AD 275 380

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

ASD-TR-61-710

CHEMICAL WARFARE DETECTION AND WARNING SYSTEM

TECHNICAL DOCUMENTARY REPORT No. ASD-TR-61-710

MARCH 1962

DIRECTORATE OF OPERATIONAL SUPPORT ENGINEERING
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEM COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

Project No. 6338

62-3-4

(Prepared under Contract No. AF 33(616)-8380
by Beckman Instruments, Incorporated, Fullerton, California;
James G. Myers, Author)

Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-61-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. illus.

Unclassified report

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of the chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

ed. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED

Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-61-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. illus.

Unclassified report

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of the chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

ed. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED

Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-61-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. illus.

Unclassified report

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of the chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

ed. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED

Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-61-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. illus.

Unclassified report

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of the chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

ed. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED

Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-61-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. illus.

Unclassified report

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of the chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

eronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-1-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. llus.

Unclassified report

he basic requirements of Long Path Infrared LOPAIR) systems for detecting and warning of he presence of the chemical warfare (CW) aents are discussed. Several varieties of active LOPAIR systems together with their adantages and disadvantages are reviewed. A implified version of a non-dispersive infraed analyzer which employs a monobeam pneumatc selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

ed. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED

d. The results of some successful preliminary ests performed at George Air Force Base, California, are presented and discussed. The tests hich were over ranges of 4,350 feet and 10,825 eet (0.824 and 2.05 statute miles) were made n the presence of atmospheric scintillation nd through the exhaust trails of various airraft. Successful operation through scintilltion is essential to LOPAIR systems. Previous ests on other LOPAIR systems showed them to e adversely affected by scintillation. Conlusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendatons and conclusions, and possible test proedures for an active LOPAIR system of the onobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED

FOREWORD

This report was prepared by Beckman Instruments, Inc. under USAF Contract AF 33(616)-8380. This contract was initiated by the Flight Control Branch, Flight Vehicle Division, Directorate of Operational Support Engineering under Project 6338 - CW Detection and Warning Equipment. The work was performed by the Special Projects Division of Beckman Instruments, Inc., for the Aeronautical Systems Division, Wright-Patterson AFB. Mr. Fred J. Smith, of the Flight Control Branch, was Project Engineer in charge of the research and development work. Mr. James G. Myers of Beckman Instruments, Inc., was Engineer in charge of the work covered under Contract AF 33(616)-8380. This report covers work conducted from 11 August 1961 to 22 December 1961.

The author wishes to acknowledge and thank the following Beckman personnel for their suggestions and assistance: C. H. Beebe, Dr. W. S. Gallaway, H. S. Hanson, M. D. Liston, M. M. Lyons, and R. L. Madsen. Mr. Madsen is the author of Appendix II, Proposed LOPAIR Detection System.

A debt of gratitude and thanks is extended to Mr. Harvey Tannenbaum of the Army Chemical Center for lending optical equipment and consulting advice.

ABSTRACT

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compared. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

David V. Stockman

DAVID V. STOCKMAN
Chief, Flight Vehicle Division
Directorate of Operational
Support Engineering

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

I. INTRODUCTION

The use of long path infrared radiation systems (LOPAIR) as a means of monitoring the gaseous content of the atmosphere is a well recognized method. LOPAIR permits monitoring, measuring and even identifying certain gases at a great distance without any physical contact with the gases*. There does not appear to be any other method of accomplishing this task. In one simple form, active LOPAIR consists of a beam of infrared (IR) radiation optically projected through the atmosphere to a distant receiver and infrared detector circuit. Certain gases or vapors occurring in the path will absorb some of the radiation, and the detector and circuit will indicate this condition.

A LOPAIR system appears to be excellent for detecting and warning of the presence of chemical warfare (CW) agents. However, in tests of certain active LOPAIR systems it was soon found that atmospheric scintillation** (random variations in the index of refraction of the air path caused by varied air temperatures) presented a large obstacle. Scintillation caused the detection systems to fluctuate wildly and they were either inoperative or reporting false alarms when no CW agent was present. It was therefore decided to test for immunity to scintillation at the earliest possible moment before presenting any recommendations to the Air Force. An active, operational desert air base was chosen so that there would be (1) atmospheric scintillation and (2) aircraft and motor vehicle exhaust vapors, more or less typical for air base operations.

---

* Yates, H. W. and Taylor, J. H., "Infrared Transmission of the Atmosphere" NRL Report 5453, Washington, D. C., June 1960.
Hackforth, H. L., "Infrared Radiation", McGraw Hill Book Co., New York, 1960.
Also many references in Proceedings of the IRE, Vol. 47, No. 9, p. 1457, September, 1959.

** Fuld, K. M., "Investigation of Atmospheric Scintillation and the Elimination of Its Influence Upon LOPAIR Systems", Final Report on Contract No. DA-18-108-405-CML-511, U.S. Army Chemical Center, University of Chicago, 1960.

Manuscript released by author November 1961 for publication as an ASD Technical Report

II. ACTIVE LOPAIR SYSTEMS

A. General:

In an active LOPAIR system, there is a distant source of IR radiation which the receiver (detector) system views. The source may be interrupted or "chopped", or it may be a steady, uninterrupted source. In the latter (steady) case, the system approaches a "passive" system in which the detector views an IR source such as the sky or background. Since "passive sources" are continually varying in temperature, or a warm or hot object may enter the detector field of view (even a warm, IR emitting cloud of toxic gas) and the system would not report an alarm, then the passive system leaves much to be desired as an optimum, fixed, stable, and permanent alarm system.

The chopped active system allows the detector to discriminate between the true IR source and extraneous IR sources. The detector senses and should respond only to the chopped IR signal.

To obtain stability, it is essential to compare a steady reference signal with the analytical or sample signal. For a LOPAIR system to detect a CW agent, the sample signal would be derived from the wavelengths of IR radiation which the CW agent will absorb, (hereafter called λ_s) and the reference signal from one or several wavelengths which the CW agent will not absorb (hereafter called λ_r, or λ_{r1}, λ_{r2}, λ_{r3}, where more than one λ is used). Both wavelength regions (the sample and reference) should traverse identical paths, and of course must be in spectral regions to which the atmosphere is transparent. Furthermore, varied concentrations of nontoxic gases, vapors, aerosols, smoke, and dust, sand clouds, haze, smog, fog, rain, snow, and hail should be transparent to the spectral regions used. Transmission through all of these over an extremely long path cannot be achieved, but can be approached reasonably well for most conditions. The atmosphere is quite transparent from 8 μ to 13 μ. Fortunately, some nerve agents absorb energy in a region of high atmospheric transmission---9.8 μ.

B. Detectors:

Two types of uncooled infrared detectors have detectivities sufficiently high to be useful for LOPAIR. These are: (1) blackbody radiation absorbers, (2) pneumatic selective detectors. Neither type needs cooling, whereas the fast response and high detectivity photoconductors such as doped Germanium require from liquid nitrogen to liquid helium temperatures and are obviously unsuitable. The blackbody radiation absorbers can be thermistors, thin film bolometers, thermistor bolometers, thermocouples, or Golay cells. Each of these is responsive to radiant energy of nearly all IR wavelengths and is relatively linear in response. Each needs a wavelength sorter (such as a monochromator or filters) to eliminate all except the sample and reference wavelength regions.

The pneumatic selective detectors are not blackbody absorbers. Instead, they are filled or charged with some of the very gas to be detected, or with a gas having a common absorption region with the gas to be detected. These selective detectors are responsive to IR wavelengths only in the regions where the charging gas absorbs radiant energy. Pneumatic selective detectors do not need monochromators or filters to sort the desired from the undesired wavelengths.

In order to compare the wavelength regions where the sample gas (gas to be detected) absorbs energy (λ_s) with the reference wavelength regions (gas to be detected does not absorb here, λ_r), there are two basic methods which are best suited. Both methods have an identical view of the IR source, but one method views at alternate time periods while the other views at identical times.

1. Measurement of λ_s and λ_r in Alternate Time Periods:

In this method, a beam switching mechanism is used to direct the source image consisting of λ_s only to a detector for a given period of time. In the next period of time, the source image consisting of λ_r only is switched to the detector. At no time does the detector view both λ_s and λ_r at the same instant. This can be done by switching at the receiving end, or by selective chopping at the source, such as by a filter wheel.

Advantages:

a. Enables use of a single detector for viewing of λ_s and λ_r. Matched detectors are therefore not required.

b. Method has had considerable development work, both in LOPAIR systems and IR spectrophotometry. The familiar double beam spectral recording instruments use the beam switching technique. Filter wheel LOPAIR systems have also been developed.

Disadvantages:

a. The alternate time period of view system is adversely affected by scintillation. When the frequency of viewing is near (or slower than) the frequency of scintillation, drastic performance degradation and false alarms occur. λ_s and λ_r are "chopped by scintillation" of a varying frequency. To escape effects of scintillation, high speed switching of alternate views is required, and this decreases the detectivity of the detectors.

b. A degree of mechanical complexity is introduced to do the alternating, such as vibrating or rotating mirrors or filters. Also, some method of balancing the relative strength of λ_s against λ_r must be accomplished, introducing further complexity.

2. Measurement of λ_s and λ_r in Identical Time Periods:

In this method, λ_s and λ_r are viewed at the same instants at all times. No beam switching is required. The use of a beam splitter is a good example, where a percentage of the view is reflected from a partial reflecting surface, and the remaining percentage is transmitted through the surfaces of a beam splitter. Other methods can be used to produce the same result, some more efficiently.

Advantages:

a. This is the best way to eliminate the adverse effects of scintillation.

b. No mechanical motion required at receiver.

Disadvantages:

a. Requires the use of two detectors which must be balanced in response times. They must remain balanced in response time and detectivity with both ageing and temperature variation.

b. Unless care is taken as to how the IR beam is divided, there can be a loss of energy and hence a loss in detectivity of the detectors. For instance, a 50% reflecting and 50% transmitting beam splitter divides the radiant energy to each detector by two.

C. Methods of Obtaining Proper Wavelength Bands:

There are a variety of ways to obtain the desired wavelength bands, λ_s, and λ_r (or λ_{s1}, λ_{s2}, etc. and λ_{r1}, λ_{r2}, etc.)

1. Dispersive systems, such as prism or grating monochromators and interferometer systems, can be efficient and accurate. Mechanical complexity, expense, and a certain degree of fragility and temperature dependency are disadvantages which they introduce.

2. Filters, both natural occurring (like plastic films) and single or multi-layer interference filters can also be efficient and accurate. They can be produced in quantity within relatively tight tolerances, can be stable in performance, and have a good life expectancy.

3. Selective detectors, as previously mentioned, do not need any filters or dispersive systems. They are rugged, and have relatively fast response characteristics. Some disadvantages are found in obtaining charging gases with all the desired characteristics. Although the gases can usually be found, either some search is required or the gas must be chemically synthesized.

In all of the previously cited possibilities, one form or another of the pneumatic selective detector can be used in place of the blackbody absorbing detectors. All that is required is that the pneumatic detector have sufficiently fast response. Since the pneumatic detector is already selective in its response (depending on the charging gas) no filters, monochromators, or interferometers are required. This is a considerable simplification. There is, however, one further modification in the use of a certain pneumatic selective detector which results in another simplification of considerable magnitude. This serves as an introduction to the monobeam system.

