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NASA CR 92065

PERKIN-ELMER

OPTICAL GROUP NORWALK, CONNECTICUT

ENGINEERING REPORT NO. 9148

FRAUNHOFER LINE DISCRIMINATOR
FINAL REPORT

DATE: APRIL 15, 1968

PREPARED FOR: NASA MANNED SPACECRAFT CENTER
GENERAL RESEARCH PROCUREMENT BRANCH
HOUSTON, TEXAS 77058
N.M. HATCHER/TE2, TECHNICAL MONITOR
Contract: NAS 9-7447

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SPO 27807

Table of Contents

LIST OF ILLUSTRATIONS

1.0 SUMMARY AND INTRODUCTION

This final report serves several purposes:

1. It contains a short description of the function and purpose of the overall system and gives information about other possible applications of the same basic principle as realized in the Airborne Fraunhofer Line Discriminator.
2. A short design description is added for completeness; however, it is not as elaborate as the description given in the Design Review Report, Perkin-Elmer Engineering Report No. 8916.
3. The program history is shown in comparison with the contract schedule.
4. Some chapters are devoted to component as well as system tests; information on calibration and storage are provided.
5. Operation and maintenance is described in detail to provide a guide for the training of operators and for trouble shooting in the field.
6. A paragraph of recommendations is added to summarize ideas which might be helpful in designing a second generation system.

It can be said that during the design and fabrication no difficulties were found which required elaborate redesign of the optical, mechanical, or electronics of the system. The system was accepted in seven and one half months after receipt of contract.

2.0 PURPOSE AND FUNCTION OF THE SYSTEM

The FLD instrument employs a new optical sensing technique which appears to have a large number of applications. The basic principle appears to have been exploited first by several astronomers who used a spectrometer to examine the Fraunhofer line profiles of light reflected from various parts of the lunar surface. The presence of fluorescence material superimposes a broad, relatively flat spectrum on the sharply notched solar spectrum thereby reducing the intensity ratio between the continuum and the center of the Fraunhofer Lines.

Reducing this principle to a practical airborne measurement system capable of coping with the wide spectral differences of natural terrain as well as the vibration environment of the aircraft, required several novel developments. The most important of these was a narrow band filter located on the center of the 0.7 Ångstrom wide Fraunhofer sodium D line at 5890 Ångstroms. A bandwidth of 0.7Å is about a factor of 10 narrower than the narrowest multilayer dielectric filter. Normally it could be attained with a spectrometer only at the cost of greatly reduced signal-to-noise due to the very small area of the entrance and exit slits. In the present instrument the required spectral resolution was achieved with a glass-spaced Fabry-Perot filter, which is very difficult to manufacture, but which is immune to any temporal or vibration induced spectral changes. A variable temperature housing around each of the Fabry-Perot filters allows it to be tuned over a small spectral range. Figure A shows the filter transmission in reference to the Sunspectrum at the vicinity of the Sodium lines.

A second novel feature is a compact optical design which provides for continuous sampling of the solar spectrum without a tracker or any

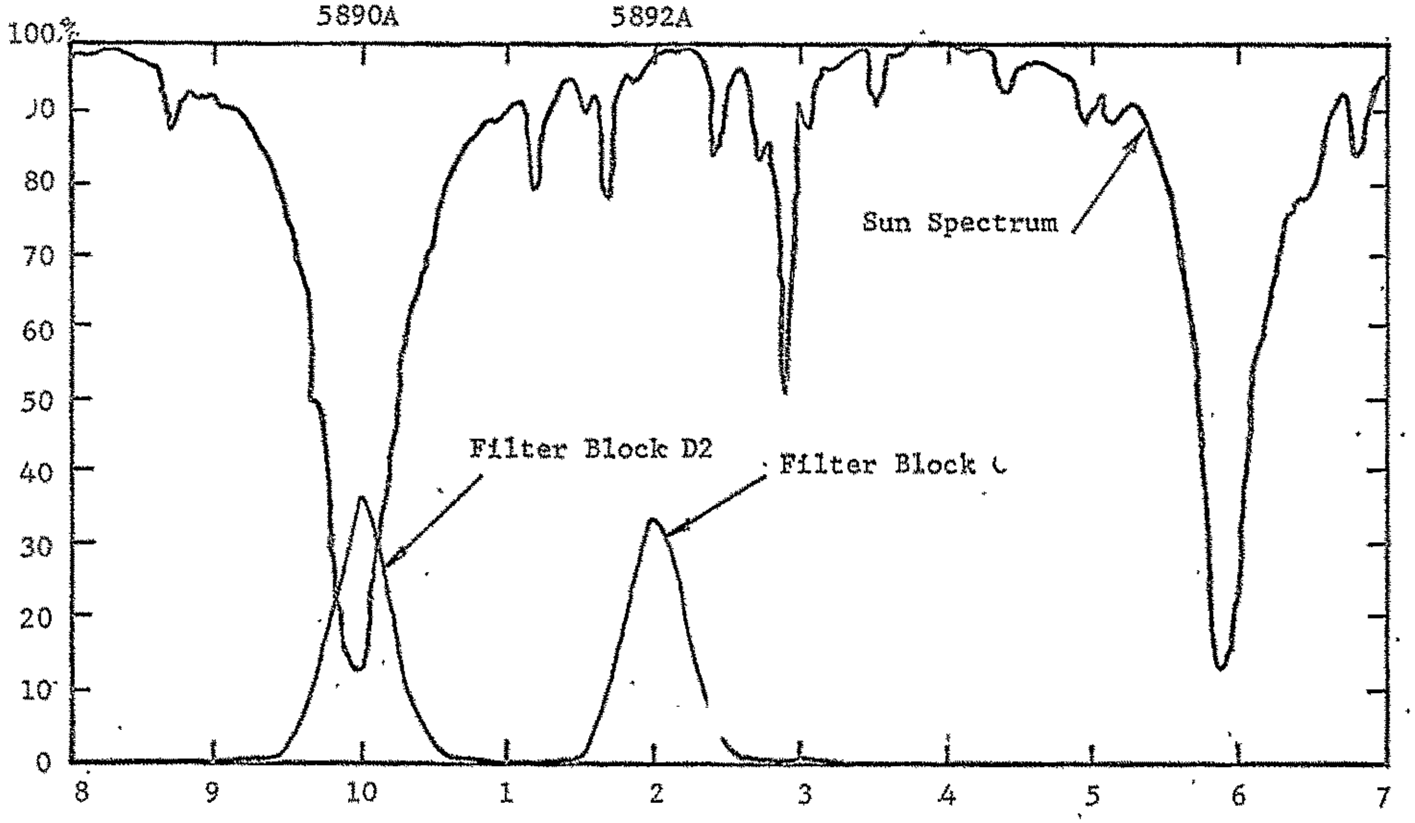


Figure A.. Filter Transmission & Sun Spectrum limitations on the aircraft direction. The design also eliminates any effect of photomultiplier or preamplifier gain changes on the output signal. Vibration induced photomultiplier noise has been avoided by the use of a very rugged EMR venetian-blind dynode phototube constructed to operate in a missile launch environment.

The data processing problem which faced the first users of the Fraunhofer Line Technique has been greatly reduced by a real time analogue computer which indicates a normalized fluorescence value directly. A normalized value is desirable since it is characteristic of the target only and does not depend upon solar zenith angle or atmospheric conditions. Multiplication and division are performed by analogue log and exponential units in a temperature controlled environment to minimize temperature offset errors. Temporal changes in these components as well as small functional errors due to deviations in the exponential behavior of the active circuit components can be rather well compensated by an adjustable correction network built into the computer.

As originally conceived by the U.S. Geological Survey the instrument will be used to measure concentrations of rhodamine B in aqueous solution from a low flying Twin Beech aircraft. If successful, this approach will result in a considerable saving of time over the usual approach which involves taking and labeling a great many samples from a number of locations so that the dye tracer concentrations can be measured in the laboratory with a spectrophotofluorimeter. USGS has also suggested the possible application of a similar instrument as a prospecting tool for phosphate and other fluorescent minerals. For this application it would probably be desirable to employ a

Fraunhofer Line nearer to the blue end of the spectrum such as the CaII line at 3968.5A which is 10A wide. Other applications may include pollution detection by observation of the fluorescence of detergents and oil slicks, fish finding by observation of the oil slick associated with large schools of fish and plant studies based on the natural fluorescence of chlorophyll.

3.0 DESIGN DESCRIPTION

This paragraph contains a description of the design of the instrument and an explanation of the arrangement and installation in the aircraft of the Fraunhofer Line Discriminator. The following figures should be used as references:

3.1 OPTO-MECHANICAL DESIGN

Figures 1 through 12. and 625-2000

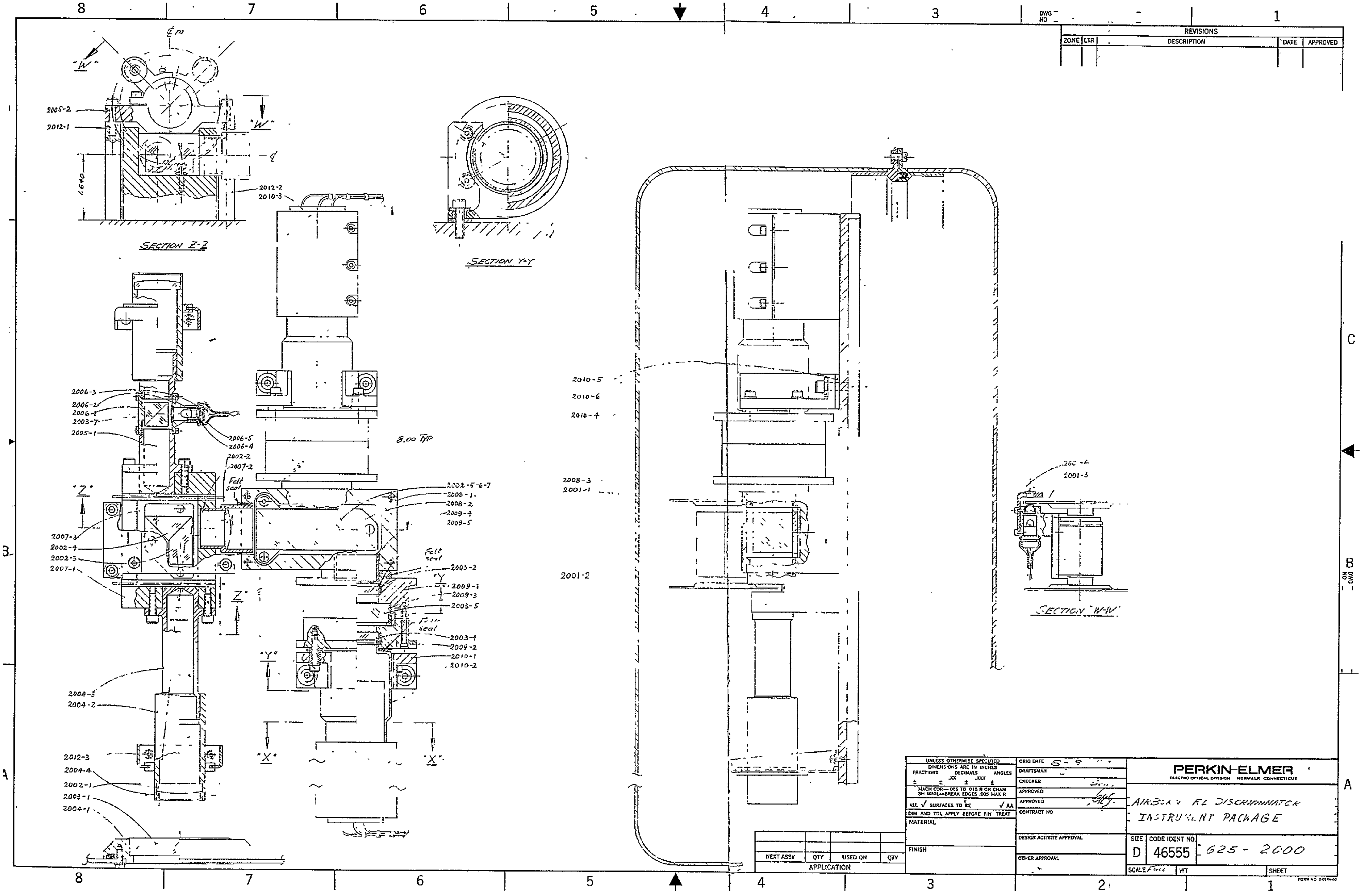
NOTE

The first digit of each part number is the figure number.

Figure 1 shows the instrument package mounted on the base plate which, in turn, is mounted via shock mounts to the instrument housing 1001.

No. 102 is a 3/4 inch thick aluminum plate which is used as a base for the instrument. Sunlight from the sun target enters the instrument through the telescope 101 which has a focal length of five inches and an aperture of one inch. A calibration light is located on this telescope to provide light input via the beamsplitter in housing 103 to the aperture stop of this telescope.

For an explanation of the use of the calibration light, see operation and maintenance number 10.0. The sunlight reflected from the ground enters the instrument package through the other telescope number 118. Just beyond the field stop, chopper wheels, 104 and 106, are located. Both chopper wheels are driven from a single motor. The motors housing appears in Figure 1, between the chopper wheels, 104 and 106.



REVISIONS

ZONE	LTR	DESCRIPTION	DATE	APPROVED

NEXT ASSY	QTY	USED ON	QTY

APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±
MACH COR—.005 TO .015 R OR CHAM
SH MATL—BREAK EDGES .005 MAX R
ALL √ SURFACES TO BE √ AA
DIM AND TOL APPLY BEFORE FIN TREAT
MATERIAL
FINISH

ORIG DATE 5-9
DRAFTSMAN
CHECKER
APPROVED
APPROVED
CONTRACT NO
DESIGN ACTIVITY APPROVAL
OTHER APPROVAL

PERKIN-ELMER
ELECTRO OPTICAL DIVISION NORWALK CONNECTICUT

AIRBORN FL DISCRIMINATOR
INSTRUMENT PACKAGE

SIZE D
CODE IDENT NO. 46555
625 - 2000
SCALE Full
WT
SHEET

FORM NO 2-0244-00

Figure 1 - AFLD INSTRUMENT WITHOUT HOUSING

101	Sun Target Telescope
102	Mounting Plate
103	Calibration Lamp Housing
104	Chopper Blade for Sunlight
105	First Beamsplitter Housing
106	Chopper Blade for Ground Reflected Light
107	Chopped Light Reference Pickup
108	C Photomultiplier Housing
109	C Photomultiplier
110	C Filter Block
111	Second Beamsplitter Housing
112	Chopped Light Reference Pickup
113	D_2 Filter Block
114	D_2 Photomultiplier
115	D_2 Photomultiplier Housing
116	Electronics on Rear of 102
117	Mounting Holes on 102
118	Ground Light Telescope

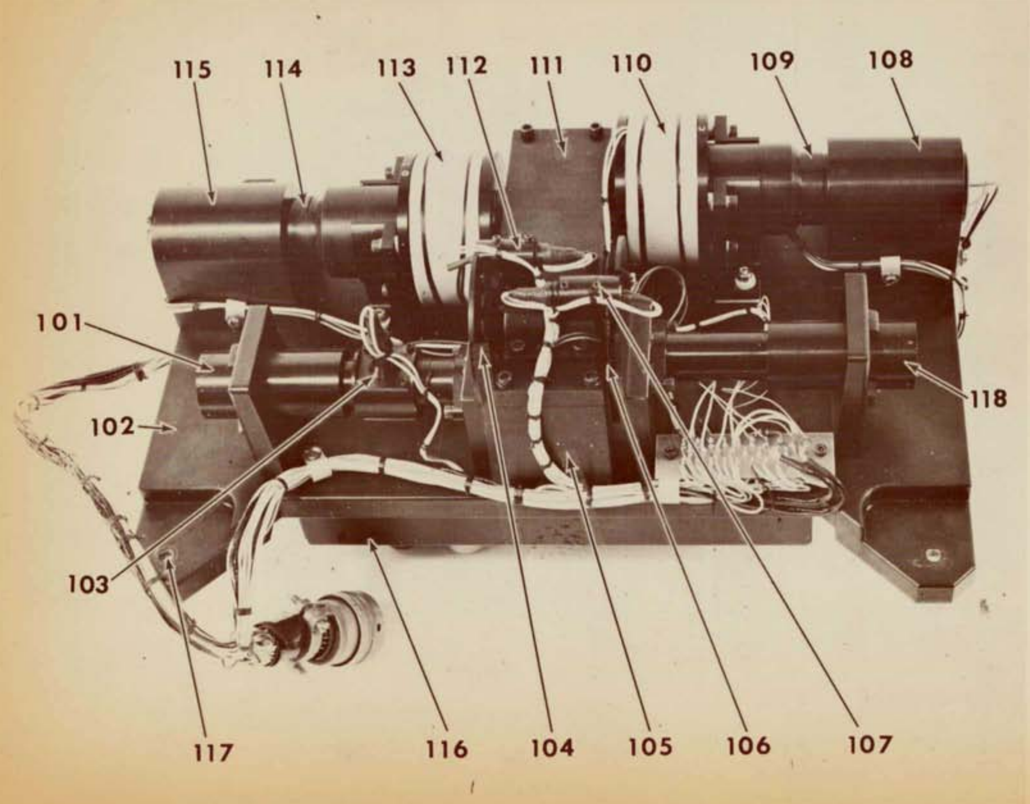


Figure 1. A. E. L. D. Instrument Without Housing

Figure 2 - AFLD INSTRUMENT IN HOUSING, COVER REMOVED

201	Mounting Plate 102 From Rear
202	Electronic Box Cover
203	Coupling Transformers
204	Synchronous Detectors
205	Connecting Plug
206	Mounting Screws for 102 to Shock Mounts
207	Preamplifier and Ref. Amplifiers
208	Motor Capacitor
209	Instrument Housing

The weight of the Instrument in Housing is 36 pounds.

