Technical Proposal

LARGE SCALE DISC FILE

GENERAL PRECISION INC.

LIBRASCOPE GROUP

SURFACE EQUIPMENT DIVISION

GENERAL PRECISION INC.

LIBRASCOPE GROUP

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LARGE SCALE DISC FILE

Prepared for

Lawrence Radiation Laboratory
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Livermore, California

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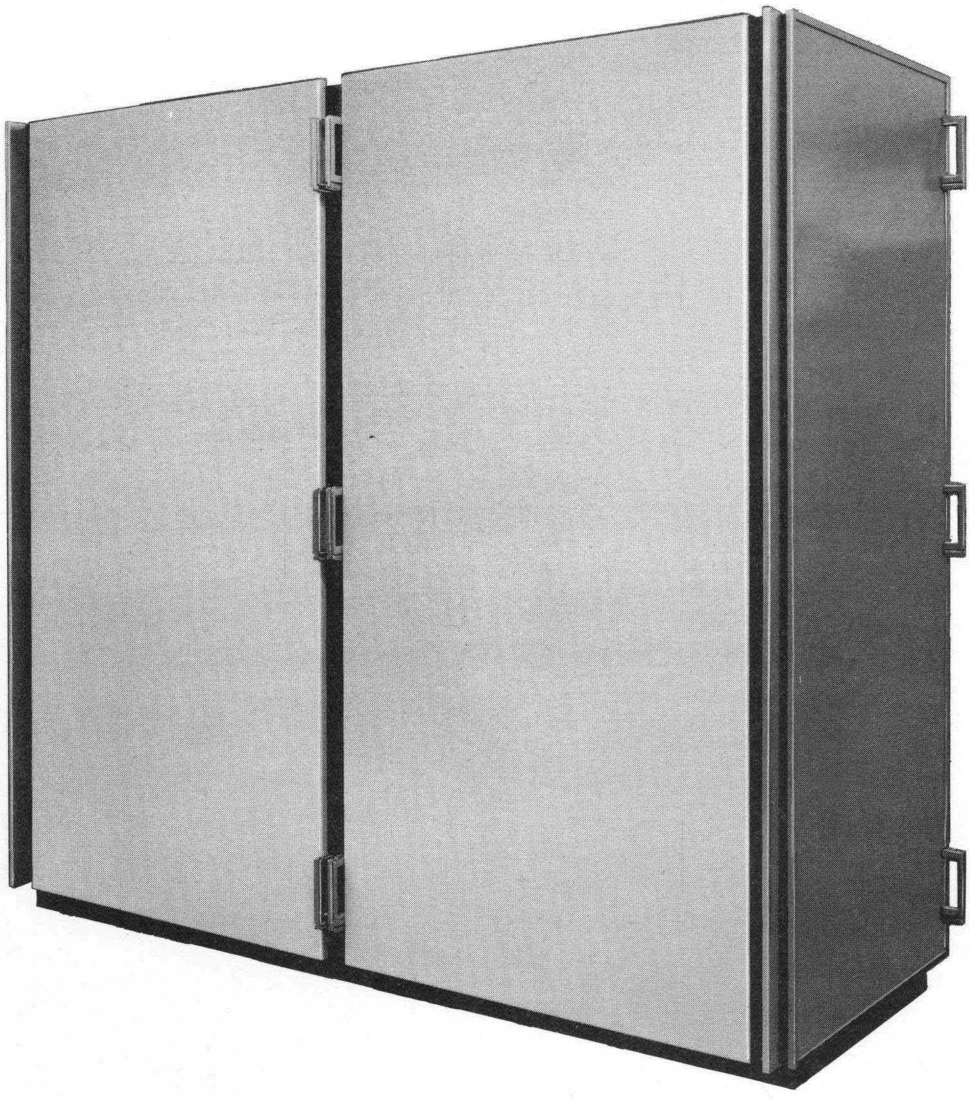


Proposed Disc File Cabinet

Section 1

INTRODUCTION & SUMMARY

In response to the request by the United States Atomic Energy Commission, Lawrence Radiation Laboratory, dated 19 February, Librascope Group of General Precision, Inc. is pleased to submit this technical proposal for a Large Scale Disc File. This proposal is completely responsive, without deviations or exceptions, to the requirements set forth in the Specification LES 11908, dated 3 February 1965 and issued by the Electronics Engineering Department at Livermore, California.

Based on the requirements for the system and experience in building disc files identical to this configuration, Librascope is confident that it can deliver the Large Scale Disc File on schedule. The design of the disc file reflects the improved version of the disc file contracted by USAF to double the storage capacity of the original file for the 473-L Command and Control System. While the logical configuration and the interface requirements for the proposed disc file are unique, all the component parts and circuit boards designed to meet the specifications for the 473-L system can be applied to this program.

The proposed Large Scale Disc File will meet the preliminary and final acceptance tests, since reliability and maintainability, primary goals for identical systems, have been reached with success. Since 14 October 1964, two disc memories have been continuously on-line 24 hours a day. During this time approximately 750,000 head bar operating hours have been logged without an incident requiring head bar replacement.

Since Librascope has had extensive experience in testing, installing, and checking out large systems, it does not anticipate any major problems with respect to any of the requirements, as stated in the specification. Experienced personnel are available to provide the maintenance, training, and final acceptance tests at the installation site in Livermore.

Librascope has manufactured over 1,000 digital computers of 15 different configurations, utilizing solid state and rotating memories. Experience in the design, development, manufacturing, and testing of computer memories and disc files are major elements in Librascope's capability and qualifications for participation in this program.

Section 2

TECHNICAL DESCRIPTION

2.0 STATEMENT OF COMPLIANCE

Librascope group offers a system in absolute compliance with Specification LES11908 dated 3 February 1965.

Additional features, provided at no additional cost to LRL, are described in Paragraph 2.4 of this proposal (Special Features).

The proposed Disc File System is comprised of two (2) Disc File Units, each storing in excess of 400 million data bits, and a Controller to provide all the necessary control, interface, and read/write electronics required to store and retrieve the data.

The Disc File Units, except for specific data organization, are identical to six (6) units currently being produced by the Librascope group under contract with the U.S. Air Force for the 473L Command and Control System.

The Controller (see Figure 2-1.) will utilize circuit cards and mechanical elements that have been developed and manufactured under the same 473L contract. The logic will be configured to implement the specific requirements of Specification LES11908. A maintenance panel will be provided to display the condition of the system, fault indicators, and a built-in PDP-6 simulator to facilitate rapid off-line fault isolation.

The entire system has been designed to meet rigorous military specifications and has been proven by many successful months of operation at the Pentagon. High reliability has been combined with comprehensive fault isolation and modular construction to provide high system availability.

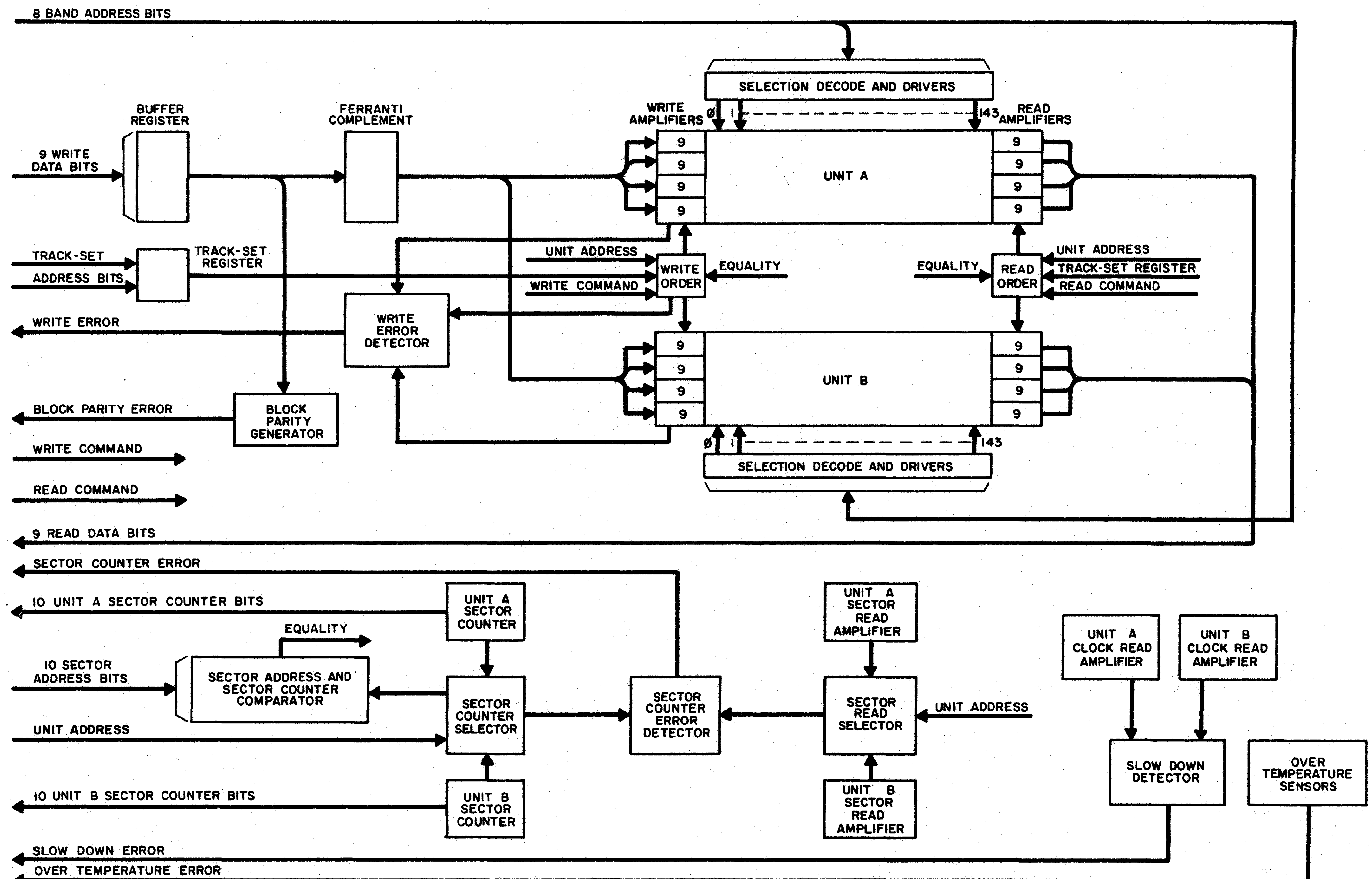


Figure 2-1. LRL Disc System Block Diagram

2.1 DISC FILE SYSTEM PHYSICAL AND OPERATING CHARACTERISTICS

2.1.1 Specifications

Size of each rotating element cabinet	74 in. wide × 72 in. high × 36 in. deep
Size of electronics cabinet	64 in. wide × 72 in. high × 36 in. deep
Combined size of cabinets bolted together	212 in. wide × 72 in. high × 36 in. deep
Required access door clearance	34 in. on each side
Weight of each rotating element cabinet	2894 lbs.
Weight of electronics cabinet	1750 lbs.
Combined weight	7538 lbs.

2.1.1.2 Supporting Surface. The supporting surface must be capable of supporting a concentrated load of 1400 lbs. per square foot or a distributed load of a 135 lbs. per square foot and must be flat and horizontal within two degrees.

2.1.2 Power Requirements

Two sets of input lines from the external power source are required. Primary power source requirements are: 3 phase, 208 ±10% volts phase-to-phase, wye 4-wire, 60 ±2cps.

Rotating element	3.5 KVA; 10 amp/phase
Electronics	2.5 KVA; 7 amps/phase

Approximately 100 amperes per phase are required for motor starting current. Convenience outlets with a capacity of 15 amperes will be available on the electronics cabinet.

Power lines are brought in from the bottom of the cabinets and connect, through conduit, to a filter box mounted in each cabinet. Each cabinet is equipped with its own circuit breakers.

Interlocks and safety devices will comply with State of California Codes and LRL Electronics Engineering Safety Standard (LE 3088-14).

2.1.3 Operating Environmental Limitations

Ambient temperature	+55°F to +100°F
Temperature gradient	15°F per hour maximum
Relative Humidity	40 to 80 percent

The rotating element cabinet provides .3-micron air filtration and a positive air pressure. The discs should not be run when exposed to contamination. The disc portion of the cabinet is baffled from the electronics cabinet, so that maintenance can be performed on the latter without shutting down the discs. The rotating element cabinet is provided with a built-in plastic enclosure to provide a cloistered environment for maintenance.

2.1.3.1 Radio Frequency Interference. The cabinets for the rotating element and electronics are of sheet metal designed to meet MIL-I-26600 RFI specifications.

2.1.4 Equipment Cooling

The disc file system is designed for water cooling and each of the three cabinets contains a copper air-to-water heat exchanger. The air within each cabinet is recirculated by fans and the heat load is transmitted through each heat exchanger to a central water cooling system. Each cabinet dissipates approximately 2,000 watts with approximately 60% of this heat being transmitted to the water cooling, depending upon the room ambient air temperature. Therefore, the cooling requirements are approximately five gallons of water per minute at an inlet temperature not to exceed 60°F.

2.1.5 Start-up Time

Less than five minutes is required to bring the unit up to speed. Approximately 30 minutes should be allowed for the discs to reach thermal equilibrium.

2.2 DISC UNIT

The basic disc unit is mechanically identical to the mass memory unit used on the AN/FYQ-11 Command and Control System. The disc unit contains the memory discs, heads, motor, selection matrix and head retraction equipment. The disc unit is mounted inside a larger cabinet used as an enclosure for protection and supply of cooling air. The disc unit is enclosed with its own cover, which is sealed against contamination and is supplied with its own clean air from a two-stage 0.3 micron air filter. The head bars used are gas-lubricated "invarient intercept", "very close proximity" type, which are insensitive to shock and vibration. The memory heads are assembled in groups of thirteen (12 active - 1 spare) with the head selection matrix diodes mounted directly on the head bar (See Figure 2-9).

2.2.1 Disc Unit Main Frame and Enclosure

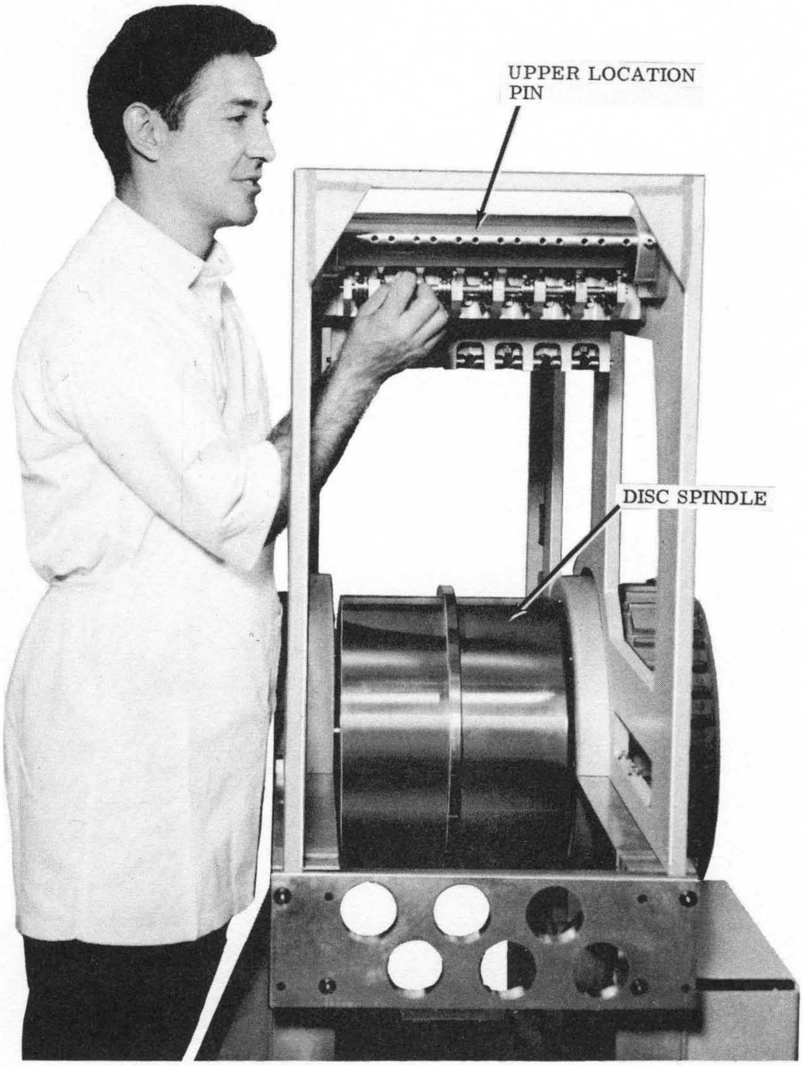
The disc spindle is supported by a main frame by means of a pair of ABEC Class 9 selected ball bearings. (See Figures 2-4 and 2-5.) On the spindle are mounted a set of six magnetically plated memory discs. The drive motors are mounted at each end of the spindle shaft and on starting both are energized.

As the unit achieves its nominal RPM, one motor is programmed to be de-energized. Either motor may be used to drive the unit and upon failure of one side, the other may be used until a repair may be made. The main frame is totally enclosed by a cover which seals out external volatile and particulate contamination. Access to the unit for service is made through a removable front panel.

2.2.2 Head Mounting Plates

The head mounting plates (Figures 2-6 and 2-7) are mounted interstitially between the memory discs. Each plate may be retracted individually from between its adjacent discs. (See Figure 2-8.)

