MCR-69-355

COPY NO. 13

CONTRACT NAS9-8144

PROTOTYPE MICROFILM STORAGE AND DISPLAY

FINAL REPORT

June 1969

Prepared for
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas 77058

Martin Marietta Corporation
Denver, Colorado
80201

CR [redacted]
101846

MCR-69-355

COPY NO._______________

CONTRACT NAS9-8144

PROTOTYPE MICROFILM STORAGE AND DISPLAY

FINAL REPORT

June 1969

John T. Polhemus
Program Manager

Prepared for
National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas 77058

Martin Marietta Corporation
Denver, Colorado
80201

TABLE OF CONTENTS

FIGURES

TABLES

INTRODUCTION

This report describes a Microfilm Storage and Display Unit built under NASA contract NAS9-8144. Some of the trade off studies performed are described, as well as the more important techniques and processes involved in building this prototype.

SPECIFICATIONS

MICROFILM STORAGE AND DISPLAY

Size	1/4 cu ft
Weight	12 lb
Power	30 watts
Capacity	3000 pages of 8 1/2 x 11 text = 6000 frames
Access	Each frame randomly addressable within 12 sec, average access 4 sec, working access 1 sec
Light Source	Xenon lamp, 500 hr life, 2 spare lamps available in easily replaceable lamp modules
Storage Medium	16 mm film, cassette loading
Controls	ON-OFF, address push buttons Nos. 0 thru 7, advance, regress
Environment	Designed to Apollo flight qualification specifications

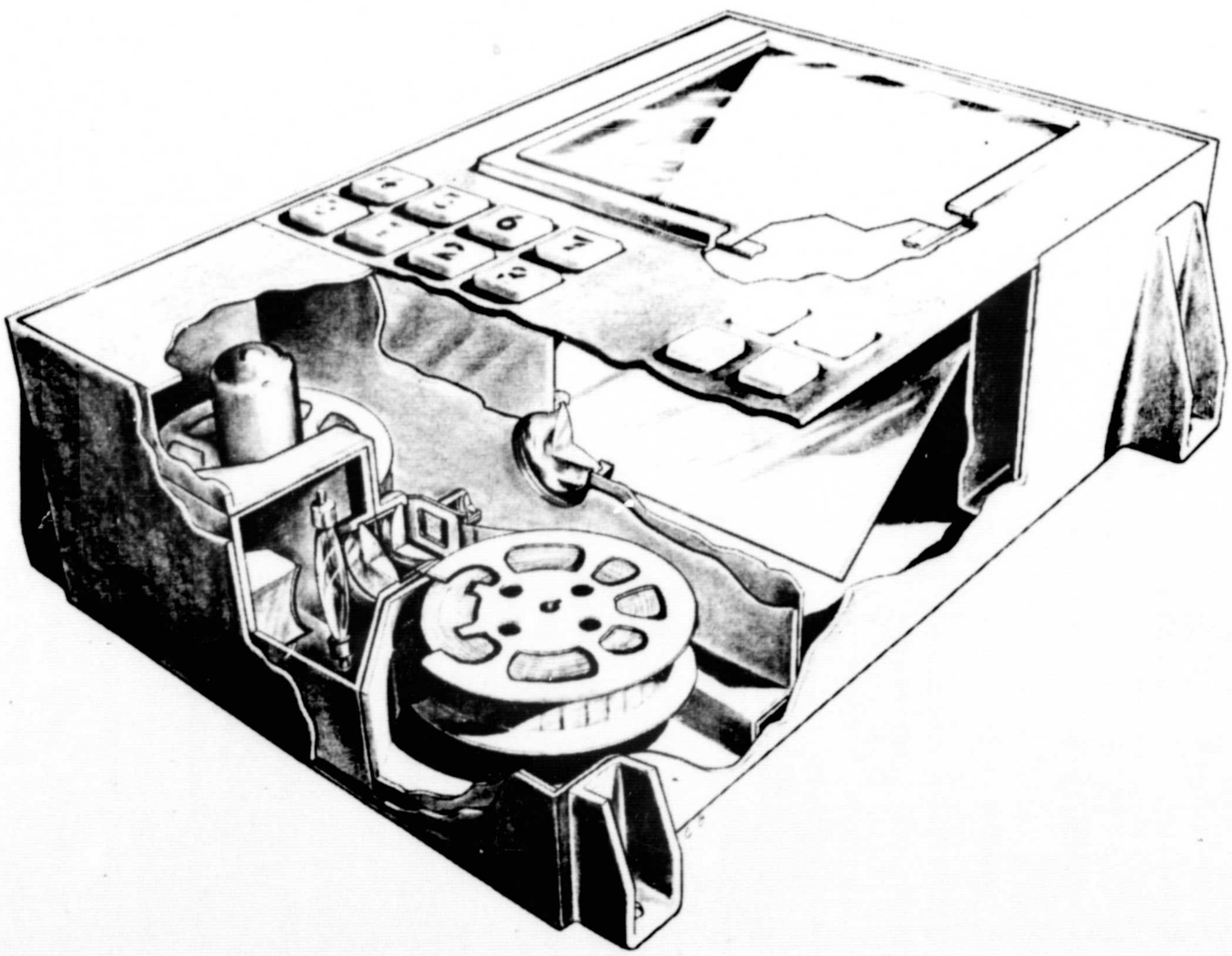


Figure 1.

USES OF THE MSD

The MSD's primary function is to rapidly and conveniently provide documentation to an astronaut. Information such as flight plans, check lists, malfunction procedures, system diagrams, and charts and graphs can be included on a film.

Where large quantities of documentation are required on long, complex missions additional cassettes may be carried. This allows greatly increased data storage while only increasing weight slightly. The 6000 frames held in each cassette are equivalent to 30 pounds of documentation.

The MSD has many advantages over the normal paper manuals including less weight, greater safety due to decreased fire hazard, and more convenient handling. As a fully indexed, pushbutton device, the MSD allows an operator to find a desired frame quickly using only one hand after the unit is removed from its storage compartment and fastened into place, or used as a hand held instrument. Subsequent frames can be displayed by simply pressing the advance pushbutton. All controls are designed to be operated by an astronaut wearing gloves.

The MSD could be used with a computer to automatically call up critical frames in an onboard checkout system. In this application it becomes a combined indicator and guide to corrective action. For example, if the computer determines a malfunction has occurred in a certain system it can immediately call up a frame that indicates the problem and lists the actions to be taken.

While the MSD is designed for use in the spacecraft, it would also be useful to flight controllers on the ground. Each station could have an identical copy of the film used in the spacecraft so that coordination with the astronauts could be improved. Additionally, ground stations could have film cassettes relating to their specific responsibilities.

MECHANICAL DESIGN

A cutaway view of the MSD is shown in Figure 1. The unit is formed so it can be mounted into a panel by the mounting feet, clipped or hung in a convenient location, or used as a "lapboard" display. All controls and indicators are on the same face as the display screen and the film cassette also loads from this side. Retrieval of data is accomplished by entering the desired five-digit octal frame address and pressing a select pushbutton; the 16-mm film is automatically searched and the proper frame quickly displayed. For "turning pages" (stepping a frame at a time), advance and regress pushbuttons are provided.

To facilitate changing films or replacing a lamp source, a quick-change cassette design has been chosen. The replaceable lamp module fits into the cassette (Fig. 2). To avoid troublesome rotating shaft seals and optimize weight and space, the drive motors, film reels, film gate, and several lenses are included in the cassette, with the lenses serving as the seal points in the optical path. This facilitates maintainability, for the components most likely to require maintenance or replacement are all in a compact, easily replaceable module. The cassette handles or fastening devices are not shown, although they are furnished (see Fig. 3).

A xenon light source is used, for in addition to being more efficient than an incandescent lamp, it allows a more efficient projection system to be employed. The start circuits, xenon lamp, and some condensing optics are housed in a replaceable unit called a lamp module, which is hermetically sealed.

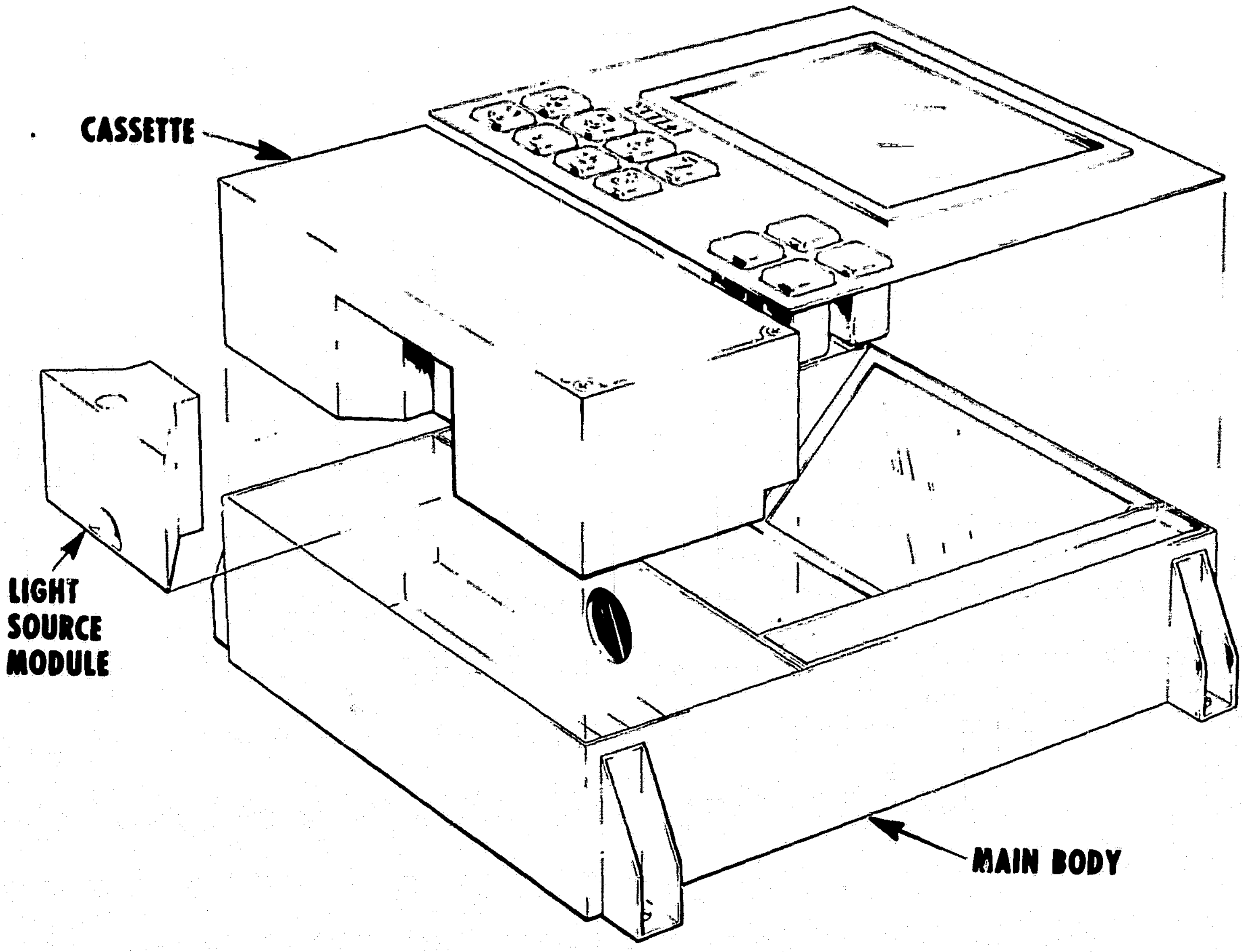


Figure 2

An optical coding system is used to control the search for the desired film frame, with the film being driven by integral motor gearhead reel systems. This approach avoids capstans or sprockets that are likely to cause serious misalignment or stress problems in the film or film gate. A variable-drive electronic servosystem is used to obtain a rapid but smooth film drive.