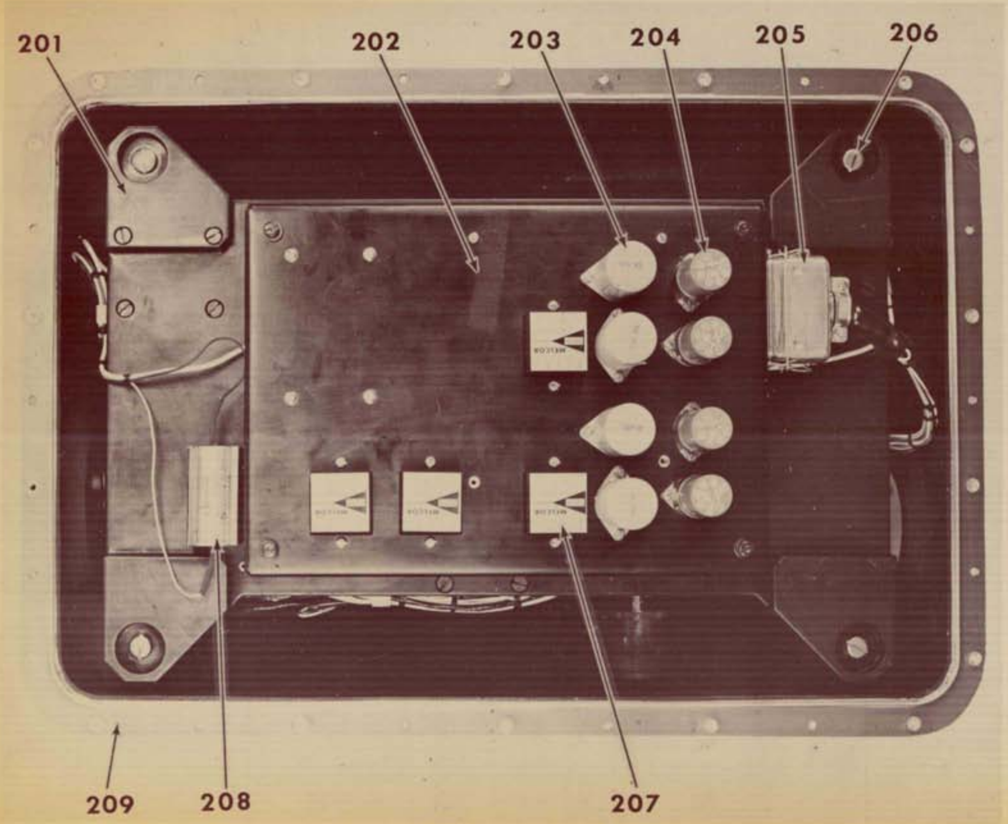


Figure 2. A. F. L. D. Instrument in Housing, Cover Removed

Figure 3 - AFLD ELECTRONICS IN INSTRUMENT HOUSING

301	Connector 205
302	Synchronous Detector Socket Z2
303	Coupling Transformer T1
304	Connector Plug 205
305	Precision Resistors R26
306	Capacitor C10
307	Capacitor C13
308	Precision Resistor R21
309	Electronics Housing
310	Mounting Screws
311	High Voltage Power Supply
312	Socket A1
313	Motor Capacitor
314	High Voltage Pins

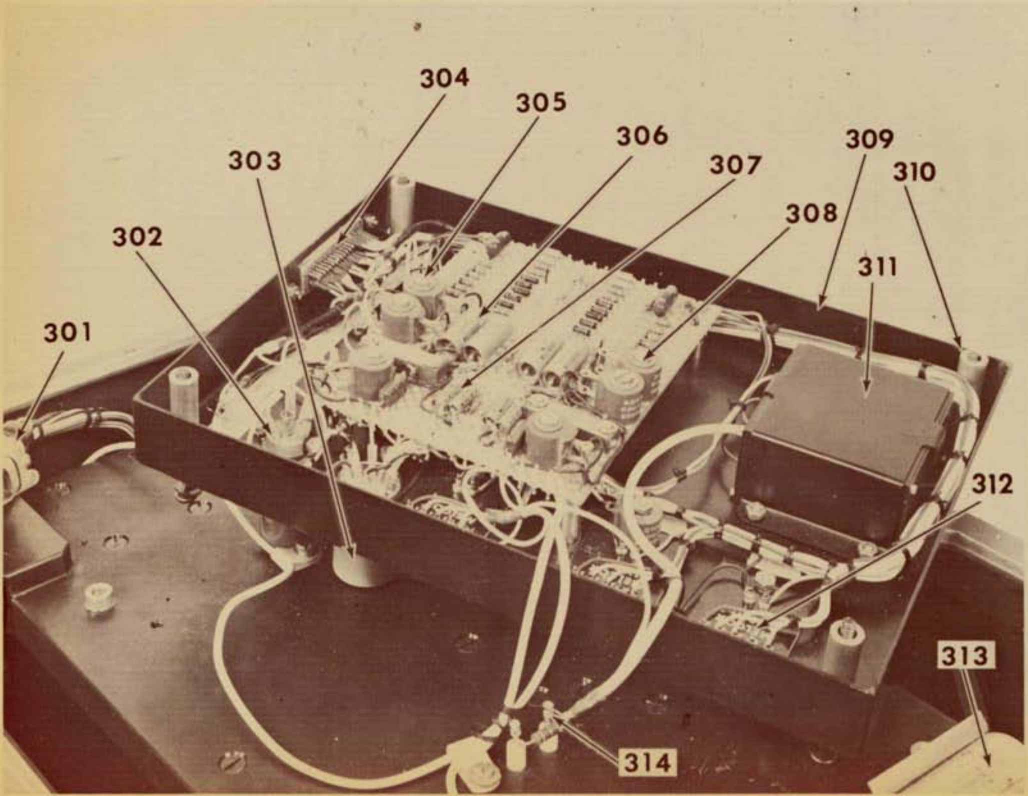


Figure 3. A. F. L. D. Electronics in Instrument Housing, Electronics Box Turned Over

Figure 4 - AFLD ELECTRONIC CONSOLE, FRONT VIEW

401	Panel Mounting Screws
402	Phone Jack B/A Signal
403	Phone Jack ρ Signal
404	C Filter Block Temperature Indicator
405	Scope Scale Factor Switch
406	D_2 Filter Block Temperature Indicator
407	Bandpass Selector (Scope)
408	D_2 Filter Block Temperature Setting
409	A-B-C and D Signal Outputs
410	Fuses
411	Main Power Switch
412	Bandpass Selector B/A Indicator
413	Bandpass Selector ρ Indicator
414	B/A Indicator
415	ρ Indicator
416	Oscilloscope
417	Console Housing
418	Sensitivity Selector for Scope
419	Phone Jack for Use of 416 for Test

The weight of the Electronic Console is 142 pounds

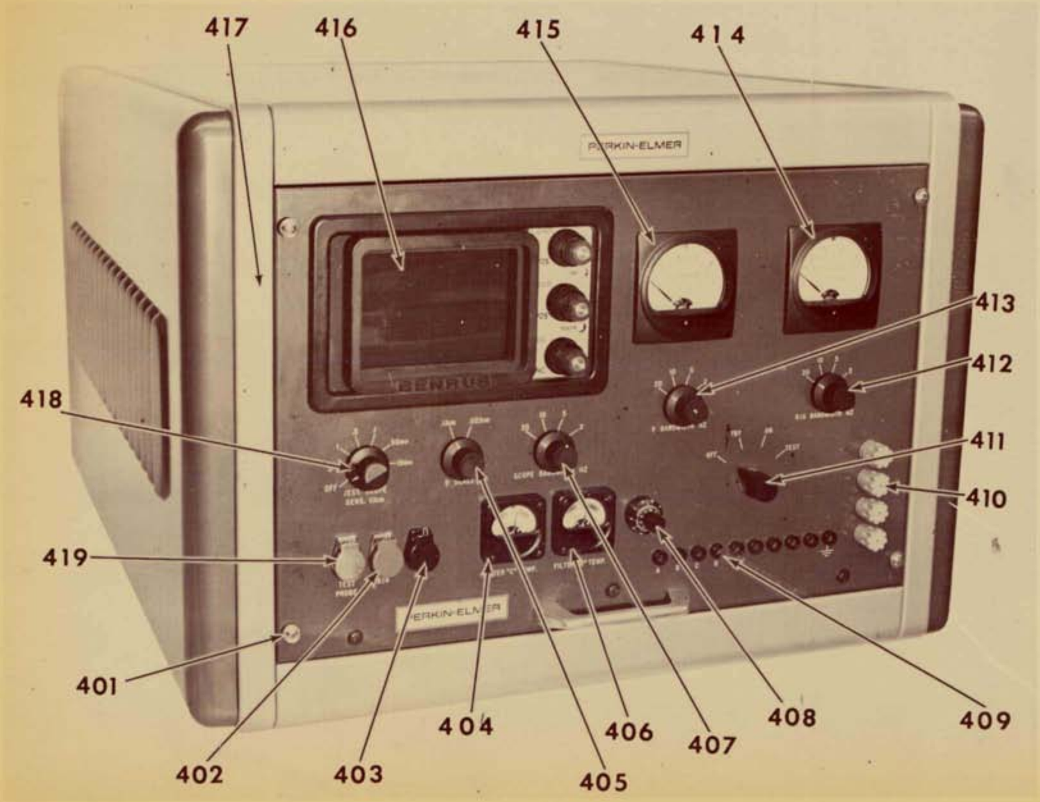


Figure 4. A.F.L.D. Electronic Console, Front View

Figure 5 - AFLD ELECTRONIC CONSOLE REAR VIEW, COVER REMOVED

501	B/A Indicator
502	ρ Indicator
503	Oscilloscope Housing
504	Scope Connector
505	±15 Volt DC Supply
506	Cover for Temperature Controlled Electronics
507	Fuses

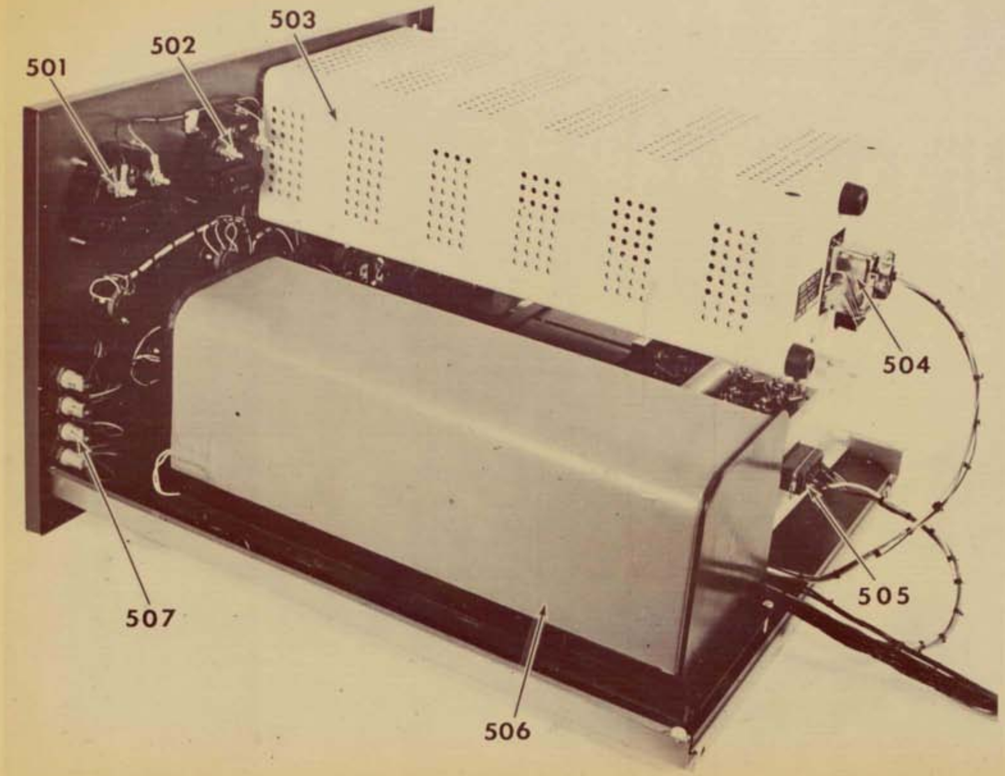


Figure 5. A. F. L. D. Electronic Console Rear View, Cover Removed

Figure 6. AFLD ELECTRONICS IN CONSOLE, SIDE VIEW

601	Lower Amplifier Board 625-2043
602	Middle Amplifier Board 625-2042
603	Upper Amplifier Board 625-2042
604	Test Switches
605	Oscilloscope Housing
606	Z1 Log. Element
607	Z2 Exp. Element
608	Z3 Exp. Element
609	Z4 Log Element
610	Z5 Exp. Element

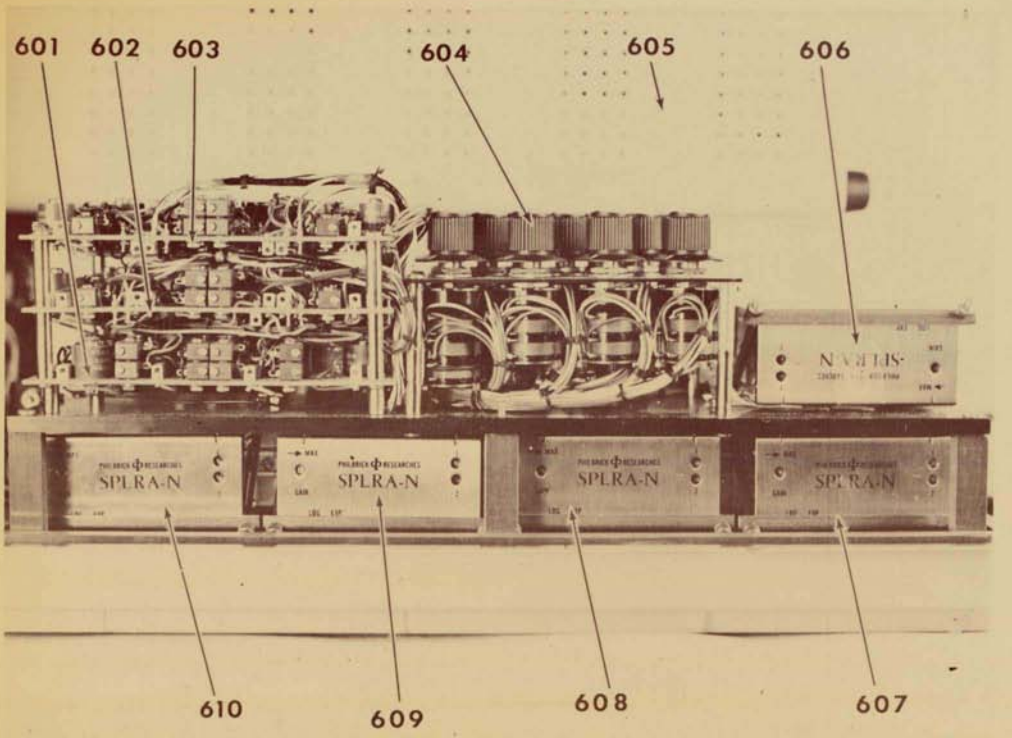


Figure 6. A. F. L. D. Electronics in Console, Side View

Figure 7 - AFLD ELECTRONICS IN CONSOLE, PLAN VIEW

701	Temp. Indicator D_2
702	Temp. Indicator C
703	Phone Jack 403
704	Phone Jack 402
705	Phone Jack 419
706	Resistor R116
707	Test Network R125
708	Test Network R124
709	Test Network R117
710	28 VDC Supply
711	C Filter Heat Control
712	D_2 Filter Heat Control
713	Over Voltage Protection
714	Log. Element
715	Adjustment Switches 604
716	Precision Resistor R6
717	Offset Adjustment R13
718	Trim Resistor R18
719	Trim Resistor R38
720	Precision Resistor R31
721	Offset Adjustment R33
723	Filter Amplifier A2
724	Filter Amplifier A1

