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PETROLEUM OIL DETECTION BUOY SYSTEM

Herbert R. Gram

Spectrogram Corporation

Prepared for:

Coast Guard

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Herbert R. Gram



MARCH 31, 1975

FINAL REPORT

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16. Abstract <p>Extended capability floating buoy designed to detect petroleum oils ranging in composition from crude to kerosene has been developed and performance tested. This buoy is powered by a land based low voltage direct current power supply at nominally 12 volts. The average total power requirements for the buoy are less than 0.75 watts.</p> <p>The detection system employs fluorescent techniques whereby the oils floating on the water surface are excited by short wavelength ultraviolet radiation and produce, by fluorescence emission, radiation in the near ultraviolet and blue end of the visible spectrum. The fluorescent radiation is selectively detected to produce an alarm condition.</p> <p>Improvements have been made to the mechanical packaging to facilitate deployment and field service.</p>					
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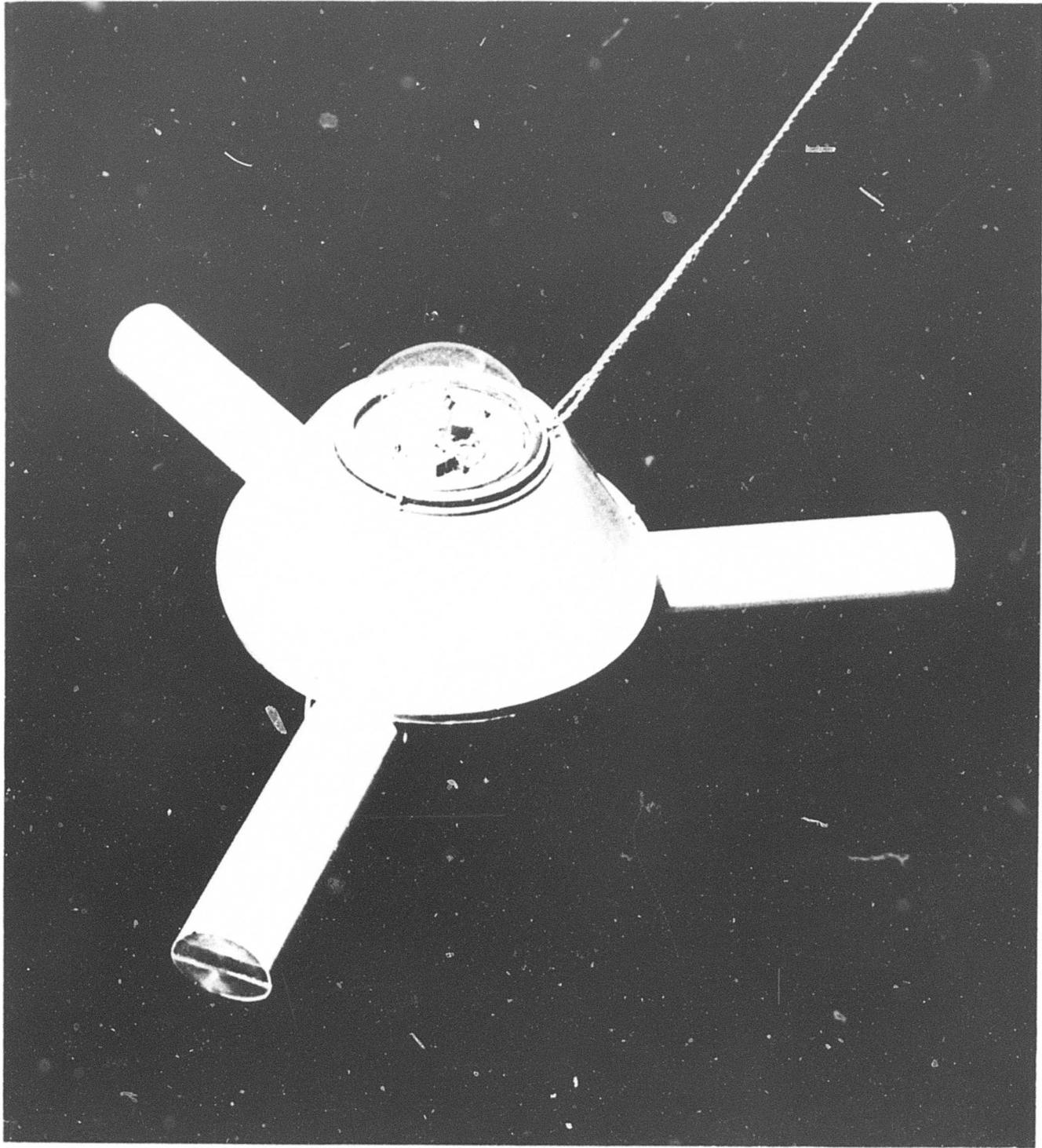
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OIL DETECTION BUOY

INTRODUCTION

This report describes the results of a research and development effort to modify and extend the capability of the Spectrogram Corporation's oil detection buoy system and supply a complete, modified system for field evaluation. This work was conducted under Department of Transportation Contract Number DOT-CG-43345-A, for the United States Coast Guard.

The Spectrogram Corporation of North Haven, Connecticut has successfully designed, developed and field tested a floating buoy system for continuous, rapid, in situ oil spill detection and identification. The present system, currently in operation at a utility company dock side, provides a contact closure alert signal when a petroleum oil is present on a water surface and further provides a contact closure alarm signal when the oil detected is a No. 6 fuel oil. Through this feature, oils not normally handled at the monitored site will not initiate alarm condition.

It has been well documented in the literature that petroleum products exhibit a fluorescent characteristic when subjected to high energy excitation. That is to say, if an oil sample is irradiated with high energy emission such as short wavelength ultraviolet or X-ray energy, the sample will absorb a portion of the excitation energy and re-radiate lower energy of a longer wavelength such as visible light. Further, it has been established that both the wavelength of maximum energy absorption and the wavelength of maximum re-radiated energy are a function of the molecular composition of the oil type. This principle is the basis upon which the Spectrogram oil detection buoy operates and which makes possible the buoy's ability to provide an alarm signal upon the detection and identification of a specific oil type.

The basic system consists of a land station, 3 buoys (2 simultaneously operational, one stand-by) and the interconnecting cables. The land station or main console contains the power supplies, strip chart recorders and the alert/alarm logic circuitry. Each buoy contains an excitation energy source, a multi-channel optical detection system, solid state detectors, integrated circuit photometric amplifiers and logic circuitry, and various local power supplies. The buoys derive operating power from the main console via the interconnecting cable. This waterproof cable also carries the necessary data signals from the buoys to the console recorders and the alert/alarm network, thus providing final contact closures for external and remote indications such as lights, audible alarms, or the "shut-down" of the transfer pumping system.

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The original prototype systems were placed under test, round-the-clock, for a period of twelve (12) months. One system installed at a tidal river location, and the second system in a barge transfer slip on Long Island Sound. Although neither site has experienced an actual oil spill, controlled spills of both general petroleum products (gasoline, No. 2 fuel oil, SAE 10 W 30 lubricating oil, etc.,) and No. 6 fuel oil were periodically made to verify the performance of the detector. During the field test period, winter/summer weather and sea conditions varied substantially.

