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RESULTS OF A TROPICAL TEST OF A SHORE BASED MID RANGE INFRARED CAMERA

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U.S. COAST GUARD RESEARCH AND DEVELOPMENT CENTER
AVERY POINT, GROTON, CONNECTICUT 06340-6096

FINAL REPORT
MAY 1988

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16. Abstract

A forward looking infrared device (FLIR) operating at 3.5-5 microns was tested for comparison against a previously tested FLIR operating at 9-12 microns. Results from both tests are used to compare operating ranges of the devices in the tropics. Theory suggests an increased detection and recognition range should be possible by using the mid infrared region.

A low infrared profile, 110' Coast Guard patrol boat, served as a target for the mid infrared tests. Tests were conducted off the northern coast of San Juan, Puerto Rico, with temperature and relative humidity conditions similar to those experienced during earlier tests of the far infrared camera.

The target vessel was consistently detectable at a range of 7 nmi and sometimes detectable at a range of greater than 10 nmi. Previous similar tests with the far infrared camera found typical detection ranges were less than 5 nmi even with large vessels.

The low profile target vessel was recognizable (classifiable) at a range of 3 nmi. Similar recognition tests with the far infrared camera found typical recognition ranges from 1 nmi with small vessels to a maximum of 3 nmi for large vessels.

The mid infrared camera outperforms the far infrared cameras in tropical conditions.

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tropical	vessel recognition	

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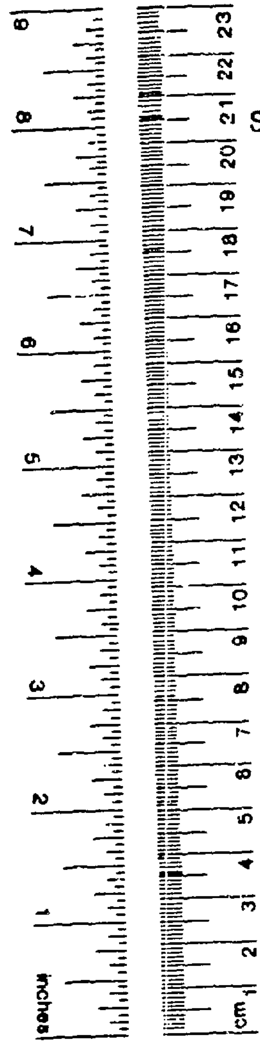
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

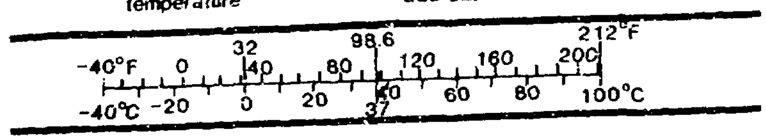
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (WEIGHT)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (EXACT)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25. SD Catalog No. C13.10:286



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (WEIGHT)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (EXACT)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 INTRODUCTION

The topic of infrared radiation has been studied extensively in the recent past, especially by the military. This type of radiation is emitted by any warm object and is an outstanding source of energy for a detection system. The advantages of using infrared radiation are that the infrared system is a passive system, unlike radar, and also produces a picture which can be used to identify the target. This category of electromagnetic radiation extends from a wavelength of .77 microns out to 1000 microns and has been further subdivided into four classes: near-IR (.77 microns to 1.5 microns), mid-IR (1.5 microns to 6 microns), far-IR (6 microns to 40 microns), and the extreme-IR (40 microns out to 1000 microns). The problem experienced in trying to use the IR energy is that the atmosphere absorbs and/or scatters much of the emitted energy. Atmospheric molecules have resonances which absorb much of the incident energy if it is the correct wavelength. Certain electromagnetic wavelength bands do exist which do not correspond to any molecular absorption in the atmosphere. Radiation within these bands can be transmitted through the atmosphere a long distance before being dissipated. The bands are called windows and the quality of the window is directly dependent upon the local atmospheric conditions at the time of transmission. Figure 1 illustrates the transmission of IR radiation. The two most useful windows are easily seen at wavelengths of 3-5 microns and 8-12 microns. However, Figure 1 is for ideal conditions and a 2 km path at sea level and cannot be used for all conditions and locations. The humidity, wind velocity, sea spray, dust, any other pollutant, and increases in range reduce the transmission coefficient of the infrared radiation.