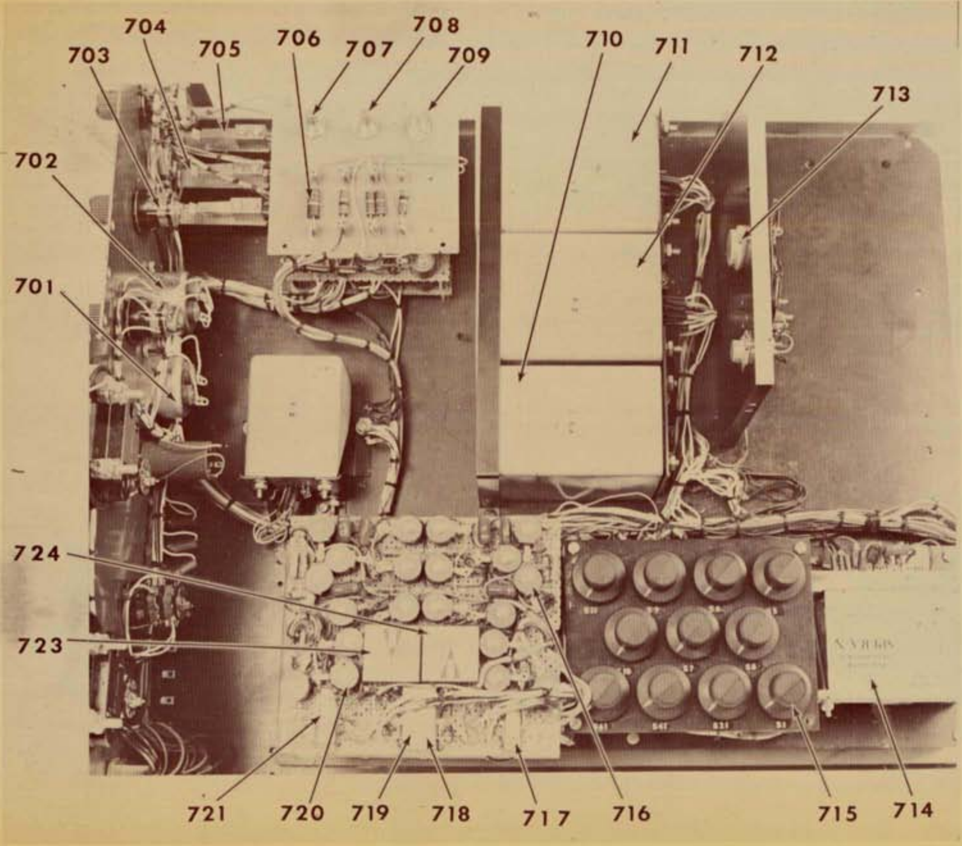


Figure 7. A.F.L.D. Electronics in Console, Plan View

Figure 8.- ELECTRONICS IN CONSOLE TOP, PLATES TURNED OVER

801	Precision Resistor R130
802	Precision Capacitor C62
803	ρ Meter Amplifier A8
804	Precision Resistor R51
805	Trim Resistor R58
806	Trim Resistor R78
807	Offset Adjustment R73
808	Precision Resistor R77
809	Filter Amplifier A4
810	Filter Amplifier A5

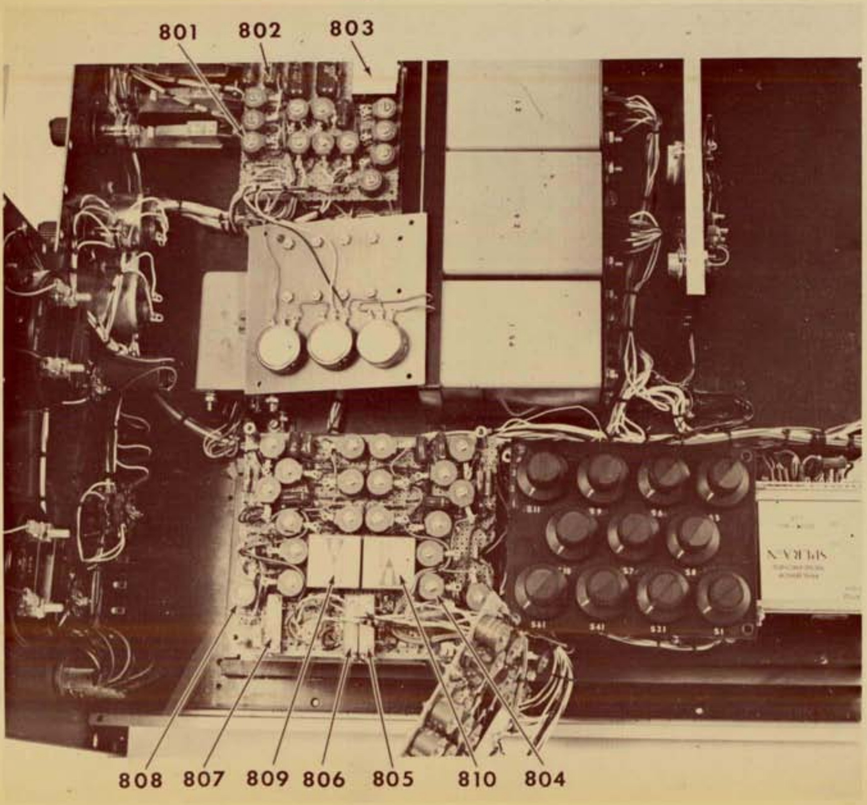


Figure 8. Electronics in Console, Top Plate Turned Over

Figure 9 - ELECTRONICS IN CONSOLE, TOP OF SECOND PLATES TURNED OVER

901	Precision Resistor R161
902	Precision Resistor R158
903	Offset Adjustment R162
904	Difference Amplifier A5
905	Trim Resistor R99
906	Difference Amplifier A6
907	Trim Resistor R103
908	Precision Resistor R137
909	B/A Meter Amplifier A7
910	Precision Capacitor C53

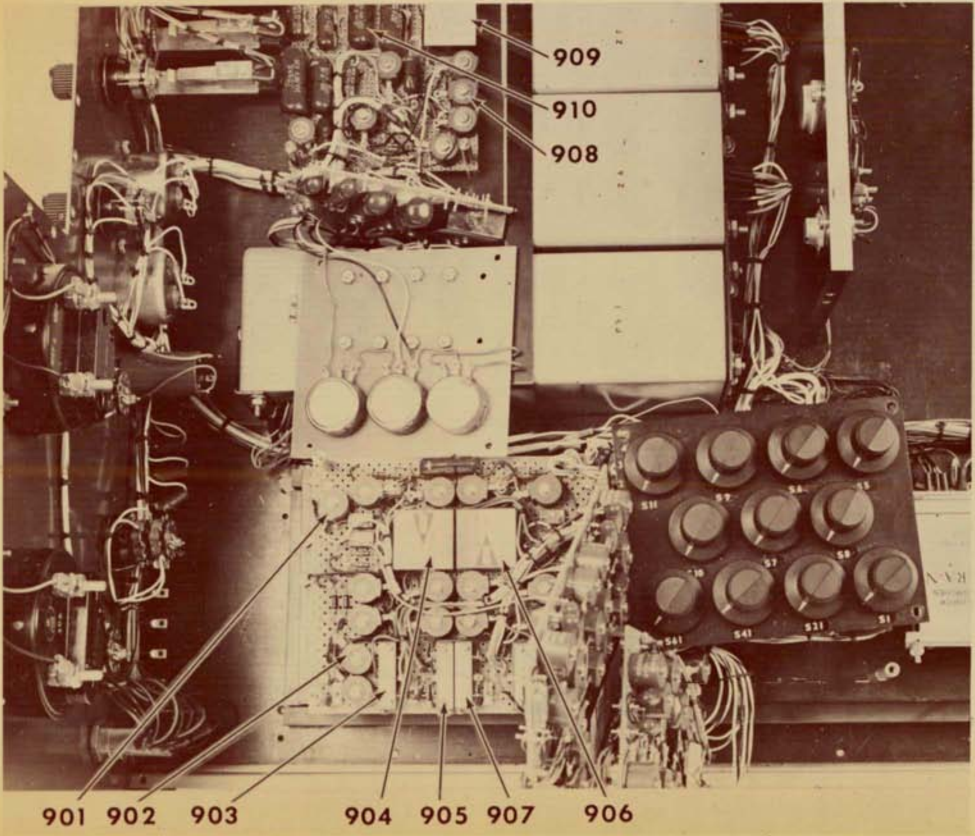


Figure 9. Electronics in Console, First and Second Plates Turned Over

Figure 10 - AFLD INSTRUMENT IN TEST FIXTURE

1001	Instrument in Housing
1002	Pressure Release Valve
1003	Test Fixture Removable Wall
1004	Blower Motor for Tungsten Lamp