The objective of this contract was to design and produce one (1) oil detector buoy and land based power source complete with a five hundred (500) foot interconnecting cable. The buoy must be capable of detecting as little as a mono-molecular layer of petroleum oil floating on a water surface, where the oil composition can range from heavy grades of crude and fuel through the medium grades to the lighter grades, such as gasoline. Included within the detection capability are used oils, defined as principally waste lubricating oils, such as machine cutting oils or crankcase oils.

The primary design goal was to reduce the input power requirements of the previous design to allow for future battery operation. The previous system operates with an input power of approximately forty (40) watts per buoy. A realistic goal for this contract was a reduction by a factor of ten (10), or four (4) watts input power from a nominal twelve (12) volt DC voltage source. This power limitation was not to include the power required by any beacon or marker light nor any data telemetering and communications equipment.

Additionally, improvements are desired in the mechanical packaging allowing for a reduction in weight and the buoy's capability to withstand unattended operation for prolonged periods of time under severe environmental conditions. Finally, the prototype buoy system must be field tested on fresh, brackish, and salt water to demonstrate the equipment's operation. The final field tests shall be conducted in conjunction with U. S. Coast Guard personnel and serve as an acceptance test.

To accomplish the objectives and goals of this contract, the efforts were divided into eight (8) tasks as outlined below:

Task I - Determination of Optimum Fluorescent Wavelength

The Spectrogram Corporation had previously developed a partial library of fluorescent spectra as emitted by some petroleum oils when excited directly (undiluted) by a low pressure mercury discharge lamp. The existing library includes most

medium grades of oils ranging from SAE 90 lubricating oil to the lighter kerosene grades. The object of this task is to extend the existing library to include the heavier grades of crude and fuel oils along with lighter grades, such as jet aircraft fuel. Laboratory apparatus is set up in such a fashion to irradiate test oils directly from a low pressure discharge lamp and optically collect and scan the fluorescence radiation as intensity versus wavelength. Spectral scans are obtained for the following oil types: crude, No. 6, No. 5, No. 4, No. 2, kerosene, jet fuel, gasoline residue, and lubricating oils. Each oil sample is scanned in the "as received" (fresh) condition, and after weathering periods of four (4) hours, twenty-four (24) hours and one (1) week. The data as developed by the spectra scans is compared to determine what effect weathering exposure has on the fluorescent energy and pattern characteristics. Further, the scans of all oils are compared to determine those spectral regions that afford minimal variation as a function of both weathering and oil types.

Task 2 - Excitation Lamp Power Supply and Optical Coupling

The object of this task is to improve both the coupling of the excitation lamp's ultraviolet optical energy to the water surface and the pulsed inverter lamp power supply conversion efficiency. A study is performed to determine the optimum parameters such as gas fill pressure and choice of lamp tubing material to provide maximum radiation of the short wavelength ultraviolet spectra. The principal power consumer in the existing buoy design is the lamp excitation power supply. This task studies the minimum "on - off" duty cycle commensurate with efficient oil fluorescence excitation along with improvements in the electronic conversion efficiency of the inverter power supply.

Task 3 - Photodetector Power Supply Review and Redesign

It is the object of this task to redesign and improve the conversion efficiency of the multiplying phototube high voltage inverter-type power supply. Subsequent to the receipt of this contract and as the result of research surrounding medical instrumentation development, Spectrogram learned of new, high quantum efficiency silicon ultraviolet detector diodes that afford detection limits similar to those obtained using multiplying phototubes. As these silicon ultraviolet detectors do not require high voltage bias supplies, we shall elect to study the possibilities of employing silicon detectors in the buoy system. Feasibility is demonstrated and the requirements for the photodetector power supply redesign is eliminated. Circuitry developed for the medical instrument is directly employed in the buoy design.

Task 4 - Signal Amplifiers and Automatic Gain Control Circuit Review and Redesign

It is the object of this task to redesign the signal amplifier incorporating automatic gain control circuitry to correct for variations in signal due to excitation lamp output and changes in battery supply voltage. Further included is the master timing and logic circuitry required for gating the excitation lamp and controlling the signal multiplexers and phase-lock detectors. For improved reliability, the incorporation of environmentally independent electronic components is performed during the redesign.

As bipolar power is required by the electronic amplifier circuitry, a positive and negative five (5) volt switching regulator power supply previously developed is incorporated to provide complete independence from the primary buoy power supply.

Task 5 - Mechanical Packaging

Within this task the overall mechanical packaging design of the existing buoy is reviewed with the intention of lowering the package weight and improving the physical strength and rigidity to allow for continuous duty. Modular construction techniques are employed to facilitate field service requirements. To minimize the effects of salt water corrosion, the principal construction materials remain as in the previous buoy design.

Task 6 - Land Based Power Recorder Console

To simulate ultimate buoy battery operation, a regulated twelve (12) volt DC power supply is designed with provisions for varying the terminal voltage over the range of ten (10) to fourteen (14) volts. A five hundred (500) foot underwater interconnecting cable is used to carry power from the land console to the buoy and return various signals for monitoring.

To assure that the terminal voltage at the buoy is maintained at the desired preset levels, a remote sensing feature is incorporated in the power supply design. Provisions are incorporated in the power supply to continuously monitor the current requirements of the buoy during prolonged field test operation. Two (2) strip chart recorders are incorporated in the land power console to continuously monitor the analog signals from the fluorescence and reflectance channels.

Task 7 - Field Tests

Upon satisfactory completion of various laboratory tests evaluating the final buoy prototype design, the entire buoy system is evaluated in a test pool for performance and oil detection capability on brackish water. Upon completion and acceptable testing in the pool facility, the buoy system is moved to a location on Long Island Sound for field testing in actual open water conditions. It is the object of the field tests to verify the buoy's ability to withstand severe environmental conditions and satisfactorily detect oils floating on water surface. The buoy system performance is monitored continuously by the strip chart recorders.

Task 8 - Manuals, Drawings and Report

The culmination of this contract includes the buoy system complete with an operating instruction manual and electro-mechanical drawings. Under this task is further included the preparation of this final report describing the complete evolution of the design and development of the final prototype buoy.

TASK 1 - DETERMINATION OF OPTIMUM FLUORESCENT WAVELENGTH

1.1 Oil Sample Collection

In an effort to obtain a wide variety of petroleum oils from as many manufacturers as possible, the Spectrogram Corporation contacted the major firms by telephone and letter, and requested that they provide one (1) quart containers of as many products as possible. Further, we obtained many samples of lubricating oils and fuel oils by direct purchases from retail terminals. Many firms cooperated. However, certain companies absolutely refused to provide any material for fear of inter-company espionage.

Table 1 provides a list of the samples obtained for this program.