Recent experiments conducted by the Coast Guard Research & Development Center in the far-IR window of 8 to 12 microns have shown that, in the tropics, the humidity and atmospheric particulates severely degrade the IR signal. A Texas Instruments Model AN/KAS-1 CWDD (Chemical Warfare Detection Device) with a recognition range of 13 nmi for large tankers in the northern latitudes was found to have a recognition range of about 3 nmi in the Gulf of Mexico and the Caribbean Sea. Such levels of performance are inadequate and avenues of improvement were sought.

Initially, the possibility of improving image contrast by the use of IR filters was considered for the 8 to 12 micron device. After various computer calculations, it was realized that adequate improvement could not come from filters but could come from a change from far-IR radiation to mid-IR radiation. A completely different detector technology was now required to make

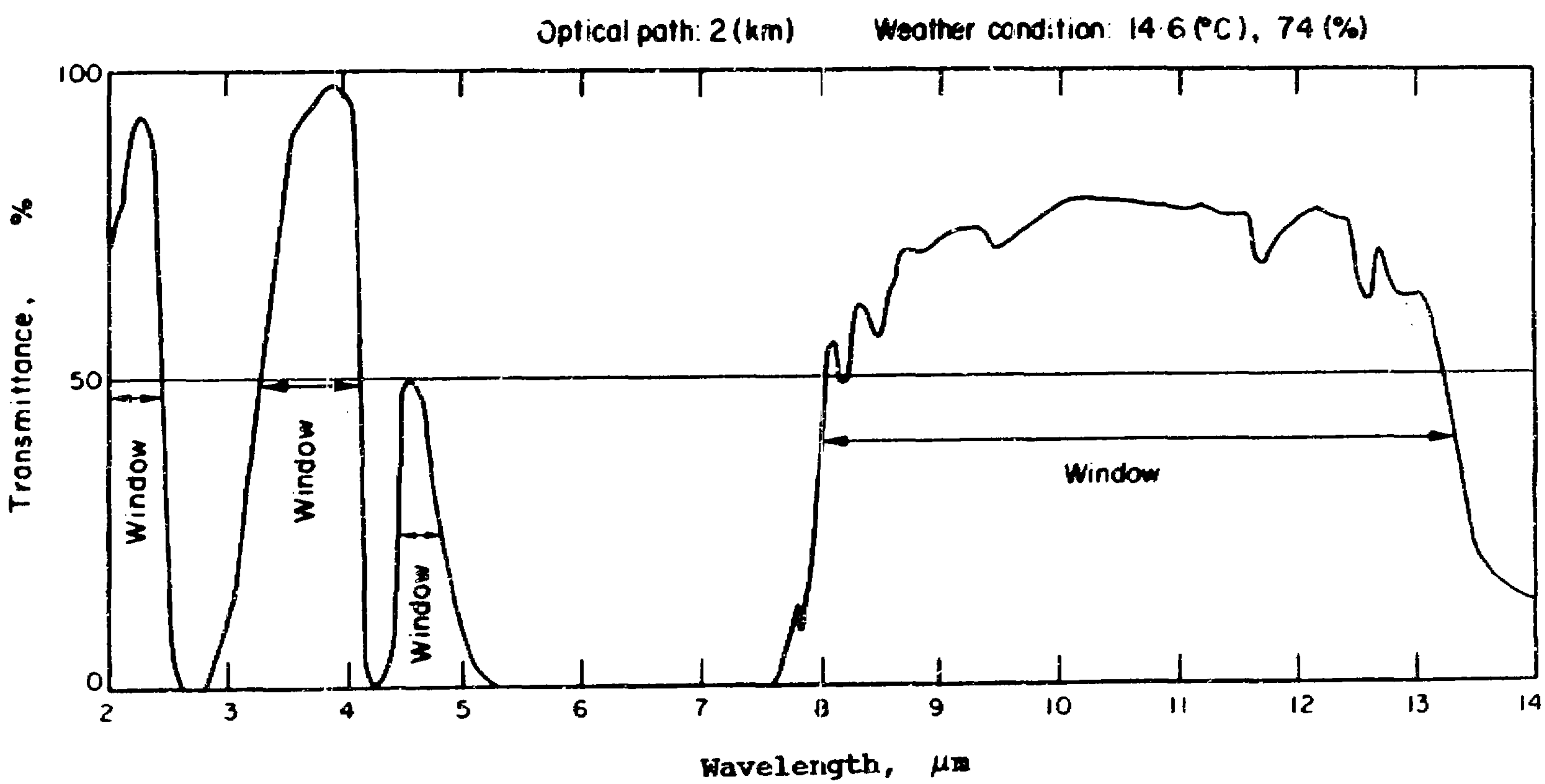


Figure 1. Illustrative IR Transmission Windows for a 2km Path at Sea Level.
Source: Reference 1

use of the mid-IR band of energy. The required equipment and expertise were found at Rome Air Defense Center / Electronic System Evaluations (Hereafter referred to as RADC/ESE) of Hanscom Air Force Base in Lexington, Massachusetts. Their services were contracted for and a trial of their equipment was arranged in San Juan, Puerto Rico. Puerto Rico was chosen because our interests were in the ability of this instrument to perform in a tropical climate, the worst environment for the previously tested, far-IR, FLIR (an acronym for Forward Looking Infrared imaging apparatus).

2.0 BACKGROUND

The Coast Guard has compiled a set of operational requirements for electo-optical sensors for high and medium endurance cutters. These requirements call for a night detection range of 10 nmi and the identification of deck objects at 5 nmi. A recently released Coast Guard Research and Development Center report titled "Results of FY87 tests of Shipboard Electro-Optical Apparatus" [Ref. 2], details the operational evaluation of a common module FLIR. The FLIR tested was a Texas Instruments Model AN/KAS-1 CWDD (Chemical Warfare Detection Device) which operated in the far-IR at 8 to 12 microns. In northern latitudes, the performance was adequate with a large vessel recognition range as high as 13 nmi. However, the warmer, more humid climate of the tropics caused severe degradation of the FLIR performance as explained in the following excerpt of Reference 2.