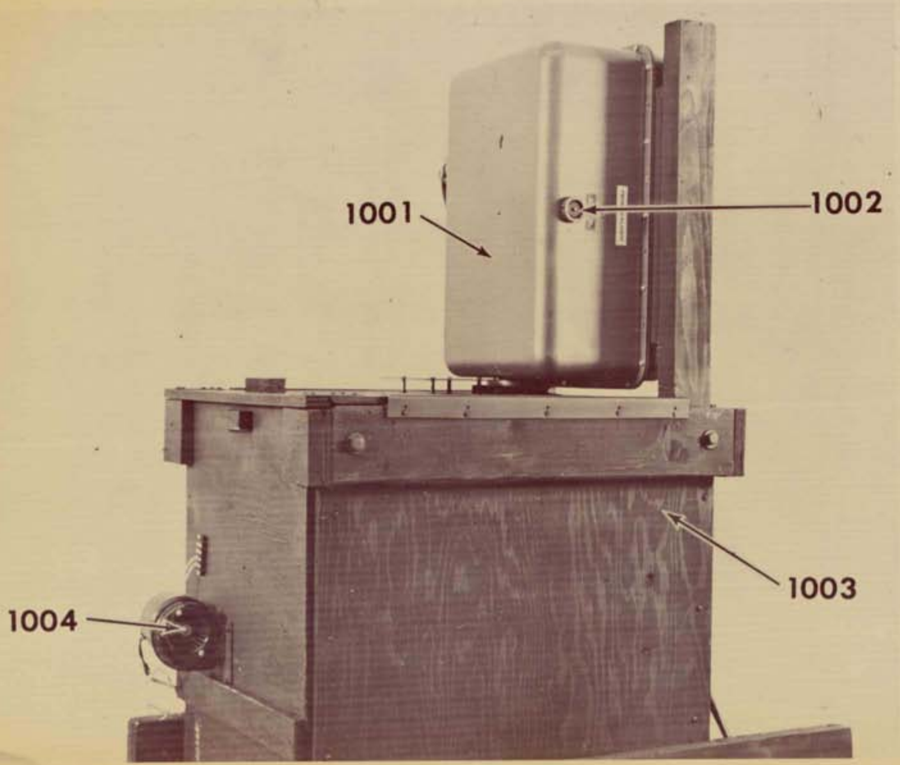


Figure 10. A. F. L. D. Instrument in Test Fixture

Figure 11 - AFLD INNER VIEW OF TEST FIXTURE

1101	Tungsten Lamp Housing
1102	Light Exit for Lamp
1103	Diffuser
1104	Diffuser Holder

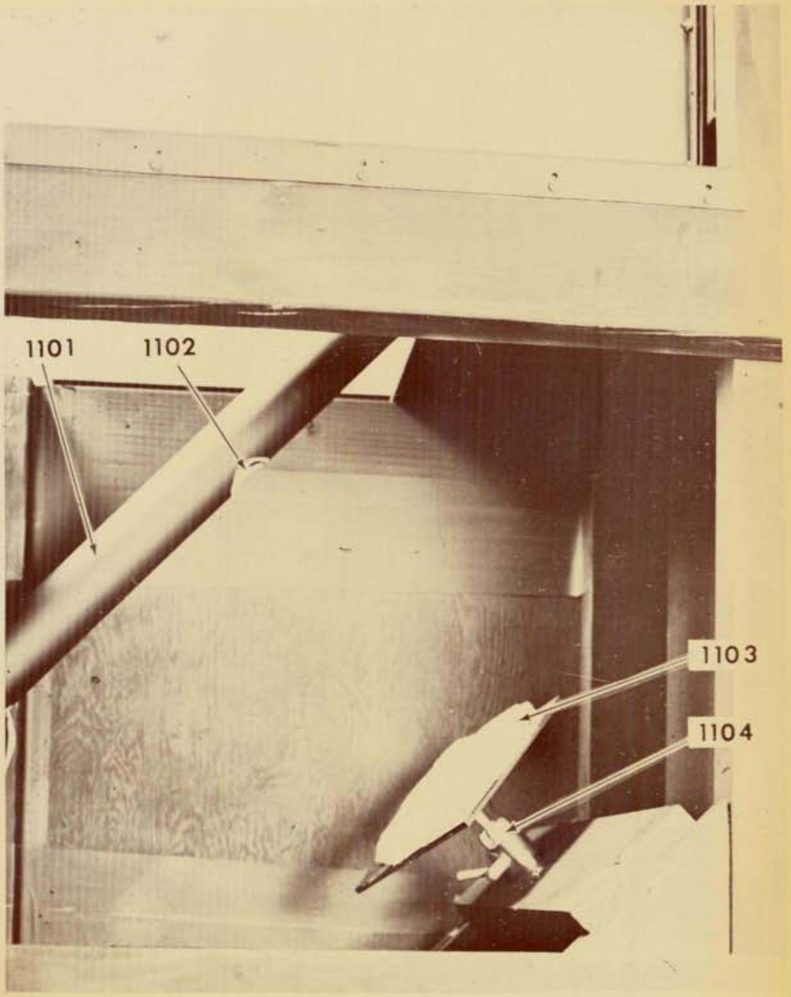


Figure II. A.1. [illegible] D. Inner View of Test Fixture

Figure 12 - AFLD SUN TARGET

1201	Mounting Ring
1202	Diffuser Plate
1203	Stand Off
1204	Mirror
1205	Mirror Holder

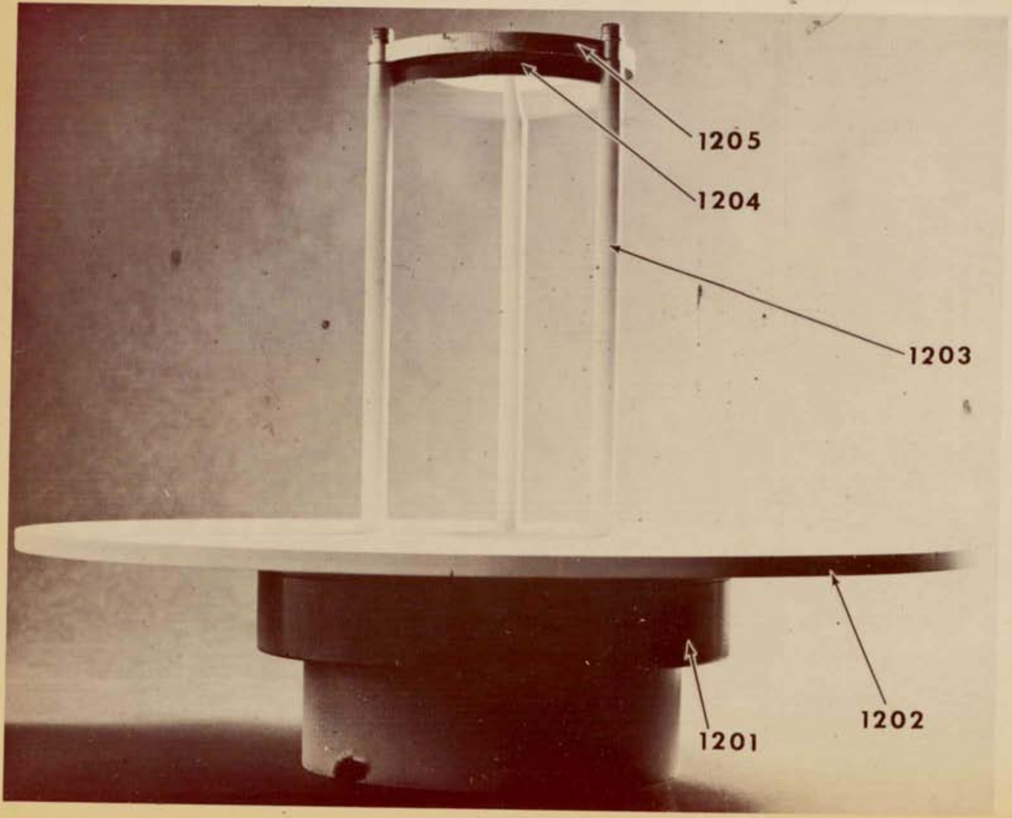


Figure 12. A. F. L. D. Sun Target

The light from the telescopes then enters a reversed beamsplitter which combines the beams. The ratio of ground reflected light transmitted by the beamsplitter to sunlight transmitted is 4:1. The combined light bundle is collimated by a lens located in the far end of housing 105. The light then enters the prism block located in housing 111. This prism block has three 45° surfaces. The first surface has a polarizing coating which rejects one plane of polarization. The next surface splits the beam again in a ratio of 1:1. The reflected light goes to the D-2 line filter block. The transmitte light is totally reflected at the third surface and directed into the continuum filter block and thence into the lower photomultiplier. The light bundle which enters the D-2 filter next enters the window of the upper photo multiplier.

The lower photomultiplier is shown in locations 108 and 109. Th continuum filter block has its heating element and temperature sensor at location 110. The upper in-line filter block, physically similar to 110, is shown in location 113, and the other photomultiplier in locations 114 and 11 Location 116 shows part of the electronics chassis located underneath the mounting plate 102.

The electronic parts are described in a later chapter. Figure 2 and 3 show the mounting plate from the opposite side.

Figure 4 shows a view of the electronics console. A detailed description of its function is given in Chapter 6. The holding screws which must be removed to slide the front panel with all the electronic parts out of housing 417 appear as item 401.

402, 403, and 419 are phone jacks with spring covers for connection of a recording instrument for $\frac{B}{A}$ and ρ signals. 419 is for use of the oscilloscope 416 for test and adjustment purposes.

The temperature control indicators are in locations 404 and 406. 408 is a temperature-set knob which can be used to change the temperature of the in-line filter package. (Normal setting: 170). 409 are test points for signals A, B, C, and D. 411 is the main switch. It has OFF, STANDBY, ON, and TEST positions. Fuses necessary to protect the system are in location 410. 414 is an indicator for the $\frac{B}{A}$ ratio. 412 switches bandwidth of this signal from 20 - 10 - 5 - 2 cps. 415 indicates the ρ signal. It has a bandwidth switch 413 allowing bandwidth to be changed from 20 to 2 cps in the same steps as 412. The sensitivity of the system oscilloscope can be changed when used as a test instrument. This can be done on adjustments 418. The ρ scale can be changed by switch 405.

Figure 5 shows the interior of the electronics console. The rear view of the front plate is shown in location 507. Certain elements, such as the analogue computer, need to operate in a controlled temperature range. This is accomplished by a heater blanket on cover 506 which is controlled to about 35°C. Oscilloscope housing 503 can be removed from the front panel by removing the hold screws and the plug 504. The 505 plug connects between electronic assemblies. The 15V precision DC power supply is at location 505. 502 show the instruments indicating ρ and 501 $\frac{B}{A}$ shown from the rear. Note: The temperature controller for 506 is not shown in Figure 5, it was after the photo was taken installed piggy back on box 506. Figure 6 shows the electronics in the console with the heater cover 506 removed. It is a side view. Details are described in paragraph 6. Figures 7, 8, and 9 are also described in detail in paragraph 6.

Figure 10 shows the instrument in the text fixture. (See test descriptions.)

Figure 12 shows the sun target. It consists of a 10-inch horizontal plate covered with a white diffusely reflecting paint. The sunlight, having access to the horizontal plate, is diffusely reflected; and collected by mirror 1204 which sends it down through the center of the diffuser 1202 into the upper window of the instrument.

3.2 CIRCUIT DESCRIPTION

3.2.1 Signal Flow (Instrument) Reference 625-2021

The light entering the telescopes is chopped at 240 Hz and 480 Hz for the ground and sky looking telescopes, respectively. Each of the photomultiplier tubes receives light from both telescopes. V-1 is the energy at the wavelength of the sodium absorption line and V-2 the energy at a wavelength approximately 2Å removed from the absorption line. The resulting four signals are in a sequence which has been arbitrarily labeled as follows for convenience:

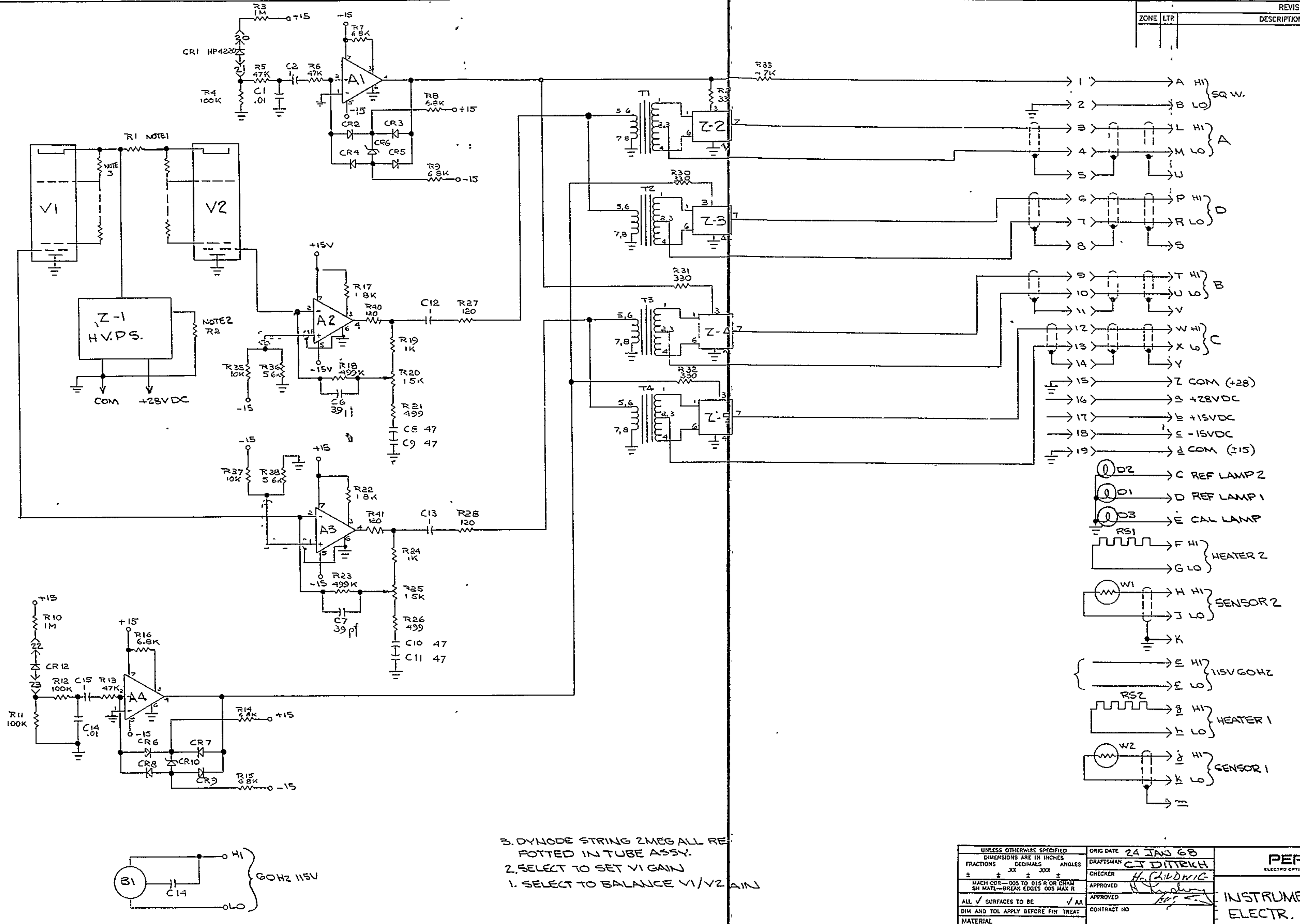
A = sky looking continuum (480 Hz - V2)
B = sky looking sodium line (480 Hz - V1)
C = ground looking sodium line (240 Hz - V1)
D = ground looking continuum (240 Hz - V2)

These signals are applied to synchronous detectors (Z2-Z5) which have as their output a D.C. component proportional to the signals.

The filter amplifiers A-1 through A-4, in the electronics console, remove the ripple component and prepare the signal for application to the computer.

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED

DWG NO —



3. DYNODE STRING 2MEG ALL RE POTTED IN TUBE ASSY.
2. SELECT TO SET V1 GAIN
1. SELECT TO BALANCE V1/V2 GAIN

NEXT ASSY	QTY	USED ON	QTY

APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±
MACH COR—.005 TO .015 R OR CHAM
SH MATL—BREAK EDGES .005 MAX R
ALL √ SURFACES TO BE √ AA
DIM AND TOL APPLY BEFORE FIN TREAT
MATERIAL
FINISH

ORIG DATE 24 JAN 68
DRAFTSMAN C J DITTRICH
CHECKER H. Ludwig
APPROVED
APPROVED
CONTRACT NO
DESIGN ACTIVITY APPROVAL
OTHER APPROVAL

PERKIN-ELMER
ELECTRO-OPTICAL DIVISION NORWALK CONNECTICUT

INSTRUMENT PACKAGE
ELECTR. SCHEMATIC

SIZE D
CODE IDENT NO. 46555
625-2021
SCALE —
WT
SHEET

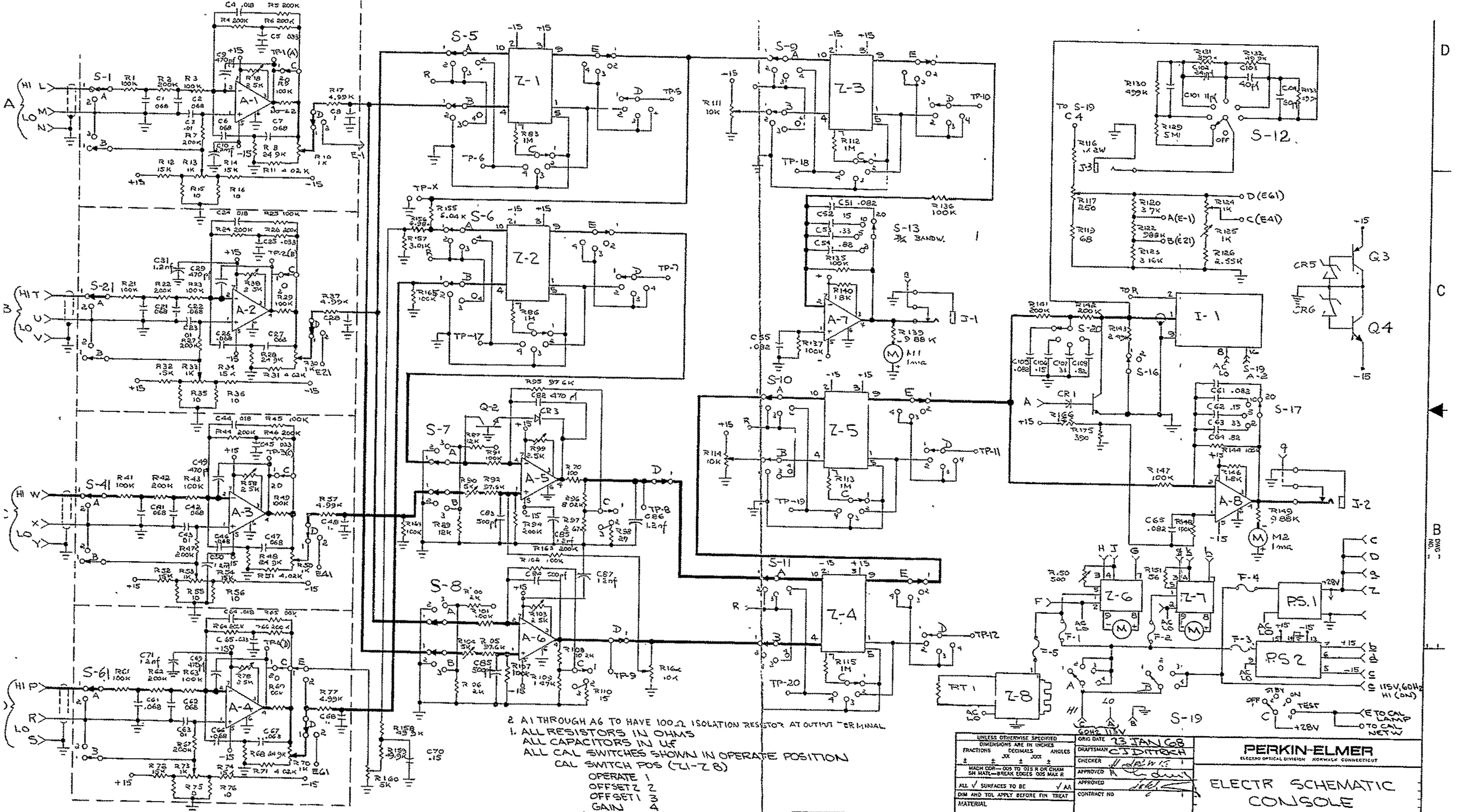
3.2.2 Signal Flow (Console) Reference 625-2023

The first computer element Z-1 has B and A applied to it and as its output K log B/A where K is a gain constant. Z-3, operating in the exponential mode, receives the input K log B/A and a scale factor, and produces an output $K_1 \frac{B}{A}$. This output is buffered by A-7, a unity gain amplifier, which, in addition to driving a meter, may be loaded with a 1.2K Ω load. The output of Z-1 is also applied through a voltage divider to the exponential element Z-2 which, as the second input, receives the signal D such that its output is equal to $\frac{BD}{A}$. This voltage is applied to the inverting terminal of the differential amplifier A-5. The noninverting terminal has the signal C applied to it plus a signal n(A-B) where n is less than one. The amplifier has a gain of four and consequently at its output appears the signal $4\left(C - \frac{BD}{A}\right) + 4n(A-B)$. This is one signal applied to the logarithmic element Z-4. The signals A and B are also applied to the noninverting and inverting terminals of the differential amplifier A-6 which, because of its gain of 8, has as its output the signal 8 (A-B). This is the second signal applied to Z-4, which performs the division and has as its output

$$K_{\log}\left(\frac{4\left(C - \frac{BD}{A}\right) + 4n(A-B)}{8(A-B)} = \frac{1}{2(A-B)}\left(C-\frac{BD}{A}\right) + \frac{n}{2}\right)$$

The exponential element Z-5 has this signal applied to it plus a scaling constant. Its output is then

$$\frac{K_2}{(A - B)}\left(C-\frac{BD}{A}\right) + K_3$$



2. A1 THROUGH A6 TO HAVE 100Ω ISOLATION RESISTOR AT OUTPUT TERMINAL

1. ALL RESISTORS IN OHMS
ALL CAPACITORS IN UF
ALL CAL SWITCHES SHOWN IN OPERATE POSITION
CAL SWITCH POS (Z1-Z8)
OPERATE 1
OFFSET 2 2
OFFSET 1 3
GAIN 4
(A1—A8
OPERATE 1
OFFSET 2

NEXT ASSY	QTY	USED ON	QTY

APPLICATION

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
FRACTIONS DECIMALS ANGLES
± .XX ± .XXX ± ±
MACH COR—.005 TO .015 R OR CHAM
SH MAT—BREAK EDGES .005 MAX R
ALL √ SURFACES TO BE √ AA
DIM AND TOL APPLY BEFORE FIN TREAT
MATERIAL
FINISH

ORIG DATE 23 JAN 68
DRAFTSMAN C J DITTRICH
CHECKER
APPROVED
APPROVED
CONTRACT NO
DESIGN ACTIVITY APPROVAL
OTHER APPROVAL

PERKIN-ELMER
ELECTRO OPTICAL DIVISION NORWALK CONNECTICUT

ELECTR SCHEMATIC
CONSOLE

SIZE D
CODE IDENT NO. 46555
625-2023

where:

K_2 and K_3 are constants

This signal is applied to the meter buffer amplifier A-8 and the oscilloscope attenuator.