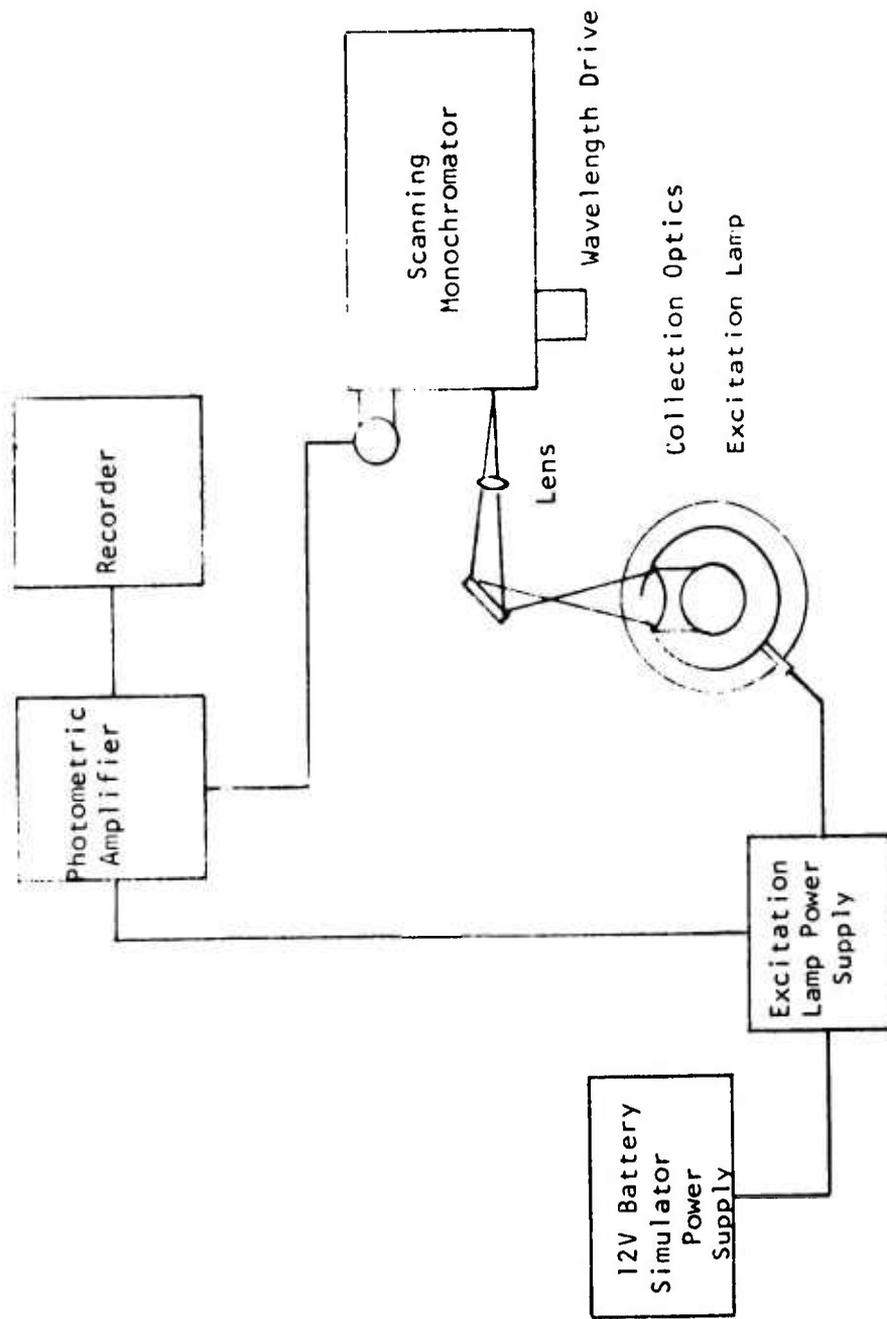
1.2 Laboratory Test Set-Up

Referring to Figure 1, a combination of laboratory apparatus and the excitation lamp/collection optic assembly as used in the previously designed buoy was set up in such a fashion to irradiate the oil samples when floated on brine water contained in a thirteen (13) inch diameter plastic pan. The fluorescent energy from the oils was collected and collimated by a two (2) lens system and directed by a forty-five (45) degree mirror to the entrance slit of our laboratory scanning monochromator. The half-meter monochromator entrance and exit slit were adjusted to three hundred (300) microns, providing approximately one (1) nanometer resolution. A Hamamatsu Type R446 multiplying phototube was used as the optical detector. A Spectrogram Model LPA laboratory photometric amplifier provided both signal amplification and phaselock detection along with bias voltage for the multiplying phototube detector. The output signal from the photometric amplifier was recorded on a ten (10) inch balancing strip chart recorder. An excitation lamp inverter power supply was modified for operation from a twelve (12) volt power supply and incorporated in the laboratory test set-up to provide power to the low pressure mercury discharge excitation lamp. Additional details are provided under TASK 2.

A twelve (12) volt battery simulator power supply was designed in accordance with the requirements for TASK 7 and also incorporated into the laboratory test set-up to provide the necessary power for the excitation lamp power supply. The excitation lamp inverter power supply is modulated on a fifty (50) percent duty cycle at four hundred (400) Hertz by the sync output from the photometric amplifier. Thus, the laboratory

<u>SAMPLE NO.</u>	<u>TYPE</u>	<u>REMARKS</u>
J1	Jet Fuel	Aircraft Commercial Gulf Oil Company
J2	Jet Fuel	Aircraft Commercial Mobil Oil Company
J3	Jet Fuel	Electric Power Company Turbin Generator JMS-55 Hartford Electric Light Co.
D1	Diesel Fuel	Union "76" Super Diesel
D2	Diesel Fuel	Texaco Std. Commercial Grade
D3	Diesel Fuel	Gulf Oil Co. Std. Grade
D4	Diesel Fuel	Elm City Fuel Company
2F-1	No. 2 Fuel	Gulf Oil Co. #2 Home Heating Fuel
2F-2	No. 2 Fuel	Exxon #2 Commercial Fuel
2F-3	No. 2 Fuel	Mobil Oil Corporation
2F-4	No. 2 Fuel	American Petroleum Institute Std. Sample #2 Fuel Oil
4F-1	No. 4 Fuel	Exxon #4 Industrial Low Sulfur Fuel
6F-1	No. 6 Fuel	Gulf Oil #6 Residual Fuel
6F-2	No. 6 Fuel	Exxon #6 Industrial Low Sulfur Fuel
BC-1	Bunker "C" Fuel	Exxon Bonded Bunker "C"
RF-1	High Energy Fuel	Exxon Baltimore Residual Fuel
C1	Crude Oil	Iranian Medium Crude
C2	Crude Oil	Kuwait Crude Oil
C3	Crude Oil	Florida Light Crude
C4	Crude Oil	Cabinda African Crude
C5	Crude Oil	West Texas Semi-Sweet Crude
C7	Crude Oil	La Rosa Venezuela Crude
C8	Crude Oil	Arzew North African Crude
C9	Crude Oil	Lagunilla's Venezuela Crude
C10	Crude Oil	Light Nigerian Crude

TABLE I
OIL SAMPLE LIBRARY



LABORATORY MEASUREMENT SYSTEM ASSEMBLY

FIGURE 1

test set-up simulated as closely as possible the anticipated conditions for the final buoy prototype design. The scanning monochromator which incorporates a wavelength drive mechanism, was adjusted to scan at the rate of twenty (20) nanometers per minute. This rate appeared to be a good compromise between total time per scan and the system response and resolution time.

