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Method and instrumentation for monitoring sea surface contamination

Lewis E. Somers
Lehigh University

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METHOD AND INSTRUMENTATION
FOR MONITORING SEA SURFACE CONTAMINATION

By

Lewis E. Somers

A Thesis
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of Lehigh University
in Candidacy for the Degree of
Master of Science

Lehigh University
1963

This thesis is accepted and approved in partial fulfillment of the requirements for the degree of Master of Science.

May 22, 63
Date

John J Karakash
Professor in Charge

John J Karakash
Head of the Department

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I would like to thank J. Rozwood for his assistance in constructing the instrumentation and assisting with its operation at sea.

Professor J. J. Karakash, Head of the Department of Electrical Engineering, deserves special credit for his cooperation in preparing this work.

ABSTRACT

This paper describes the development and operation of instrumentation capable of monitoring the presence of surface contamination in the open sea. The instrumentation consists of a light source, optics, phototubes, electronic data processors and recorders. It is sensitive to changes in the sea surface slope distribution caused by the presence of surface contamination.

The instrumentation system was developed by the author for the Electronics Laboratory of the General Electric Company. This thesis relates this development, and includes an analysis of performance leading to recommendations for improvements.

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METHOD AND INSTRUMENTATION FOR MONITORING SEA SURFACE CONTAMINATION

INTRODUCTION

The purpose of this work is to develop instrumentation capable of monitoring the sea for surface contamination (e.g. oil films). This capability was required to support oceanographic experiments in which the radar cross section of the sea was being measured. Oil films were used to simulate the absence of wind in these experiments and a monitor was required for them. The instrumentation was developed by the author for the General Electric Company and was used at the United States Naval Mine Defense Laboratory facilities in the Gulf of Mexico.

METHOD

The choice of instrumentation is constrained by the format of the oceanographic experiments being supported. The experiments will be performed at sea from a bottom-mounted stage (a structure similar to a Texas tower). They will be performed continuously throughout the day and night in all reasonable weather. The results of any single experiment are to be available as the experiment proceeds or immediately thereafter with a minimum of operator effort.

Prior to describing the method of instrumentation, a word of explanation concerning the radar-oceanographic experiments is in order, since they govern the choice of the method.

The purpose of the experiments is to obtain a quantitative measure of the back scattering characteristics of the sea surface at microwave frequencies. A significant parameter in describing the back scattered energy is the wind. Its significance is due to the close coupling between the wind velocity, capillary structure, and back scattered energy. In particular, the amplitude and doppler shift at X band or shorter microwave wavelengths is dependent on the amplitude and velocity of the capillary structure, which is in turn dependent on the wind velocity. The capillary waves on the surface of the sea are distinguished from the gravity waves by their dependence on surface tension (as opposed to gravity) for a restoring force (Reference 1, Article 265 - 267). They are also distinguished by their dependence on a wind velocity in excess of 0.5 knots for existence at all, and fast decay (less than 30 seconds) after the wind driving force is removed. And finally, they are distinguished from gravity waves by their contribution to the larger values of the sea surface slope distribution (Reference 2, Article 9, part I).

The significance of these oceanographic facts is twofold:

1. It is possible to simulate the transient absence of wind (and thus measure its effects) by removing the capillary structure from the sea surface. This can be readily done by reducing the surface tension of the sea by spreading a thin layer of oil on the surface (Reference 1, Article 350, 351 and Reference 2, Sections 16, 18 and 20).

2. The presence or absence of transient oil films can be determined by monitoring the changes in back scattered energy from different sea surface slope components.

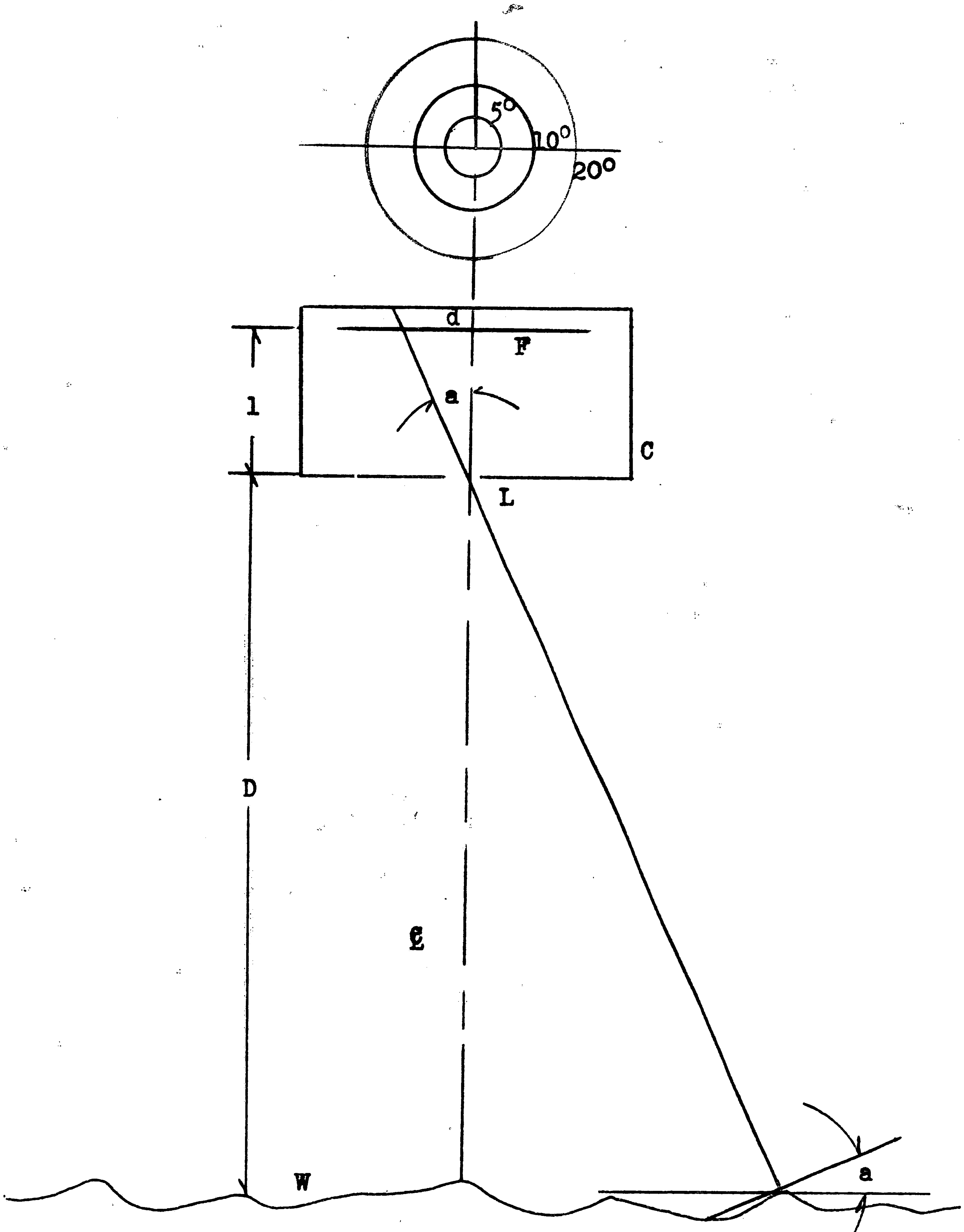
Thus, the radar experimenter chooses to use oil films to aid his experimentation and requires an adequate monitor for them. Additionally, and more important to this work, the attenuation of the larger values of sea surface slope by the oil films provides the key to monitoring. In the following pages we are concerned with methods of measuring changes in the surface slope distribution of the sea.

Sea surface slope distribution per se have been measured accoustically, electrically, and optically in recent years. These methods differ in their ease of implementation and accuracy. For example, the placement of submerged hydrophones in the open sea is sufficient to render accoustic methods undesirable. Duntley (Reference 3) has measured the surface slope components on Lake Winnipesaukee, New Hampshire, by recording electrically the difference in immersion of pairs of thin vertical wires passing through the water surface. This method suffers two major disadvantages. First, it requires physical contact with the sea surface with the attendant problems of mounting, stabilization and corrosion. Second, the wires and their support are suspected of altering the measured mean square slope by a factor as large as 2.5 due to ripples generated by the wires themselves(the classical fish line problem).

Cox and Munk (Reference 2) have used photographs of the sun's glitter pattern to measure the sea surface slope distribution. To implement this method they photographed the sea surface from aircraft. The resulting negatives were developed and examined photometrically. It was necessary to relate the position of an exposed area of the film to the corresponding surface slope; a sun and aircraft position dependent coordinate transformation. The experiments were weather dependent and can be performed only during clear days.

Schooley (Reference 4), of the United States Naval Research Laboratory, has suggested a much simpler method for measuring the distribution of sea surface slopes. He studies the glitter pattern resulting from a photographic flash lamp in a special case of the method used by Cox and Munk. The special case is accomplished by placing the "sun" at the camera position through the use of a flash lamp attached to the camera. The technique is illustrated in Figure 1. Schooley's description of operation follows.

> "C represents a camera with film F and lens L directed vertically downward towards the water surface W. It is assumed that the flash bulb is approximately a point source located close enough to the lens, as compared with the distance from the camera to the water, so that parallax can be neglected. Thus, the light and the lens are both considered to be at point L. The light from L is projected downward and is reflected from the water surface. If the water surface is perfectly calm, the light reflected from the portion of the surface directly below the lens of the camera will enter the camera and be focused as a spot in the center of the film. All other rays from the flash reflected from the portions of the surface will not be intercepted by the lens and hence will not reach the film.
>
> "As the surface of the water becomes rough, it is evident that reflections from waves having a given slope are intercepted by the lens only if the wave facet is perpendicular to a line drawn between the facet and the lens. Consequently, the distance of the sparkle image from the center of the film is related to the slope a of the water wave facet by the equation
>
> $$a = \tan^{-1} (d/l)$$



GEOMETRY OF INSTRUMENTATION

Figure 1

where l is the focal length of the camera lens."