3.2.3 Auxiliary Circuits

Besides the signal processing circuits, the electronic console contains power supplies, temperature controls, reference generators, and test circuits.

3.3 CIRCUIT DESCRIPTION - INSTRUMENT - REFERENCE 625-2021

The photomultiplier tubes are potted assemblies containing the dynode divider string. They are operated with their anodes grounded and negative high voltage applied to the cathodes. R1 serves to equalize approximately the gain of V1 and V2 by lowering the high voltage across V2. The high voltage is derived from Z-1, an externally adjustable switching type supply operating with a 28VDC input. R2 is selected to adjust the HV to between 1800 and 3500V. The signal from V-2 is applied to the preamplifier A-2. This is a high input impedance operational amplifier. R35 and R36 form a voltage divider that serves to offset the zero signal output voltage to approximately 6 volts. This allows a peak-to-peak signal excursion of nearly 18 volts at the output. The feedback is tapped off the voltage divider formed by R19, R20, R21, C8, and C9. The position of the slider on R20 determines the portion of the output voltage that is fed back to the input at chopping frequency. At DC, all of the output current is fed back, thus suppressing dark current effects on the voltage swing capability of the amplifier. R17 is the operational amplifier trim resistor and R40 is a suppression resistor to forestall high frequency oscillations. The same description applies to A-3. C12 serves to block the DC component; A C is applied via the isolation resistor R27 to the coupling transformers T1 and T2.

The secondary windings of the transformers apply the signal to the transistor choppers Z-2 through Z-5. The reference phase for the choppers is derived from the reference lamps D2 and D3 mounted on the motor assembly. Their light output is modulated by the same chopper wheel that modulates the signal light beams. PIN diodes CR1 and CR12 are exposed to the modulated beams and produce a current output of the same frequency characteristics. The PIN diodes are backbiased by +15V through R3 and R10 respectively. The ground return and load resistors are R4, R5, and R6 on CR1 and the appropriate resistors on CR12. C1 is a filter capacitor. C2 blocks the DC from the operational amplifier input. A-1 is a high gain operational amplifier that operates essentially open loop until the zener diode CR6 conducts and limit any further rise or fall in the output voltage. R7 is the trim resistor and R8 and R9 provide bias for the zener diode. The output of A-1 is coupled via R29 and R30 to Z-2 and Z-4, and via R33 supplied to the electronics console. The output of A-4 drives the chopper Z-3 and Z-5 via the limiting resistors R30 and R32. The choppers Z2-Z5 connect alternately the two secondary windings to the output at the reference phase, thus demodulating the square wave input. The outputs are fed through shielded pairs to the electronics console.

3.4 CIRCUIT DESCRIPTION ELECTRONICS CONSOLE - Reference, Diagram 625-2025

The four filter amplifiers (A1 to A4) are identical; therefore only one will be discussed. A-1 is a high gain operational amplifier operating at unity gain from DC to approximately 20 Hz. The resistor, capacitor networks consisting of R1, C1, R2, C2, R3, R4, R5, R6, C4, C5, C6, C7, and R8 provide a -18 db/octave slope from the cutoff frequency. R18 is the trim resistor. R7 and C3 provide an impedance to the noninverting input similar to that seen by the inverting input. The resistor network R12 through R16 allows a voltage offset to be introduced as compensation for any zero offset that may exist in the demodulators. R17 and C8 form another filter section before application of the signal to the computer. The switch S-1 allows the inputs to be grounded and, by removing the short across R9, raises the amplifier gain to simplify the zero adjustment. S-1 also disconnects the output from the computer, connecting the latter to point A on the calibration network. The network consists of R116, R117, R119, R120, R122, R123, R124, R125, and R126. The D amplifier A4 differs from the A, (A1) B, (A2) and C (A3) amplifiers in the switch and load arrangements. An additional pole on switch S61 connects R160 to the amplifier in position ONE and to the test network in position TWO.

The logarithmic-exponential elements are sealed plug-in units, their only external circuitry being the calibration resistors, switching arrangement, and the compensation network discussed below. The calibration resistors R83, R86, R112, R113, and R115 are placed across the appropriate input terminals by the associated switches S-5, S-6, S-9, S-10, and S-11 for zero and gain adjustment. Terminal R is connected to pin 2 on the oscilloscope connector and has the oscilloscope sweep wave form applied to it. The compensation network R115, R156, R157, R158, R159, and R160 is located between Z-1 and Z-2. R155, R158, and R159 are isolation resistors. R156 and R157 form a voltage divider, allowing a portion of D tapped off by R160 to be applied to pin 10 on Z-2. The scaling potentiometers R111 and R114 complete this portion of the computer.

A-5 is a differential amplifier as long as the input voltage to noninverting side exceeds the input to the inverting side. The output, therefore, is restricted to positive voltages. This is achieved by Q-2 which will conduct as soon as the output tends to go negative, clamping its collector to the input existing at R90. The latter serves to equalize the gain of the two inputs. A-6 is a second differential amplifier using the same type of operational amplifier and circuit configuration as A-5 except that there is no constraint placed on the output. The X8 gain of A-6 is achieved by tapping the feedback off the divider formed by R108 and R109. R162 allows portion of the A-6 output to be fed to A-5 to achieve a constant offset at the output of the computer. The meter amplifiers A-7 and A-8 are unity gain amplifiers which, by means of switch selected capacitors in their feedback loops, allow the output bandwidth to be restricted to 20, 10, 5, or 2 Hz. A similar bandwidth restriction is placed on the scope display by switching in C105, C106, C107, or C108. Q-1, by chopping the scope signal at reference phase rate, provides a reference line on the oscilloscope. This eliminates the need for periodic checking of zero position. Regulated (0.05%) ±15 volts is supplied by the Philbrick PR300C power supply. This unit should not be field repaired but rather returned to the manufacturer. The same holds true for the sealed +28 volt power supply and the sealed temperature controllers. The latter, however, depend on the external sensor, load and control resistors for proper operation. The control resistor for Z-6 is the ten turn potentiometer R150 mounted on the front panel. Z-7 has a fixed control resistor R151. The sensors are high resistance wires wound around the filter cells in the instrument. Control bridge imbalance is indicated by the front panel zero center meters M3 and M4.

4.0 PROGRAM HISTORY

The following work statement lists the actual work performed in comparison with the schedule of the contract.

1. Work started on August 11, 1967. After a brief study of the optical end, the electrical layout was started.
2. Since the whole program was scheduled to be performed during a five-month period, long lead purchase items had to be ordered as soon as possible.
3. A purchase parts list was delivered to the customer for approval on September 1, 1967.
4. The purchasing of parts was essentially concluded in the middle of September, 1967.
5. On August 18, 1967, the opto-mechanical layout was started and was concluded on September 22, 1967.
6. On September 29, 1967, a design review was held at Perkin-Elmer. It was agreed to follow the design as proposed. We were, therefore, able to start detailing and finish ordering special parts to be fabricated.
7. About 70 percent of all purchase parts were received by November 10, 1967.
8. An end item test plan was presented. After several changes were made, the plan was put into final form by December 15, 1967.
9. On December 1, 1967, assembly of the opto-mechanical instrument was started. It was finished by December 29, 1967. Fabrication of the electrical console was finished by January 5, 1968.
10. A storage procedure for the end item was delivered by December 29. 1967.
11. Preliminary tests were performed and the Acceptance test was scheduled for January 30. 1968.

12. Considering that this instrument was built for the first time and not enough experience was available concerning its operation and trouble shooting, further work was performed to minimize noise and to find reasons for the variation of the B/A signal. Spurious high frequency oscillations which had developed were suppressed by additional bypass and feedback capacitors. Low frequency variations were found to originate from undesired chopper blade motions. A motor with 3 times the speed was substituted moving such noise contributions outside the bandpass of the instrument. (20 cps)

13. This work took longer than expected but was concluded by March, 1968. A handicap was the lack of sunny days at this time in New England.

14. Material for the final report was assembled at this time and the final report delivered at the 15th of April, 1968.

15. The Acceptance Test was held on March 28, 1968. The instrument was accepted.

5.0 COMPONENT TEST

5.1 INSTRUMENT BOX PRESSURE TEST

The instrument housing was subjected to a simulated altitude of 90,000 feet for a duration of fifteen minutes. At low pressure the indicator switch installed in the housing showed that a minimum pressure of .07 standard atmosphere pressure was maintained in the housing. No deformation was observed. On return to ambient pressure the release valve had to be activated for release of the cover.

5.2 PMT VIBRATION TEST

The photomultiplier tubes were vibration tested at the tube manufacturer's facility. The tubes were subjected to vibration of 5 g's from 15 to 500 cps and a displacement of .25 inch from 5 to 15 cps along the major axis of the tubes. Perkin-Elmer personnel observed no vibration effects.

5.3 AMPLIFIER BANDPASS

Filter amplifier bandpass was measured using an audio oscillator with 15V peak-to-peak as the signal source. The output voltage versus frequency in db below the input is shown on the attached bandpass curve, Figure 13.

5.4 TEMPERATURE CONTROLLERS

The temperature of the optical filter blocks was monitored with a thermocouple instrument. The measurement indicated that the controllers stabilize the temperature such that resolution of the thermocouple instrument limits the experiment. (±0.5°C)

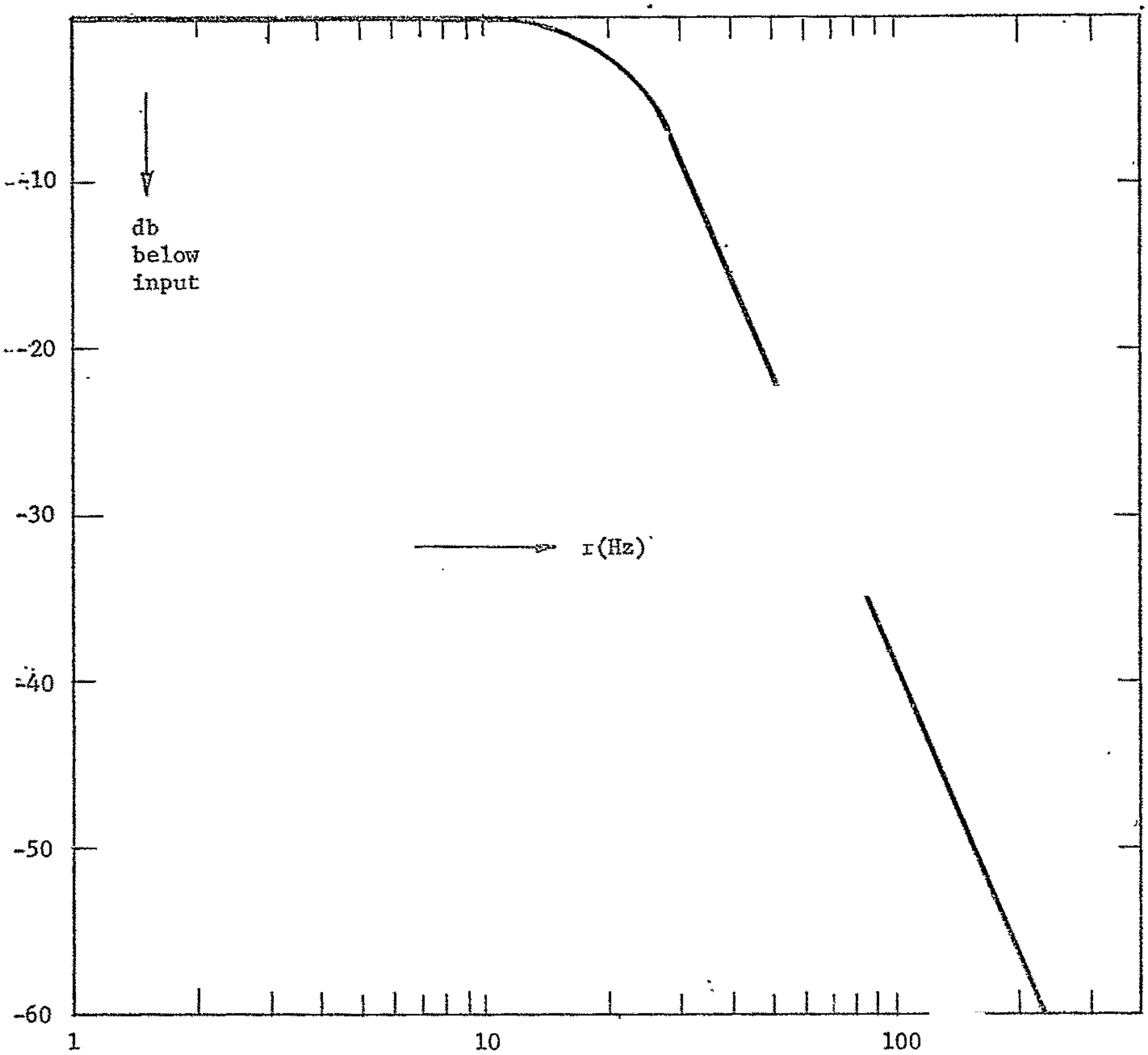


Figure 13. Amplifier Bandpass Curve

5.5 MOTOR SPEED

Motor synchronous speed was measured by two independent methods: (1) the frequency of the reference generator was measured and (2) a fiducial marker on a chopper blade was observed using a strobe light.

5.6 COMPUTER ELEMENTS

The computer elements were tested for accuracy and dynamic range. It was found that compensation for a quadratic deviation from linearity had to be incorporated to achieve the necessary accuracy. For this purpose a portion of the multiplier applied to the exponential element is added to the logarithm of the ratio as yielded from the logarithmic element. Published accuracy figures of the computer elements are 0.1 percent. However, laboratory measurements showed that an overall accuracy of two to five percent at any point in the dynamic range more accurately describes the units. Since the error appears essentially quadratic as mentioned above, it remains small for most of the range. The added compensation, hoever, reduces the error to ±10 mv anywhere in the dynamic range. (worst condition 0.25%)

5.0 ELECTRONICS CONSOLE INITIAL ADJUSTMENT PROCEDURE

Switch Settings

Front Panel

Function Switch	Off
Bandwidth switches	20 Hz
Scope sensitivity	High
Test scope	Off

Internal

All switches to maximum CCW position (OP)

Turn function switch to STBY. Oscilloscope power on. Allow at least thirty minutes warm-up before proceeding.