1.3 Spectral Scans and Weathering Program

Brackish water was obtained from a nearby tidal river and each thirteen (13) inch plastic pan was filled with approximately three (3) gallons of the brackish river water. Forty (40) milliliters of each oil type was poured on top of the brackish water. This provides a film thickness of approximately five-tenths (0.5) millimeters.

Upon placing the oil in each pan, the pan was then placed in a laboratory fluorescent test set-up and a spectral scan was generated covering the range of three hundred (300) nanometers through six hundred (600) nanometers. Upon completion of each spectral scan, the oil pans were then placed in the weathering platform. Having completed the scans on all fresh oils, at the end of four (4) hours each oil pan was then returned and re-scanned over the same wavelength range. This procedure was again repeated at the end of twenty-four (24) hours, and at the end of one (1) full week. The weather conditions during the four (4) hour and twenty-four (24) hour periods were warm, sunny, fall conditions. During the one (1) week weathering period a mixture of warm, fall weather with one rain storm afforded a good variety to simulate actual weather field conditions.

1.4 Results

The oil scans were then correlated by oil type and re-plotted covering the wavelength range of interest, three hundred twenty (320) nanometers to five hundred fifty (550) nanometers, to graphically present the variations both in over-all intensity and as a function of wavelength.

We became suspicious of the persistent peak found in the three hundred sixty (360) nanometer region and suspected a light leak of the three hundred sixty-five (365) nanometer mercury line which subsequently proved to be true.

The data gathered still proved useful in that the region of interest for the fluorescent detection of oil lay between the four hundred (400) nanometer and five hundred (500) nanometer region. It was ultimately determined that the four hundred fifty

- - Arzew Crude Fresh
- - Arzew. Crude Weathered
- X - #6 Fuel Fresh
- X - #6 Fuel Weathered

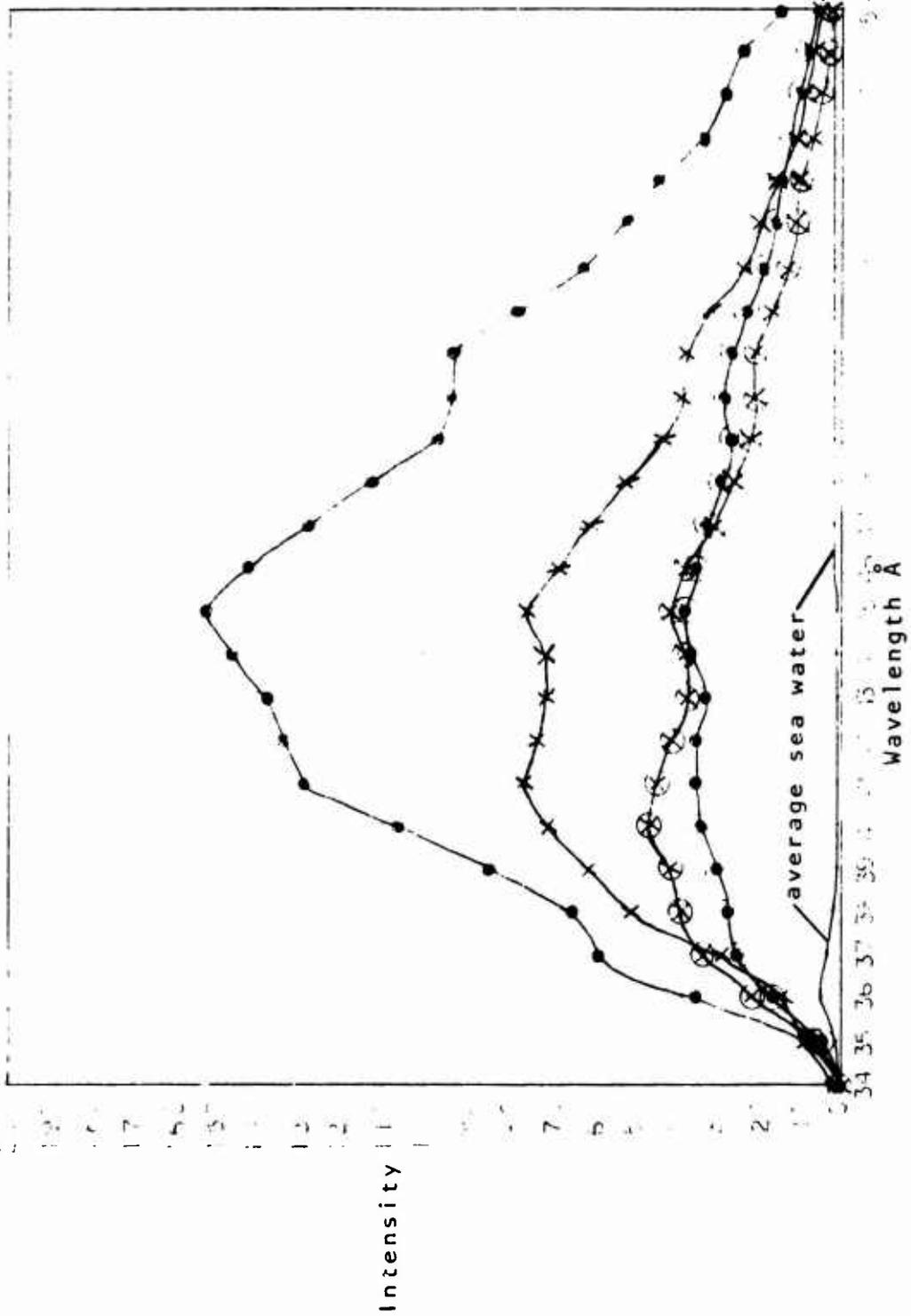


FIGURE 2 - CRUDE AND NO. 6 OIL SCANS

(450) nanometer region would prove to be the best compromise between the fluorescent patterns as obtained from the heavy oils and that obtained by the lighter oils. For the purposes of establishing an accurate library of direct excitation oil fluorescent patterns, the data previously submitted was rescanned, eliminating the three hundred sixty-five (365) nanometer light leak.

Figure 2 depicts a typical combined scan as obtained from a crude oil and a No. 6 fuel oil. Further included in Figure 2 is an averaged scan of sea water which clearly demonstrates that a background signal does exist. However, it is obvious that for the selected excitation conditions, this background level is well below the levels of fluorescent intensity obtained from petroleum oils.

It is known that both chemical and living organisms exhibit fluorescent characteristics, and that these materials are found both in fresh and ocean waters. It is this level that determines the minimum threshold level to which the oil detection buoy may be adjusted.