It is seen that this method meets the requirements of the present problem in that it is independent of the time of day and requires no coordinate transformation. It suffers the liability of requiring photometric processing of the film (with its time delay) to obtain the results.

Schooley's method could be implemented with photoelectric elements taking the place of the film in the camera. The output of the photoelectric element could be readily processed by conventional electronic means and displayed on a strip chart recorder. This would provide a real time (within processing delay) indication of the sea surface slope distribution. The price paid for having data available in real time is a quantizing of the angular field of view. This is a result of being limited to a finite number of photoelectric elements. The photographic flash lamp in Schooley's method could be replaced with an electronic flash lamp capable of operating at some pulse repetition frequency (PRF). An automatic camera, synchronized with the flash lamp, might also be used to record the actual condition of the sea as Schooley did. This will provide a recording of the raw data and a visual indication of the conditions of the experiment for subsequent evaluation.

Thus, previous workers have provided guidance to a method of instrumentation which can satisfy the requirements of the radar-oceanographic experiment. The objective of this author has been to implement this method. The remainder of this paper presents the results of this effort.

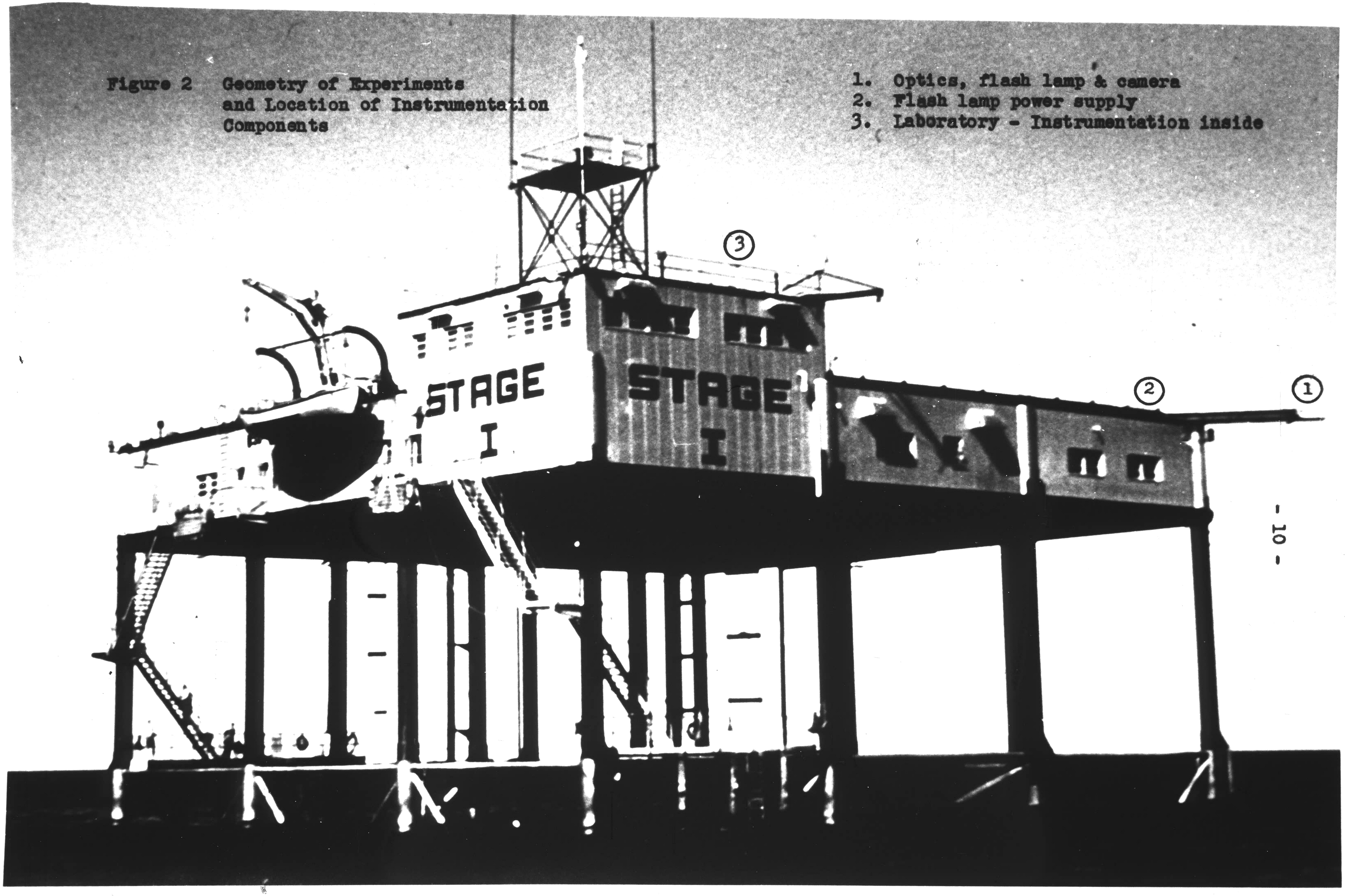
INSTRUMENTATION

The salient features of the instrumentation include a pulsed light source, angular selective optics, phototubes, analogue electronic data processing, and strip-chart recording. In addition, an automatic 35 mm camera is placed with the optics and light source to record the happenings in the field of view. It documents the raw data as well as the presence of anomalies (e.g. sea gulls and whitecaps).

The geometry of the experiments and location of the instrumentation components is shown in Figure 2. Figure 3 is a block diagram of the functional aspects of the instrumentation. In operation, the system is driven by the PRF generator. The PRF generator supplies triggering pulses to the power supply for the xenon flash lamp. The flash lamp is triggered at 1 or 10 pulses per second; each flash has a duration above half power of 40 microseconds. These pulses of light are directed downward by the reflector surrounding the xenon flash lamp and illumniate a circular area about 20' in radius (35° from the vertical). Back scattered light, from favorably oriented facets, is collected by one of three optical systems. The optics-phototube assembly is mounted adjacent to the light source and have concentric fields of view (see Figure 1). For

Figure 2 Geometry of Experiments and Location of Instrumentation Components

1. Optics, flash lamp & camera
2. Flash lamp power supply
3. Laboratory - Instrumentation inside



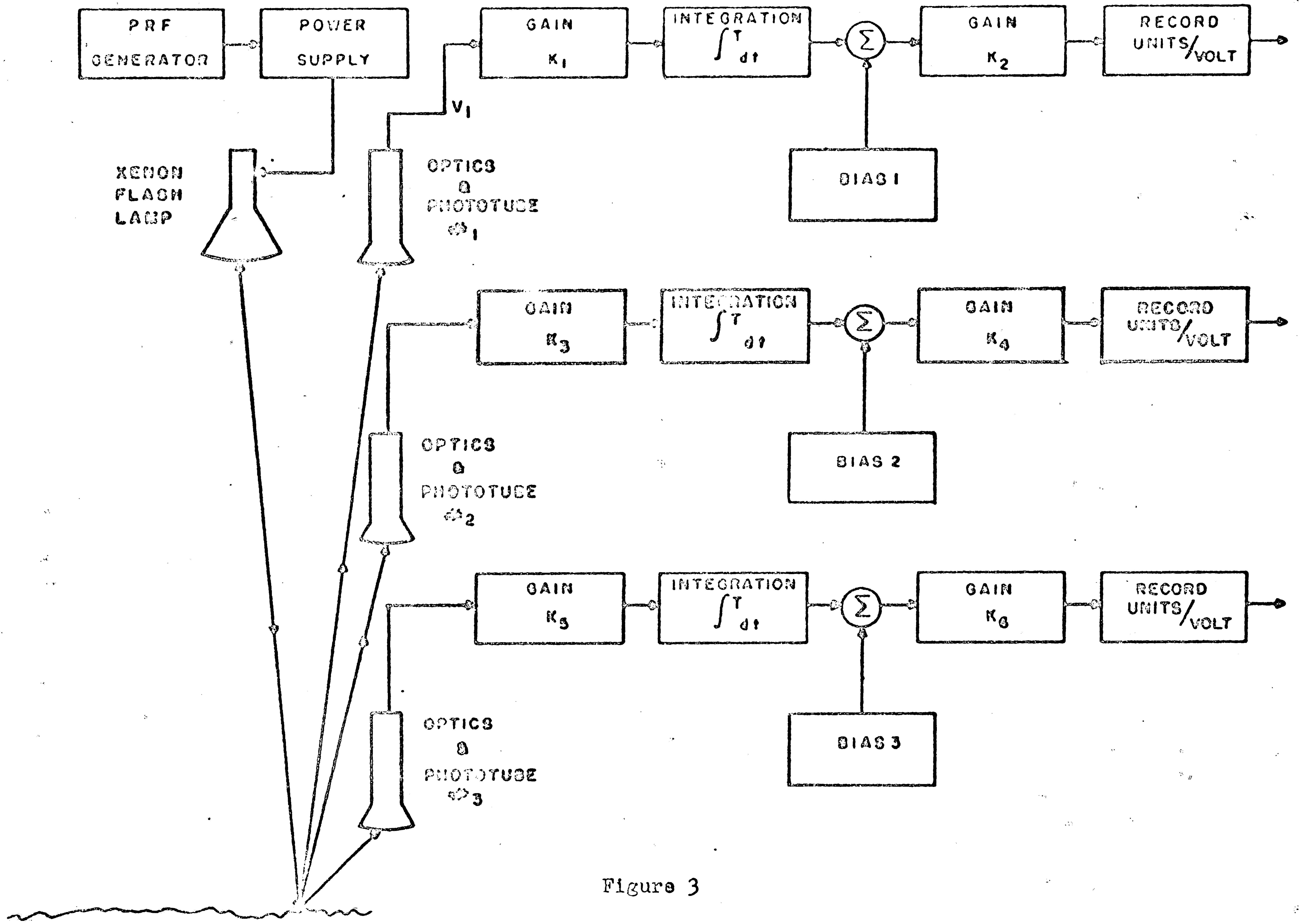


Figure 3

SYSTEM BLOCK DIAGRAM

example, channel 1 might have an angular coverage of 0 - 5°, channel 2 a coverage of 5 - 10°, and channel 3 a coverage of 10 - 20°. All angles are measured from the vertical and are equivalent to surface slope. The light collected by the three optical systems is converted to a voltage for data processing via multiplier phototubes. The phototube output is filtered, amplified, rectified, integrated, and recorded on a Brush strip-chart recorder. Simultaneously, the automatic camera is exposed once every 16 seconds. Detailed consideration is given the light source in Appendix A, the phototube and optics in Appendix B and the electronics in Appendix C.