D. The Monobeam System As Applied To LOPAIR:

As an active LOPAIR system, the monobeam system makes use of a distant source of IR radiant energy mounted at the focal point of a sufficiently large positive optical projector (See Fig. 1). The source view is chopped at 5 cycles per second (5 cps) by a rotating opaque shield. (Further developments may permit pulsing the IR source electrically, thus eliminating mechanical chopping.) The IR beam is projected to the receiving optics which intercept a small portion of the large source image. The receiving optics collect the intercepted rays and form a reduced image of the distant source optics aperture at the focal plane. The radiation entrance port of the detector is centered to accept fully the source image.

The detector itself (Fig. 1 and 2) is comprised of two similar sections optically in tandem. This is the essential point; radiation which is not used by the first detector section (D1, the "sample detector") is passed on without loss (other than optical window surface reflection-transmission losses of 4 to 18%) to the second detector section (D2, the "reference detector"). D1 is typically charged with the gas to be detected, or with a gas having at least one absorption band in common with the gas to be detected. D2 is charged with a gas which does not have any bands common to the gas to be detected. It is desirable that the energy absorbing regions of D2 be relatively close to the D1 region, and if possible, be on both the long and short wavelength side of D1. Operation as just described can be termed bichromatic (for two wavelengths) or polychromatic (for three or more wavelength absorbing regions). Each section of the detector is essentially a condenser microphone. A part of the detector wall consists of a flexible diaphragm in electrical contact with the detector body, and closely spaced from the diaphragm is a fixed plate electrode. The two parts then form the plates of variable-space capacitor. Absorption of IR radiation causes the gas to expand which in turn causes the flexible diaphragm plate to change spacing with respect to the fixed plate, thus varying the capacity. A useful signal may be extracted by using any electronic system which will measure or compare very small changes in capacitance. There are several well known and reliable techniques. The detection information may be presented in a difference of signals system (D1 signal minus D2 signal) or in a ratio of signals system (actually the ratio of difference of the signals to the sum of the signals.

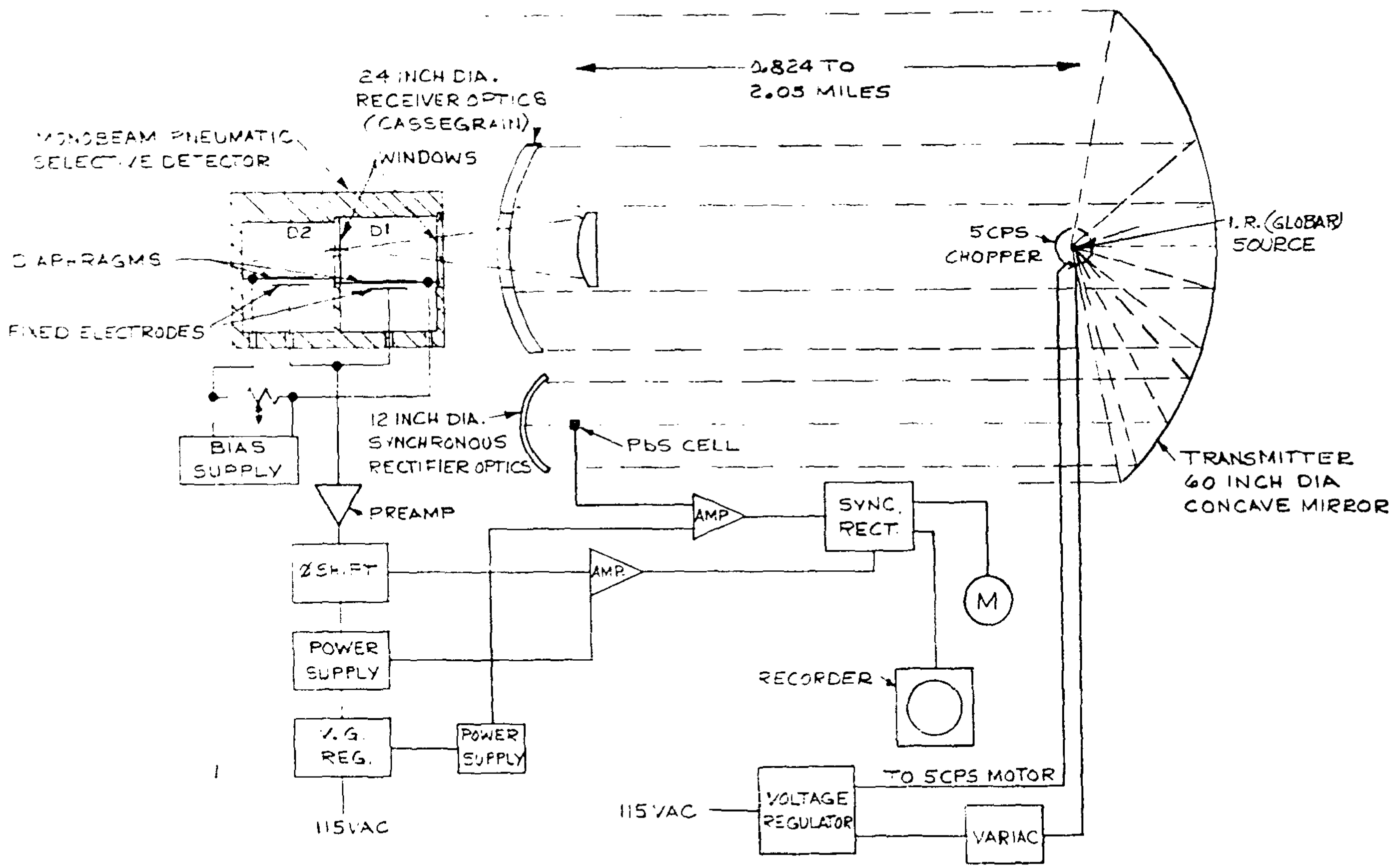


FIGURE 1. DIAGRAM OF MONOBEAM LOPAIR DIFFERENCE SIGNAL SYSTEM USED FOR GEORGE AFB TEST

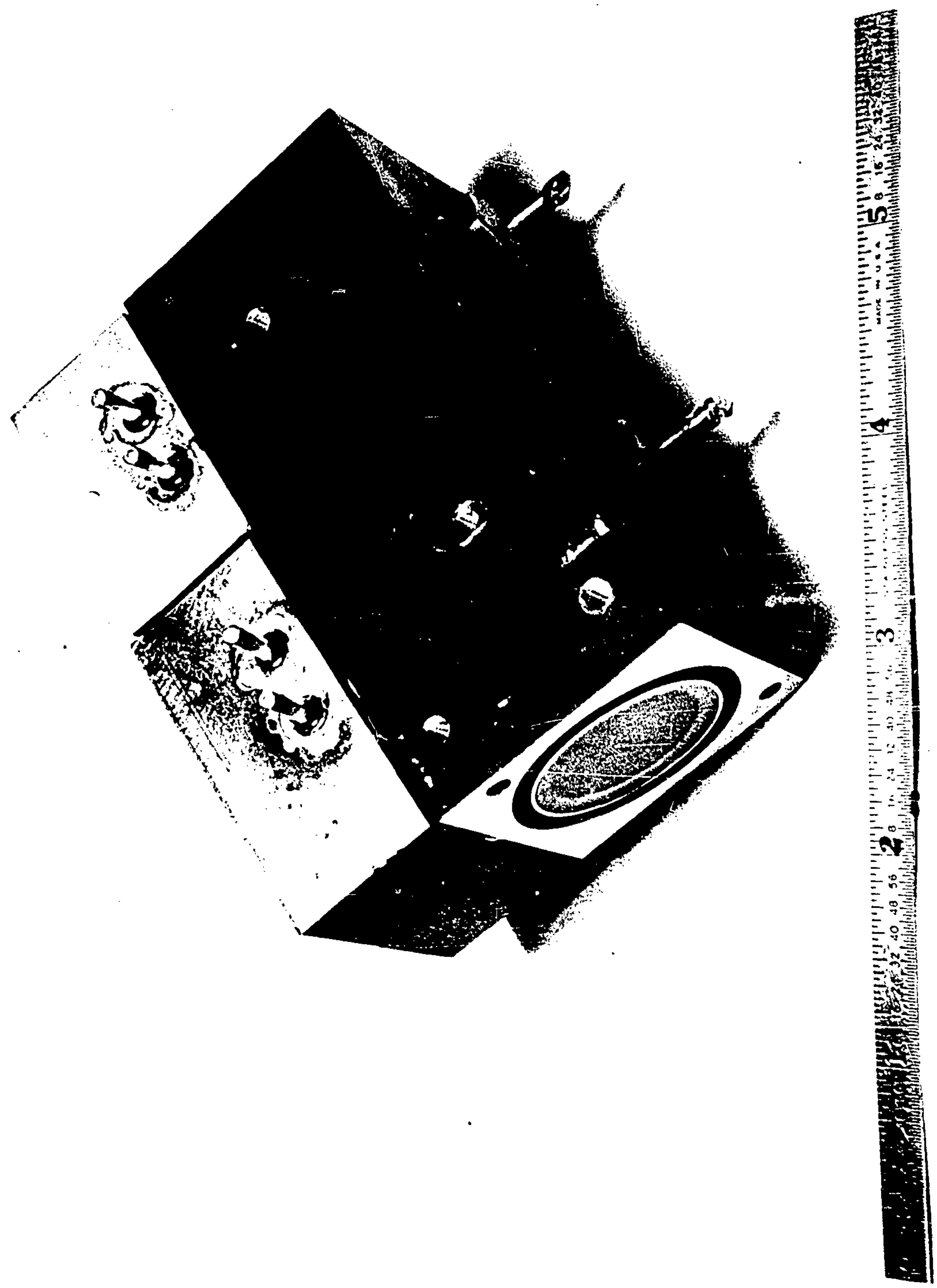


FIGURE 2. MONOBEAM PNEUMATIC SELECTIVE DETECTOR

E. IR Sources:

There is a variety of IR emitting sources which are suitable to LOPAIR systems. The IR source must meet the following requirements:

1. Give off sufficient spectral radiant emittance in the wavelength regions of interest.

2. Consume a minimum of power.

3. Be sufficiently stable in output.

4. Be of long life---on the order of 1000 to 2000 hours or more.

5. Be capable of being re-newed easily.

6. Be started easily.

7. If the synchronizing signal is transmitted optically, then the IR source must give off sufficient spectral radiant emittance for whatever detector response is used.

The silicon carbide "Globar", Nernst glower, Welsbach mantle, and heated metal filaments or ribbons appear best in meeting the requirements.

There are other possibilities which are attractive, but at the present time also have drawbacks.

1. The large area "stove" would not require transmitting optics and would not produce any visible radiation if operated from 400° to 500° C. It would require much electrical power for heating, or gasoline, oil, L-P gas, etc., could be used. Chopping of the large source would be somewhat awkward.

2. The carbon arc has been used for long path IR studies. It is a good IR source, operating at about 3700° C. High power consumption, short life, and intricate feed mechanisms are the disqualifying drawbacks.

3. The enclosed concentrated zirconium arc offers some interesting possibilities. The high operating temperature near 3000° C with black body characteristics produces considerable IR radiation. Average life ranges from 700 to 1000 hours. The small arc has a tendency to wander in position, and a technique must be developed for hermetically sealing an IR transmitting window onto the lamp envelope. Power consumption would range between 10 watts and 100 watts. The radiant output at 10 μ is more than twice that of the Globar.