The projection screen, a mirror for angling the light beam, power supplies, electronics, and the decoding photo devices are in the main body.

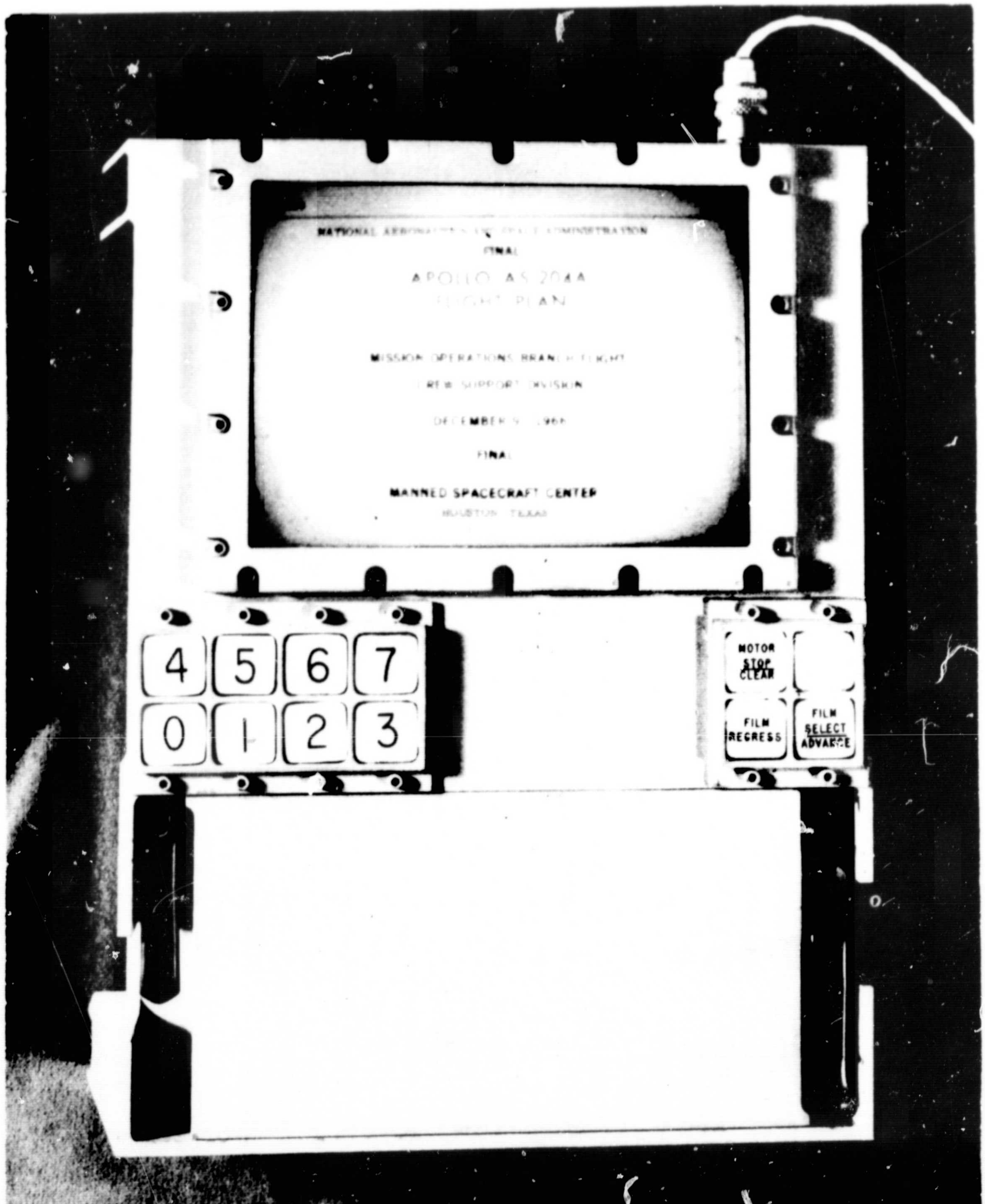


FIGURE 3. MICROFILM STORAGE AND DISPLAY UNIT

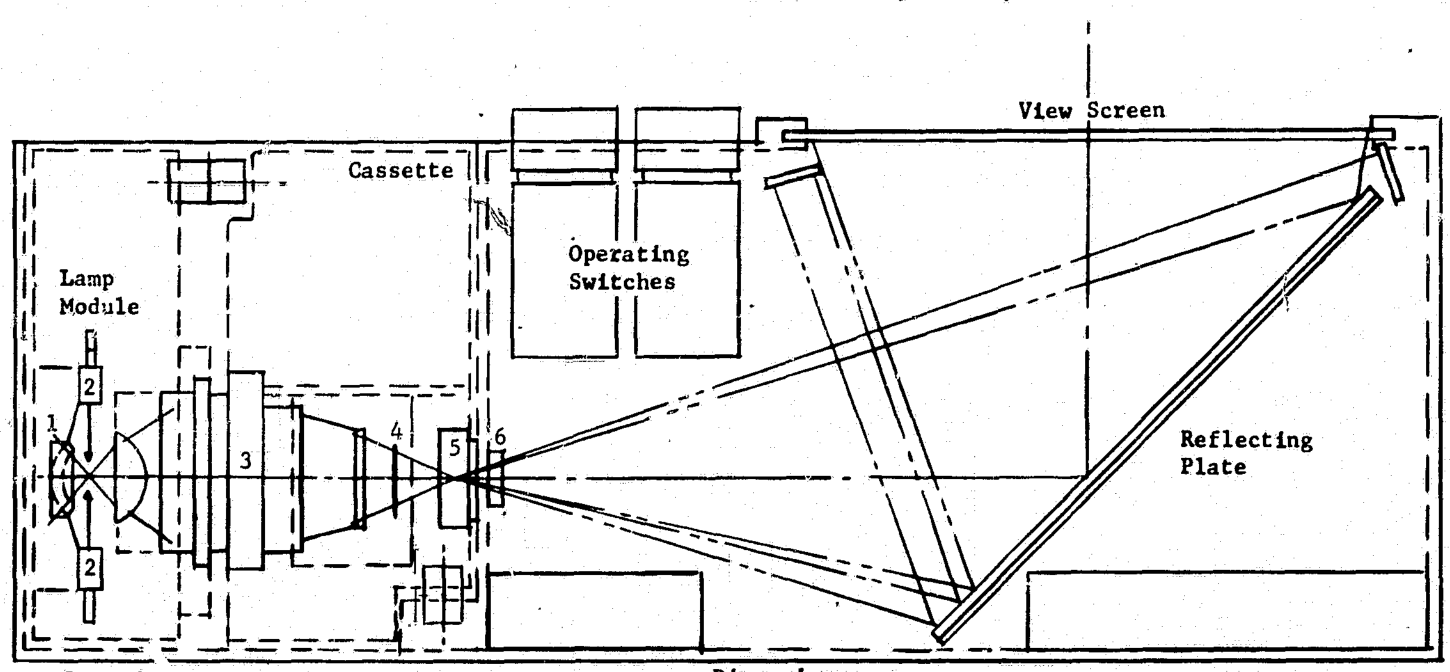
The entire unit is constructed of milled magnesium, designed to withstand the environments imposed, and constructed for mounting on a cold plate.

In designing the present unit, we have drawn heavily on our previous experience with devices similar to the MSD. While the cassette, lamp modules, and optics presented interesting challenges for the designer, the electronics, motor control system, coding method, and basic system design utilized techniques already proved, at least in part.

PROJECTION SYSTEM DESIGN

The many interacting constraints and tradeoff considerations of the MSD system design made the optical design problem a rather unusual one and required a rather unusual solution. The primary constraints on the optical design are that the optics be insensitive to the unavoidable misalignments that occur during the changes of cassettes and light source assemblies, and that the different portions of the optical paths must be hermetically sealed to the environment while the light efficiency must be maintained at a very high level. These requirements are opposing/conflicting, so an optical system was designed for this unit by Baus Optics Corp. A schematic of this system is shown in Figure 4.

Microfilm Storage and Display Unit Optical System



Legend:

1 Condensing Reflector
2 Xenon Lamp
3 Condensing Lens Assembly
4 Film Gate
5 First Projection Lens
6 Second Projection Lens

Dimensions
12x4.5x8.5 in.
460 cu in.

Figure 4

The light source assembly is a component of the cassette as far as operational replacement is concerned. The removal of the cassette is a simple operation, and replacing the light source module in the cassette is equally simple, so a light source can be replaced quickly and without tools.

This arrangement presents another benefit. Inserting the light source assembly in the cassette results in inaccuracies only from the fit between the cassette and the light assembly; if the cassette and the light source assembly each were inserted into the main device enclosure, the tolerance of the location of the light source assembly with respect to the cassette would be the composite of the two fits.

The MSD has a shape roughly similar to a thick book for ease of manipulation and operation in the event it is used as a "lapboard" display. The dimensions of approximately 8 1/2 inches wide, 12 inches long, and 4 1/2 inches high result in a reasonable shape.

To keep the number of optical surfaces to a minimum, the optical elements are used as seals for the enclosures wherever possible instead of using separate pieces of plane glass. This reduces the number of glass-air surfaces with a corresponding increase in brightness of the image, or, more correctly, with a corresponding decrease in the lamp power required.

To reduce the dimensions of the MSD system, the magnification ratio from film image to the displayed picture was chosen to be 26, judged to be the maximum feasible under the constraints imposed. The limit of 26 is the result of two factors -- the increased heat and light density on the smaller film image, and the design difficulty and availability problems with a very short focal length lens film gate.

To reduce the volume of the MSD, the largest practical projection angle was used since the volume of the device to a first approximation is proportional to the cotangent of the projection angle, i.e., halving the projection angle makes the MSD device roughly twice as large. The usage of very large projection angles was traded against (1) the reduction in uniformity of illumination of the screen caused by increased vignetting in the optical system and condensing systems, and because of strong divergence of the light impinging on the display screen, (2) the increased aberrations of the optical system causing reduced resolution and increased color fringing, and (3) greater sensitivity to proper initial alignment and focusing. Early in the program, the problem areas associated with large projection angles were defined to determine the optical system required. We arranged for optical design consultation, tne fabrication services from Baus Optics Corp. to provide special, nonstandard, optical components that were required.

These consist of a five element condensing system that utilizes about 100° of subtended angle from the light source, a projection lens that fits in the front wall of the cassette, a spherical mirror which is placed behind the light source to increase efficiency, and a plexiglas mirror to angle the projection beam to the screen.

The first condenser lens element is in the lamp module, and serves as the optical exit port. The other four condenser elements are mounted in a barrel, with the last two elements sealed in place, and the barrel captured in the cassette by a retaining ring and sealed by an O-ring.

The projection lens is a four element lens that fits in a circular mounting ring, and the seals are made with RTV potting.

A window of plane optical glass serves as the entrance port into the main body. Also in the main body, the plexiglas mirror, mounted on the same structure as the multilayer printed circuit board, turns the projection 90° to the screen.

LIGHT SOURCE

The choice of light source presented an interesting tradeoff study. Both the type and the power of the source to be used had to be very carefully weighed against the overall system performance requirements. It is obvious that more efficient use of the light emitted from the light source allows the light source to be less powerful, other things being equal. Of course, the overriding consideration in the choice of a light source is the reliability of the source. One should note that the expected lifetime of the light source is not necessarily a good indication of the reliability of the light source for relatively short missions. Theprobability of light source failure is almost zero up to the time when the wearout process has been completed, and is almost one after that time. To base the choice of light source on the average or mean expected lifetime, assuming that the longer lifetime means better mission reliability, may lead to inappropriate choices. Ruggedness of the light source is also an important consideration. For the MSD, we have chosen the xenon arc lamp (X-15, built by PEK Labs Inc., Sunnyvale, Calif.). It is rugged, compact, efficient, very reliable, and shows graceful degradation when reaching end of life.* This was substantiated by testing, both by the vendor and ourselves; while no formal test program was run, one lamp put on life test has run in excess of 800 hours without reaching the end of its useful life.