Section VII. USER'S CRITICISMS - USCGC DECISIVE

> "Only on very few occasions were any vessels visible through the FLIR at a range of over three miles. Between the latitudes of 15 and 12 degrees north, we were not generally able to detect contacts farther than one mile. Outside Tampa Bay, the first ship observed was a 600 ft cruise liner. Not until a range of approximately two miles was the ship identified by type with the FLIR." [Ref. 2, p. 38]

The source of the excerpt above was the After Action Report filed by the USCGC DECISIVE. The complete text of the After Action Report is included in this report as Appendix A.

Such a system clearly does not meet any of the operational requirements as set forth by the Coast Guard. Alternative solutions to this problem were sought. Initially, the possibility of improved performance by the use of filters was considered for the FLIR. To test out this option, the LOWTRAN computer simulation routine was employed. The LOWTRAN computer routine models atmospheric transmissions on the basis of location of interest and user input variations to the atmospheric conditions. As a foundation, the transmission factors for much of the IR spectrum in the tropics were computed and the lack of far-IR transmission was validated. Unexpectedly, it was found that mid-IR radiation was more readily transmitted through the tropical climate. This is shown by Figures 2 and 3. Further computations in all climates have shown that mid-IR transmission factors are nearly equal or superior to far-IR factors [Figs. 4 through 7]. This new information generated interest in the mid-IR FLIR as the best possible solution. Filtering was dismissed as an option because the achievable contrast was found to be inferior to that obtainable in the mid-IR band.

It was now necessary to find and test a mid-IR FLIR. RADC/ESE out of Hanscom Air Force Base in Massachusetts was found to be conducting research in the mid-IR spectrum. A contract was let for RADC/ESE to conduct a two day test of their mid-IR camera in a tropical climate. A land based test of the equipment was conducted on February 24-25 1988 in San Juan, Puerto Rico. The target for the tests was a U.S. Coast Guard 110' patrol boat, the USCGC OCRACOKE (WPB 1307).