4. Excited gases and vapors require extremely high pressures and temperatures for operation in the 10 micron region. Some have very high power requirements. These sources have not been

developed enough to make them attractive. The rather large size and short life are further disadvantages.

5. The IR maser is still in a developmental stage. If a 10 μ region emitter does not already exist, there is no theoretical reason why it cannot be made. Research and development are required. IR masers (or irasers) are attractive for the spectrally pure, high radiancy which can be obtained in a very narrow beam. Furthermore, no transmitting optics would be necessary and possibly only small size optics would be needed at the receiver for a 3 mile path. There are some possible disadvantages, some of which can only be conjectured. A continuous wave iraser will be complicated compared to the present IR sources. It may also be very temperature sensitive. The life expectancy is unknown. Alignment problems and maintaining of alignment could be very serious. The mirage effect, a gradual bending of the IR beam caused by varied air refractive index, could be drastic. A beam deviation of only one milliradian (0.057°) would require a receiver position shift of about 16 feet at a 3 mile range. The spectral bandwidth of IR emission could be very narrow---perhaps too narrow to permit detection of more than one CW agent.

Of the four best IR sources, two have been used successfully in the monobeam LOPAIR system---the Globar and the Welsbach gas mantle. The other two sources---Nernst glower* and metal filaments---were not tried but should work satisfactorily. The high output of the concentrated arc makes it a fifth possibility worth considering.

In tests performed at the Beckman plant the Globar and mantle were compared over path lengths of 566, 800, and 9,190 feet in a modified monobeam LOPAIR system. Absolute signal levels for each section of the detector were measured.

The Globar (silicon carbide) rod 1/5" diameter by 2" long, was operated at 1400° to 1500° C, and consumed from 130 to 150 watts of power. The mantle was a Veritas Alpha type 73769, heated by tanked liquid petroleum gas (propane-butane). For the near maximum operating conditions used, signal level comparisons showed the Globar to be from 1.1 to 1.3 times better in output than the mantle. The test showed that the gas mantle could be used as a secondary IR source which does not require electrical power. Electrical power would still be required to operate a chopper motor, but a thermoelectric generator energized by heat from the mantle could furnish the motor power.

Globar operation is relatively simple. The heater rod is rugged, and has enough thermal intertia so as not to fluctuate badly in the wind. No pre-heater circuit is required to start it.

---

* The Army Chemical Corps has used Nernst glowers satisfactorily.

III. TEST RESULTS

In order to verify certain assumptions and calculations, measurements were made over 1.74 miles path at the Beckman Instruments, Inc., plant at Fullerton, California and at .824 miles and 2.05 miles at George Air Force Base, California. The IR source used was a Silicon Carbide Globar at about 1500° C, mounted at the focal point of a 60 inch diameter, 25.56 inch focal length antiaircraft searchlight mirror. The source was mechanically chopped at 5 cps.

The monobeam pneumatic selective detector was mounted at the focal point of a two foot diameter Cassegrain system (this system was obtained on loan from the Army Chemical Center). The monobeam detector sections, D1 and D2, had a wavelength response as shown in Fig. 3, and had noise equivalent power (NEP) values of about 3×10^{-9} watts at 5 cps, 0.12 cps amplifier bandwidth. This NEP measurement was made in the laboratory under the best of conditions and used an RF oscillator circuit. In the George AFB tests, an electrometer circuit was required to record a difference signal, so the NEP value was degraded. In Fig. 3, note that D1 shows response to 8.0 and 8.5 microns. This is not desirable, it being preferable that D1 respond only in the 9.8 μ band. However, this detector was experimental and did not contain an optimum charge. Other detectors have been built since this one, and showed response entirely at the 9.8 μ band. Fig. 4, curve C, shows a recently built detector with a more desirable response characteristic.

A synchronous rectifier system consisting of a lead sulphide (PbS) cell detector in a separate optical system (12" parabola, f/0.5) was used to rectify the 5 cps signal from the amplifier.

All the long path tests were made using a difference signal system. Response then showed D1 signal minus D2 signal. The gain was adjusted such that modulations or losses of the sample wavelength absorption band produced an upscale meter or recorder deflection of from 7.0 to 7.5% modulation for full scale deflection. Each record presented is marked to show the value of modulation which results in a full scale deflection. The detector circuit was arranged such that by pushing a switch button a known percent modulation would be superimposed on the detectors, and the recorder would register the resulting upscale deflection.

At the 1.74 mile Beckman Plant tests, the effects of Los Angeles smog and other unidentified vapors were apparent. General visibility to the eye was about 3/4 to 1 mile, but the orange colored source could just be seen through the haze. Two way radio voice communication was used to aid in the optical alignment. A sufficiently strong IR signal was received, and the test site was then moved to George AFB, 100 miles northeast of Los Angeles, in the Mojave Desert region.

RESPONSE SPECTRA FOR EACH SECTION
OF MONOBEAM PNEUMATIC DETECTOR
D_1 = FRONT (SAMPLE) DETECTOR
D_2 = REAR (REFERENCE) DETECTOR

