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LABORATORY EVALUATION OF FECKER AND LORAL OPTICAL IR PWI SYSTEMS

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16. Abstract

Flight hardware and a flight test evaluation of two Electro-Optical Pilot Warning Indicators, using a flashing xenon strobe and silicon detectors as cooperative elements, were prepared by the previous NASA group prior to the closure of ERC in June 1970. Several design deficiencies are pointed out. The present laboratory evaluation program, which provides the ideal environment for performing the most detailed studies of the PWI system, has corrected these faults which prevented the equipment from operating, and has calibrated the sensitivity of both systems in azimuth elevation and range.

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LABORATORY EVALUATION

I. INTRODUCTION

The closure of ERC in June 1970 brought into focus several programs which would be completed by the Dept. of Transportation Systems Center. Pilot Warning Indicator systems using a flashing xenon strobe and silicon detectors as cooperative elements was one of these programs. Flight hardware has been delivered and a flight test evaluation on two Electro-Optical Pilot Warning indicators has been prepared in FY 1970 by the previous NASA group.*

The flight test results clearly pointed out several design deficiencies which prevented a complete evaluation of the equipment on hand. The present laboratory evaluation program has corrected these faults which prevented the equipment from operating, and has calibrated the sensitivity of both systems in azimuth, elevation and range. These tests serve as a basis for the flight test simulation and plans. The measurement data will be used to refine the models of the alarm and hazard envelopes of the equipment.

The laboratory provides the ideal environment for performing the most detailed studies of the PWI system. The temperature and humidity can be controlled or held constant and atmospheric scintillation effects on the strobe emission are reduced to zero.

The laboratory tests were performed on an optical bench and consisted of three basic components:

(1) A xenon strobe lamp whose output is monitored at the PWI detector by a separate calibrated detector to give pulse to pulse information on energy content in the .8 to 1.1 μ region at the receiver.

(2) A strobe light attenuating optics which is calibrated photometrically to provide simulated range.

(3) A positioning table on which the PWI system under study is mounted. This table provides spatial location coordinates for all data points. A detector is used to monitor the pulse amplitude of the received IR energy.

The detectors are scanned to determine the sensitivity structure as a function of detector position and simulated range.

*Reference:

1. NASA: Flight-Test Evaluation, Two Electro-Optical Pilot Warning Indicators, National Aeronautics and Space Administration, Electronics Research Center, Cambridge, Mass., June 30, 1970.

II. LABORATORY EQUIPMENT MODIFICATION

Previous testing of the two PWI systems disclosed several problem areas which limited system performance. No changes to the optical designs were made because only a short time was available for modification. The modification program focused on "fixes" to the electronics and the following changes were made:

(1) Radio Frequency Interference (RFI).- One prevalent problem that existed in past tests was the activation of the indicator lights whenever the radio transmitter was turned on. It was determined that the problem was due to RFI interference. The problem was corrected in the lab by incorporating EMI line filters and appropriate shielding and grounding which will also be implemented into flight units. These modifications permit operation of a transmitter or chattering relay at any distance from the PWI without producing an alarm indication.

(2) Photo Diode Biasing Arrangement.- The original Fecker design called for a silicon photo diode back biased to about 150V. It was found that some of the diodes exhibited breakdown noise when operated in the dark. This behavior was found to be intermittent and was dependent upon the value of bias voltage. In every case, the bias voltage could be reduced to a value at which this effect did not occur. In order to avoid breakdown effects over a long period, the bias voltage was changed to 15 volts and the input circuitry was scaled down appropriately so that the same sensitivity was obtained over the same background range.

The reduction of bias voltage will allow the use of a photodiode with a smaller guard ring area so that the size of dead zones in the lobe pattern will be reduced considerably.

The new bias and Input circuitry is shown in Fig. 1. The reduced bias voltage specification on the diode will increase the reliability and will decrease the cost of the system substantially.

Frequency Response

The low frequency cutoff was raised to about 600 Hz for the Fecker unit to provide better rejection signals below 100 Hz such as propeller effects. This was achieved by changing the capacitors in the second stage of the amplifier as shown in Fig. 2.

The frequency response of the first and second stage before and after these changes are plotted in Fig. 3.

Cross Coupling Instabilities

It was found that the "turn on" and "turn off" of the display lamp of one channel would turn on a different channel so that, once started, the whole system would oscillate with a period of several seconds of no light input. This trouble was traced to the fact that the lamp currents were driven at logic level speeds. By placing a large capacitator (15 MF) across the input of the lamp driver, the higher frequencies of the current surge were surpressed and the system no longer responded to lamp "turn on" and "turn off".

Discriminator Level Setting

The last stage of the Fecker amplifier chain feeds directly into a level discriminator shown in Fig. 4.

Injecting a current pulse into the first stage of the amplifier will produce a voltage pulse at the input of the discriminator similar to the signal from the xenon strobe pulse. With the pulse height fixed at a given value, the level potentiometer is adjusted until the discriminator just triggers.

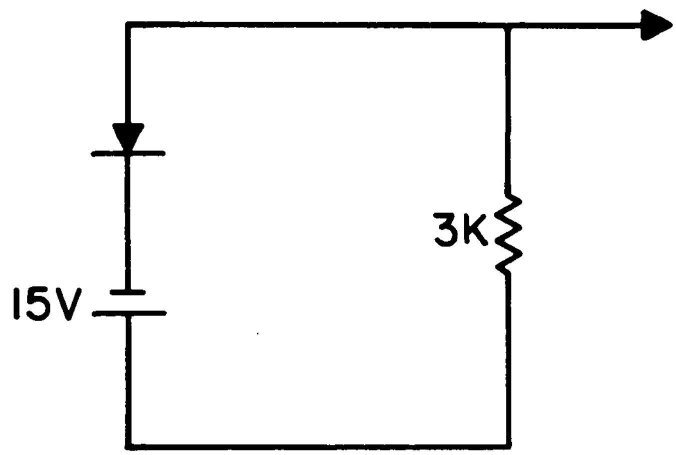


Figure 1

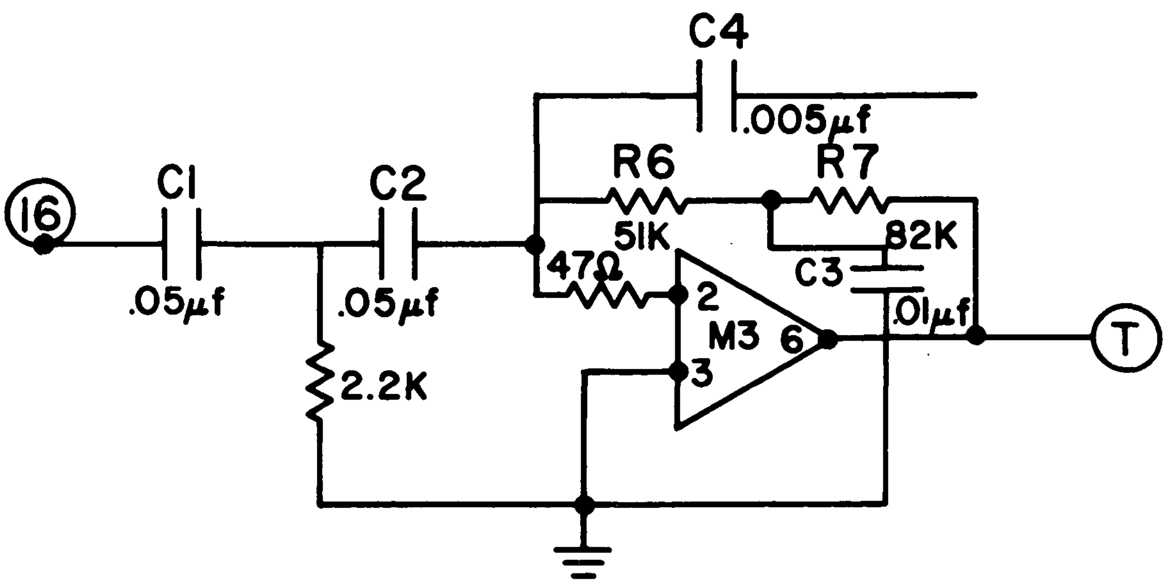


Figure 2

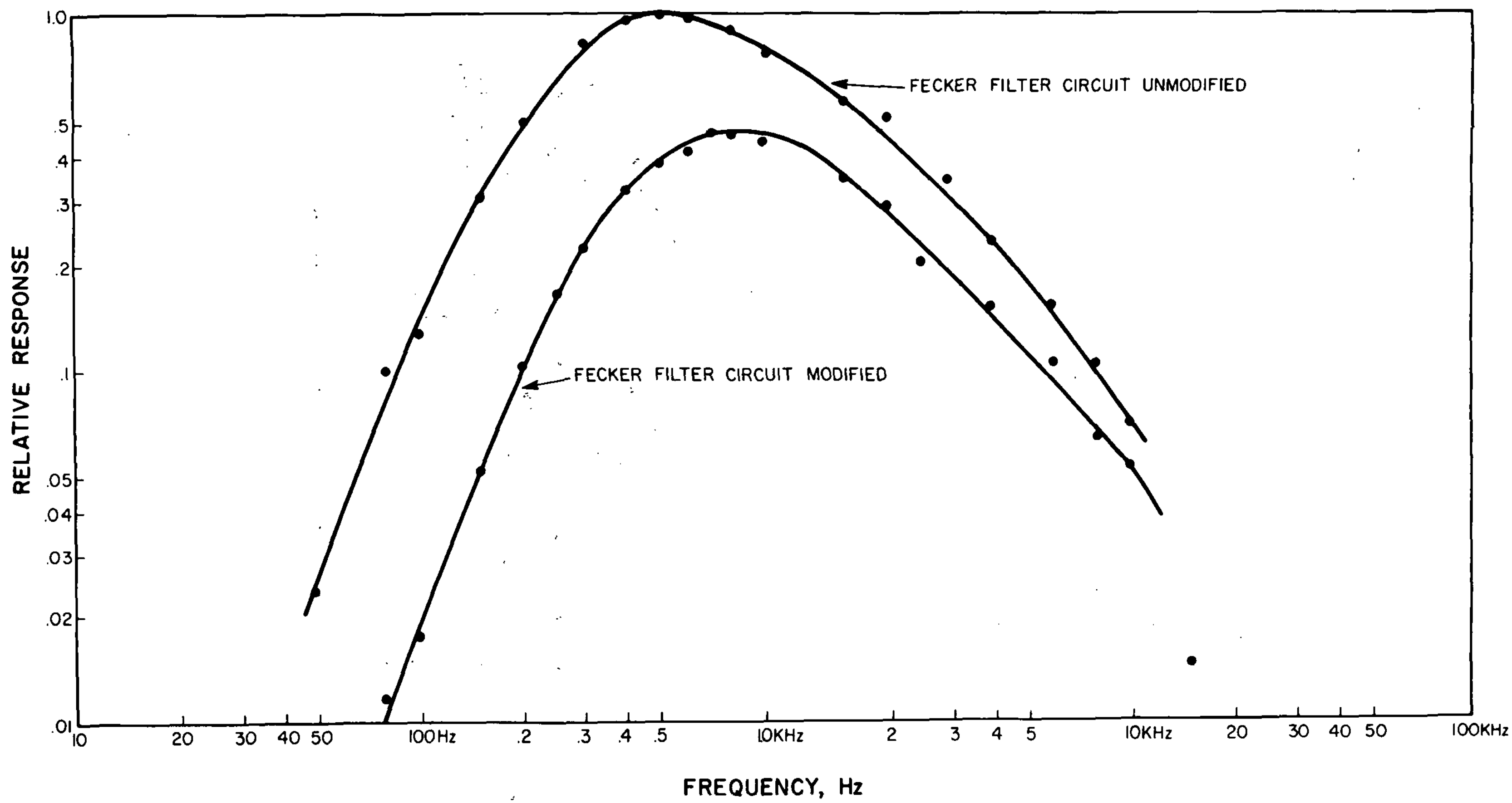

FECKER FILTER CIRCUIT UNMODIFIED
FECKER FILTER CIRCUIT MODIFIED
RELATIVE RESPONSE
1.0
.5
.4
.3
.2
.1
.05
.04
.03
.02
.01
10
20
30
40
50
100Hz
.2
.3
.4
.5
10KHz
2
3
4
5
10KHz
20
30
40
50
100KHz
FREQUENCY, Hz

Figure 3.

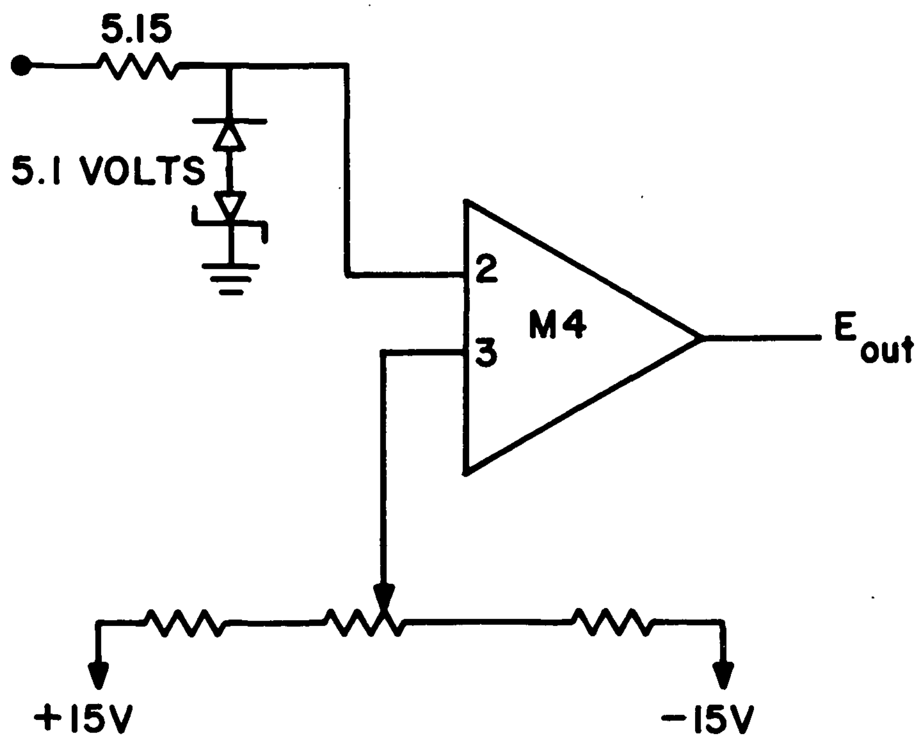


Figure 4

For the laboratory tests the levels were set for 4, 6, 8 and 10 volts, so that the lobe pattern which was taken at a discriminator level of 6 volts could be scaled if it were found necessary to change the level settings later in either the field test or the flight test.

Two changes were made to facilitate the level setting procedure. The last amplifier stage coupling to the discriminator was changed from Dc to Ac. This change avoided drift of the second stage which would be amplified by 200 times the gain of the third stage.

Video Test Points

Two video test points from each channel were brought out to a connector in the front of the Fecker Electronic processing unit – the input to the discriminator and the diode load resistor. The first point gives the signal and the second is a measure of the background.

Mechanical Modifications

To protect the Fecker Systems ball lens assembly from dirt and debris, a Plexiglas shield was designed and molded.

III. ROOF TOP TEST

As a first step in the PWI Test Program a simple roof top test was made from the roof of the 13 story Systems Management Building at T.S.C. The purpose of this test was to provide a realistic operating environment for the PWI so that bounds could be placed on the range of discrimination levels used for the laboratory test. The roof top test also determined whether there were any glaring deficiencies in the equipment which would have to be corrected before the test program began.

The roof top test was conducted on the roof of the Systems Management Building located near Kendall Square in Cambridge, Mass. From this location there are four different xenon strobe lamps in view. These lamps are affixed on buildings in Boston and all are within 2.5 miles of T.S.C. One Whalen strobe was placed on the roof of the State Street Bank Building in Boston by T.S.C. personnel. The State Street Bank Building is located about 1.8 miles from T.S.C.

Direct exposure to the sun would cause a number of channels to alarm. The noise level at the discriminator rose rapidly from about 3 volts P-P to 15 volts (the amplifier saturation voltage) as any channel was scanned from 30° off sun to full sun illumination. It was found that a discriminator setting of 6 volts would be enough to cause false alarms. At this level, detection of the Whalen lamp at 1.8 nm was marginal. There exists the possibility that the discriminator level may have to be lowered in the field tests.

IV. SPECIAL TEST EQUIPMENT AND CALIBRATION

Both the Fecker and Loral PWI systems use ball lenses coupled to discrete detectors and thus the range sensitivity of these PWI's are strongly dependent on the azimuth and elevation of the flashing Xenon source. To map out the lobed sensitivity patterns, a special test facility was constructed and calibrated. Under NASA/ERC the sensitivity tests consisted of simulating a single range (between 1300 and 1700 feet for the Fecker tests and between 8700 and 11500 feet for the Loral tests) for each azimuth or elevation scan and inferring an overall range capability from the single scan. The DOT/TSC laboratory tests were designed so that any range from 200 feet to about 6 nautical miles can be simulated. Conventional radiometers could not be used because of the extreme variation in range.

The output from the range simulator is range if one makes the following assumptions: (1) an inverse square fall-off of intensity, (2) no aerosol scattering or water-vapor absorption or scintillation, and (3) a value for the number of joules/steradian emitted by a Whalen lamp fitted with a Fresnel lens. The first two assumptions will be removed in the field tests when actual ranges and atmospheric paths are used. The third assumption will be removed in the near future when the lamps are calibrated. With the three restrictive assumptions, the laboratory measurement of the lobed sensitivity patterns is really a measurement of the fixed geometry or configuration of the optical sensors of the two PWI systems.

The major components of the Range Simulator are shown in the block diagram. Light from the Xenon strobe passes through a diffuser which was mounted in the lamp housing and then through a pinhole aperture. After passing through a series of irises to eliminate stray light, the slightly divergent beam enters the variable neutral density filter which is used to control the light flux. The attenuated beam then either fills the PWI optics

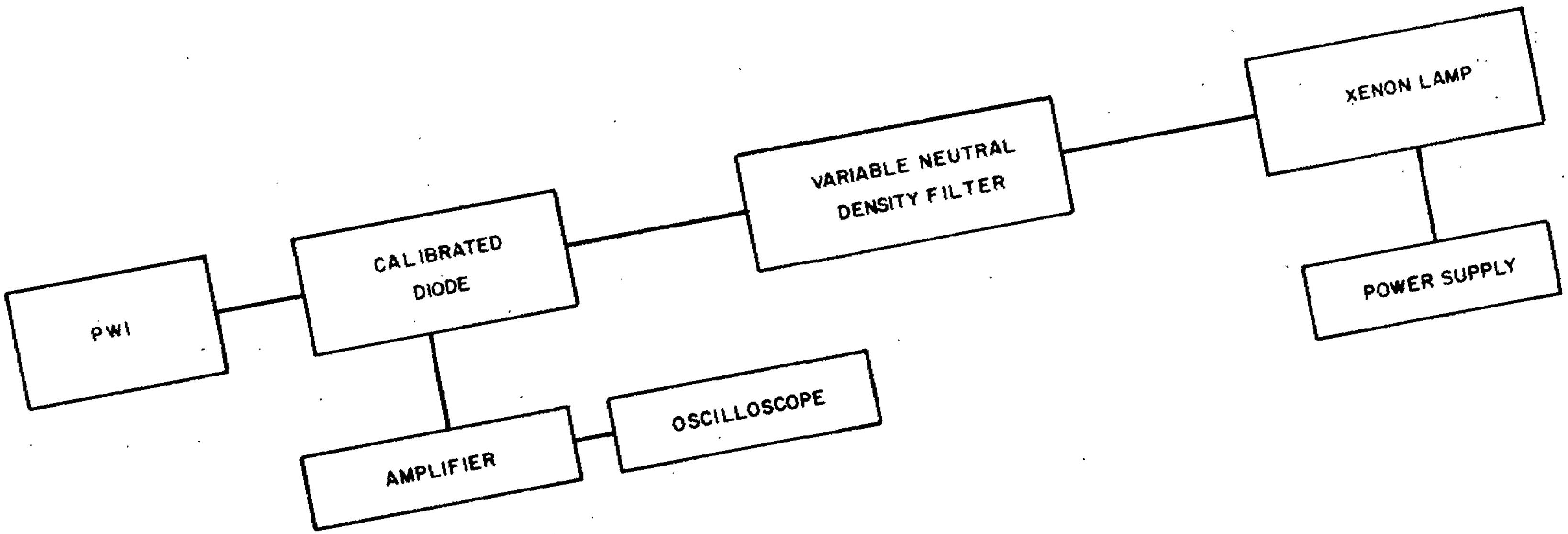


Figure 5.- Block Diagram of the Range Simulator

or is monitored with a calibrated diode. To standardize all the measurements, the diode current is amplified until a one volt output signal is attained and displayed on an oscilloscope. The gain of the amplifier required to deliver a one volt signal is proportional to the square of the range.