3.0 EXPERIMENT

3.1 HARDWARE

The infrared device used for this experiment was designed and built by the contractor, RADC/ESE of Hanscom Air Force Base, Massachusetts. The detector employed was manufactured by RCA. It consisted of a 160 x 244 array of individual detectors. This apparatus, which employs staring array technology, looks sequentially at the IR signals on each detector element in the the detector array and uses this information to generate the raster scan used in TV imaging. This particular detector assembly was cryogenically cooled with liquid nitrogen, but an electric refrigeration unit is available. A 300mm, telephoto, infrared lens which focused the thermal image on the detector assembly comprised the optics of this system (see Figure 8).

Table I lists the various characteristics associated with this infrared system.

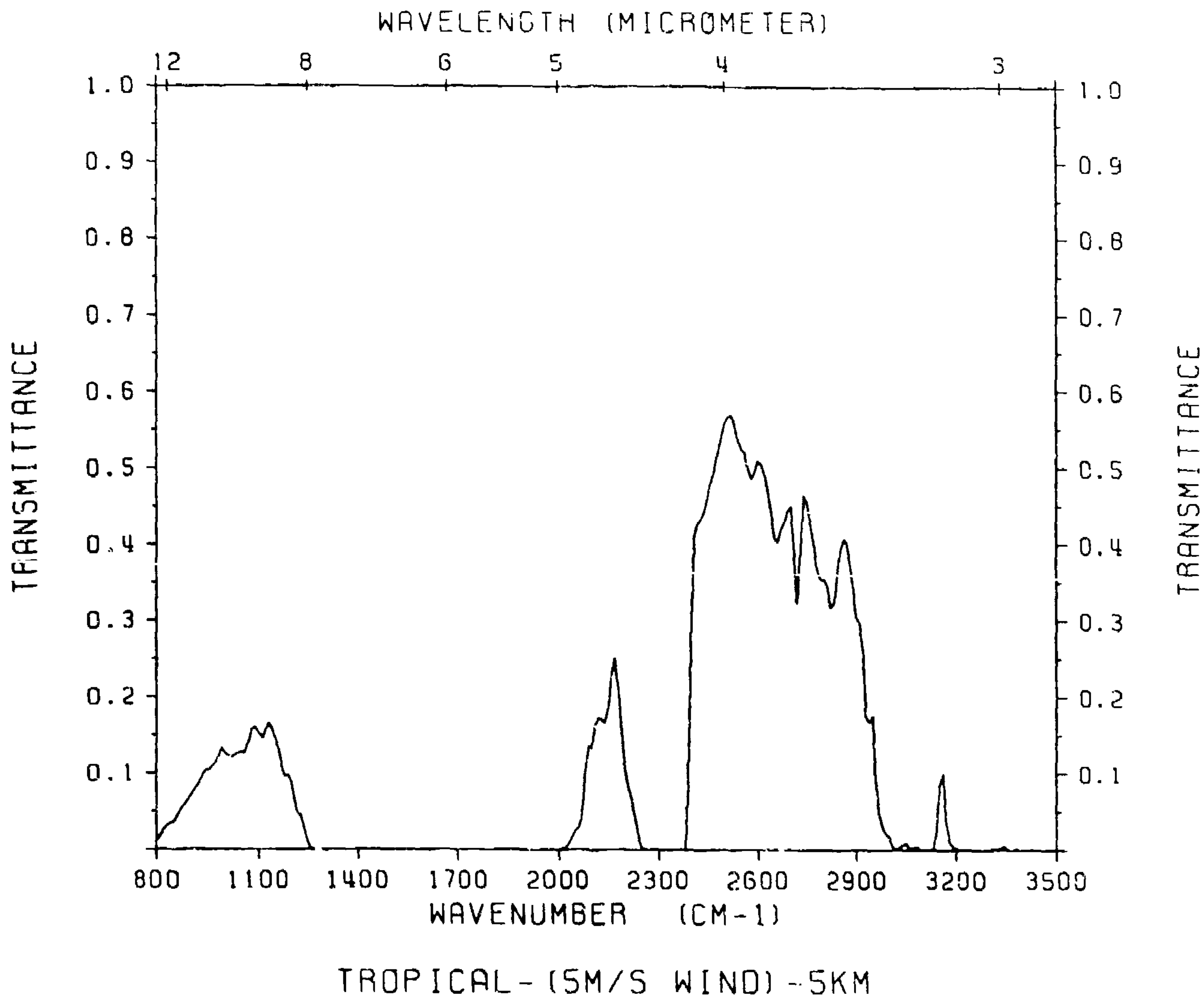


Figure 2. LOWTRAN Transmission Windows for a 5km Path in a Tropical Climate with a 5 m/s Wind.