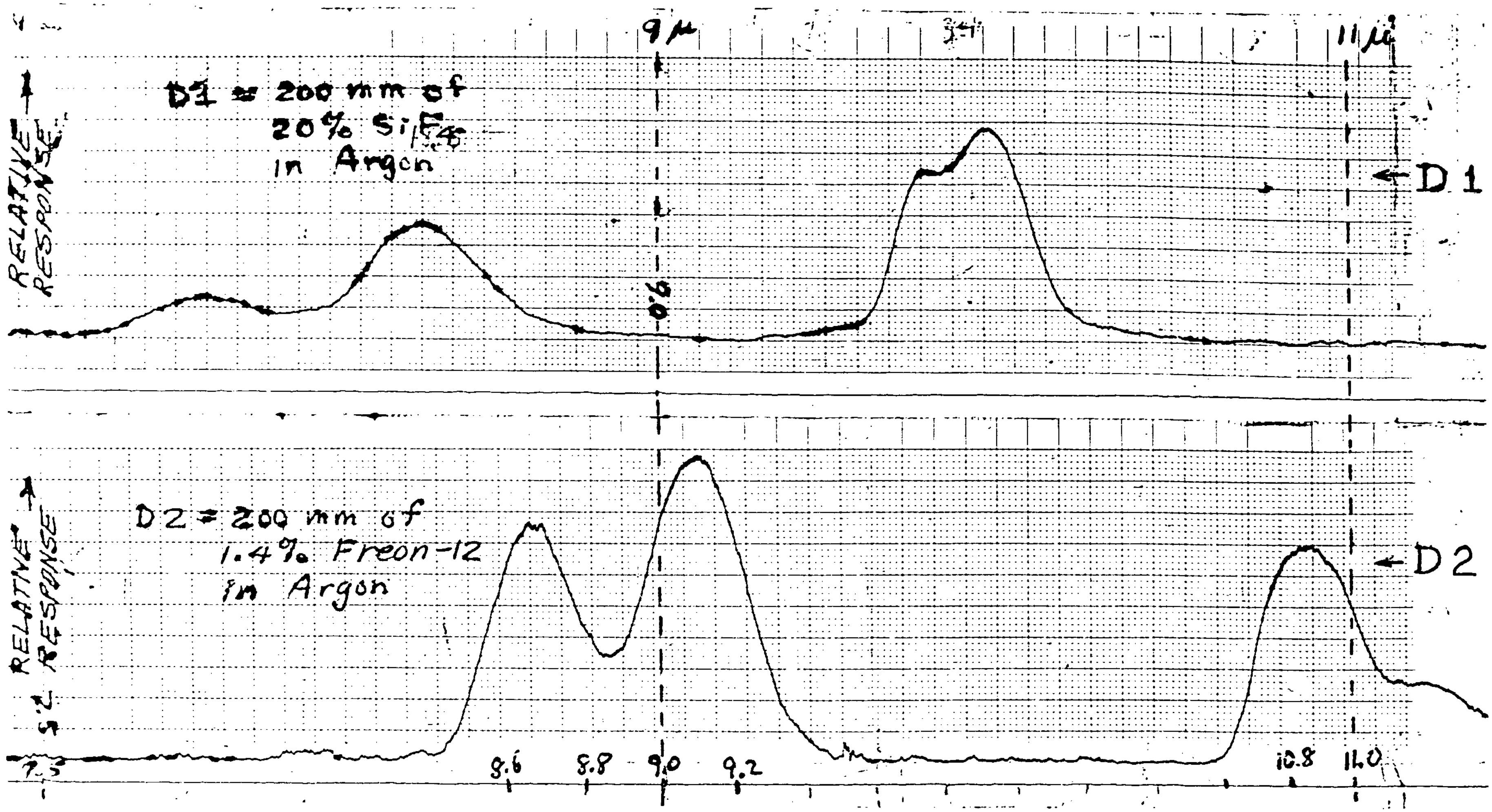


FIGURE 3. MONOBEAM PNEUMATIC SELECTIVE DETECTOR CHARGES

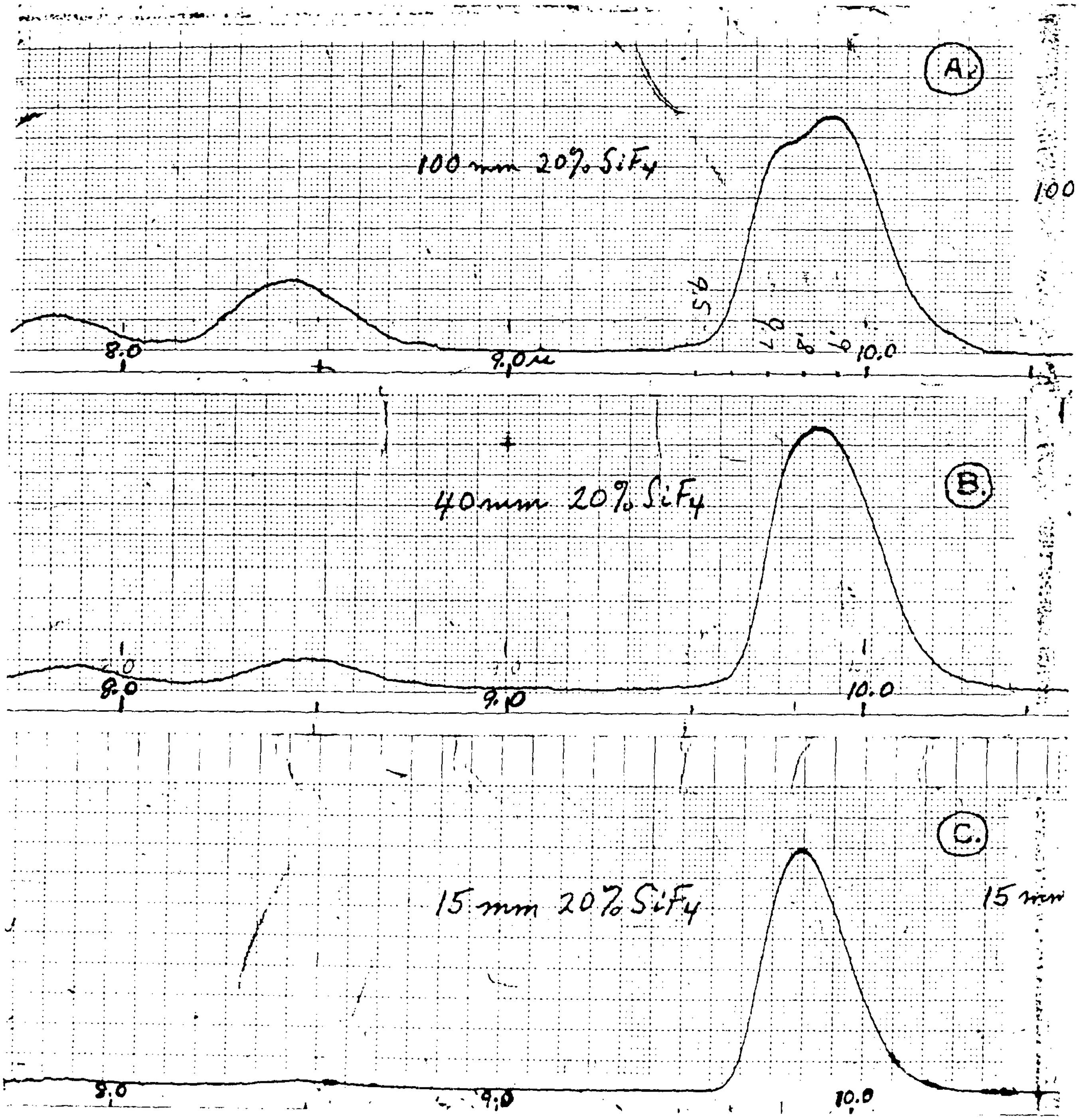


FIGURE 4. DETECTOR WITH VARIOUS CHARGING PRESSURES OF SILICON TETRAFLUORIDE

Fig. 5 shows the layout of the test sites. An important feature lies in the fact that the wind blew primarily from south to north (or was at times entirely calm) for most of the four days of long distance tests---and therefore, jet engine and also reciprocating engine exhaust gases drifted or remained in the optical path for considerable periods of time. At one time, the smoke trails from a variety of colored smoke flares, about 1/2 mile upwind, drifted through the optical path. The monobeam detector did not show response to any of these various gases, vapors, or smokes. The detector did show response to methyl alcohol (methanol, MeOH) sprayed into the beam with a hand spray. MeOH has a strong absorption band between 9.3 μ and 10.3 μ (See Fig. 6). An easier check of detector response to assure proper operation was to insert a thin film (about .002" thick) of polystyrene. Although there are some conflicting absorption bands, the absorption band at 9.724 μ with a half intensity bandwidth about 0.2 μ simulates a gas absorption well enough for crude test purposes (See Fig. 7). There are other plastic materials which can also be used for such purposes, or even small gas cells charged with appropriate gases. A further check on the monobeam system functioning is provided in a calibrate button---a switch which introduces a positive and foolproof electrical test signal into the detectors for an indication of the percent modulation range or span of the system.

Some partial records of the George AFB tests are presented in Fig. 8 and Fig. 9. It should be remembered that these were preliminary tests and the circuitry used was an open, unshielded breadboard system. The noise which shows originated entirely from the preamplifier system, for when the IR beam was blocked off with an opaque shutter, the noise level stayed the same. The curves are unchanged from the original runs and with the clarifying captions are relatively self-explanatory.

Upon returning to the Beckman Plant, the actual calibrate signals were carefully determined by use of a Fluke Differential Voltmeter. The measurements showed 7.0% modulation for full scale deflections on the 4,350 foot path, and 7.5% modulation for full scale on the 10,825 foot path. Also, using the same electrometer circuit as at George AFB, NEP values for the detector were determined to be D1 = 1.1×10^{-8} watts and D2 = 5.2×10^{-8} watts. More recently built detectors showed signal improvements by a factor of 1.8 for D1 and 4.4 for D2. Upon using a radio frequency (RF) oscillator circuit in place of the electrometer circuit on the George AFB detector, an improvement of signal to noise (S/N) ratio of 2.2 for D1 and 2.6 for D2 was realized.

On one of the newer detectors, the RF circuit versus electrometer circuit was better in S/N by a factor of 3.5 for D1 and 3.4 for D2.

Thus, it was possible to improve upon both the detectors and electronics such that NEP values of D1 = 1.7×10^{-9} watts and D2 = 5.5×10^{-9} watts are realized.