A range measurement consists of the following operations: The PWI system is set to a given azimuth and elevation using two indexing tables. The intensity of the flashing light is varied until the PWI just registers an intruder; a slightly lower intensity would not be sensed by the PWI. This setting represents the maximum range of the PWI for the given orientation. The calibrated diode is then placed into the optical train. It generates a current proportional to the number of watts falling onto the detector surface. (Note that the face of the diode is covered with a Schott RG-780 filter and that the diode is made of Silicon — the wavelength region being measured is the 0.8 to 1.1 micron region.) Determining the number of amps/watt delivered by the diode in the 0.8 to 1.1 micron region is the prime objective of the calibration. The signal from the diode is fed to an amplifier whose gain is adjusted so that a one volt signal is produced and displayed on a fast rise-time oscilloscope. From the relationship of the amplifier gain as a function of the incident current required to produce a one volt signal, the total charge collected is determined by measuring the area under the voltage-time curve displayed on the oscilloscope. Thus from the number of amps/watt or equivalently the number of coulombs/joule, the total energy collected by the diode can be determined. Knowing the amount of energy emitted per steradian by the lamp and assuming an inverse square fall-off of energy with distance, the measurement of the range capability of the PWI is reduced to the recording of the gain of the amplifier.

The following sections discuss each of the components of the range simulator and their calibration and possible introduction of error.

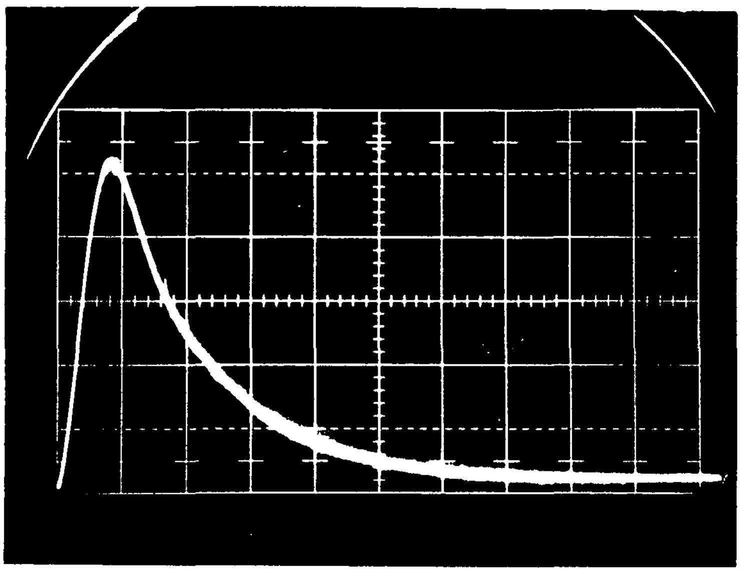


Figure 6.- Pulse Shape of the Delta Products Lamp
The Time Base is 0.2 milliseconds/cm.

A. Xenon Lamp.- A Delta Products "Sky Strobe" Xenon flash lamp was used for the laboratory tests even though the Whelan lamp will be used for the flight tests. A Whelan lamp was not available; however, the Delta lamp has roughly the same pulse width (about 400 microseconds at the half power points) and it emits about 1/4 the energy of the Whelan. (See accompanying photograph.)

B. Variable Neutral Density Filter.- An Optical Coating Laboratory Inc. variable neutral density filter was used to attenuate the beam from the flash lamp. The device consists of two counter-rotating filter wheels allowing a continuous variation in neutral density.

It was not necessary to calibrate the filters (although it is expected that they would be linear in the 0.8 to 1.1 micron region).

C. Calibrated Diode.- A United Detector Technology Pin-10 Large area (1.25 cm^2) photodetector was calibrated and used as the range measurement standard. It has a Schottky barrier on silicon construction, a response time of less than 10 nanoseconds and a dark current of less than a microampere. With the Schott RG-780 filter mounted on the face of the active area, the spectral response is from 0.8 to 1.1 microns. The linearity is rated at better than 2% from 10^{-11} watts to 10^{-4} watts. It remains to determine the sensitivity in the desired spectral range and this was the object of the calibration procedure. A nine volt bias was put on the detector in order to be able to operate in a DC-light environment.

To calibrate the Pin-10 diode, a Reeder RHL-7c thermopile was used. This thermopile is traceable to NBS and has a rated sensitivity of 2.38 microvolts per microwatt. Light entered the device through a 20 square-millimeter quartz window and the output voltage was read on a nanovoltmeter. The procedure

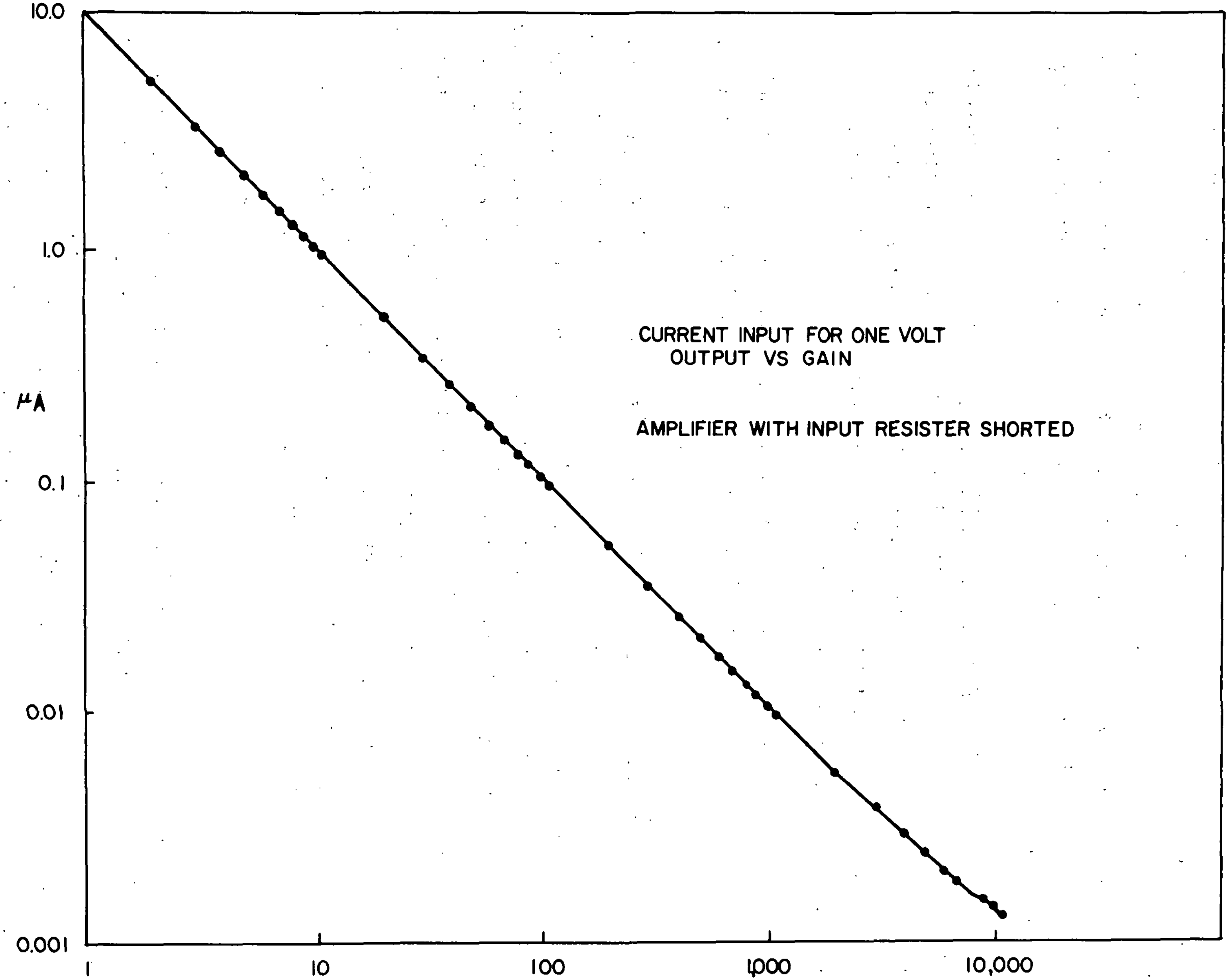


Figure 7.- Amplifier Gain

consisted of aligning a GaAs laser on the optical rail and first reading the diode-amplifier-oscilloscope combination and then the thermopile-nanovoltmeter combination. A value of 0.498 microamps/microwatt was obtained which should be good to 10%. As a double check, the GaAs laser was replaced by a projection lamp and only the (roughly) 0.8 to 1.1 micron radiation selected by passing the light through a Schoeffel monochrometer. Using the detectors as described above, a value of 0.51 microamps/microns was found which at least increased the confidence in the calibration procedure.

One problem that became apparent midway in the range sensitivity measurements is that the Pin-10 diodes age rapidly. However, as they age the sensitivity (and hence the calibration) does not change significantly, but the dark current increases by a large amount. Fortunately, this did not affect the measurements but it did complicate the data taking.

D. Amplifier.- A Dymec amplifier was used to amplify the diode current sufficiently to produce a one volt output signal (obviously a function of the impedance). The linearity of the Dymec was checked by applying a known current across a load and tabulating the gain required to produce a one volt signal and the result is shown in an accompanying graph. In addition, since one is detecting a signal which rises up to a peak value in about 100 microseconds, the frequency response of the Dymec was checked. On the times 100 potentiometer setting (see the accompanying figure) the frequency response could severely affect the measurements. Fortunately, such a high gain was not required more than a couple of times.

E. Oscilloscope.- A Tektronics 547 oscilloscope was used to determine when one had a one volt output signal. The unit and its associated plug-in were calibrated using a square-wave generator prior to the tests and the diode calibration.

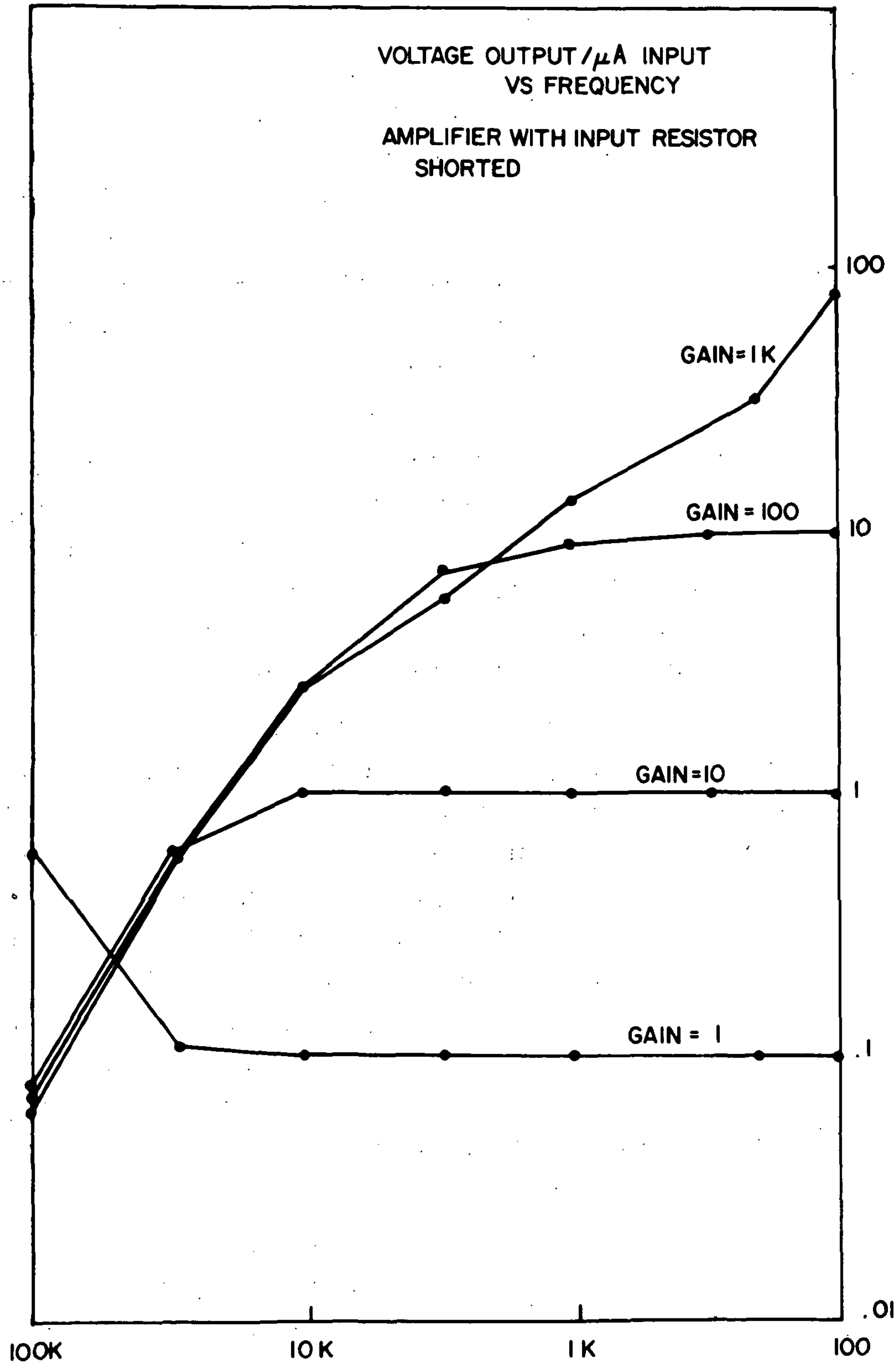

VOLTAGE OUTPUT/μA INPUT
VS FREQUENCY
AMPLIFIER WITH INPUT RESISTOR
SHORTED
GAIN=1K
GAIN = 100
GAIN=10
GAIN = 1
100
10
1
.1
.01
100K
10K
1K
100

Figure 8

V. LABORATORY TESTS

A. Introduction and Range Calculation

In the range simulation section it was emphasized that the lobed sensitivity patterns represented the geometry of the PWI systems. The data presented in this section are in two forms: (1) in the arbitrary "gain" units previously explained which allow one to appropriately change the data if (say) the Fecker discriminator level is changed during field or flight tests, and (2) in units of range (nautical miles) without atmospheric effects.

To assign a range performance capability due to the lobed sensitivity patterns, a "standard" Xenon strobe must be defined. The range values given in the report assumed a Whelan lamp which emits one joule in the 0.8 to 1.1 micron region and is equipped with a Fresnel lens so that the radiation is emitted in 2Π radians of azimuth but only $\pm\ \Pi/18$ radians in elevation. This gives $(2\pi^2/_9)$ joules/steradian emitted horizontally. Using these factors and a simple inverse-square law for intensity:

$$\text{Range (n.m.)} = 0.0339\ (\text{Gain})^{1/2}$$

B. Fecker Systems PWI

The Fecker Systems PWI uses a ball lens of 1.5-inch radius and is formed out of SF-18 glass. SF-18 glass (sometimes denoted 722293) has an index of refraction of about 1.72 at the Sodium doublet and n = 1.69756 at the infrared Mercury line (1014.0 nm). It has a density of 4.49 g/cm^3 and is rated in group 2 for resistance to climatic variations (i.e., under normal humidity conditions during use or storage, only a small change in the surface of an uncoated glass may occur.)

Because of the configuration for mounting detectors on a facetted surface, a lobed structure sensitivity should be expected. Surrounding each detector is a guard ring 0.05 inches wide and each detector-guard ring unit is separated by about 0.02 inches to prevent electrical problems. The image of a strobe will be a circle of 0.11 inch radius when normal to a detector. Portions of the image are not detected when the image falls between the detectors on the guard-ring or electrical dead space. A rough calculation shows that as one scans along zero degrees elevation, a condition can be attained between detectors such that only 25% of the signal will be sensed by each of two detectors (the detector area sensitivity is ignored). A 25% figure indicates that a 16:1 variation is possible in the range sensitivity due to geometry alone. If the image is positioned at a junction of four detectors, the signal may fall to less than 5% of full intensity, thus indicating a severe lobed structure — a 50:1 variation in range!

The data to be presented in this section are for two Fecker systems: #19336A, TSC's modified version of the delivered system, and #19335B, a working version of the system delivered and tested for NASA/ERC.

As a guide for the laboratory (and field and flight) tests, the centers of peak sensitivity for each channel were located. (Figure 9 shows for reference the indicator for the Fecker and the convention used in this write-up to indicate a particular channel.) Table I lists the centers of peak sensitivity in a coordinate system in which the center of sensitivity of diode or channel 7 is defined as the origin for both azimuth and elevation. Note that channels 5 and 9 have two sensitivity centers as two detectors are tied to each of these channels.

Data were collected along seven scans or traversals. Referring to Table I, the scans were:

(1) 1-3-7-11-13 Constant Azimuth, Varying Elevation
(2) 5-6-7-8-9 Constant Elevation, Varying Azimuth
(3) 2-3-4 Constant Elevation, Varying Azimuth

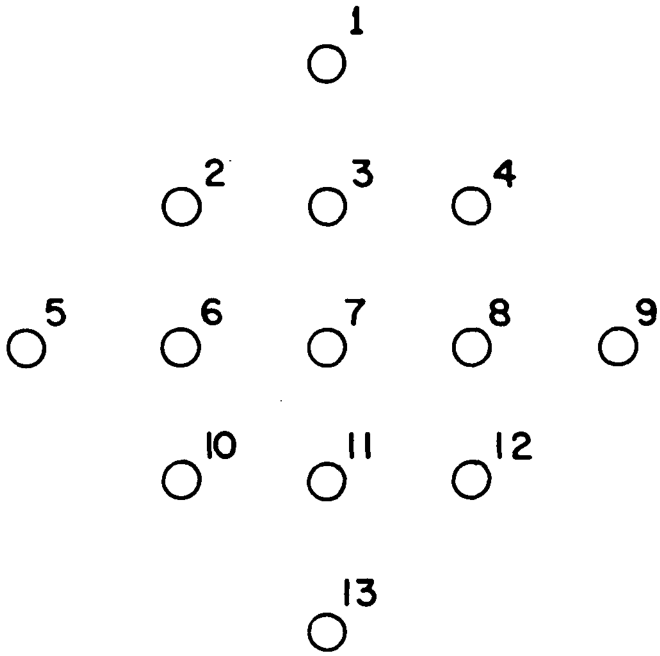


Figure 9.- Fecker Indicator and Numbering Convention
Used in the Data Collection

TABLE I.- CENTERS OF PEAK SENSITIVITY

Channel	Fecker #19336A		Fecker #19335B	
Number	Azimuth	Elevation	Azimuth	Elevation
1	0°	44°	0°	44°
2	-21	24	-22	20
3	0	25	0	19
4	21	23	23	22
5	-44	0	-41	0
	-65	0	-52	-3
6	-22	0	-23	0
7	0	0	0	0
8	21	0	23	0
9	44	0	43	-1
	63	0	63	0
10	-20	-14	-22	-23
11	0	-22	3	-25
12	21	-23	24	-25
13	-3	-42	3	-42

(4)	10-11-12	Constant Elevation, Varying Azimuth
(5)	2-6-10	Constant Azimuth, Varying Elevation
(6)	4-8-12	Constant Azimuth, Varying Elevation
(7)	7-12 or 7-4	Varying Azimuth, Varying Elevation

The range capability of the Fecker PWI's depends upon the level or discriminator voltage selected. The roof tests (Section IV) determined that a 6-volt setting will adequately discriminate against background noise and all the ensuing data were collected for this 6-volt value. However, as was experienced in the previous flight tests, one may wish to change this value; so a conversion factor was found for operating with a different threshold voltage. Table XVIII lists a multiplicative factor by which the gain values (to be presented) must be multiplied by in order to predict the range capability for a threshold value of other than 6 volts.