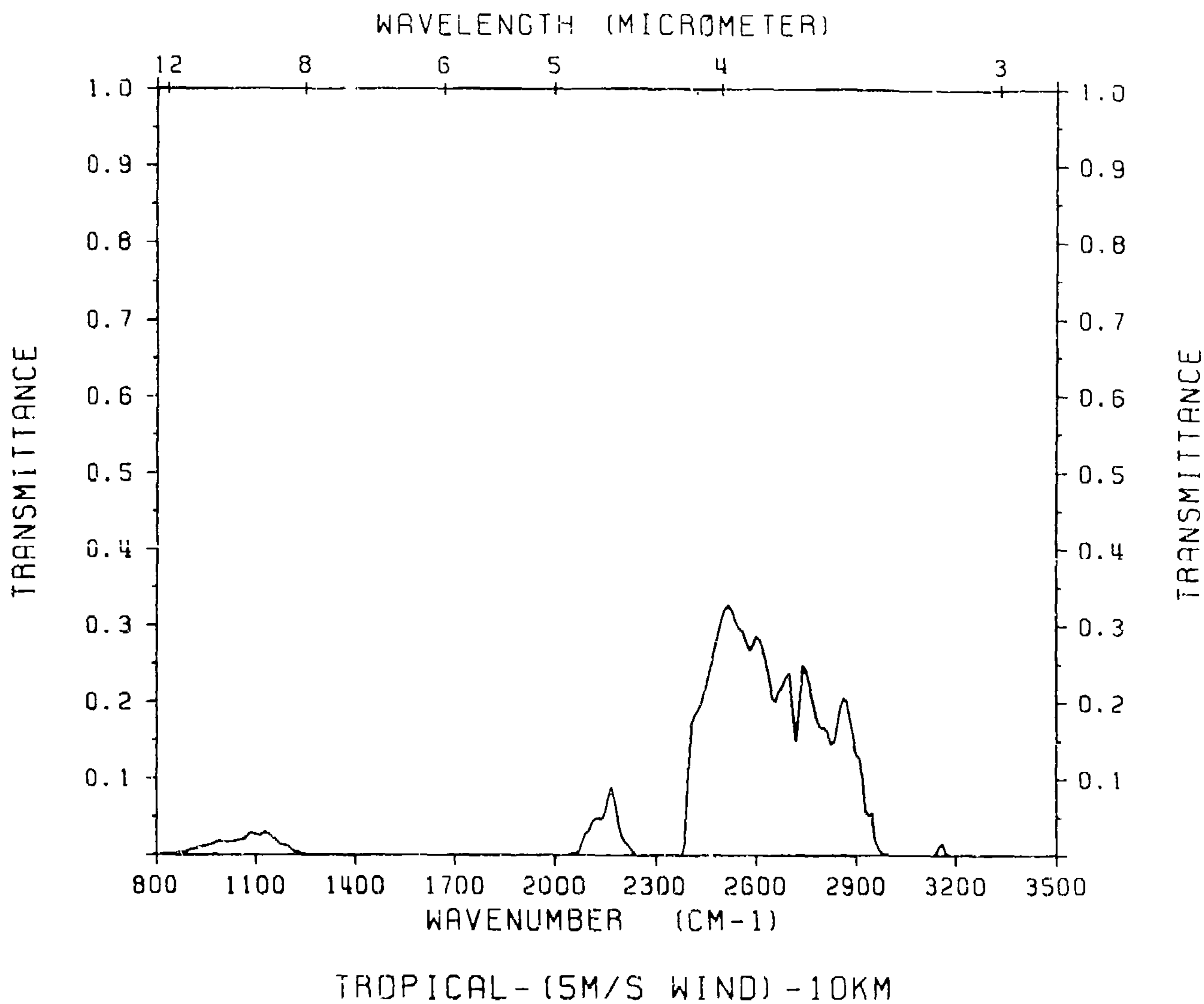


Figure 3. LOWTRAN Transmission Windows for a 10km Path in a Tropical Climate with a 5 m/s Wind.