---

*Defined as the time when the arc begins to shift position with respect to the electrodes, which will cause perceptible flickering within the displayed image but not render it useless.

As the xenon arc lamp requires some auxiliary energy source for starting the arc, such as high voltage, ionizing radiation, or some similar high-energy source. We have chosen to integrate a high voltage starter circuit into the light source enclosure to reduce the EMI and surge voltages to easily managed proportions. Once started, the lamp operates at about 15 watts.

A problem encountered with the short arc xenon lamp was that the arc, being essentially a point source, caused color aberrations to appear on the screen from minute imperfections in the optical system or from dust or emulsion particles anywhere in the optical path. This was found to be objectionable to a viewer, so the lamp was frosted to broaden the source. While solving the problem of color aberrations, this caused some loss of intensity and slight defocusing at the corners of the screen.

The lamp is held in place in the lamp module by potting after adjustment has been made in optical jig. The adjustment fixture, with the lamp held in the lamp module is shown in Figure 7. General Electric RTV 560 is used for potting. The cure cycle for the RTV was found to be important, in that unless a relatively long cure at room temperature (24 hours) is performed, outgassing at lamp operating temperatures will occur, fogging the first condenser lens in the lamp module. After the room temperature cure, the temperature is elevated 50°C on 8 hour intervals until the expected operating temperature is reached.

PROJECTION SCREEN

The search for an optimum material and coating led to the trial of many items, finally resulting in the use of a plexiglas screen with a Polacoat proprietary coating. Three screens with various types of coatings have been furnished with the unit for human factors evaluation. These are (all Polacoat):

1. LS60, medium gray.
2. Photocopy, dark gray, non glare.
3. TR50, off white, non glare.

Blue and green coatings were also evaluated, but have been rejected. In the near future the high gain LS60 screen will be available with what is termed a "velvet coat" finish on both sides to further reduce reflections from ambient lighting.

Fresnel lens screens were evaluated, however the flat screen provided a more pleasing effect, and a wider viewing angle.

To meet the requirement for non-burnable, shatterproof material, VICOR safety glass with the Polacoat coating would be a good choice, except that relatively it is much heavier than plexiglas. To circumvent this weight penalty, samples of plexiglas were prepared with a teflon coating on each side. These were submitted to NASA for burn testing; they failed the test. Hence, a plexiglas screen is furnished in the prototype unit, with VICOR glass recommended for flight units.

CASSETTE AND LIGHT SOURCE MODULE

The cassette assembly (Figs. 5 and 6) includes the film drive system, consisting of a pair of drive motors, film reels, film and film gate; the case, which has lenses sealing the optical entrance and exit paths, two electrical connectors, and purge and vent valves; and the removable light source module.

It was considered best to include the drive motors in the cassette because rotating shaft seals would compromise the reliability of the MSD. The motors are recessed into the film drive reels to conserve space. The film is guided and aligned by the film gate and driven directly by the reels so potentially troublesome capstans or sprockets are avoided. Direct-current motors were chosen to ensure high torque over a wide speed range. These are American Electronics 13DG20 motors of a type that has been space qualified. They are specially designed to exhibit a very low cogging effect, and have a 7.8/1 ratio integral gear head.

The case contains one lens of the condensing system as the optical entrance port, and a portion of the projection lens system as the optical exit port. These lenses also provide the seals for the optical path through the cassette. Two electrical connectors are provided, one to bring motor control power and lamp power into the unit, the other to provide lamp power to the light source module.

The film gate is built of Nylatron GS, which is nylon with a molybdenum disulphate filler for lubrication. (Chrome plated brass picked up dirt quickly, and was discarded.) This film gate is designed to hold the film by the edges in curved grooves, providing stability without causing film wear in the image areas.

The light source module fits into a recess in the cassette and is easily removable. It contains the xenon lamp, a condensing mirror, and a portion of the condensing lens system; the latter provides the seal for the optical path.