Tables II through XVII consist of the laboratory data describing the lobed sensitivity patterns for a level of 6 volts. Each table consists of azimuth, elevation, R1 gain, R1 range, R2 gain, and R2 range. Polar plots are given for the R1 range (in nautical miles) as a function of either azimuth or elevation. The lobes have been identified by indicating the channel which registered an event.

The data for each scan were consistent in that any value could be repeated within two percent. However, there existed a small discrepancy from day-to-day due perhaps to the slowly increasing dark current in the diode. Since the effect of the atmosphere has not as yet been incorporated into the range values, the small inconsistancies will be removed when the data are fitted to the field test results. The aerosol scattering and water vapor absorption effects will be determined as a function of temperature, humidity, and visibility so that given these parameters, one may (hopefully) accurately predict the range performance of the Fecker PWI.

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
0°	0°	7	426.	.700	165.	.436
	- 1	7	426.	.700	165.	.436
	- 2	7	426.	.700	165.	.436
	- 3	7	387.	.667	150.	.415
	- 5	7	294.	.581	114.	.362
	- 8	7	169.	.441	65.3	.274
	- 9	7	125.	.379	48.5	.236
	-10	11	100.	.339	38.7	.211
	-12	11	188.	.465	72.9	.289
	-15	11	286.	.573	111.	.357
	-18	11	358.	.641	139.	.400
	-20	11	348.	.632	135.	.394
	-21	11	361.	.644	140.	.401
	-22	11	358.	.641	139.	.400
	-23	11	354.	.638	137.	.397
	-24	11	354.	.638	137.	.397
	-25	11	356.	.640	138.	.398
	-26	11	327.	.613	127.	.382
	-29	11	198.	.477	76.8	.297
	-32	11	101.	.341	39.2	.212
	-33	11	70.0	.284	27.2	.177
	-34	13	83.6	.310	32.4	.193
	-37	13	172.	.445	66.9	.277
	-39	13	203.	.483	78.9	.301
	-40	13	207.	.488	80.6	.304
	-41	13	217.	.500	84.3	.311
	-42	13	223.	.506	86.4	.315
	-43	13	223.	.506	86.4	.315
	-44	13	218.	.501	84.9	.312
	-45	13	211.	.492	81.7	.306
	-46	13	206.	.487	80.0	.303
	-47	13	202.	.482	78.2	.300
	-48	13	167.	.438	64.8	.273
	-50	13	122.	.374	47.6	.234
	-52	13	74.5	.293	28.9	.182
	-53	13	50.0	.240	19.4	.149
	-54	13	34.0	.198	13.2	.123
	-56	13	10.2	.108	3.94	.067

Level: 6 Volts

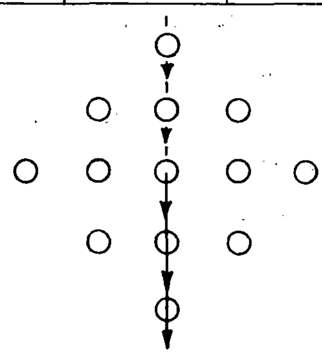


Table II

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
0°	59°	1	7.11	.090	2.76	.056
	58	1	27.6	.178	10.9	.112
	57	1	48.2	.235	18.5	.146
	56.5	1	51.9	.244	20.7	.154
	56	1	68.9	.281	26.7	.175
	55.5	1	79.9	.303	31.7	.191
	55	1	106.	.349	39.0	.212
	52	1	174.	.447	68.2	.280
	49	1	297.	.584	115.	.365
	46	1	328.	.614	127.	.382
	45	1	328.	.614	127.	.382
	44	1	326.	.612	126.	.381
	43	1	310	.597	120.	.371
	42	1	276.	.563	107.	.351
	39	1	161.	.430	62.2	.267
	37	1	94.2	.329	36.5	.205
	36	3	70.3	.284	27.2	.177
	34	3	159.	.427	61.8	.267
	31	3	274.	.561	103.	.344
	28	3	334.	.619	129.	.385
	27	3	344.	.629	133.	.391
	26	3	344.	.629	133.	.391
	25	3	351.	.635	136.	.395
	24	3	372.	.654	144.	.407
	23	3	351.	.635	136.	.395
	22	3	357.	.641	138.	.398
	21	3	357.	.641	138.	.398
	20	3	331.	.617	128.	.712
	19	3	308.	.595	119.	.370
	17	3	218.	.501	84.6	.312
	15	3	124.	.378	48.0	.235
	14	3	85.2	.313	33.0	.195
	13	7	88.8	.320	39.4	.213
	12	7	142.	.404	55.1	.252
	10	7	232.	.516	90.0	.322
	7	7	331.	.617	128.	.384
	5	7	426.	.700	165.	.436
	3	7	401.	.679	155.	.422
	2	7	434.	.706	168.	.439
	1	7	434.	.706	168.	.439

Level: 6 volts

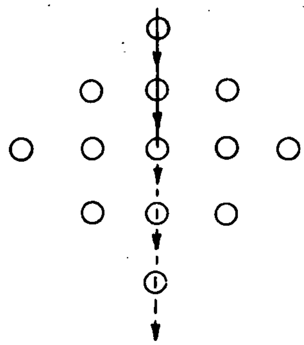


Table III

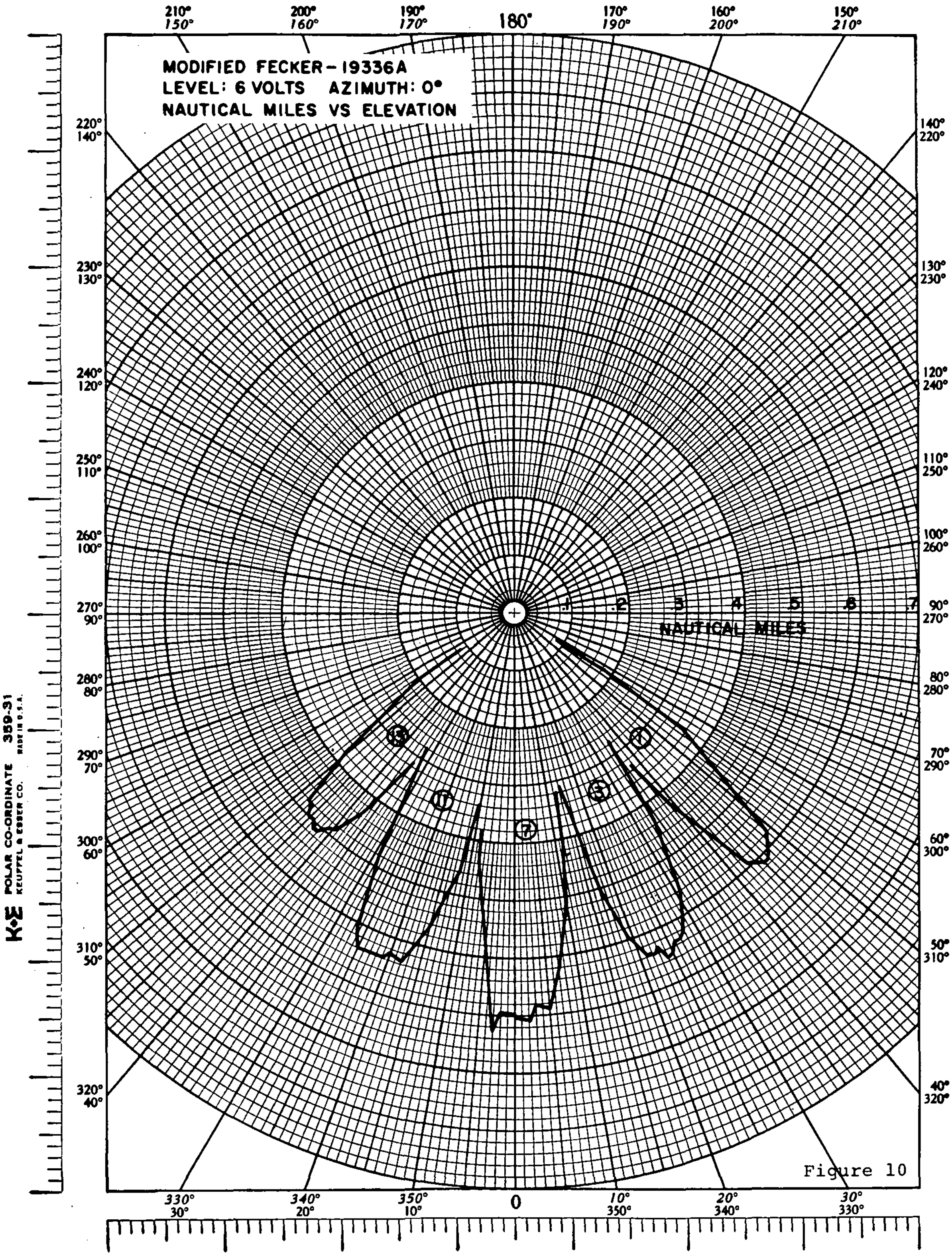

MODIFIED FECKER-19336A
LEVEL: 6 VOLTS AZIMUTH: 0°
NAUTICAL MILES VS ELEVATION
NAUTICAL MILES
Figure 10

Figure 10

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
-20°	38°	2	3.39	.062	1.31	.039
	37	2	31.3	.190	12.2	.118
	36	2	71.4	.286	27.7	.178
	34	2	172.	.445	66.8	.277
	32	2	231.	.515	89.4	.321
	30	2	353.	.637	137.	.397
	28	2	402.	.680	156.	.423
	26	2	405.	.682	157.	.425
	24	2	413.	.689	160.	.429
	22	2	413.	.689	160.	.429
	20	2	391.	.670	152.	.418
	18	2	293.	.580	114.	.362
	16	2	202.	.482	78.3	.300
	14	2	101.	.341	39.1	.212
	12	2	45.7	.229	17.7	.143
	11	6	142.	.404	55.0	.251
	10	6	284.	.571	110.0	.356
	8	6	385.	.665	149.	.414
	6	6	495.	.754	192.	.470
	4	6	608.	.836	235.	.520
	2	6	612.	.839	238.	.523
	0	6	640.	.858	248.	.534
	- 2	6	652.	.866	253.	.539
	- 4	6	499.	.757	194.	.472
	- 6	6	374.	.656	145.	.408
	- 8	6	216.	.498	83.7	.310
	-10	6	92.8	.327	36.0	.203
	-11	10	124.	.378	48.1	.235
	-12	10	130.	.387	50.4	.241
	-14	10	138.	.398	53.5	.248
	-16	10	107.	.351	41.5	.218
	-18	10	100.	.339	38.8	.211
	-20	10	79.0	.301	30.6	.186
	-22	10	14.9	.131	5.78	.081
	-24	10	11.1	.113	4.31	.070
	-26	10	6.87	.089	2.66	.055

Level: 6 Volts

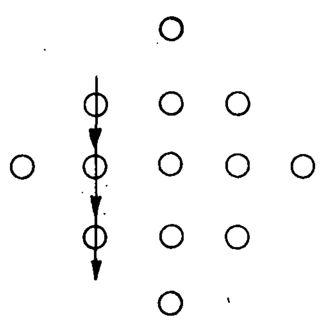
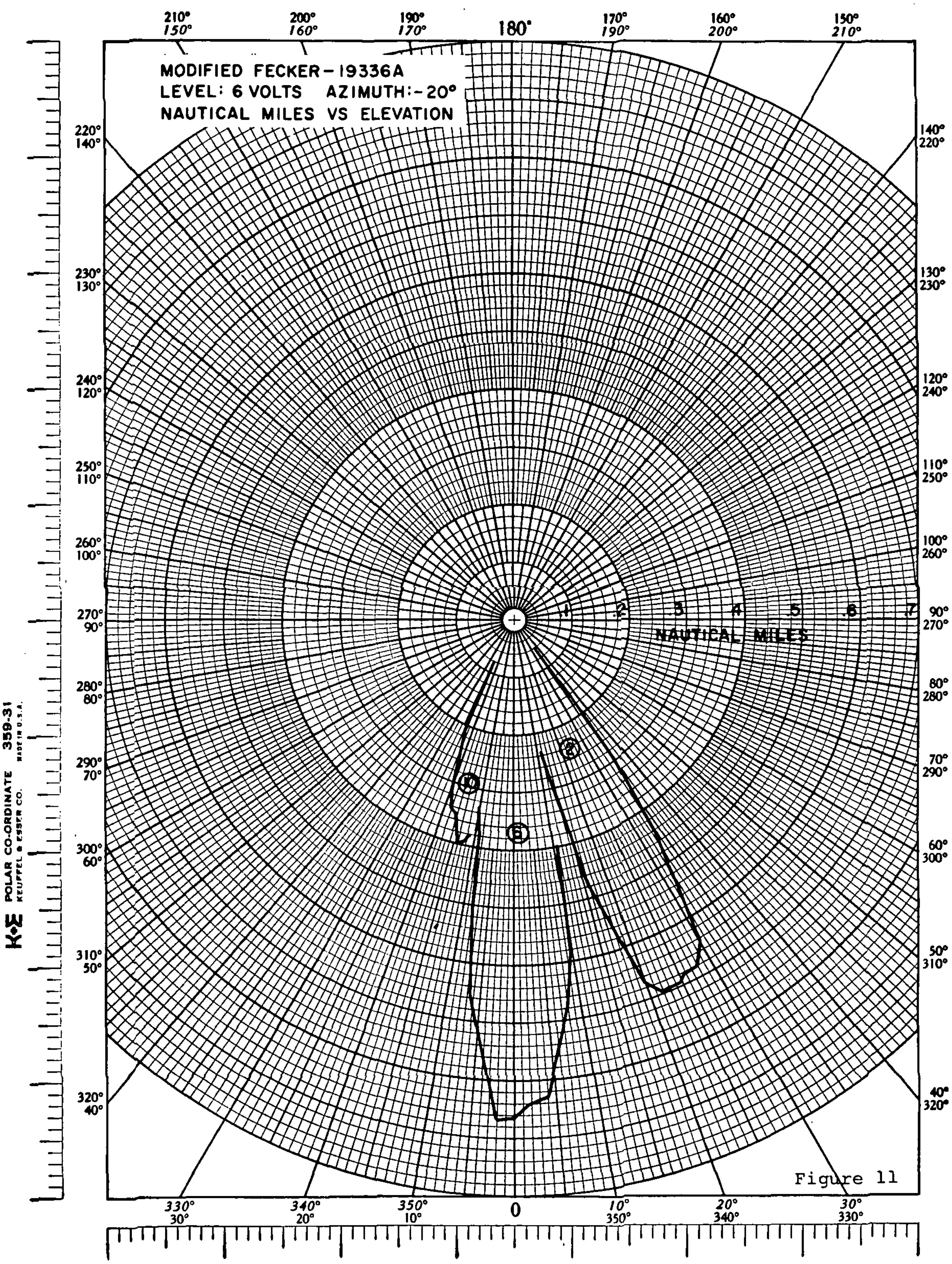


Table IV



MODIFIED FECKER-19336A
LEVEL: 6 VOLTS AZIMUTH:-20°
NAUTICAL MILES VS ELEVATION
180°
0
.1 .2 .3 .4 .5 .6 .7
NAUTICAL MILES
Figure 11
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 11

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
-77	0°	5	16.1	.136	6.25	.085
-76		5	26.4	.174	10.3	.109
-74		5	52.8	.246	20.4	.153
-72		5	70.0	.284	27.1	.177
-70		5	73.9	.291	28.6	.181
-68		5	77.7	.299	30.1	.186
-67		5	80.0	.303	31.0	.189
-66		5	84.0	.320	32.6	.194
-65		5	86.8	.316	33.6	.197
-64		5	84.0	.311	32.5	.193
-63		5	88.2	.318	34.2	.198
-62		5	77.4	.298	30.0	.186
-60		5	55.0	.251	21.3	.157
-58		5	39.7	.214	15.0	.131
-57		5	48.5	.236	18.8	.147
-56		5	64.6	.273	25.0	.170
-54		5	138.	.398	53.9	.249
-52		5	208.	.489	80.8	.305
-50		5	292.	.579	113.	.360
-48		5	286.	.573	111.	.357
-46		5	307.	.594	119.	.370
-45		5	318.	.605	123.	.376
-44		5	318.	.605	123.	.376
-43		5	305.	.592	118.	.368
-41		5	282.	.569	109.	.354
-38		5	174.	.447	67.4	.278
-36		5	106.	.349	41.3	.218
-35		6	87.6	.317	34.0	.198
-33		6	177.	.451	68.6	.281
-29		6	398.	.676	154.	.421
-26		6	522.	.775	202.	.482
-24		6	541.	.789	210.	.491
-23		6	540.	.788	209.	.490
-22		6	580.	.816	225.	.509
-21		6	522.	.775	202.	.482
-19		6	529.	.780	205.	.485
-16		6	358.	.641	139.	.400
-13		6	164.	.434	63.9	.271
-12		7	129.	.385	50.0	.240
-11		7	204.	.484	79.2	.302

Level: 6 Volts

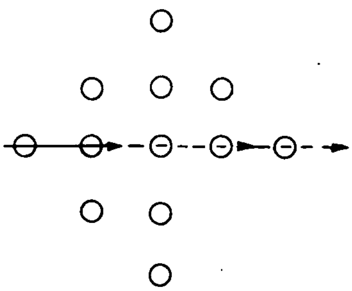


Table V

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
-8°	0°	7	328.	.614	127.	.382
-6		7	388.	.668	150.	.415
-3		7	426.	.700	165.	.436
-2		7	429.	.702	166.	.437
-1		7	434.	.706	168.	.439
0		7	444.	.714	172.	.445
1		7	426.	.700	165.	.436
2		7	429.	.702	166.	.437
3		7	429.	.702	166.	.437
4		7	382.	.663	148.	.412
7		7	279.	.566	108.	.352
10		7	122.	.374	47.1	.233
11		8	157.	.425	60.7	.264
14		8	310.	.597	120.	.371
17		8	475.	.739	184.	.460
19		8	504.	.761	197.	.476
20		8	500.	.758	194.	.472
21		8	506.	.763	198.	.477
22		8	508.	.764	200.	.479
23		8	483.	.745	187.	.464
25		8	449.	.718	174.	.447
27		8	398.	.676	154.	.421
30		8	228.	.512	88.2	.318
32		8	119.	.370	46.2	.230
33		8	82.3	.308	31.9	.192
34		8	45.8	.229	17.6	.142
35		9	51.8	.244	18.2	.145
38		9	81.6	.306	31.6	.191
41		9	104.	.346	40.3	.215
43		9	106.	.349	41.0	.217
44		9	106.	.349	41.0	.217
45		9	103.	.344	40.0	.214
46		9	100.	.339	38.7	.211
48		9	97.0	.334	37.6	.208
51		9	56.1	.254	21.7	.158
52		9	45.5	.229	17.6	.142
53		9	30.5	.187	11.8	.117
54		9	42.6	.221	16.5	.138
57		9	101.	.341	39.4	.213
60		9	177.	.451	68.7	.281

Level: 6 Volts

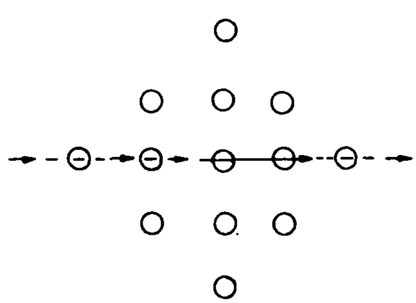


Table VI

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
61°	0°	9	202.	.482	78.2	.300
62		9	201.	.481	78.0	.299
63		9	203.	.483	78.6	.301
64		9	199.	.478	77.5	.298
65		9	199.	.478	77.5	.298
66		9	199.	.478	77.5	.298
67		9	192.	.470	74.4	.292
68		9	192.	.470	74.4	.292
69		9	182.	.457	70.5	.285
71		9	158.	.426	61.4	.266
73		9	91.4	.324	35.5	.202
75		9	28.6	.181	11.1	.113
76		9	17.0	.140	6.60	.087
77		9	11.7	.116	4.56	.072
78		9	7.88	.095	3.05	.059
79		9	6.91	.089	2.68	.056
80		-	-		-	