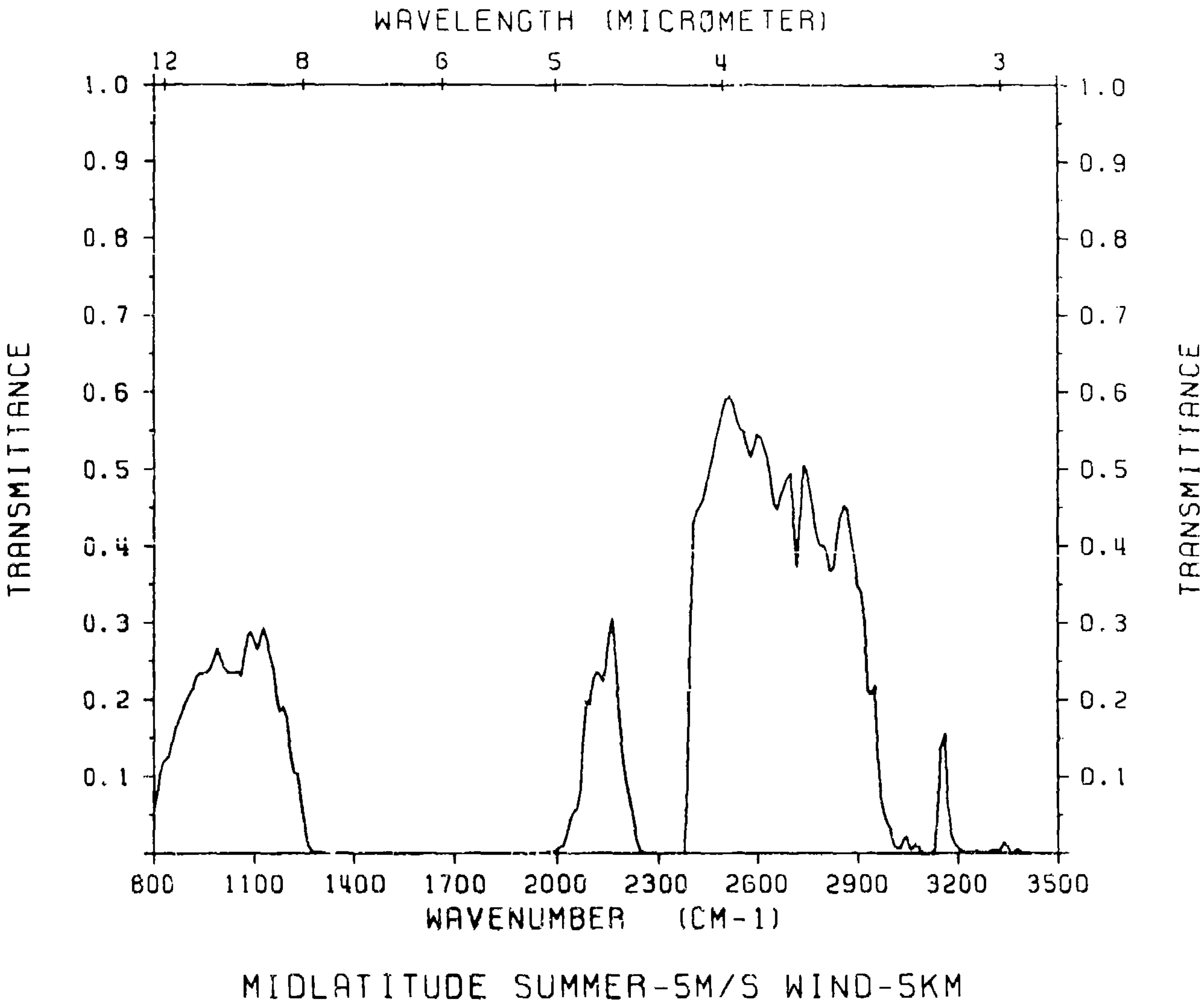


Figure 4. **LOWTRAN Transmission Windows for a 5km Path in a Midlatitude Summer Climate with a 5 m/s Wind.**