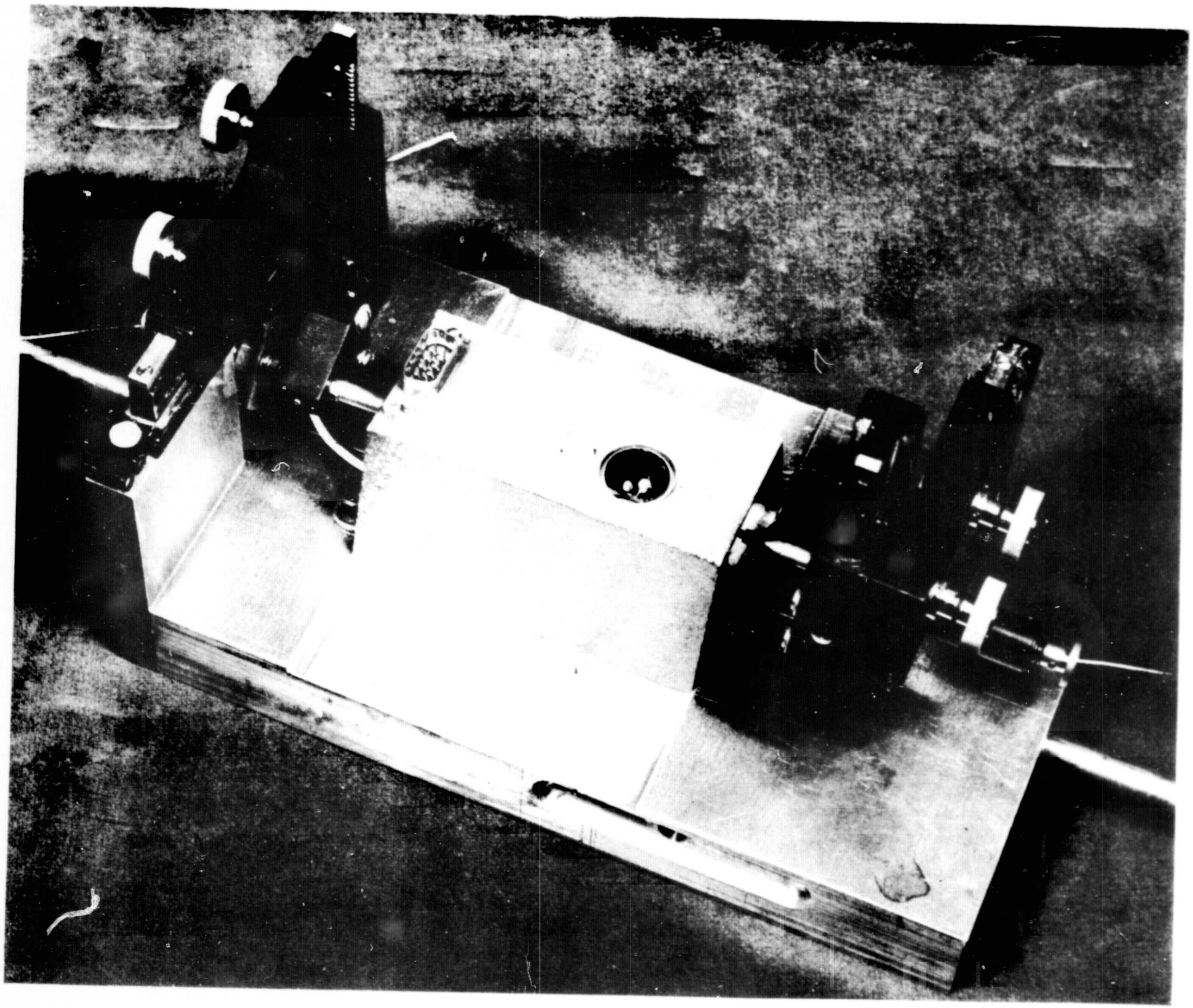


FIGURE 5. LAMP ADJUSTMENT FIXTURE

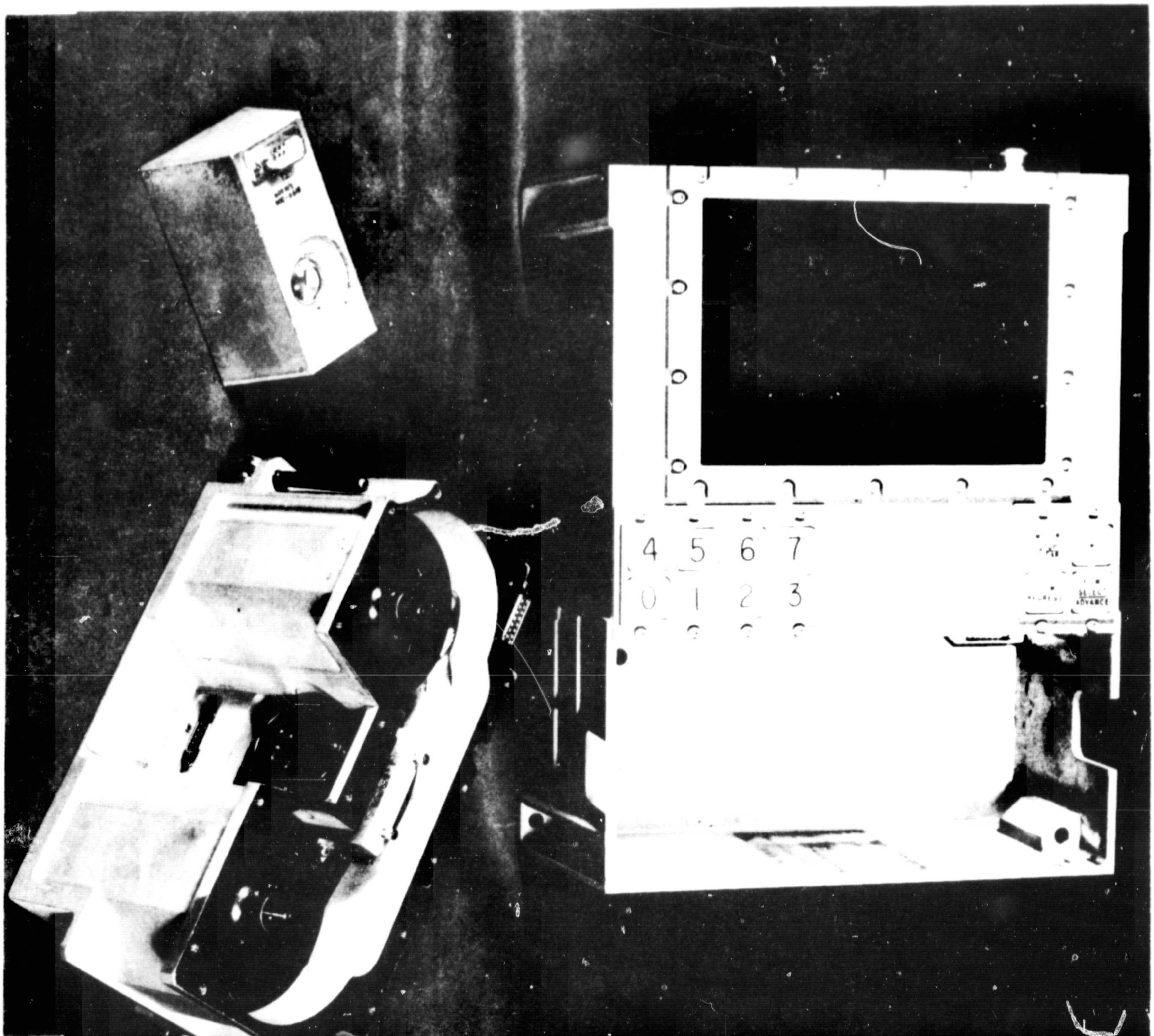


FIGURE 6. MSD, WITH CASSETTE AND LAMP MODULE REMOVED

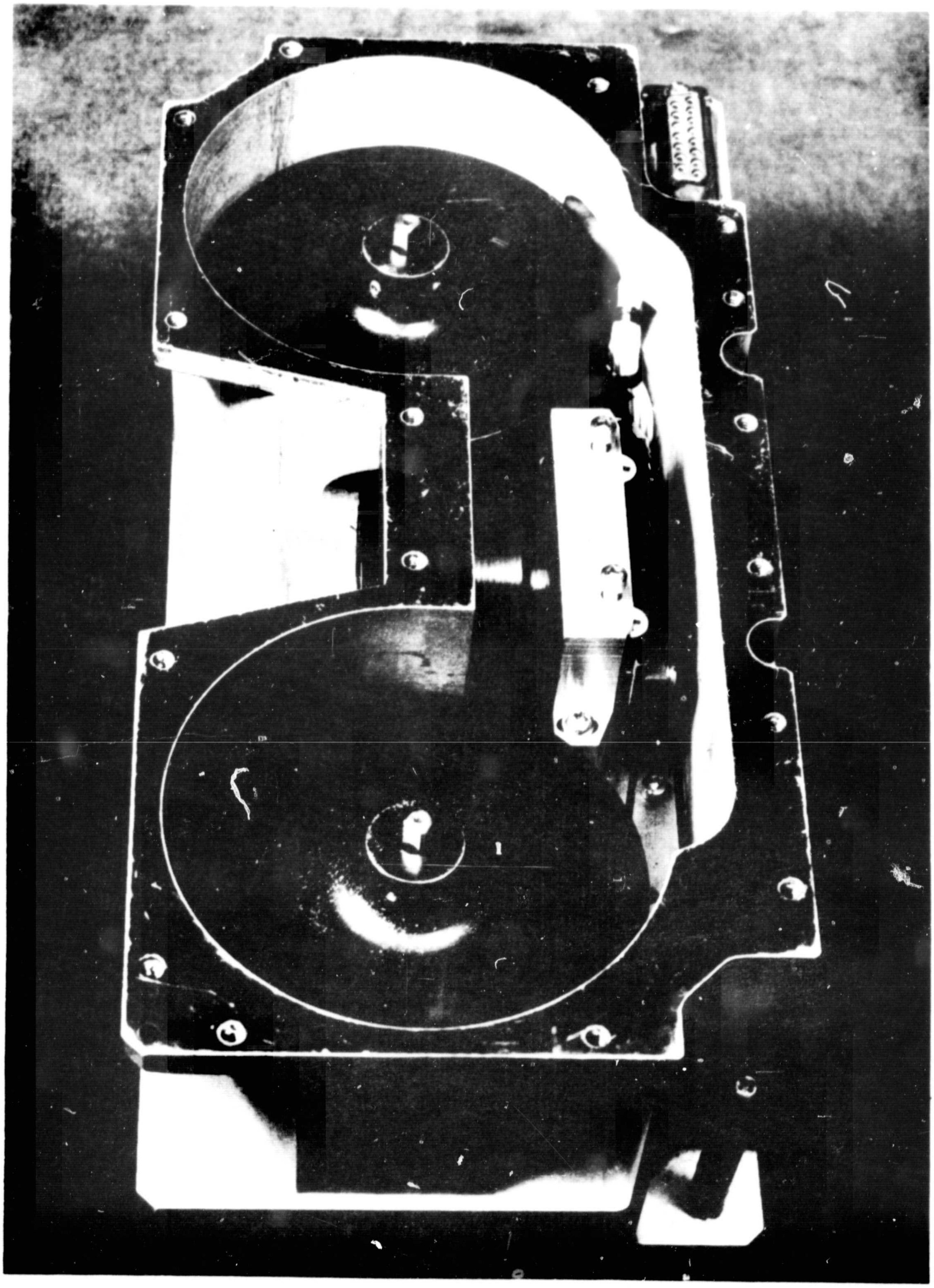


FIGURE 7. CASSETTE

Machined mating surfaces and suitable mechanical fasteners are provided so the light source module, cassette, and main body fit together in proper alignment.

If in the future the hermetic seal requirement on the cassette could be relaxed, a cassette having only film and a film gate should be considered. This would allow even greater efficiency in the storage of a film library.

ELECTRONICS

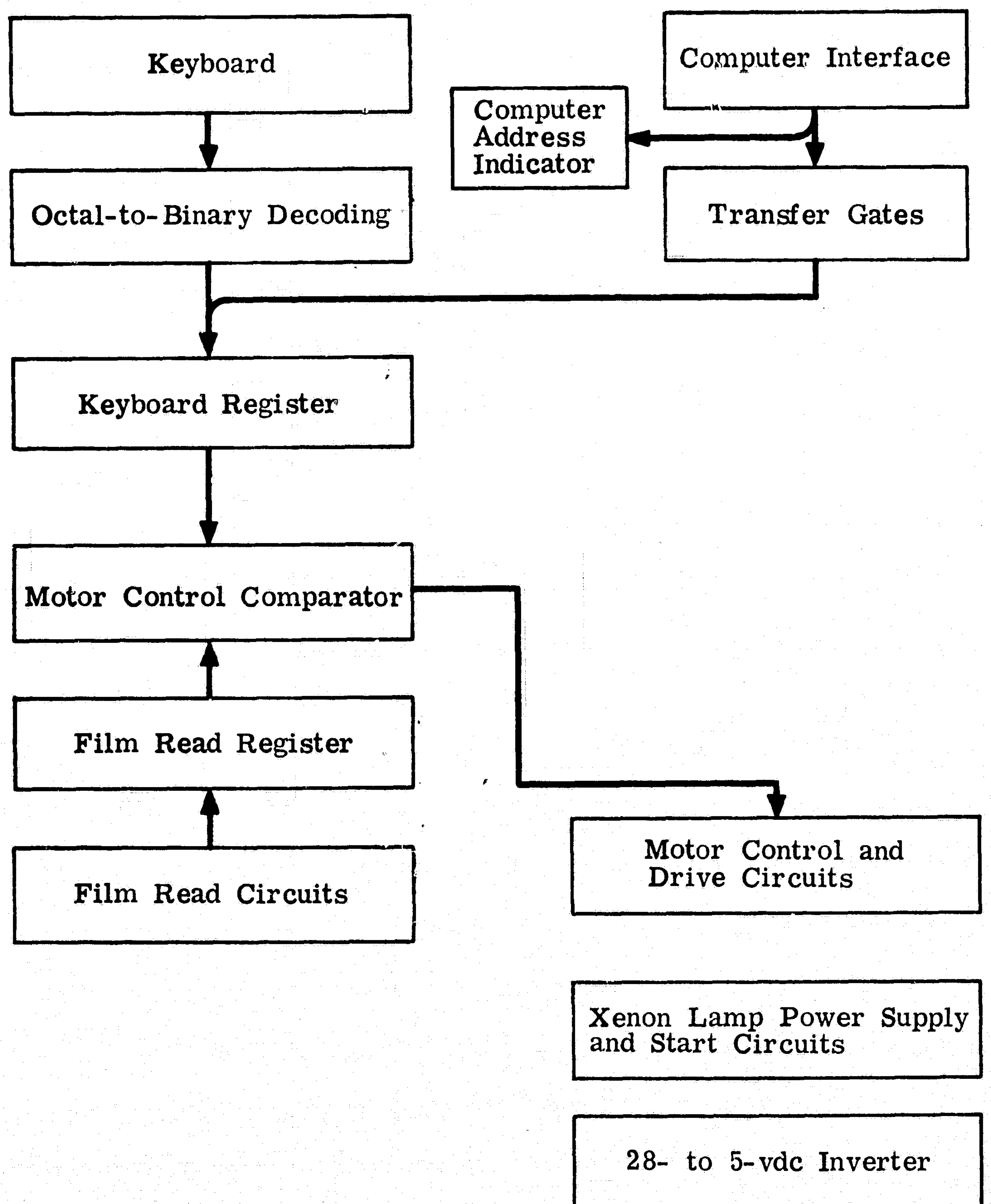
The MSD unit provides for display of any one of several thousand different pages of written data on a single screen. This is done by storing the desired information on a film, along with a 14-bit binary address represented by light and dark bars on the film. The desired frame is selected by reading the film address with photo detectors and comparing it with the address of the desired frame. The output of the comparator controls a two-motor servosystem that drives the film until the film address matches the desired frame address. The motors are then turned off and the stored information is projected on a screen.

BASIC SYSTEM OPERATION

Figure 8 is a block diagram of the basic electronic control circuits. The desired parameter is selected by entering a 5-digit octal code via the keyboard. This is then converted to a 14-bit binary code and stored in the keyboard register.

The film address is read from the film by photo detectors that drive high beta transistor photo detector amplifiers. The amplifier outputs are strobed into the film address register at the proper time. This allows the film address to be read and transferred into the film address register only when the code bars from the film are projected onto the proper photo detectors.

The 14-bit film address is compared to the keyboard address in the motor control comparator. If the film address has a higher numerical value than the keyboard address, the motors drive the film in the direction of the lower number, and vice versa. Thus the film is always driven in the direction of the correct address. When the film address matches the keyboard address, the motor drive is removed and the motors stop.



Block Diagram, MSD Electronics

KEYBOARD REGISTER - The keyboard register circuit (Fig. 9) converts the 5-digit octal code entered via the keyboard to a 14-bit binary code and stores it in a 14-bit storage register. The actual decoding is done by electronic decoders. The transfer gates are enabled in groups starting with the two most significant binary bits for the first octal digit and then in groups of three until the last of the five octal numbers is entered into the three least significant bits of the keyboard register. The set of gates that are enabled is determined by advancing a "1" down a 5-bit shift register each time an octal key is depressed. The cycle is started over again by a RESET pulse that occurs each time the film search key is depressed.