The primary design consideration has been the necessity to compete favorably with the background radiation provided by the sun (10^5 lumens/meter^2). Calculations in Appendix A show that an FT-524 xenon flash lamp can illuminate the field of view with a radiation density on the order of 10^6 lumens/meter^2 to provide a signal to background ratio of 10. The calculations are based on measured lamp and reflector characteristics and are representative of actual conditions. When the flash lamp is operated at maximum output, useful tube life (Reference 7) limits the average power input to about 500 watts. Calculation shows the pulse repetition frequency (PRF) is thereby limited to 1 pulse/second. If the tube is operated at less than maximum output, the PRF can be correspondingly increased.

A higher PRF is desirable from the data processing point of view. Marple (Reference 5) indicates a need to average 1000 or more samples to generate useful results. With this in mind, the instrumentation PRF's were chosen to be 1/second and 10/second, and the integration time constants of the exponential averaging circuits in the data processor were chosen to be 1, 10, 30 and 60 seconds. Thus, a higher PRF is available when the flash lamp is not required to compete with the sun (e.g. overcast days and night operation).

EXPERIMENTS AND RESULTS

Experiments were performed at sea with the instrumentation serving as monitor. The performance of the instrumentation can be measured directly by its output and indirectly by observing its operation. A thorough discussion of these and related subjects is presented in this and the following section.

The oceanographic experiments took place 11 miles at sea in the Gulf of Mexico, south of Panama City, Florida. The facilities of the United States Naval Mine Defense Laboratory were used. The flight deck of a bottom-mounted stage standing in 100 feet of water was the platform from which the experiments were performed. The flight deck is 55 feet above the sea surface. A cantilever beam extends 16.5 feet over the sea and is mounted on one corner of the stage. It was from this vantage point that the instrumentation surveyed the sea surface. The photograph in Figure 2 shows the stage.

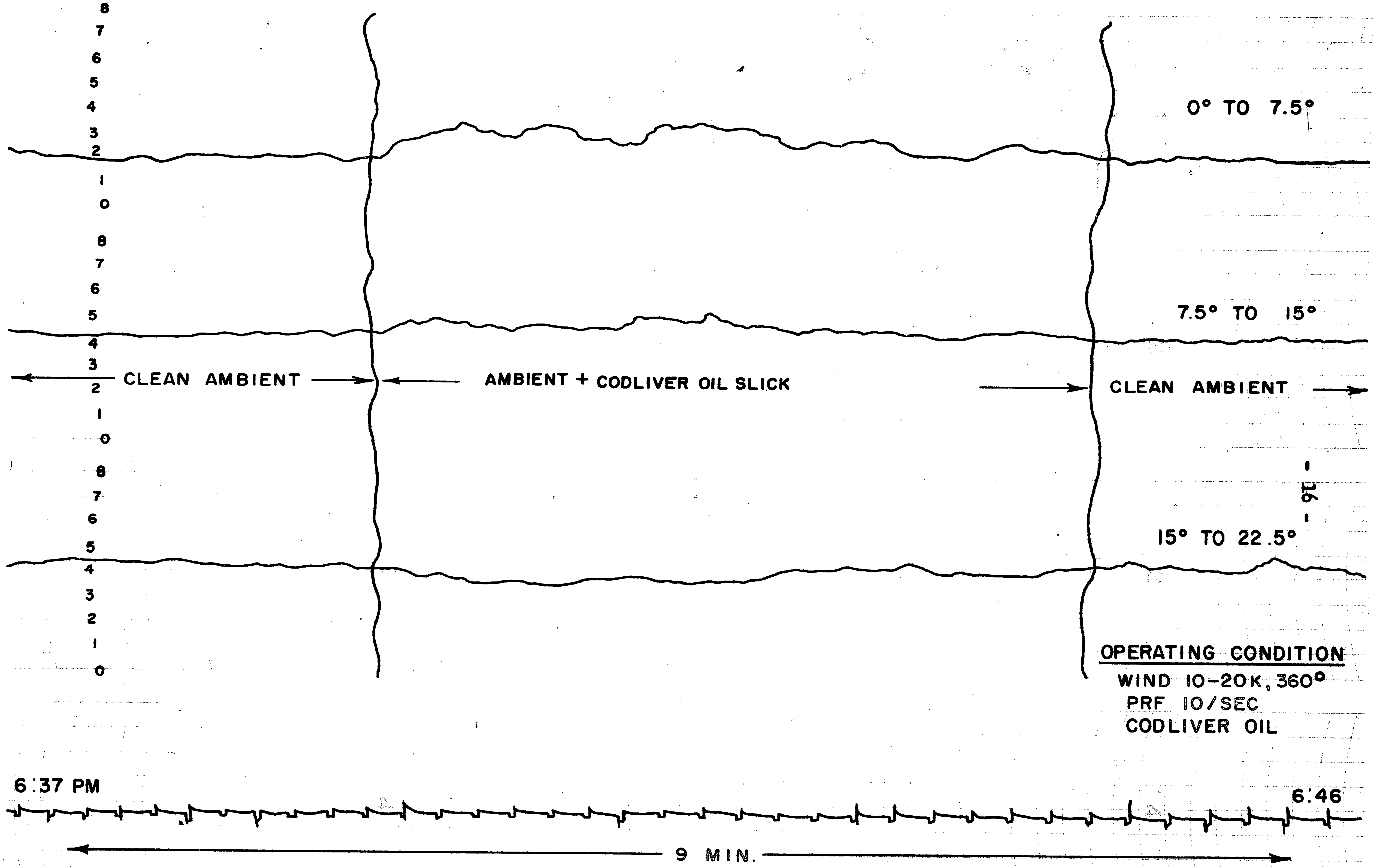
The equipment was located at various places on the stage. The light source, optics, and automatic camera were mounted at the end of the cantilever beam. They were directed vertically downward. The power supply and condensers for the light source were placed on the flight deck at the stage end of the cantilever beam. The rack containing the data processor, phototube power supply, PRF generators, and recording equipment was located in the laboratory on the flight deck.

Prior to performing the experiments it was necessary to calibrate the individual channel gain and align the optics. The channel gains were adjusted to provide a unit output for unit light input in each channel. When this was accomplished the experiments were performed. Numerous individual experiments or runs, were performed. The procedure used in each run was always the same. The results of a typical run are shown on the following page (Figure 4). Time advances from left to right. In the nine minute period shown, the following sequence of events took place:

1. A number of minutes of clean ambient sea surface reflections were measured and recorded as seen at the left of the page. In this particular run (Run #4, 3/11/60) the wind was gusty, 10 to 20 knots from the North, the PRF was 10 pulses/second, and codliver oil was used. The angular coverages of channels 1, 2, and 3 are indicated. This recorded signal is referred to as a clean ambient condition.

2. After recording sufficient clean ambient conditions to render them meaningful, an oil film was laid from a 45 foot fishing boat using a pressure sprayer with an atomizing nozzle. This oil film was laid sufficiently far up wind to insure time to spread and fill the entire field of view of the equipment prior to arriving in the field.

3. As the oil film approaches there is an increase in the back scattered energy measured



RUN # 4
Figure 4

in channels 1, and 2, and a decrease in the energy measured in channel 3. These altered conditions result from a decrease in the mean square slope due to the presence of the oil film (which simulates the absence of wind). This condition in referred to as the ambient + film condition.

4. As the wind continues to blow, the oil film is blown outside the field of view and the clean ambient condition returns. A significant amount of this condition is also recorded for comparison with the clean ambient recorded prior to the run.

The automatic camera is recording the visible happenings in the field of view throughout a run. The bottom trace on the strip chart records the time of camera exposure.