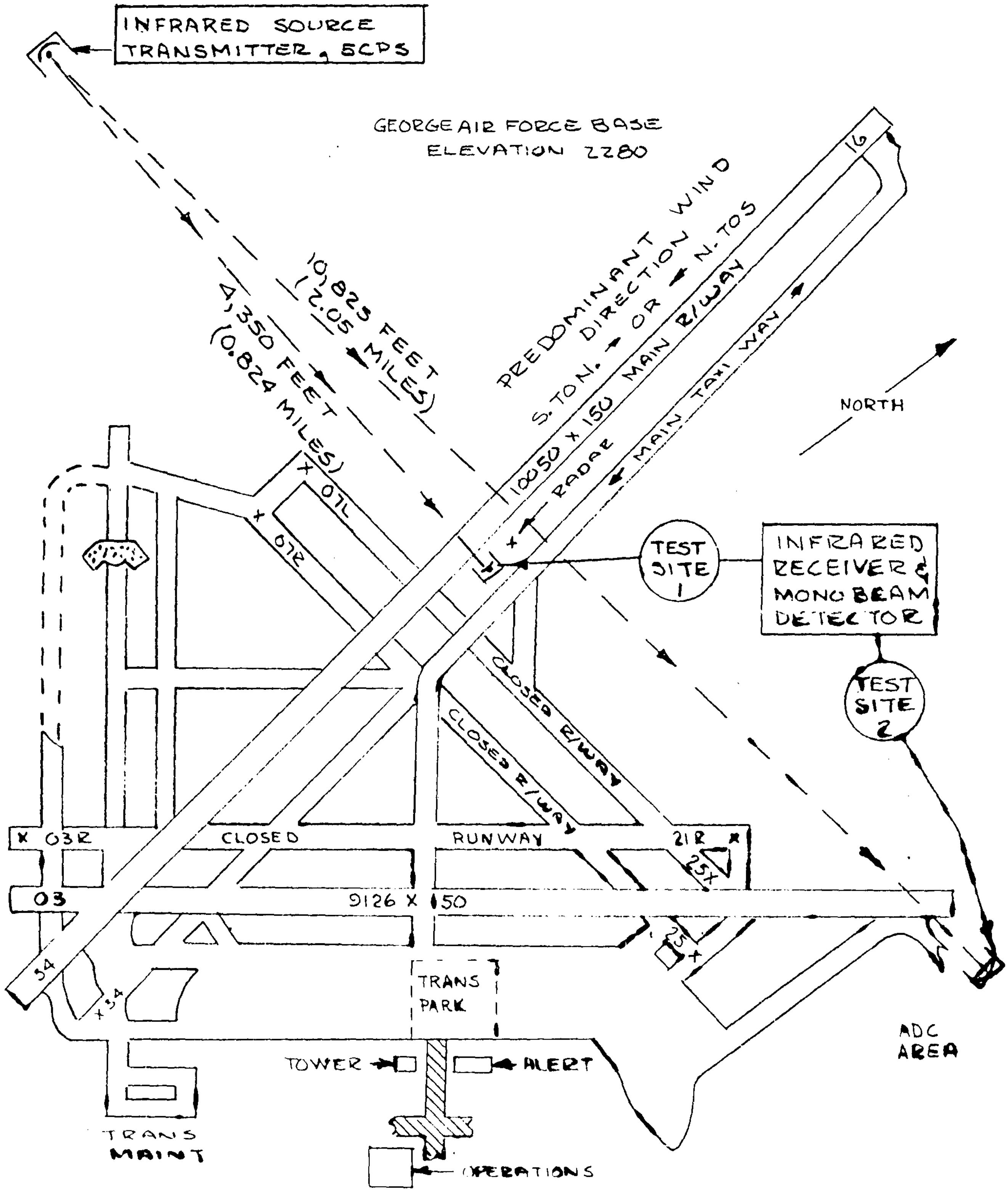


FIGURE 5. GEORGE AFB TEST SITES

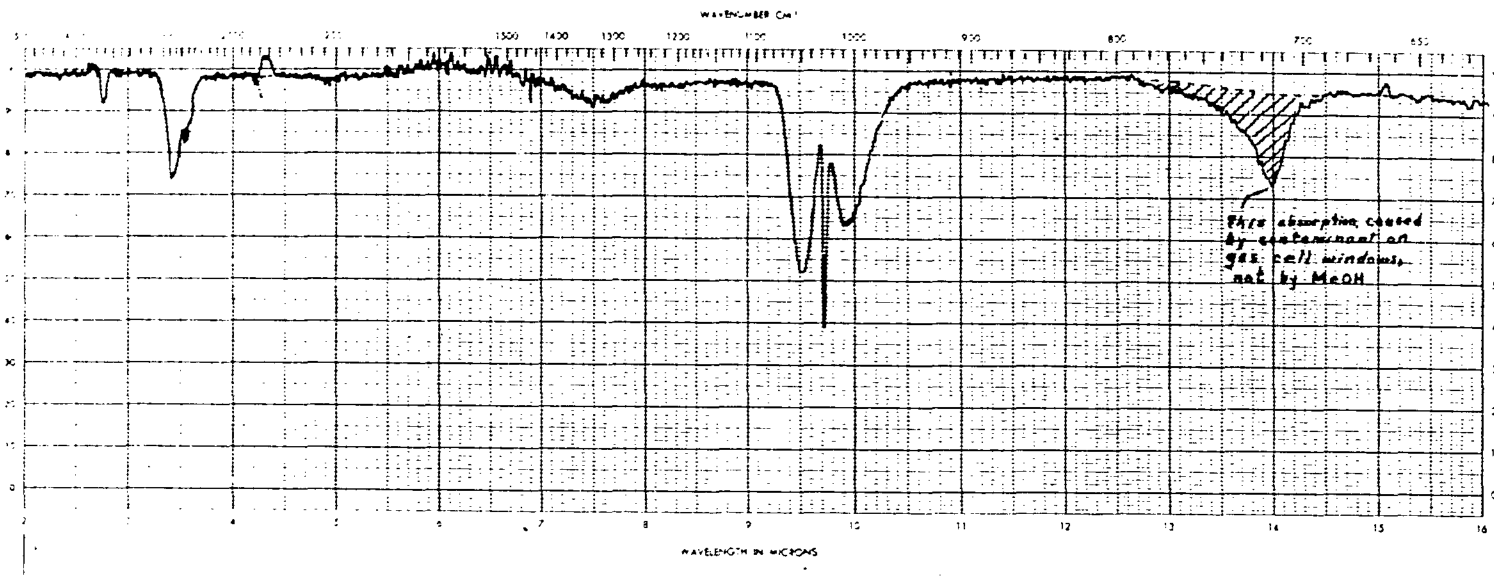


FIGURE 6. SPECTRUM OF METHYL ALCOHOL VAPOR. 1.0% MeOH WITH N_2 TO A TOTAL OF 1 ATMOSPHERE

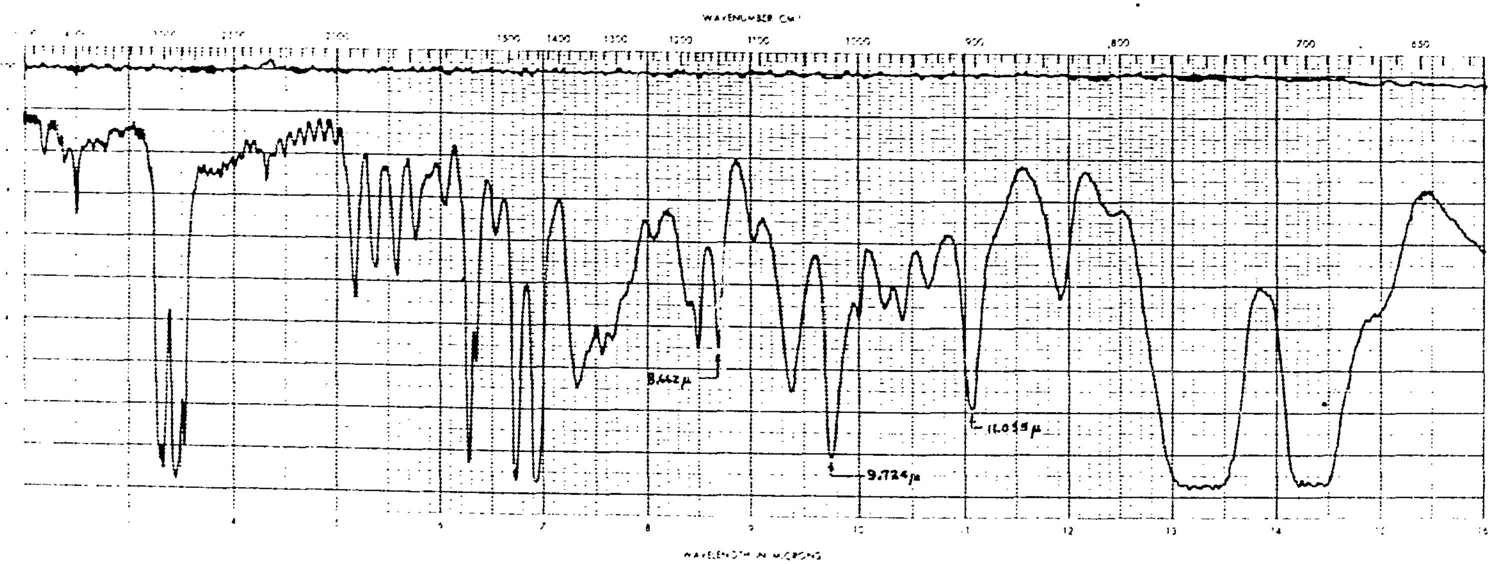


FIGURE 7. SPECTRUM OF POLYSTYRENE FILM. 0.002" THICK

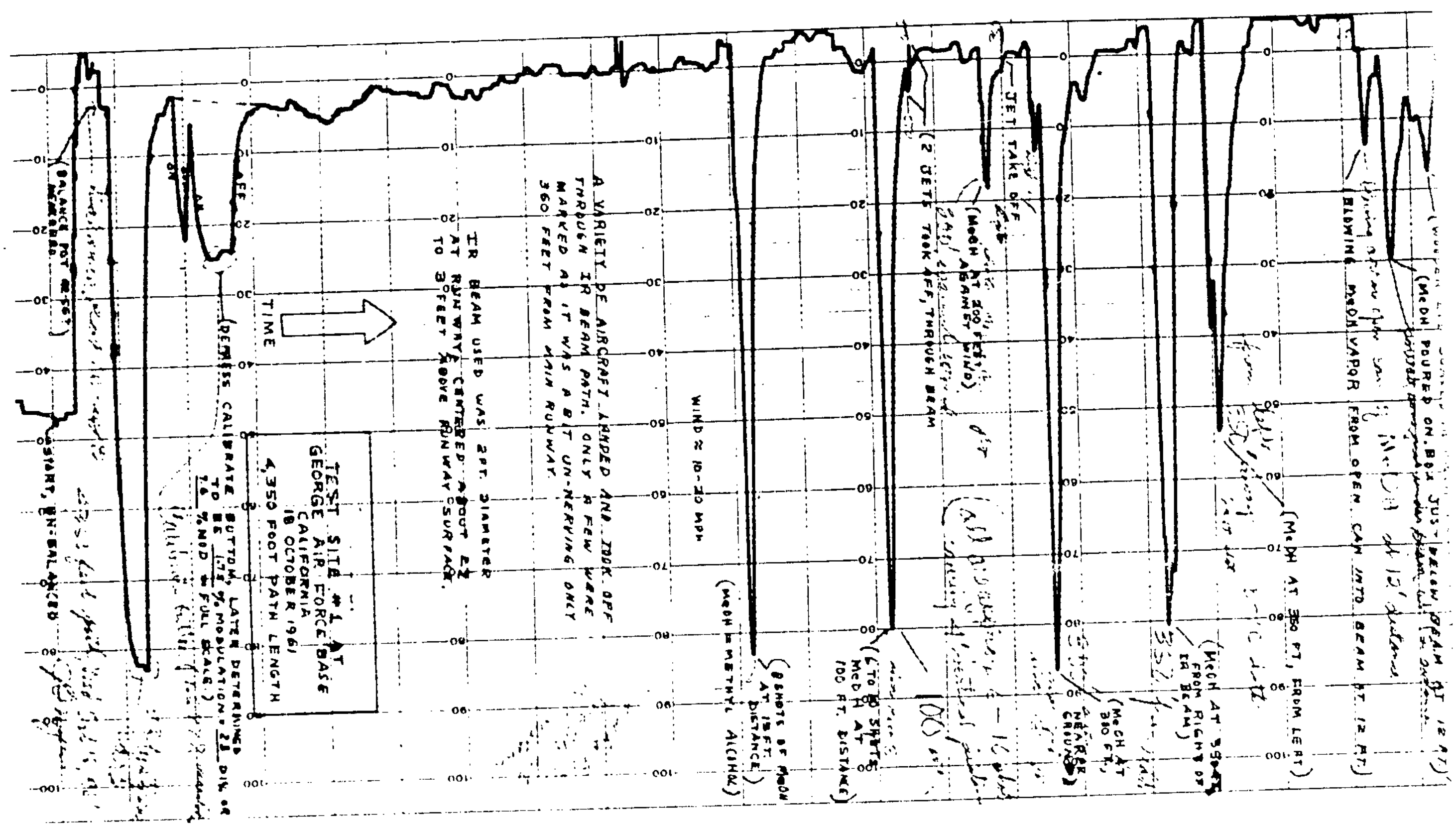
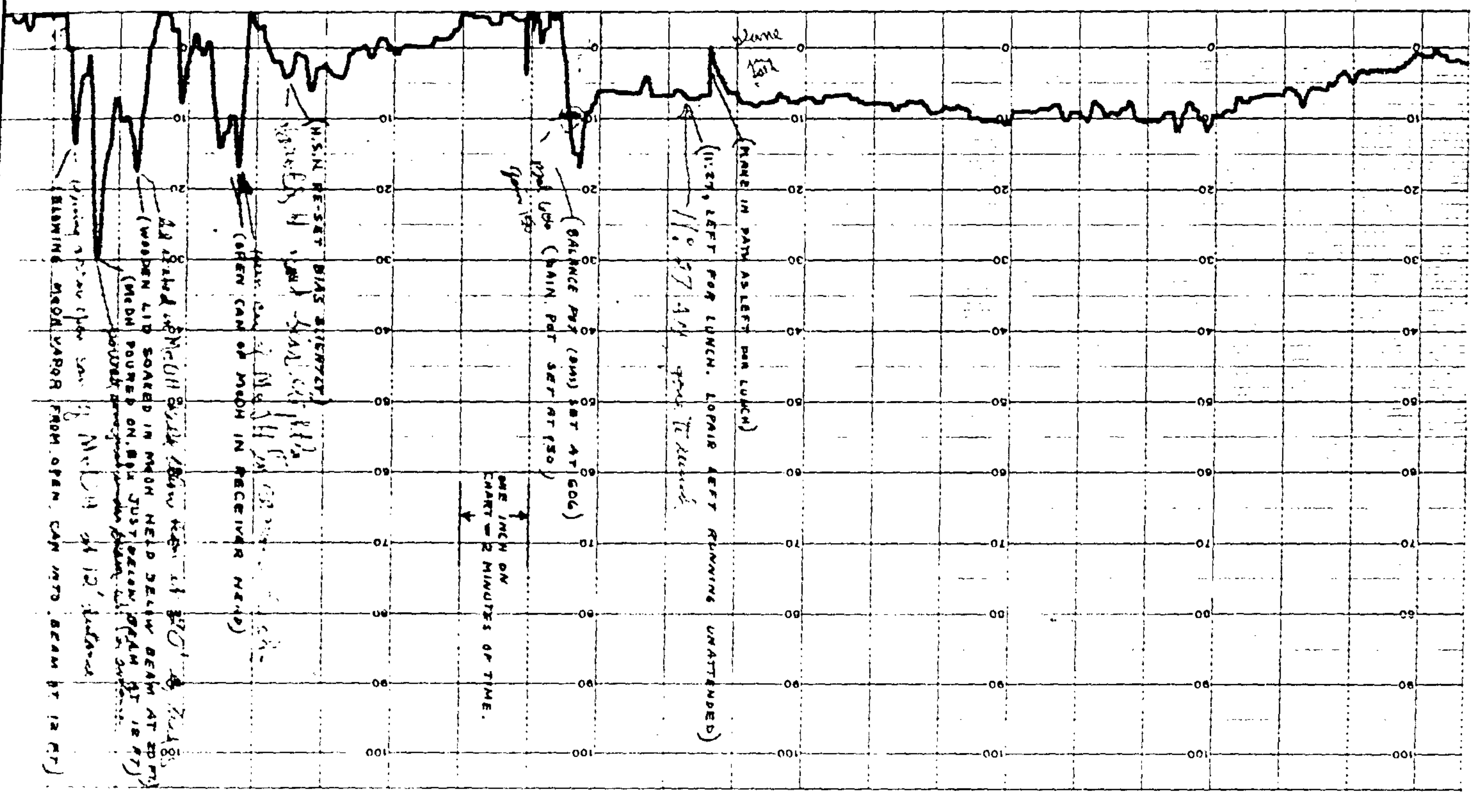


FIGURE 8. RECORD AT TEST SITE #1, GEORGE AFB


(BLOWING MEOH VAPOR FROM OPEN CAN INTO BEAM AT 12 FT)
(WOODEN LID SOAKED IN MEOH HELD BELOW BEAM AT 20 FT)
(MEOH POURED ON BOX JUST BELOW BEAM AT 12 FT)
(OPEN CAN OF MEOH IN RECEIVER HEAD)
(N.S.N RE-SET BIAS SLIGHTLY)
(BALANCE POT (BM) SET AT 606)
(MAIN POT SET AT 930)
ONE INCH ON CHART = 2 MINUTES OF TIME.
(11:27, LEFT FOR LUNCH. LOPAIR LEFT RUNNING UNATTENDED)
(PLANE IN PATH AS LEFT FOR LUNCH)
plane