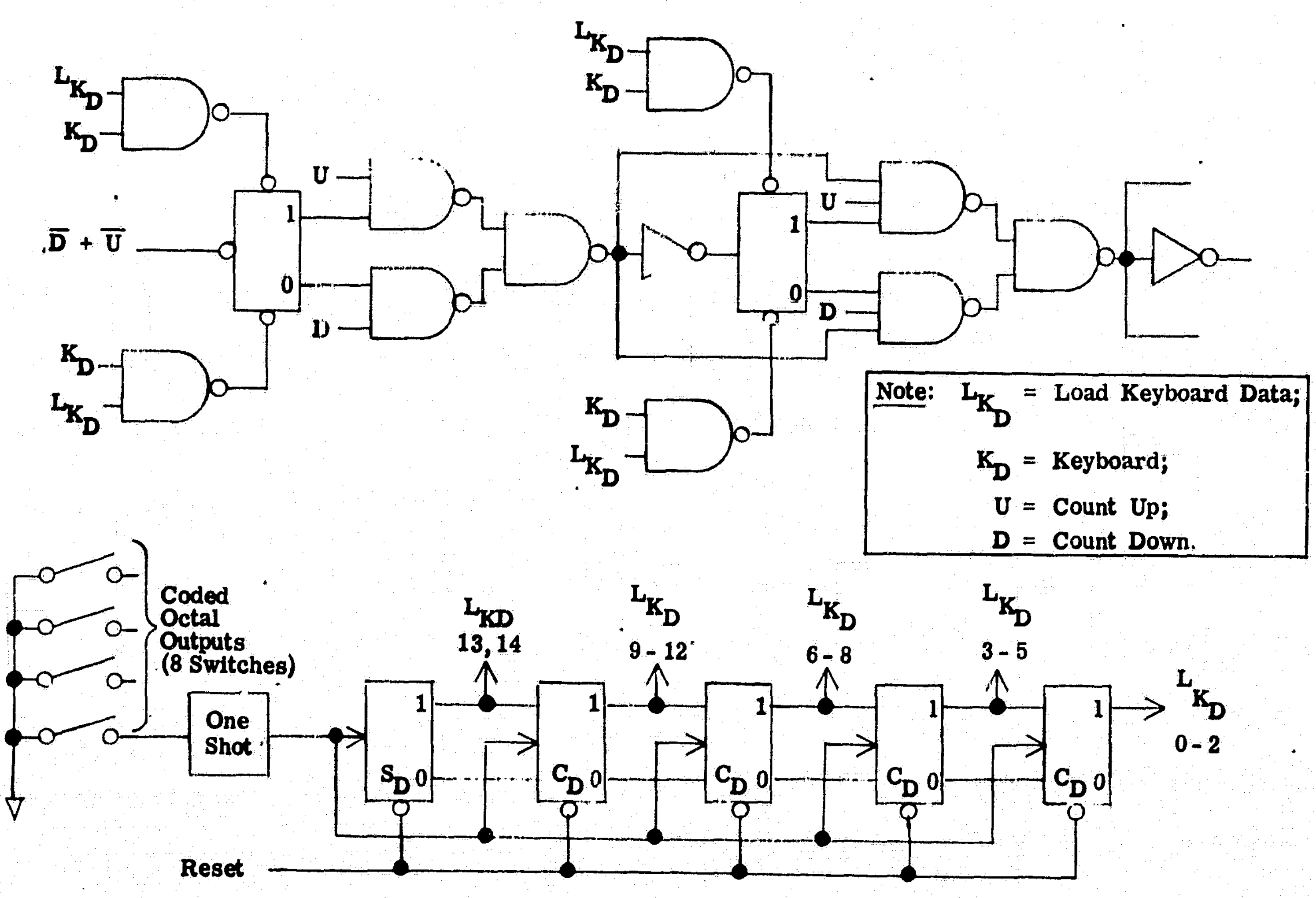


Figure 9

FILM READ REGISTERS - The film code consists of a set of light and dark bars on the film. The light bars are 1's and the dark bars are 0's. With each set of code bars is a strobe bar and a centering bar. The strobe bar is slightly shorter in length than the code bars so a new code is not transferred into the register until the new code is completely over the address photo detectors. When exposed to light, the photo detectors furnish about 200 to 400 microamperes of current to the high beta transistor amplifiers, which furnish the D inputs to the film read register. When the strobe light bar comes onto the strobe photo detector, the strobe to the "Cp" inputs of the film register goes high, which enters the film address into the register. As the film moves on to the next address, the strobe goes low and then high again but, since the D-type flip-flop reads only when Cp goes high, each address remains in the film register until a new one is read.

MOTOR CONTROL ADDRESS COMPARATORS - This comparator supplies the control signals to the motor controls circuits during film search. The comparator circuit is made up of four - 4 bit micro-logic comparators and associated gates to provide an "up" signal to the motors if the film address if lower than the keyboard address, and a "down" signal if the film address if higher than the keyboard address. When the film has been driven so that the film address and the keyboard address are equal, then the centering circuit provides the motor drive signals until the two photo detectors are both inside of the strobe light bar. The motor bar is then removed.

When the film has been driven so the last bit compares, then the centering circuit at the end of the comparator chain is enabled. Two photo detectors, which are activated by the centering light bar on the film, then control the film drive until the film frame is centered. The centering detectors are spaced far enough apart so they will both fall just within the light area of the centering bar as shown in Figure 10. In Figure 11, the photo detectors show as dark spots on the two slender printed circuit boards; the decoding detectors are in a row on each board, and the strobe and centering detectors are arranged in a triangle.

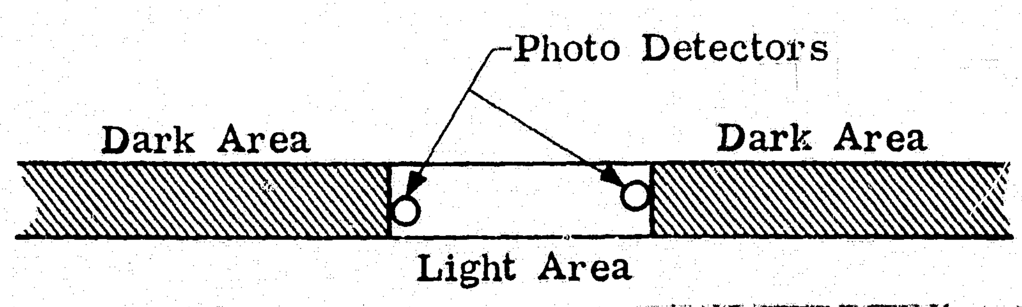


Figure 10

Centering Bar and Detectors

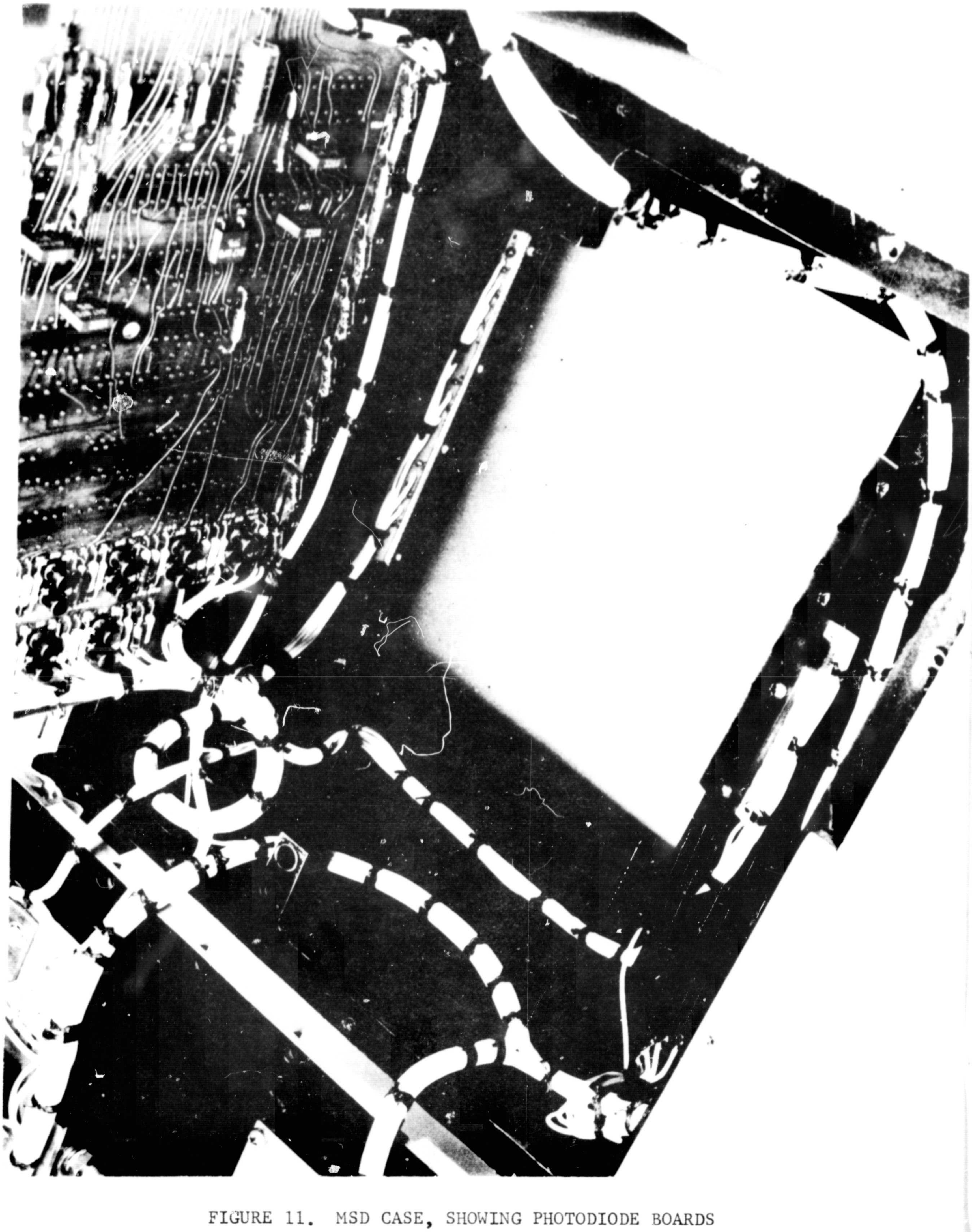


FIGURE 11. MSD CASE, SHOWING PHOTODIODE BOARDS

If the film is positioned such that one of the photo detectors is in the dark portion of the film, the associated gate output will be low causing a signal to be sent to one of the comparator OR gates, thus causing the motor to drive the film back until both photo detectors are in the light. The two centering gates are crosscoupled so that if the film goes far enough for both photo detectors to fall in a dark portion of the film, the control signal to the motor will still cause it to drive back toward the light bar. The centering process will continue back and forth until both photo detectors are within the light bar. Then with no control signal to the motors, the film will stop.

MOTOR CONTROL CIRCUIT - The motor control circuits furnish the control signals to the motor drive amplifiers. They include up or down signals, motor turn off while the address is being entered in the keyboard register, motor turn off if an invalid address is selected, and motor turn off if the film is driven all the way to either of the film.

ADVANCE-REGRESS CIRCUITS.- The advance-regress circuits allow the film to be advanced or backed up one frame at a time. This is done by generating a pulse with a one shot when either the advance or the regress switch is momentarily depressed. This pulse is fed into the centering circuit and controls the drive of the motors until the film has been driven off the centering bar toward the next frame. The direction, up or down, is determined by which switch is depressed. After the film has been driven off the centering bar, it continues to drive in that direction until it gets to the next centering bar. The film then centers on that frame in the normal manner.

SLEW CIRCUIT - This circuit allows the film to be searched without using the keyboard, keyboard register, film read circuitry, or comparator circuits. Therefore, a failure in any of these circuits would not completely disable the machine.

The film can be slewed forward or backward by depressing either the advance or regress buttons and holding it down about one half a second. A delay pulse provided a one shot then ends and allows the signal from the advance or regress switch to be fed directly into the motor drive control circuits. The film will run as long as the switch is held down. When the button is released, the centering circuit then operates in its normal manner and the film centers on a frame.

The slew control can be used in this manner to get to the approximate location of the desired frame. Then the stepping feature can be used to step to the desired frame.

MOTOR DRIVE AMPLIFIERS - The motor drive amplifiers provide drive power to the motors during film search and centering. They provide proportional control to the motors that compensates for the change in drive requirements as the film enters the centering mode. This provides the minimum search time consistent with minimum stress on the film and motors.

POWER SUPPLIES - Several power supplies are required to satisfy the various power needs of the MSD. A 28V to 5V DC to DC inverter and regulator provides power for the micro-logic. The 5 VDC is chopper regulated providing a high efficient regulated voltage.

This inverter also provides a 40 VDC output which supplies the xenon lamp power. The 40 VDC is fed to the xenon lamp through a constant current regulator supplying a constant current of 1.2 amperes to the xenon lamp. This is necessary because the xenon lamp requires a voltage of about 40 volts for starting and the voltage across the lamp drops to about 13 volts when the lamp is running.

The xenon lamp also requires a start pulse of about 10 KV to 15 KV to ionize the xenon gas. This is provided by the lamp start circuit which takes a 10 VPP square wave pulse from the 28V to 5 VDC inverter which is stepped up in voltage and rectified into a capacitor. The capacitor is then discharged by an SCR through a high voltage coil which goes to the third electrode of the lamp. The circuit continues to charge and discharge at about 10 pulse per second rate until the lamp starts. When the lamp starts, the lamp current is sensed and the lamp start circuit is disabled.

The motor drive power is supplied by a 28V to 28V DC to DC inveter for isolation and a current regulator which limit the maximum current that can be supplied to the motors. The current limiter allows full power to the motors during normal search but limits the power during start up and during centering. This protects the motor drive components and motors from overload even if the motors should be stalled for any reason. The reduction of power during centering is necessary for the motor drive centering circuit to operate properly, providing for smooth, fast centering.

POWER SWITCHING

Most of the electronic circuits are turned off when no search is being made. This is done as follows: Power is left on the keyboard register to provide memory of the address and all other circuits would be turned off. As soon as the select/advance or regress is pushed, the power is turned on and the proper command executed. After the film search has been completed, the power is again turned off.