Level: 6 Volts

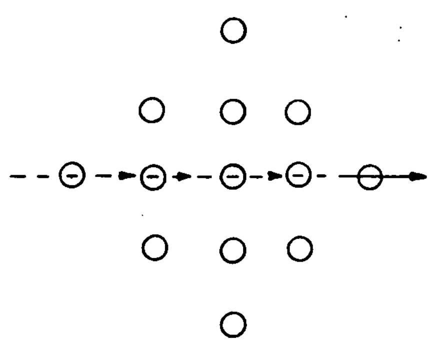


Table VI continued

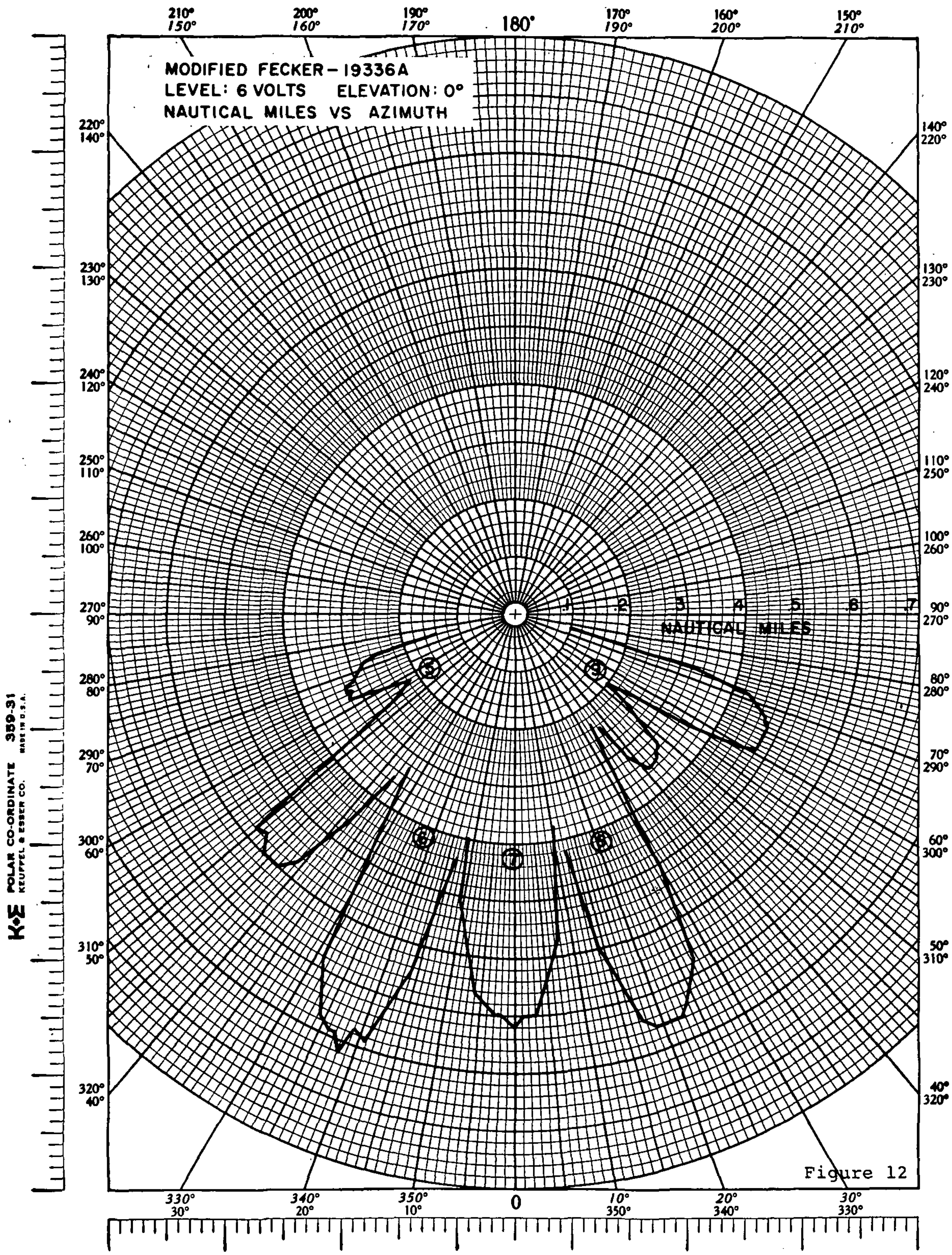

MODIFIED FECKER - 19336A
LEVEL: 6 VOLTS ELEVATION: 0°
NAUTICAL MILES VS AZIMUTH
NAUTICAL MILES
.1
.2
.3
.4
.5
.6
.7
180°
0
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO.
Figure 12

Figure 12

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
21°	36°	4	12.9	.122	5.0	.076
	34	4	35.5	.202	13.8	.126
	30	4	95.4	.331	37.0	.206
	28	4	111.	.357	43.0	.222
	25	4	124.	.378	48.1	.235
	24	4	132.	.390	51.1	.242
	23	4	136.	.395	52.8	.246
	22	4	122.	.374	47.3	.233
	21	4	124.	.378	48.0	.235
	19	4	100.	.339	38.7	.211
	16	4	62.9	.269	24.4	.168
	14	4	37.9	.209	14.7	.130
	13	8	31.0	.189	12.0	.117
	10	8	215.	.497	83.3	.309
	7	8	425.	.699	165.	.436
	4	8	546.	.792	211.	.492
	2	8	549.	.794	212.	.494
	1	8	538.	.786	208.	.489
	0	8	505.	.762	196.	.475
	- 1	8	512.	.767	198.	.477
	- 2	8	540.	.788	209.	.490
	- 3	8	469.	.734	182.	.457
	- 6	8	348.	.632	135.	.394
	- 9	8	154.	.421	59.8	.262
	-10	8	119.	.370	46.2	.230
	-11	12	90.0	.322	34.8	.200
	-14	12	215.	.497	87.3	.317
	-17	12	335.	.621	130.	.387
	-20	12	376.	.657	146.	.410
	-22	12	389.	.669	151.	.417
	-24	12	389.	.669	151.	.417
	-26	12	389.	.669	151.	.417
	-28	12	298.	.585	116.	.365
	-30	12	288.	.575	112.	.359
	-32	12	119.	.370	46.2	.230
	-34	12	54.4	.250	21.6	.158
	-36	12	10.0	.107	3.71	.065

Level: 6 Volts

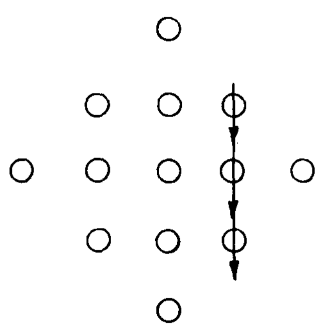


Table VII

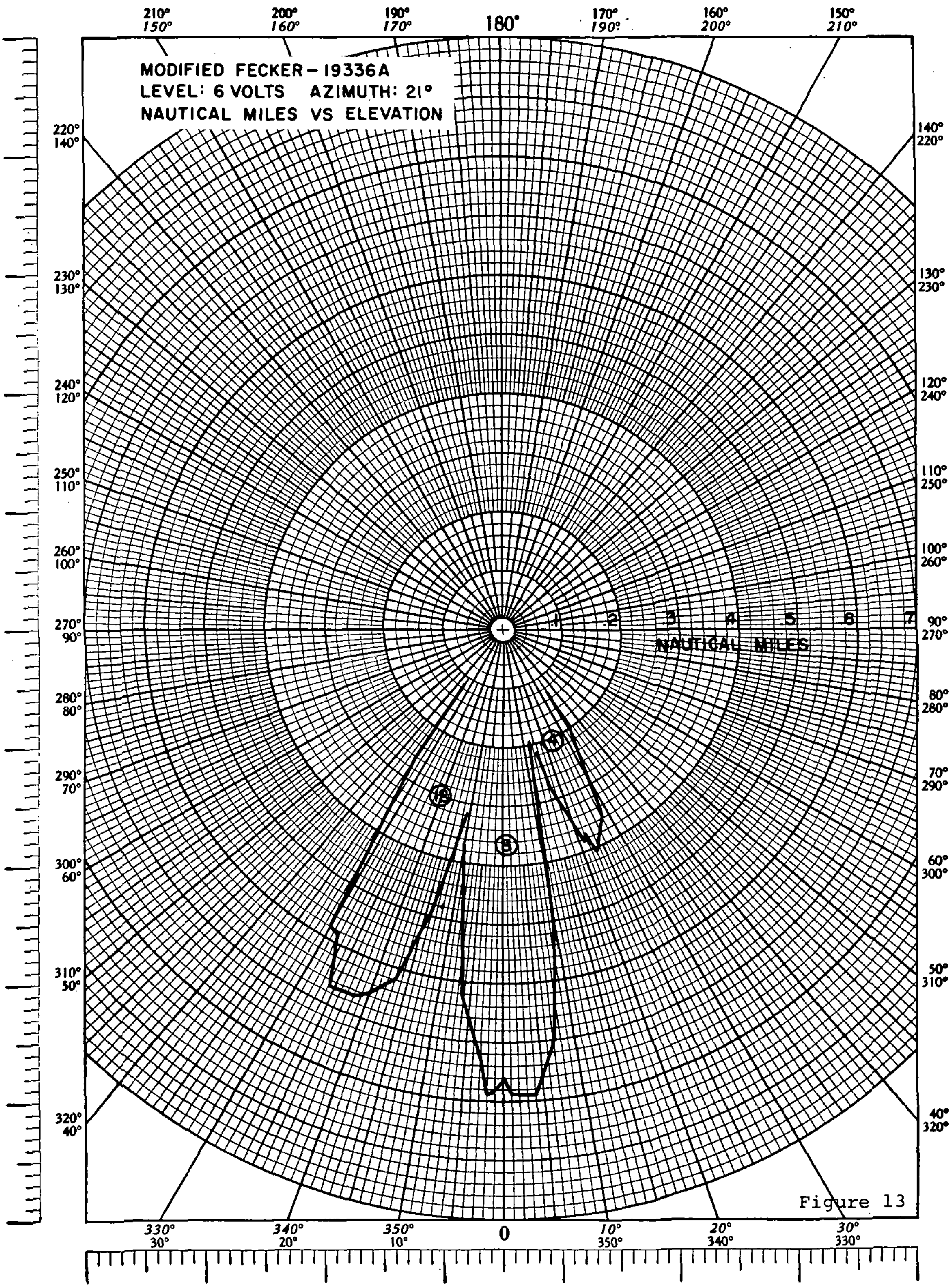

MODIFIED FECKER - 19336A
LEVEL: 6 VOLTS AZIMUTH: 21°
NAUTICAL MILES VS ELEVATION
NAUTICAL MILES
1 2 3 4 5 6 7
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.
Figure 13

Figure 13

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
-37°	24°	2	19.2	.149	7.43	.092
-36		2	41.5	.218	16.1	.136
-33		2	128.	.384	49.9	.240
-30		2	224.	.507	87.2	.317
-27		2	300.	.587	116.	.365
-24		2	317.	.604	123.	.376
-22		2	278.	.565	108.	.352
-21		2	332.	.618	129.	.385
-20		2	289.	.576	112.	.358
-19		2	278.	.565	108.	.352
-16		2	191.	.469	74.0	.292
-13		2	105.	.347	40.9	.217
-12		3	78.7	.301	30.5	.187
- 9		3	172.	.445	66.9	.277
- 6		3	257.	.544	99.9	.339
- 3		3	358.	.641	139.	.400
- 2		3	358.	.641	139.	.400
- 1		3	361.	.644	140.	.401
0		3	335.	.621	130.	.387
1		3	335.	.621	130.	.387
2		3	335.	.621	130.	.387
3		3	335.	.621	130.	.387
5		3	278.	.565	108.	.352
8		3	184.	.460	71.3	.286
9		3	156.	.423	60.6	.264
10		3	99.2	.338	38.5	.210
11		3	78.0	.299	30.3	.187
12		4	81.1	.305	31.4	.190
13		4	117.	.367	45.5	.228
16		4	214.	.496	83.0	.309
19		4	276.	.563	107.	.351
20		4	300.	.587	116.	.365
21		4	327.	.613	127.	.382
22		4	341.	.626	132.	.390
23		4	325.	.611	126.	.381
24		4	325.	.611	126.	.381
25		4	314.	.601	122.	.374
28		4	278.	.565	108.	.352
31		4	153.	.419	59.4	.261
33		4	72.3	.288	28.0	.179
37		4	8.24	.097	3.20	.061

Level: 6 Volts

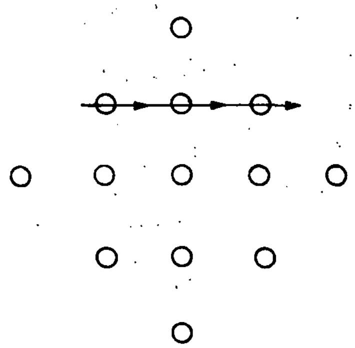


Table VIII

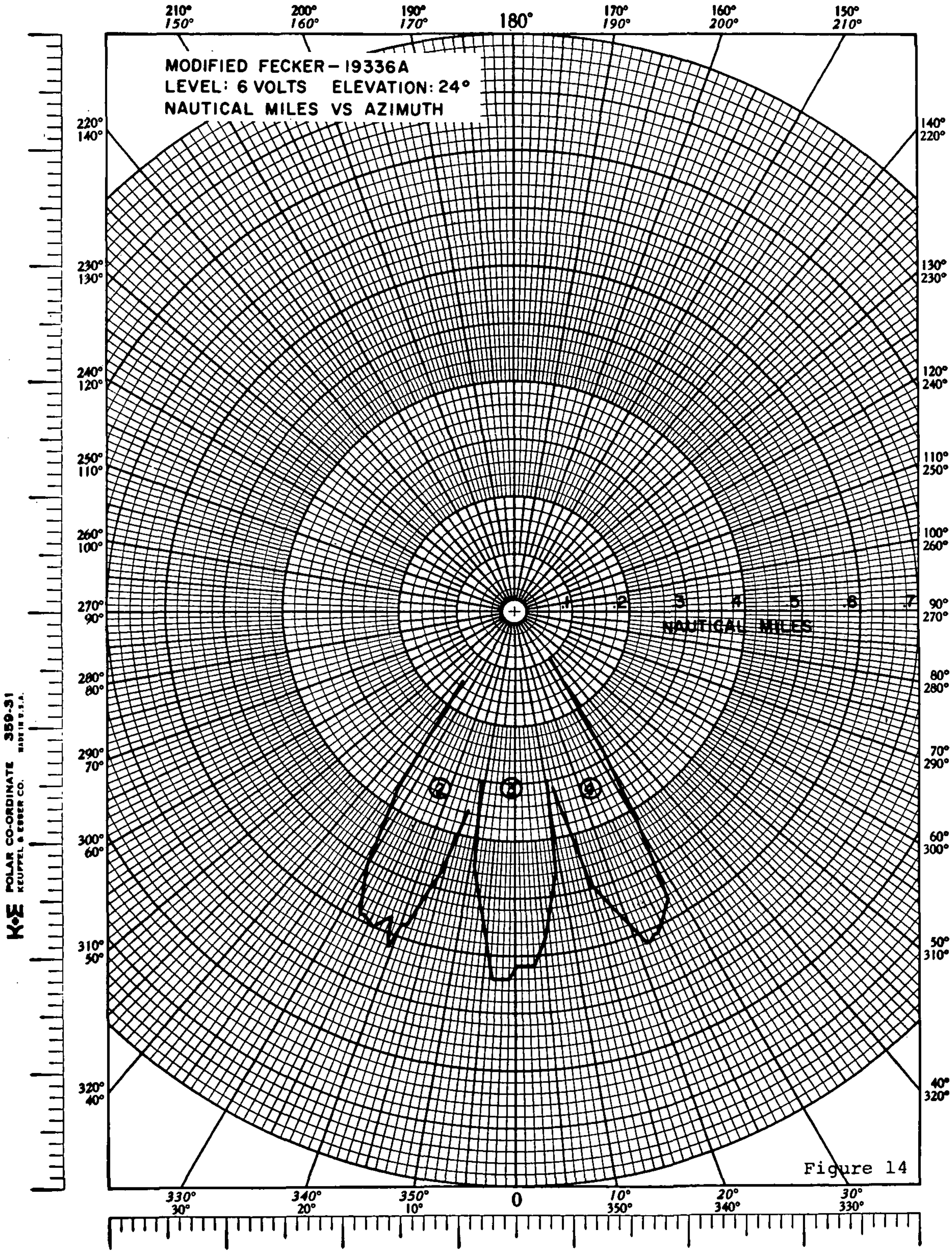

MODIFIED FECKER-19336A
LEVEL: 6 VOLTS ELEVATION: 24°
NAUTICAL MILES VS AZIMUTH
NAUTICAL MILES
.1
.2
.3
.4
.5
.6
.7
180°
0
Figure 14
K+E POLAR CO-ORDINATE 359-31

Figure 14

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
35°	-22°	12	14.0	.127	5.42	.079
34		12	32.2	.192	12.5	.120
31		12	60.0	.263	23.3	.164
28		12	120.0	.371	46.6	.231
24		12	186.	.462	72.3	.288
23		12	182.	.457	70.3	.284
22		12	180.	.455	70.0	.284
21		12	190.	.467	73.3	.290
20		12	190.	.467	73.3	.290
19		12	186.	.462	72.2	.288
16		12	148.	.412	57.2	.256
13		12	102.	.342	39.7	.214
11		12	60.0	.263	23.3	.164
10		12	41.0	.217	15.9	.135
9		11	54.1	.249	21.0	.155
7		11	87.0	.316	33.8	.197
3		11	158.	.426	61.1	.265
1		11	188.	.465	73.0	.290
0		11	190.	.467	73.7	.291
- 1		11	180.	.455	70.0	.284
- 2		11	172.	.445	67.0	.278
- 5		11	156.	.423	60.8	.264
- 8		11	127.	.382	49.1	.238
-11		11	78.0	.299	30.2	.186
-13		11	43.4	.223	16.8	.139
-14		11	27.0	.176	10.5	.110
-15		10	10.4	.109	4.03	.068
-16		10	13.3	.124	5.18	.077
-19		10	12.2	.118	4.74	.074
-20	↓	10	3.90	.067	1.51	.042

Level: 6 Volts

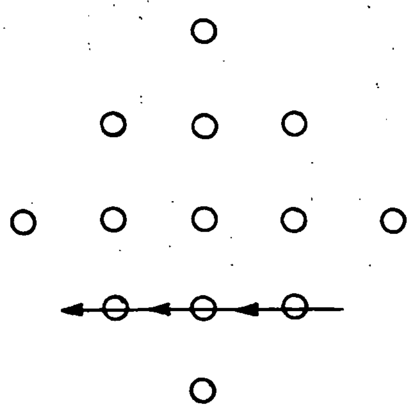


Table IX

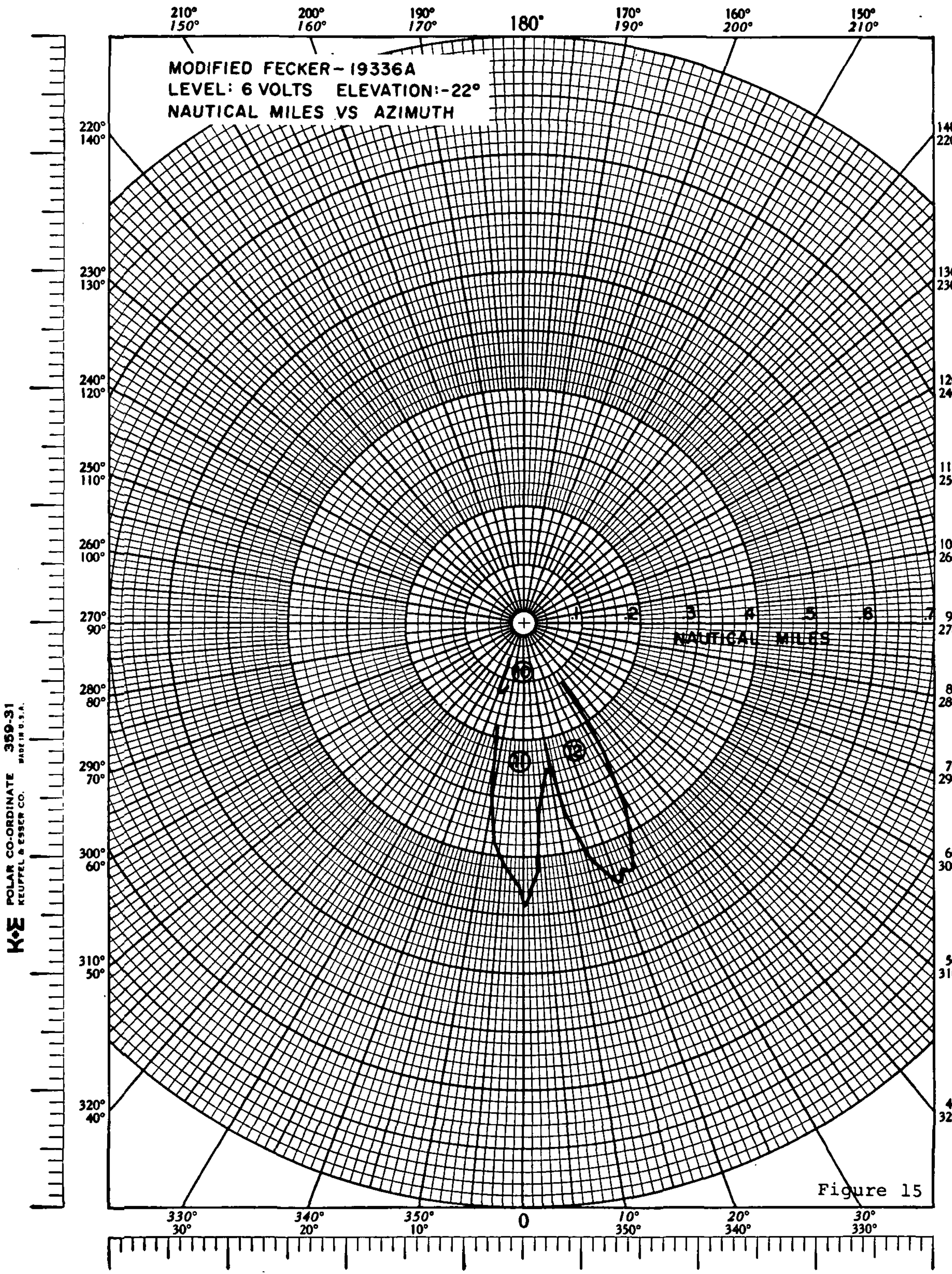

MODIFIED FECKER - 19336A
LEVEL: 6 VOLTS ELEVATION: -22°
NAUTICAL MILES VS AZIMUTH
NAUTICAL MILES
180°
0
Figure 15
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO.