Memory Unit - Side View



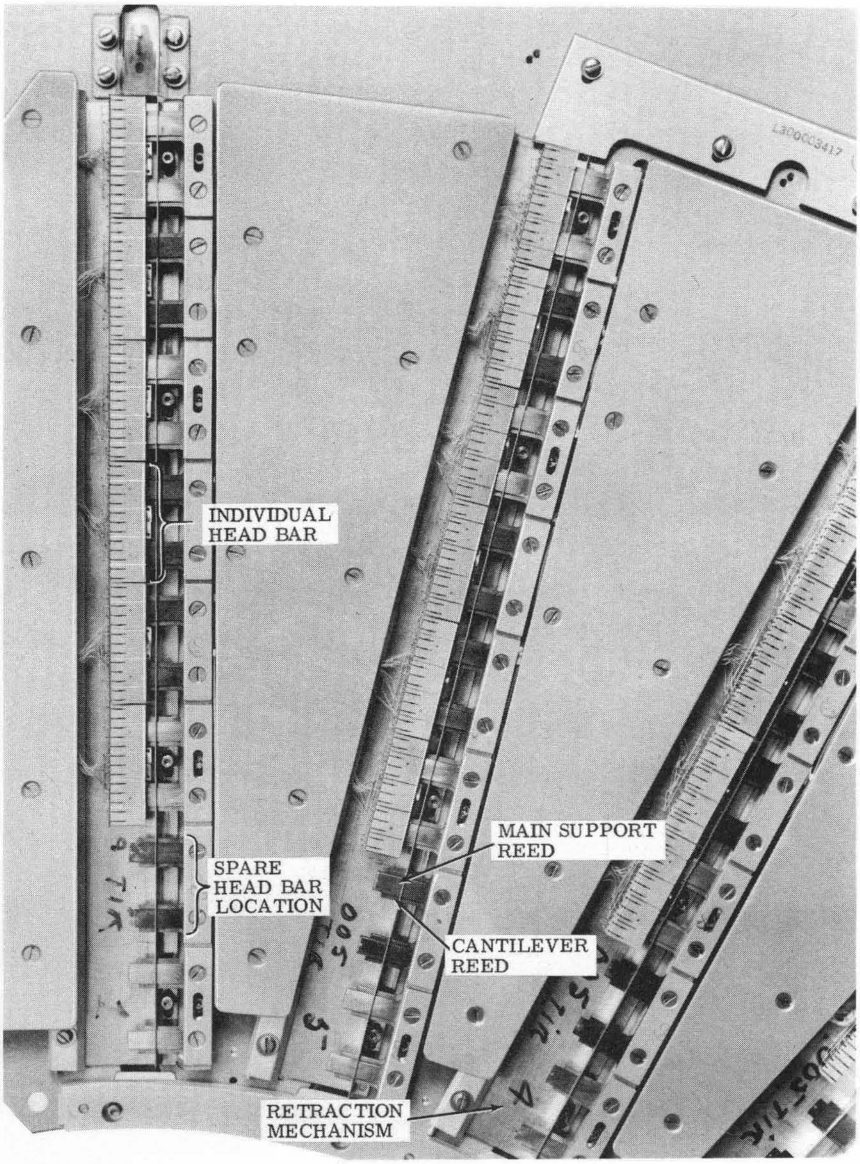
Memory Unit - Front View

Each head mounting plate weighs approximately forty (40) pounds. It is supported by means of a spring and cable, so that the plate will be counter-balanced both in the service position and operating position. The head mounting plates, when extended, overhang the base unit by approximately 32 inches, and extend beyond the cabinet by 22 inches. When in this position, all heads are accessible, and may be inspected and serviced. To replace a head, all that is required is to remove wire covers, disconnect the head's connector, remove the head, and replace with a new head. No adjustment to the new head is necessary; in fact, no adjustment of the head is possible. When the head is fabricated, it is accurately measured and a permanently-affixed pivot is installed and will operate at that time optimally. The heads are mounted radially in six (6) columns each containing six (6) blocks of heads. Each head block contains twelve (12) heads and one (1) spare, yielding a total of 432 active heads and 36 spares per head mounting plate side. There is a spare position for each head block column which may be used as a spare position in case it is desirable to bridge some gross difficulty on the disc's surface.

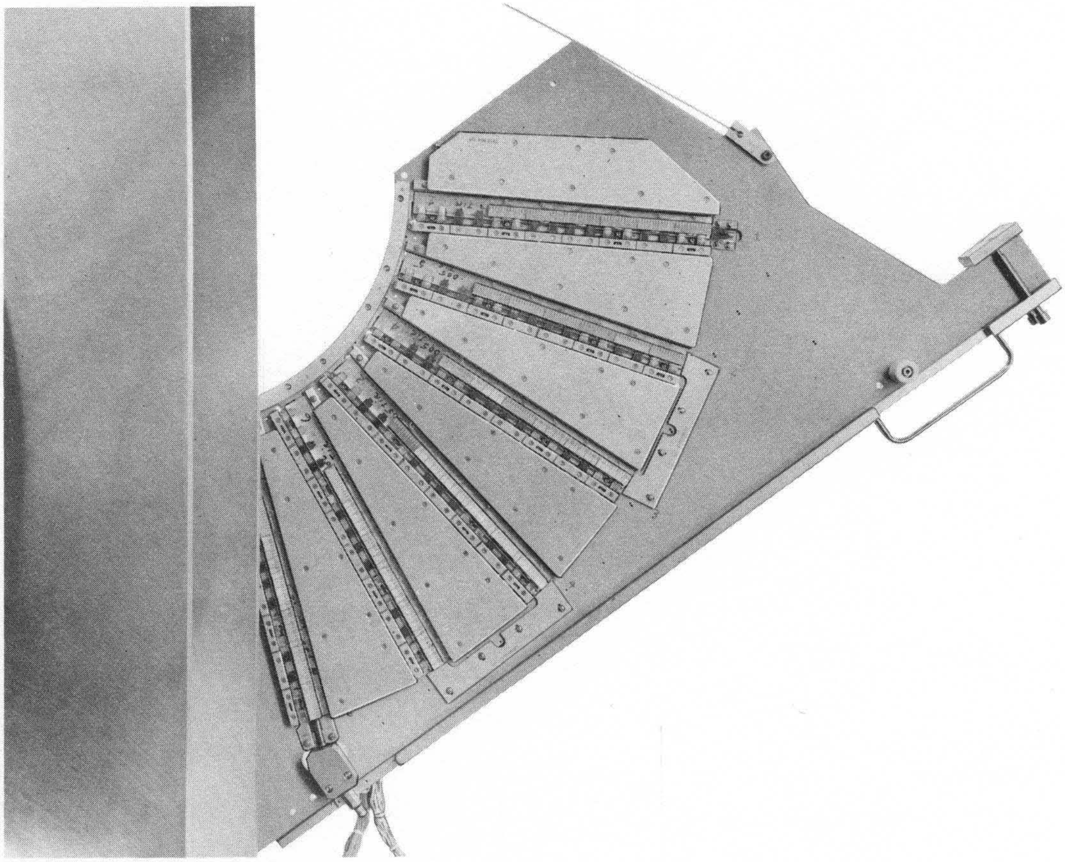
In case an individual head is damaged by some technician's misadventure, it is possible to bridge in the spare head by merely connecting the spare head as a substitute for the defective head. The worse case inner track packing density; i.e., position seven (7) is 1000 bits per inch. This density is well within the capabilities of the present magnetic head. Using a column of six (6) head blocks, the maximum packing density will be 900 bits per inch. The present capabilities of the "head-disc" combination is well over 1300 bits per inch.

2.2.3 Head Bar Detailed Description

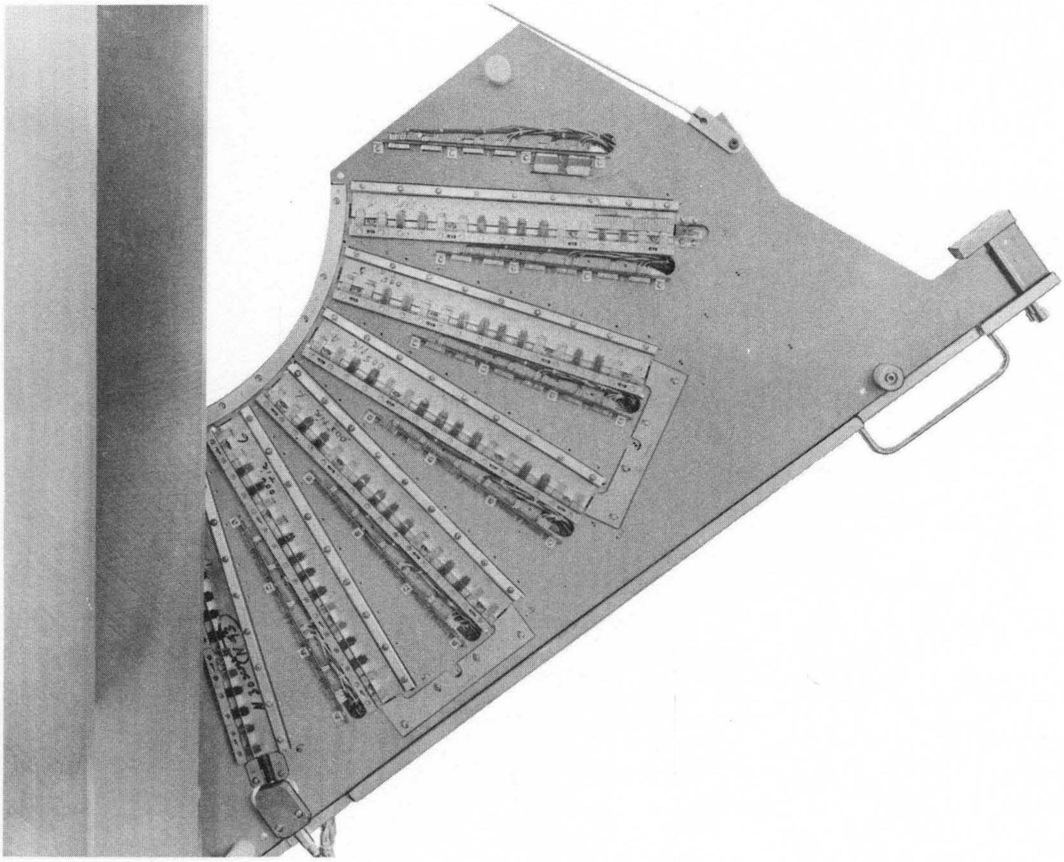
The Head Bar consists of an assemblage of thirteen magnetic heads. Each head is 0.015 inches wide, and the track interlace is 6 tracks, providing a track density of 48 tracks per inch. The guard band between tracks is 0.006 inches.



Detailed Section of Head Mounting Plate



Head Mounting Plate - Service Position

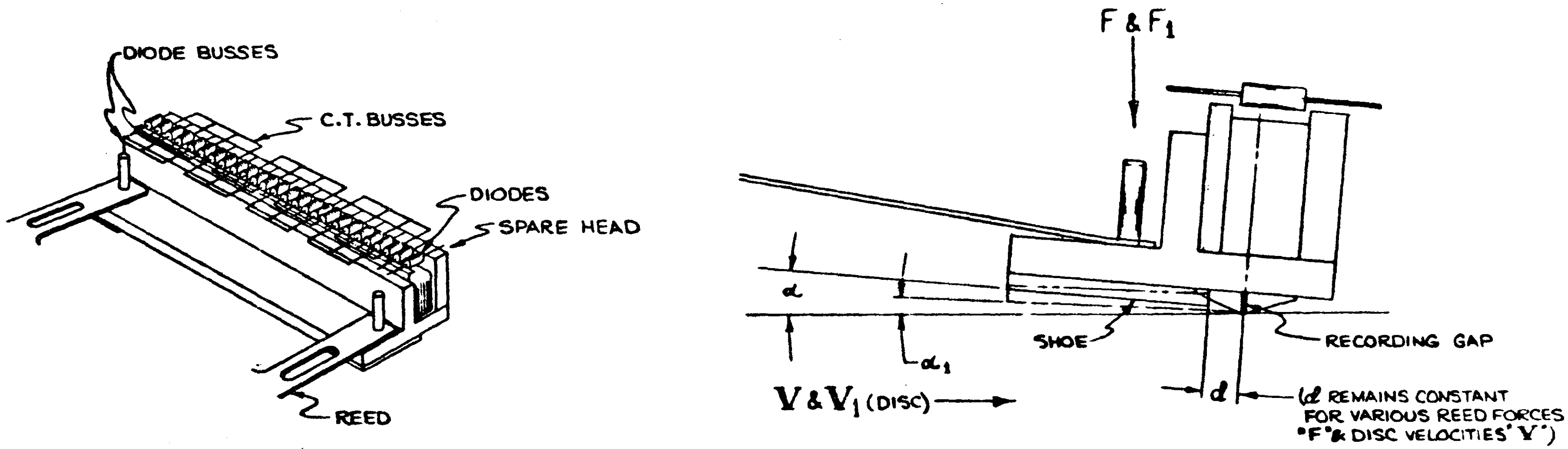


Head Mounting Plate - Wire Covers Removed

The head bar is a gas lubricated slipper bearing. Precision pads located on the bottom of the head bar act as the bearing surfaces. The pads support the head bar so that contact with the disc's surface occurs only during a small part of the start and stop cycle. The recording gap of the head is located behind the lubricating surface and is positioned slightly forward of the intercept line of the pad and the disc. (See Fig. 2-9.) As long as the slipper bearing operates in the laminar flow or incompressible region of the lubricating gas, the intercept point (of the pads and disc) is a constant distance behind the pad.

This relationship remains constant for a great variation of reed force from 0 to 720 grams (See test result Figures 2-10 and 2-11). The head also is insensitive to velocities from 25 in/sec to 3300 in/sec. The force used on the head when running is 300 grams. The weight of the head is 4 grams. Theoretically then, and neglecting other secondary effects, the head should be able to withstand accelerations of 75-g's away from the disc surface and more than 75-g's toward the disc surface without a change in read back voltage. The lift force produced by the pneumodynamic wedge varies inversely to the square of the exit height of the lubrication pad. The stiffness or spring constant for the gas wedge is approximately 54, 000 lbs/inch per square inch of pad. This yields head bar natural frequencies of vibration over small displacements of 10^5 cycles per second.

Each head will contain its own selection matrix diodes. The diodes will be mounted integrally on the head bobbins. The basic selection matrix will be 3×4. The interconnections will be made on the head assembly by means of solid leads. This technique allows a reduction of service leads from 36 to 10. The main support reeds, which control the position of the head bars with respect to the head mounting plates, are made of beryllium copper which has a temperature coefficient of expansion different from that of the aluminum discs and head support plates. To insure no errors in clocking, the main support reeds are compensated by an equivalent length mounting bar also made of beryllium copper, which will result in a zero shift in head bar position with respect to the discs.



TYPICAL HEAD ASSEMBLY

HEAD FLIGHT

Figure 2-9. Head Bar Assembly

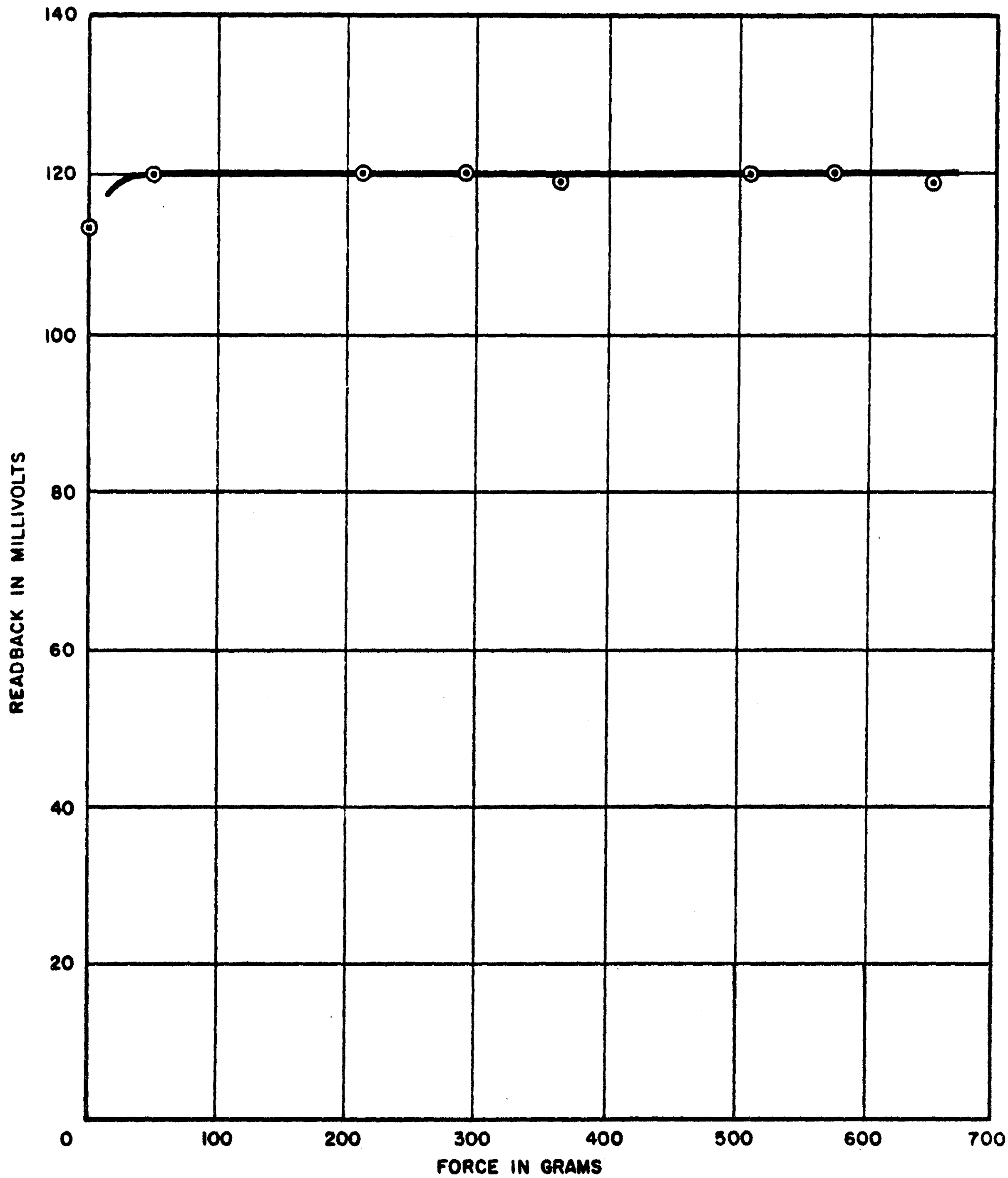
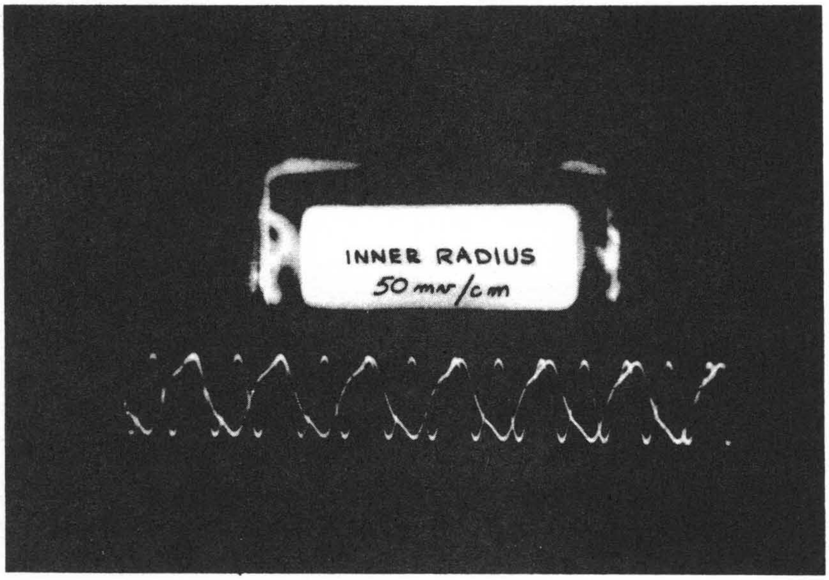


Figure 2-10. Readback vs. Reed Pressure



PHASE MODULATION HALF AND FULL FREQUENCIES (ALL ONES VS ONE-ZERO PATTERN)
50 Mv/Cm, 1100 BITS/IN, 1000 IN/SEC, FCA HEADBAR NO. 4