ELECTRONICS PACKAGING

The heart of the system is the logic system, which is packaged on a multiplayer (4 layer) printed circuit board (Figs. 12 and 13). This board is specially designed to obtain a high packing density of microelectronic flat packs, each of which contains from two to four complete electronic circuits. This board is mounted on the back of the structural member that also supports the plexiglas mirror in the main body.

The power supplies are mounted in individual compartments to provide isolation, and the power transistors are stud mounted in the walls of the compartments. As the power supply compartments are a part of the bottom plate, good heat sinking is assured.

The motor drive amplifier is mounted between the motors in the cassette. This helps to isolate electromagnetic interference from motor surges and reduces wire runs for the relatively high power signals required for motor drive.

CONTROLS

The controls for the MSD are all of the pushbutton type and their function has been covered elsewhere.

Reed switches were used in the MSD for both power and logic switching. They were procured from the George Risk Co., and these have proven very satisfactory.

Concern was expressed by the NASA Technical Monitor as to whether the contact resistance would increase with use. Therefore, ten switches selected at random were tested for 10.5 million cycles by the George Risk Co. The results are shown in Table 1.

It is suggested that in future units, consideration be given to solid state switches which have even less mechanical wear action than the Reed switches. These solid state switches are presently becoming available for evaluation.

FINISH

The exposed surfaces were painted with grey, velvet coat 3M epoxy paint. Mating surfaces were finished with an HAE coating, call-out MIL-M-45202A, Type I, Class A, Grade 2. This latter finish did not hold up well under abrasion, such as two surfaces sliding together, and in this usage was soon removed, exposing the Magnesium.

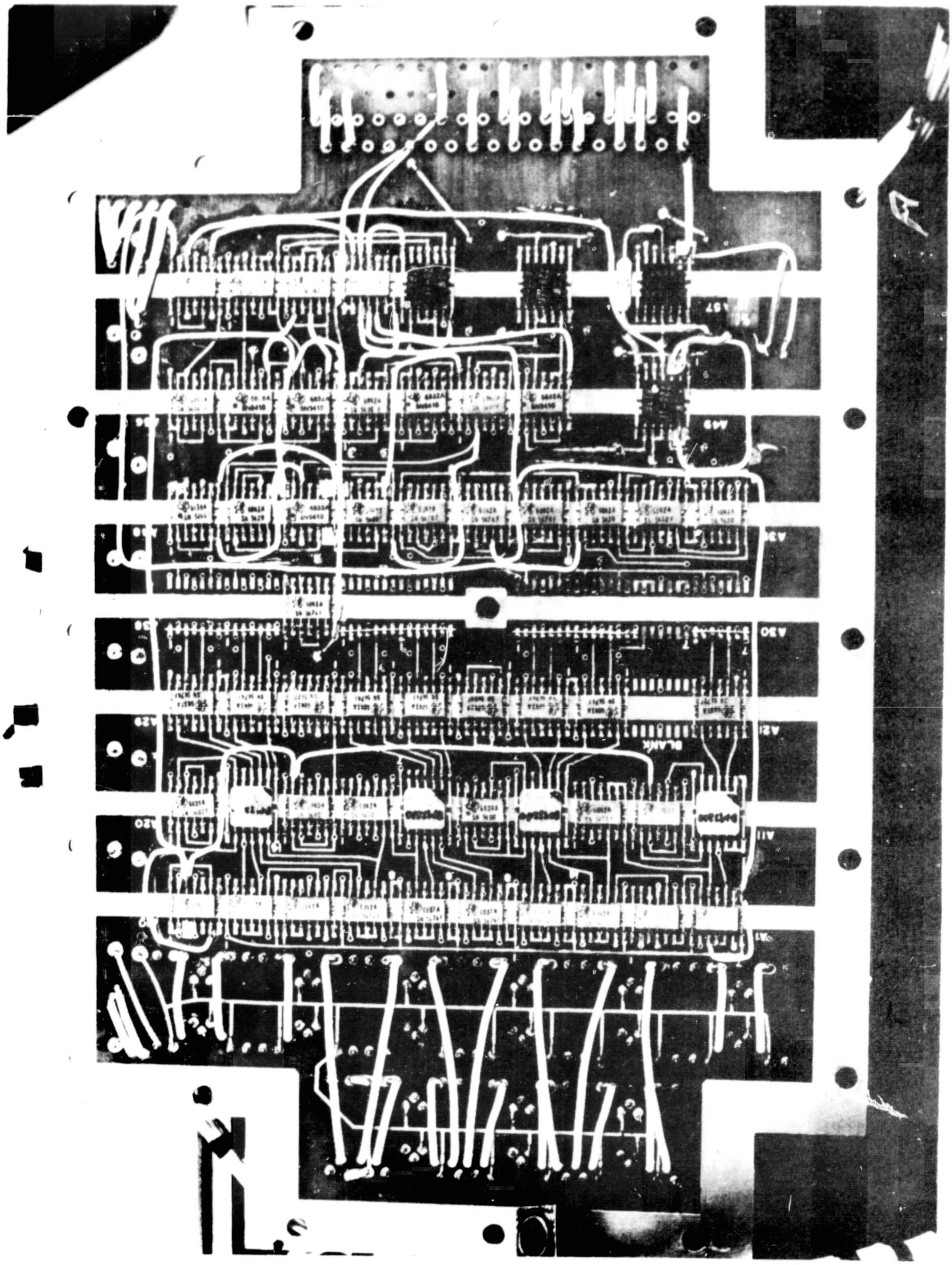


FIGURE 12. MULTILAYER PRINTED CIRCUIT BOARD, COMPONENT SIDE

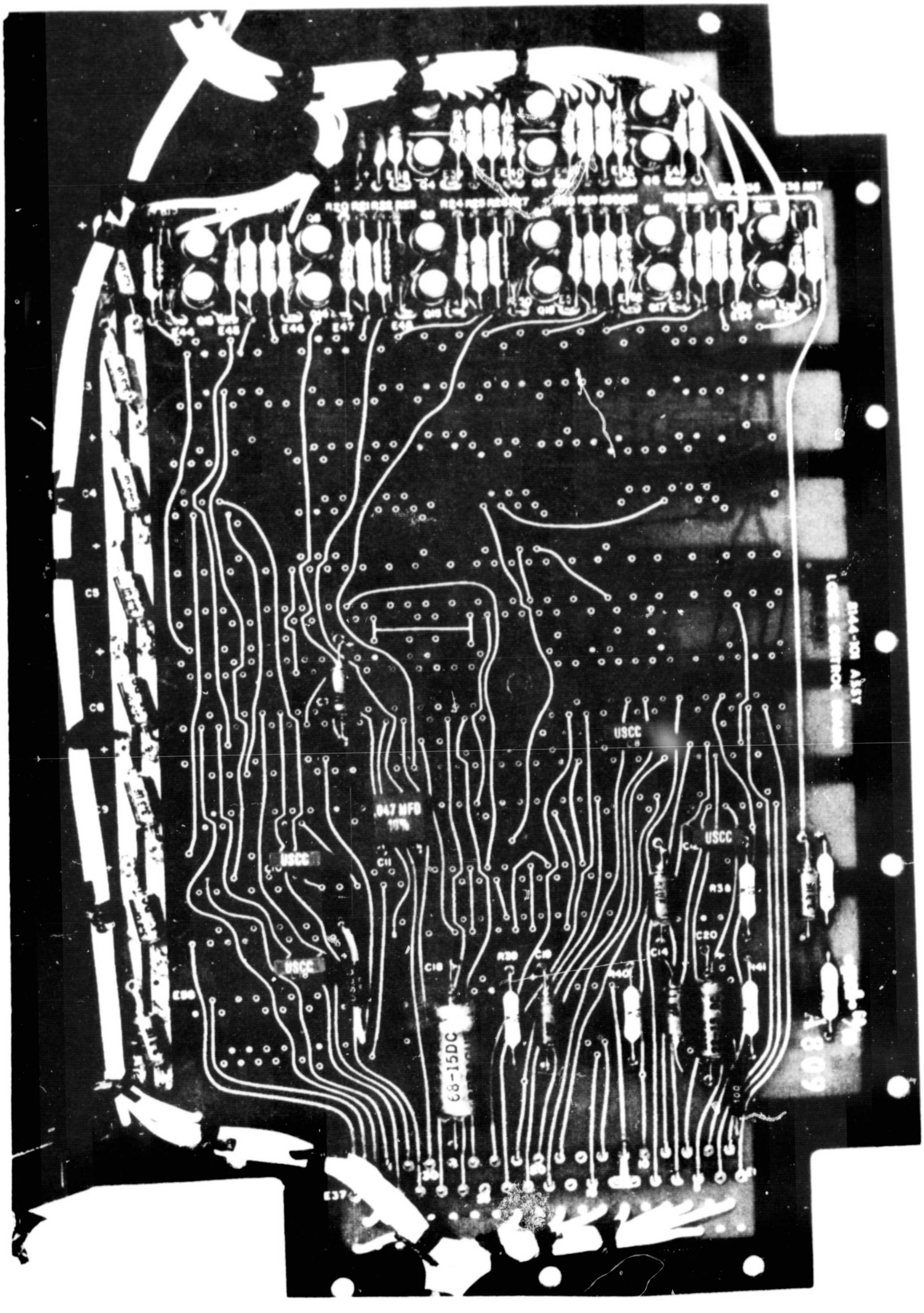


FIGURE 13. MULTILAYER PRINTED CIRCUIT BOARD, CIRCUIT SIDE.

This is copy made at Martin Marietta Corporation 3/21/69
Original furnished by George Risk Company, dated March 4, 1968

(Contact Resistance - Life Cycling of G. Risk Push Button Switches at 12 ma, 5v) per J.T.P.

"Test Results on KB Switch"

SWITCH NUMBER

NEW KB SWITCH TEST	1	2	3	4	5	6	7	8	9	10	11	12
Count / Contact Resis.	0 / 190 mΩ	87	130	60	200	78	150	45	98	111	164	140
Count / Contact Resis.	50,000 / 193 mΩ	90	126	67	47	90	154	50	107	108	165	155
Count / Contact Resis.	100,000 / 180 mΩ	95	133	80	80	100	156	73	157	100	160	186
Count / Contact Resis.	150,000 / 180 mΩ	103	140	40	86	111	170	81	98	100	180	174
Count / Contact Resis.	200,000 / 150 mΩ	115	170	37	154	109	165	81	100	100	187	153
Count / Contact Resis.	250,000 / 160 mΩ	110	200	38	150	180	173	80	50	43	185	178
Count / Contact Resis.	300,000 / 170 mΩ	110	210	50	146	169	168	74	52	22	200	190
Count / Contact Resis.	350,000 / 177 mΩ	110	140	56	170	150	165	76	140	15	210	143
Count / Contact Resis.	400,000 / 177 mΩ	105	144	176	174	140	163	75	196	79	230	200
Count / Contact Resis.	450,000 / 170 mΩ	118	166	180	160	147	160	80	200	80	225	250

Table 1

Page 2
Copy made at Martin Marietta Corporation 3/21/69
Original furnished by George Risk Company, dated March 4 , 1968

"Test Results on KB Switch"

SWITCH NUMBER

NEW KB SWITCH TEST	1	2	3	4	5	6	7	8	9	10	11	12
Count Contact Resis.	500,000 185 mΩ	170	184	154	190	150	150	92	238	154	248	247
Count Contact Resis.	550,000 200 mΩ	168	176	167	192	143	175	93	240	156	229	223
Count Contact Resis.	600,000 234 mΩ	154	120	158	199	222	182	21	221	147	237	231
Count Contact Resis.	650,000 228 mΩ	190	84	194	254	150	220	47	218	146	234	251
Count Contact Resis.	700,000 230 mΩ	199	82	190	260	165	110	50	232	132	238	256
Count Contact Resis.	750,000 165 mΩ	244	81	185	281	138	45	75	229	121	232	250
Count Contact Resis.	800,000 187 mΩ	306	59	143	291	121	86	64	210	157	230	268
Count Contact Resis.	850,000 181 mΩ	281	59	142	234	122	54	87	197	147	246	264
Count Contact Resis.	900,000 154 mΩ	243	23	177	229	143	78	68	215	155	259	277
Count Contact Resis.	950,000 196 mΩ	243	158	186	160	165	80	43	216	152	261	279