2

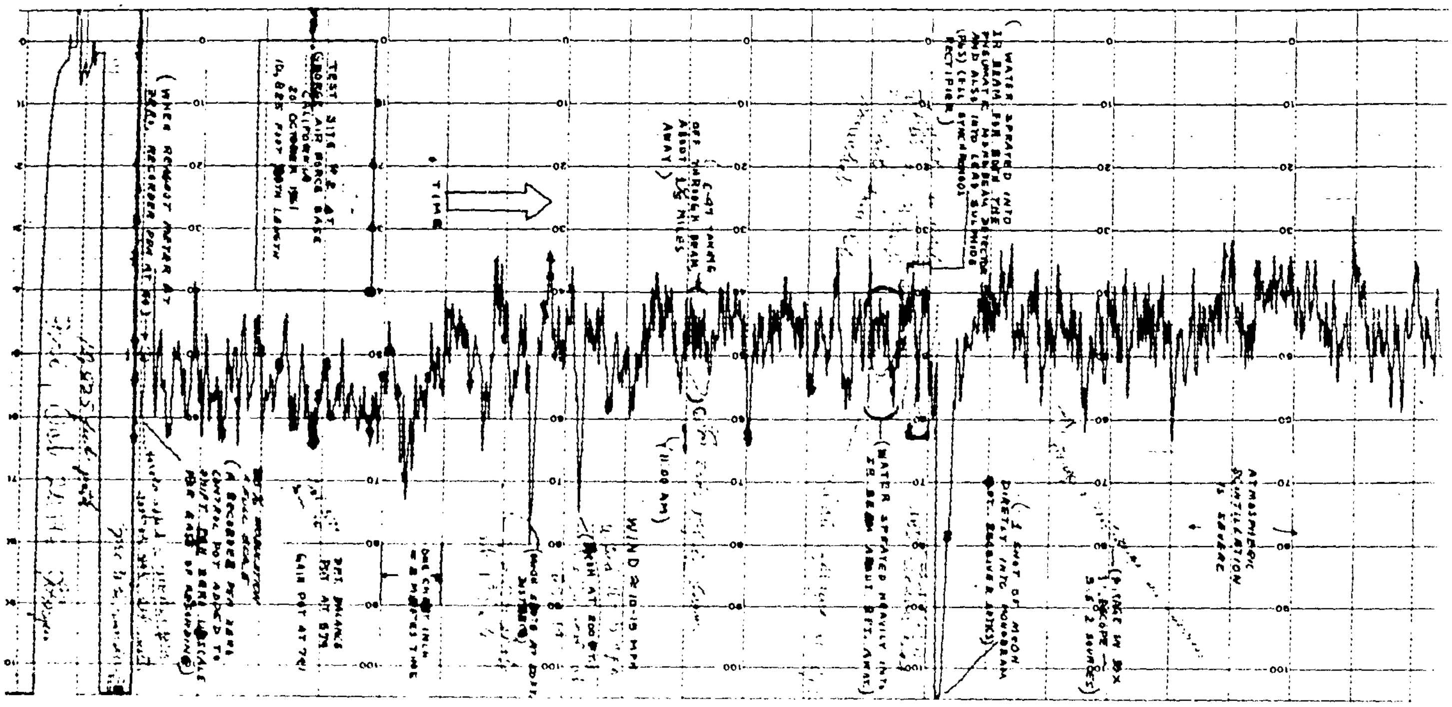
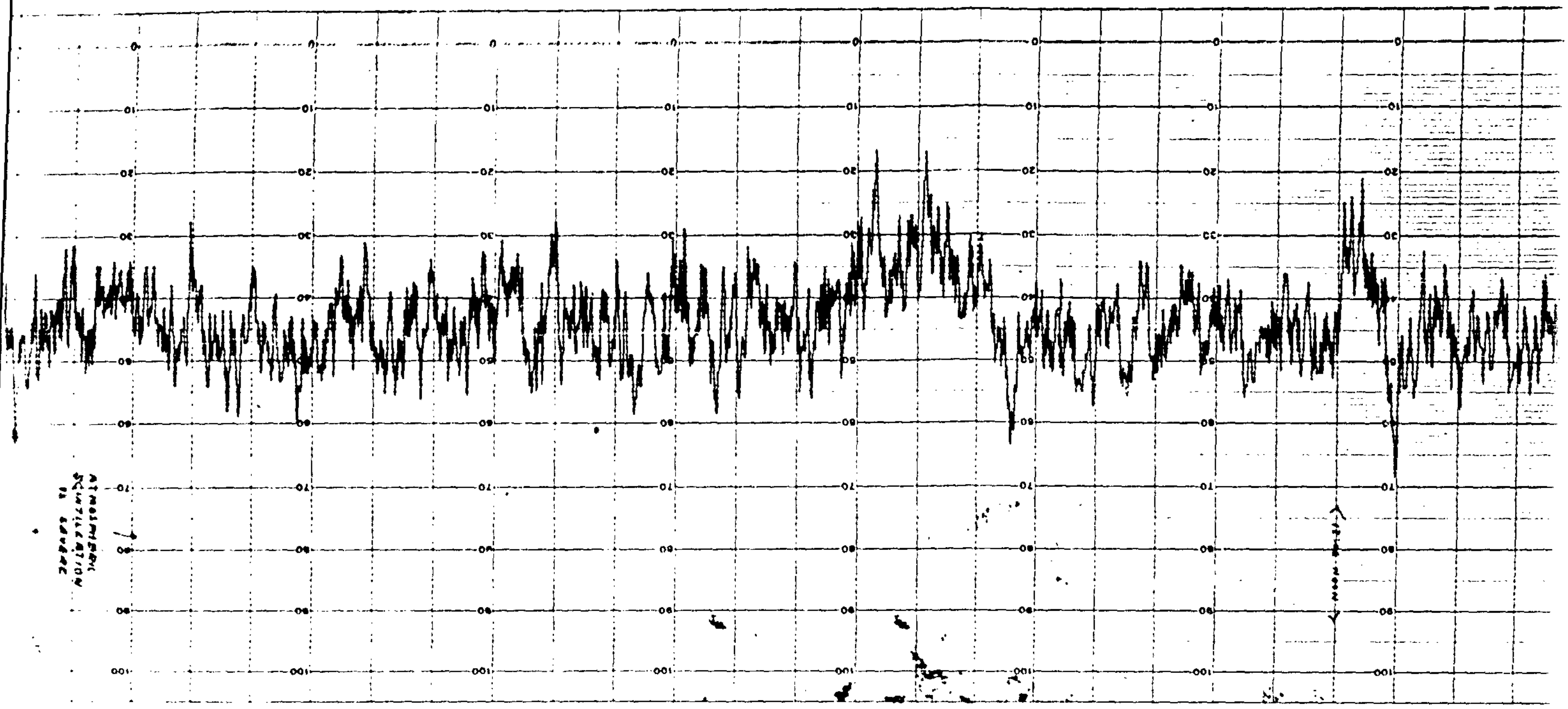


FIGURE 9. RECORD AT TEST #2, GEORGE AFB



2

The Special Projects Division of Beckman Instruments, Inc., is presently engaged in a concentrated detector improvement program. The best NEP value thus far observed is 9×10^{-10} watts, and there is reason to hope that this value may be improved upon.

Summary and Conclusions On The Air Base Tests:

1. The preliminary breadboard monobeam LOPAIR system operated successfully over a 2.05 mile path in the presence of moderately severe atmospheric scintillation. The span was such that 7.5% modulation of sample beam gave a full scale recorder and meter reading. No degradation of response was observed due to scintillation.

2. At no time did system show a "false alarm". This would be true even if span were set such that 5% modulation were full scale or alarm.

3. The monobeam LOPAIR system appears to be unaffected by jet or propeller driven aircraft taxiing, landing, or taking off across the beam path.

4. Signal flare smoke and water sprayed into the beam path had no observable effect.

5. At no time when a recording was in process did the system show any indication of being inoperative. The system always responded to the introduction of calibrate test signals, to methyl alcohol vapor, and to the polystyrene sample.

6. Detectors and circuits can be constructed which will give a ten-fold better performance. Since the noise encountered was system noise, this should result in a 10 fold noise reduction.

IV. COMMENTS ON THE NARROW ABSORPTION INFRARED (NAIR) SYSTEM

The term "NAIR" is taken from the meaning Narrow Absorption Infra-Red, which is descriptive of the pneumatic selective infrared detector.

A study of a particular problem encountered by Wright Air Development Center was made and reported by the Southwest Research Institute*. The problem was the detection of explosive vapors inside operational rocket-powered aircraft. Excellent descriptions of the non-dispersive type instruments are given. A detector similar to the monobeam detector is cited in the Study of Explosive Vapor Detection (page 20). Many other non-dispersive systems are also cited.

Important conclusions of the study were two optimum methods for the detection of encountered vapors; 1) Mass spectroscopy; and, 2) Non-dispersive infrared analyzers.

The monobeam detector is a NAIR-type detector and is an extended path non-dispersive positive type infrared analyzer.

The problem of CW detection and warning is similar to explosive vapor detection in that moderately low concentrations of a gas must be detected---but of course, not within the framework of a rocket aircraft.

A primary problem for the pneumatic selective detector is the obtaining of spectrally suited gas charges. Non-dispersive analyzers of both positive and negative types** are discussed and compared in the Proceedings of the IRE***. The article concludes that non-dispersive infrared analyzers are the superior instruments for continuous chemical process control. CW agent monitoring is a similar process. Beckman Instruments, Inc., alone has sold over one thousand of these analyzers for use in chemical process plants. Often, these analyzers which are encased in sealed housings must

---

* Shaw, T. M.; Truby, F. K.; Wood, W. R.; "Study of Explosive Vapor Detection", WADC Technical Report 56-293, Contract AF 33(616)-2802, Project No. 6075, p. 12-36, Southwest Research Institute, San Antonio, Texas; June, 1956

** Positive type---only the energy absorbed by the gas being detected is measured and reported.

Negative type---detector measures and reports the energy of the beam reduced by an amount equal to the absorption of the gas being detected.

*** Ibid., pages 1633-1635.

operate under very poor environmental conditions such as near vibrating machinery and hot furnaces, under dripping pipes, in noxious chemical atmospheres, or outdoors in extremes of climatic conditions.

A selective pneumatic detector can be used to detect any CW agent detectable by its IR spectrum.

V. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are reached:

1. In the matter of overcoming the adverse effects of scintillation, the simultaneous (non-alternating) viewing system is superior to the alternate viewing system. This is borne out theoretically and from the results of the available, rather limited, experimental data. It is recommended that future systems be of the simultaneous, (non-alternating) view type. As summarized in the George AFB Tests section, the monobeam LOPAIR system (a breadboarded difference signal system) did perform admirably under moderately adverse conditions. This performance is better than any other known system built to date.

2. There are several satisfactory methods of achieving the necessary spectral responses. Each method possesses both advantages and disadvantages. Dispersive systems and filter systems both can be efficient and changeable in the field. The monobeam LOPAIR system offers a degree of changeability, in that it is believed that suitable detector gas-charge combinations can always be found to meet the demands of any gas detection problem which can be analyzed with infrared systems, analysis must be confined to the regions and conditions of atmospheric transmission.

3. Of the LOPAIR systems that have been proposed, the active monobeam system is the most simple and practical which encompasses the essential configurations for a three mile range system. The detector is simple, dependable, and rugged. A sophisticated version of this detector and circuitry has passed U. S. Navy Mil Spec Tests (MIL-T-17113) for shock, vibration, and inclination, and also MIL-I-16910, Tests for Radio Interference, 14K to 1,000 megacycles.

4. The IR sources which appear to be most suitable to LOPAIR systems are in essence the old stand-bys of IR spectrophotometry---the silicon carbide Globar, Nernst glower, and heated metal filaments or ribbons. The gas mantle is feasible as far as energy output is concerned, but introduces fragility, pressure regulation, starting, and gas supply problems. An item worthy of mention is the size of the IR source. The desirability of using a small size and low power consuming IR source must be balanced against the possible tightening of tolerances on the transmitting optics for surface accuracy, aberrations, temperature coefficients, alignment and maintenance of alignment, precision of replacement, and the effects of shock and vibration. If these requirements are not too stringent, then the concentrated arc is a fifth IR source possibility.