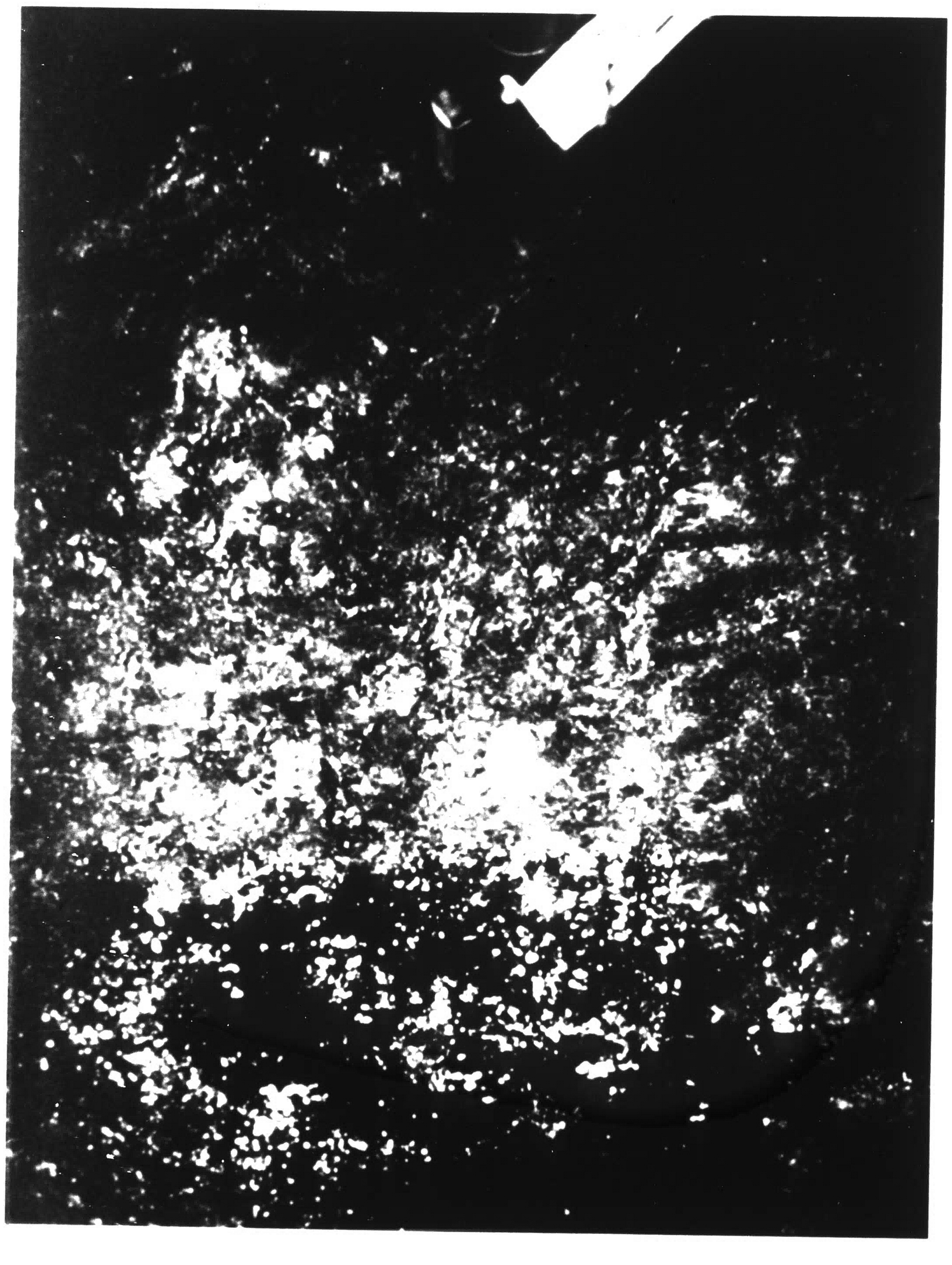


Figure 5

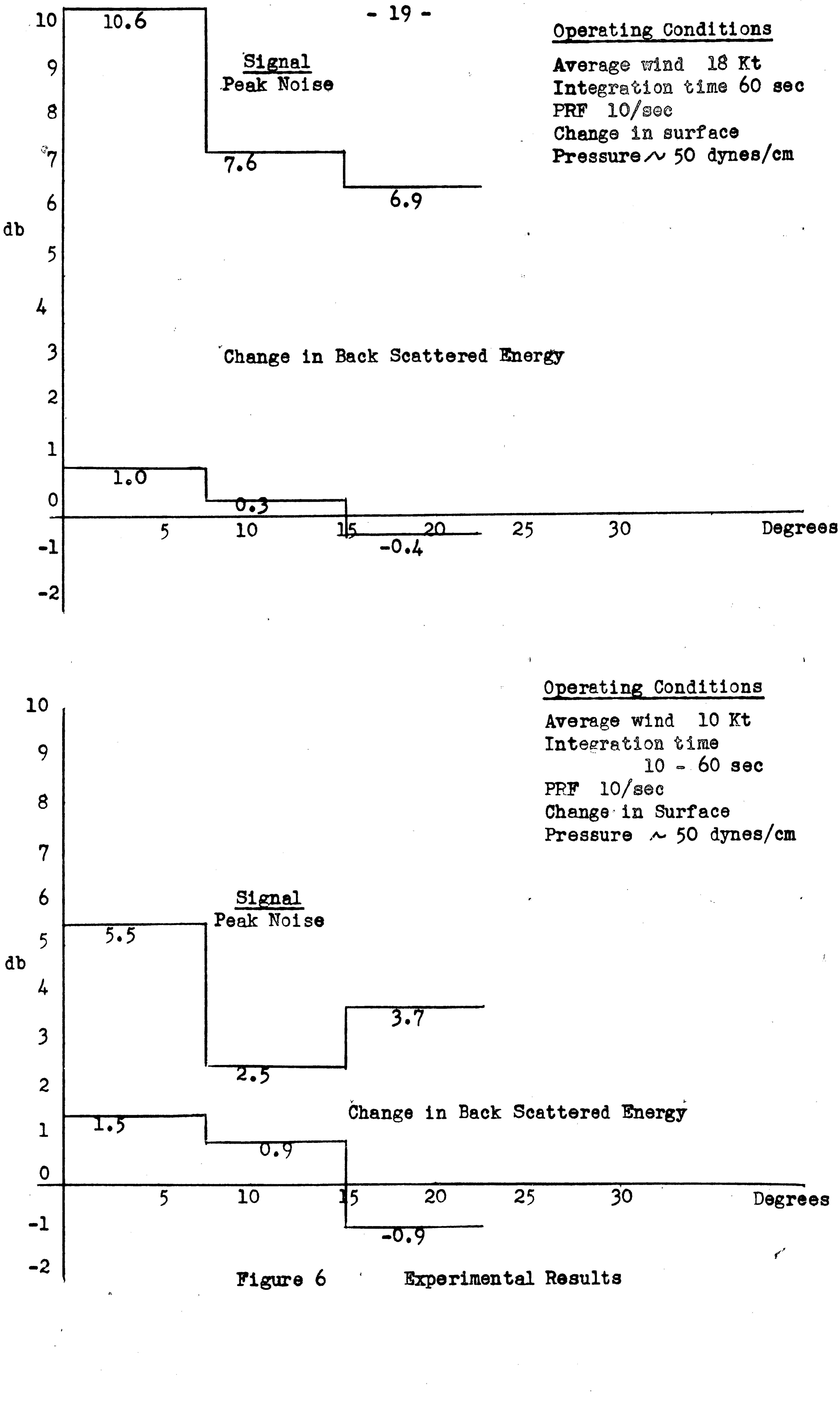
Figure 5 is a photograph from the automatic camera and shows the partial presence of an oil film. The brighter area at the center of the picture is made up of numerous small facets associated with the capillary structure. The dark area with few highlights at the bottom of the picture is altered by the presence of an oil film.

Experimental data is recorded in The Table of Experimental Data which is found at the end of the Appendix section. A plot of this data is shown in Figure 6. The instrumentation characteristics have been obtained from this data and are expressed as:

1. change in back scattered energy Δ E, and
2. the signal-to-noise ration S/N.

These two characteristics are sufficient to describe the response of the instrumentation to the presence of an oil film. For convenience they are expressed in db; 3 db corresponds to a ratio of $\frac{1}{2}$. Figure 7 defines the characteristics in terms of the strip chart recording.

The change in back scattered energy ΔE, is chosen as one characteristic because it is a quantitative expression of the response to be expected from the instrumentation. The S/N ratio is chosen as the other characteristic because it expresses the change in output in terms of the uncontrolled



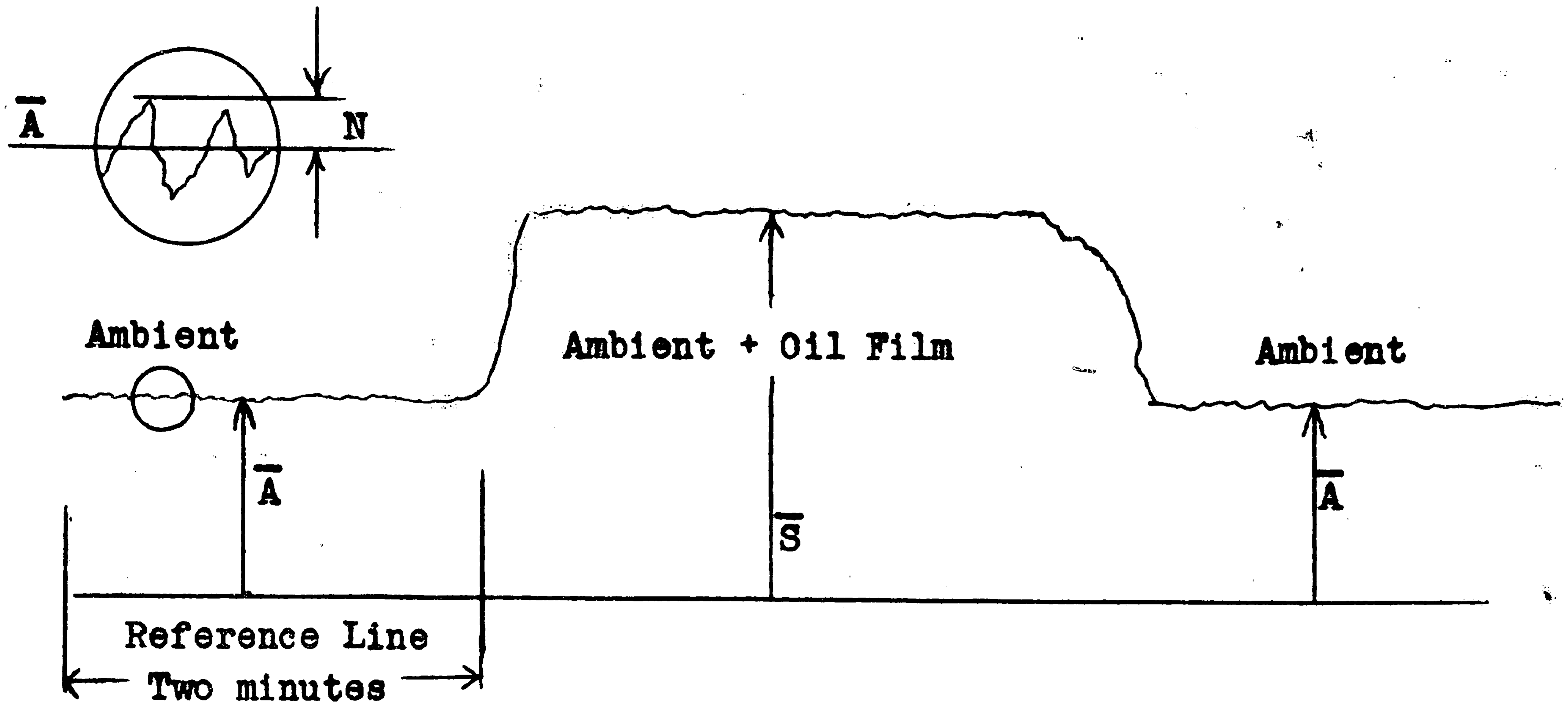
Operating Conditions

Average wind 18 Kt
Integration time 60 sec
PRF 10/sec
Change in surface
Pressure ~ 50 dynes/cm

Operating Conditions

Average wind 10 Kt
Integration time
10 - 60 sec
PRF 10/sec
Change in Surface
Pressure ~ 50 dynes/cm

Figure 6 Experimental Results



$\bar{S}$ ≡ The average (ambient + oil film) value

$\bar{A}$ ≡ The average (ambient) value

N ≡ The peak noise excursion about $\bar{A}$ in a two minute period

$$\Delta E = 10 \log_{10} \frac{\bar{S}}{\bar{A}} \qquad \frac{S}{N} = 10 \log_{10} \frac{\bar{S} - \bar{A}}{N}$$

Definition of Characteristics
Figure 7

random output (noise). It is thus a measure of the confidence one can place in the monitor output.