TASK 2 - EXCITATION LAMP POWER SUPPLY AND OPTICAL COUPLING

2.1 Excitation Lamp Design

As a part of this contract, we elected to study the parameters surrounding the low pressure mercury excitation lamp used in the previous buoy design. A literature survey revealed several interesting articles which discussed mercury lamp efficiency as a function of both excitation current and mercury vapor pressure.⁽¹⁾ Several experimental mercury discharge lamps were constructed utilizing different cathode designs and operating at different mercury vapor pressures. The results of this study demonstrated that the parameters originally selected for the excitation lamp were, in fact, optimal and that the current and, in particular, the current waveform, proved to develop maximum ultraviolet emission as a function of average lamp input power.

2.2 Excitation Lamp Reflector Housing

In an effort to concentrate the maximum amount of UV energy to the water surface, we studied the efficiency of the reflector housing design and again elected to remain with the design as conceived and used on the previous buoy system. We did find a ten (10) percent improvement through the use of an Alzac coating directly applied to the aluminum housing as opposed to the previous polished aluminum surface.

The previous design incorporated an ultraviolet pass filter, Corning No. 9863, located immediately in front of the excitation lamp. This ultraviolet pass filter absorbed approximately fifty (50) percent of the ultraviolet energy as generated by the excitation lamp. It does, however, prevent the longer wavelength mercury emission lines from reaching the water surface whereupon by reflection they can be collected by the fluorescent collection optics. By slightly adjusting the selected wavelengths for the fluorescence channels, we determined that the ultraviolet pass filter could be eliminated with a significant improvement in the fluorescent signal as returned by the oils under test.

(1) Hammond, T. J. and Gallo, C. F., Appl. Optics 13, 2164 (1974)

2.3 Excitation Lamp Power Supply

As noted above, it was determined in the laboratory that the excitation lamp operating current and current waveforms proved optimum for maximum ultraviolet efficiency. The basic design of the previous inverter power supply was retained for this buoy design. As the principal power consuming element in the buoy design is, in fact, the excitation lamp and its power supply, additional effort was put forward to improve the conversion efficiency of the inverter supply and raise it from the previous eighty-five (85) percent efficiency to a nominal ninety-two (92) percent efficiency. The present design as again with the previous design, calls for modulating the inverter output such that the lamp is in the "ON" condition for nominally one (1) millisecond and "OFF" for a period of one (1) millisecond. This provides an operating duty cycle of fifty (50) percent. A series or train of nine (9) such fifty (50) percent pulses are generated followed by a dwell or "OFF" period of nominally six hundred (600) milliseconds. Therefore, the lamp is "ON" or actually powered for nine (9) milliseconds out of every six hundred (600) milliseconds, which yields a final duty cycle of approximately one and five-tenths (1.5) percent. As the lamp and inverter power supply consume approximately forty (40) watts during the "ON" period, the average power consumed, taking into account the one and five-tenths (1.5) percent duty cycle, is nominally six-tenths (0.6) watts.

TASK 3 - PHOTODETECTOR POWER SUPPLY REVIEW AND REDESIGN

3.1 Change in Design

The use of multiplying phototubes as detectors in the buoy system poses two problems, those being: fragility of the detectors and additional power consumed by the bias power supply. Development work in another area surrounding medical instrumentation uncovered new developments in silicon ultraviolet photodetectors with significantly improved quantum efficiency and signal-to-noise ratios over previously available devices. We elected to pursue the concept of replacing the multiplying phototubes and the power supply requirement with the silicon ultraviolet photodetectors. It was determined that the silicon detectors having somewhat poorer signal-to-noise characteristics than multiplying phototubes at these low light levels, provided adequate signal-to-noise in our laboratory set-up ratios to warrant further investigation.

Through discussions with two manufacturers, we obtained silicon detectors having improved signal-to-noise and response time characteristics. These detectors in conjunction with the low noise preamplifier circuitry developed for the medical instrumentation have been incorporated in the present oil detector buoy design. The multiplying phototubes and the bias power supply have, therefore, been eliminated from the design. We estimate this change eliminated an additional one (1) watt requirement on buoy input.

TASK 4 - SIGNAL AMPLIFIER AND AUTOMATIC GAIN CONTROL CIRCUIT REVIEW AND REDESIGN

4.1 System Concepts

Please refer to Figure 3. The oil detector buoy optical head employs three (3) silicon optical detectors and preamplifiers. One (1) detector is located directly above the excitation lamp. Through a far ultraviolet pass filter this detector directly monitors the lamp intensity. Two (2) additional detectors are employed in the fluorescent signal collection optics. One (1) detector employs an interference filter selected for the four hundred fifty (450) nanometer region. This channel is referred to as the FLUORESCENT CHANNEL. The third detector employs a mid-UV bandpass filter covering the region from three hundred forty (340) to three hundred eighty (380) nanometers. This channel basically observes the reflectance of the three hundred sixty-five (365) nanometer mercury line as returned from the water surface. Therefore, this channel is referred to as the REFLECTANCE CHANNEL.

The three (3) preamplified signals are multiplexed through a low noise signal amplifier. The amplified composite signal is then demultiplexed and separated back to the three (3) individual signals. Each signal is then phaselocked, detected and filtered to provide a DC voltage representative of the original light intensity falling upon the selected detector. The DC signal representing the lamp monitor detector is fed to an error amplifier where it is compared to a fixed reference voltage. The error signal generated by this difference controls the automatic gain control network that precedes the main amplifier. The DC signals representing the fluorescent and reflectance channels after passing through the field adjustable level set controls are fed to a different amplifier whose output provides a signal that equals the fluorescent channel level minus the reflectance channel level. This difference signal again, after filtering, provides one (1) input to the threshold level detector.

A manually adjusted threshold level setting provides the reference level for the threshold detector. The output signal from the threshold level detector is amplified and drives the coil of an isolated relay which then provides the alarm signal.

To control the entire signal system, a timing and logic circuit is necessary and provides all the gating pulses and logic required by the multiplexer, the demultiplexer, the phase-lock detectors and the sync input requirements for the excita-