Table 1 (Continued)

Copy made at Martin Marietta Corporation 3/21/69
Original furnished by George Risk Company, dated March 4, 1968

"Test Results on KB Switch"

SWITCH NUMBER

NEW KB SWITCH TEST

	1	2	3	4	5	6	7	8	9	10	11	12
Count Contact Resis.	1M 198 mΩ	254	159	192	164	164	89	45	211	152	261	261
Count Contact Resis.	1.5M 211 mΩ	248	174	193	170	143	90	90	209	167	258	274
Count Contact Resis.	2M 207 mΩ	252	156	234	188	173	93	92	216	153	240	250
Count Contact Resis.	2.5M 225 mΩ	253	158	240	186	142	86	88	238	147	245	208
Count Contact Resis.	3M 219 mΩ	284	158	263	142	159	108	199	222	100	218	194
Count Contact Resis.	3.5M 224 mΩ	280	160	321	136	180	163	200	211	109	202	165
Count Contact Resis.	4M 229 mΩ	288	159	284	129	254	154	211	200	98	126	187
Count Contact Resis.	4.5M 226 mΩ	290	158	280	137	238	188	349	196	138	130	169
Count Contact Resis.	5M 232 mΩ	286	171	279	187	247	190	509	154	140	125	193
Count Contact Resis.	5.5M 213 mΩ	265	180	283	193	296	191	529	151	168	131	182

Table 1 (Continued)

Page 4
Copy made at Martin Marietta Corporation 3/21/69
Original furnished by George Risk Company, dated March 4, 1968

"Test Results on KB Switch"

SWITCH NUMBER

NEW KB SWITCH TEST	1	2	3	4	5	6	7	8	9	10	11	12
Count Contact Resis.	6M 215 mΩ	196	200	265	202	285	200	530	162	174	134	159
Count Contact Resis.	6.5M 231 mΩ	178	264	270′	221	284	226	541	158	160	138	172
Count Contact Resis.	7M 229 mΩ	184	261	220	220	266	189	546	159	173	132	160
Count Contact Resis.	7.5M 227 mΩ	183	262	178	218	261	204	545	160	176	129	158
Count Contact Resis.	8M 286 mΩ	165	261	171	121	255	204	543	154	175	126	74
Count Contact Resis.	8.5M 291 mΩ	162	261	176	108	234	210	541	146	174	134	80
Count Contact Resis.	9M 345 mΩ	151	238	154	147	245	205	549	118	180	130	87
Count Contact Resis.	9.5M 371 mΩ	140	160	78	163	220	200	550	131	182	125	99
Count Contact Resis.	10M 400 mΩ	138	130	100	164	225	201	556	102	183	118	76
Count Contact Resis.	10.5M 472 mΩ	102	135	98	164	229	200	543	110	185	110	75

Table 1 (Continued)

The Anadite Corporation, vendor for the HAE finish, furnished samples and information on other HAE coatings, and recommended a finish with call-out MIL-M45202, Type I, Class A, Grade 5. This finish is thicker than the one that was used, as the parts are processed three times instead of once, would be rather rough and of uneven dark brown color, but would have a hardness scale rating of 8.

FILM

The film used in the MSD is 2½ mil thick Estar base Kodak print film. (Estar is the Kodak trade name for mylar). This film, only recently made available by Kodak, lacks the structural stability of the more commonly used 4 mil Estar film, hence requires a carefully designed film gate to assure proper alignment during search and centering.

Kalvar 3 mil film was tried, but the prints obtained lacked the clarity of the silver emulsion film, and the added thickness obviated accommodating 6000 frames on the MSD reels.

RELIABILITY

A reliability analysis was performed which yielded an MTBF of 56,459 hrs. for the MSD. The results are summarized below and in Table 2.

Additionally a structural analysis was performed, and the MSD is considered to be structurally adequate to withstand the anticipated environments. The review report, prepared during the course of the program, is included here for completeness.

RELIABILITY PREDICTION SUMMARY

The reliability requirement for the Prototype Microfilm Storage and Display Unit (MSD) requires a minimum MTBF of 22,000 hours (without the light source). The light source requires a minimum MTBF of 300 hours. This reliability study shows in Table 2 Summary, the MSD (without light source) to have a predicted MTBF of 56,459 hours, and the Light Source a predicted MTBF of 500 hours. These predictions are both well within the requirements.

The prediction is based on an operational flight unit, built with piece parts which have been screened and acceptance tested. It was necessary to use screened parts failure rates for this prediction, therefore, as shown in Table 3, many of the failure rates were obtained from a recent industry failure rate survey. This survey of 17 companies made by Martin Marietta Corp., included both manufacturers and users alike. Other failure rates were from Martin Marietta's failure rate handbook <u>Reliability Policy and Procedures Manual M 63-3 (Rev. 3)</u>.

The total predicted failure rate for the MSD (without light source) is $17.7119/10^6$ hours and the failure rate for the light source is $2,000./10^6$ hours. The MTBF's were calculated from the following mathematical model:

$$\text{MSD MTBF (without light source)} = \frac{1}{17.7119 \times 10^{-6} \text{ hrs.}} = 56,459 \text{ hours}$$

$$\text{MSD Light Source MTBF} = \frac{1}{2000. \times 10^{-6} \text{ hrs.}} = 500 \text{ hours}$$

TABLE 2 - MSD RELIABILITY PREDICTION SUMMARY

EQUIPMENT	$Fr/10^6 hrs. \times N$
Keyboard	0.5064
Control Circuit & 1-Shot	0.6530
Computer Interface Gates	0.7322
Keyboard Address Register	0.5698
Power Switch	0.0634
Motor Current Limiter	0.2819
Voltage Regulator	0.2629
DC to DC Converter	0.4077
5 Volt Switch	0.0458
Lamp Current Regulator	0.2650
Lamp Starter	0.2344
Input Filter	0.0502
Film Address Register	0.5698
Film Code Sensors & Amplifiers	0.3346
All "1's" & All "O's"	0.4465
14 Bit Comparator	0.5877
Motor Control Logic	1.1365
Strobe & Center Sensors & Arms	0.0717
Control & Slew Circuit	0.5116
Power Control 1-Shot	0.0908
Miscellaneous:	
Connectors	0.0500
Motors (2)	0.4400
Condensing Reflector	1.2000
Condensing Lens (2)	2.4000
Projection Lens #1	1.2000
Projection Lens #2	1.2000
Mirror	1.2000
Screen	1.2000
Film Gate	1.0000
Total MSD (Less Lamp)	$17.7119/10^6$ hrs.

MTBF of MSD (less lamp) = $1/17.7119 \times 10^{-6}$ hrs. = 56,459 hrs.

TABLE 3. FAILURE RATES AND SOURCES FOR HIGH SCREENED* PARTS, i.e. 100% ENVIRONMENTAL TESTING AND 1000 HOUR BURN IN FOR ELECTRONIC PARTS

PART TYPE	FAILURE RATE PER 10^6 HRS	NOMINAL ELEC. DERATING	NOMINAL TEMPERATURE	FAILURE RATE SOURCE
Integrated Circuits	0.08	---**	$< 55^{\circ}C$	TRW - "Appraisal of Microelectronic Integrated Circuit Performance". By G. R. Van Hoorde, Oct. 1968(p125-127
Transistors	0.01	20%	$40^{\circ}C$	Recent MMC Industry Survey
Diodes	0.007	20%	$40^{\circ}C$	Recent MMC Industry Survey
Capacitors (Ceramic)	0.006	50%	$40^{\circ}C$	Recent MMC Industry Survey
Capacitors (Tantalum)	0.02	25%	$40^{\circ}C$	MMC/Industry Fr for Voyager Program
Resistors (Metal Film)	0.003	50%	$40^{\circ}C$	Recent MMC Industry Survey
Resistors (Wire Wound)	0.004	20%	$40^{\circ}C$	MMC Rel. Document M63-3
Switches	0.063	--	$40^{\circ}C$	MMC Rel. Document M63-3
Transformers	0.070	50%	$40^{\circ}C$	MMC Rel. Document M63-3
Inductors	0.011	50%	$40^{\circ}C$	MMC Rel. Document M63-3

*Ideally the screening tests for parts used in a particular application would cull out all potentially unreliable devices. In practice, however, this is not the case. The criticality of the application, time, and funding available all have to be considered when developing effective screening tests.

** Indiscrete circuit components, electrical stress derating criteria and its application have a definite value in prolonging component life or increasing MTFB by using the component below the designed capacity. However, in integrated-circuits the individual elements are present in a manner that does not make possible individual adjustments in electrical stresses. Thus, the manufacturer must insure safe and conservative application through his published maximum ratings guaranteed by specified parameters and test conditions.

Data assembled by TRW on 2,354 devices and tested at various temperatures over a two year period, has proven that temperature derating provides a realistic measure of the temperature dependence of integrated-circuit failure rates.

TABLE 3 FAILURE RATES AND SOURCES FOR HIGH SCREENED PARTS, i.e. 100% ENVIRONMENTAL TESTING AND 1000 HOUR BURN IN FOR ELECTRONIC PARTS (CON'T)

PART TYPE	FAILURE RATE PER 10^6 HRS	NOMINAL ELEC. DERATING	NOMINAL TEMPERATURE	FAILURE RATE SOURCE
Silicon Controlled Rect.	0.015	20%	40°C	MMC Rel. Document M63-3
Solder Joints	0.0001	--	40°C	MMC Rel. Document M63-3
Connectors (18 pins)	0.05	--	40°C	MIL HANDBOOK 217-A
Motors	0.22	10%	40°C	MMC Rel. Document M63-3
Zenon Lamp	2000.0	10%	40°C	Mfg'r PEK Labs
Condensing Reflector	1.2	--	40°C	MMC Rel. Document M63-3
Condensing Lens	1.2	--	40°C	MMC Rel. Document M63-3
Film Gate	1.0	--	40°C	Best Engineering Judgment
Projection Lens	1.2	--	40°C	MMC Rel. Document M63-3
Mirror	1.2	--	40°C	MMC Rel. Document M63-3
Screen	1.2	--	40°C	MMC Rel. Document M63-3

INTER-DEPARTMENT COMMUNICATION
MARTIN MARIETTA CORPORATION
DENVER, COLORADO

26 March 1969

TO: M. L. Bauer

FROM: R. A. Buck

SUBJECT: Review of Microfilm Storage Display Unit Drawings

The twenty-one, completed drawings of the Microfilm Storage Display Unit (MSD) structure were reviewed by the writer. The objective of this review was to assess the susceptibility of the unit's structural elements to damage and to the development of high-level resonances detrimental to functional components when the unit is exposed to the anticipated random vibration environment. In addition to the drawing review, the prototype MSD unit was examined in the development laboratory. Structural features not readily discernible from the drawings were observed in this examination. Questions which had arisen during the drawing review were answered and additional design information were provided by Mr. R. E. Schall, the structural design engineer.

Within the limits of the ability to perform an engineering assessment of the MSD structure design from the standpoint of vibration, by a review of the drawings and examination of the partially assembled unit, the MSD structure is considered to be adequate in all but one area. The printed circuit board which is installed on the reverse side of the mirror holder is well fastened at its edges, but has only one central point of attachment. The size of the board is such that critical response of the board to the expected vibration environment is considered possible. The overall random vibration level is expected to be about 10 Grms. The MSD design department is aware of this possible deficiency in the design and tentatively plans to add more tie-down points in the central area of the board and/or to affix rubber snubbers at appropriate locations, according to the structural design engineer.