The significant features of the results in Figure 6 are:

1. The change in energy back scattered and signal-to-noise ratio both increase with increasing wind speed.

2. The lower slopes (0° to 7.5°) exhibit the greatest sensitivity to the presence of an oil film.

3. The back scattered energy increases in the presence of an oil film for slopes less than 15° and decreases for slopes greater than 15°.

4. The averaged data of twelve runs make up the 18 knot results and are representative of these conditions. The averaged data of six runs make up the 10 knot results. Two of these runs (one at 6 knots and one at 10 knots) recorded no change (0 db) in energy back scattered.

In addition to the explicit results inherent in the strip chart data, there are a number of implicit results derived from observation. Although less quantitative, they are equally important and are recorded below:

1. The instrumentation provided reliable monitoring of the oil films on a continuous basis during both day and night. It never failed to indicate an oil film when the wind was in excess of 10 knots. It was, however, less reliable for winds in the 6 - 10 knot range and was useless at less then 6 knots.

2. During the oceanographic-radar experiment the surface pressure of the sea was measured by the calibrated spreading oil method. The oil films caused a 50 dyne/cm reduction in surface pressure. The presence of very thin films (on the order of a few mono-layers) was indicated by the lack of visible interference patterns.

3. One night there was a 4 knot wind and the sea was exceptionally calm. Under these conditions it was discovered that the two outer channels (7.5° to 15° and 15° to 22.5°) were recording 45 - 50% of the return expected at 10 - 20 knots. There were no visible surface reflections in this part of the field of view. Ideally, the output of these two channels would be zero in the absence of surface reflections. Further investigation and measurement indicated the source of the back scattered energy was sub-surface scattering.

   This second source of energy is not particularly dependent on the presence or absence of oil films and thus tends to mask the desired effect. The phenomena is referred to as clutter because of its similarity to radar clutter. This subject is discussed further in the next section.

4. The presence of white caps in the field causes an increase of 50 - 100% in the recorded output of the affected channel. It is fortunate they are of a transient nature, for their presence masks the effects of an oil film.

5. The integration time most used in the data processor was 60 seconds. This setting provided the most useful trace because it was the smoothest. The PRF most used was 10/second. It was never necessary to operate the light source at maximum peak power with

its attendant reduction of PRF to 1/second (Appendix A - Light Source). The higher PRF was used because it provided a more stable trace.

CONCLUSIONS AND RECOMMENDATIONS

The instrumentation served the purpose for which it was designed. Its conception proved sound and its implementation sufficiently conservative to provide useful and reliable monitoring. A number of improvements can be made. They will increase both sensitivity and signal-to-noise ratio and are discussed in the following paragraphs.

The most used operating conditions offer a clue to instrumentation improvement. They are:

1. a PRF of 10/second;
2. a 60 second exponential integrator time constant;
3. a peak output of 3×10^7 lumens; and
4. a pulse duration above ½ power of 30 - 40 microsecond.

From calculations in the Light Source Appendix, it is evident that discrimination against the background radiation is better than would be expected on an energy density basis alone. This could be explained by the absence of 30 - 40 microsecond pulses in the phototube response due the background. Experimental verification is in order. This suggests using even shorter pulses for better discrimination. A reduction in average power dissipation in the flash lamp could be a beneficial result.

The most used operating conditions also indicate the number of sample required to provide a usefully smooth trace on the strip chart. This number is on the order of 1800 samples; based on three exponential integrator time constants (180 sec) and 10 pulses per second.

The sub-surface clutter tends to mask the desired surface reflections. Means of discrimination should be investigated. One means would change the wavelength of the system. The present system works in the 0.35 to 0.57 micron range. This is in the visible and is also in a region of high transmission for the sea. The ideal wavelength would be at a maximum in the reflection/sub-surface back scattered ratio, and could reasonably be expected to lie in the area of maximum reflection/transmission ratio.

In final summary, the sensitivity and signal-to-noise ratio should be improved by:

1. Going to shorter duration light pulses.
2. Going to higher PRF's.
3. Changing to a wavelength which produces less sub-surface back scatter.

These changes would provide more samples for integration, resulting in better smoothing of data or a faster response by virtue of a shorter integration time. They would provide samples more dependent on surface phenomenon and less clut-

31

tered by sub-surface scattering.

The useful sampling rate can not be increased arbitrarily because the sea surface changes at a finite rate. Thus, as the PRF is increased, the samples will become more correlated and redundant information will be needlessly collected.

APPENDIX A Light Source

The light source is positioned as shown in Figure 1. For these calculations the intensity pattern is assumed to be constant over a 30° angle from the optics and light source center line (i.e. the vertical line passing throught point L).

The output of the lamp L in lumens must provide at least 10^5 lumens/meter^2 in the field of view to be competitive with sunlight plus skylight, (Reference 6). The sea surface area in the 30° field of view is 191 square meters. Thus the output of the lamp will have to be a minimum of 1.91×10^7 lumens. Typical high power xenon flash lamps are capable of peak lumen outputs of 2 to 3×10^8 lumens with durations above one-half power on the order of 100 microseconds. Thus with a properly designed reflector for the lamp, a field of view peak intensity ten times greater than the background is available.

The General Electric FT-524 flash lamp was chosen. It is capable of operating at 500 watts average power. It can be operated at higher average powers at the expense of flash lamp life. Its characteristics are shown below.

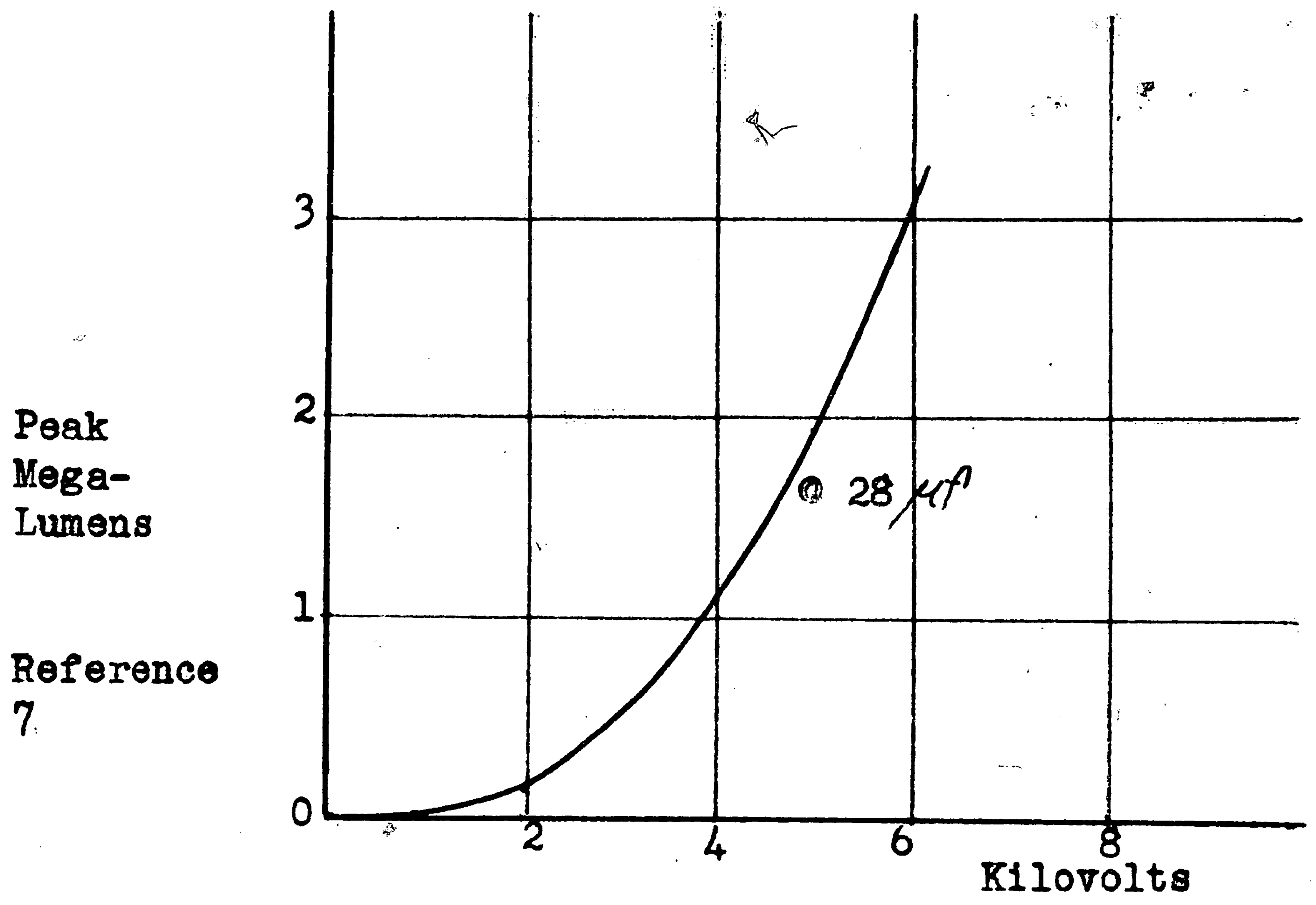


Figure 1A FT-524 Characteristics

A power supply and capacitor bank was provided for the flash lamp. The power supply has output voltages of 4, 5, 6 and 7 kilovolts and is capable of charging a 4 microfarad capacitor ten times a second or a 28 microfarad capacitor once a second. The power supply and a calibrated reflector for the FT-524 was purchased from The American Speed Light Corp. The calibration curve for the lamp-reflector combination is shown on the following page. Note that the pattern is very uniform. It varies less than 7% over ± 25° with half intensity points at about ± 38°.