Figure 2-8. Read Signal

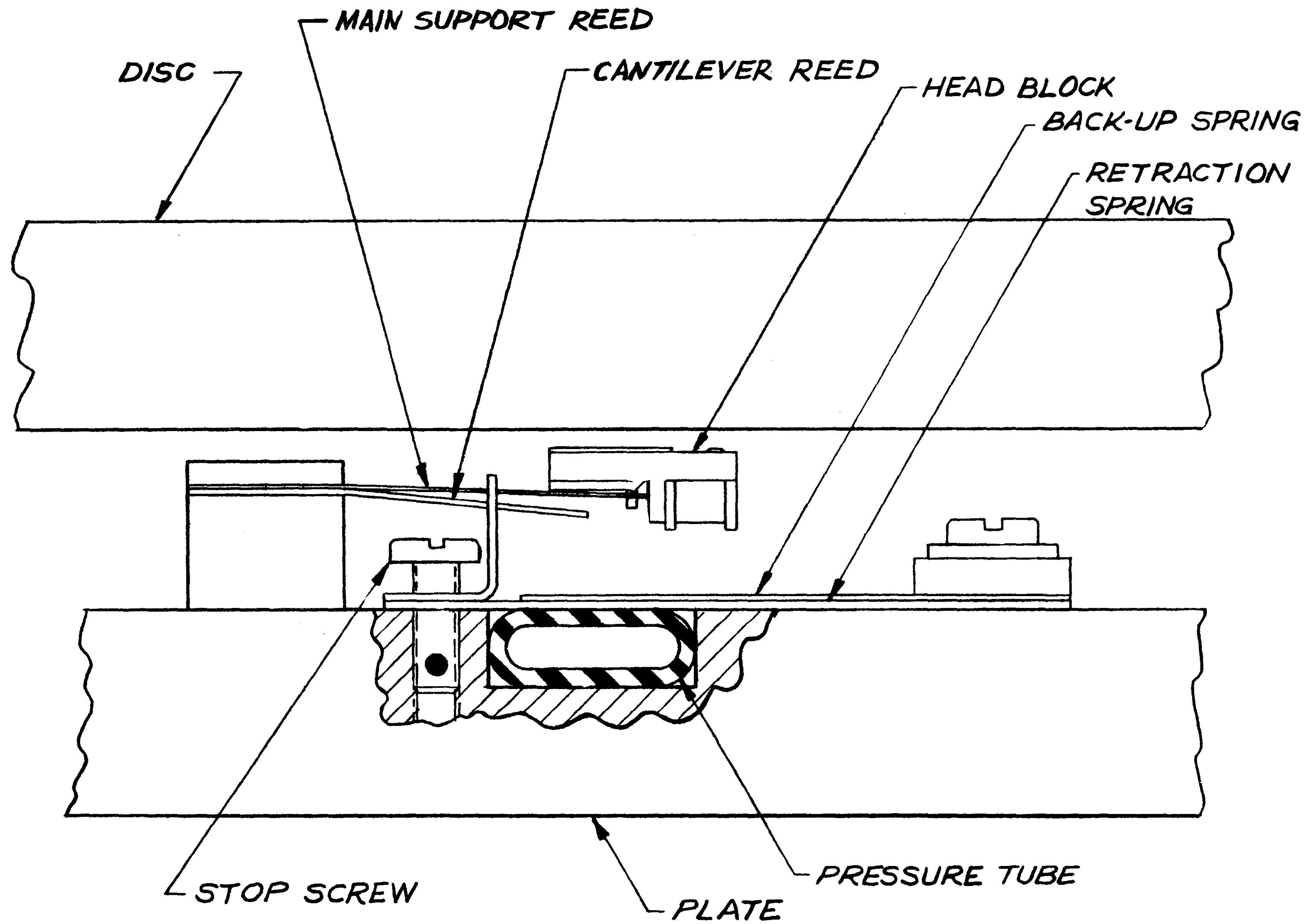
To reduce motor starting torque requirements and wear of the disc and head bars, it is desirable to start the unit with a very light force (approximately 20 grams is used). Therefore, two reeds and a retraction mechanism are employed. A 20 gram "main support reed" and a 300 gram cantilever reed are utilized.

2.2.4 Retraction Mechanism

The present retraction mechanism as used in the AN/FYQ-11 Mass Memory (See Figure 2-12) is pneumatically controlled using a closed cycle nitrogen pressure system programmed by the power control sequence network for automatic start and stop condition. The 300 gram cantilever reed is retracted or lifted from the main support reed allowing only a nominal start force of 20 grams force between the head and disc. A start/stop experimental configuration of 100 grams force was made simulating the conditions in the file. Two configurations started and stopped 20,000 times each with absolutely no evidence of degradation of the disc's surface or head's surface and performance. Another start/stop configuration has been starting and stopping for 37,000 starts and stops without any evidence of surface attrition and is still going strong.

2.2.5 Specifications

Discs	Six (6) 47.5 in. dia.
Magnetic Media	Electroless Cobalt
Speed	900 RPM Nominal
Heads	Fixed, .015 inch track width C.T. - Bifilar Wound, Integral Selection Diodes
Head Inductance	35 μh/half coil
Write Current	60 ma
Tracks Per Inch	48
Track Guard	.006 in.
Type of Recording	Phase Modulation



HEAD BLOCK SHOWN IN RETRACTED POSITION

Figure 2-12. AN/FYQ-11 Head Retraction Mechanism

2.2.6 File Organizations

Word Length	36 Bits (9 × 4)
Tracks/Word	9
Bits/Track/Word	4
Words/Sector	32
Bits/Sector	128
Parity	1 Bit
Spacer	1 Bit
Total Bits/Sector	130
Sectors/Rev.	608
Bits/Track	79,040
Tracks/File	5184
Data Bits/File	403,439,616
Total Bits/File	409,743,360 including Spacer and Parity
Data Bits/2 Files	806,879,232
Spare Heads and Data Tracks/File	300
Total Data Tracks and Write-Read Heads per File	5484
Clock Rate	1.13 Mc
Data Transfer Rate	10.17 million bits/sec.
Bit Density	891 bits/in (approximately)*
Access Time	70 ms maximum 35 ms average

*Spare data tracks at 1000 bits per inch

2.3 CONTROLLER

2.3.1 Head Matrix

Contained within each disc file unit are 5, 184 active read-write data heads. The heads are connected in such a manner that 36 are selected at one time with a positive voltage applied to their center taps. This group of 36 heads is referred to as a band, and there are 144 such bands in a unit. 144 heads, whose center taps are each tied to a different selection driver are connected together at a read amplifier and a write amplifier. There are 36 read and write amplifiers in the head matrix.

Within each band of 36 heads are four track-sets of 9 heads apiece. The read or write amplifiers of only one track-set at a time are tuned on. This means data is written or read 9 bits parallel. There is a 9 bit buffer within the unit that holds the data while it is being written or after it is read.

Each track-set is divided temporarily into 608 sectors of 128 sets of 9 bits. Thus, each head provides storage for 608×128 (=77, 814) bits plus block parity bits and pads. A block is defined as the amount of data recorded 9 bit parallel in one sector time.

2.3.2 Addressing

There are 21 parallel bits of addressing necessary in the two disc system. The most significant bit specifies the disc file unit. The next most significant 8 binary bits specify which of the 144 bands of track-sets with addresses zero through 143. The next 2 bits designate the track-set, Ø through 3; and the least significant 10 bits indicate sector address Ø through 607. Ten parallel bits from each disc file unit are presented to indicate the address of the current sector. Switching time between addresses on these lines will be less than 200 n/sec.

Provisions for adding additional disc systems at a later date are included in the system. This is done with the use of an address selector switch on the control panel that provides 8 different positions so that the disc system address has one of 8 values. This means a disc system address bit (in addition to the aforementioned 21) must be provided when 2 disc systems are used. Two disc system address bits are necessary for 3 or 4 systems and 3 system address bits for 5 to 8 systems. When only one disc system is used, the system address bits need not exist; in which case the system address is zero.

Multiple disc systems are connected on a trunkline, so that only one system at a time can be executing an operation. This also means that only the (20) sector address bits from the two units of the system addressed are present on the trunkline. Thus, to determine the current sector addresses within a system, the system must first be addressed with the system address bits.

When an operation is executed, the 2 track-set address bits are loaded into the track-set register approximately 20 microseconds before the start of the next sector. Since switching time of the selection drivers is less than 20 microseconds, the following sector can be operated upon, if the corresponding sector address was specified. When equality of the input sector address and the sector address counter is found, reading or recording is turned on at the start of the next sector. The track-set register will be incremented, if the operation extends beyond the initial track-set; and will be reset to zero, when the operation extends beyond the end of the fourth track-set.

2.3.4 Write Operation

A write operation can be initiated by turning on the write command wire to the disc file system. At approximately 20 microseconds before the start of the sector after the write command goes on, the system enters a search phase. The search phase compares the sector address input lines with the sector address counter at the start of each sector. When equality is found, write order to the write amplifiers is turned on and writing of the block begins.

At the time write order is turned on, the first 9 bit byte from the input data lines is transferred to the 9 bit buffer register. This causes the generation of the 400 n/sec disc clock signal to indicate to the transmitter than another 9 bit byte is necessary. The disc clock signal is sent each bit time immediately after the receipt of each 9 bit byte by the buffer register. The data from the buffer register is transferred to the Ferranti complement generator, which in turn drives the eight sets of 9 write amplifiers. Write order for only one set of 9 write amplifiers can be on at any one time, as governed by the unit address line and the track-set register.

After the last disc clock signal of a block has been sent, the 128th byte is written on the disc and then the block parity (BP) byte is written and no disc clock signal is generated. The block parity is generated with the use of a half adder on each of the 9 bits as each byte is written. After the BP, a pad bit is written during which write order is turned off, if the write command signal is off. There is approximately 2 disc bit times between the last disc clock signal sent and the next time the write command wire is sampled. If the write command is not off at the start of the next block, writing will continue until it is off at the start of a block. The write comman signal need not be on throughout the writing of the entire block, but must be on in order to start writing.

The block format of one track of a track-set is shown in the diagram. The pad or spacer bit is the only time at which write order may be turned on or off. It precedes the writing of the first bit of the next block and succeeds the block parity bit of the previous block. The block parity bit is an even

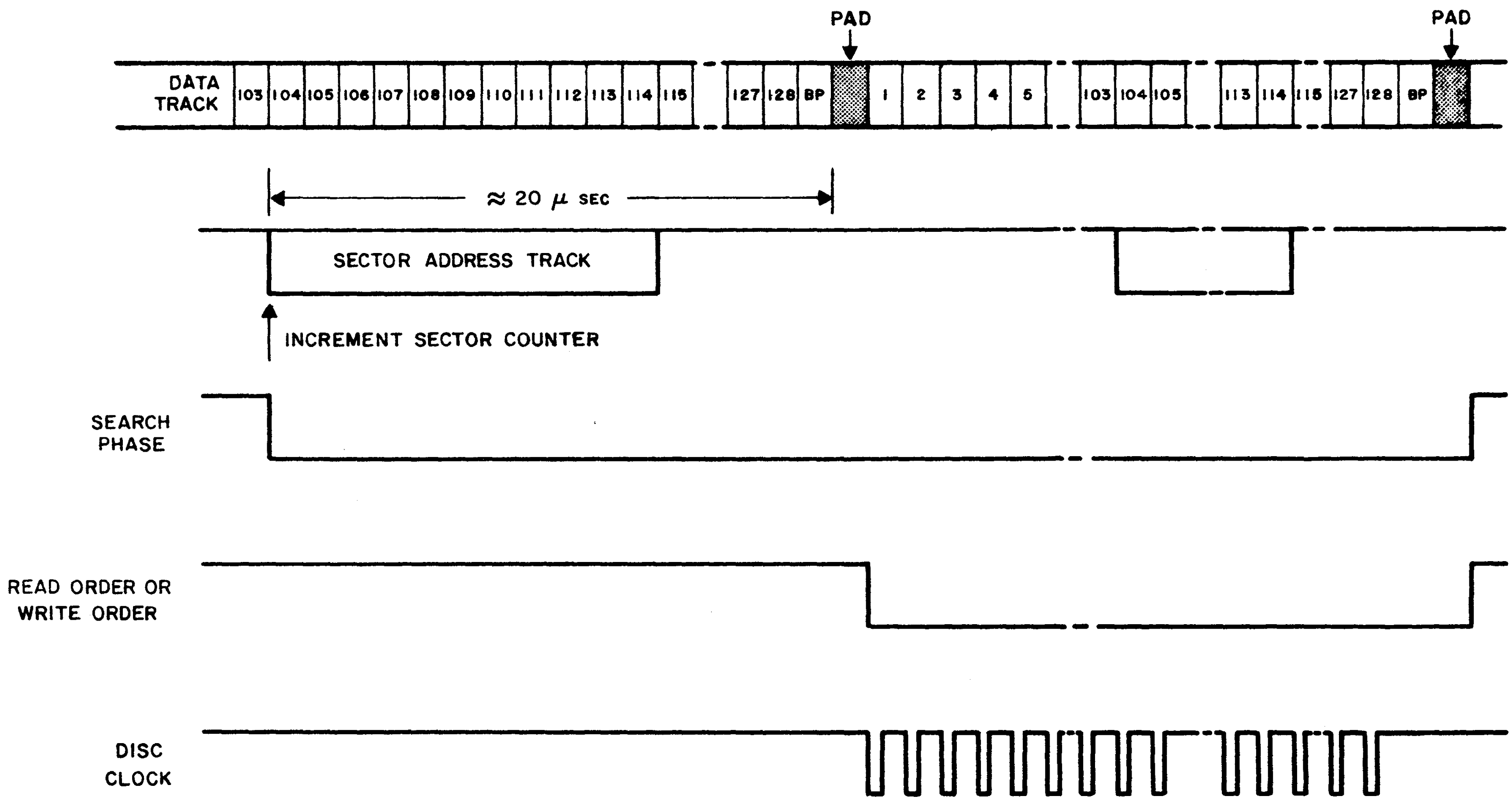


Figure 2-2. Disc Timing Diagram

parity of the bits of a block written on one track, and produced while the bits are being written. While reading, an even block parity bit is generated and compared with the block parity bit read from the track at the end of the block.

2.3.5 Read Operation

The read operation is begun when the read command signal to the disc system is turned on. At approximately 20 microseconds before the start of the next sector, the search phase is entered; and when the sector counter equals the input sector address, reading commences from the unit, band and track-set specified (i.e., read order will only be on for the one of eight sets of 9 read amplifiers as specified by the unit and track-set address lines). Each 9 bit byte is gated to the output data lines and a 400 n/sec. disc clock is transmitted with each byte. The data read is also used to generate a block parity which is compared with the 129th byte of the block to provide a means of indicating a read error. No disc clock signal is transmitted with the block parity byte.

After reading the block, read order will be turned off approximately 2 disc bit times after the last data byte and associated clock is sent, unless the read command is still on or has come back on. As it is when writing, once it is started, reading will continue to the end of the block in order to check the data read.

2.3.6 Error Signals

If a write error occurs during a write operation, the write error signal goes on and remains on until the current operation is finished and a new one is started. The write error can be caused by a failure in a write amplifier, head, clock or selection circuits.

The block parity error can only occur at the end of reading a block. The signal will again remain on until a new operation is initiated. This can be caused by a head, clock, or selection circuit or read amplifier failure.

Each time the sector address counter is incremented, it is compared with the sector address as read from the disc (a permanently recorded tract). If the two are not identical, the sector address error is turned on, but only if an operation is in progress. The error also inhibits the operation if the search phase is still being executed. The error is reset by halting the present operation and starting a new onew. This error indicates a failure in the sector address counter, read amplifier, head or clock circuits.

A slow-down error is detected by a constant monitoring of the distance between clocks read from the clock track of each disc unit. A decrease in clock frequency of approximately 5% or greater will result in the slow-down error signal going on and the start motor for the unit being turned on. The disc motor alarm indicator will be turned on because of the start motor being on. The error signal is reset at the start of any succeeding operation. A failure in the clock head or read amplifier or the disc motor can cause this error.

The over-temperature error signal is caused by any cabinet overheating, a motor bearing overheading, or a motor stator over temperature. The corresponding indicators are on when any of these conditions occur.

2.3.7 Signals Originating From Disc Systems

The following signals are on the output of the line drivers shown in schematic Number L543002063. True is negative.

Quantity	Signal	Description
1	Disc	400n/sec negative pulse at 1.13 Meg Cy for strobing data received from disc and for changing data to be received by disc.
9	Read Data Bits	Data read from disc. Data changes at 1.13 Meg Cy rate.
20	Sector Counter Bits	Ten bits from the sector counter of each disc unit. Bits change every 115 microseconds at time next address can no longer be accessed on current revolution,

Quantity	Signal	Description
1	Write Error	Goes on only during write operation. Stays on until next operation.
1	Block Parity	Can only go on at end of block during read operation. Reset by next operation.
1	Sector Address Error	Turned on by incorrect sector address after operation has started.
1	Over Temperature	Cabinet or motor sensors overheated.
1	Slow-Down Error	Clock or disc motor trouble.

A. Logic Characteristics

Logical ∅ - 0 volts

Logical 1 = -10 volts

INPUT A	INPUT B	OUTPUT
0	0	0
0	1	0
1	0	0
1	1	1

Logic Tolerances:

	Nominal Level	Range
INPUT	-10	-11 to -9
	0	0 to -0.4
OUTPUT	-10	-11 to -6
	0	+ 1 to -1

B. Electrical Characteristics

Switching Speed (nanoseconds)

	Typical	Maximum
Rise Time	40	75
Fall Time	30	50
Delay Time	60	100

C. Circuit Capabilities

The line driver is capable of operating at a maximum frequency of 1.4 megacycles per second. The circuit can be gated at the input in a manner similar to the standard logic gate circuit. The input signal requirements and load are equivalent to a gate circuit. The output of the line driver is capable of providing a minimum 6 volt signal at the terminated end of 200 feet of 75 ohm coax cable.

The line driver output is capable of being wired to the output of a similar circuit through no less than ten feet of cable for trunkline operation. An inhibit gate signal is necessary for trunkline operation. A driver is selected when the inhibit gate signal is a logical 1.

Each circuit is capable of driving a maximum of sixteen standard line receivers on a trunkline when the input to the last receiver is terminated with 75 ohms.

D. Wiring Considerations and Line Terminations

The wiring between individual system consoles must be coaxial cable that has a characteristic impedance of 75 ohms and the maximum cable length allowed is 200 feet. A recommended cable type is Amphenol 21-577 (0.1 ohm/ft.). For cable lengths greater than 200 feet and less than one mile, it is necessary to use RG/U34B/75 ohm cable. The wiring from the central processor output connector to the line driver card can be twisted pair, if the length of twisted pair is less than three feet. If the line driver is located in a magnetic tape unit or other equipment that is on a trunkline, then the wiring from the output connector to the line driver card must be 75 ohm coax cable and both ends of the trunkline must be terminated with 75 ohms. If a line driver is just driving a single coax line and a single receiver, then, the receiving end must be terminated with 75 ohms.

There are 12 line drivers per circuit card and each circuit on the card is provided with a pin connection for grounding the coax cable shield at the connector.

The line driver 75 ohm terminations are provided on separate circuit cards which provide a maximum of twenty terminations. The wiring to and from the termination card can be twisted pair, but the total length of the twisted pair should be less than five feet.

E. Power Consumption

The following line driver ratings are based on high voltage margins, nominal resistance values, and two 75 ohm line terminations. To obtain the total power per card, these ratings should be multiplied by twelve.

	0 OUTPUT		1 OUTPUT	
	I	P	I	P
-20	12.0 ma	264.0 mw	11.79 ma	259.4 mw
-10	-7.0 ma	-77.0 mw	309.5 ma	3.41 mw
+10	.877 ma	9.63 mw	1.038 ma	11.40 mw

If there is only one 75 ohm line termination, then the -10 volt supply ratings are reduced to 160.6 ma or 1.77 watts per circuit when the output istrue. The other supply ratings remain the same.

2.3.8 Signals Received By Disc System

The following signals are input to the line receivers in the disc system and must conform to the requirements of the circuit shown on schematic Number L543 002 056. Negative level is true.

Quantity		
1	Read Command	Causes disc system to search and read data specified by input address lines.
1	Write Command	Causes disc system to search and write data from write data bits.
9	Write Data Bits	Data to be written on disc. Must change at 1.13 Meg Cy rate on leading edge of disc clock.
21	Address Bits	Ten sector address bits, 2 track-set bits, 8 band bits and one unit bit. Must be stable during entire execution of operation.