R. A. Buck
R. A. Buck
Environmental Criteria Group

APPROVED:

J. Newgen
J. Newgen, Group Engineer
Environmental Criteria Group

THERMAL TESTING

During developmental testing, tests were run to determine lamp temperature in the lamp module, with the intent of modifying the design if excessive temperature rise was noted at the lamp surface. The maximum temperature reached at a simulated 1000,000 ft. altitude was 220°C, and this was judged to indicate a satisfactory design.

Additionally, the results of temperature tests on power supplies are included below.

TEMPERATURE TESTS OF BREADBOARD SECTIONS OF POWER SUPPLY

The MSD does not require rigid voltage control for normal operation. The 5 volt integrated circuit voltage must be held within 0.5 volts for all operation voltages and the lamp and motors do not have defined limits, however, the lamp starting voltage must not fall below 40 volts. Good engineering practice has been somewhat arbitrarily defined as to hold all regulated voltages to ± 5%. The motor voltage is unregulated.

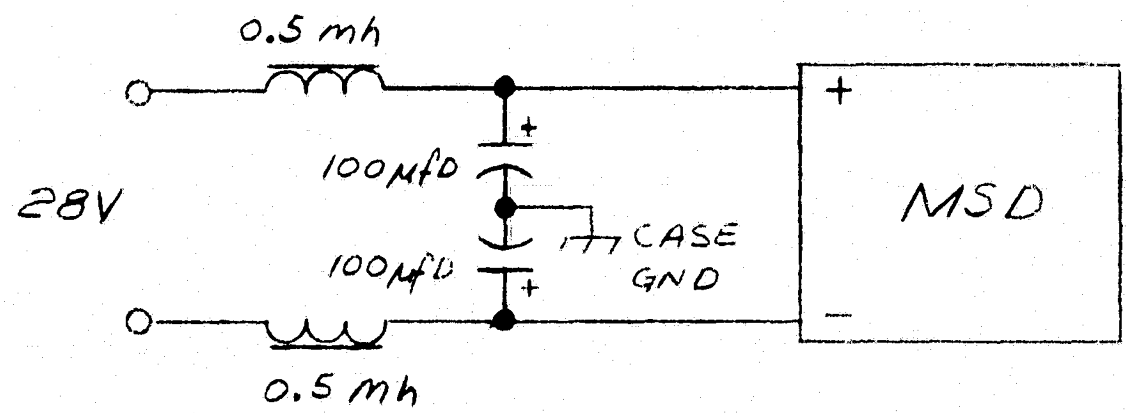
Although the requirements of the MSD with regard to temperature environment are very mild during operation, all power supply modules can be demonstrated to have considerable temperature operating margins. The required thermal/voltage margin test called out in the MSD Revised Final Reliability and Test Program Plan (MCR-68-301, Rev. 1) is restricted to a temperature range of -45°F to +165°F. Designs very similar to the MSD have been temperature operated and cycled from -55°C to +170°C on equipment provided in other present systems. Although the precise temperature characteristics of the power supply do not require monitoring, some breadboard data is available on a preregulator and a DC-DC converter. A critical and meaningful test of a converter is that it must start under load at -55°C. This has been demonstrated on at least 5 deliverable supplies similar to the MSD.

For a matter of record, typical temperature characteristics of a preregulator and a converter run separately are presented herein. Because performance at cold temperatures has presented problems from time to time, test data at cold temperature is presented for the combination of preregulator and converter as monitored on deliverable hardware. All of these supplies may be considered identical with the preregulator and DC-DC converter of the MSD except the output voltages of the converter may have slightly different values and may vary in quantity. Additionally, the thermal/voltage tests demonstrated are more severe than called for in the MSD developmental test plan.

ELECTROMAGNETIC INTERFERENCE

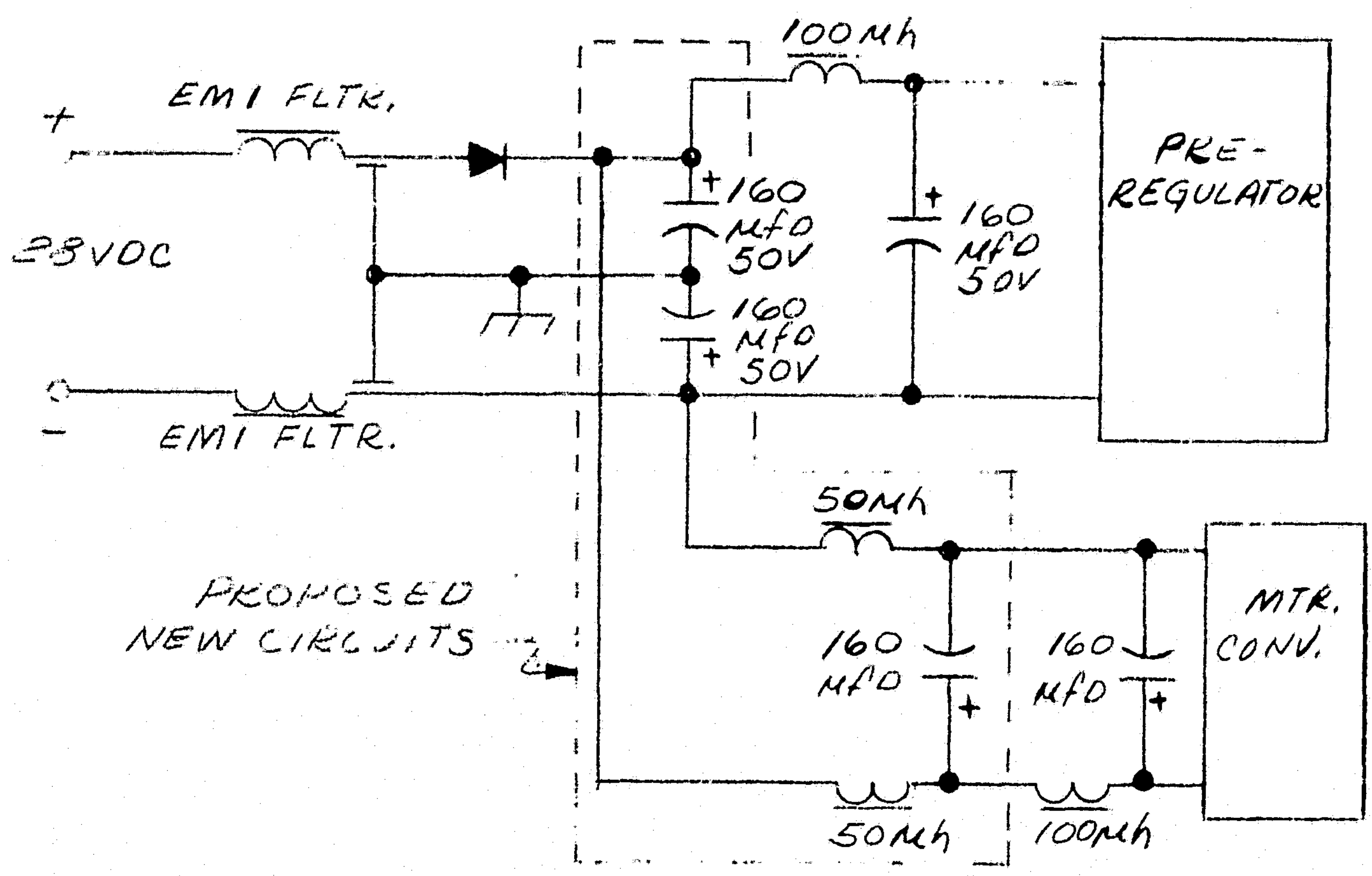
The MSD, unit as presently constructed, contains EMI filtering which is adequate for meeting conducted and radiated interference specifications during quiescent periods. However, when the motors are running and particularly during start, large amounts of low frequency interference are generated. The existing EMI filters do not adequately suppress the noises generated by the motor.

During EMI tests, circuitry to reduce low frequency interference was briefly evaluated. The addition of a low frequency L-C section consisting of two 0.5 millihenry inductors and two 100 mfd capacitors in series with the power line were sufficient to meet all interference specifications. The filter was arranged in the configuration shown below:



It was necessary to return the two capacitors to case ground because about 50% of the excess interference appeared as a common mode voltage which was only suppressed by the symmetrical bypassing of the 28 volt line and its return to the case.

Unfortunately the addition of the above specific filter is detrimental to the performance of the MSD because of excessive inductance in the line which inhibits lamp ignition. The network, however, provides us information for designing a multiple filter of low inductance with adequate low frequency rejection. The following circuit is a suggested solution:



All of the circuit configuration shown except the "proposed new circuits" exists in present configuration except for value changes. The EMI filters are U.S. capacitor filters physically identical with the present units but their inductance is reduced from 100 uh to 50 uh. The L-sections preceding both the pre-regulator and motor converter contain the present inductors but the 22 mfd capacitors should be replaced by the 160 mfd values. A pi-section consisting of two-50 microhenry inductors and three 160 mfd capacitors should be added. The input capacitor to the pi-section consists of two 160 mfd capacitors in series symmetrically connected to the MSD case.

The proposed design is based on the following criteria: The largest 50-volt tantalum capacitor compatible with reasonable case size is selected. A 160 mfd 50 volt type 109D Sprague capacitor seems representative of the state-of-the-art. This capacitor is a sintered foil, gel-electrolyte capacitor available in a hi-rel version (309D). The physical size is 3/8" x 1 1/4 nominally. The series inductance of the system shall not be appreciably increased. The reduction of the EMI filter inductance offsets the added inductors. The resulting network attenuation characteristics should simulate the results of the high inductance test circuit, but test confirmation of the final result is considered advisable.

TABLE 4 - PRE-REGULATOR TEMPERATURE TESTS

June 1968

CONDITIONS: +28 V DC input
Load - 36 ohms

TEMPERATURE	OUTPUT VOLTAGE (nominal 18.5 V)
Ambient +75°C	18.66
-20°F	18.70
-66°F	18.81
+140°F	18.57
+210°F	18.51

Variation of output voltage with input varied from 24 V to 32 V is always within ± 1% at all temperatures

---

DC - DC CONVERTER TEMPERATURE TESTS June 1968

CONDITIONS: +20 V nom input voltage constant
loads as shown

TEMPERATURE	INPUT CURRENT	OUTPUT VOLTAGE$_1$ 75 load (20 V nominal)	OUTPUT VOLTAGE$_2$ 5 load (5 V nominal)
Ambient +75°F	620 ma	20.00	4.99
-65°F	619 ma	19.94	4.98
+175°F	750 ma	20.02	

POWER SUPPLY TEMPERATURE TESTS December 1968
(Filters, Preregulator, DC-DC Converter)

CONDITIONS: 28 V DC input
Output voltages and loads as tabulated

Constant Load	+65°F Output Voltages	+75°F Output Voltages	Nominal Output Volt.	Variation w/input volt. from
470 Ω	- 23.61	- 23.88	24 V	24 V to 32 V is less than 1%
525 Ω	+ 23.59	+ 23.86	24 V	both temperatures
500 Ω	+ 14.87	+ 15.12	15 V	
500 Ω	- 14.89	- 15.14	15 V	
2K	- 25.61	- 26.33	26 V	
4K	+ 40.54	+ 41.53	40 V	
2K	+ 14.89	+ 15.14	15 V	
7 Ω	+ 4.918	+ 5.076	5 V	

Two other areas of deviation from the EMI specifications were noted, i.e.,

1) The audio susceptibility test called for 3 v.r.m.s. induced signal from 5 Hz to 15 KHz. The MSD threshold levels varied from 2.0 vrms at 5 Hz to 3 vrms at 13 Hz, and passed the test above this frequency.

2) Radiated interference, broadband. 15 KHz to 25 MHz. (Figure 7 Electromagnetic interference test, MCR-69-102 (Rev. 1).)

In the case of 1) above, the EMI specification conflicts with the susceptibility requirements called out in the acceptance test. It is felt that the voltage level is unreasonably high below 30 Hz, and the requirement should be changed.

In the case of 2) above, the curve would appear to have the correct limits for narrow band, but not wide band measurement.