Zero Adjustment of Filter Amplifiers

Function Switch to On

Use oscilloscope test probe via J3 (front panel test Jack)
oscilloscope 10 mv/cm

Set S1 to position 2

Test probe to TP-1

Adjust R18 for zero output

Set S1 to position 1

Adjust R13 for zero output

Move Test probe to TP-2

Set S21 to position 2

Adjust R38 for zero output

Set S21 to position 1

Adjust R33 for zero output

Move test probe to TP-3

Set S41 to position 2

Adjust R58 for zero output

Set S41 to position 1

Adjust R53 for zero output

Move test probe to TP-4

Set S61 to position 2

Adjust R78 for zero output

Set S61 to position 1

Adjust R73 for zero output

Remove test probe

This completes the null adjustments of the filter amplifiers.

Zero and Gain Adjustment of Computer Elements

Test probe to Z1-10

Adjust horizontal gain for 10V-p-p of ramp voltage

Adjust horizontal position for zero V at start of ram

Test probe to TP-5

Set S5 to position 2

Adjust Z1, Amp 2, for zero output (scope at 10 mv/cm)

Set S5 to position 3

Adjust Z1, Amp 1, for zero output

Remove scope probe

Set S5 to position 1

Test probe to TP-7

S6 to position 2

Z-2 log exp. switch to log.

Adjust Amp 2 for zero output

S6 to position 3

Adjust Amp 1 for zero output

Return S6 to position 1

Test probe to TP-10

Switch on Z-e to log, S9 to po

Adjust Amp 2 for zero output

Set S9 to position 3

Adjust Amp 1 for zero output

Return S9 to position 1

Test probe to TP-11

Set S10 to position 2

Switch on Z-5 to log.

Adjust Amp 2 for zero output

Set S10 to position 3

Adjust Amp 1 for zero output

Return switch on Z-5 to exp.

Return S10 to position 1

Test probe to TP-12

Set S11 to position 2

Adjust Z-4, Amp 2 for zero output

Set S11 to position 3

Adjust Amp 1 for zero output

Return S11 to position 1

This completes the zero adjustment of the computer log. exp. elements

Test probe to TP-8

Set S7 to position 2

Adjust R99 to positive output then reduce output to just reach zero, do not rotate R99 further since a negative output will not be indicated.

Set S7 to position 3

Adjust R90 in a manner similar to R99 observing the same caution, i.e., approach the zero from the positive side and do not rotate adjustment beyond just reaching zero.

Test probe to TP-9

Set S8 to position 2

Adjust R103 for zero output

Set S8 to position 3

Adjust R104 for zero output

This completes the zero adjustment of the differential elements

Set R111 to approximately mid-range

Connect a jumper lead from R111 slides to TP-6

Connect a precision voltmeter (DVM-Fluke, etc.) to TP-5

Set S5 to position 4

Adjust the gain controls of Z1 for 420 mv output

Connect a jumper from TP-6 to TP-18

Connect the meter TP-5 to TP-10

Set S9 to position

Adjust the gain of Z-3 for zero voltage on the meter

Remove jumpers and meter from the test points

Return S5 and S9 to position 1

Connect the jumper from R111 to TP-17

Set S6 to position 4

Connect the meter to TP-7

Adjust the gain control of Z-2 for an output of 262.5 mv on the meter

Move the jumper from TP-17 to TP-19

Connect a jumper from TP-19 to TP-20

Connect the meter from TP-12 to ground

Set S11 and S10 to position 4

Adjust the gain of Z-4 for 420 mv on the meter

Connect the meter from TP-11 to TP-12

Adjust the gain of Z-5 for zero output on the meter

Disconnect meter and jumpers

Return S10 and S11 to position 1

Set log. exp. switches on Z-2, Z-3, and Z-5 to exp.

This completed the gain adjustment.

Scale Factor and Offset Adjustment

Turn function switch to test, switches S1, S21, S41, and S61 to position 2

Adjust R111 to give a B/A reading of 0.75 on M1

Short circuit point A to point D with a jumper lead

Short dircuit point B to point C with a jumper lead

Turn S7 to position two.

Connect a differential meter or oscilloscope between Z-2 pin 10 and point C.

Adjust R160 for least deviation from a constant value while rotating R117 from end to end and Z-1 Amp #1 for least derivation from zero.

Remove meter or oscilloscope, set S-7 to position one and adjust R162 for zero indication on the front panel ρ meter

Remove jumpers, return all switches to position one

With a diffused lamp illuminating the aperture of the sky looking telescope adjust R10 and R30 for equal outputs on their slides

Move the lamp to the other aperture and adjust R50 and R70 fo equal outputs. If this is not attainable gain adjustment of the P.M.T. channels has to be made first.

6.1 GAIN ADJUSTMENT OF PMT CHANNELS IN INSTRUMENT

Front panel settings

Function switch	Off
Bandwidth switches	Any
Oscilloscope	Off
Sens.	0.02/cm

Turn function switch to STBY and allow at least thirty minut warmup. R20 and R25 maximum cw. Oscilloscope test probe A-3-4. Substitute decade resistance box for R2

Function switch to test

Adjust resistance box for V p-p on the oscilloscope

Function switch to STBY

Note decade box reading and obtain and connect precision resistor of the noted value for R2

Substitute decade resistance box for R1

Oscilloscope test probe to A-2-4

Function switch to test

Adjust decade resistance box for V p-p on the oscilloscope

CAUTION: DECADE BOX MUST BE FLOATED AT -2.5kV FOR THIS TEST

Function switch to STBY

Note decade box setting, obtain and connect appropriate precision resistor for R1

Function switch to test

Further equalize gain by comparing the voltages at A-2-4 and A-3-4 and trimming for equal output with R20 and R25

Function switch to off

Remove test probe

7.0 SYSTEM ACCEPTANCE TESTS

7.1 ACCEPTANCE TESTS PROCEDURE FOR FRAUNHOFER LINE DISCRIMINATOR

7.1.1 General

The Acceptance review of the Fraunhofer Line Discriminator (FLD) will be attended by representatives of NASA, the Geological Survey, the Illinois Institute of Technology Research Institute. Outdoor tests will be conducted on a reasonably clear and cloudless day.

7.1.2 Information

The following information was received by the attendees prior to the acceptance tests.

a. Curves verifying absolute transmission (percent versus wave length of both Fabry-Perot filters. Performance was verified with a calibrated monochromator capable of 0.1Å (one-tenth Angstrom) spectral resolution. Transmission curves included both principal and adjacent orders within 20Å of the center wavelength of each filter.

b. Data indicating spectral shift in either center wavelength or finesse due to change in temperature for both Fabry-Perot filters.

7.1.3 Sensitivity Test Arrangement

Figures 10 and 11 show the arrangement which will be used for acceptance tests at the Perkin-Elmer plant. The test equipment consists of a light tight wooden box which is painted matt black inside. The sides of the box will be removable. The box has a 45 degree surface covered with a white non-luminsecing diffuser 1103 to reflect incoming sunlight into the ground-looking window of the instrument.

The sun-looking window will be directed upward toward the sky. The FLD will stand vertically (see Figure 10), and the box on which it is mounted will be rotated as the sun angle changes in order to maximize the time during which tests can be made. The mounting box will be equipped with a sun shade and a DC powered tungsten lamp, location 1102, both of which can be installed or removed as required. A power control will permit the intensity of the tungsten lamp to be regulated.

7.1.4 Required Sensitivity Tests Procedure

All mechanical, optical, and electronic elements of the FLD will be operated during the required tests.

Step a. - The shade and lamp will be removed from the mounting box and a calibrated light meter will be used to measure the incident solar radiation at the ground-looking window at the time the test is performed. (This measurement will help to compensate for any local atmospheric conditions that may affect the intensity of the solar radiation at the time of the tests.) The calibrated meter will be provided by the Government. A neutral density filter will be placed in front of the ground-looking window; this filter will have sufficient absorption that when used with the white diffuse reflector, the combination will simulate a ground reflectance value of less than 50 percent at the aperture of the instrument. The gain of the D channel signal will be monitored to ensure that saturation does not occur for reflectance values below 50 percent, and this gain setting will be noted. The sunlight opening will then be closed with the sun-shade. The lamp will be installed and its current adjusted until the D channel signal indicates either 0.14 times its former value or that fractional part of the calibrated light meter reading which is appropriate to achieve 5.8 x 10^{-11} watts/CM^2/Å/degree of arc. (0.14 times its former value would be appropriate if published values for the solar flux are used for the reference level; this choice will be made at the time of the tests.) This lamp adjustment will be noted and subsequently used to simulate the required fluorescence level.

Step b. - With the lamp operating and the sun-shade remaining in position, the sides of the mounting box will be removed, permitting skylight to illuminate the white diffuse reflector. (In effect, this will superimpose a Fraunhofer spectrum on the simulated fluorescence signal from the lamp, and the combined signals will represent an operational condition under which the contractually - required minimum detectable luminescence signal, 5.8 x 10^{-11} watt/CM^2/Å/deg., is superimposed upon a ground-reflected signal.) The ρ output of the FLD will then be recorded.

Step c. - The lamp will then be turned off to simulate a zero-luminescence condition and the noise level on the ρ output of the FLD will be recorded.

Detection of the contractually - required radiation level will be considered adequate if the ρ signal recorded in step b has at least a 2:1 signal to noise ratio, as read on the FLD panel oscilloscope, compared with the ρ signal recorded in step c.

7.1.5 Environmental Tests

The environmental tests will be performed as required in paragraph 2.0, Appendix V of the contract.

7.1.6 Desired Sensitivity Test - Detection of emission of Rhodamine dye in fresh water

Weather permitting, tests will be conducted with Rhodamine WT, a dye with emission properties identical to Rhodamine B, but with higher stability and insignificant absorption qualities. The FLD will be set up out of doors in sunlight at a convenient distance from a suitable tank which will be provided by the USGS. The bottom and sides of the tank will be painted flat black to reduce reflected light.

The tank will be placed on a utility cart and filled with fresh water. The water will be permitted to stand overnight in order to reduce chlorine content. (Chlorine has a quenching effect on rhodamine emissions.) In preparation for the tests the long dimension of the instrument will be oriented parallel to the sun's rays. The ρ output of the instrument will be read to establish a background noise without dye emission. Next, dye will be inserted in a quantity sufficient to achieve a concentration of 5 parts per billion by weight and the instrument ρ output read again.

Sufficient dye will then be added in several steps to achieve higher concentrations as results indicate until a ρ signal significantly above the noise level is detected.

The dye will be provided by the USGS. A suitable outdoor site, utility cart, instrument mounts, and a suitable power supply will be furnished by the Perkin-Elmer Corporation.

7.2 SYSTEM ACCEPTANCE TEST Reference Record 1a, 1b, 2a, 2b, 3a, 3b. 4a. 4b and 5a.

7.2.1 General

After a final adjustment following the procedure outlined in paragraph 6, the acceptance test was scheduled. The weather was finally acceptable on the twenty-eight of March. Mr. William Hemphill and Mr. F. Gilpatrick, both from USGS, witnessed the tests and had the authority to accept the instrument on behalf of the NASA office.

7.2.2 Threshold Tests

The D signal was attenuated by a factor of 2 and measured to be 4.25V. It was shielded from direct sunlight; and the B/A ratio was 0.92. The box was closed and the angle of the diffuser was set to accept light from the tungsten lamp. (Note: For all the tests the test fixture as illustrated in Figure 12, were used.

References recordings 1a and 1b.

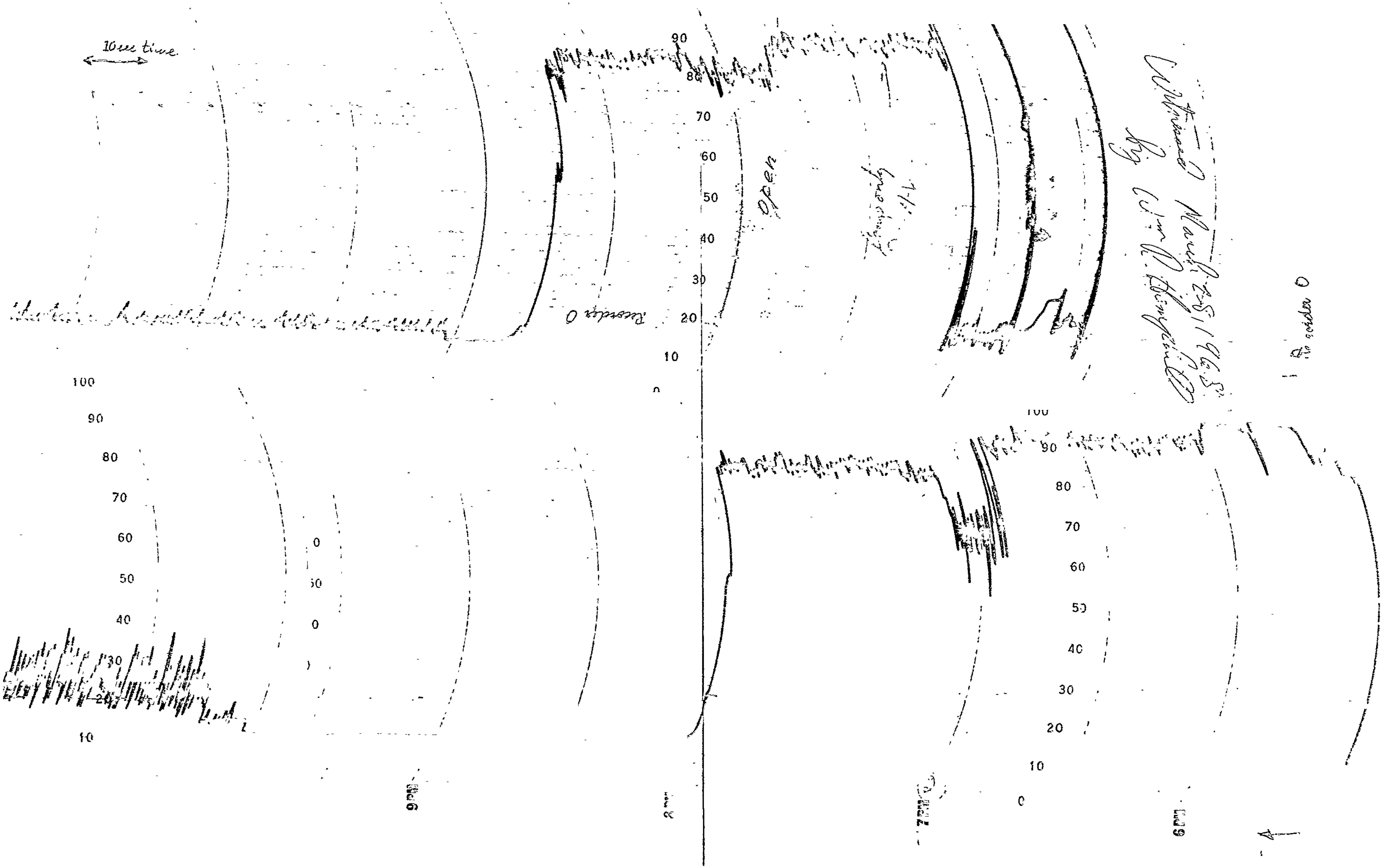
Note: All ρ values are noted in scale intervals of 415.

(1) The D was set to 0.39V. This resulted in a ρ output of 1.0.

(2) The box was opened and the diffuser 1103 shielded from direct sunlight. The ρ was found to be 0.88 and the B/A ratio was 0.93. The light was then turned off and a slightly negative ρ was indicated on meter 415.