Figure 15

MODIFIED FECKER - 19336A						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
0°	0°	7	216.	.498	83.8	.310
2	- 2	7	182.	.457	70.8	.285
4	- 4	7	154.	.421	59.8	.262
6	- 6	7	114.	.362	44.4	.226
8	- 8	7	56.8	.256	22.0	.159
10	-10	7	19.0	.148	7.40	.092
12	-12	12	21.6	.158	8.39	.098
14	-14	12	49.0	.237	19.0	.148
16	-16	12	79.5	.302	30.8	.188
18	-18	12	119.	.370	46.1	.230
20	-20	12	166.	.437	64.5	.272
22	-22	12	157.	.425	61.0	.265
24	-24	12	157.	.425	61.0	.265
26	-26	12	118.	.368	45.6	.229
28	-28	12	72.6	.289	28.1	.180
30	-30	12	36.6	.205	14.2	.128
32	-32	12	10.7	.111	4.16	.069
33	-33	12	3.77	.066	1.46	.041

Level: 6 Volts

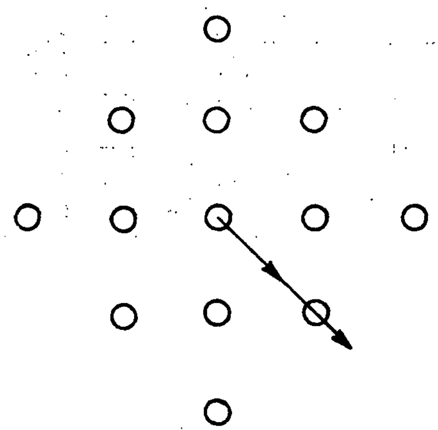


Table X

UNMODIFIED FECKER - 19335B						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
-37°	20°	2	36.3	.204	12.2	.118
-36		2	68.3	.280	24.1	.167
-35		2	105.	.347	37.3	.207
-32		2	172.	.445	66.5	.276
-30		2	264.	.551	102.	.342
-27		2	413.	.689	160.	.429
-25		2	480.	.743	186.	.462
-23		2	475.	.739	184.	.460
-22		2	465.	.731	180.	.455
-20		2	472.	.737	183.	.459
-18		2	387.	.667	150.	.415
-14		2	204.	.484	79.1	.302
-13		2	148.	.412	57.3	.257
-12		2	111.	.357	41.3	.218
-11		3	141.	.403	54.7	.251
- 8		3	284.	.571	110.	.356
- 5		3	425.	.699	165.	.436
- 2		3	492.	.752	191.	.469
0		3	507.	.763	196.	.475
3		3	498	.757	193.	.471
5		3	429.	.702	166.	.437
8		3	264.	.551	102.	.342
11		3	126.	.381	42.0	.220
12		4	93.3	.327	32.3	.193
13		4	121.	.373	46.9	.232
15		4	194.	.472	75.3	.294
18		4	289.	.576	112.	.359
20		4	351.	.635	136.	.395
22		4	402.	.680	156.	.423
24		4	374.	.656	145.	.408
27		4	359.	.642	139.	.400
30		4	231.	.515	89.9	.321
33		4	129.	.385	42.7	.222
35		4	69.6	.283	23.4	.164
37		4	18.2	.145	6.62	.087
41		4	3.06	.059	1.18	.034

Level: 6 Volts

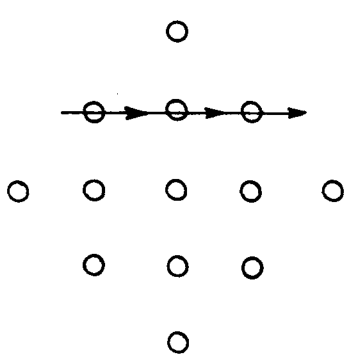


Table XI

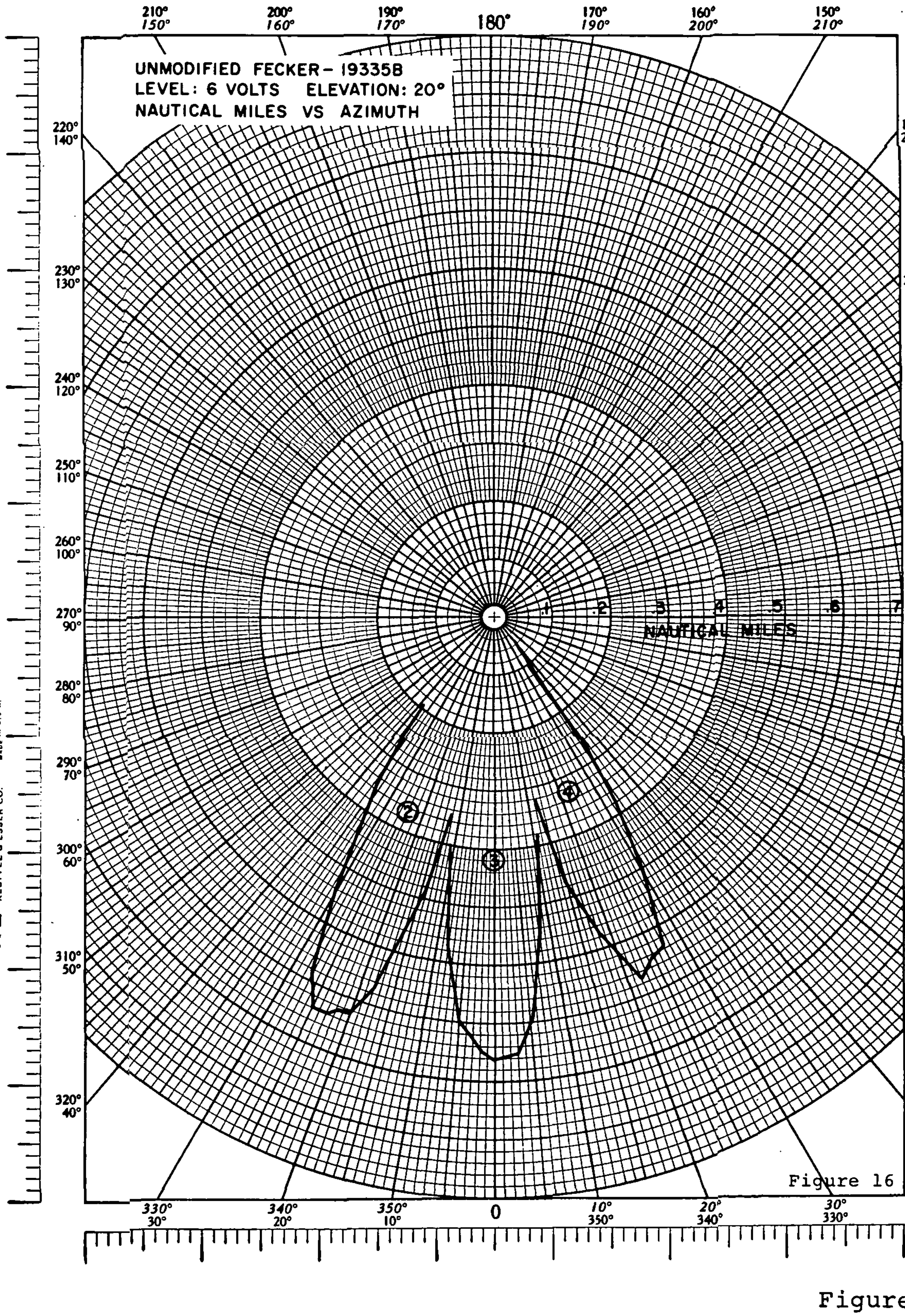

UNMODIFIED FECKER- 19335B
LEVEL: 6 VOLTS ELEVATION: 20°
NAUTICAL MILES VS AZIMUTH
NAUTICAL MILES
Figure 16
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO.

Figure 16

UNMODIFIED FECKER - 19335B						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
23°	39°	4	2.59	.055	1.01	.034
	37	4	10.3	.109	3.36	.062
	35	4	102.	.342	39.8	.214
	32	4	238.	.523	92.8	.327
	29	4	307.	.594	119.	.370
	28	4	325.	.611	126.	.381
	27	4	335.	.621	130.	.387
	26	4	337.	.622	131.	.388
	25	4	337.	.622	131.	.388
	24	4	337.	.622	131.	.388
	23	4	343.	.628	133.	.391
	22	4	345.	.630	134.	.392
	21	4	345.	.630	134.	.392
	20	4	327.	.613	127.	.382
	18	4	245.	.531	95.0	.330
	15	4	112.	.359	43.6	.224
	14	4	51.6	.244	20.0	.152
	13	8	51.6	.244	20.0	.152
	9	8	153.	.419	59.3	.261
	5	8	279.	.566	108.	.352
	2	8	279.	.566	108.	.352
	0	8	279.	.566	108.	.352
	- 1	8	279.	.566	108.	.352
	- 2	8	273.	.560	106.	.349
	- 5	8	176.	.450	68.2	.280
	- 8	8	84.0	.311	32.6	.194
	- 9	8	49.8	.239	19.3	.149
	-10	12	64.0	.271	24.8	.169
	-13	12	276.	.563	107.	.351
	-16	12	340.	.625	132.	.390
	-19	12	400.	.678	155.	.422
	-22	12	400.	.678	155.	.422
	-26	12	400.	.678	155.	.422
	-27	12	366.	.649	142.	.404
	-29	12	279.	.566	108.	.352
	-32	12	113.	.360	43.9	.225
	-35	12	24.8	.167	9.61	.105
	-36	12	10.0	.107	3.79	.066
	-37	12	7.89	.095	2.50	.053
↓	-40	12	2.52	.054	1.00	.034

Level: 6 Volts

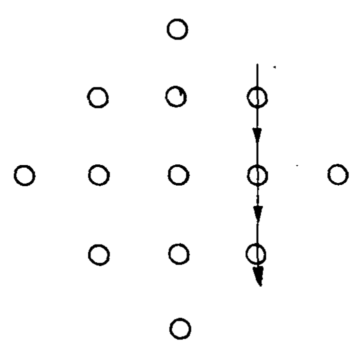


Table XII

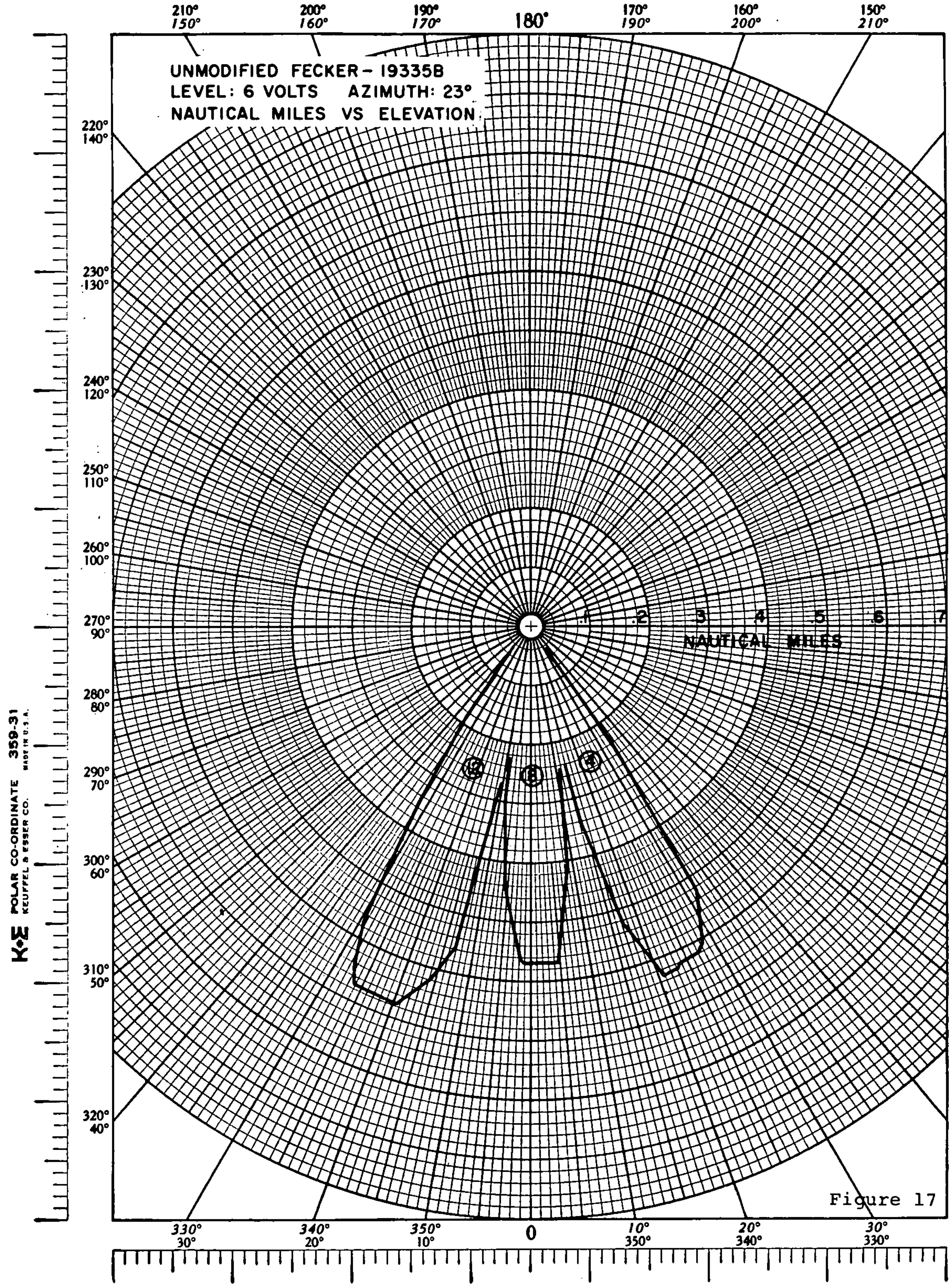

UNMODIFIED FECKER - 19335B
LEVEL: 6 VOLTS AZIMUTH: 23°
NAUTICAL MILES VS ELEVATION
NAUTICAL MILES
Figure 17
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 17

UNMODIFIED FECKER - 19335B						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS, R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS R2 RANGE
-81°	0°	5	3.71	.065	1.44	.041
-80		5	4.97	.076	1.92	.047
-79		5	8.91	.101	3.45	.063
-78		5	13.7	.126	4.52	.072
-77		5	33.6	.197	11.0	.112
-76		5	82.8	.309	27.0	.176
-75		5	124.	.378	44.3	.226
-74		5	146.	.410	56.9	.256
-70		5	230.	.514	89.3	.320
-66		5	241.	.526	93.2	.327
-63		5	266.	.553	103.	.344
-61		5	259.	.546	100.	.339
-59		5	192.	.470	74.7	.293
-57		5	136.	.395	47.3	.233
-55		5	141.	.403	47.4	.233
-53		5	187.	.464	72.6	.289
-51		5	258.	.545	100.	.339
-49		5	317.	.604	123.	.376
-47		5	325.	.611	126.	.381
-45		5	340.	.625	132.	.390
-43		5	356.	.640	138.	.398
-41		5	356.	.640	138.	.398
-39		5	284.	.571	110.	.356
-36		5	159.	.428	62.0	.267
-35		5	142.	.404	48.6	.236
-34		6	140.	.401	46.9	.232
-31		6	206.	.487	80.0	.303
-28		6	358.	.641	139.	.398
-26		6	392.	.671	152.	.418
-24		6	407.	.684	158.	.426
-22		6	418.	.693	162.	.432
-18		6	403.	.681	156.	.423
-16		6	333.	.619	129.	.385
-13		6	186.	.462	72.2	.288
-12		6	135.	.394	52.6	.246
-11		7	161.	.430	62.5	.268
- 9		7	275.	.562	106.	.349
- 7		7	410.	.686	159.	.428
- 4		7	560.	.802	217.	.499
- 1		7	600.	.830	233.	.518

Level: 6 Volts

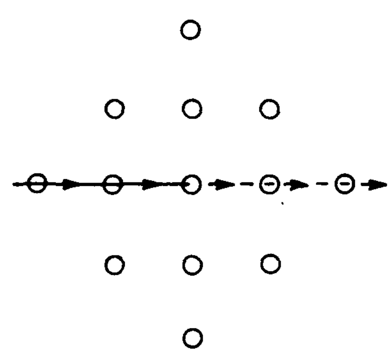


Table XIII

UNMODIFIED FECKER - 19335B						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
0°	0°	7	600.	.830	233.	.518
1		7	600.	.830	233.	.518
2		7	600.	.830	233.	.518
3		7	600.	.830	233.	.518
4		7	600.	.830	233.	.518
6		7	521.	.774	202.	.482
10		7	262.	.549	102.	.342
12		7	143.	.405	48.6	.236
13		8	145.	.408	44.4	.226
14		8	154.	.421	59.9	.262
18		8	284.	.571	110.	.356
21		8	335.	.621	130.	.387
23		8	333.	.619	129.	.385
25		8	333.	.619	129.	.385
27		8	289.	.576	112.	.359
29		8	238.	.523	92.7	.326
32		8	137.	.397	39.2	.212
33		9	97.4	.335	31.0	.189
34		9	136.	.395	44.2	.225
37		9	227.	.511	88.2	.318
40		9	304.	.591	118.	.368
41		9	325.	.611	126.	.381
43		9	325.	.611	126.	.381
45		9	325.	.611	126.	.381
47		9	310.	.597	120.	.371
48		9	323.	.609	125.	.379
50		9	323.	.609	125.	.379
51		9	323.	.609	125.	.379
52		9	260.	.547	101.	.341
56		9	175.	.448	68.0	.280
57		9	170.	.442	66.0	.275
58		9	180.	.455	70.0	.284
61		9	263.	.550	102.	.342
64		9	296.	.583	115.	.364
67		9	276.	.563	107.	.351
70		9	271.	.558	105.	.347
73		9	192.	.470	74.2	.292
75		9	128.	.384	43.6	.224
77		9	32.1	.192	11.0	.112
78		9	19.2	.149	7.15	.091
80		9	10.4	.109	3.38	.062
84		9	3.01	.059	1.16	.037