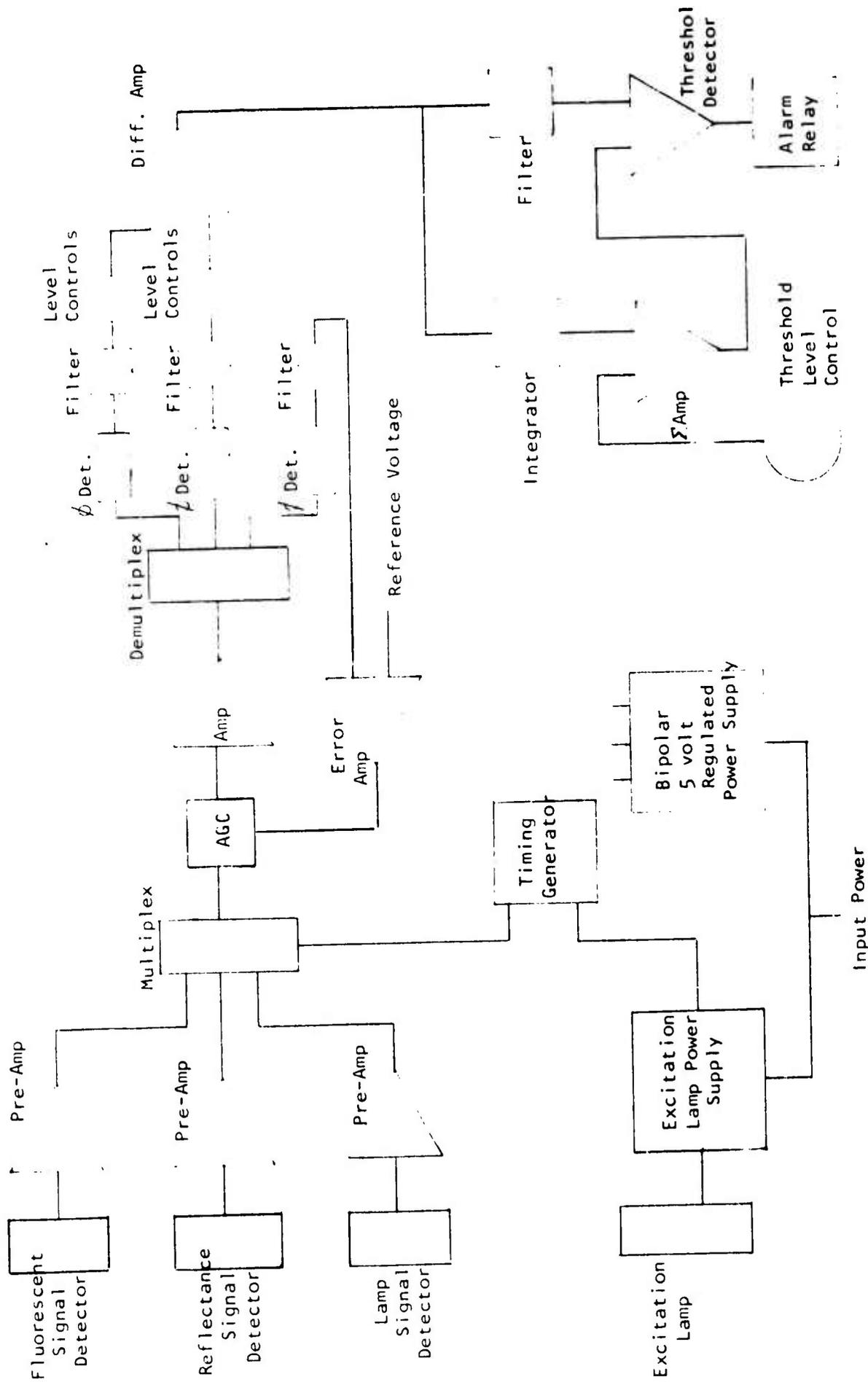


FIGURE 3 - OIL DETECTOR BUOY BLOCK DIAGRAM

tation lamp power supply. To provide stable operating voltages, a bipolar five (5) volt regulated switching power supply was designed and incorporated in the electronic system.

4.2 Preamplified Design

The preamplifier design utilizes a single low noise-low power super gain operational amplifier. The silicon detector cell is connected as a current source to provide minimum variation as a function of temperature. Feed forward as well as feed back techniques are employed to provide maximum gain bandwidth and stable operation. Gain controls are incorporated to compensate for variations in cell sensitivities.

4.3 Multiplexer Amplifier and Automatic Gain Control

The output from each preamplifier is multiplexed by a digitally controlled MOS-FET gate to a single composite signal. Please refer to Figure 4. The multiplexed signal passes through an automatic gain control (AGC) network to a high gain operational amplifier. The amplifier output is demultiplexed by the MOS-FET gate to three (3) amplified signals, each representing a sampling of the three (3) silicon detected signals. The demultiplexed signals are phase or synchronously detected and filtered to produce three (3) direct current voltages that are proportional to the detected signals.

It is known that the excitation lamp output intensity will vary as a function of time, temperature, and input power. Rather than regulate the input power to the excitation lamp, as this would have proven to only partially correct for intensity output variations, we elected to monitor the intensity directly and utilize this signal to control automatically the gain by which the fluorescent and reflectance signals would be amplified.

The DC lamp monitor signal serves as one (1) input to a high gain error amplifier. The reference input is derived from a stable voltage divider from the regulated positive five (5) volt supply. The error amplifier output signal controls the pass gain of the AGC network such that the DC lamp monitor signal is maintained at a constant voltage.

In this way, changes in lamp intensity are immediately corrected and further because the fluorescent and reflectance signals are also amplified by the same network, these signals are also corrected.

