be limited by means of series resistors. By employing a multiturn potentiometer a greater correction capability could be achieved while still maintaining the resolution.

(3) A high voltage supply of the solid state converter design capable of running off of a 110 v ac input would greatly simplify the power supply design. This supply should be regulated. Electronic Research Associates makes such a supply, Model SAR 1 K/. 1; however, delivery time prohibited its inclusion in the present system.

Running the high voltage supply from the ac line would reduce the current requirements of the low voltage supplies and smaller size units might be procured or designed.

(4) A redesign of the motor control circuit might be found that would eliminate the need for the positive supply. Then, if the high voltage supply were run off of the ac line, the positive low voltage supply could be eliminated entirely.

(5) It would be desirable to add a second cam and cam-actuated switch so that both the cw and the ccw limits of the motor driven potentiometer could be bracketed. The wiring could then be altered so that when the potentiometer arm is driven off limits in a given direction, only the motor control relay in operation at the time would be electrically disabled. In that case the other relay would still be in operation if the error signal changed polarity. This is the situation that would exist if the potentiometer were driven off limits by a momentary transient.

(6) A further reduction in size could be achieved if a smaller multiplier phototube were employed. Such a tube is the RCA type C 70129B, which is 1.37" high by .51" in diameter.

(7) The imaging lens, filter, and lamp assembly employed was one used in the Model 31, Macbeth-Ansco reflection densitometer head. For a production prototype, the design of a new unit of this type should effect a saving in size. This would be especially true if it were designed around the RCA C 70129B multiplier phototube.

5.0 TELETYPE TAPE DISCRIMINATOR INSTALLATION INSTRUCTIONS

5.1 General

The tape discriminator consists of two parts, the tape head and the electronic chassis. The equipment is intended to be installed on an AN/UGC-6 teletypewriter, its function being to sense the color of the tape being inserted into the TT-251/UG Transmitter Distributer. To install the discriminator the top plate from the TT-251 is removed, together with its side cover, and the discriminator head is snapped on in its place, care being taken to first feed the cable inside of the UGC-6 console. Figure 1 illustrates various details of the installation.

The electronic chassis is next to be installed in the vacant area to the left of the auxiliary equipment rack. The cable from the discriminator head can be fed down into this area and plugged into the electronic chassis. Control of the TT-251 by the color discriminator is effected by unplugging the TT-251 plug from its socket and plugging the discriminator cables in series with it.

For ordinary operation there are no controls whatsoever on the discriminator that need to be adjusted. The electronics chassis is simply plugged into the 110-volt line. It is intended that the equipment be operated continuously.

If the amber indicator lights, it is an indication that the automatic calibration capability of the equipment has been exceeded. Normally this is an indication of a component failure; however, it is conceivable that it is the result of an exceedingly intense line

transient of long duration. A quick check is to remove the front cover plate from the electronic chassis and turn on the override switch. If the motor can reach a balance condition and stop, the override switch can be turned off and the equipment operated as before. On the other hand, if the motor operates continuously it is an indication of a more serious problem and the equipment must be serviced.

5.2 Installation of the Electronics Chassis

The electronics chassis is to be installed in the lower part of the UGC-6 console to the left of the auxiliary equipment rack. The door panel must first be removed together with the left hand adjacent panel. The electronics chassis is fastened to the bottom of the console by two 1/4 x 20 bolts into tapped foot blocks on the chassis. For added support there is a bracket on the electronics chassis that is to be attached to the back of the cabinet via the mounting holes on the back. If speed nuts are available they can be clipped onto the mounting hole flange. Otherwise, a short bar tapped for two No. 8 screws has been furnished by the Visibility Laboratory. This bar can be placed in back of the mounting hole flange and the rear mounting bracket on the chassis screwed onto the back of the cabinet with No. 8 screws. Do not plug the line cord in until the cable from the discriminator head has been connected to the chassis.