Level: 6 Volts

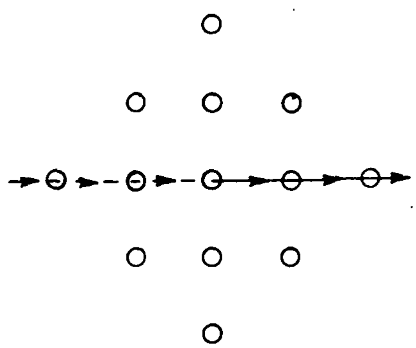


Table XIII
continued

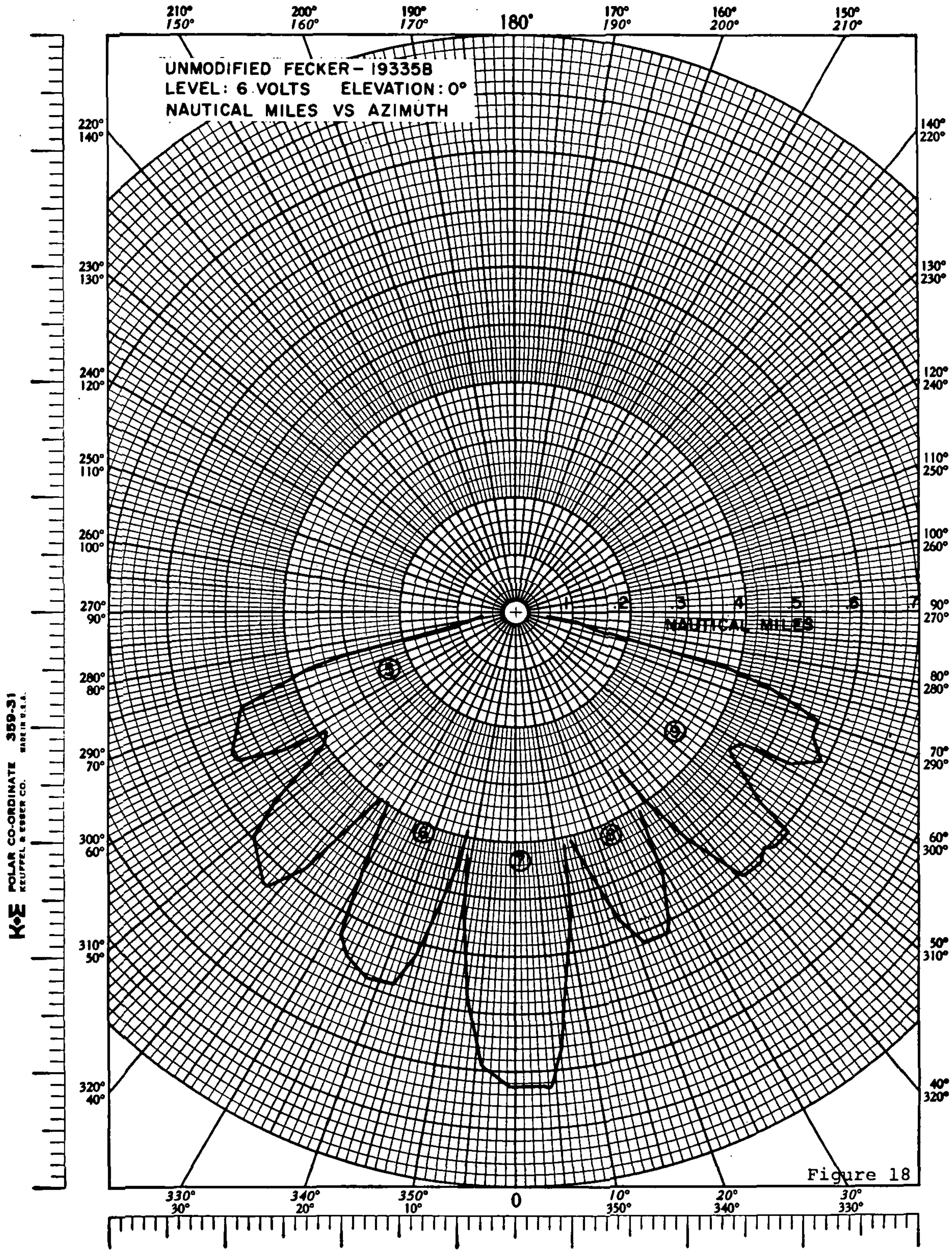

UNMODIFIED FECKER- 19335B
LEVEL: 6 VOLTS ELEVATION: 0°
NAUTICAL MILES VS AZIMUTH
NAUTICAL MILES
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.
Figure 18

Figure 18

UNMODIFIED FECKER - 19335B						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
-23°	35	2	6.06	.084	2.34	.052
	34	2	58.1	.258	22.6	.161
	33	2	76.2	.296	29.7	.185
	31	2	208.	.489	81.0	.305
	28	2	331.	.617	129.	.385
	25	2	375.	.657	146.	.410
	23	2	385.	.665	150.	.415
	21	2	390.	.670	152.	.418
	20	2	398.	.676	155.	.422
	19	2	372.	.654	145.	.408
	16	2	233.	.518	91.0	.323
	13	2	93.0	.327	36.2	.204
	12	6	134.	.392	52.1	.245
	11	6	180.	.455	70.0	.284
	8	6	277.	.564	108.	.352
	4	6	329.	.615	128.	.384
	2	6	326.	.612	127.	.382
	1	6	326.	.612	127.	.382
	0	6	326.	.612	127.	.382
	- 1	6	329.	.615	128.	.384
	- 2	6	321.	.607	125.	.379
	- 5	6	295.	.582	115.	.364
	- 8	6	178.	.452	69.6	.283
	-10	6	104.	.346	40.5	.216
	-11	10	85.9	.314	33.4	.196
	-14	10	238.	.523	92.8	.327
	-17	10	340.	.625	132.	.390
	-20	10	378.	.659	147.	.411
	-22	10	378.	.659	147.	.411
	-23	10	380.	.661	148.	.412
	-24	10	388.	.668	151.	.417
	-25	10	388.	.668	151.	.417
	-27	10	380.	.661	148.	.412
	-28	10	380.	.661	148.	.412
	-29	10	290.	.577	113.	.360
	-31	10	194.	.472	75.8	.295
	-33	10	105.	.347	35.0	.201
	-34	10	56.9	.256	22.1	.159
	-35	10	34.0	.198	13.2	.123
	-36	10	17.4	.141	6.09	.084
	-37	10	8.08	.096	2.48	.053

Level: 6 Volts

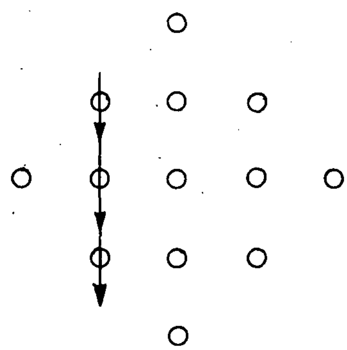
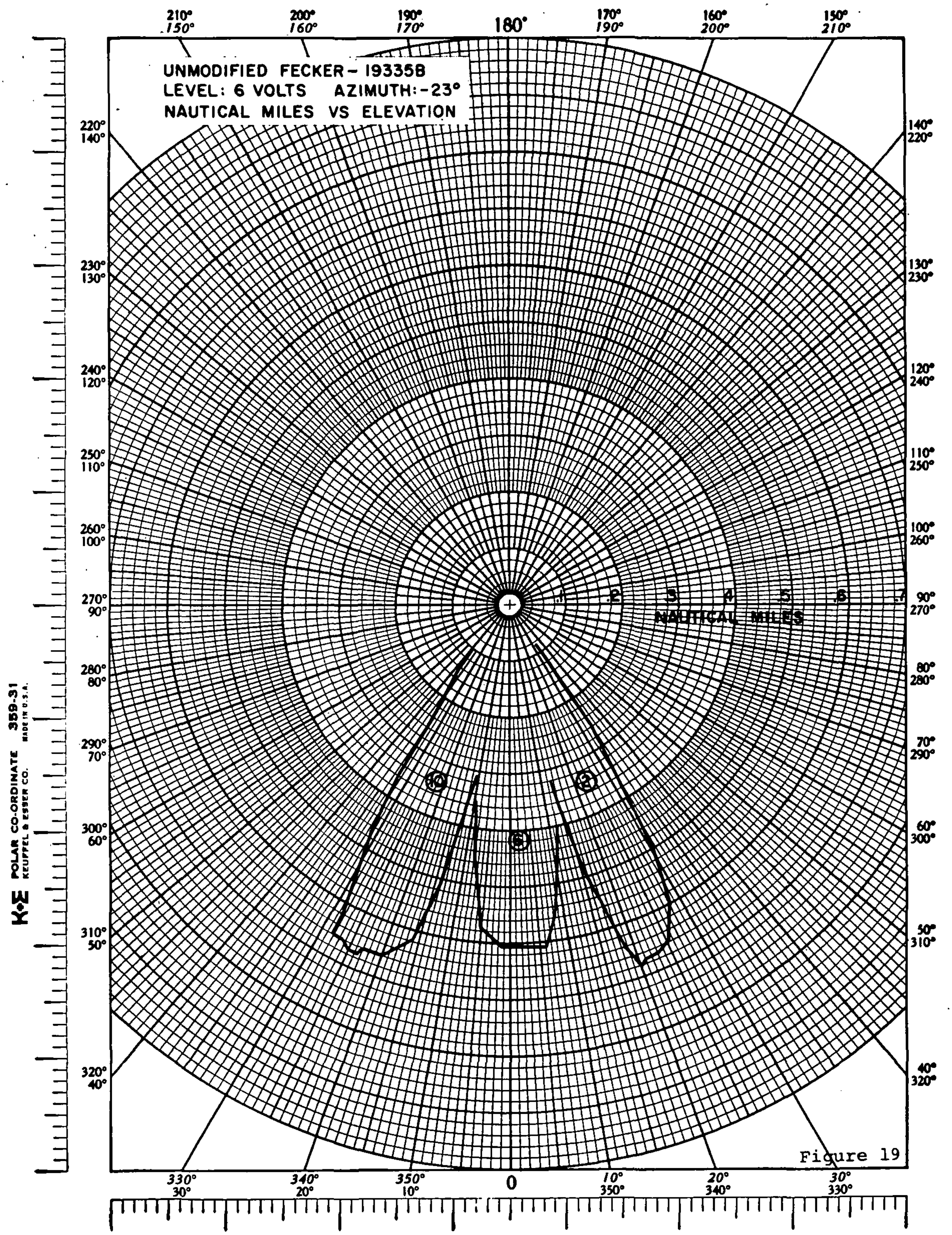


Table XIV



UNMODIFIED FECKER- 19335B
LEVEL: 6 VOLTS AZIMUTH:-23°
NAUTICAL MILES VS ELEVATION
NAUTICAL MILES
Figure 19
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 19

UNMODIFIED FECKER - 19335B						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
-37°	-25°	10	2.80	.057	1.04	.035
-36		10	15.1	.132	4.97	.076
-33		10	108.	.352	41.8	.219
-30		10	239.	.524	92.9	.327
-27		10	354.	.638	137.	.397
-24		10	390.	.669	151.	.417
-23		10	403.	.681	156.	.423
-22		10	403.	.681	156.	.423
-21		10	403.	.681	156.	.423
-19		10	390.	.670	151.	.417
-16		10	282.	.569	109.	.354
-13		10	156.	.423	60.2	.263
-11		10	79.3	.302	30.7	.188
-10		11	104.	.346	40.5	.216
- 9		11	145.	.408	56.2	.254
- 7		11	230.	.514	89.2	.320
- 5		11	302.	.589	117.	.367
- 2		11	392.	.671	152.	.418
0		11	398.	.676	154.	.421
1		11	398.	.676	154.	.421
2		11	408.	.685	158.	.426
3		11	392.	.671	152.	.418
5		11	354.	.638	137.	.397
8		11	256.	.542	99.8	.339
10		11	154.	.421	59.8	.262
11		11	110.	.356	42.5	.221
12		12	104.	.346	40.4	.216
16		12	274.	.561	106.	.349
19		12	364.	.647	141.	.403
20		12	372.	.654	144.	.407
21		12	408.	.685	158.	.426
22		12	408.	.685	158.	.426
23		12	408.	.685	158.	.426
24		12	388.	.668	150.	.415
27		12	354.	.638	137.	.397
30		12	255.	.541	99.0	.337
33		12	122.	.374	47.1	.233
35		12	55.0	.251	21.3	.157
37		12	9.38	.104	3.22	.061

Level: 6 Volts

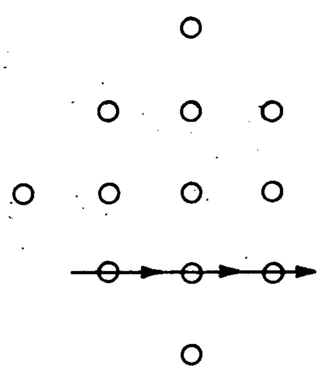
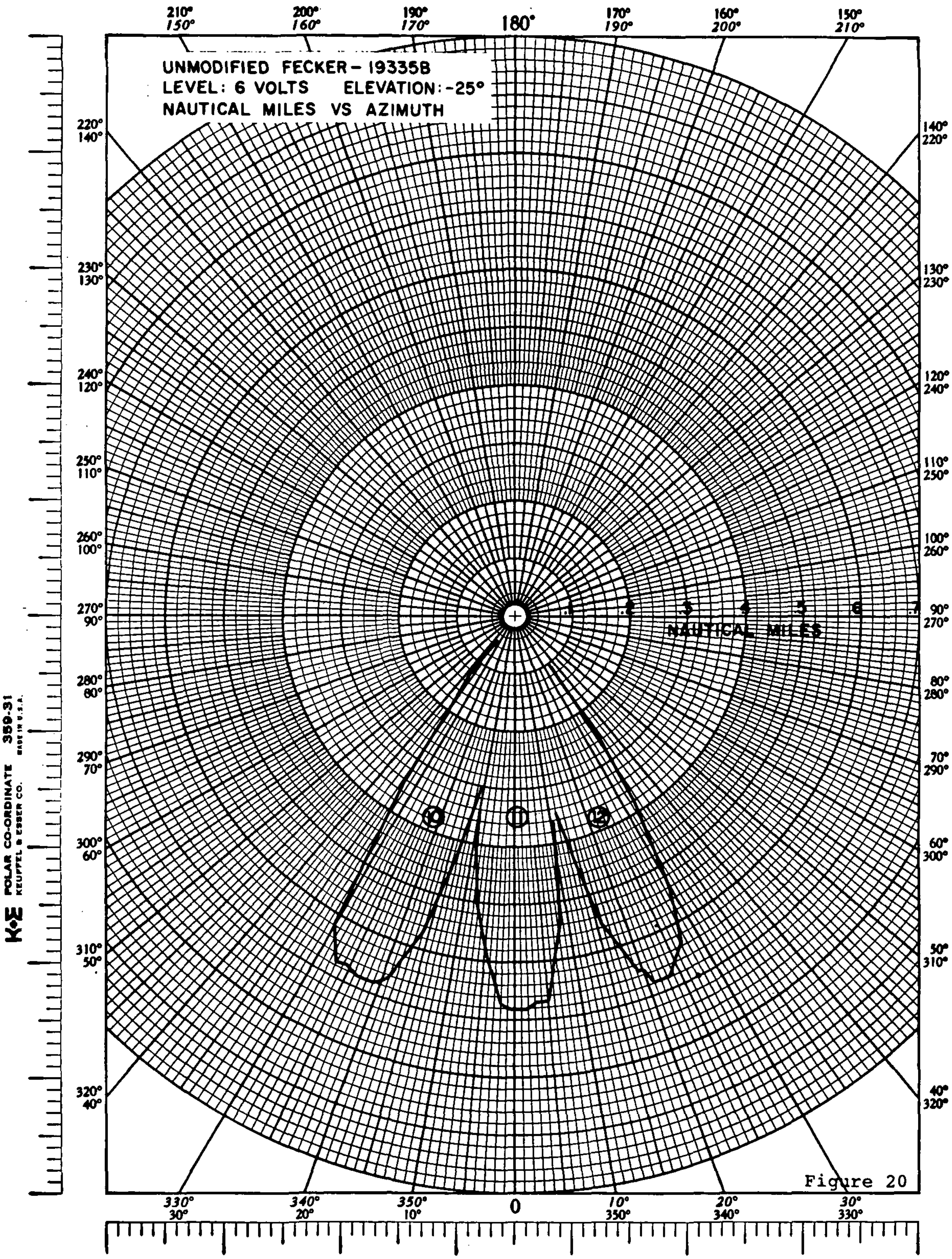


Table XV



UNMODIFIED FECKER - 19335B
LEVEL: 6 VOLTS ELEVATION: -25°
NAUTICAL MILES VS AZIMUTH
180°
0
NAUTICAL MILES
10
11
12
Figure 20
K+E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO. MADE IN U.S.A.

Figure 20

UNMODIFIED FECKER - 19335B						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
1°	59°	1	3.61	.064	1.40	.040
	58	1	18.1	.144	5.54	.080
	57	1	39.2	.212	15.2	.132
	56	1	75.9	.295	14.7	.130
	54	1	161.	.430	62.3	.268
	51	1	247.	.533	96.0	.332
	47	1	296.	.583	115.	.364
	45	1	330.	.616	128.	.384
	43	1	330.	.616	128.	.384
	42	1	322.	.608	125.	.379
	39	1	204.	.484	79.0	.301
	36	1	85.6	.314	33.2	.195
	35	1	54.8	.251	10.6	.110
	34	3	99.0	.337	19.2	.149
	31	3	256.	.542	99.1	.338
	28	3	369.	.651	143.	.405
	25	3	429.	.702	166.	.437
	22	3	429.	.702	166.	.437
	19	3	429.	.702	166.	.437
	17	3	390.	.669	151.	.417
	14	3	194.	.472	75.4	.294
	13	3	130.	.387	50.2	.240
	12	7	186.	.462	72.1	.288
	9	7	374.	.656	145.	.408
	6	7	490.	.750	190.	.467
	3	7	505.	.762	198.	.477
	1	7	508.	.764	200.	.479
	- 1	7	508.	.764	200.	.479
	- 4	7	508.	.764	200.	.479
	- 5	7	472.	.737	183.	.459
	- 8	7	266.	.553	103.	.344
	-10	7	136.	.395	52.7	.246
	-11	7	90.2	.322	35.0	.201
	-12	11	108.	.352	42.1	.220
	-15	11	222.	.505	86.0	.314
	-18	11	364.	.647	141.	.403
	-21	11	364.	.647	141.	.403
	-24	11	375.	.657	145.	.408
	-25	11	375.	.657	145.	.408
	-27	11	351.	.635	136.	.395
	-29	11	268.	.555	104.	.346

Level: 6 Volts

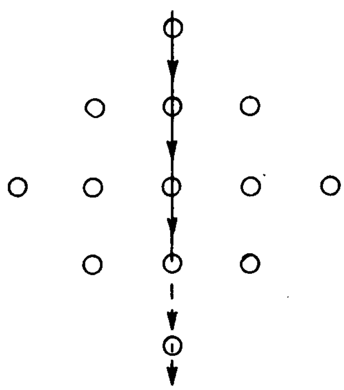


Table XVI

UNMODIFIED FECKER - 19335B						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
1°	-31°	11	181.	.456	70.2	.284
	-32	11	128.	.384	49.6	.239
	-33	13	90.0	.322	34.8	.200
	-36	13	244.	.530	94.9	.330
	-39	13	356.	.640	138.	.398
	-42	13	408.	.685	158.	.426
	-44	13	397.	.676	154.	.421
	-46	13	377.	.658	146.	.410
	-48	13	377.	.658	146.	.410
	-51	13	214.	.496	83.0	.309
	-54	13	78.3	.300	28.2	.180
	-55	13	49.0	.237	19.0	.148
↓	-57	13	10.0	.107	3.83	.066