A. Logic Characteristics

Logical 0 = 0 volts

Logical 1 = -10 volts

INPUT A	INPUT B	OUTPUT
0	0	1
0	1	1
1	0	1
1	1	0

Logic Tolerances:

	Nominal Level	Range
INPUT	-10	-11 to -6
	0	+ 1 to -1
OUTPUT	-10	-11 to -9
	0	0 to -0.4

B. Electrical Characteristics

Switching Speed (Nanoseconds)

	Typical	Maximum
Rise Time	30	80
Fall Time	75	150
Delay Time	20	40

C. Circuit Capabilities

The line receiver is capble of operating at a maximum frequency of 2.0 megacycles per second. The circuit has a maximum fan-out of two.

This circuit can be inhibited by applying a false signal to the inhibit input diode. The inhibit input load is equivalent to three standard gate loads.

A. Logic Characteristics

	INPUT A	INPUT B	OUTPUT
Logical 0 = 0 volts	0	0	1
Logical 1 = -10 volts	0	1	0
	1	0	0
	1	1	0

Logic Tolerances:

	Nominal Level	Range
INPUT	-10	-11 to -6
	0	+ 1 to -1
OUTPUT	-10	-11 to -9
	0	0 to -0.4

B. Electrical Characteristics

Switching Speed (Nanoseconds)

	Typical	Maximum
Rise Time	30	50
Fall Time	75	150
Delay Time	20	40

C. Circuit Capabilities

The line receiver is capable of operating at a maximum frequency of 2.0 megacycles per second. The circuit has a maximum fan-out of four.

This circuit can be inhibited by applying a negative signal to one of the input diodes. The inhibit signal can be generated by a standard logic gate but this gate may only be used to inhibit the line receiver.

D. Wiring

There are twenty line receivers per card. Twisted pair may be used to wire from the input connectors to the line receiver cards in all cases. The length of the twisted pair leads should be less than five feet. One of the twisted pair should be grounded at the line receiver card connector and the same lead should be tied to the coax shield of the cable from the line driver. The wiring from the output of the line receiver should be the same as the standard gate.

E. <u>Power Consumption</u>

The following ratings are based on high voltage margins and nominal resistance values. To obtain the total power per card these ratings should be multiplied by twenty.

	0 OUTPUT		1 OUTPUT	
-10	8.3 ma	91.3 mw	0 ma	0 mw
+10	1.16 ma	12.8 mw	1.04 ma	11.44 mw

2.3.9 Testing and Maintenance

On the maintenance panel will be located several indicators and controls to aid in trouble-shooting the disc units. These will include indicators for all the error conditions and addresses, and switches for performing read and write operations. These controls in conjunction with a simulator (tester) plugged into the disc system input-output connect will allow complete exercising of the system. The tester is built into the disc system, but is not completely functional without being plugged into the disc system connector. Off-line trouble-shooting will require the simulator to be connected in order to perform the necessary operations.

The tester will have facilities for generating data patterns that can be written and read and compared with the disc data. The tester will be used to perform the worst patterns test prior to delivery. This test consists of recording the data pattern on all heads and then reading and comparing the data read with what was written.

A test plan will be produced for manual testing of all controls and indicators. An operational test for checking disc and electronics operating characteristics will be provided. This test will be run with the use of the built-in test facilities of the disc systems, and will consist of continuous running of the worst patterns test for a period not less than 8 hours. All 800 million bits of the system will be written and read and tested approximately 150 times.

Spare clock and sector address tracks exist on each disc unit. With the use of the tester, the sector address track or the clock can be copied onto any head in the unit; with, of course, no loss of the data previously recorded on the disc. The sector address can be generated and re-written without copying an existing track, but previously stored data will be lost. The system does not include facilities for generating a clock track, for this requires special clock recording equipment. Hence, the reason for multiple spare clock tracks.

2.4 SPECIAL FEATURES

The following features exceed the requirements of Specification LES 11908 dated 3 February 1965 and are provided at no additional cost to Lawrence Radiation Laboratories.

2.4.1 Rotating Element

2.4.1.1 Spare Heads. Each headbar consists of twelve (12) active heads and one spare head. At least 70% of the headbars delivered with the system will have a usable spare head which may be patched-in to replace a defective head on that headbar.

2.4.1.2 Spare Clock and Sector Headbar. A spare headbar will be provided with redundantly recorded clock and sector data. Facilities to transfer this data will be provided so as to enable rapid recovery from inadvertant loss of such information.

2.4.1.3 Spare Track Locations. For each six (6) active tracks, approximately one (1) spare track is provided. In the event of disc damage, a headbar may be moved to one of these spare tracks thus extending the operating life of the system, and permitting rapid recovery from failure.

2.4.1.4 Maintenance Tent. A maintenance tent is packaged in each Disc File cabinet to provide contamination control during maintenance and alleviating the need to purchase such an item as support equipment.

2.4.1.5 Two Motor System. Each rotating element is provided with two motors. In the event of a motor failure while the disc is operating, a fail-safe system cuts in the idle motor.

2.4.2 Controller Features.

2.4.2.1 Expandability. The logic of the controller is configured in such a manner as to permit expansion of the system to include sixteen disc files (6.4 billion bits) on one trunk line.

2.4.2.2 PDP-6 Simulator. A simulator is built-in to the system with off-line controls so that the performance of the disc file system can be comprehensively tested.

2.4.2.3 Maintenance Panel. A maintenance panel is provided which operates a comprehensive set of indicators and signals to alarm errors or unsafe conditions. These error signals are made available to the PDP-6. The error signals include (1) write error, (2) block parity error, (3) sector counter error, (4) slow down error, and (5) overtemperature error. The disc is automatically shut-off in the event of cabinet over-temperature or loss of pressure in the pneumatic retraction mechanism.

2.4.2.4 Re-write of Clock and Sector Data. The controller is provided with the capability to re-write clock and sector data from a spare track.

2.4.2.5 Voltage Margin Testing. Marginal circuit behavior may be detected by means of voltage margin tests that are settable at the maintenance panel.

2.5 MECHANICAL CONSTRUCTION OF ELECTRONICS CABINET

The electronics cabinet which is located between the two disc file cabinets and attached to them weighs approximately 1750 lbs. and has the dimensions of 64 in. wide × 72 in. high × 36 in. deep. It is fabricated from mild sheet steel into a basic uni-strut framework. This allows great adaptability for the placement of circuit card cages eithe fixed or swinging and location of power supplies. Both sides of the cabinet are fully accessible through full opening doors. The cabinet is modern in appearance and fully adaptable to installation in computing sytem facilities requiring raised decking and submerged cabling.

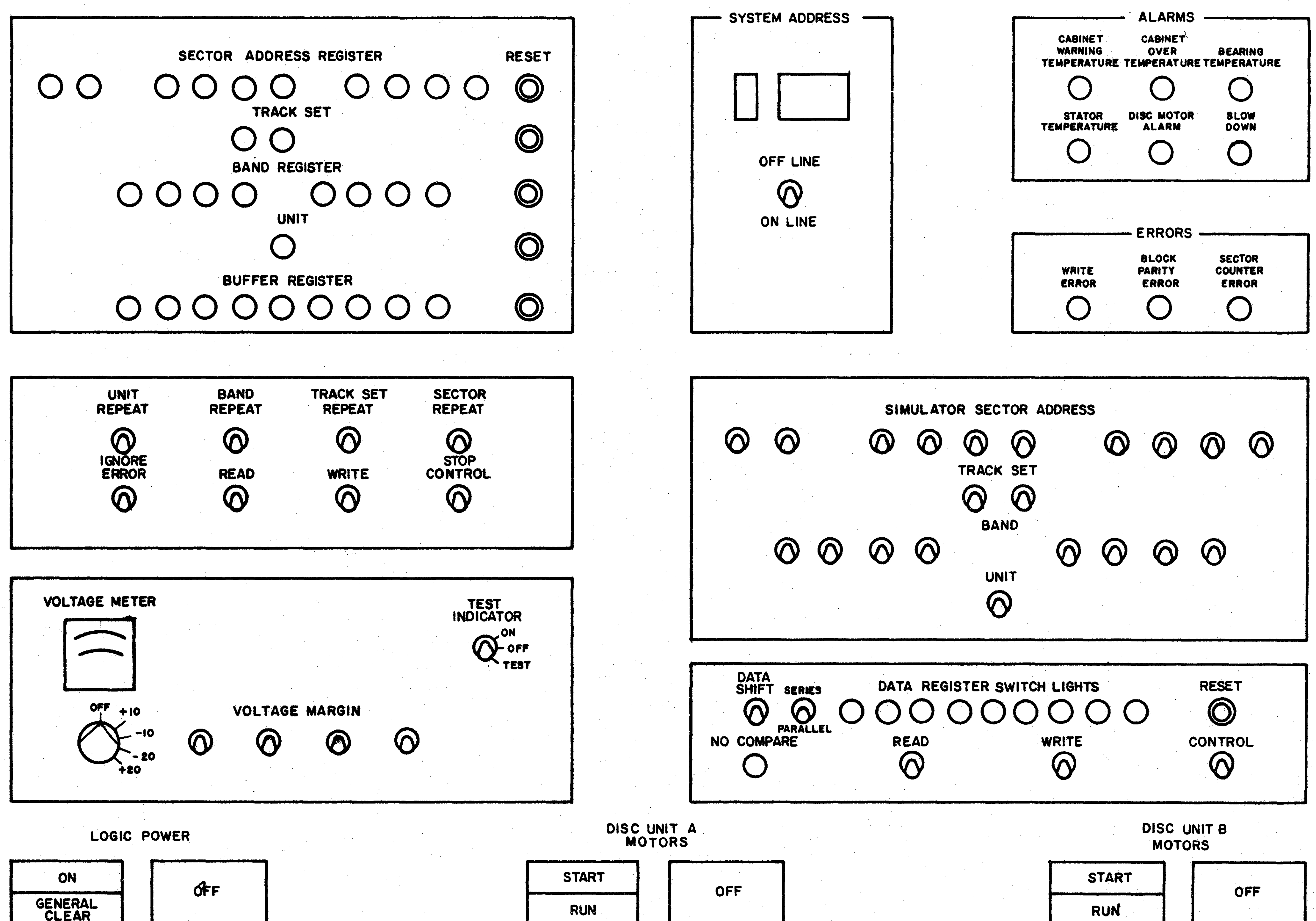


Figure 2-3. Maintenance Panel

2.6 INSTALLATION

The installation of the proposed system will be accomplished in approximately two and one-half days. This will include the following:

a. Unpacking the system

b. Moving the file to its final operation position

c. Leveling and interconnecting the three cabinets that comprise the system

d. Connection of cables for both signal and power

e. Connection of the cooling system

f. Preparation of the system for testing

2.7 TESTING

2.7.1 Testing at Librascope

The disc file system will be tested by Librascope personnel in the presence of members of the Lawrence Radiation Laboratory to demonstrate that it meets the intent of Specification LES 11908 dated 3 February 1965. The built-in PDP-6 simulator and automatic warnings of the maintenance panel will facilitate this testing.

2.7.2 Testing at Lawrence Radiation Laboratory

Testing at Lawrence Radiation Laboratory will be conducted in accordance with paragraphs 5 and 6 of Specification LES 11908 dated 3 February 1965. All maintenance during the acceptance tests will be performed by Librascope personnel. Librascope will bear the cost of all spare parts prior to final acceptance.

2.8 MAINTENANCE AND SPARES

The maintainability features of the system are designed to effect the concept of quick on-site fault isolation and replacement of defective components. A self-test capability provided by means of the built-in PDP-6 simulator and maintenance panel contributes measurably to minimize down time and maintenance cost.

The training and manuals provided to Lawrence Radiation Laboratory personnel will permit them to rapidly correct the majority of malfunctions. When necessary, Librascope stands ready to provide on-site maintenance as well as factory overhaul.

2.8.1 Preventive Maintenance

Each 13-track head bar is quickly and easily removed or installed. The 13-head bar, complete with its selection diodes is replaceable on site as a unit in 15 minutes. Easily removable connectors permit connection to a spare head bar in less than 10 minutes. Rotors and stators in the integral twin-drive motor system can be replaced on site.

All circuits are mounted on plug-in printed circuit boards which can be replaced with minimum down time. Power supplies can also be removed for repair and replacement on site. The recommended preventive maintenance routine is as follows:

1st 6 months of operation - Every two months

After six months - Every six months

The preventive maintenance consists of examination of the disc surfaces, wiping only when necessary; inspection of the disc air filter; and, operation of the disc file controller in a voltage margin test procedure. A periodic inspection procedure of indicators, pushbuttons, switches, and switchlights will also be provided by item and schedule.

2.8.2 Spares

The Spare Parts List that will be made available to LRL will consist of replaceable circuit boards, head bars, neon lamps, indicators, incandescent lamps, and power supply components.

Circuit Boards

One (1) each of the following types:

Z3, Z4, Z5, Z7, Z8, Z9, Z11, Z29, Z30, Z32, and Z51

Two (2) each of the following types:

Z1 and Z13

Three (3) each of the following types:

Z2 and Z12

Seven (7) each of Z14

Types of Boards: 16

Total Number of Spare Boards: 28

Head Bars: 10

Neon Lamps: 3

Lamp Indicators: TBD

Incandescent Lamps: 3 voltages - quantities TBD

Power Supply: components and quantities TBD

Replaceable Filters

2.9 DOCUMENTATION

With respect to the requirements of LRL Specification LES-11908, Librascope will prepare instructions adequate for operation, maintenance, and servicing of the equipment. Five complete sets of the manual, consisting of three volumes, will be supplied to the customer. The three volumes will cover:

1. Operation and Maintenance Instructions

2. Wire List

3. Circuit Cards and Related Logic Functions

The manual will be prepared to good commercial standards and all material used in the preparation of the documentation will be supplied by Engineering. Five months after authority to proceed on contract, Publications will freeze data for inclusion into the manual. Copy will be available for Engineering review 45 days prior to delivery of equipment. The 45 days following Engineering review will be used for incorporating Engineering comments and actual publication.

Librascope will also supply four complete sets and one reproducible set of the following:

a. Circuit schematics

b. Mechanical drawings, (limited to installation type)

c. Wiring diagrams

The drawings will be reduced, as required, to conform to the LRL size 4 maximum, based on our understanding that an LRL size 4 is approximately 22" × 34", or equivalent to our D size drawing.

2.10 TRAINING

Librascope will instruct personnel appointed by LRL to maintain the equipment, limited to a maximum of 6 persons, in the logic, electronics, and mechanics of the entire system. This training will be accomplished at Livermore during a four week period. Librascope proposes that this training be scheduled to run parallel with the acceptance test, because it will have personnel and conditions available to demonstrate the discussion with hardware familiarization. In addition, the trainees can perform analysis of malfunctions that might occur during testing and increase participation in trouble shooting.

Section 3

RELIABILITY AND MAINTAINABILITY

To satisfactorily meet the operational requirements, the Lawrence Radiation Laboratory Large Scale Disc File must provide a high degree of on-line availability. Although high reliability has already been established, a continuing product assurance surveillance program is conducted within the Librascope Rotating Memories Section to improve this reliability. This program includes design reviews environmental testing, life testing, and product field data analysis. Continued implementation of this product assurance surveillance effort will effectively monitor the L.R.L. Large Scale Disc File program.

3.1 RELIABILITY AND LIFE PREDICTIONS

An initial assessment of the reliability plus the qualitative analysis of the maintenance and recovery techniques available with the system will provide an indication of system availability.

The design of the mechanical sections are such that on-site repairs requiring removal of the disc motors, and bearings are not recommended. For this reason, a distinction must be made between failures for which repair action requires repair of the rotating elements and those for which repair may be accomplished without disturbing the rotating portions of the Mechanical Section.

The only first failures which result in the necessity of major repair are those which involve extensive damage to the discs, motor, or bearing. The most probable mode of failure in the Mechanical Section is failure of a head to provide error free operation due to head winding or core faults, such as electrical component failure. This may be corrected by connecting in the wired-in spare head(s) or replacement of a head bar. Thus, correction of such failures can be effected on-site provided that spare head(s) and head bars are available.

3.1.1 Controller (Electronics)

The electronics used to perform the various read, write, and logic requirements are contained on printed circuit assemblies which are plugged into closed entry connectors. Interconnections between circuit card connectors are made by use of taper pins. External connectors use crimp type contacts.

Cooling air flow is required mainly to provide adequate cooling to the power components.

The design life of the electronics assembly is 10 years under any combination of permitted storage and operating conditions.

Individual component failure rates were summarized to provide the circuit assembly failure rates as given in Table 3-1.

Combining the assembly failure rates as shown in Table 3-1 indicates an estimated mean time between failure of 330 hours for the Controller Section. It should be noted that included in the Controller Section reliability prediction are the power supplies and the maintenance panel facilities.

3.1.2 Disc Mechanical Section

The Mechanical Section of the disc is designed to perform the required system function of writing, storing, and receiving data on magnetic discs with an acceptable low over-all frequency of failure and an absolute minimum probability of factory repairable failures.

The distinction between on-site repairable and factory repairable failures is related to the logic design, the patch-in redundant read/write data bands, and the frequency of failures for which neither logic design or patch-in redundant data bands is effective.

In classical reliability studies, it is generally considered that a component failure always results in a system failure unless redundant - on line - equipment is available. A more sophisticated way of looking at the problem is to define a failure as an incident which reduces system performance

Table 3-1
Lawrence Radiation Laboratory
Large Scale Disc File
Controller Section Reliability Summation

Circuit Assembly	Number	Assembly Failure Rate % per 1000 hours	Total Assembly Failure Rate % per 1000 hours
Flip-Flop	15	2.355	35.325
Two Input Gate	22	1.860	40.920
Three Input Gate	7	1.675	11.725
Four Input Gate	4	1.535	6.240
Five Input Gate	4	1.228	4.912
Line Receiver	2	1.455	2.910
Diode Network	1	.749	.749
Line Driver	4	1.797	7.916
Neon Driver Amplifier	3	1.115	3.345
Read Amplifier	27	1.363	36.801
Write Amplifier	24	1.016	24.384
Selection Driver	72	1.280	92.160
Incandescent and Magnet Driver Amplifier	2	.659	1.318
Resistor Network	12	.538	6.456
Multivibrator	3	.977	2.931
Power Supply ±20 volts; ±10 volts	4	2.886	11.544
Power Supply 30 volts; 70 volts	2	2.178	4.356
Maintenance Panel	1	5.500	5.500
Interconnection	1	3.300	3.300

Total Failure Rate = 302.692% per 1,000 hours

$$\text{Electronic Section MTBF} = \frac{\%\text{ per 1,000 hrs}}{\text{Failure Rate}} = 330\text{ hours}$$

below the threshold of acceptability for a period of time which seriously interferes with the effective performance of the mission.

There can be no doubt that, for example, failure of the motor or a bearing would result in system failure, since the residual Disc Assembly performance would be nil. On the other hand, failure of a single read/write head or its associated diode will merely reduce data storage capacity minutely. The ability of the system to make use of the remaining data storage capacity would, of course, depend on the system programming capability. The components whose failure will directly affect all memory capability, which will result in need for factory repair, and the considerations in their design are bearings, read/write heads, recording surface, head selection diodes, drive motor, and head retraction mechanism.