Graphical integration of the intensity pattern shows 68% of the lamps total output distributed between ±30°. A calculated radiation density of 1.08×10^6 lumens/meter^2 is available if the phototube is operated at 6 KV.

The spectral characteristics of the lamp are discussed in the Optics Appendix.

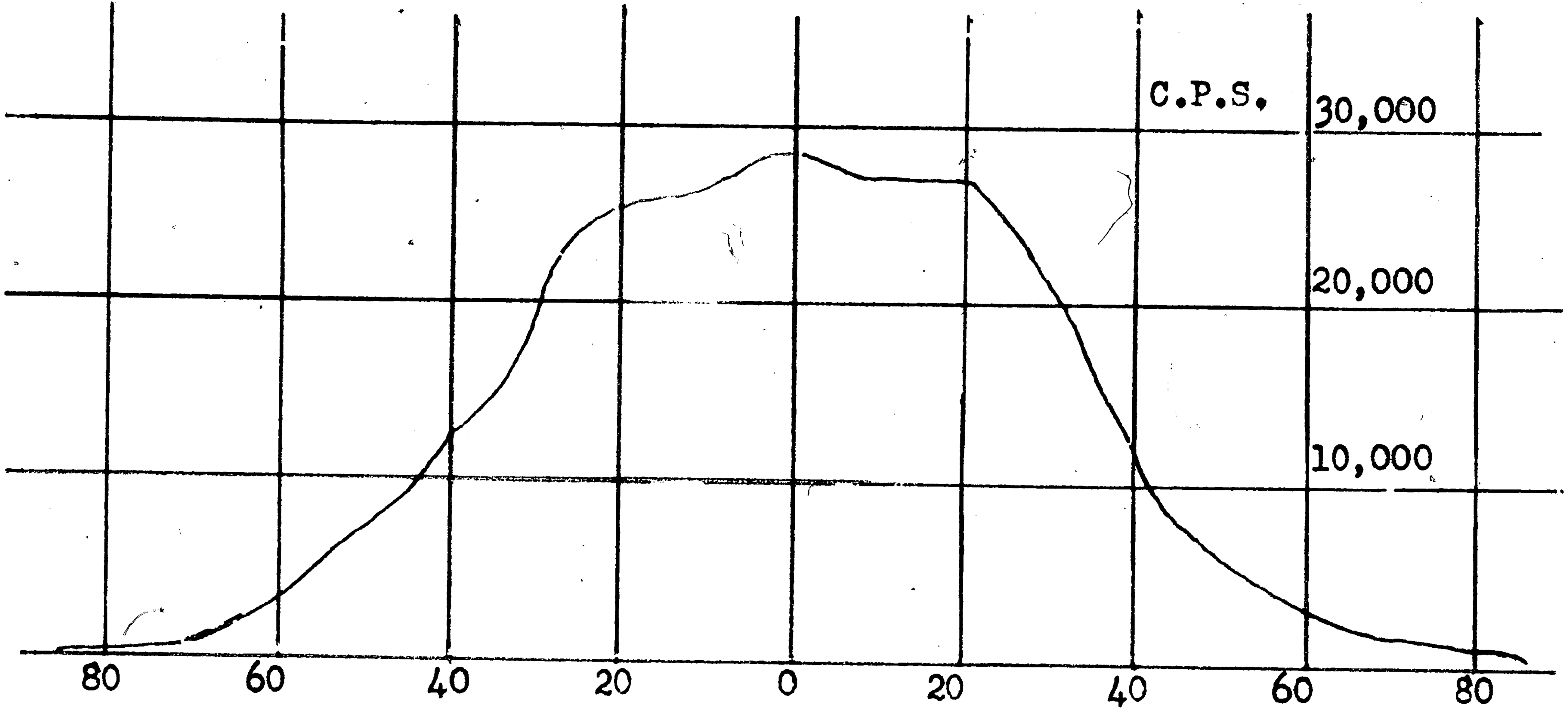


Figure 2A

APPENDIX B Phototube and Optics

The purpose of the phototube assembly is to convert the correct surface reflection into a useful voltage for processing. The optical system consists of three lens systems aligned parallel so that each images the same field of view onto a separate photomultiplier tube. The outward appearance of the optics is seen in Figure 1B. A circular slit aperture is located behind the objective lens in each system to block out all but the desired field of view (angular coverage). The three lens systems cover a total field of 30 degrees from a vertical center line drawn perpendicular to the water surface (Figure 1). The specific areas of observation may be varied by selection of suitable circular slit apertures.

The objective lenses are wide-angle Leicas' with a focal length of 28 mm. The circular slit aperture is placed at the image plane of the objective. Behind the aperture is a demagnification lens that images the aperture onto a small segment of the photocathode. Only a small portion of the photocathode is used to minimize the effects of photocathode non-uniformity. The photomultiplier is a 9-stage Dumont 6291. A schematic representation of the phototube assembly is

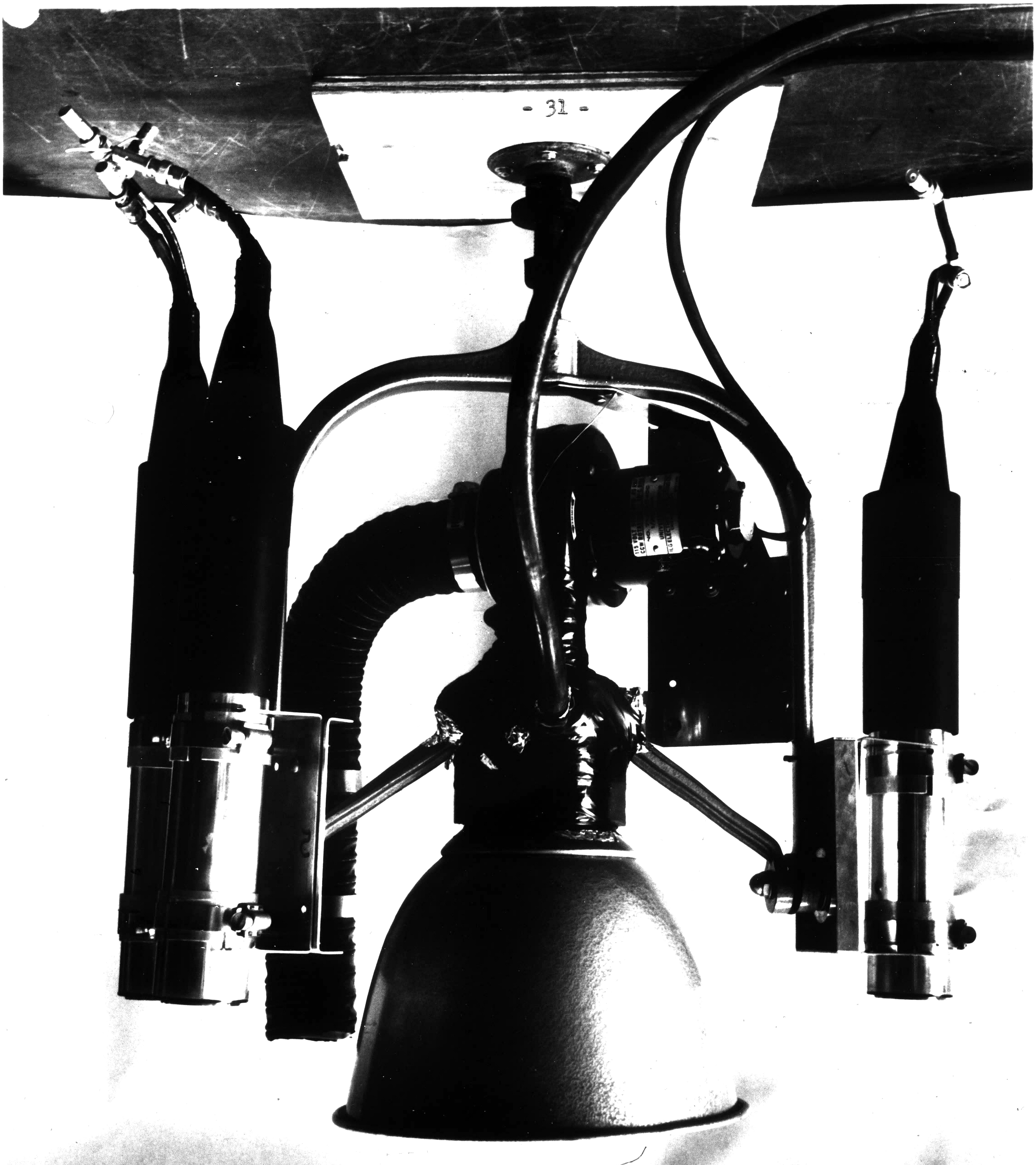


Figure 1B Flashlamp and Phototubes

shown in Figure 2B.