Level: 6 Volts

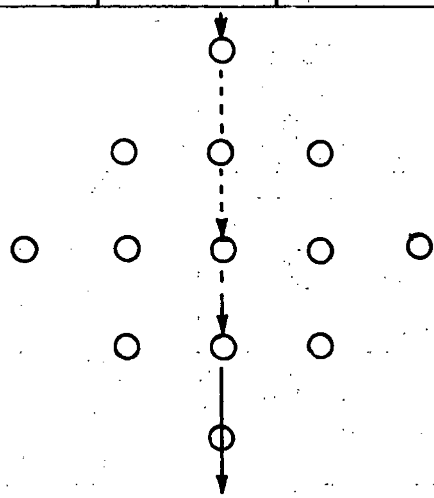


Table XVI
continued

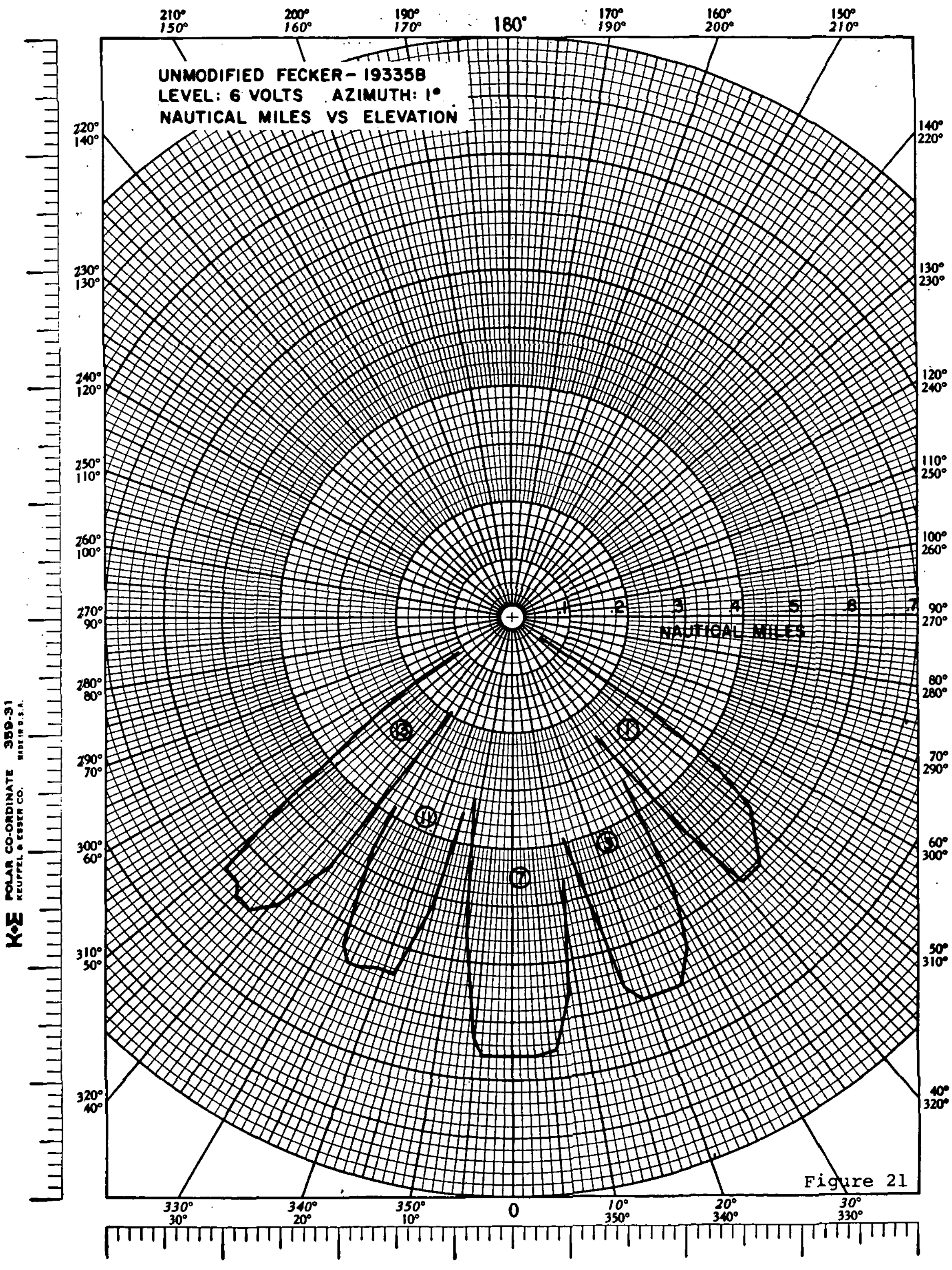

UNMODIFIED FECKER- 19335B
LEVEL: 6 VOLTS AZIMUTH: 1°
NAUTICAL MILES VS ELEVATION
NAUTICAL MILES
.1 .2 .3 .4 .5 .6 .7
180°
0
K&E POLAR CO-ORDINATE 359-31
KEUFFEL & ESSER CO.
Figure 21

Figure 21

UNMODIFIED FECKER - 19335B						
AZIMUTH	ELEVATION	DIODE	NO ATMOS. R1 GAIN	NO ATMOS. R1 RANGE	NO ATMOS. R2 GAIN	NO ATMOS. R2 RANGE
1°	0°	7	493.	.753	191.	.469
3	2	7	493.	.753	191.	.469
5	4	7	480.	.743	186.	.462
7	6	7	356.	.640	138.	.398
9	8	7	247.	.533	96.0	.332
11	10	7	84.3	.311	32.7	.194
12	11	7	40.7	.216	15.8	.135
15	14	4	38.2	.210	14.8	.130
17	16	4	107.	.351	41.6	.219
19	18	4	284.	.571	110.	.356
21	20	4	356.	.640	138.	.398
23	22	4	354.	.638	137.	.397
25	24	4	349.	.633	135.	.394
27	26	4	313.	.600	121.	.373
29	28	4	219.	.502	85.0	.313
31	30	4	126.	.381	49.1	.238
33	32	4	52.2	.245	20.3	.153
35	34	4	7.27	.091	2.59	.055

Level: 6 Volts

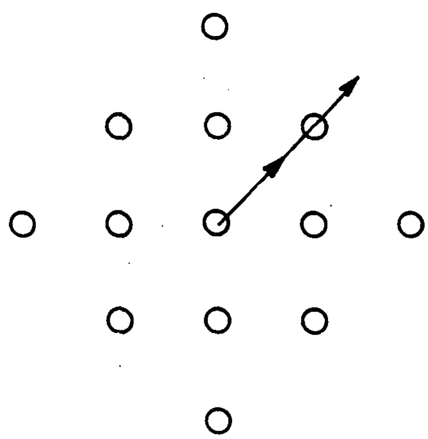


Table XVII

TABLE XVIII.- MULTIPLICATIVE FACTORS FOR DIFFERENT THRESHOLD VOLTAGE LEVELS

Voltage Level	Fecker #19336A	Fecker #19335B
10 volts	0.61	0.59
8	0.73	0.72
6	1.00	1.00
4	———	1.60

C. Loral PWI

The Loral PWI optical system consists of spherical optics, an aperture stop, filter, and light "pipes". Incident light is collected by a hemispheric lens and is directed through an aperture stop to reduce spherical aberration. A Schott RG-780 filter cuts off the radiation below 0.8 microns. After the filter, the light enters a second hemispheric lens which forms a spherical focal surface. To utilize the smallest detectors, to reduce the danger of sun damage, and to minimize the reduced contour sensitivity at the junctions between detectors, the optical system employs light "pipes" between the focal hemisphere and the photoconductors.

(As an aside, it was found expeditious in the data collection to monitor the video take-out points. A 565-Techtronix dual-beam oscilloscope was used to trigger the time base and measure the pulse size just as the audio alarm sounded. This technique allowed one to see the relative size of the signal in the Loral PWI and, hence, to know how to adjust the variable neutral density filter.)

The Loral system consists of two pods — one for each wing. Figure 22 shows the coordinate system and the location of the centers of sensitivity for each photoconductor. Although the system is equipped with a down-looker, it was not checked in the laboratory tests.

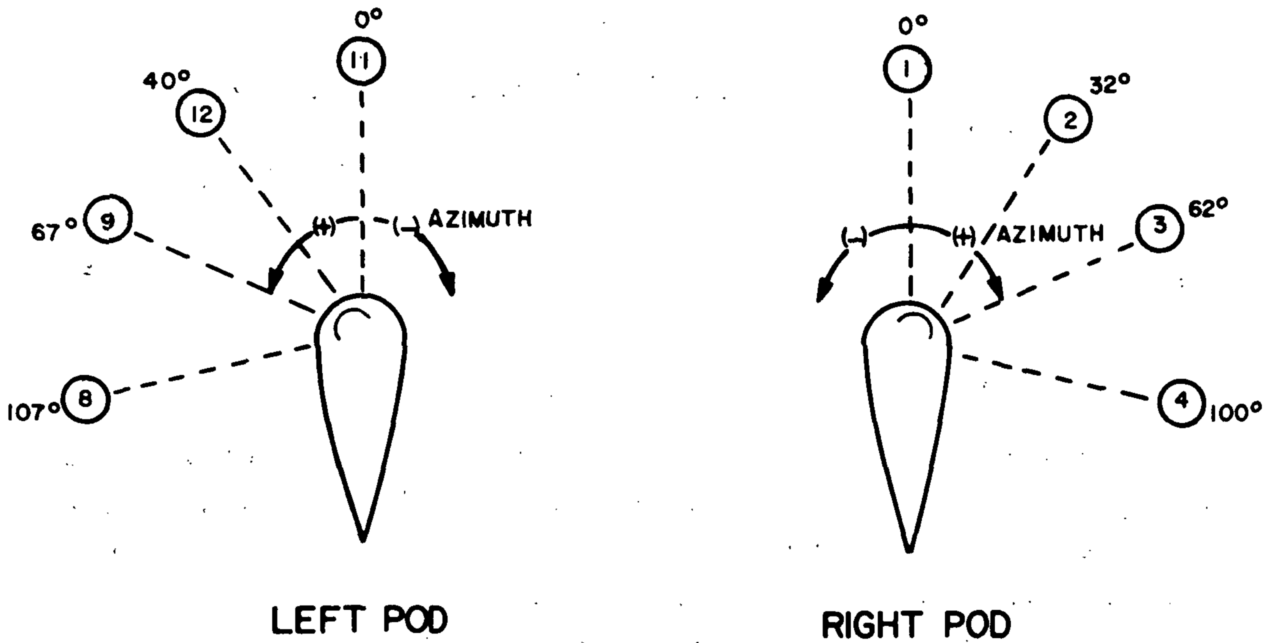


Figure 22.- Coordinate system used for the Loral Laboratory tests. (Positive elevation is into the plane of the paper. The numbers indicate the centers of sensitivity of the channels or detectors, System 19329B.)

The setting of the sensitivity control (located on the Loral display panel) controls the range capability of the PWI. The potentiometer control, unfortunately, has no indicator markings so the position of the setting was determined by measuring the voltage across the potentiometer. It is imperative that this voltage be known during the field and flight tests (as the data will show), and it is recommended that either a multiposition calibrated switch or a single voltage be selected for future tests.

In addition to the sensitivity voltage, the background environment in which the photoconductors operate is a critical parameter. The laboratory tests used three backgrounds: dark, daylight illumination, and a headlight inclined 15° to the

Loral 19329B							Left Pod
Photo-conductor	Sensitivity Voltage	Dark Test		Room Daylight		Headlight	
		Gain	Range	Gain	Range	Gain	Range
8	2	139.	.340	97.0	.334	———	———
	3	4602.	2.30	140.	.401	9.72	.106
	4	11259.	3.60	3534.	2.02	9.91	.107
	5	12231.	3.75	5442.	2.50	16.5	.138
	6	29322.	5.80	7980.	3.03	17.9	.143
	7	138510.	12.6	9072.	3.23	21.8	.158
	8	146205.	13.0	13122.	3.88	21.2	.156
↓	9	137295.	12.6	10287.	3.44	18.2	.145
9	2	75.2	.294	45.9	.230	5.77	.081
	3	2278.	1.62	1224.	1.19	53.8	.249
	4	3062.	1.88	2090.	1.55	77.8	.299
	5	5565.	2.53	2538.	1.71	93.2	.327
	6	5767.	2.57	3564.	2.02	117.	.367
	7	5605.	2.54	3709.	2.06	147.	.411
	8	8270.	3.08	4074.	2.16	157.	.425
↓	9	5905.	2.61	4590.	2.30	157.	.425
10	2	131.	.388	70.2	.284	9.49	.104
	3	5836.	2.59	1645.	1.37	131.	.388
	4	8060.	3.04	2446.	1.68	189.	.466
	5	11583.	3.65	2584.	1.72	261.	.548
	6	40905.	6.86	5426.	2.50	319.	.606
	7	46332.	7.30	6688.	2.77	364.	.647
	8	51840.	7.72	9196.	3.25	398.	.676
↓	9	42282.	6.97	6445.	2.72	444.	.714
11	2	102.	.342	43.7	.224	6.21	.085
	3	2926.	1.83	255.	.541	85.2	.313
	4	2105.	1.55	242.	.527	136.	.395
	5	1018.	1.08	328.	.614	175.	.449
	6	745.	.925	128.	.384	214.	.496
	7	745.	.925	118.	.368	255.	.541
	8	684.	.887	58.4	.259	285.	.572
↓	9	821.	.971	50.0	.240	275.	.562

Table XIX

Loral 19329B					Right Pod
Photo-conductor	Sensitivity Voltage	Room Daylight		Headlight	
		Gain	Range	Gain	Range
4	2.5	0	0	0	0
	3.0				
	3.5	10125.	3.41	242.	.527
	4.0	11016.	3.56	291.	.578
	4.5	16200.	4.31	311.	.598
	5.0	12555.	3.80	388.	.668
	5.5	16200.	4.31	416.	.691
	6.0	17253.	4.45	442.	.712
	6.5	26487.	5.52	489.	.750
	7.0	27378.	5.61	439.	.710
	7.5	27702.	5.64	424.	.698
	8.0	29646.	5.84	471.	.736
	8.5	30618.	5.93	602.	.831
	9.0	30618.	5.93	522.	.775
	9.5	2576.	1.72	522.	.775
3	2.5	0	0	26.8	.175
	3.0	5832.	2.59		
	3.5			160.	.429
	4.0	13365.	3.92	151.	.417
	4.5			201.	.481
	5.0	27540.	5.63	186.	.462
	5.5			186.	.462
	6.0	112428.	11.37	238.	.523
	6.5			250.	.536
	7.0	2158650.	49.81	229.	.513
	7.5			233.	.517
	8.0			239.	.524
	8.5			228.	.512
	9.0			273.	.560
	9.5			225.	.509
2	2.5			16.6	.138
	3.0	1307.			
	3.5			123.	.375
	4.0	2493.		135.	.394
	4.5			150.	.415
	5.0	3086.		173.	.446
	5.5			192.	.470
	6.0	3747.		227.	.510
	6.5			207.	.488
	7.0	4256.		245.	.530
	7.5			232.	.516
	8.0	4834.		243.	.529
	8.5			264.	.550
	9.0	5411.		264.	.550
	9.5			288.	.575

Table XX

Loral 19329B					Right Pod
Photo-conductor	Sensitivity Voltage	Room Daylight		Headlight	
		Gain	Range	Gain	Range
1	2.5			4.47	.072
↓	3.0	791.			
	3.5			19.0	.148
	4.0	1123.		12.0	.122
	4.5			12.9	.139
	5.0	1423.		16.4	.137
	5.5			18.2	.145
	6.0	1152.		19.7	.150
	6.5			18.5	.146
	7.0	365.		25.5	.171
	7.5			26.1	.173
	8.0	287.		26.1	.173
	8.5			24.3	.167
	9.0	503.		24.7	.168
	9.5			29.9	.185

Table XXI

Xenon strobe. As a rough measure of the IR background, a Luna-Pro light meter was used whose sensitive area was covered with a RG-780 filter. On a typical day the readings were:

dark:	3
room background:	12 1/3
headlight (at 15°):	18 1/3
headlight (directly):	20 1/3

So one can assert that the dark test environment was 1/650 the room background in daylight and that the headlight (at 15°) was 64 times as bright as the room in daylight. Tables XX and XXI list the gain and range of the Loral as functions of the sensitivity voltage and the background.

The data collected with the headlight mounted at 15° must be interpreted with some care. The roughly parallel light from the headlight always flooded the ball lens at an elevation of 15° (for azimuth scans) and at an elevation of 15° larger than the elevation recorded. There will be instances, especially when the warning transfers from one channel to the next, when the headlight will be illuminating one photoconductor and data will be collected on another.

The data were collected by selecting a sensitivity voltage (usually 3 or 4 volts for convenience) and a background, and by varying either azimuth or elevation. Tables XXII thru XLI present the laboratory data for Loral system 19329B. The patterns are not as lobed as in the Fecker PWI, and this is attributable to the light "pipe" design for avoiding inter-detector gaps.

Loral 19329B					Left Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
0°	24°	11	2	3.75	.066
	20°	11	2	5.67	.081
	16°	11	2	11.0	.112
	12°	11	2	43.5	.224
	8°	11	2	118.	.368
	4°	11	2	82.82	.309
	2°	11	2	81.28	.306
	0°	11	2	84.74	.312
	-2°	11	2	72.19	.288
	-6°	11	2	58.1	.258
	-10°	11	2	23.4	.164
	-14°	11	2	7.24	.091
	-18°	11	2	4.39	.071
	-21°	11	2	3.04	.059
40°	-25°	10	2	3.34	.062
	-22°	10	2	4.37	.071
	-18°	10	2	7.02	.090
	-14°	10	2	12.6	.120
	-10°	10	2	33.7	.197
	-6°	10	2	107.	.351
	-2°	10	2	116.	.366
	0°	10	2	97.	.334
	2°	10	2	100.	.339
	4°	10	2	137.7	.398
	8°	10	2	118.	.367
	12°	10	2	35.2	.201
	16°	10	2	11.	.110
	20°	10	2	5.67	.081
	24°	10	2	3.46	.063
67°	19°	9	2	3.5	.063
	16°	9	2	5.1	.077
	12°	9	2	14.	.127
	8°	9	2	36.2	.204
	4°	9	2	59.2	.261
	2°	9	2	51.2	.243
	0°	9	2	56.8	.256
	-2°	9	2	69.8	.283
	-6°	9	2	84.	.311
	-10°	9	2	39.6	.213
	-14°	9	2	7.23	.091

Dark Test

Table XXII

Loral 19329B					Left Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
67°	-18°	9	2	4.31	.070
	-20°	9	2	3.08	.059
107°	-19°	8	2	3.36	.062
	-14°	8	2	6.97	.089
	-10°	8	2	38.4	.210
	-4°	8	2	91.	.323
	-2°	8	2	102.	.343
	0°	8	2	101.	.341
	2°	8	2	98.7	.337
	4°	8	2	93.8	.328
	8°	8	2	35.	.200
	12°	8	2	21.5	.157
	16°	8	2	5.6	.080
	19°	8	2	3.46	.063

Dark Test

Table XXIII

Loral 19329B					Left Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
135°	0°	8	3	2.76	.056
132°	↓	8	3	3.55	.064
129°		8	3	4.0	.068
125°		8	3	47.8	.234
121°		8	3	181.	.455
117°		8	3	361.	.644
113°		8	3	806.	.962
109°		8	3	3791.	2.10
105°		8	3	5192.	2.44
101°		8	3	3953.	2.13
97°		8	3	4188.	2.19
93°		8	3	1623.	1.37
89°		8	3	1854.	1.46
85°		8	3	1718.	1.41
82°		8	3	1474.	1.3
81°		9	3	1504.	1.31
77°		9	3	7120.	2.86
73°		9	3	3945.	2.13
69°		9	3	2786.	1.79
65°		9	3	3807.	2.1
61°		9	3	2649.	1.74
57°		9	3	5216.	2.45
53°		9	3	2244.	1.61
52°		9	3	1436.	1.28
51°		10	3	1794.	1.44
47°		10	3	6909.	2.82
43°		10	3	5208.	2.45
39°		10	3	5314.	2.47
35°		10	3	29970.	5.87
31°		10	3	12231.	3.75
27°		10	3	10449.	3.47
24°		10	3	6051.	2.64
23°		11	3	20250.	4.82
19°		11	3	603450.	26.3
15°		11	2	234.8	.519
19°		11	2	230.	.514
11°		11	2	145.	.408
7°		11	2	120.	.372
3°		11	2	98.2	.336
-1°	↓	11	2	78.6	.301

Dark Test

Table XXIV

Loral 19329B					Left Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
-5°	0°	11	2	68.2	.280
-9°	↓	11	2	28.4	.181
-13°	↓	11	2	10.6	.110
-17°	↓	11	2	4.26	.070
-21°	↓	11	3	18.9	.147
-24°	↓	11	3	6.84	.089