3.1.2.1 Bearings. Bearing life is a function of operational environment in a rather complex manner. We find, for example, that bearing life under the most benign shock and vibration conditions is only slightly greater than that observed for the worst shock and vibration environment for which preload is not exceeded. Thus, the life of a given bearing is compromised by designed in capability to withstand severe mechanical environments, without special regard for the actual environment.

To a certain extent, a similar set of conditions exist with regard to lubrication in that selection of a lubricant which will operate over a wide temperature range compromises bearing life under less severe operational conditions.

The design approach used to maximize life, consistent with the meeting all mechanical and thermal environments, includes selection of the most suitable bearing and lubricants to minimize bearing pre-load consistent with ability to meet system vibration and shock environmental conditions. Since the preload force required to withstand a given level of acceleration is proportional to rotor mass, special effort will be made to minimize rotor mass without sacrifice of other requirements.

Reliability of bearings is related to life only to the extent that wearout cannot be anticipated and that the first manifestation of bearing wearout is complete failure.

The characteristics of bearings is such that approach of the end of their useful lives is indicated by a fairly sharp increase in bearing noise and temperature.

Bearing temperature sensors such as are presently employed in the Mass Memory in the Data Processor Set AN/FYQ-11 will be used to prevent bearing wearout from causing operational failures and/or extensive damage to other components.

Non-data tracks and associated read and/or read/write heads will be duplicated. A realistic time delay to modify an adaptive program to bypass a failed data band is at maximum 2 minutes.

Alternately, the equipment may be shut down for a period of time estimated at 22 minutes to patch in a spare read/write head or head group to replace the group with a failed element.

Both the program (software) method of bypassing a failed data storage area and the manual patch in of spare data storage capability are limited by the number of spare read/write heads and their versatility.

The number of data blocks which may be bypassed by software means instead of (or in addition to) patching in the spare data blocks depends only on the software capability. If the software is capable of operating with as little as 90% of installed capacity, the probability of having so many independent failures that the system cannot operate will be vanishingly small.

It cannot be over-emphasized that the ability to make use of the designed in program bypass and manual patch in features depends on preserving independence of failures and minimizing the frequency of failures which directly affect all memory elements (for example; motors, bearings, etc.)

Under such conditions the rate of failure will approximate that for a low speed motor. In accordance with MIL-HDBK-217, Figure 44, a bearing failure rate (per set) of .040% per 1000 hours is predicted.

3.1.2.2 Read/Write Heads and Recording Surface. Life and wear characteristics of read/write heads and the recording surface has been the subject of extensive theoretical and laboratory study.

It has been found that the major factors influencing wear and damage are related to starting and stopping the Disc and to transportation.

During the starting and stopping operations, as well as during transportation, the disc may rotate at speeds such that the heads do not fly. Under such circumstances wear of both the heads and recording surfaces exist. The transportation wear problem is solved by holding the heads off the disc except when power is supplied to the drive motor, at which time only a light pressure is applied.

Wear during startup and slowdown is kept to an acceptable rate by control of surface hardness, minimizing the time during which the head is not flying (high torque motor during start up, dynamic braking during slowdown) and by use of a light head pressure during startup and slowdown. Start stop tests have been conducted which indicate a start stop capability well in excess of operational requirements (20, 000 start-stop cycle.)

The assumption of negligible wear or damage during normal operation is valid only for a completely clean system.

Cleanliness is, of course, absolutely necessary to prevent introduction of solid particles of sufficient size to cause damage. However, contamination due to polymerization of organic vapors, in the atmosphere as well as those emitted from wire insulation, encapsulating materials, lubricants, etc., can be completely controlled only by use of a sealed assembly and extreme care in the selection of materials and processes which minimize the emission of organic vapors. Even then, long life and high reliability can only be achieved by inclusion of suitable "getter" agents and by designing all pneumodynamic components to be insensitive to the residual organic materials and solid particles.

In addition to minimizing the probability of head failure, it is necessary to give proper consideration to damage propagation. That is, a chance particle which damages a head without damage to the disc (or at most, damages the disc only on the affected track) is a field repairable failure, wherea, if the damaged head broke up and damaged other heads which damaged still other heads, etc., the failure may not be field repairable.

Prediction of read/write head failure rate is based on data in RADC Reliability Notebook, and is similar to the method used on the AN/FYQ-11 program and approved by the 473-L program SPO.

The electrical failure rate of the read/write heads predicted on the basis of failure data on small signal transformers which they resemble. The base failure rate from Figure 8-40 is 0.050% per 1000 hours for MIL-T-27A Class T insulation at 80° C. This value is modified by Table 8-15 for encapsulated small signal transformers to a value of .030% per 1000 hours.

In addition to the electrical failure rate, a failure rate of .025% per 1000 hours is allowed for each head bar support mechanism based on an analogy with the physical structure of a brush support on a motor.

It is assumed that the recording surface will not fail by itself, but will be subject to damage due to certain kinds of head failure, as noted previously.

3.1.2.3 Head Selection Diodes. The head selection diodes selected are extremely sturdy and are not adversely influenced by their mechanical environment. Thermal design is such that junction temperature is only slightly above the internal ambient temperature which is conservatively assumed to be 60°C.

The failure rates presented above have been substantiated by preliminary reports on the AN/FYQ-11 installation in which 750,000 head bar operating hours have been accumulated without failure. This corresponds to a demonstrated failure rate of 0.133% per 1,000 hours.

3.1.2.4 Drive Motor. Drive motor reliability is computed by use of MIL-HDBK-217 Figure 43 and Table XVIII for a hot spot temperature of 90°C (20° Rise under run conditions), MIL-T-27A Class T insulation. No supplementary failure rate (MIL-HDBK-217, Figure 44) is required since the drive assembly does not include bearings, or brushes. The predicated Drive Motor failure rate is .075% per 1000 hours.

3.1.2.5 Head Retraction Mechanism. There is no basis in MIL-HDBK-217 to estimate the failure rate of the head retraction mechanism. However, the nature of the device is such that its failure will result in system degradation rather than complete failure (that is, read back may be intermittent under severe vibration and shock conditions but will not prevent system operation when more benign conditions are restored).

3.1.2.6 Mechanical Section Life and Reliability Summary. Each mechanical section MTBF is determined from the failure rates and numbers of the in-line elements of the assembly. See Table 3-2.

The frequency of factory reparable failures, using the conservative MIL-HDBK-217 based on reliability prediction, is the failure rate of the motor and bearings added to 2% of the failure rate of the active read/write heads. (Power Control Sequence network failures are considered to be on-site reparable.)

3.2 MAINTAINABILITY

3.2.1 Corrective Maintenance

Much has already been said concerning the interaction of on-site reliability and maintenance. However, it should be added that system design criteria will consider the physical factors which control the logistic support and manpower requirements for maintaining the Large Scale Disc File electronic and electromechanical units.

Table 3-2
Lawrence Radiation Laboratory
Large Scale Disc File
Mechanical Section Reliability Summation

Assembly	Number	Assembly Failure Rate % (per 1,000 hours)	Total Assembly Failure Rate % (per 1,000 hours)
Drive Motor	1	.075	.075
Bearing Set	1	.040	.040
Read/Write Head Bar (12 active heads; 24 matrix diodes; connector including internal connections)	432	.625	270.000
Power Sequence Network	1	.100	.100
Interconnections	1	.400	.400

Total Failure Rate = 270.615% per 1,000 hours

Mechanical Section MTBF $= \frac{\text{\% per 1,000 hrs}}{\text{Failure Rate}} =$ 370 hours (for each of 2 disc files)

As part of normal design procedure, Librascope has developed a maintainability design guide which requires designers to consider maintainability factors for optimum on-site servicing.

3.2.2 Preventive Maintenance

Provision will be included for operation under margin voltage conditions. The same margin voltage criteria used in the Data Processor Set AN/FYQ-11 and the L-3020 Air Traffic Control Data Processor will be used. Use of plus and minus 10% margin voltages has proven highly effective in detailing parts which are drifting toward their failure threshold of performance limits in a timely manner.

Margin voltage testing, in addition to being effective in detecting marginal electronic parts is also effective in detecting read/write heads which have suffered a gradual reduction in magnetic coupling efficiency and which will eventually fail under normal operating conditions.

There will be an absolute minimum need for preventive maintenance, other than testing under margin voltage conditions and normal housekeeping actions.

3.3 AVAILABILITY

The availability of the Large Scale Disc File depends on two factors:

1. Mean Time Between Failure (MTBF) or Mean Time Between Preventive Maintenance.
2. Mean Unscheduled Down Time or Mean Scheduled Down Time.

The reliability calculations presented in Section 3 provide an indication of the equipment mean time between failures and mean down times. Incorporating these values plus preventive maintenance estimates into the following Availability equation will provide an estimate of system availability. The general Availability equation is:

$$A = \frac{MTBDT}{MTBDT + MDT} = \_\_\_\_\%$$

and $$A_{system} = \sum_{i=1}^{k} A_1 A_2 \text{---} A_i$$

where MTBDT = Mean Time Between Down Time

MDT = Mean Down Time

K = Number of Assemblies in System

3.3.1 Availability of the Mechanical Section

It has been estimated from previous systems data that the mean down time to rewire or replace a data head bar is 22 minutes. This time includes 10 minutes to rewire or replace, 7 minutes to start and stop the rotating element, and 5 minutes for isolating fault. This MDT would account for an estimated 98% of failure problems in the Mechanical Section. The other 2% of the expected failures would involve more extensive repair, possibly shipment to the factory and return. It is estimated that the mean down time for these repairs will take 48 hours. The Availability of each Mechanical Section for unscheduled failures is therefore,

$$A_{UM} = \frac{370}{370 + \Sigma\frac{22}{60}(0.98) + 48(0.02)} = 0.9964$$

Scheduled preventive maintenance time for the Mechanical Section should not exceed 30 minutes every week. Thus,

$$A_{SM} = \frac{168}{168 + 0.5} = 0.9970$$

3.3.2 Availability of the Controller (Electronics) Section

From previous system data it has been estimated that the mean down time to repair an electronics failure is 15 minutes. This includes

5 minutes location time, 5 minutes replacement time, and 5 minutes checkout time. The Availability calculation for unscheduled failures is:

$$A_{UE} = \frac{330}{330 + 0.25} = 0.9992$$

Scheduled preventive maintenance time for the electronics should not exceed one hour per week, therefore:

$$A_{SE} = \frac{168}{168 + 1.0} = 0.9941$$

3.3.3 System Availability

The Availability of the total system (including both Mechanical Sections) is:

$$A_{system} = (A_{UM})^2 (A_{SM})^2 (A_{UE}) (A_{SE})$$

$$= (0.9964)^2 (0.9970)^2 (0.9992) (0.9941)$$

$$= 0.9804$$

The estimated availability is significantly higher than the 0.95 value required.

Section 4

STATEMENT OF WORK

This statement of work defines the scope of effort Librascope intends to perform in engineering design, manufacture, test, installation, checkout, and documentation of one (1) disc file system in accordance with Specification LES 11908, dated 3 February 1965 and issued by Lawrence Radiation Laboratory, Electronics Engineering Department, Lawrence, California.

4.1 DEFINITION OF INTENDED WORK

4.1.1 Engineering Design

Engineer and design the following units in accordance with this Technical Proposal and the respective LRL specification LES 11908.

a. Two magnetic disc files per paragraph 3.0 and 4.0 of reference specification.

b. One controller per paragraph 3.0 and 4.0 of reference specification.

4.1.2 Manufacturing

Fabricate, assemble, wire, and adjust one disc file system to fulfill the requirements of specification LES 11908, dated 3 February 1965, section 4.0.

4.1.3 Design Documentation

Prepare and submit design documentation which is adequate for operation and maintenance of items a. and b. of 4.1.1. One reproducible set and four complete sets of documentation shall be submitted as listed below, and reduced to no larger than LRL size 4 engineering drawings:

1. Complete circuit schematics
2. Complete logic drawings
3. Complete wiring diagrams or wiring lists
4. One installation drawing

4.1.4 Tests

Perform tests at Librascope's plant in Glendale and at LRL's site in Livermore in accordance with paragraphs 5.0 and 6.0 inclusive of Specification LES 11908, dated 3 February 1965.

4.1.5 Installation

Ship and install the disc file system at the site selected by LRL in Livermore and according to installation drawings prepared by Librascope and approved by LRL.

4.1.6 Instruction

Instruct a maximum of six (6) LRL maintenance personnel in the logic, electronics, and mechanics of the entire system. This instruction will be given at LRL facilities concurrently with the acceptance testing of the system.

4.1.7 Manuals

Supply five (5) complete sets of manuals adequate for use in operation, maintenance, and servicing of the equipment.

4.1.8 Spares

Supply a complete Recommended Spare Parts List for use in maintenance of equipment. Supply and bear cost of all spare parts prior to final acceptance.

4.1.9 Maintenance Contract

Librascope will provide maintenance support to LRL on an on-call, fixed-rate, yearly basis.

4.2 DELIVERY SCHEDULE

Librascope will deliver the complete system to LRL nine (9) months after receipt of contract. The following schedule is a preliminary plan indicating principal milestones.

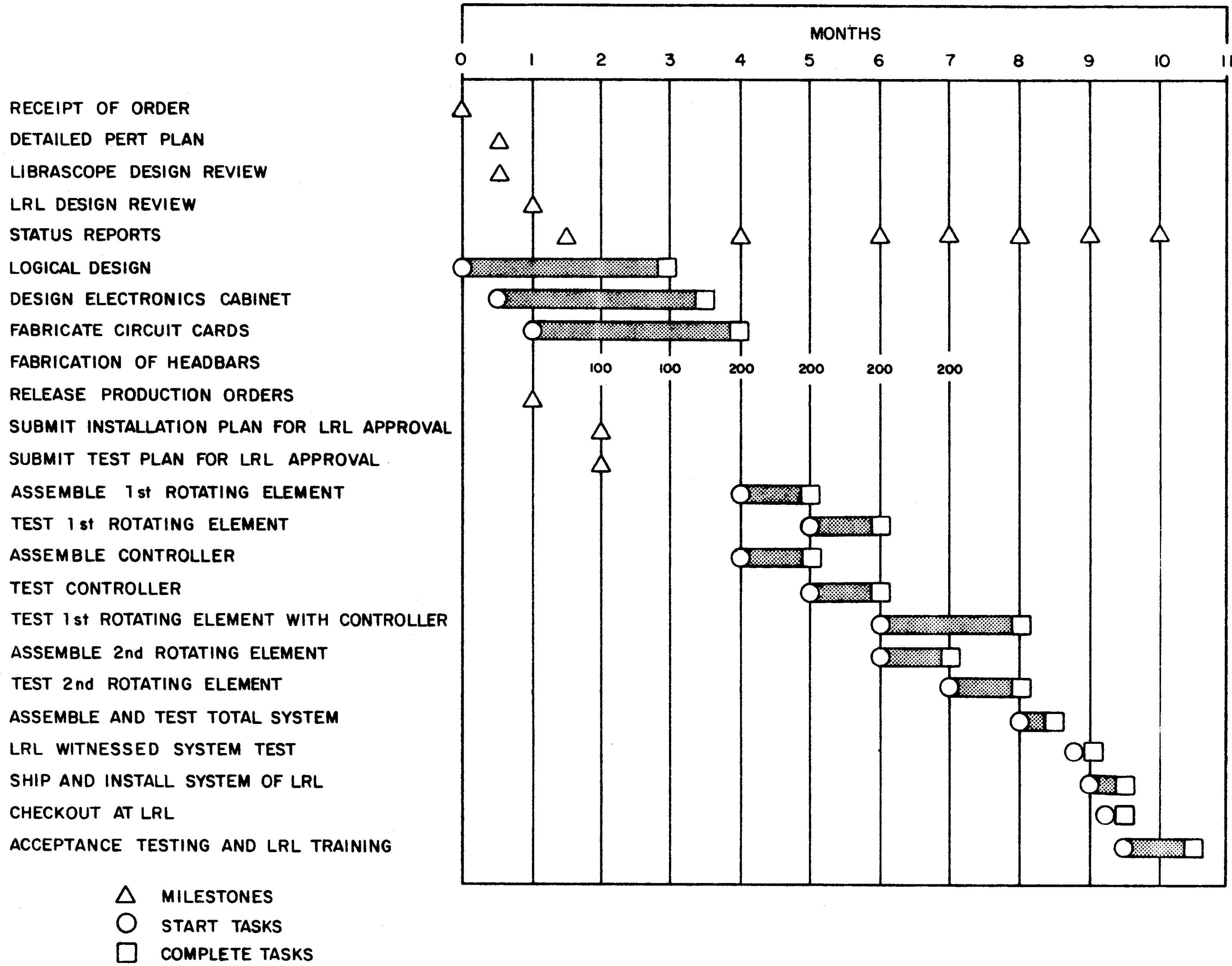


Figure 4-1. Milestone Chart

Section 5

PROJECT ORGANIZATION

Librascope's project organization for management of production of the Large Scale Disc File is presented in this section. Details concerning implementation plan and schedules for the project are described in the technical part of the proposal and the Statement of Work.

Figure 5-1 shows the project organization. The project will be accomplished under the cognizance of the Surface Equipment Division Vice President and General Manager, who will represent the project for Librascope Group and General Precision, Inc. He will be directly responsible to both organizations for satisfactory execution of the proposed effort.

The Engineering and Project Assurance organizations report directly to the Vice President and General Manager of the Surface Equipment Division. The chief engineer will be responsible for technical review of the project, and the manager of the Product Assurance group is responsible for quality control and reliability phases of the operation.

The Project Manager, Mr. H. Anderson, is directly responsible and has necessary authority including expenditure of project funds for proper execution of the contracted effort. The project manager is the focal point for management of the project, delegation of tasks, and direct contact with Lawrence Radiation Laboratories. Members of the project staff directly support the project manager, concerning matters of Engineering Liaison, Contract Administration, Finance, and Purchasing.

The Reliability Assurance Engineer, Mr. H. Jacks, from the Product Assurance group is directly responsible to the project manager for all product assurance support to the project. This support includes quality control of purchased items and manufacturing quality control to meet all contract specifications, environmental and performance testing, and acceptance testing of the finished project.

Mr. Felts, Staff Engineer of the Rotating Memories department, will be responsible for assembly and checkout of disc file assembly.