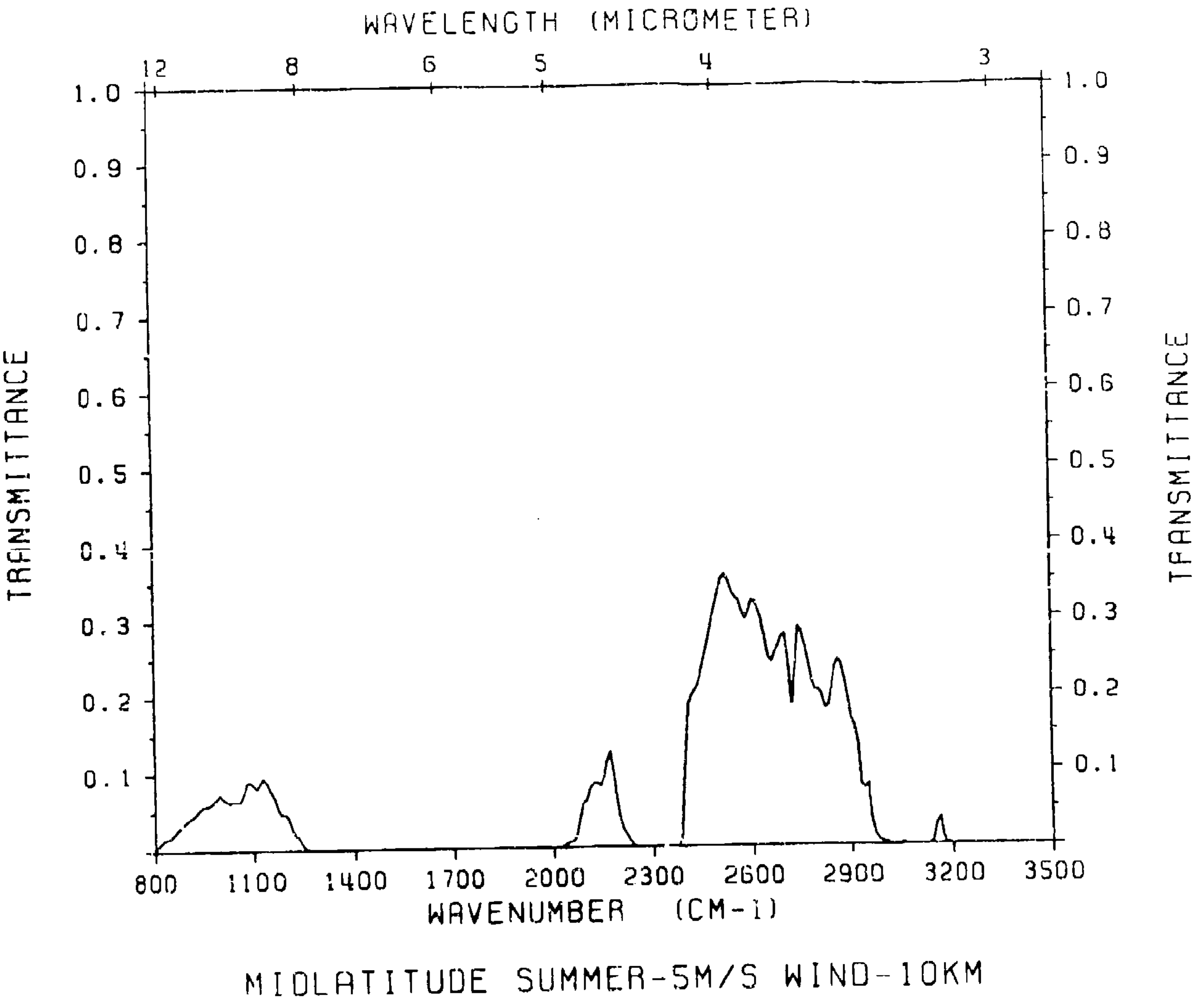


Figure 5. **LOWTRAN Transmission Windows for a 10km Path in a Midlatitude Summer Climate with a 5 m/s Wind.**