Dark Test

Table XXV

Loral 19329B					Left Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
121°	0°	8	2	2.78	.057
117°	↓	8	2	5.89	.082
113°		8	2	15.3	.133
109°		8	2	65.	.274
105°		8	2	70.4	.284
101°		8	2	49.	.273
97°		8	2	51.7	.244
93°		8	2	54.2	.250
89°		8	2	71.2	.286
85°		8	2	69.8	.283
82°		8	2	25.5	.171
81°		9	2	26.5	.175
77°		9	2	69.8	.283
73°		9	2	42.	.22
69°		9	2	37.5	.208
65°		9	2	39.3	.213
61°		9	2	40.7	.216
57°		9	2	75.4	.294
53°		9	2	37.3	.207
52°		9	2	27.5	.178
51°		10	2	25.3	.171
47°		10	2	73.6	.291
43°		10	2	68.6	.281
39°		10	2	94.8	.330
35°		10	2	130.	.387
31°		10	2	77.8	.300
27°		10	2	92.4	.326
24°		10	2	66.	.275
23°		10	2	43.2	.223
22°		11	2	45.	.230
19°		11	2	106.	.350
15°		11	2	103.	.344
11°		11	2	62.3	.286
7°		11	2	57.	.256
3°		11	2	47.	.232
-1°		11	2	41.8	.22
-5°		11	2	44.	.225
-9°		11	2	12.8	.121
-13°		11	2	4.3	.070
-15°	↓	11	2	2.6	.055

Daylight Test

Table XXVI

Loral 19329B					Left Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
0°	14°	11	2	3.23	.061
↓	11°	11	2	17.7	.143
	8°	11	2	37.	.206
	5°	11	2	37.2	.207
	2°	11	2	35.8	.203
	0°	11	2	37.7	.208
	-2°	11	2	36.3	.204
	-5°	11	2	34.	.200
	-8°	11	2	18.	.145
	-11°	11	2	6.6	.087
	-14°	11	2	2.7	.056
40°	-19°	10	2	2.8	.056
↓	-16°	10	2	4.9	.075
	-14°	10	2	7.4	.092
	-11°	10	2	15.5	.133
	-8°	10	2	41.	.217
	-5°	10	2	59.	.260
	-2°	10	2	72.	.287
	0°	10	2	74.	.291
	2°	10	2	74.	.291
	5°	10	2	97.	.335
	8°	10	2	91.	.323
	11°	10	2	31.	.188
	14°	10	2	8.5	.099
	17°	10	2	4.4	.071
	20°	10	2	2.7	.055
67°	16°	9	2	2.8	.057
↓	14°	9	2	4.3	.070
	11°	9	2	12.3	.119
	8°	9	2	27.	.176
	5°	9	2	46.	.230
	2°	9	2	48.	.235
	0°	9	2	49.	.237
	-2°	9	2	60.	.263
	-5°	9	2	68.	.279
	-8°	9	2	42.	.220
	-11°	9	2	24.	.166
	-14°	9	2	6.99	.090
	-17°	9	2	3.3	.061
	-19°	9	2	2.5	.054

Daylight Test

Table XXVII

Loral 19329B					Left Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
107°	-19°	8	2	2.75	.056
↓	-17°	8	2	3.25	.060
	-14°	8	2	6.95	.089
	-11°	8	2	21.1	.156
	-8°	8	2	52.0	.244
	-5°	8	2	91.4	.324
	-2°	8	2	110.	.354
	0°	8	2	125.	.378
	2°	8	2	141.	.402
	5°	8	2	121.	.372
	8°	8	2	75.2	.294
	11°	8	2	29.4	.184
	14°	8	2	6.25	.085
	17°	8	2	3.38	.062
↓	18°	8	2	2.64	.055

Daylight Test

Table XXVIII

Loral 19329B					Left Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
110°	11°	8	2	2.43	.053
	8°	8	2	4.75	.074
	5°	8	2	8.13	.097
	2°	8	2	7.18	.091
	0°	8	2	6.38	.086
	-2°	8	2	6.53	.087
	-5°	8	2	6.18	.084
	-8°	8	2	4.89	.075
	-10°	8	2	2.78	.057
67°	-11°	9	2	3.23	.061
	-8°	9	2	8.77	.100
	-5°	9	2	10.9	.112
	-2°	9	2	10.8	.111
	0°	9	2	9.23	.103
	2°	9	2	11.1	.113
	5°	9	2	11.0	.112
	8°	9	2	8.25	.097
	11°	9	2	3.53	.064
40°	11°	10	2	3.10	.060
	8°	10	2	7.89	.095
	5°	10	2	8.10	.096
	2°	10	2	7.36	.092
	0°	10	2	5.85	.082
	-2°	10	2	6.31	.085
	-5°	10	2	5.42	.079
	-8°	10	2	3.94	.067
0°	-10°	11	3	2.74	.056
	-8°	11	3	3.44	.063
	-5°	11	3	9.21	.103
	-2°	11	3	9.16	.103
	0°	11	3	9.78	.106
	2°	11	3	11.8	.116
	5°	11	3	8.58	.099
	8°	11	3	6.63	.087
	11°	11	3	3.53	.064
	12°	11	3	2.69	.056

Headlight Background Test

Table XXIX

Loral 19329B					Left Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
113°	0°	8	2	2.57	.054
109°	↓	8	2	6.90	.089
105°		8	2	5.00	.076
101°		8	2	5.37	.079
97°		8	2	8.88	.101
93°		8	2	8.70	.100
89°		8	2	18.5	.145
85°		8	2	15.1	.132
82°		8	2	2.99	.059
81°		9	2	2.97	.058
77°		9	2	6.22	.085
73°		9	2	4.06	.068
69°		9	2	9.03	.102
65°		9	2	8.12	.097
61°		9	2	10.9	.112
57°		9	2	19.7	.150
53°		9	2	5.91	.082
52°		9	2	2.87	.057
51°		10	2	2.71	.056
47°		10	2	5.52	.080
43°		10	2	4.41	.071
39°		10	2	6.80	.088
35°		10	2	6.63	.087
31°		10	2	7.11	.090
27°		10	2	10.5	.110
23°		10	2	2.83	.057
22°		11	2	—	—
22°		10	3	16.0	.136
21°		11	3	8.21	.097
17°		11	3	8.02	.096
13°		11	3	7.87	.095
9°		11	3	13.6	.125
5°		11	3	11.9	.117
1°		11	3	8.86	.101
-3°		11	3	9.50	.104
-7°		11	3	3.14	.060
-8°	↓	—	—	—	—

Headlight Background Test

Table XXX

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
-30°	0°	1	4	3.79	.066
-28	↓	1	4	9.69	.106
-26		1	4	17.6	.142
-24		1	4	35.7	.203
-22		1	4	43.1	.223
-20		1	4	66.2	.276
-18		1	4	111.	.359
-16		1	4	125.	.379
-14		1	4	230.	.514
-12		1	4	323.	.609
-10		1	4	392.	.671
-8		1	4	510.	.766
-6		1	4	511.	.766
-4		1	4	663.	.873
-2		1	4	752.	.930
0		1	4	942.	1.04
2		1	4	889.	1.01
4		1	4	866.	.998
6		1	4	803.	.961
8		1	4	866.	.998
10		1	4	874.	1.00
12		1	4	505.	.762
14		2	4	632.	.852
16		2	4	935.	1.04
18		2	4	1198.	1.17
20		2	4	1582.	1.35
22		2	4	1718.	1.41
24		2	4	1763.	1.42
26		2	4	1672.	1.39
28		2	4	1403.	1.27
30		2	4	1403.	1.27
32		2	4	1514.	1.32
34		2	4	1593.	1.35
36		2	4	2128.	1.56
38		2	4	2402.	1.66
40		2	4	2599.	1.73
42		3	4	2113.	1.56
44		3	4	3614.	2.04
46		3	4	11096.	3.57
48	↓	3	4	10640.	3.50

Dark Test

Table XXXI

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
50°	0°	3	4	9720.	3.34
52		3	4	14726.	4.11
54		3	4	10530.	3.48
56		3	4	11502.	3.64
58		3	4	8149.	3.06
60		3	4	13592.	3.95
62		3	4	16346.	4.33
64		3	4	10854.	3.53
66		3	4	9801.	3.36
68		3	4	6107.	2.65
70		3	4	8562.	3.14
72		3	4	5937.	2.61
74		3	4	2811.	1.80
76		4	3	2371.	1.65
78		4	3	5816.	2.59
80		4	3	5249.	2.46
82		4	3	6002.	2.63
84		4	3	5184.	2.44
86		4	3	5881.	2.60
88		4	3	6772.	2.79
90		4	3	6812.	2.80
92		4	3	6812.	2.80
94		4	3	4925.	2.38
96		4	3	4058.	2.16
98		4	3	5022.	2.40
100		4	3	3848.	2.10
102		4	3	2365.	1.65
104		4	3	1663.	1.38
106		4	3	1079.	1.11
108		4	3	645.	.861
110		4	3	474.	.738
112		4	3	279.	.566
114		4	3	143.	.406
116		4	3	87.7	.317
118		4	3	15.6	.134
120		4	3	3.12	.060

Dark Test

Table XXXII

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
-30°	0°	1	4	3.42	.063
-27		1	4	11.5	.115
-24		1	4	29.0	.183
-21		1	4	50.0	.240
-18		1	4	100.	.339
-15		1	4	193.	.471
-12		1	4	291.	.578
-9		1	4	410.	.686
-6		1	4	533.	.782
-3		1	4	924.	1.03
0		1	4	1111.	1.13
3		1	4	1096.	1.12
6		1	4	1042.	1.09
9		1	4	1042.	1.09
12		1	4	789.	.952
16		2	4	689.	.890
18		2	4	1696.	1.40
21		2	4	1920.	1.49
24		2	4	1892.	1.47
27		2	4	1558.	1.34
30		2	4	1687.	1.39
33		2	4	1786.	1.43
36		2	4	2075.	1.54
39		2	4	2485.	1.69
42		2	4	1816.	1.44
43		2	4	1490.	1.31
44		3	4	1702.	1.40
47		3	4	4332.	2.23
50		3	4	7448.	2.93
53		3	4	7549.	2.95
56		3	4	7403.	2.92
59		3	4	11502.	3.64
62		3	4	13527.	3.94
65		3	4	7298.	2.90
68		3	4	6998.	2.84
71		3	4	6577.	2.75
74		3	4	3645.	2.05
75		4	3	2052.	1.54
78		4	3	5457.	2.50
81	↓	4	3	4957.	2.39

Daylight Test

Table XXXIII

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
84°	0°	4	3	4674.	2.32
87	↓	4	3	5500.	2.51
90		4	3	4568.	2.29
93		4	3	4334.	2.23
96		4	3	4285.	2.22
99		4	3	4520.	2.28
102		4	3	2827.	1.80
105		4	3	1733.	1.41
108		4	3	836.	.980
111		4	3	426.	.699
114		4	3	202.	.482
117		4	3	77.0	.297
120		4	3	8.47	.099
123		4	3	5.83	.082
126		4	3	4.65	.073
129		4	3	3.71	.065
130		4	3	3.34	.062

Daylight Test

Table XXXIV

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
0°	-15°	1	3	64.6	.273
0	-13	1	↓	114.	.361
0	-10	1		228.	.512
0	-7	1		362.	.645
0	-4	1		657.	.869
0	-1	1		657.	.869
0	2	1		457.	.725
0	5	1		489.	.750
0	8	1		419.	.694
0	11	1		214.	.496
0	14	1		106.	.349
0	17	1		70.5	.245
0	20	1		43.8	.224
0	22	1		30.4	.187
0	24	1		21.8	.158
0	27	1		18.9	.147
0	30	1		17.8	.143
0	33	1		11.3	.114
0	-18	1		60.0	.263
0	-21	1		38.7	.211
0	-24	1		29.5	.184
0	-27	1		18.2	.145
0	-30	1		13.5	.125
39	-27	2		50.1	.240
39	-24	2		49.3	.238
39	-21	2		73.4	.290
39	-18	2		99.7	.338
39	-15	2		186.	.462
39	-12	2		325.	.611
39	-9	2		700.	.897
39	-6	2		1357.	1.25
39	-3	2		1771.	1.43
39	0	2		1619.	1.36
39	3	2		1664.	1.38
39	6	2		1664.	1.38
39	9	2		1224.	1.19
39	12	2		507.	.763
39	15	2		315.	.602
39	18	2		138.	.400
39	21	2	↓	114.	.362

Daylight Test

Table XXXV

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
39°	24°	2	3	76.5	.297
39	26	2	↓	59.6	.262
62	55	3		11.2	.113
62	51	3		16.1	.136
62	47	3		22.0	.159
62	43	3		28.7	.182
62	39	3		39.3	.213
62	35	3		58.9	.260
62	31	3		77.4	.298
62	27	3		103.	.344
62	23	3		172.	.444
62	19	3		311.	.598
62	16	3		472.	.737
62	13	3		928.	1.03
62	10	3		2478.	1.69
62	7	3		3899.	2.12
62	4	3		3884.	2.11
62	1	3		3709.	2.06
62	-2	3		4773.	2.34
62	-5	3		4081.	2.17
62	-8	3		1870.	1.47
62	-12	3		853.	.990
62	-16	3		360.	.643
62	-20	3		128.	.384
62	-24	3		68.0	.280
62	-28	3		49.6	.239
62	-32	3		25.4	.171
62	-36	3		18.0	.144
62	-40	3		11.2	.113
62	-44	3		7.88	.095
62	-48	3		4.70	.073
100	-46	4		5.27	.078
100	-43	4		12.7	.121
100	-40	4		17.3	.141
100	-37	4		30.4	.187
100	-34	4		39.5	.213
100	-31	4		59.1	.261
100	-28	4		67.3	.278
100	-25	4		109.	.354
100	-22	4	↓	157.	.425

Daylight Test

Table XXXVI

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
100°	-19°	4	3	298.	.585
↓	-16°	4	↓	497.	.755
	-13	4		1042.	1.09
	-10	4		2029.	1.53
	-7	4		4932.	2.38
	-4	4		5403.	2.49
	-1	4		5873.	2.60
	2	4		6383.	2.71
	5	4		6480.	2.73
	8	4		5063.	2.41
	11	4		3390.	1.97
	14	4		1292.	1.22
	17	4		932.	1.03
	20	4		339.	.624
	23	4		245.	.530
	26	4		195.	.473
	29	4		137.	.397
	32	4		113.	.360
	35	4		48.0	.235
	38	4		41.5	.218
	41	4		36.7	.205
	44	4		31.0	.189
	47	4		21.7	.158
	50	4		14.5	.129
	53	4		8.10	.096
	56	4		7.09	.090
↓	59	4	↓	3.45	.063

Daylight Test

Table XXXVII

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
-17°	0°	1	3	2.84	.057
-13	↓	1	↓	13.6	.125
-9		1		31.6	.191
-5		1		31.6	.191
-1		1		31.6	.191
3		1		36.4	.205
7		1		43.0	.222
11		1		46.5	.231
15		1		42.5	.221
17		1		33.6	.197
18		2		38.3	.211
22		2		73.0	.290
26		2		80.8	.305
29		2		106.	.349
33		2		105.	.347
37		2		84.7	.312
41		2		84.7	.312
45		2		68.1	.280
46		2		56.6	.255
47		3		61.8	.266
51		3		134.	.393
55		3		132.	.389
59		3		128.	.384
63		3		125.	.379
67		3		84.7	.312
71		3		109.	.354
75		3		85.8	.314
76		4		95.7	.332
80		4		202.	.482
84		4		245.	.530
88		4		277.	.564
92		4		257.	.544
96		4		209.	.490
100		4		264.	.550
104		4		283.	.570
108		4		183.	.459
112		4		83.6	.310
116		4		29.4	.184
120	↓	4	↓	2.88	.058

Headlight Background Test

Table XXXVIII

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
0°	28°	1	3	2.91	.058
0	25	1	↓	3.84	.066
0	22	1		4.48	.072
0	19	1		6.00	.083
0	16	1		7.89	.095
0	12	1		15.8	.135
0	9	1		26.5	.175
0	6	1		36.5	.205
0	3	1		35.5	.202
0	0	1		37.0	.206
0	-3	1		36.7	.205
0	-7	1		27.1	.176
0	-11	1		11.0	.112
0	-15	1		7.62	.094
0	-19	1		5.25	.078
0	-23	1		4.03	.068
0	-27	1		2.80	.057
0	-30	1		2.78	.057
32	36	2		3.69	.065
32	32	2		4.54	.072
32	28	2		6.58	.087
32	24	2		8.77	.100
32	20	2		14.8	.130
32	16	2		24.0	.166
32	12	2		47.3	.233
32	8	2		81.8	.307
32	4	2		124.	.377
32	2	2		126.	.380
32	0	2		127.	.382
32	-2	2		114.	.362
32	-6	2		115.	.364
32	-10	2		54.5	.250
32	-14	2		25.0	.170
32	-18	2		13.7	.125
32	-22	2		9.95	.107
32	-26	2		6.96	.089
32	-30	2		4.66	.073
32	-34	2		2.70	.056
62	54	3		2.13	.049
62	50	3	↓	2.80	.057

Headlight Background Test

Table XXXIX

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
62°	46°	3	3	4.40	.071
62	42	3	↓	5.86	.082
62	38	3		7.15	.091
62	34	3		10.2	.108
62	30	3		10.3	.109
62	26	3		15.8	.135
62	22	3		17.5	.142
62	18	3		25.9	.173
62	14	3		39.9	.214
62	10	3		79.2	.302
62	6	3		93.7	.328
62	4	3		109.	.354
62	2	3		130.	.386
62	0	3		122.	.375
62	-2	3		131.	.388
62	-6	3		118.	.369
62	-10	3		46.7	.232
62	-14	3		35.3	.201
62	-18	3		23.7	.165
62	-22	3		17.3	.141
62	-26	3		12.0	.117
62	-30	3		9.45	.104
62	-34	3		6.00	.083
62	-38	3		4.94	.075
62	-42	3		2.96	.058
100	58	4		2.67	.055
100	54	4		4.87	.075
100	50	4		5.76	.081
100	46	4		11.1	.113
100	42	4		13.7	.125
100	38	4		13.0	.122
100	34	4		16.2	.136
100	30	4		17.6	.142
100	26	4		20.0	.152
100	22	4		23.0	.163
100	18	4		35.9	.203
100	14	4		52.8	.246
100	10	4		131.	.388
100	6	4		191.	.468
100	2	4	↓	214.	.496

Headlight Background Test

Table XL

Loral 19329B					Right Pod
Azimuth	Elevation	Channel	Sensitivity Voltage	Gain	Range Nautical Miles
100°	0°	4	3	201.	.481
↓	-2	↓	↓	233.	.517
	-6			227.	.510
	-10			130.	.386
	-14			53.4	.248
	-18			35.6	.202
	-22			24.0	.166
	-26			14.8	.130
	-30			13.7	.125
	-34			13.3	.124
	-38			8.61	.099
	-42			5.31	.078
	-46			2.40	.053

Headlight Background Test

Table XLI

CONCLUSIONS

The laboratory evaluation has produced three significant results. The equipment (Fecker System) has been made operable and more reliable by the elimination of the RFI problem, the redesign of the photo diode biasing arrangement, frequency response, lamp drivers, discriminator level setting, and a new design for a plexiglas shield. The second significant accomplishment from the laboratory tests is the "test set up and procedure". The instrumentation set up on the optical bench enables the calibration and testing of any PW1 System using a flashing Xenon lamp as the cooperative element.

Finally, laboratory test results have produced lobe patterns for the Fecker and Loral optical heads, which are to be used in the upcoming flight tests. These patterns are presented as functions of azimuth and elevation angles referenced to axes fixed in the optical head.

These results are now being incorporated in a simulation being constructed by S. Ross & Co. This program will utilize as inputs these lobe patterns, along with models of atmospheric effects, etc. The basic function of the program is to calibrate simulation runs to actual flight test runs. This calibration will serve to fix various simulation modelling parameters, and, in general, improve the models. This done, a system parameter analysis may then be undertaken, resulting in a more optimum set of: instrument settings, test flight trajectories, flight parameters for given weather conditions, and so forth.

The severe lobe structures clearly indicate that the flight tests must be conducted in the region of maximum sensitivity of the lobe pattern. The lobe structure also drastically reduces the effectiveness of the present PW1 systems. It is anticipated that a completely new redesign will eliminate this problem.