5. Although all of the monobeam LOPAIR tests were performed using a difference of signals system, there is a distinct advantage in using a ratio of signals system. The ratio system offers a constant span; i.e., if the system is set up such that a 5% modulation (5% absorption of the λ_s signal) is to cause an agent alarm, this alarm point remains the same so long as there is sufficient loop gain in the reference detector channel. As the signal strength of both λ_s and λ_r decreases, such as flat losses caused by atmospheric attenuation (fog, snow, etc.), a point will be reached where there is insufficient λ_r signal feed back and the system will become sluggish in response and finally inoperative. Even while the system is sluggish, the alarm point remains at a 5% modulation value. It is estimated that a ratio system should remain operative when the original reference signal has been reduced by a factor of between 4 and 8 times.

The difference system will change the agent alarm point in an inverse proportion to the loss of reference signal. For example, if a difference system is set up for a 5% modulation alarm point, and the signal strengths of both λ_s and λ_r are decreased by one-half, then a 10% modulation is required to cause an agent alarm. Thus, the CW agent concentration must be about 2 times greater to cause an alarm for the original 5% set up conditions.

Therefore, in order to maintain a constant agent alarm point, some form of a ratio system appears to be superior.

The following recommendations are given:

1. The existing equipment should be used for more extensive tests. The test trials should be conducted under the surveillance and guidance of the Army Chemical Corps and Air Force officials concerned. The tests should be done over a 3 mile path, in the presence of severe scintillation and other atmospheric disturbances which can degrade performance. Actual nerve agents should be used in the trials.

2. Simultaneously with the above tests, production designs should be arrived at and formalized. This would be culminated in a finished prototype which would be suitable for production and would meet military specifications' requirements*.

3. Concurrently with the above programs, a threefold study-monitor-develop program should be run. This would consist of the following:

---

* See Appendix for calculation of necessary optics, and proposed electronics.

a. Development of detectors to an ultimate in detectivity.

b. Develop optical projection systems to an optimum for given situations and placements.

c. Examine the infrared spectra of possible CW agents and determine charging gases to solve the problems.

d. Develop better sources of infrared radiant energy with the purpose of obtaining preferential 10 micron region emitters, electronic chopping, increased efficiency at lower input power, invisible emitters to eliminate IR source filters.

e. Monitor the state-of-the-art of infrared maser development. Approximately 1 to 10 microwatts of radiant power in each wavelength region used is required by the detector. Maser action in the 10 μ region is feasible and could offer considerable size and weight reduction of optics.

VI. TEST PROCEDURE PROGRAM

A. Since one of the major problems is scintillation, the test program should first of all cover this area thoroughly.

1. It is desirable that natural scintillation be synthesized so that systems can be tested in the laboratory or in the production line.

2. If synthetic scintillation is not practical or available, systems should be tested under severe natural scintillation such as would be found in desert areas.

B. Several LOPAIR units should be built and the following performed:

1. Test for the nerve agents of interest.

2. Record outputs under all test conditions.

3. Record atmospheric conditions as measured by a transmissometer.

4. Test at different locations which are representative of the proposed useage---such as high and low altitude deserts, sea coast, mountain, arctic areas, industrial air pollution areas, jungle and high humidity areas, etc., under varied weather conditions (rain, fog, etc.).

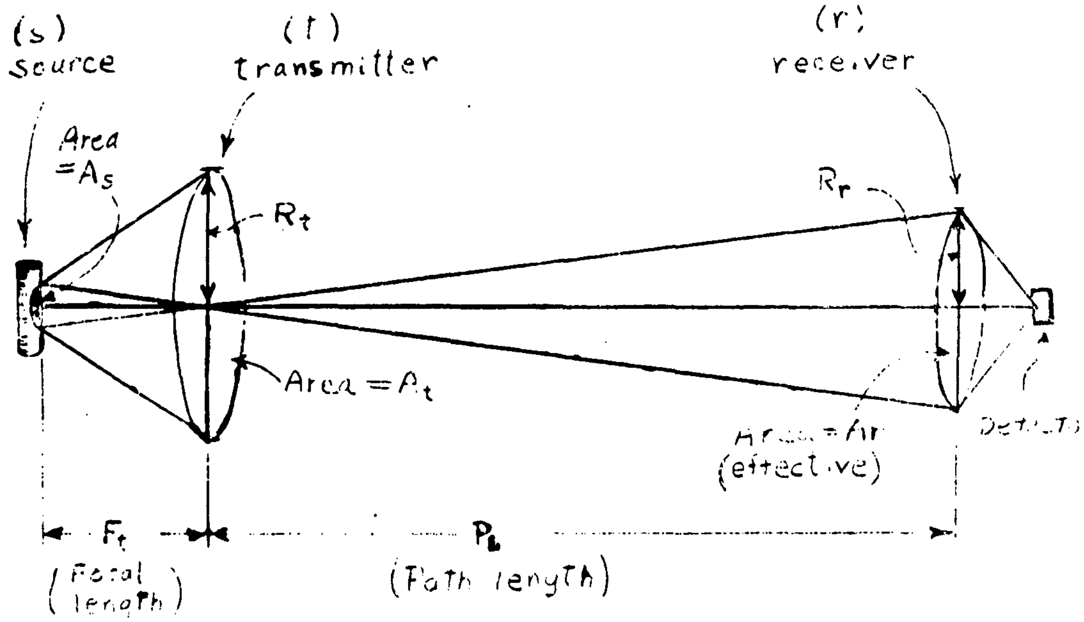
5. Test under the worst conditions in which the equipment is still expected to function---such as at high noise level of jet or rocket exhaust; explosions; distant nuclear blasts; sonic booms; and lightning flash, incendiary bombs, aerial photograph flares, and signal flares in the optical path. For some of these tests, the actual or natural conditions may not be obtainable. In such case, the condition should be synthesized, or the effects calculated using the latest and best information obtainable.

APPENDIX I

CALCULATION OF OPTICS

The requirements for the diameters and focal length of the transmitting optics, and the diameter of the receiver primary are based on these calculations.

The "effective emitting area" (A_e) gives a measure of the power into the detector. This is calculated for the tests at George AFB at 10,825 ft. (2.05 miles) and then used to extrapolate for a value at 15,840 ft. (3.00 miles).



The direct area (A_s) is the conjugate projection of the receiver aperture (A_r) onto the source.

$$\frac{R_s}{R_r} = \frac{F_t}{P_L}, \qquad R_s = \frac{F_t}{P_L} R_r \tag{1}$$

$$A_s = \pi R_s^2, \tag{2}$$

$$A_s = \pi \left(\frac{F_t R_r}{P_L} \right)^2 \tag{3}$$

Assuming hemispherical radiation by the source, the portion of this hemisphere which is intercepted by the transmitter optics is E_c:

$$\text{Portion collected} = E_c = \frac{\text{Area intercepted by mirror}}{\text{Area of hemisphere of radiation}}$$

The radiant power P to the detector is $P = \epsilon W_\lambda E_c A_s$

where W = spectral radiant emittance with units of watts/cm^2/hemisphere/$\Delta\lambda$,u

ϵ = emissivity of Globar (ϵ = .8)

The following have not been taken into account, but do not need to be at this time. They would remain constant for any given set of conditions and definitely would have to be accounted for if an exact value for P to the detector were sought:

1. Filter transmittance (filter on source to eliminate visible radiation).

2. Losses due to form of chopping of source (if square wave chopping, ÷ 2).

3. Transmittance of the atmospheric path in the wavelength regions of interest.

4. The reflectances of all optical mirror surfaces, or the Fresnel reflective loss at lens surfaces.

5. Losses due to imperfect optics or the encountered aberrations.

6. Losses due to any protective covers over transmitter or receiver optics.

7. Losses due to any nontoxic gases or vapors encountered and which cannot be considered "normally atmospheric".

8. Losses at detector windows, lenses, mirrors, filters, or dispersive systems.

The "effective emitting area" (A_e) of the source is the product of the energy collected (E_c) and the direct area (A_s) used of the source.

$$A_e = \frac{P}{\epsilon W_\lambda} = E_c A_s \qquad (4)$$

Converting all measurements to centimeters:

P_L	=	10,825 ft.	=	3.30×10^5 cm
F_t	=	25.56 inches	=	64.9 cm
R_r	=	0.968 ft.	=	29.5 cm
R_t	=	2.50 ft.	=	76.2 cm

Acceptance angle of transmitter = 120° cone from source.

$$E_c = .500 \qquad A_s = 10.6 \times 10^{-5}\ \text{cm}^2$$

$$\boxed{E_e = E_c A_s = 5.30 \times 10^{-5}\ \text{cm}^2} \tag{5}$$

For the system used at George AFB, the effective emitting area was 5.30×10^{-5} cm^2.

To calculate a new system, consider using f/1.0 optics where the diameter = focal length, $F_t = D_t = 2R_t$ for transmitter. Also, let transmitter = receiver in size.

$$\text{For f/1.0, } E_c = .117 \text{ and } F_t = 2\,R_t = 2\,R_r = X \tag{6}$$

The addition of a filter over the source to eliminate the visible light (90% T), and 2 polyethylene covers (one over each optic) for weather protection (83% T each, $.83^2 = 69\%$ T), gives a total of $.69 \times .90 = .62$ or 1.61 times <u>less</u> energy than at George AFB tests.

With the improved detectors which have been realized, it is calculated that about 1/5 the energy of the George AFB tests will be sufficient. This effectively gives a factor of 5 times <u>more</u> energy. This conclusion is reached as follows: The detector and electrometer circuit of the George AFB tests had an NEP of 5×10^{-8} watts. The newer detector and circuitry gives NEP = 3.5×10^{-9} watts. This is a factor of 15 improvement of S/N which is realized. In the George AFB tests, the noise was about 40% of full scale with 7.5% modulation › full scale. The noise is therefore equivalent to 3% modulation. If the span had been set such that 5% modulation = full scale, the noise would still be equivalent to 3.0% modulation. In order to operate successfully, as optical surfaces deteriorate, and in the presence of poor atmospheric transmission, it is desirable to operate with a noise which is not more than one-fifth of full scale modulation (5% modulation = full scale = alarm condition) which will be 1.0% noise. The desired improvement is then 3.0/1.0 = 3 times. The improvement already realized is 15 times. 15/3 = 5.

With the subscript (1) used for 10,825 ft. and subscript (2) for 15,840 ft., the optics for 3 miles are calculated as follows:

$$E_{c1}\,A_{s1} = \frac{E_{c2}(5)}{(1.61)}\,A_{s2} = 5.30 \times 10^{-5}\ \text{cm}^2 \qquad (7)$$

$$\text{but } A_{s2} = \pi\left(\frac{F_{t2}R_{r2}}{P_{L2}}\right)^2 \quad \text{and } X = F_{t2} = 2R_{r2} \qquad (8)$$

[from (3) and (6)]

$$= \pi\left(\frac{XX}{2P_{L2}}\right)^2 = \frac{\pi}{4P_{L2}^2}\,(X)^4 \qquad (9)$$

$$X^4 = \frac{4\,P_{L2}^2}{\pi}\;\frac{(1.61)}{(5)}\;\frac{(E_{c1}\,A_{s1})}{(E_{c2})}$$

[from (7) and (9)]

$$X^4 = \frac{4\,(4.83 \times 10^5)^2}{\pi} \cdot \frac{(1.61)}{(5)} \cdot \frac{(5.30 \times 10^{-5})}{.117}$$

$$X^4 = 4.33 \times 10^7\ \text{cm}^4$$

$$X = 81.1\ \text{cm} = F_t = 2R_{r2} = 2\,R_{t2}$$

$$81.1\ \text{cm} = 2.66\ \text{feet} = 31.9\ \text{inches}$$

Any improvement in detectivity will permit reduction of optics sizes. An improvement of at least 30% is expected, and the odd size of 31.9 inches may be reduced to a more workable even number of 30.0 inches.