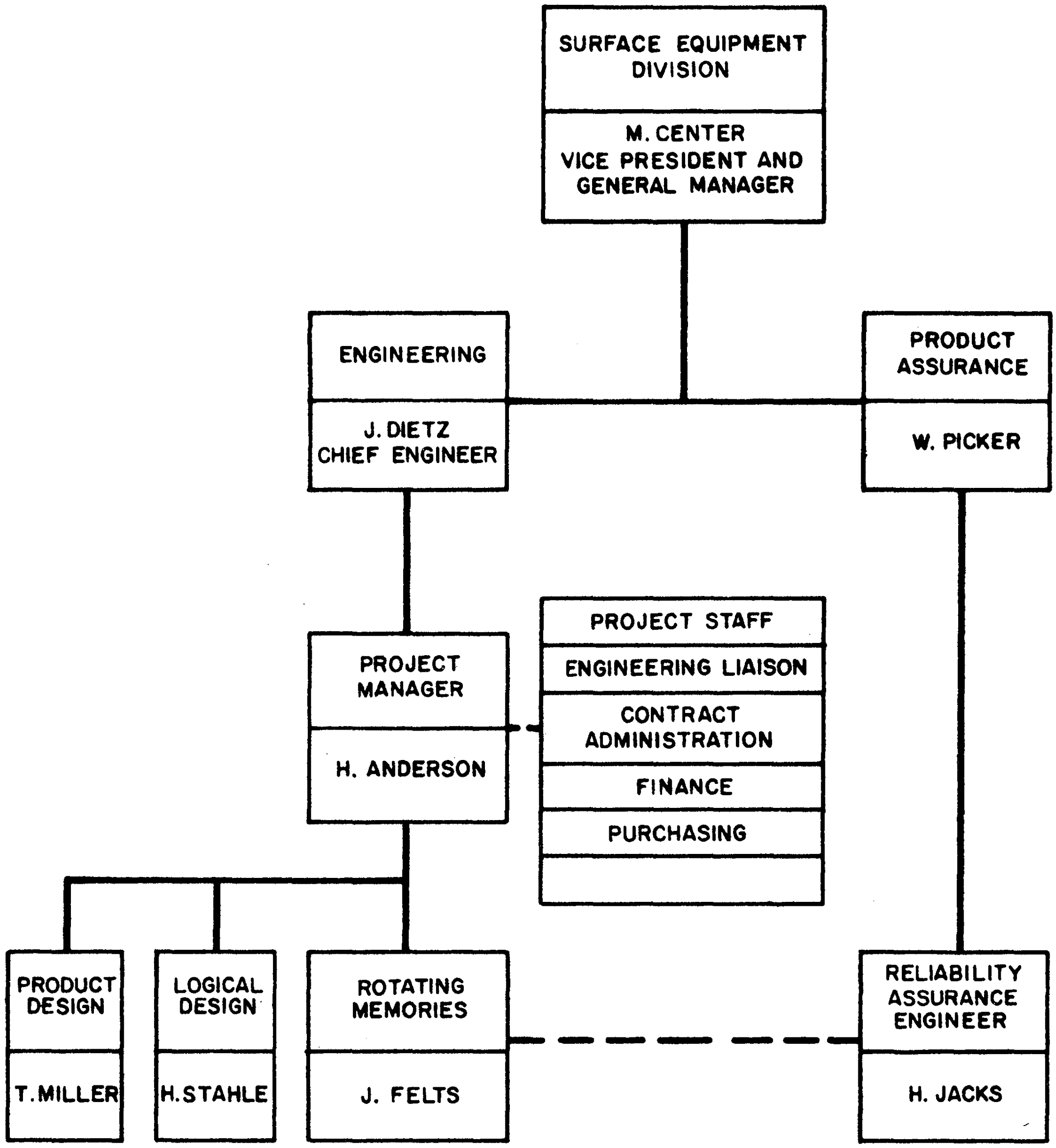


Figure 5-1. Large Scale Disc File Project Organization

Mr. H. Stahle will be responsible for the logical design and system check-out. He will also be assigned to direct acceptance tests of disc file system at Lawrence Radiation Laboratories and the training of LRL personnel at Livermore.

Mr. T. Miller will be responsible for packaging the controller, satisfying the mechanical integrity requirements of the disc file system, and the mechanical interface. Mr. Miller will also be responsible for installation of the Large Scale Disc File at the site selected by LRL.

Resumes of personnel, listed on the organization chart and having direct responsibility for the project, are included in the following pages. These men will be assigned to this project immediately upon formal notification of contract award.

HAROLD M. ANDERSON — Manager, Rotating Memory Department

- Systems engineer and project manager for airborne radar fire control, flight control, air data, analog/digital computer, communications, navigation, and display systems.

- B. S. in Electrical Engineering, Polytechnic Institute of Brooklyn.
- Graduate work in digital computer design, UCLA.

Manager, Rotating Memory Department
LIBRASCOPE - 1961 to present

Responsible for design and development of a 40-million character disc memory. Served as director of commercial computer development section. As program manager, responsible for design and development of LGP-21 Computer. Conducted studies of air traffic control, inventory control, and digital communications.

Field and Systems Engineer
HUGHES AIRCRAFT COMPANY - 1953 to 1961

As systems engineer, responsible for several subsystems of MA-1 weapon system for F-106 aircraft, including communications, navigation, and landing support equipment. As field engineer on E-4 fire control system, responsible for mechanization of changes in system attack flight geometry resulting in exceeding theoretical probability of kill. Engaged in technical liaison for Hughes with Canadian Aviation Electronics on both field and depot problems for MG-2 fire control system. Responbible for operation and maintenance training, problem investigation, and cold weather suitability tests for E-4, E-5, and E-6 fire control systems.

HOWARD L. STAHLE — Senior Engineer

- Design engineer experienced in design of data processing systems and memory devices.

- B.S. in Physics - 1957, University of Washington.

Senior Engineer
LIBRASCOPE - 1957 to present

While assigned to the Commercial Computer Division, participated as a project engineer in various phases of the design and development of Data Processing System RPC-9000. Responsibilities included memory design, buffer design, input-output design, and production test equipment design. Subsequent assignments included design of the L-3455 mass memory for use in Librascope's Data Processor Set AN/FYQ-11, a component part of the U.S. Air Force 473L Command and Control System. Allied experience includes active participation in training programs for service personnel, development of new applications for digital data processing, and customer liaison.

HERBERT G. JACKS Staff Engineer

- Extensive experience in analyzing operational effectiveness of sophisticated electronic and electromechanical systems and directing integrated reliability and maintainability programs.

- B.S. in Engineering Physics - 1952, University of Tennessee.

Staff Engineer
LIBRASCOPE - 1962 to present

As staff engineer in Reliability, planned the Present Development Program and wrote the Maintainability Design Guide for Fire Control System Mk 48. Conducted operational effectiveness and reliability analyses of large data processing systems including the Spacecraft Television Ground Data Handling System. Served as Reliability Manager for Data Processor Set AN/FYQ-11. Performed system and subsystem evaluations to determine design weakness due to misapplication of parts or system configuration.

Research Engineer "A"/Associate Research Engineer "A"
THE BOEING COMPANY, Seattle, Washington - 1956 to 1962, 1953 to 1955

As research engineer, responsible for design review and reliability analysis of Minuteman electronic and electrical systems and circuits. Established criteria for optimum application of parts. Studied deterioration and failure mechanisms for reliability upgrading. Performed reliability and effectiveness analyses of communication, bombing, fire control, and stability augmentation systems on B-52 aircraft. As associate research engineer, developed a stochastic method of radar detection range prediction, a distribution-free technique for fire control system accuracy evaluation, and a safe and accurate method of measuring the effect of gunfire on radar-servo accuracy.

HERBERT G. JACKS - Continued

Electronic Engineer, GS-9

FEDERAL AVIATION AGENCY - 1956

Conducted propagation and logistics studies and directed field surveys to determine optimum radio communication station locations. Developed an accurate technique for estimating propagation path characteristics.

THOMAS A. MILLER — Supervisor - Mechanical-Optical Design

- Supervisory engineer experienced in fire control systems project management, including mechanical and electronic engineering design.

- B.S. in Mechanical Engineering - 1949, University of Michigan
- Graduate and extension courses in Engineering - University of California Berkely, UCLA, San Fernando Valley State College

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Supervisor, Mechanical-Optical Design
LIBRASCOPE - 1959 to present

Directs electromechanical, mechanical, and optical engineering design for such projects as Fire Control System Mk 113 (SUBROC), Fire Control System Mk 114 (FRAM), Fire Control Group Mk 111 (ASROC), the X-Y Plotter, special servo modules, and pilot sights. Responsible for design of analog equipment for SUBROC. Participated in design of missile capability equipment for SUBROC and mechanical redesign of ASROC equipment.

Engineering Design Coordinator
ATOMICS INTERNATIONAL - 1955 - 1959

Coordinated design and development projects such as research reactors for several foreign countries. Responsible for engineering design on a number of development projects, including control-rod drive systems, magnetic-jack control rods, remote-control handling equipment, and fuel elements.

Engineer
RADIATION LABORATORY, UNIVERSITY OF CAL-1951 to 1955

Participated in engineering and design of numerous research projects in the field of high-energy particles, including vacuum and refrigeration systems for a bevatron (10-billion electron volt accelerator), ion probe for a 90-inch cyclotron, and a hydrogen bubble chamber.

JOHN A. FELTS Staff Engineer

- Specialist in magnetic recording research and development with respect to hard environment and high bit density recording.
- Eight patent applications pending for magnetic recording and associated devices.

- B.E. in Mechanical Engineering - 1951, University of Southern California

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Staff Engineer

LIBRASCOPE - 1950 to present

As project engineer, designed memory for LGP-21 Digital Computer the L-119 Buffer Processor, and the Mass Memory System for the AN/FYQ-11 Data Processing System (473-L System). Performed research on the Gravity-Gradient Sensor for the Air Force. As mechanical project engineer, designed input/output display and control section for the ASN-24 Airborne Navigational Computer. As project engineer, participated in the development of Attack Director Mk 7 used in Fire Control System Mk 110 (RAT). Participated as project engineer on a mechanical camera control system for the Air Force and on Position Keeper Mk 2 and associated equipments for a Navy torpedo boat.

Section 6

LIBRASCOPE'S QUALIFICATIONS

6.1 GENERAL PRECISION, INC. (GPI)

General Precision, Inc. (GPI) is engaged in research, design, development, and production of electronic systems, subsystems, and components with applications largely in the military and space fields. GPI is organized into three Groups (Figure 6-1): The Librascope Group, Aerospace Group, and Simulation and Control Group.

The Librascope Group is primarily concerned with development of electronic equipment, including military command and control systems, mass memories, business control systems, general and special purpose computers, naval fire control systems, and control systems for aerospace and commercial applications. The group maintains a Research and Systems Center which performs advanced research and development in support of diversified Librascope activities.

The Aerospace Group major areas of interest are advanced guidance, navigation, and control systems, and components for application in space vehicles, missiles, and aircraft. This group is also supported in development of new products and techniques by a Group Research Center.

The Simulation and Control Group principle areas of interest are simulation systems for flight and tactical training in aircraft and space programs, specialized aerospace equipment, and control systems and components for industrial applications.

While the three groups, operate as specialized entities, General Preicision, Inc., provides effective interconnection of all managerial and technical skills. Research, development and engineering production resources of the groups are mutually available to one another, or to individual divisions or projects. From this firm base, General Precision, Inc., undertakes and accomplishes total prime or support programs within the full range of its activities.

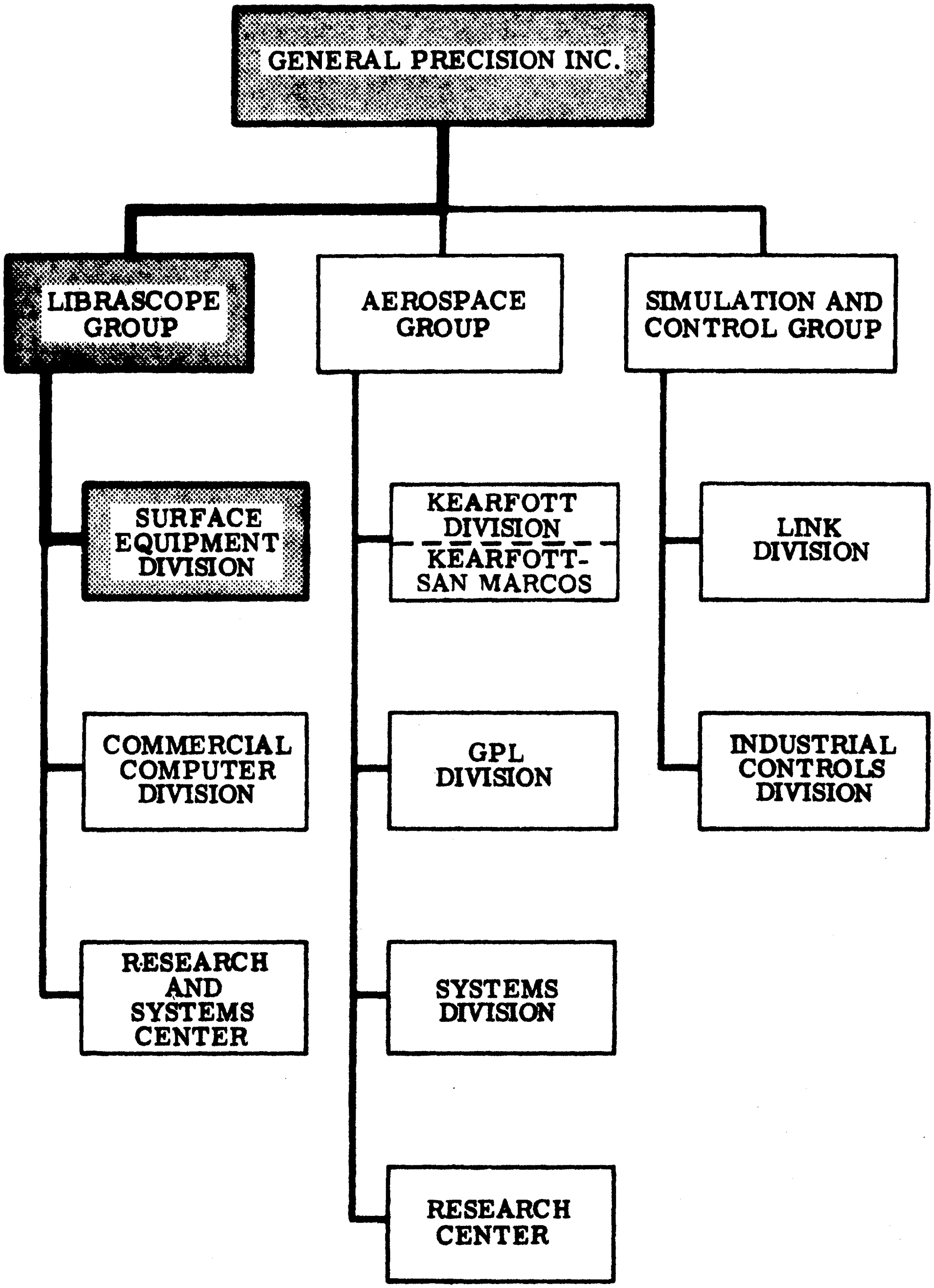


Figure 6-1. General Precision., Organization

Librascope Disc Memory Group Used in USAF 473-L System

6.1.1 Librascope Group

The Librascope Group of General Precision, Inc., is composed of three divisions; the Surface Equipment Division, Commercial Computer Division and Research and Systems Center. All divisions of the Librascope Group are located in the Glendale-Burbank area of Southern California.

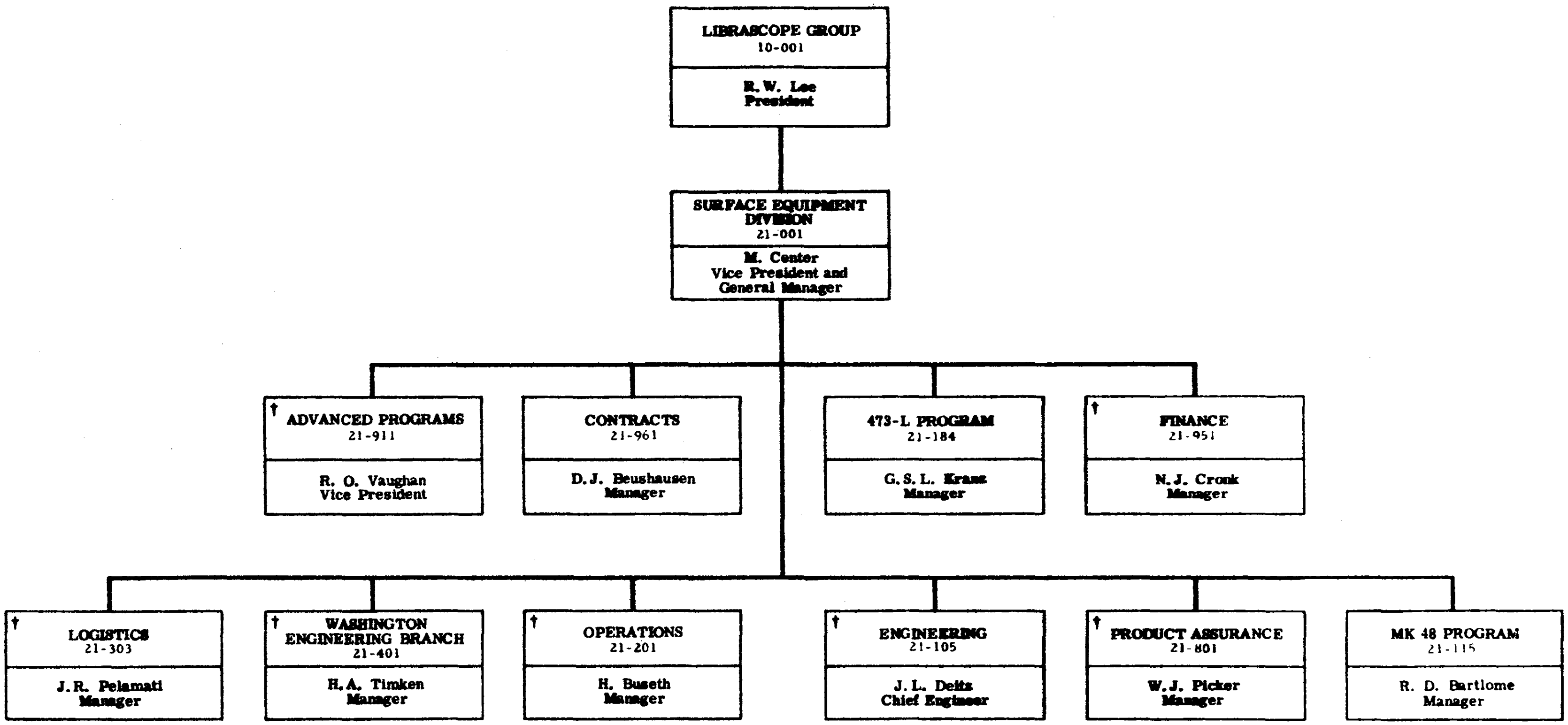
The Surface Equipment Division, which has assumed responsibility for the Large Scale Disc File Project is active in the area of mass storage equipment development and production for both large systems, and for ruggedized field applications. Other areas of interest are Command and Control Systems, general and special purpose computers, and computing systems for shipboard fire control, ASW, surveillance, and navigation.

The Commercial Computer Division is primarily concerned with development and production of computers and data processing systems for commercially oriented scientific and industrial applications. This division also participates in development of storage devices, as well as computer components, accessory equipment, and precision instruments.

Research and Systems Center programs support the divisions in study and conceptual design of military, space, and industrial technical requirements, and studies related to the specific needs of each division. The center is presently engaged in several government funded and company funded studies related to advanced mass memory techniques.

6.1.2 Surface Equipment Division

Figure 6-2 shows the organization of the Surface Equipment Division of Librascope Group. The majority of engineers and technicians assigned to the project have been participating in previous USAF 473-L mass memory activities, as well as development and production of disc memories for other systems and applications. Adequate resources in the form of special development, manufacturing, and testing facilities, and a favorable working environment are provided. Additional technical assistance and facilities are available from other operating units of Librascope and GPI.



† Detailed Organization Chart Available

Figure 6-2. Surface Equipment Division Organization Chart

6.2 ROTATING MEMORIES DEPARTMENT

The Rotating Memories Department facilities occupy a total area of approximately 9,200 square feet. Complete facilities and capabilities exist for development and assembly of magnetic storage drums and disc memories. Coating and lapping of discs, fabrication and lapping of magnetic flying heads, and prototype construction of logic circuitry are all performed within these facilities. Additional facilities exist within the same area for final assembly and specialized testing. Additional testing facilities are available at the nearby Product Assurance Facilities.