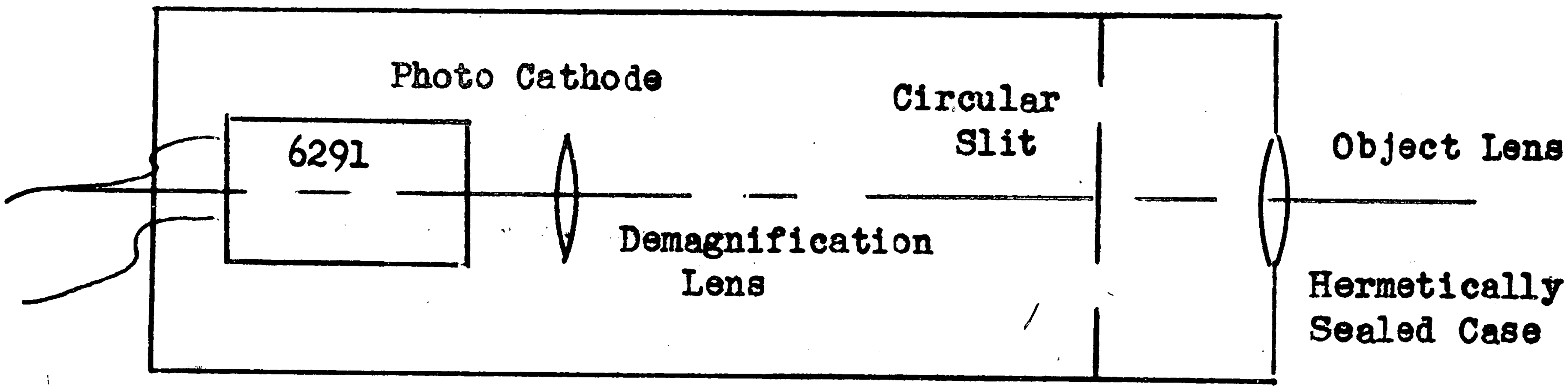


Figure 2B Schematic Representation of Optics

The spectral response of pulsed xenon lamps has a peak at 0.48 microns (Reference 7). The photocathode of the 6291 is type S-11, and has a broad peak centered about 0.45 microns (Reference 8). Thus the lamp and photocathodes have virtually identical spectral characteristics and provide a system of maximum sensitivity.

APPENDIX C Electronics

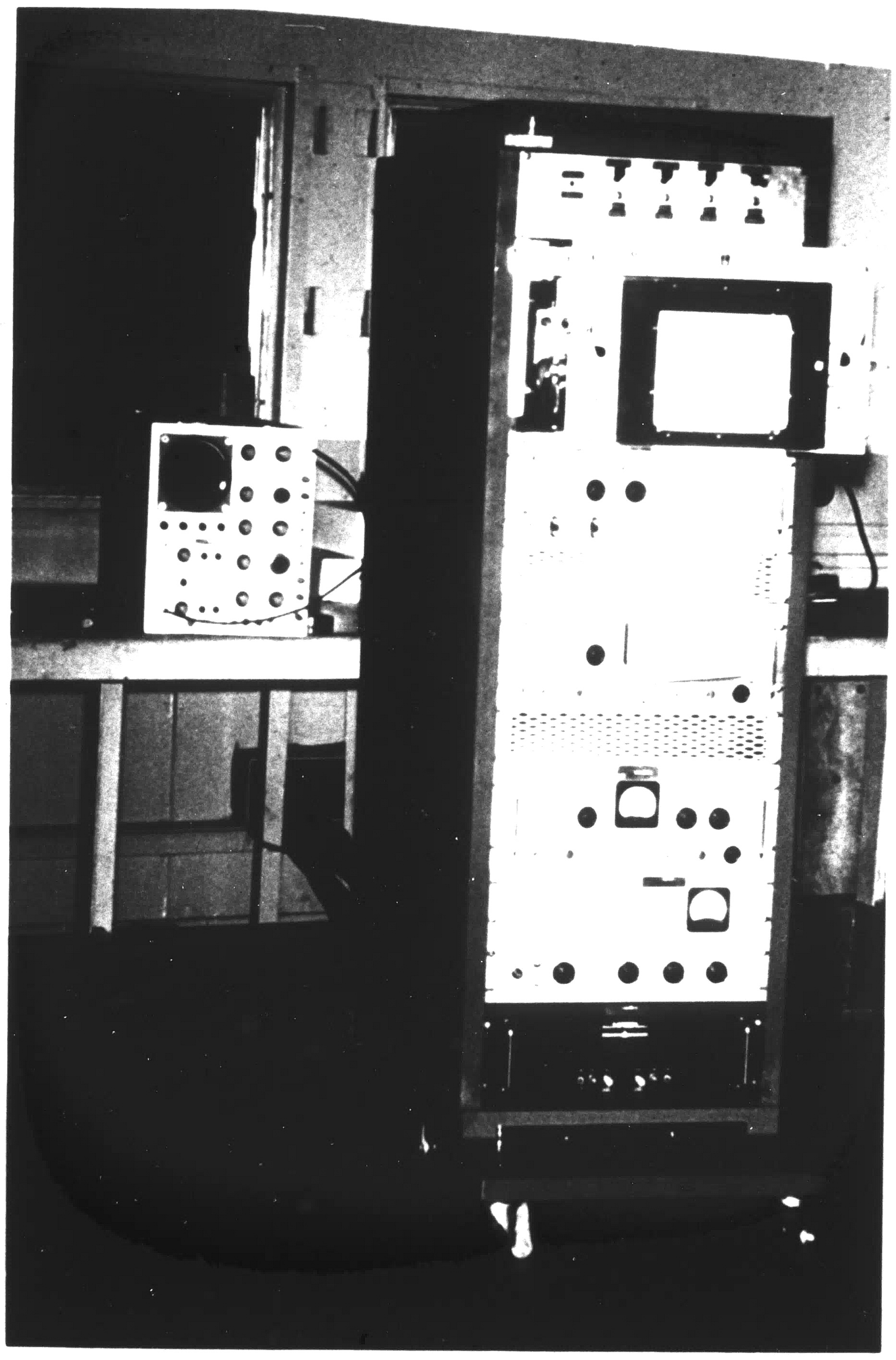
The electronics are made up of the following components:

1. power supplies for flash lamp, multiplier phototubes, and data processor;
2. data processor chassis;
3. Brush 4 channel strip chart recorder and amplifiers.

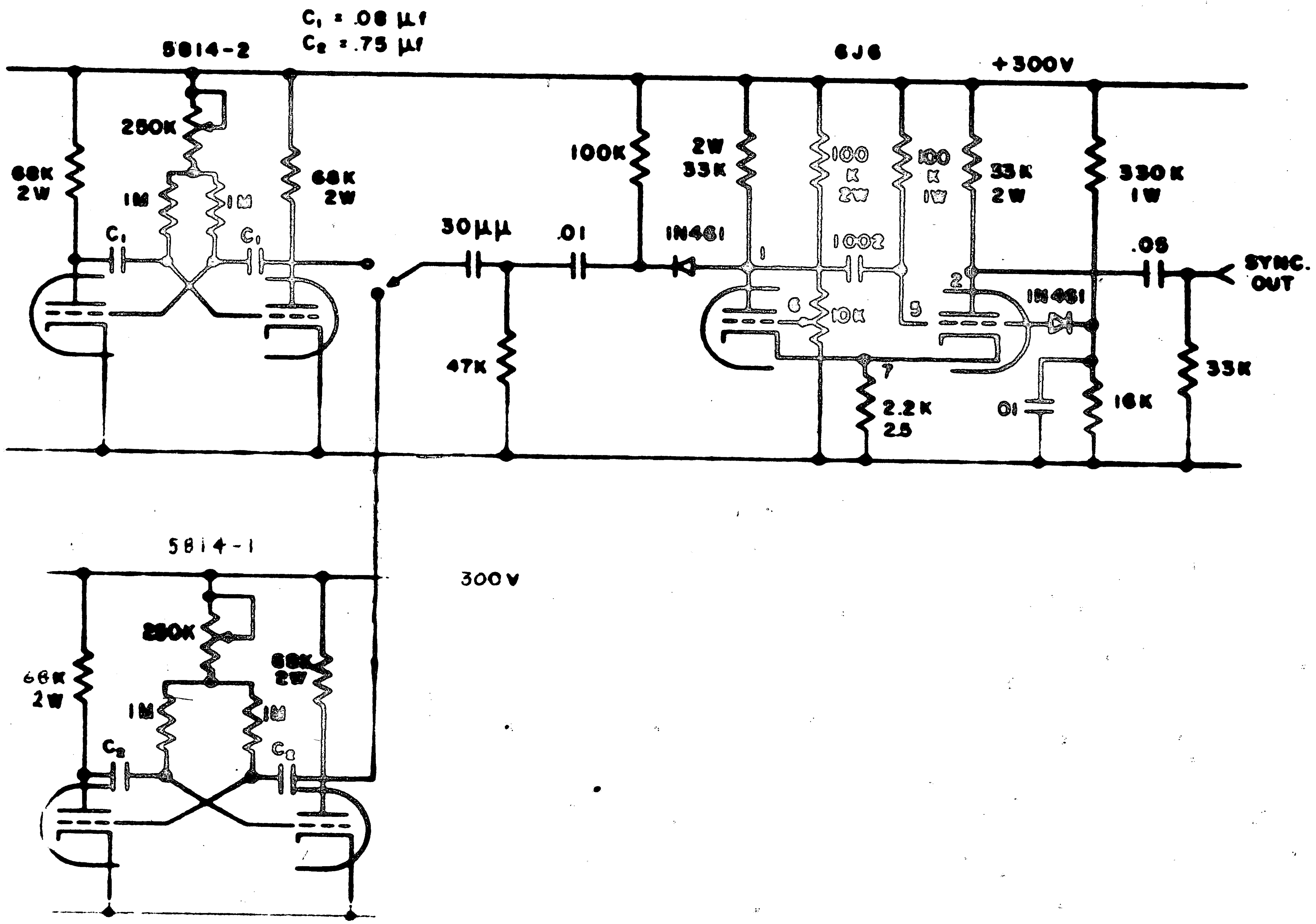
The power supplies and 4 channel recorder are of conventional design and were purchased items. The data processor was a custom design and is described in the following paragraphs. Figure 1C is a photograph of the instrumentation rack in the laboratory at sea. Schematics of the salient circuits make up Figure 2C and 3C.