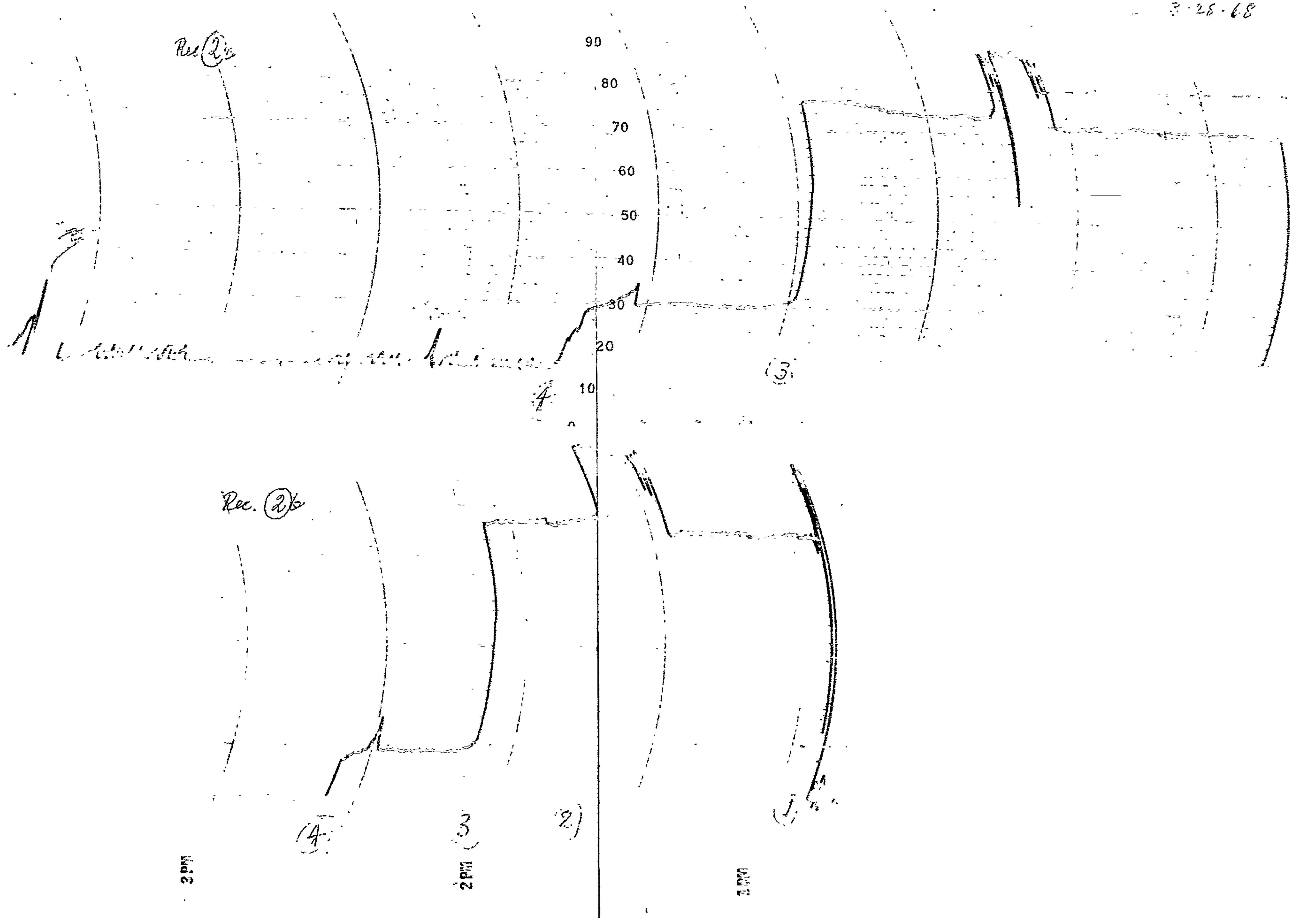
(3) The box was closed and the ρ showed a negative value; B/A was 0.96.

(1)a MADE IN U.S.A. ESTERLINE ANGUS INDIANAPOLIS, IND., U.S.A. G



Witnessed March 25, 1963
by Wm. R. Dingfield

[illegible] INDIANAPOLIS, IND., U.S.A. CHART No. 4313-C
3-28-68



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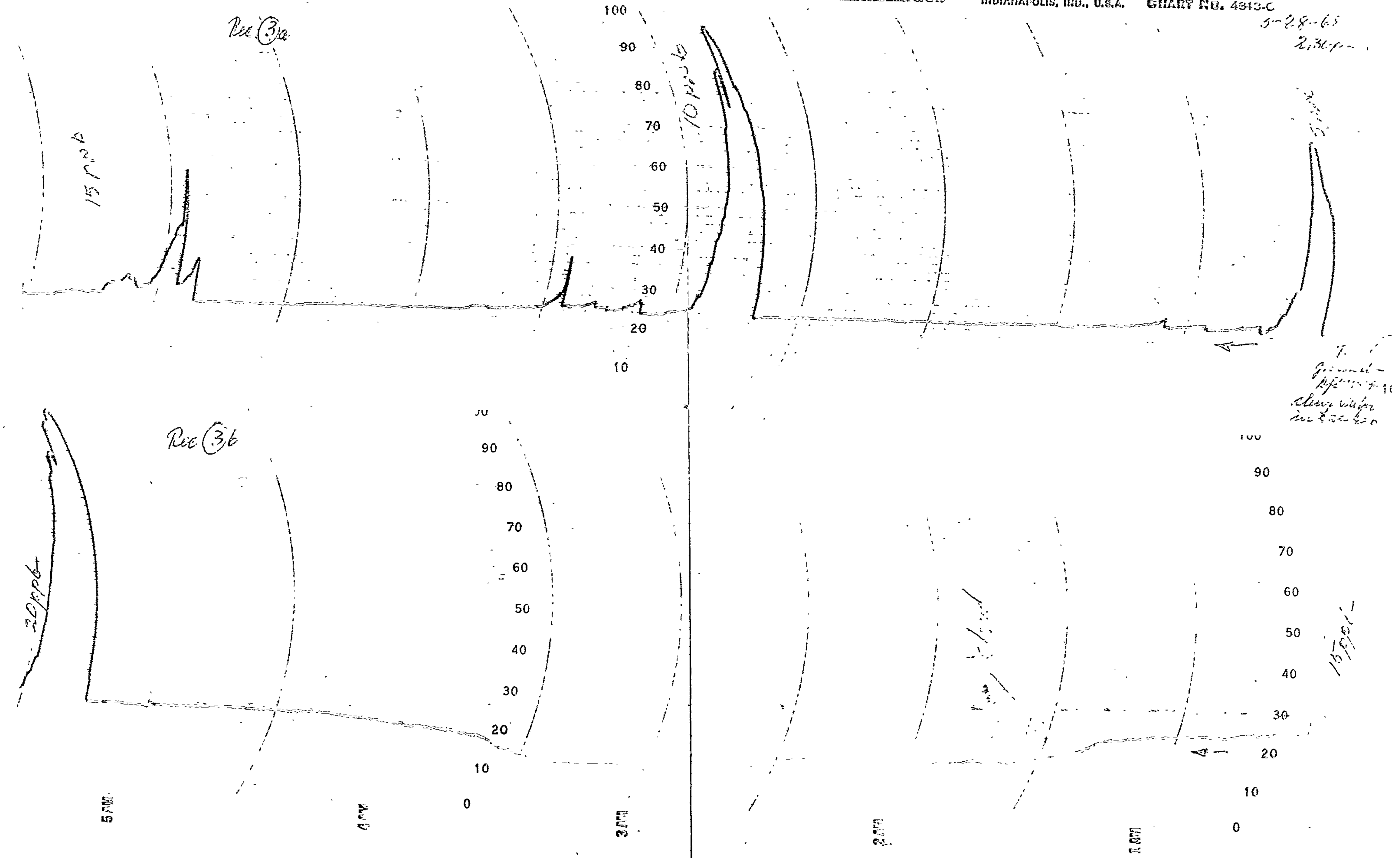
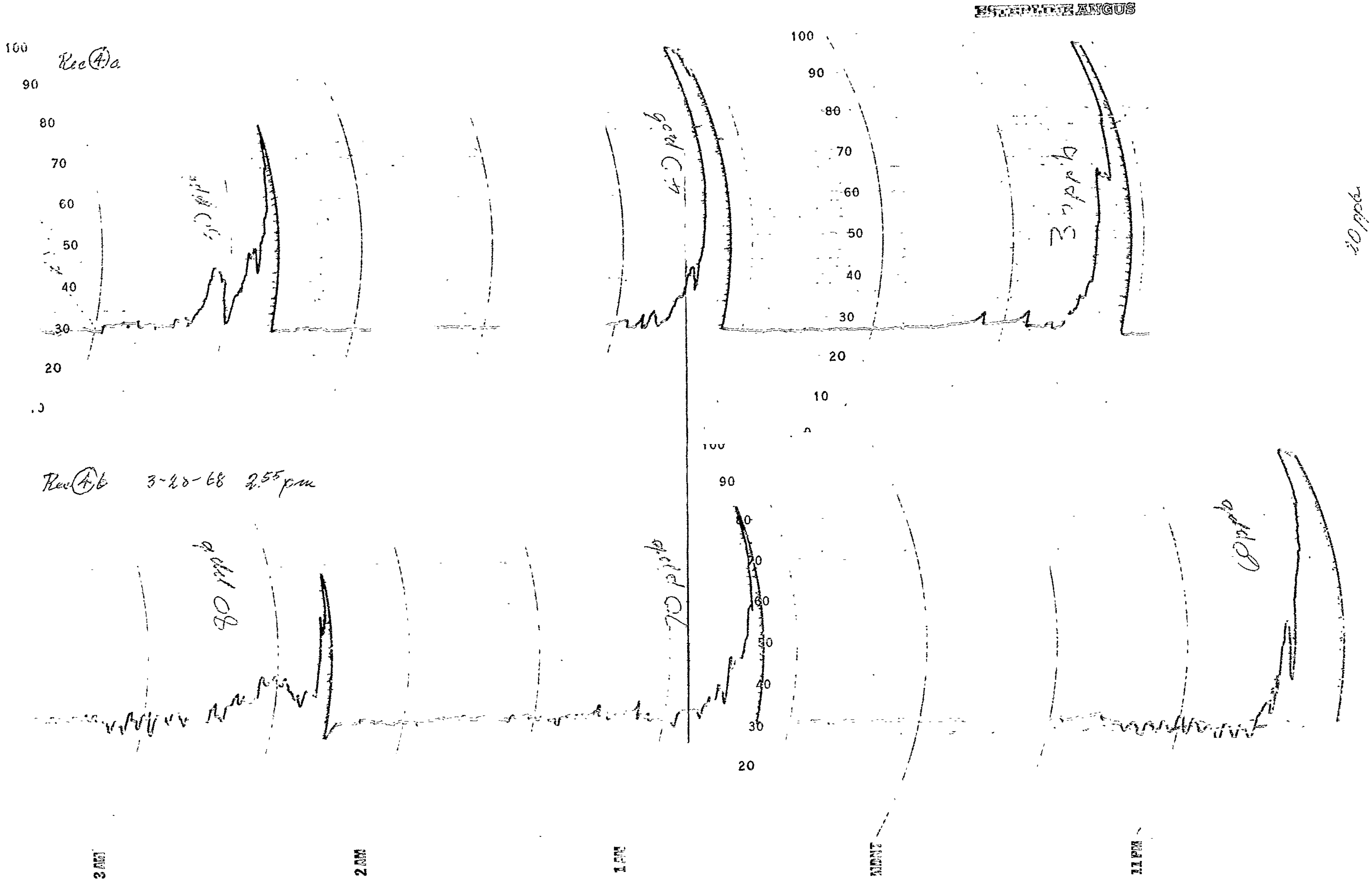
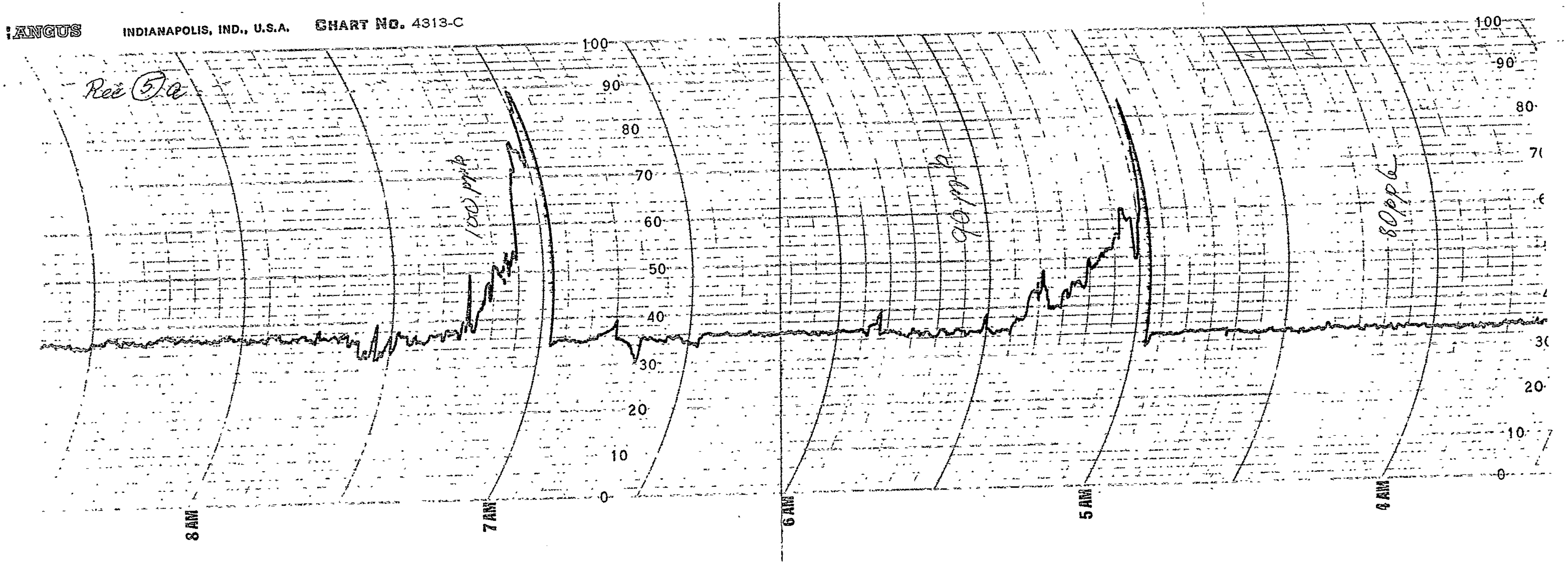
5-28-65
2:30 pm




ESTERLINE ANGUS
Rec ④a
Rec ④b 3-28-68 2.55 pm
100
90
80
70
60
50
40
30
20
10
0
40 ppb
3 ppb
10 ppb
80 ppb
70 ppb
8 ppb
3 AM
2 AM
1 AM
MIDNT
11 PM

Rec ⑤a



100 ppb

90 ppb

80 ppb

(4) A recheck was made of the D signal and was found to be 5V indicated by an instrument connected to plug 409.

A slight negative ρ indication was present and the offset was then adjusted and the test continued.

The diffuser 1103 was attenuated by a factor of 2. D was found to be 5V; direct skylight was shielded. The box was closed and the angle of the diffuser 1103 changed to accommodate the tungsten lamp 1102.

The following points refer to recordings 2a.

(1) D was set to 0.5; B/A was read to be 0.87. These readings are meter readings on 414. The indicated ρ was 0.67.

(2) All covers were removed and the diffuser shielded from direct sunlight. ρ was found to be 0.75 and B/A was 0.86.

(3) The light was turned off and ρ was indicated to be 0.1. The B/A was 0.86.

(4) All covers were put back on and ρ showed a slightly negative value. (Recorder zero line at 20 for all recordings.)

At 11:40 a.m. a new threshold test was started which references recordings 2b. The D signal was found to be 4.8V with the diffuser shielded from direct sunlight and attenuated by a factor of 2. The box was then closed and the angle changed to the diffuser to accommodate the tungsten lamp. See Recordings 2b.

(1) D was set to 0.48 by changing the lamp current. B/A at this time was 0.87 and the indicated ρ 0.80.

(2) The covers were removed and the diffuser shielded from direct sunlight. The ρ indication was 0.83; B/A was 0.87.

(3) The light was turned off. The indicated ρ was 0.12 B/A at this time was still 0.87.

(4) The covers were put on. ρ was -0.05 leaning slight below 0 on the indicator; B/A had shifted slightly to 0.88.

The specifications call for a threshold measurement as describe above to be at least twice the noise in the ρ indication at 20 cps bandwidth. The actual measurement show that this specification has been met.

7.2.3 The specifications call for a desirable test which was made by using a water tank of 2 feet x 2 feet x 6 feet, painted inside black, and filled with clear water to 1/2 meter depth. The water was then made fluorescent by dissolving various amounts of Rhodamine dye.