6.2.1 Magnetic Coating Facility

A laboratory devoted exclusively to techniques of depositing magnetic coating on magnetic memory discs and drums is a part of the Rotating Memories Department facilities inventory. The plating laboratory occupies a floor area of 1200 square feet. Both research and production facilities for plating are located in a single area under the direction of a research chemist. Discs up to four feet in diameter have been plated.

6.2.2 Rotating Memory Laboratory

The Rotating Memory Laboratory performs testing and assembly of discs and read/write heads. Special precise measuring equipment is provided to attain the rigid tolerances necessary. The surface of a flying head must be flat within 20 millionths of an inch over the entire surface. A recent addition to the array of equipment employed by the laboratory, is the D-309 plano-interferometer (see Figure 6-3), a precision testing instrument which uses a monochromatic light source to permit optical non-contact measurement by means of light fringe bands.

Dynamic weight balancing of discs is performed, and new designs are built and tested on disc assemblies in the laboratory. Special tests are performed here, as well as in the Product Assurance and 473-L Project facilities. The Rotating Memory Laboratory is also responsible for final assembly and checkout of rotating memory units produced by the department.

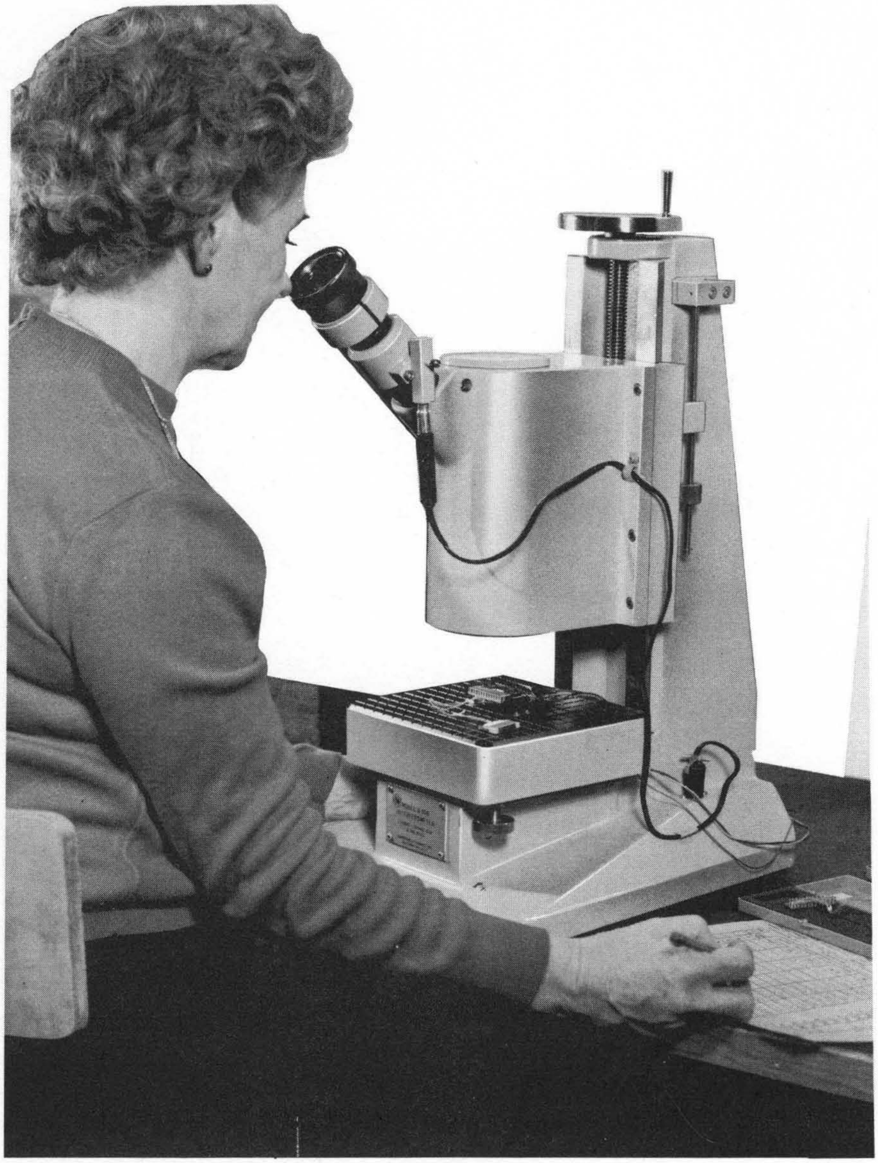


Figure 6-3. Plano Interferometer

A tool maker's microscope is provided for inspection of heads and measurement of mechanical dimensions. With this instrument it is possible to inspect and measure head dimensions to 0.0001". See Figure 6-4.

6.2.3 Magnetic Discs

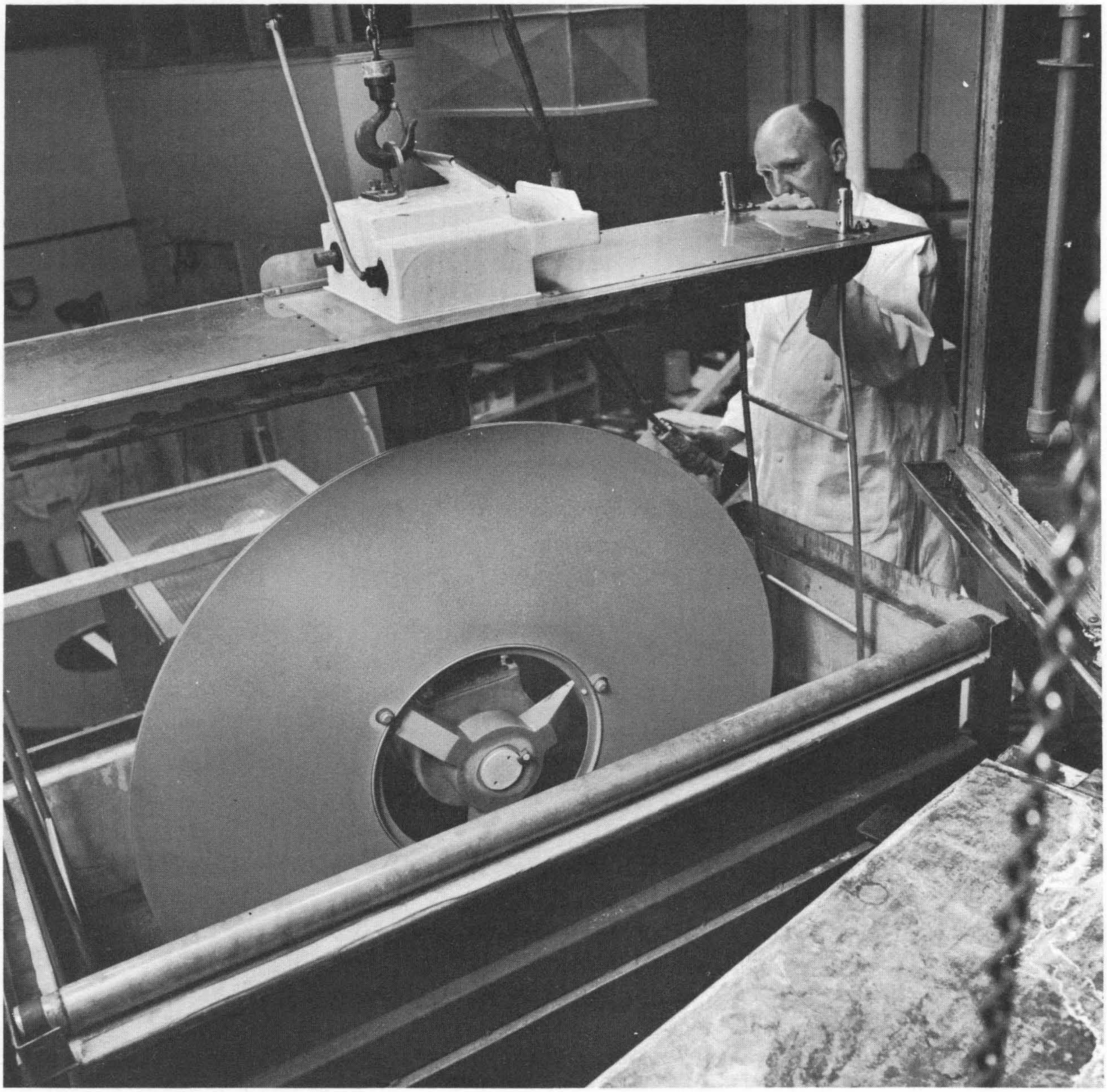
Early recognition of the higher storage capacity potential of rotating magnetic discs spurred Librascope's development efforts in this field. Discs began to take the place of magnetic drums in Librascope computers. Development of the "flying head" principle into a working practical reality, greater packing densities, and production of ruggedized disc memories, shifted emphasis in the rotating memory field from drums to discs.

A Librascope ruggedized 8 inch diameter disc is employed in the L-2010 General Purpose Computer. This computer is designed to perform reliably in a rugged military field environment, and perform flexibly in a number of different applications with a wide variety of input/output equipment. Other ruggedized discs are used in a variety of computers built by both the Surface Equipment and the Commercial Computer Divisions of Librascope Group.

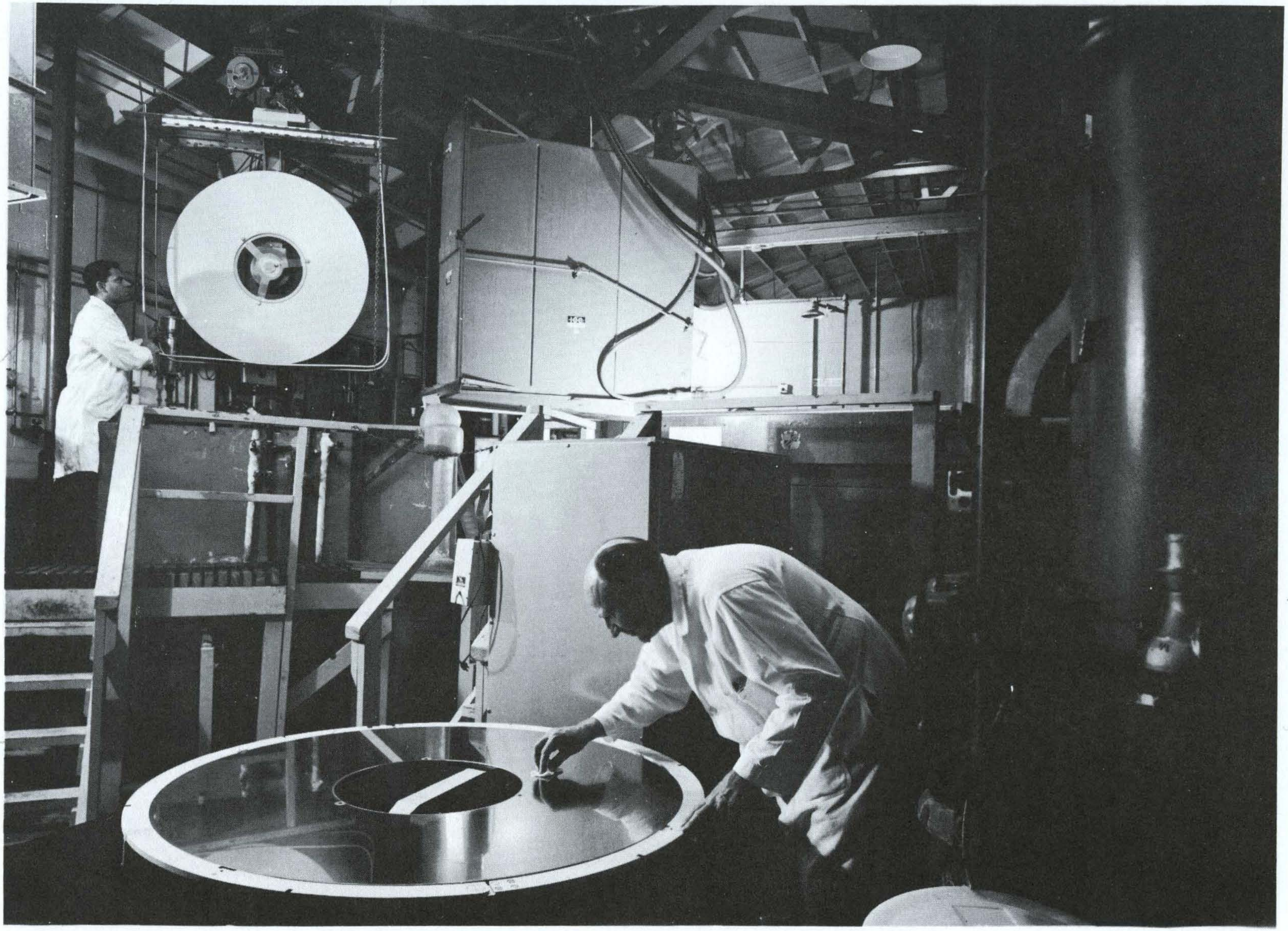
The Company has attained a position of leadership in supplying magnetic discs and mass storage disc files for numerous applications in large data systems. This position was gained, and is maintained, by constant research into new techniques and processes to develop new disc, head, and control logic designs; and is maintained by continuous probing and study into ways of improving existing rotating memory equipment.

Librascope magnetic discs are employed in the AN/FYQ-11 System, a major subsystem of the USAF 473-L Command and Control System. Massive economical data storage is provided by large disc memory groups. This information is stored on six 48-inch rotating discs. Fixed read/write heads employing the "flying-head" principle, eliminate requirements for moving arms, and permit fast data access times.

Figure 6-4. Tool Maker's Microscope



Disc is Lowered into Plating Tank for Application
of Cobalt Magnetic Surface



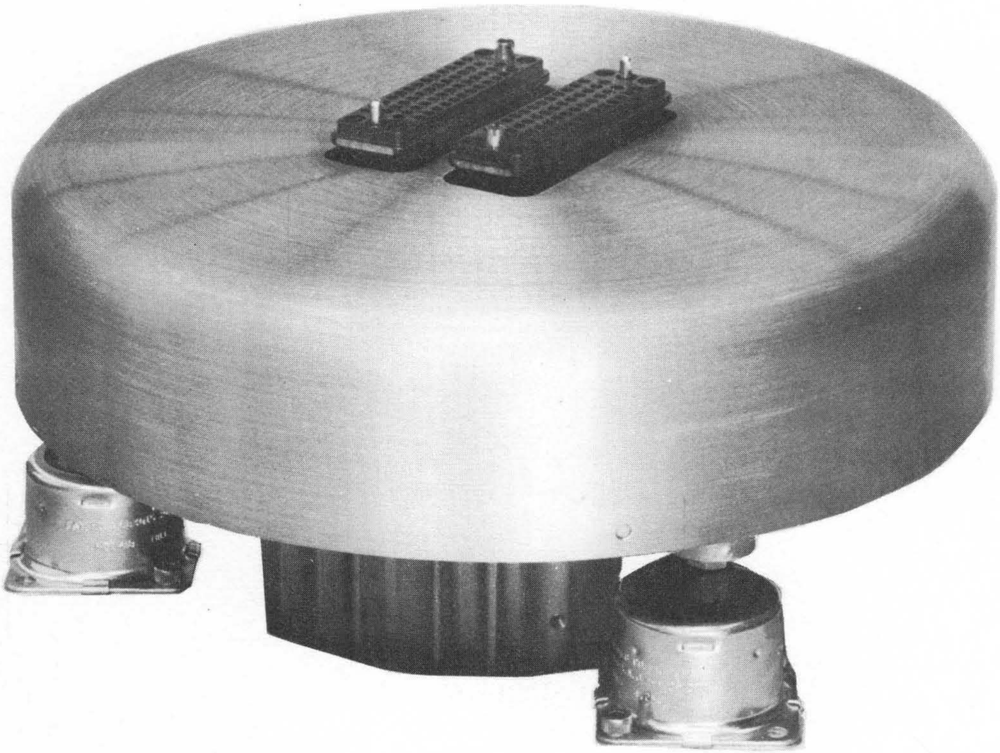
A Cobalt Disc Surface is Cleaned and Inspected

Information is entered and retrieved electromagnetically from the surface of the 48" diameter discs. The disc surface is coated with cobalt, which is deposited by a proprietary Librascope electroless plating method. A major feature of the disc memory is a patented search-by-content capability. In response to brief key inquiries, the disc memory can run a search of it's entire file in about 35 milliseconds and extract all records associated with the key. The disc group also has a dual recording capability that guards against loss of data and enables automatic comparison for accuracy when information is read out of the file. Disc rotation at a rate of 900 rpm is provided by two 2 1/2 horse power motors. Both motors are required to start, one motor for continuous running. Dynamic braking is used to stop disc rotation. Quick start and stop operation minimizes wear on flying heads. The only wear to which flying heads are exposed, occurs during the stopping and starting periods. During operation the heads do not contact the disc, but "fly" on a cushion of air along the disc surface.

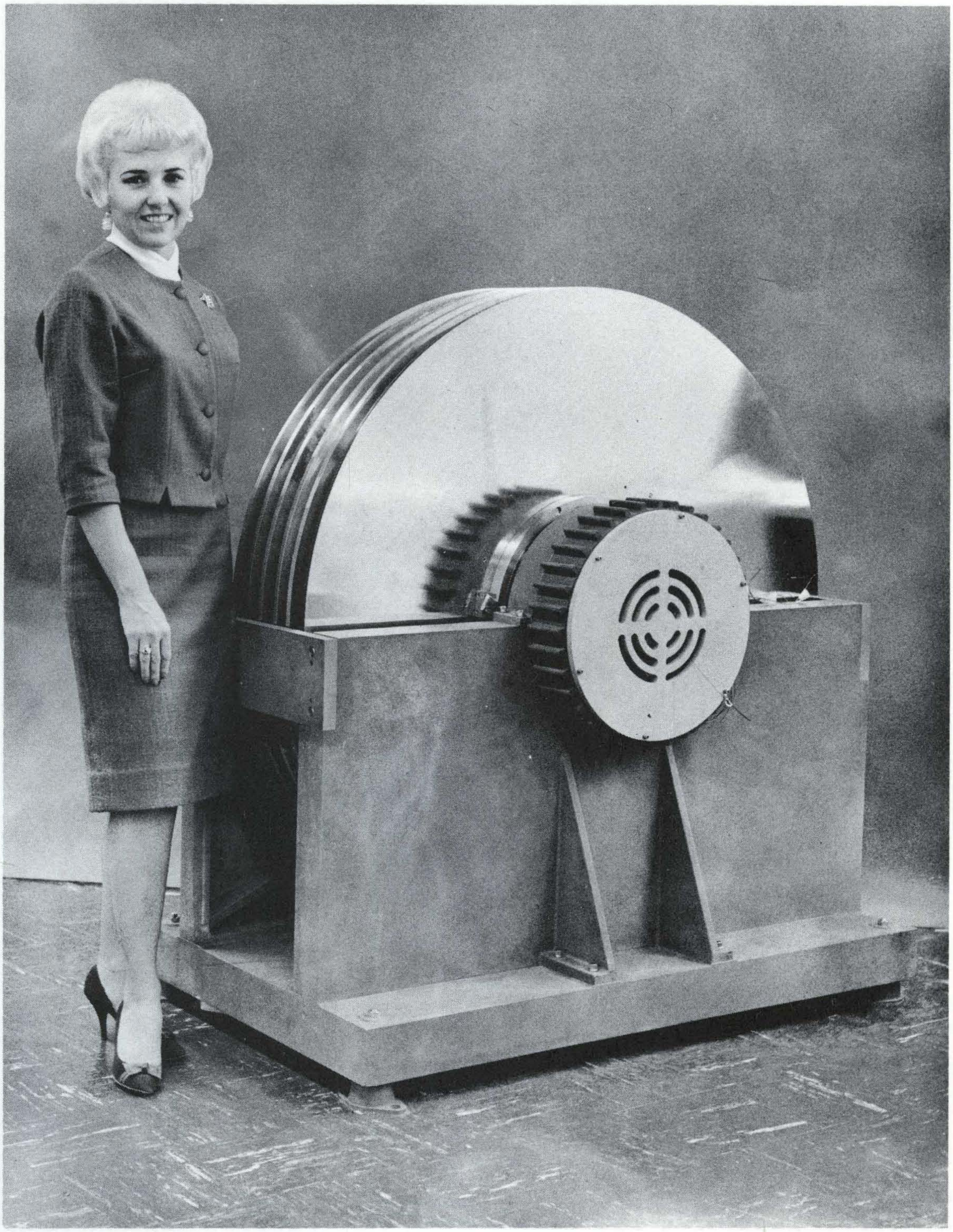
The L-119 Buffer Processor Group in the AN/FYQ-11 System employs an inexpensive and reliable 8-inch diameter magnetic disc rotating at 8000 rpm to perform off-line data buffering. Operation is controlled by an internally stored program controlled for input or output.