The PRF generator is made up of two astable plate to grid coupled multivibrators, Reference 10, PC-40. One operates at 10 and the other at 1 pulse per second. The multivibrators drive a monostable multivibrator through a PRF selection switch. The monostable multivibrator generates the synchronizing pulse used by the xenon flash lamp.

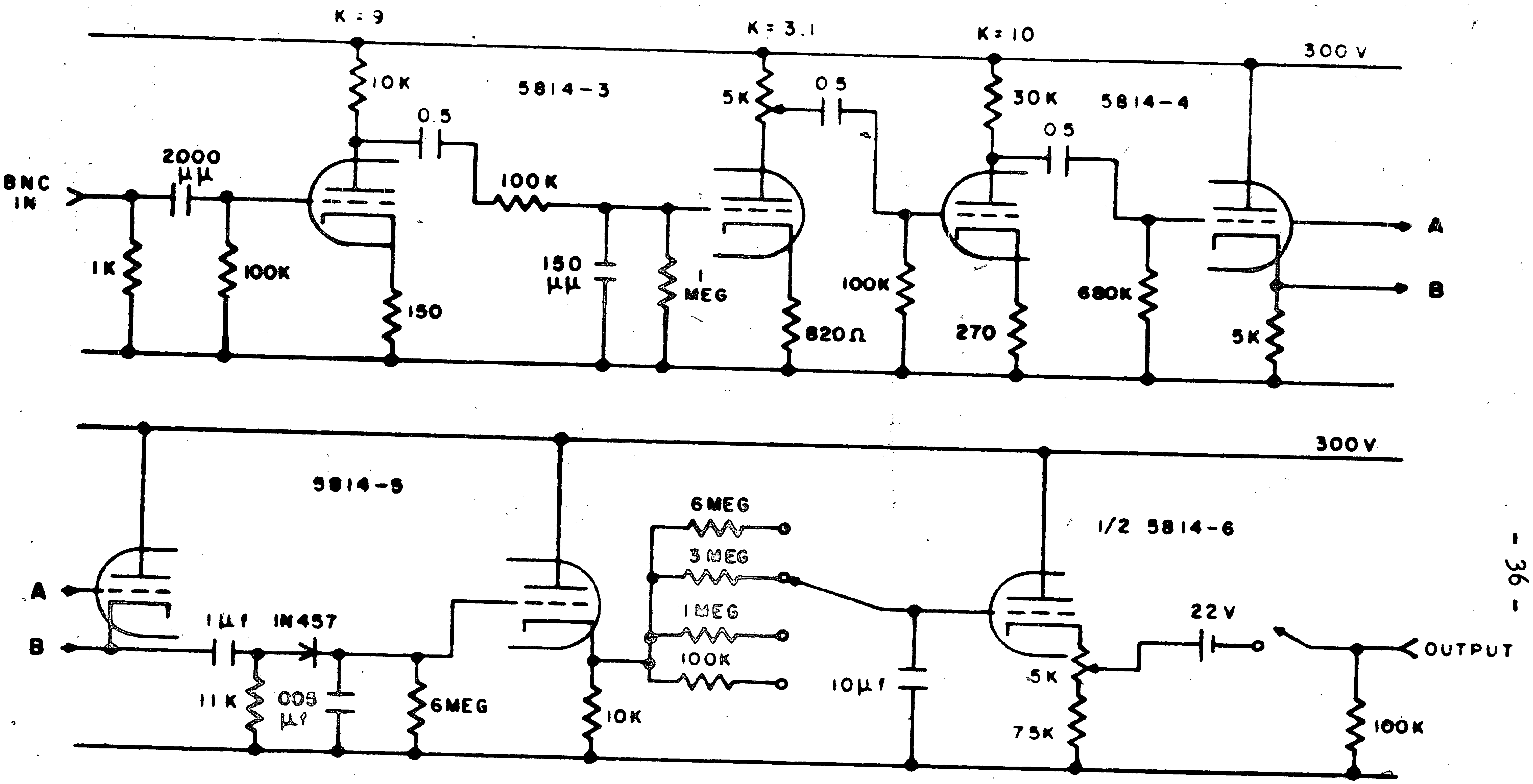
The remainder of the data processor chassis is taken up by four identical channels; three for operation and one spare. A channel is made up of a c coupled amplifiers, a ½ wave diode detector, an r c integrator, and d c coupled cathode follower output. The time constants of the integrator are adjustable at 60, 30, 10 and 1 seconds. There is a gain adjustment potentiometer and a bias adjustment potentiometer. The latter provides a bias adjustment on the output of the final d c coupled cathode follower.



Instrumentation Rack
Figure 1 C



PRF GENERATOR
Figure 2C



CHANNEL AMPLIFIER & INTEGRATOR
Figure 3C

TABLE OF EXPERIMENTAL DATA

Date	Run No.	Wind	Integration Time	PRF	Angular Field	Signal Peak Noise	Change in Reflected Energy
3/9/60	2	10 Kt 30°	30 sec	10/sec	0° to 5°	8.8 db	2.2 db
					7.5° to 15°	3.0 db	0.4 db
					20° to 30°	6.5 db	-1.1 db
3/9/60	5	12-15 Kt 180°	30 sec	10/sec	0° to 5°	7.2 db	1.5 db
					7.5° to 15°	---	---
					20° to 30°	3 db	-0.4 db
3/9/60	7	10 Kt 180°	60 sec	10/sec	0° to 5°	0 db	Signal in Noise
					7.5° to 15°	0 db	
					20° to 30°	0 db	
3/9/60	10	6 Kt 210°	10 sec	10/sec	0° to 5°	0 db	Signal in Noise
					7.5° to 15°	0 db	
					20° to 30°	0 db	
3/10/60	2	10 Kt 40°	30 sec	10/sec	0° to 7.5°	6.7 db	1.4 db
					7.5° to 15°	9.5 db	1.3 db
					15° to 22.5°	---	---
3/10/60	4	10 Kt 20°	60 sec	10/sec	0° to 7.5°	10.4 db	1.0 db
					7.5° to 15°	0 db	Signal in noise
					15° to 22.5°	9 db	-1.1 db
3/11/60	2	22-24 Kt 360°	10 sec	10/sec	0° to 7.5°	9.8 db	3.1 db
					7.5° to 15°	7.8 db	1.1 db
					15° to 22.5°	7.0 db	-1.1 db

Date	Run NO.	Wind	Integration Time	PRF	Angular Field	Signal Peak Noise	Change in Reflected Energy
3/11/60	4	10-20 Kt 360°	30 sec	10/sec	0° to 7.5°	11.8 db	2.4 db
					7.5° to 15°	9.5 db	0.8 db
					15° to 22.5°	6.5 db	-1.0 db
3/12/60	4	18 Kt 360°	60 sec	10/sec	0° to 7.5°	11.8 db	1.6 db
					7.5° to 15°	7.0 db	0.7 db
					15° to 22.5°	3.0 db	-0.2 db
3/12/60	5	22 Kt 360°	60 sec	10/sec	0° to 7.5°	13.4 db	2.8 db
					7.5° to 15°	7.8 db	1.0 db
					15° to 22.5°	8.5 db	-0.8 db
3/12/60	8	18-22 Kt 340°	60 sec	10/sec	0° to 7.5°	8.8 db	2.0 db
					7.5° to 15°	5.4 db	0.8 db
					15° to 22.5°	7.4 db	-0.6 db
3/12/60	9	18-22 Kt 340°	60 sec	10/sec	0° to 7.5°	12.3 db	2.7 db
					7.5° to 15°	8.0 db	1.2 db
					15° to 22.5°	7.8 db	-0.7 db
3/12/60	9'	18-22 Kt 340°	60 sec	10/sec	0° to 7.5°	11.1 db	2.0 db
					7.5° to 15°	12.3 db	1.4 db
					15° to 22.5°	8.5 db	-0.7 db
3/12/60	10	20 Kt 360°	60 sec	10/sec	0° to 7.5°	10.0 db	1.8 db
					7.5° to 15°	7.8 db	0.6 db
					15° to 22.5°	5.1 db	-0.8 db

Date	Run No.	Wind	Integration Time	PRF	Angular Field	Signal Peak Noise	Change in Reflected Energy
3/12/60	11	10-20 Kt 360°	60 sec	10/sec	0° to 7.5°	11.8 db	2.3 db
					7.5° to 15°	7.8 db	0.6 db
					15° to 22.5°	9.0 db	-0.9 db
3/12/60	12	18 Kt 360°	60 sec	10/sec	0° to 7.5°	7.8 db	1.8 db
					7.5° to 15°	3.0 db	0.4 db
					15° to 22.5°	4.8 db	-0.7 db
3/12/60	13	18 Kt 360°	60 sec	10/sec	0° to 7.5°	11.8 db	2.3 db
					7.5° to 15°	8.5 db	0.7 db
					15° to 22.5°	7.8 db	-0.7 db
3/12/60	13'	18 Kt 360°	60 sec	10/sec	0° to 7.5°	11.1 db	2.0 db
					7.5° to 15°	8.4 db	0.7 db
					15° to 22.5°	6.0 db	-0.5 db

--- no data

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BIOGRAPHY

I was born in Hazleton, Pennsylvania on August 18, 1933. I graduated from Lehigh University in June 1955. While an undergraduate I was a Cooperative Student of the Philco Corporation.

I joined the General Electric Company in 1955 and was selected for its Advanced Engineering Program, a three-year graduate level program of study in engineering and mathematics supplemented by appropriate laboratory assignments. Since 1958 I have been a permanent member of the Electronics Laboratory, currently in the Data Recording and Display component.

I have helped develop airborne mapping radars, long-range coded pulse radars, and new data recording and display techniques. Two patent awards have been granted for thermoplastic recording inventions.

I am a member of the Institute of Electrical and Electronic Engineers, Society of Photographic Scientists and Engineers and Eta Kappa Nu.