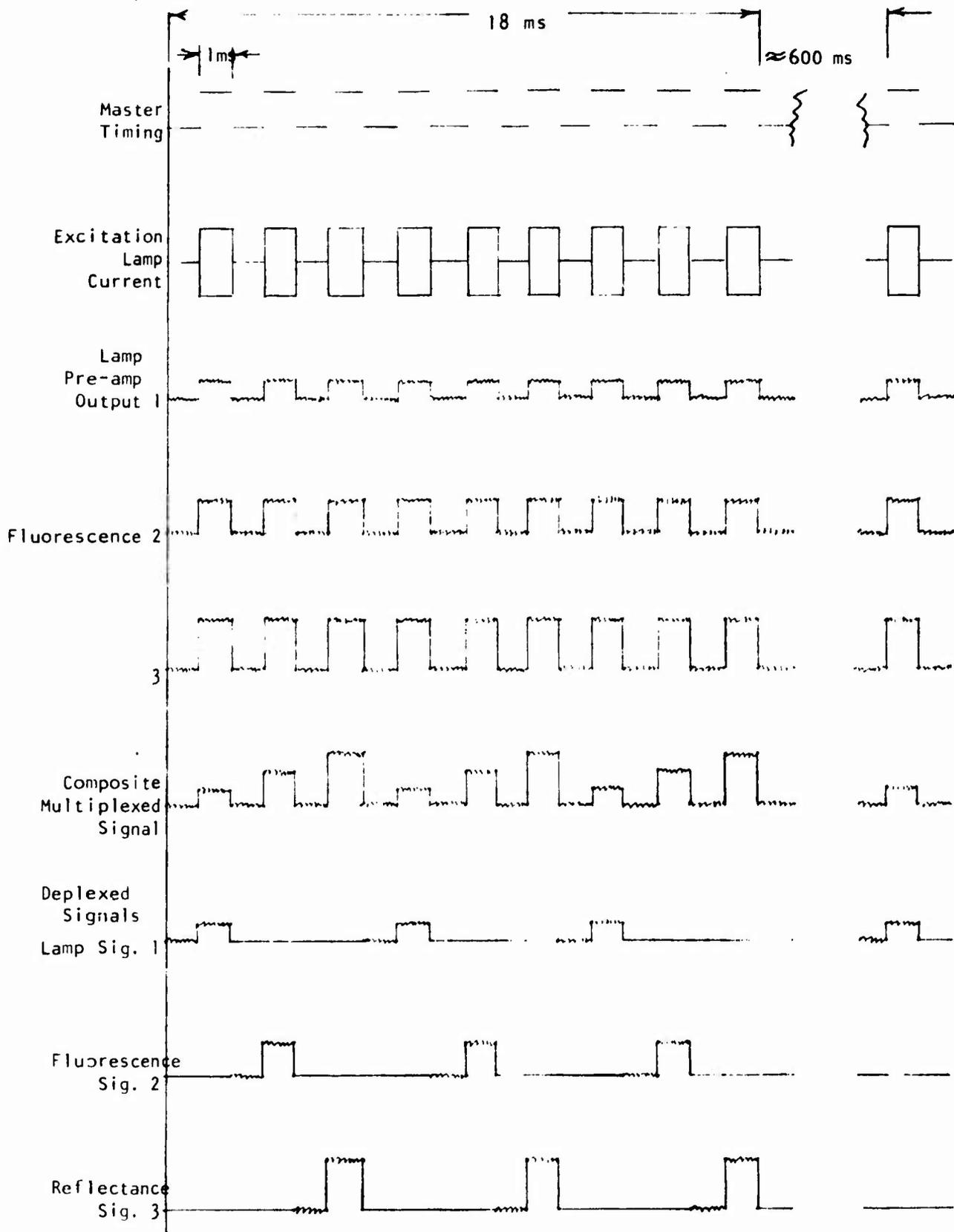


FIGURE 4 - SIGNAL WAVEFORMS

4.4 Alarm Detection Circuits

The detected and filtered output signals from the reflectance and fluorescent channels are directed to field adjustable gain controls located under the beacon dome. Operating signal levels and sensitivity can be adjusted for the particular deployed location. The adjusted levels are inputs to a differential amplifier where the output signal is proportional to the fluorescent signal minus the reflectance signal. This circuitry tends to compensate for floating debris and water surface conditions not related to petroleum materials. The difference signal serves as one (1) input to a threshold level detector which in turn activates the alarm relay. The reference input signal is derived from a field adjustable control, again to be adjusted for the specific required location sensitivity. The one (1) ampere rated alarm relay contacts are returned to the land based console via the interconnecting cable as an isolated switch to control a selected audio/visual alarm device.

TASK 5 - MECHANICAL PACKAGING

5.1 System Concepts

Please refer to Figure 5. Having reviewed the design of the previous buoy, its tripod mounting, weight and other considerations, we elected to concentrate the efforts of this task on weight reduction, improved rigidity and lowering the profile to minimize the wind resistance of the buoy. Our experience has demonstrated that the tripod mounting proved to offer maximum stability even in rough seas. We, therefore, elected to retain this basic flotation technique.

The use of PVC and polyurethane plastics for the exterior construction also proved most practical from the point of rigidity, impact resistance, and self-cleaning capability. Although the PVC wets with oil, the adhesion appears to be limited and consequently continuous wave action tends to rinse and wash off the exterior housing. As the previous buoy design stood approximately two and one-half (2-1/2) feet above the water surface, we did notice considerable motion and wind dependence. To minimize this effect, we set a maximum height of eighteen (18) inches on the new design. This decision also lowers the center of gravity. Finally, to facilitate field service, the electro-optical system housing is a modular insert in the basic flotation frame and can readily be removed and exchanged in the field. The beacon light and field adjustable controls are located beneath a clear plastic dome cover. The balance of the electro-optical system is contained within a pressurized air-tight housing.

5.2 The Flotation Base Frame

The main base frame is fabricated from thick wall PVC twelve (12) inch tubing that has been machined to remove non-structural excess material. In this way the mechanical qualities of the PVC are retained but with a substantial reduction in weight. Each of the three (3) trimount flotation legs are fabricated from high impact thin wall PVC tubing with machined and chemically welded end plugs. Each leg is filled with an ultra-low density, closed pore, epoxy foam. Should the PVC outer jacket be damaged or crack, the closed pore foam would continue to provide the required flotation. A polyurethane, molded sunshield is fastened to the main base frame and at the outer rim to each of the flotation legs. The flotation legs are further fastened to the main base frame by two (2), one-half (1/2) inch nylon bolts. The flotation base frame is assembled and fastened using only plastic and marine grade stainless hardware.