A primary mission of the L-119 Buffer Processor Group is that of linking the 473-L System with the U. S. world-wide military communications network. Direct functions performed by the buffer are code conversion, formatting, error checking, and handling data link coordination procedure.

The CCN #1 Disc File Project is another result of Librascope's continuing disc memory product improvement program. The USAF has recently contracted with Librascope for a disc file that will provide double the 120 million data bit capacity of the original file in the AN/FYQ-11 Data Processor of the USAF's 473L System. The improved file is housed in the same physical enclosure, and incorporates hardware innovations to improve maintenance access. This improved file which utilizes a bit packing



L-2010 Computer Ruggedized Disc Memory



Librascope Disc Memory Group Used in USAF 473-L System density of approximately 800 bits per inch, is scheduled for completion in May 1965. Existing magnetic headbars have been proven to operate with no evidence of bit crowding at 1600 bits per inch.

6.3 FACILITIES

Table I provides a convenient reference to the basic facilities of the offeror. The following sections describe in greater detail the facilities available.

The Librascope Group occupies 470,000 square feet of usable area, located in Glendale and Burbank, California, and employs in excess of 1600 personnel. Approximately 25 percent of this number represents technical talent. Modern facilities for research, manufacturing and testing include environmental laboratories for simulating conditions likely to be encountered by Librascope systems and components; ultra-clean areas for assembly and top-quality metrology service available, with standards approved and periodically checked by the National Bureau of Standards and the Bureau of Naval Weapons. Photographs of typical Librascope buildings are attached.

Table I. Facilities Summary

Facilities Characteristic	Librascope
Usable Area, Sq. Ft.	470,000
Total Personnel	1,605
Technical Professional Personnel	498
Comprehensive Environmental Test Facility	Yes
Modern R&D Test Equipment and Labs	Yes
Research Library	Yes
Modern Production Fabrication and Assembly Equipment (Electronic and Mech.)	Yes
Complete Production Test Equipment (Electronic) and Mech.)	Yes
Quality Assurance (QC and Reliability) Programs reporting to top management	Yes
Facility Clearance	Top Secret

6.3.1 Engineering

The Librascope engineering department is housed in 75,000 square feet of modern, air-conditioned building space specifically designed for its use. Facilities available to, and controlled by, the engineering department include:

Engineering Electronic Laboratory

The purpose of this laboratory is circuit research, development and design. Electronic portions of new Librascope products are developed and theory translated into fact. Personnel, facilities, equipment and experience to operate, maintain, calibrate and standardize all types of electronic instruments are readily available. Extreme accuracy and precision are standard procedure, with calibrations made to 0.01 percent, or better, and with secondary standard checked against primary standards whenever necessary. Equipment in the electronics laboratory is both diversified and complete, new equipment is added whenever needed for projects at hand.

Microelectronic Packaging Laboratory

This laboratory has been established for the purpose of providing studies, recommendations and services in all aspects of electronic packaging, with primary emphasis on microminiature electronic packaging techniques. The laboratory facilities include the very latest equipment available in this area such as resistance and resistance gap welders, photometallographic microscopes, metallurgical polishers, pull and strip testers and other facilities for the complete laboratory fabrication and test of microminiature electronic packages.

Mechanical Laboratory

This facility is designed to provide a quick response in the area of mechanical fabrication for the engineering staff. Its personnel includes craftsmen experienced in all type of metal and plastic fabrication, supplied with various types of machine tools and test equipment for this purpose. Typical facilities include: lathes, drill presses, sheet metal equipment, mills, jig bores, height gages, gage blocks, micro-projectors, etc.

Computer Laboratory

The purpose of this facility is to provide assistance to the engineering staff for mathematical studies and system analyses of analog or digital nature. Special computer programs have been developed for projects peculiar to Librascope such as ray trace calculations as well as standard programs for producing PERT reports. Equipment includes LGP-30, RPC 4000 and L1000 digital computers engineered and manufactured by Librascope. In addition an IBM 1410 system is available on premises for engineering use.

Technical Library

The engineering technical library with its own full time staff contains complete engineering reference data and thousands of volumes and journals devoted to subjects of interest to Librascope. A search and reference service is available on an on-call basis. In addition the Technical Library maintains a subscriber service with the libraries of the California Institute of Technology, the University of California, the University of Southern California, and the City of Los Angeles. Reference works and technical journals are available from these sources on a daily basis.

Research and Systems Center

The services of the Librascope Research and Systems Center are directly available to, although not controlled by, the engineering department. The center is staffed by 21 scientists, 6 development engineers and 6 skilled technicians. It occupies 18,000 square feet of floor space and contains special technical equipment for advanced and applied research. Such equipment includes ultra-high vacuum facilities, induction heating vacuum station, an electron microscope, and other equipment of this type.

6.4 PRODUCTION ASSEMBLY

The production assembly department is housed in a modern, masonry, fully air-conditioned, 85,000 square foot building. The building is specifically designed for the assembly and check-out of electronic assemblies, is completely floored with asphalt tile, has a maintained light level of 120 foot-candles at bench height and is equipped with a variety of power. Both low and high pressure compressed air is available throughout the building as well as recirculating deionized cooling water for those systems requiring it. Both floor mounted and ceiling hung material handling equipment is available.

Incoming material is received directly into this facility, passes through incoming inspection and moves directly to production stock room located on the periphery of the building. Production quantities are prepared for assembly in stockrooms and released directly to the assembly floor. Each assembly area is designed and equipped for the particular project to be accomplished. All assembly is performed under the direct supervision of experienced foremen using well trained wiring and mechanical personnel together with modern test equipment. Items such as a Hughes FACT (Fully Automatic Continuity Tester) are used to facilitate the quality production of assemblies.

A controlled-access area, inspected and approved by INSMAT, is available directly off the assembly floor for the final assembly or check-out of classified items.

Complete facilities are available for the manufacture of printed circuit boards from raw material through final assembly. Automatic equipment for precision drilling, component insertion and soldering of such assemblies is available and is regularly used by Librascope in its manufacturing process.

6.4.1 Production Machine Shop

The Production Machine Shop is well equipped for the manufacture of precision components to meet the rigid standards and specifications required for military environments. High quality machines of both American and European manufacture are used. For greater versatility and precision, major Machine Shop facilities are Librascope designed.

Facilities in the Machine Shop are grouped into these sections: boring, lathe, milling, grinding, gear cutting, and precision drill. Production manufacturing facilities that may be of special interest include:

A Jig Boring Department, 2000 square feet in area, temperature controlled to 68°F. +2. Included in this department are five Sip Jig Bores fully equipped with all accessory equipment including optical dividing tables and several Sip Tilting Rotary Tables; two De Vlieg Jig Mills, Model 3B48, with automatic positioning; four other horizontal and vertical jig boring machines; and two Fosdick N54P - 3-Axes, Tape-controlled Jig Borer.

One Lucas, Model 42B60, Horizontal Boring and Milling Machine equipped for automatic positioning and thread cutting. Vertical capacity, 48 in.; horizontal capacity, 60 in.

Eighteen Librascope Precision Boring Machines. These machines provide a means of putting precision jig boring on a production basis. Hole spacing and bore accuracies to 0.0001 in.

An extensive Gear Cutting Department including gear hobbing, gear shaping, gear shaving and the latest types of bevel gear cutting equipment. This department consisting of eighteen gear cutting machines is tooled to cut spur gears, helical gears, racks, worms, spiral, hypoid and straight bevel gears.

Heald and Excello Horizontal Boring Machines equipped with special tooling for the manufacture of precision gear blanks and other high precision components requiring precision boring with simultaneous facing operations.

A Turret and Engine Lathe Department with equipment to machine bar stock from 1/1 in. diameter to 6 in. diameter. Included in this department are two German automatics and three Monarch Precision, Model 1000, Engine Lathes (one equipped with hydraulic tracing) in addition to 24 other turret and engine lathes.

A Milling Machine Department of 30 machines including hydraulic duplitors and several large horizontal mills equipped with power-driven over-arms.

A Grinding Department equipped with a double-disc grinder, Blanchard Grinder, centerless grinder, cylindrical and internal grinders surface grinders and honing and lapping machines.

A Drill Press Department equipped with the latest models of Leland Gifford, Burgmaster, American and Carlton Drill Presses and Radial Drilling Machines. Many of these units are equipped with sub tables to utilize the Librascope Boring Machine Technique. Outstanding are two Burgmasters, Model 2BHTL, six-spindle, two-axes, tape controlled drill presses with Hughes positioning controls.

6.4.2 Fabrication Standards

Librascope has had extensive experience in fabrication and assembly of electronic and mechanical equipment to the highest quality according to electronic industry standards. Engineering and Standards Manuals used by Librascope include:

a. Librascope Standard Engineering Practice Manual

b. Electronic Components Manual

c. Hardware Standards Manual

d. Quality Control Manual

e. Wiremans Workmanship Manual

f. Plating and Solutions Manual

The Standard Engineering Practice Manual establishes standard engineering design and drafting practices which conform with military requirements for the classes of products developed and manufactured by Librascope. The Electronic Components Manual lists electronic components with their commercial and military identifications. These components represent a preferred list, especially selected as suitable for use in Librascope designed hardware. The Hardware Standards Manual lists mechanical parts representing preferred items suitable for use in Librascope designed hardware. The Quality Control Manual is a guide and reference establishing methods and procedures for assuring the quality of products and assemblies manufactured by Librascope. The Wiremans Workmanship Manual is a guide and reference for production employees and assemblers. The manual establishes standards for procedures and techniques for electronic assembly. It covers such subjects as tools, mechanical wire connections, wire preparation, soldering, and harness making and applicable practices used in the manufacturing of shipboard and ground based equipment. The Plating and Solutions Manual covers the processes and materials used in the manufacturing of etched circuitry and similar modules. These manuals will be available for review by LRL personnel on request.

6.4.3 Test Facilities

A well equipped environmental laboratory is available for use as a design tool and to perform contractually required tests for equipment procured on specific programs. The laboratory is equipped to perform tests on electronic systems, devices, and components which must be thoroughly evaluated and qualified to meet Mil Spec requirements. The facilities permit performing the following categories of environmental and/or reliability tests:

ALTITUDE	MIL-STD-202, MIL-STD-810, MIL-E-5272, MIL-E-5400, MIL-E-5422, From zero to 170,000 ft. Capacity: 120 cu. ft. (4 ft. × 5 ft. × 6 ft.)
HIGH VACUUM	5×10^{-5} Torr. Capacity: 18-in. diameter × 2-ft. high. Has multiple feed-through capabilities.

IMMERSION	MIL-STD-202, MIL-STD-810. Controlled temperatures from zero to 100°C. Capacity: 18 in. × 12 in. × 6 in.
R. F. I.	MIL-I-6181D, MIL-I-26600. Equipped for conduction, susceptibility, and radiation testing. 0.15 to 1000 megacycles.
SALT SPRAY	MIL-STD-202, MIL-STD-810, MIL-E-5272. Ambient to 160°F.
SHOCK	MIL-STD-202, MIL-STD-210, MIL-E-5272, MIL-E-5400, MIL-E-5422. Load to 400 lb., 1 millisecond to 32 milliseconds, half sine pulse shapes, 1500 g's max. Capacity: 3 ft. × 3 ft. working area.
SHOCK, HIGH IMPACT	MIL-STD-202, MIL-S-901, MIL-T-17113. Load to 400 lb. approximately 5000 g's at 0.2 millisecond. (Navy lightweight, high-impact shock tester.)
TEMPERATURE	MIL-STD-202, MIL-STD-304, MIL-STD-810, MIL-E-5272, MIL-E-5400, MIL-E-5422. -296°F to +600°F. Capacity to 120 cu. ft. (4 ft. × 5 ft. × 6 ft.)
TEMPERATURE - ALTITUDE	MIL-STD-810, MIL-E-5272, MIL-E-5400, MIL-E-5422. -100°F to +500°F zero to 170,000 ft. Capacity: 120 cu. ft. (4 ft. × 5 ft. × 6 ft.)
VIBRATION	MIL-STD-167, MIL-STD-202, MIL-STD-810, MIL-E-5272, MIL-E-5400, MIL-E-5422. 5 to 3000 cps, 5000 force pounds, 12-in. circle. 1-in. double amplitude sine only. 5 to 60 cps, 3000 force pounds, maximum load 300 pounds, sine only.

DATA REDUCTION	LGP-30 and RPC-4000 digital computers are available for efficient data reduction. Capability includes a library of statistical data-reduction and analysis programs.
HUMIDITY	MIL-STD-202B, MIL-STD-810, MIL-E-5272, MIL-E-5400, MIL-E-5422. 5 to 95% RH. Temperature from 32°F to 150°F.

The following is a partial inventory of specialized test equipment employed in the laboratory. All equipment and instrumentation is rigidly tested and regularly certified by an approved Secondary Standards Laboratory with accuracies traceable to the National Bureau of Standards.

THERMAL EFFECTS CHAMBER for semiconductor studies. Temperature range, -100°F to 500°F. 250 sample capability.

SCAT-24 (Sequential Component Automatic Tester) for high-speed testing of varied semiconductor devices. Data is printed out for immediate review and simultaneously prepared for computer analysis.

TYPE N HIGH-SPEED SAMPLING SYSTEM capable of checking high-speed semiconductor parameters.

DIGITAL SAMPLING SCOPE, TYPE 567, with programmable capabilities for checking high-speed semiconductors with a digital read-out and wave form observation.

ORSAT ANALYZER for gas concentration measurement used in sterilization tests.

COSMON (Component Open-Short Monitor) Device for simultaneously checking up to 50 components for opens and/or shorts on a continuous basis while under environmental conditions.

DILLON TENSILE TESTING MACHINE. MIL-STD-151. 10,000-pound load maximum with associated strain gage instrumentation for stress-strain curve determination yield point measurements, etc.

LOAD RACK for multiple component life testing. Capacity: 300 three-terminal devices.

INSERTION-WITHDRAWAL TESTER. Pneumatically operated. Automatically completes 10 cycles per minute. Measures insertion/withdrawal forces of connectors and printed circuit boards.

DYNAMIC LINEARITY TESTER. Linearity can be checked on multi-turn potentiometers to an accuracy of .005%. The error signal is recorded on a Sanborn recorder using a Servo-Monitor Pre Amp. Variable input shaft speed control. The Master is a Gertch Ratio Tran, 1000 turn with an accuracy of .002% through the 1000 turns. Will accept all size synchro mounts.

CAPABILITY for failure analysis, test evaluation and data reduction.

STANDARD QUALITY ASSURANCE components testing with such specialized equipment as:

TACHOMETER TEST STAND. Up to size 18 Military Specification parameters. Output accuracy up to .05%.

VERNITESTER. AC or DC potentiometers. Maintain .05% accuracy up to 10 turns. Output information printed on Leeds & Northrup Recorder.

RESOLVER TEST STAND. Linearity accuracy ±20 seconds.

RESISTORS. Resistors up to and including .01% accuracy.

RELAY TEST STAND. Relays built to Military Specifications.

CONTRIBUTING MEMBER OF IDEP (Inter-Service Data Exchange Program). Access to other test programs insures non-redundancy of effort with subsequent savings in time and money.

MATERIALS PREPARATION & INVESTIGATION LABORATORY, for potting, sectioning, or grinding of specimens prior to chemical analysis and/or physical analysis such as structural, lattice, eutectic and crystallographic investigation.

Should a unique test or equipment size go beyond the capability of the laboratory, the services of one of the many fine environmental laboratories in the Los Angeles area are retained.

6.5 PRODUCT ASSURANCE

The Product Assurance department of the Librascope Group reports to top management at the same level as production and engineering. All phases of design and manufacture are performed under the continuous surveillance of the Reliability and Quality Control sections of the Product Assurance department. All inspection of manufactured items as performed through the use of Quality Control instructions based on the Librascope Quality Control Manual. The manual is written well within the objectives of MIL-Q-9858.

The Product Assurance department is composed of three sections: Reliability Assurance, Inspection, and Quality Control. The Quality Control section has cognizance of the company owned Test Equipment pool. All test equipment is controlled for calibration by instrument marking and by data processing review. Equipment includes a full complement of the latest scopes, meters, power supplies, component testers, etc.

6.6 LOGISTICS & SUPPORT

The logistics department of Librascope Group is a separate department reporting to top management. The department is housed in its own area of 17,000 square feet immediately adjacent to the engineering department and its laboratories.

Included within the logistics department are the following sections each in its own area and with facilities as noted.

6.6.1 Art and Production

The art and production section has the ability and facilities for preparing and producing art work, photography, book layout and production necessary for all types of military publications. The section is well versed in a wide variety of graphic arts and has facilities in being for producing its design. Such facilities include: a Robertson 24 inch, 18 foot Comet precision process camera, three 30 inch by 40 inch vacuum contact printers, three 4 inch by 5 inch enlargers, one 18 inch by 10 inch enlarger, two 26 inch dryers, one gloss and one matte, two print dryers, one litho-film dryer, five light-controlled dark rooms - temperature controlled for color and black and white processing, light table for retouch work and a full complement of candid and view cameras.

Directly accessible to the art and production section are the company reproduction sections with such equipment as: two multilith duplicators, one automatic system offset machine, one 17 inch by 14 inch offset color press, one 34 inch by 44 inch electrocon paper master camera, one eight station automatic rollator and stapler, one twenty station semi-automatic rollator and other support equipment.

6.6.2 Writing and Editing

The writing and editing section is well experienced in writing, editing and preparing manuals of the type required for this program. Their experience includes the production of a 32 volume set of operation and maintenance manuals in 105 sets for the Navy SUBROC project. Other than the physical office area provided for this section, special facilities include 14 proportional spacing typewriters for the preparation of justified or nonjustified typesetting, dictating and transcribing equipment and other equipment normal to the writing and editing of technical manuals.

6.6.3 Spares Provisioning and Packaging

The spares provisioning and packaging section is centrally located within the logistics area. The section is staffed by professionals well acquainted with the military requirements for spares provisioning and packaging. Other than normal office area no special facility is required for this section.

6.6.4 Training Facilities

Training facilities include three each twenty-men fully equipped private classrooms and three private laboratory spaces each sufficient to house one complete set of equipment.