5.3 Installation of the Discriminator Head

Remove the top cover plate and the side cover from the TT-251. Feed the cable through the side of the UGC-6 console via the area that is exposed by the removal of the TT-251 side cover. Continue to feed the cable around the base of the reperforator unit and down through the hole that leads into the auxiliary equipment

rack area of the UGC-6. Plug this end of the cable into the socket on the electronics chassis.

The TT-251 plug is now disconnected and plugged into the mating socket on the discriminator cable. The other plug on the discriminator cable can now be connected to the socket that the TT-251 plug formerly connected into.

The side cover of the TT-251 can now be replaced.

5.4 Operation

After the discriminator head has been connected to the electronics chassis and the TT-251 connected in series with the cable, the electronics chassis can be plugged into any 110-volt AC outlet. It is intended that the equipment be operated continuously. Under normal operating conditions no adjustments are needed.

As described previously, it is conceivable that the amber indicator might light because the equipment has been thrown out of range by a severe transient. Under these conditions turning on the override switch will enable the motor to rebalance. After rebalance the override switch should again be turned off. Under no circumstances should the equipment be allowed to operate unattended with the override switch on.

PARTS LIST FOR TELETYPE TAPE DISCRIMINATOR

Part Name	Unit Cost	Quantity	Total Cost
Power Supplies			
ERA Trans-pac, Mod. V 30	$ 45.00	1	$ 45.00
ERA Trans-pac, Mod. MD 1K/.1A	105.00	1	105.00
Technipower, Mod. M-17.5-100	55.00	1	55.00
Transformers			
Stancor P6134, 6.3 V RMS at 1.2A	2.05	1	2.05
Relays			
Potter and Brumfield, Mod. ML 11D	6.50	4	26.00
Potter and Brumfield, Mod. ML 17D	7.20	2	14.40
Potter and Brumfield, Mod. RS5D	2.85	1	2.85
Potter and Brumfield, Mod. KCP 14	8.25	1	8.25
Motors			
Hurst motor with clutch brake, Mod. PC-DA, 115 V, 60 cps, 5 rpm	15.00	1	15.00
Transistors			
2N1381	.72	8	5.76
2N2959	2.70	9	24.30
2N398	1.30	2	2.60
2N2608	13.80	1	13.80
2N456	2.60	3	7.80
Diodes			
1D39B	5.60	2	11.20
1N746	2.75	3	8.25
1N752	2.75	1	2.75
1N755	2.75	1	2.75
1N756	2.75	2	5.50
1N972	4.80	2	9.60
1N2071	.84	2	1.68
1N2979	3.71	1	3.71
1N3042	3.71	1	3.71
BR 72, Bridge Rect. 140 v RMS at 2A	5.00	1	5.00
HD 4420	.25	1	.25
Photo diode, LSX-600	13.00	3	39.00
Meters			
Simpson, Mod. 1212C 0-50 a	15.75	1	15.75

PARTS LIST FOR TELETYPE TAPE DISCRIMINATOR
(Cont.)

Part Name	Unit Cost	Quantity	Total Cost
Potentiometers			
10 K Servo pot, end stop removed	$ 1.25	1	$ 1.25
.5 K Min pot	5.00	1	5.00
1 K Min pot	5.00	1	5.00
2.5 K Min pot	5.00	1	5.00
5 K Min pot	5.00	5	25.00
50 K Min pot	5.00	1	5.00
Switches			
Min. S.P.D.T.	3.22	2	6.44
Cam operated Micr Sw S.P.D.T.	1.50	1	1.50
Tubes			
R.C.A. 931A	12.40	1	12.40
Fuse Holders + Fuses			
Pnl. Mount fuse holder	.32	2	.64
Fuse, 1.5 A	.06	1	.06
Fuse, .75 A	.06	1	.06
Lamp Sockets + Lamps			
No. 2. 25 v, .25 A, used in Ansco head	.17	4	.68
Min lamp holder, Dialco No. MS 25256-2	1.19	1	1.19
Min lamp holder, Dialco No. MS 25256-6	1.19	1	1.19
Min lamp No. 345, 6 v A .04 A	1.40	2	2.80
Neon lamp No. NE-2	.10	2	.20
Min lamp No. 9	1.25	3	3.75
Connectors			
Teletype connector, No. 158258	1.45	1	1.45
Teletype connector, No. 158259	3.30	1	3.30
Cannon DBM 17W2P	2.14	1	2.14
Cannon DBM 17W2S	3.67	1	3.67
Cannon DM-053742-5001	1.62	2	3.24
Cannon DM-053740-5001	1.60	2	3, 20