The weather conditions changed to the worse; more haziness appeared in the clouds. A water test was made which showed at about 40 ppb concentration, a distinct increase in indicated ρ. The test was conducted up to 100 ppb concentrations.

The conclusion of this test was that the test should be repeated when the weather conditions were better. The test was repeated at 2:30 p.m. that same afternoon and showed results which are recorded in the following:

The test fixture was set on the water tank so that the ground looking telescope pointed toward the sunlit water in the tank. (Diffuseer 1103 removed.) The tank was filled with fresh water. The following list indicates ρ, the B/A ratio, and the A signal as indicated by a voltmeter plugged into outlet 409. Note recordings 3a, 3b, 4a, 4b, and 5a. The recordings were made at the same time the readings on meters 415 and 414 and the A signal.

The readings are listed on the following table:

Rhadamine in ppG.	ρ Intervals	B/A	A Volts	Remarks
Fresh Water	0.08	0.82	1.03	Rec. 3a
5	0.09	0.83	1.00	
10	0.09^{+}	0.835	0.98	
15	no R.	no R.	no R.	Rec. 3b Cloud
20	0.10	0.85	0.80	Rec. 4a Cloud
30	0.13	0.85	0.92	
40	0.15	0.85	0.90	2.45 p.m.
50	0.16	0.85	0.75	
60	0.185	0.86	0.70	Cloud Rec. 4a 2.55 p.m.
70	0.20	0.86	0.78	
80	0.24	0.86	0.77	
90	0.26	0.86	0.75	Rec. 5a
100	0.275	0.85	0.74	

The water temperature was found to be +45°F at the end of the test at 3:40 p.m. The remaining available solution of water was mixed with the water. The ρ indication was 1.0; B/A at this time was 0.87 and the A signal was found to be 0.55V. The low magnitude of A was due to the time of the measurement. It can be seen on the recordings 3b and 4a that the ρ value was obscured at times. Clouds were covering the sun. It can also be seen that these are excellent results since a threshold of 5 ppb was recorded at a B/A ratio of 0.83 which is typical for Connecticut weather conditions at the time of these tests. On clear days the B/A ratio was found to be 0.75 to 0.7 which would decrease the noise.

8.0 AIRBORNE FRAUNHOFER LINE DISCRIMINATOR STORAGE PROCEDURE FOR END ITEM

8.1 GENERAL

The End Item is shipped in wooden boxes made from 1/2 inch navy plywood with stiffened edges. The container has two handles for easy transportation. The cover plate is screwed on for easy removal of the instrument. There are two boxes - one, for the electronics; one, for the instrument. The larger box, to be approximately 30 x 30 x 20 inches high, houses the electroni console. This box has a compartment for the 10-foot connecting cable and the cable for the prime power of 115 V 60 cycle. The boxes have soft padding inside to avoid vibration or shock damage to the equipment.

The instrument shall be stored in the provided wooden container, which is approximately 12 x 18 x 22 inches high. This box is also wrapped in soft padding.

When the system is not in use the instrument as well as electronics console and cables should be stored in the shipping containers provided, to avoid physical damage. Storage temperature should be limited to 0°C to +50°C. After each flight, the pressure release button on the instrument should be depressed in order to make sure that atmospheric pressure is regained in the instrument metal housing.

The instrument housing contains, behind the pressure relief valve, a dessicator. After long periods of storage, the instrument box should be opened in a room containing air below 50 percent humidity and the Silica Gel replaced if the blue color has changed to pink. The electronics console should be stored in dry air environment. Dessicators should be placed in the shipping container inspected and, if necessary, replaced periodically.

9.0 SUN TARGETS AND SCALING OF THE SYSTEM

Perkin-Elmer has experimented with several different types of sun targets.

9.1 SUN TARGETS

We have made one sun target (No. 1) which projects a ten inch diameter disc painted matte white and containing a 2 1/4 inch hole in the center. Light striking the upper surface of the disc is directed by means of a convex first surface mirror into the upper window of the instrument to create the A & B signal A second sun target (No. 2) consists of a large tube polished on the inside with Plexy-glass windows at the top and the bottom of the tube. The lower window is frosted. A third sun target (No. 3) consists of parts of a fish eye lens. We have also tried such simple sun targets (No. 4) as frosted glass plates or opaque plates.

We found that any omidirectional sun target which would not require mirror adjustment becomes inefficient at low sun elevations. This deficiency can be compensated for to a certain degree by adjustment described later under scaling of the system.

Perkin-Elmer will deliver all the sun targets including experimental targets which were made with the instrument for use as the observer ma require for different weather conditions.

Our experiments showed that the entrance aperture of the sun-looking telescope should be evenly illuminated; it is, therefore, advisable to use sun targets which have diffuser plates incorporated. At high sun angles the simple frosted or opaque glass used as sun target is sufficient.

Sun targets No. 2 and 3 are less efficient than No. 1.

9.2 ρ FACTOR SCALING

The scale factor voltage applied to Z-5 in the computer is based on the 4:1 beamsplitting in the optics and the present selection of full scale deflection for a ρ of 0.5 (i.e., the output voltage is equal to 20ρ). The beamsplitting of 4:1 assumes a 100 percent efficient sun target. For any other target efficiency, therefore, allowance must be made for the scale factor which may be corrected to 0.5ρ equals full scale by resetting R114 to a voltage proportional to the efficiency of the sun target where 100 percent equals 10 volts. If the scale factor is not adjusted as suggested above the full scale reading on the meter no longer represents 0.5ρ. Note: 0.5ρ x target efficiency = full scale. For the effects of such targets on signal-to-noise ratio and detectivity see Perkin-Elmer Report 8916, page 10.

10.0 OPERATION & MAINTENANCE

10.1 INSTALLATION INTO THE AIRCRAFT

The instrument must be installed so that the upper window points toward the sun target and the lower window points toward the floor opening in the aircraft. The installation of the sun target requires an adapter ring which should be fixed by appropriate means to the top of the cabin of the aircraft. The ring in which the sun target is mounted is shown in drawing No. 625-2019-2 with six screw-holes for the location of the different sun targets which are delivered with this instrument.

The instrument box contains shock mounts on mounting plate 102. The natural frequency of the mount plate is on the order of 13 cps. The windows in the instrument box are large enough to permit soft mounting of the instrument; however, it is not required.

A ten-foot cable is delivered with the equipment to serve as a connecting cable between the electronic console and the instrument itself. A second ten-foot cable connects the electronics console to the aircraft 115V, 60Hz power source.

The electronics console can be mounted in any convenient location in the aircraft, preferably where the operator can see the sun target to check proper illumination. It is required that the electronics console be soft mounted. The use of foam rubber or other suitable material is recommended to cushion the console with respect to the mounting frame in the aircraft. The best way to mount the console would be to have a framework surrounding the console and to have a foam rubber cushion at least two inches thick between the hard mounted frame and the outside of the console.

10.2 POWER REQUIREMENTS

The only power required to operate the Airborne Fraunhofer Line Discriminator is 115-volts, 60 Hz. The maximum power input with all the heaters in operation will be approximately 500 watts, of which 300 watts are for heating.

10.3 OPERATION OF THE INSTRUMENT

First: Turn the Main Switch on the console, No. 411, from OFF to STANDBY. This will activate all the heaters and warm the amplifiers to stable operating temperature. The warmup time depends on the environmental temperature but should not be shorter than one-half hour.

Second: Turn the Main Switch to the ON position and one step further to TEST. At the test position meter 414 should read between 0.9 and 1.0 for the B/A ratio. Turning the switch to test position activates the whole system. The calibration lamp indicates proper operation of the system.

The next step is to switch to the ON position. Operation of the system can now begin.

If recording of data is required, phone jacks 402 and 403 are available for the B/A ratio and ρ recording. 10 volts full scale at 9 ma maximum are available at the phone jacks. Recorders for B/A and/or ρ may also be connected to pins n and q respectively on the rear connector. The separate A, B, C and D signals at the front panel may be measured and recorde with instruments with no less than 2000Ω input impedance. A, B, C and D are approximate signal values (±10 percent).

10.3 Maintenance

In case of malfunction refer to this troubleshooting chart.

Function	Symptom	Possible Cause	Corrective Action
STBY	Temp. ind. show no change	60 cps power off. Instrument not connected. F1, F2 blown. Sensor open. Heat controller defective	Check prime power-check cable connectors. Check fuses. Measure resistanc at Terminal board in instrument. Return to P.E. for repairs
	Meters show no indications	60 cps power off. F4 blown. ±15V power supply defective	Apply prime power. Check fuse. Check for ±15V at P.S. connector if defecti return to P.E.
	No trace on scope	60 cps power off. ON OFF switch on scope off.	Apply prime power. Power switch located on scope to ON
		Trace off scope	Turn vert and hor. gain max. ccw. locate trace with hor. and vert. pos. (approx. midway)
		Intensity too low. Fuse blown. Connector off. Scope defective	Adjust intensity. Check fuse. Check connector. Return for repair
ON	No double trace on scope	Chopper motor not running	Check motor voltage, capacitor
		Ref. lamp not on	Check +28V, F3, lamp bulb. Check square wave output from A-1. If none exists return for repair
	ρ indication saturated	Check position of switches. S1, S21, S41, S61, S5, S6, S7, S8, S9, S10, S11	Set all switches to Pos.
	B/A inoperative	Filter temperature not stabilized	Allow temp. indicators to reach white zone

Function	Symptom	Possible Cause	Corrective Action
		Light input too low	Check that window is unobstructed and sun target in order. Tp. A and B sh have approx. .2V min.
		Internal switches in wrong position	Check S1, S21 and switche on Z1 and Z3
		Meter or meter connections defective	Check B/A output at phone jack (1 volt/.1 ma)
		No high Voltage	Check for H.V. in Instru.
		Z3 defective	Check RIII slider for +10V Check Tpx for approx -60 m Check connections at Z3 socket. If Z3 is found defective return for repai
		Z1 defective	Check connection at Z1 socket. If Z1 is found defective return for repai
		Meter amplifier defective	Check for B/A output at Z-3-9. Check connections to A-7. If faulty compone is not located return for repair
ON	ρ Indication defective	Ref. output missing	Check for square wave outpu from A-4 in instrument. If no output check reference light source, diode, amplifier and connections
		No light input	Check that instrument windo is unobstructed
		Filter amplifiers defective	Check C and D output at Pa If none check C and D input at amplifiers. If amplifie defective return for repair
		Computer defective	Check connections and switc positions. If a computer element is defective return for repair
Test	B/A indication ther than 1±.1	Test lamp not on	Check bulb
		Other causes and procedures as under ON.	

11.0 RECOMMENDATIONS

This chapter contains recommendations concerning operation, service and future systems.

11.1 This will be the very first airborne instrument to employ the Fraunhofer Line technique to sense solar stimulated fluorescence. During the design, considerable care and attention were taken in order to minimize known sources of electrical or optical errors. For example, in order to minimize the effect of rapid spectral changes in the background radiation, the two filter packages have been made with components as nearly identical as possible, with minimal response in the wings of each filter and with the centers of the two filters separated from each other by only a few angstroms. Similarly, compute errors have been reduced until they are comparable to the system shot noise. This was done by the use of a constant temperature thermal enclosure and an adjustable correction system for the critical analog units. However, the unexpected should be anticipated, particularly with the first-of-a-kind airborne unit which does not have even a close relative in the laboratory. If any unexpected limitations are discovered during testing and use of the equipment it is essential that these be clearly identified and documented so that second generations of this equipment can be constructed to take full advantage of this very new and promising technique.

11.2 The instrument was designed to operate on a clear sunny day with a maximum variation in solar intensity of about 3 to 1. During the acceptance testing in New England in January and February, much larger variations than this were noted with a barely discernable amount of cloud. If the number of sunny days sufficiently clear for operation proves prohibitively small in practice, then a number of solutions is possible. These include:

11.2.1 A gain control (automatic or manual) on the high voltage power supply which will keep the level of signal A seen by the computer at a constant value and will scale the other signals proportionally.

11.2.2 A clamping circuit on the A-B value in the computer so tha a wisp of cloud momentarily reducing the A and B signals does not produce an inordinately large fluorescence signal as a result of the $(A-B)^{-1}$ normalization factor. The clam would have to have a time constant long compared to cloud induced variations, but short compared to normal variation in solar intensity

11.2.3 Manually adjusted A-B and B/A computer values to be monito and adjusted by a human operator.

11.2.4 Very low frequency response A and B filter amplifiers.

11.3 Since spurious high fluorescence readings are possible when A and B signals become very low due to clouds it is probably desireable to monitor either A or B together with the fluorescence signal so that data can be inte preted unambiguously and corrected if necessary. Similarly, when the scope is being used to read fluorescence, a separate meter or panel light indication of the amplitude of A would be helpful in distinguishing cloud induced anomalies from legitimate high fluorescence readings.

11.4 The filter temperature indicators indicate a go-no-go condition but not the actual temperature deviation. A lamp to indicate whether the heater current is off or on would certainly be just as informative and significantly cheaper. Most preferable (and most expensive) would be a meter to indicate directly the temperature error in degrees.

11.5 During the initial testing of the instrument it was noted that the B/A ratio was a function of the portion of the telescope aperture receiving illumination. The difficulty was traced to a marked nonuniformity on one of the photocathodes. It was minimized by rotating both phototubes ir their holders. In the event that phototube removal is necessary the same procedure should be employed to minimize the B/A variation.

11.6 The calibration lamp is mounted in a spherical socket so that it can be easily adjusted. It has been found that slight motions of the lamp produce variations in the A and B signals and also in the B/A ratio. This is probably partly attributable to the small size of the calibration lamp lens when imaged on the filters and to nonuniformities in the filters and photo-cathodes. The latter are known to be very non-uniform. It is, therefore recommended that a well diffused external tungsten source be used whenever it is desired to set the gains in A and B channels equal and that the calibration lamp be used only as a secondary reference.

11.7 The sensitivity of the phototubes can be drastically altered by overexposure to light when the high voltage is on. Care should be taken to avoid this condition by ensuring that either the solar target or the light cap is in front of the solar window and that the ground looking window is never turned upward towards the sun. Recovery can take as long as 24 hours. It should be found by experience in the field if protection devices for the photomultipliers, preventing intense light exposures, are required.

11.8 During the few occasions when the B/A ratio has been monitored considerable variation, ranging from 0.7 to 0.9, has been noted. The reason for this variation is not fully understood. Possible there is some fluorescence in the atmosphere or perhaps there is sufficient sodium contained in the salt nuclei of maritime air masses to selectivity emit Na_D. A correlation of B/A with weather conditions and perhaps with ambient temperature should be attempted. To reduce the B/A ratio better filters may become available in the near future.

11.9 The need for temperature control of the analogue computer elements was not established until after the design was complete. As a result, many of the test points and bias adjustments in the computer are difficult to reach. It is suggested that considerable attention be paid to the layout of the logic in any future instrument and that key test points and adjustments be made accessible without the need to remove a heater cover.

11.10 Consideration should be given to single photomultiplier operation of future instruments. This could be achieved by a second chopper arranged to expose the single photomultiplier to first the light beam which has passed the D_2 filter block and then to the light which has passed the C filter block. The principal advantage would be an independance of nonuniformity of the photomultipliers and the effect of gain changes would be minimal.

11.11 Larger optical apertures should be considered. (Greater optical transmission efficiency is by the present state of the art not achievable.) The resulting higher light levels at the photomultipliers would better the signal to noise ratios. Signal to RMS noise ratios are as computed, however it is the signal to peak noise which the eye recognizes when viewing the ρ oscilloscope display.

11.12 Presently, A,B,C, and D signals are derived internally. The incorporation of convenient means to apply such externally derived signals would allow a more rigarous adjustment. Additional front panel controls to allow critical parameter adjustements during operation should be considered. See 11.2.3.

11.13 Increase of the efficiency of the sun target would help to reduce the noise in signal. After field tests it may be found that a change in ratio of optical efficiency between ground looking and reference light is desirable.

11.14 Since it is not contemplated to use the system on board of a fast flying aircraft, it should be considered to set the bandwidth at a fixed value of about 2 cps.

11.15 Operational use of the system may very probably indicate that the present scope presentation of ρ is not very useful, it should be changed to a fast sweep or eliminated completely.