Therefore, the following minimum size optics are recommended for a 3 mile system:

Transmitter:

f/1.0, 2.50 ft. diam., 2.50 ft. focal length.

Receiver:

2.50 ft. diam., may choose f/no. = f/1.0 and focal length = 2.50 ft.

APPENDIX II

PROPOSED LOPAIR DETECTION SYSTEM

The LOPAIR detection system is shown in Fig. 10. It consists of a modulated infrared source and a monobeam selective detector receiver separated by a 3 mile open path. In addition, there is associated electronic apparatus and alarm indications. The system can be operated as a difference system or ratio system as will be explained below.

The source consists of a continuously heated element modulated by a rotating chopper. The chopping frequency is nominally 5 cycles per second. The modulated infrared energy from the source is reflected from the source mirror into a beam focussed upon the receiver mirror. At the receiver the energy is directed into the monobeam selective detector. In addition, some of the received energy is focussed onto a lead sulfide cell developing an electrical signal which is amplified and used as a synchronizing signal for the synchronous detectors in the electronic portion of the system.

The monobeam selective detector consists of two sections separated by an infrared transparent window. In each section is a flexible diaphragm forming the plate of a capacitor. As IR energy enters the detector, it passes through gas with which the first cell is charged and then through gas with which the second cell is charged. Energy is absorbed in each section of the detector only in the spectral region characteristic of the gas charges. By choosing appropriate gases, the detector can be made selective to the desired infrared spectral regions. Typically, the first section is charged to give energy absorption in the spectral region of interest and the second section is charged to give energy absorption in the spectral regions used as a reference. As the energy is absorbed, it causes a volume change to take place moving the capacitor diaphragms to create an electrical signal in response to the diaphragm motion. The polarity of the bias is such that the signals produced from each section of the detector are in opposition. With no gas present in the open path, the system is adjusted to produce a minimum output from the detector and a zero output from the synchronous detector. When a gas is present in the open path between the source and receiver that absorbs energy in the proper spectral regions an electrical signal is produced by the resulting detector unbalance. This signal is amplified and detected by the synchronous detector and used to operate a gas alarm or other gas level indicators. By feeding back the output of the synchronous detector to the cell bias circuitry, the voltage at the output of the synchronous detector becomes proportional to the fractional changes in the diaphragm capacitance in the monobeam selective detector. Therefore, the system becomes a ratio detection system.

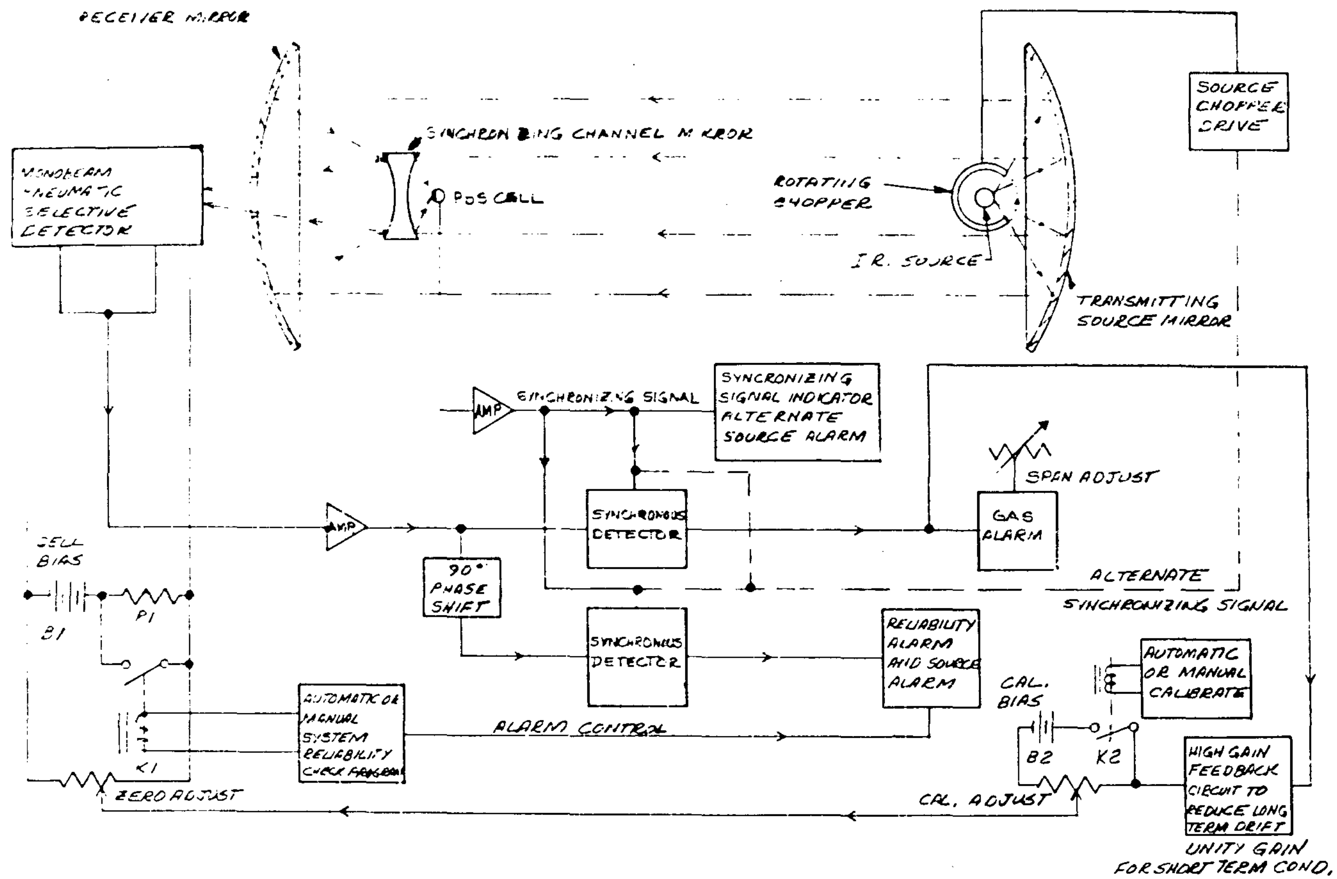


FIGURE 10. LOPAIR DETECTION SYSTEM

By opening this feedback loop and grounding the zero adjust potentiometer variable arm, the system becomes a simple difference system.

Since under balance conditions the monobeam detector output is not entirely zero but consists of a small, what might be termed "quadrature component", it is possible to detect the amplitude of this quadrature component and use it as a system reliability alarm and a source alarm. This is accomplished by a 90° phase shift circuit at the output of the amplifier and another synchronous detector. The reason this is possible is that the quadrature signal from the detector has an amplitude which is directly proportional to the incoming source energy. It is possible for the quadrature component to vary in amplitude from one detector to another but the same alarm points can be achieved by adjusting the sensitivity of the alarm circuitry. It is also possible to check the system reliability by varying the cell bias to the detector in such a manner that the bias to each cell is reduced by the same fractional amount. This is accomplished by relay K-1 and resistor R-1. Normally K-1 is closed, shorting out R-1. If K-1 is open, there will be a voltage drop across R-1 due to the current flowing from the cell bias battery B-1 through R-1 and the zero adjust potentiometer. R-1 can be adjusted to produce one-half the cell bias available before. Thus, in observing the output of the 90° phase shift synchronous detector, one would observe the output to drop by one-half. The failure of the output to respond in this manner, or to respond at all, indicates a system malfunction. The cell bias can be altered automatically on a regular schedule or can be done manually. Under balance conditions of the detector, with no gas present in the open path, the normal synchronous detector output does not change, but continues to read zero. Thus, the system reliability can be checked without disturbing the major gas alarm portion of the system.

The system is capable of being electrically calibrated to a known percent modulation by means of the calibrate bias battery B-2, the relay K-2 and the calibrate adjust potentiometer. From a zero output indication to the gas alarm circuitry condition, relay K-2 is closed, producing a voltage in series with the zero adjust potentiometer of such a magnitude to produce the desired percent modulation. Calibration can either be performed automatically or manually.

In order to overcome long term drifts in the electrical and electronic circuitry and long term temperature effects of the detector itself, a high gain feedback circuit is incorporated in the feedback loop. This circuit produces a high DC gain to very slow variations in the output of the synchronous detector driving the gas alarm circuitry. The time constant of this feedback circuit, is in the order of 8 to 24 hours. Therefore, under normal operation, this high gain feedback circuit offers unity gain, allowing the system to perform properly as a detection system. However, for the 8 to 24 hours drifts that could possibly take place, the high gain feedback reduces the effect of these variations by the amount of loop gain. Consequently, what normally might cause the system to drift full scale in 24 hours can be reduced by factors of 20 to 100, as an example. This means temperature control on the monobeam selective detector is unnecessary.

An alternate means of supplying the synchronizing signal for the synchronous detectors is shown by the dash line connected to the source chopper drive. This could be accomplished by a pair of wires between the source location and the receiver location.

Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-61-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. illus.

Unclassified report

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of the chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

ed. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED

Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-61-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. illus.

Unclassified report

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of the chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

ed. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED

Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-61-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. illus.

Unclassified report

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of the chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

ed. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED

Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. Rpt. No. ASD-TR-61-710. CHEMICAL WARFARE DETECTION AND WARNING SYSTEM. Final Rpt, March 1962, 43p incl. illus.

Unclassified report

The basic requirements of Long Path Infrared (LOPAIR) systems for detecting and warning of the presence of the chemical warfare (CW) agents are discussed. Several varieties of active LOPAIR systems together with their advantages and disadvantages are reviewed. A simplified version of a non-dispersive infrared analyzer which employs a monobeam pneumatic selective detector is described and compar-

(over)

UNCLASSIFIED

1. Systems, infrared
I. AFSC Project 6338
II. Contract AF 33 (616)-8380
III. Beckman Instruments, Incorporated
IV. James G. Myers
V. Not avail. fr. OTS
VI. In ASTIA collection

UNCLASSIFIED

ed. The results of some successful preliminary tests performed at George Air Force Base, California, are presented and discussed. The tests which were over ranges of 4,350 feet and 10,825 feet (0.824 and 2.05 statute miles) were made in the presence of atmospheric scintillation and through the exhaust trails of various aircraft. Successful operation through scintillation is essential to LOPAIR systems. Previous tests on other LOPAIR systems showed them to be adversely affected by scintillation. Conclusions on the use of Narrow Absorption Infrared (NAIR) systems are given. Recommendations and conclusions, and possible test procedures for an active LOPAIR system of the monobeam NAIR type are given.

UNCLASSIFIED

UNCLASSIFIED