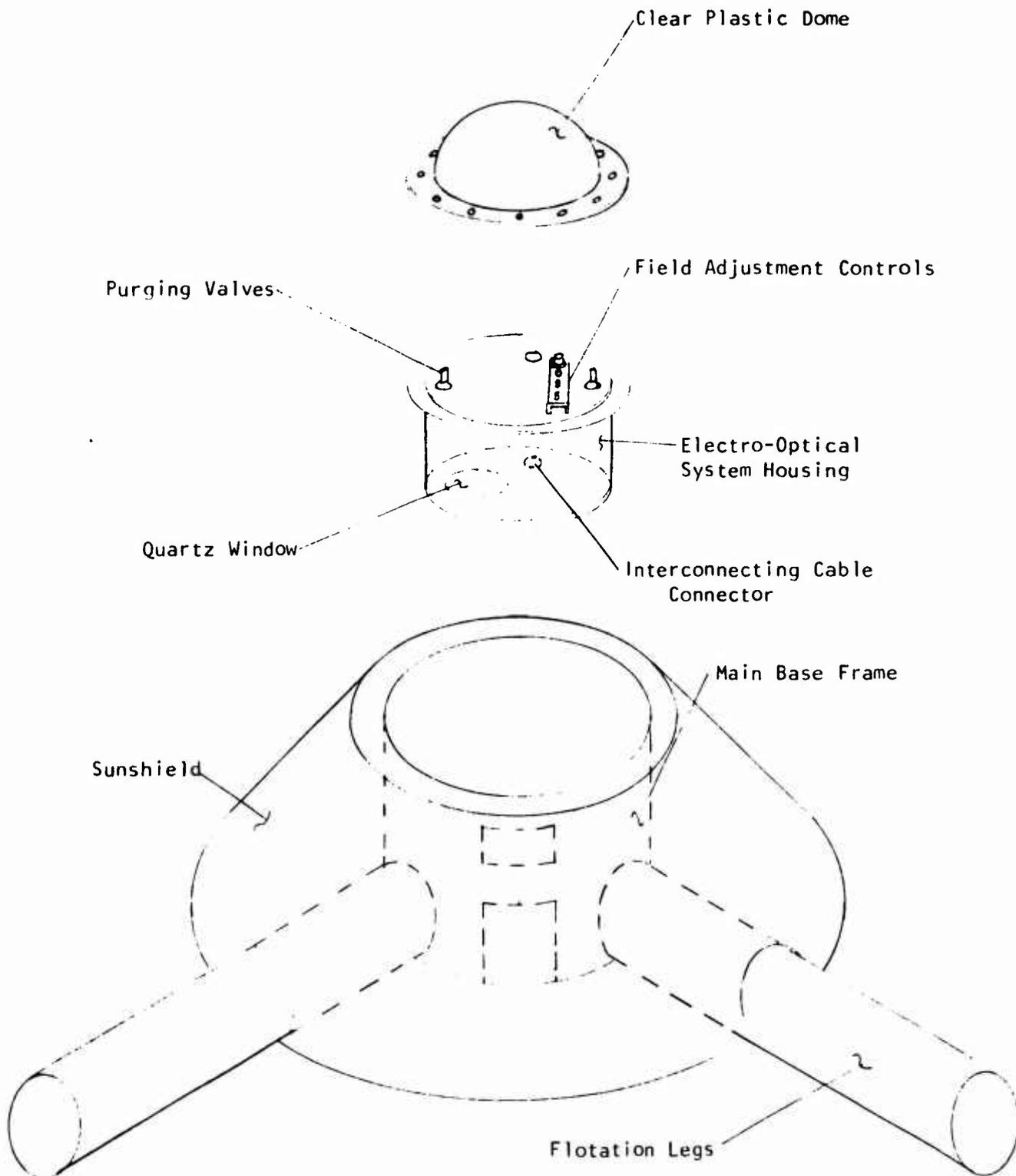


FIGURE 5 - MECHANICAL PACKAGE

5.3 The Electro-Optical Sensor Head

The entire detector system is packaged in a sealed cylindrical housing, that fits in and is fastened to the flotation base frame. This modular construction facilitates field service and provides for easy replacement of the entire sensor head.

A quartz window is sealed in the bottom of the cylinder and provides the optical window for both the excitation lamp and the fluorescent radiation collection optics. A hermetically sealed connector for the interconnecting cable is located adjacent to the quartz window. The entire optical system is fastened directly over the quartz window. This assembly is fabricated from aluminum and contains the collection optics; the beam splitter; the filter holders; the three (3) silicon detectors; and preamplifier assemblies; the excitation lamp; and the excitation lamp power supply. Adjacent to the optical assembly are two (2) plug-in printed circuit boards. One (1) board contains the main amplifier, multiplexer, and power supplies. The second board contains the alarm logic and relay. The cover for the sensor head housing is "O" ring sealed by a flange ring to the cylindrical section. A second hermetically sealed connector interconnects the field adjustment controls to the main printed circuit board. These controls along with a test box connector, beacon light, and purging valves are mounted on the top cover. A clear molded plastic dome is flange bolted with a gasket to the cylinder housing to completely seal the entire package. The inner sealed electro-optical section can be flushed with dry nitrogen or argon and pressurized at the three (3) to five (5) psi level to assure a clean moisture free environment for the optical system.

TASK 6 - LAND BASED POWER RECORDER CONSOLE

6.1 System

To simulate battery operating conditions, an adjustable regulated low voltage power supply was designed and constructed. This power supply is adjustable over the range of ten (10) volts to sixteen (16) volts DC. Voltage and current meters are provided on the front panel which indicate the actual DC voltage at the buoy and the current requirements.

Further incorporated are two (2) impulse-type strip chart recorders that monitor both the fluorescent and the reflectance DC analog signals.

The above equipment is packaged in a gray steel cabinet having the following dimensions: Depth - seventeen (17) inches, Width - twenty-two (22) inches, Height - thirty-two (32) inches.

The land based console operates from one hundred fifteen (115) VAC, sixty (60) Hertz, single phase at nominally fifty (50) watts.

TASK 7 - FIELD TESTS

7.1 Pool Tests

Upon completion of the buoy and land based console construction and test, the buoy was deployed in our test pool. Weather turned out to present a problem as the mean temperature during much of the following weeks remained at or below the freezing point. Although the pool water was pumped from a tidal river, and as such was brackish water, we still experienced nighttime freezing, which required breaking up the ice layer during the daytime testing.

Clearly the buoy produced a fluorescent signal from the plain (non-contaminated) brackish river water. It should be noted at this point that we did not perform any detailed chemical analysis of the brackish water. Therefore, although there was no observable oil sheen on the water surface, it might well be assumed that trace levels of oil might be present. Additional tests on salt water in Long Island Sound indicated a similar background characteristic assumed to be related to other organic compounds.

The oil detection buoy threshold level was adjusted to be sufficiently above this background level to prevent any false alarms under a variety of water turbulence.

From our library of oils, a variety of products were spilled on the water surface and buoy system response monitored. All oils with the exception of the jet fuels and one crude oil that didn't float, gave an alarm. These tests were repeated several times to gain statistical confidence. The buoy was then left for a period of two (2) weeks of continuous monitoring and performed perfectly with only a change in the reflectance channel signal (observed amplitude), as a function of ice forming.

7.2 Open Water Tests

The buoy system was then moved to a shoreline location in Madison, Connecticut where after obtaining the necessary approvals, the buoy was deployed at the following location:

Latitude: 41° 16' 17" N

Longitude: 72° 37' 21" W

A small wading pool was brought to the beach location and filled with ocean water. The threshold level was readjusted to a lower level as we observed that the sea water level was

lower than that obtained from the brackish river water used in the pool tests. This confirmed our laboratory fluorescent scan data.

As we did not have permission from the authorities to perform test spills directly in the Sound water, we did test the buoy response to several oil types in the small pool. The oil detection buoy provided the same readings as obtained during the pool tests performed at our plant.

An eighty (80) pound boat mooring with chain, swivel and half (1/2) inch nylon line was deployed to hold the buoy on location. The five hundred (500) foot cable was used to full length with the buoy being located approximately three hundred fifty (350) feet out from mean low tide in about fifteen (15) feet of water.

Six (6) days after the initial deployment we experienced a severe winter storm with southwesterly winds of gale force. Upon visiting the deployment site, we found that the buoy was performing properly as observed by the recorders. However, we did observe that the mooring was being dragged in the direction of a natural rock jetty. After a futile attempt to save the buoy by boat, it finally came in on the rocks. The buoy was returned to our laboratory for damage assessment and repair. The plastic dome was smashed and one of the flotation legs was cracked. The electro-optical sensor head was removed and placed in operation in the laboratory test stand. The head operated perfectly. The buoy was then repaired and tested again in the pool. The mooring was pulled and replaced in the original location with a double, twenty (20) pound Danforth to prevent dragging. The buoy was again deployed and operated satisfactorily for a period of three (3) weeks. The buoy was removed from field test as a result of another major storm which precipitated the fracturing of the galvanized eye bolt used to secure the buoy to the mooring. The buoy has been returned to our laboratory to replace the eye bolt. We intend to continue the field testing until notified of shipping instructions.

CONCLUSION

An extended capability oil detection buoy utilizing the fluorescence technique has been developed and tested. The electro-optical sensing system will operate over an input voltage range of ten (10) volts to fifteen (15) volts at an average current of less than fifty (50) milliamperes. The buoy detects petroleum oils ranging from crudes to kerosene on the water surface under a wide range of environmental conditions. Although damage to the buoy was experienced during the field tests, the basic design is considered acceptable with the blame falling on poor mooring conditions.

REFERENCES

- (1) Hammond, T. J. and Gallo, C. F., Appl. Optics 13, 2164 (1974)
"Effect of Electron Deexcitation and Self-Absorption on the Intensity of the Hg 2537-Å Radiation from Hg + Ar Discharges (ac Fluorescent Lamps)