PARTS LIST FOR TELETYPE TAPE DISCRIMINATOR (Cont.)

Part Name	Unit Cost	Quantity	Total Cost
Capacitors			
.47 fd. 230 VAC	.30	1	.30
.8 fd. 500 VDC	.78	1	.78
150 fd. 50 VDC	1.14	1	1.14
200 fd. 10 VDC	.90	1	.90
2000 fd. VDC	1.92	1	1.92
Resistors			
510 1/2 w	.24	3	.72
560 1/2 w	.24	1	.24
620 1/2 w	.24	3	.72
750 1/2 w	.24	1	.24
1.3K 1/2 w	.24	3	.72
1.5K 1/2 w	.24	3	.72
2.0K 1/2 w	.24	2	.48
2.2K 1/2 w	.24	3	.72
2.4K 1/2 w	.24	3	.72
3.0K 1/2 w	.24	2	.48
3.9K 1/2 w	.24	2	.48
4.3K 1/2 w	.24	1	.24
5.0K 1/2 w	.24	2	.48
5.1K 1/2 w	.24	3	.72
8.2K 1/2 w	.24	1	.24
10 K 1/2 w	.24	4	.96
15 K 1/2 w	.24	5	1.20
75 K 1/2 w	.24	1	.24
82 K 1/2 w	.24	1	.24
120K 1/2 w	.24	2	.48
225K 1%	.54	1	.54
1 Meg 1/2 w	.24	1	.24
1 Meg 1/2w c.f.	.54	11	5.94
620 2 w	.48	1	.48
10 5 w	.62	1	.62
Total, less cost of reflection head			$554.97
Macbeth-Ansco densitometer reflection head, Mod. 31, (inner part of head and green filter are only parts used.)			250.00
		Total	$804.00

SPARE PARTS LIST

Part Name	Unit Cost	Quantity	Total Cost
Transistors			
2N1381	$ .72	2	$ 1.44
2N2959	2.70	2	5.40
2N398	1.30	1	1.30
2N2608	13.80	1	13.80
2N456	2.60	1	2.60
Diodes			
1D39A substitute for 1D39B			
1D39B	5.60	1	5.60
1N746	2.75	1	2.75
1N752	2.75	1	2.75
1N755	2.75	1	2.75
1N756	2.75	1	2.75
1N972	4.80	1	4.80
1N2071	.84	1	.84
1N2079	3.71	1	3.71
1N3042	3.71	1	3.71
BR 72, Bridge rect. 140 v RMS at 2A	5.00	1	5.00
HD4420	.25	1	.25
Photo diode, LSX-600	13.00	1	13.00
Relays			
Potter Brumfield Mod. ML 11D	6.50	1	6.50
Potter Brumfield Mod. ML 17D	7.20	1	7.20
Potter Brumfield Mod. RS5D	2.85	1	2.85
Potter Brumfield Mod. KCP 14	8.25	1	8.25
Tubes			
R.C.A. 931A	12.40	1	12.40
Lamp Sockets + Lamps			
No. 222, 2.25 v, .25 A	.17	4	.68
Min. lamp No. 9	1.25	3	3.75
		Total	$114.08