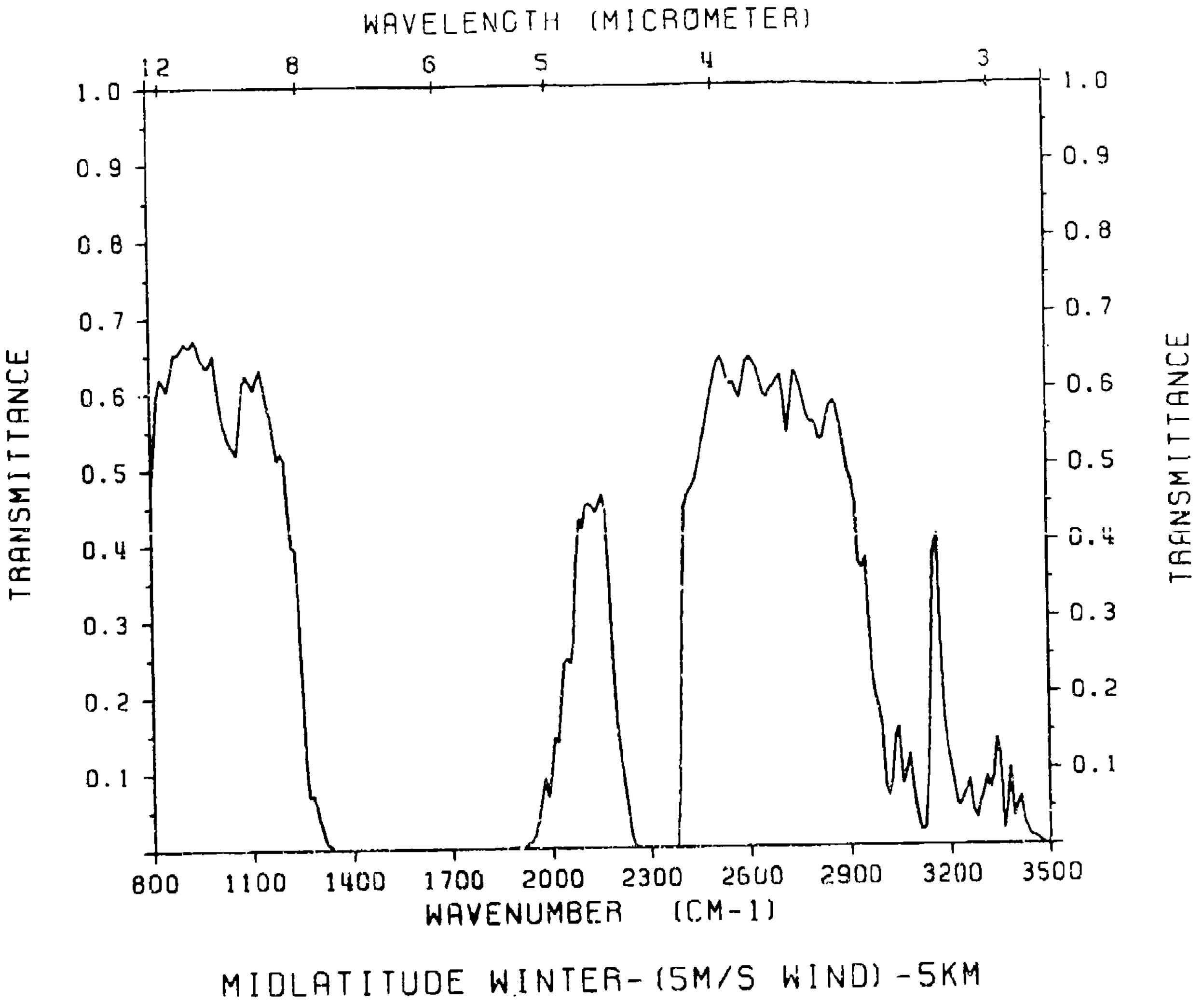


Figure 6. LOWTRAN Transmission Windows for a 5km Path in a Midlatitude Winter Climate with a 5 m/s Wind.

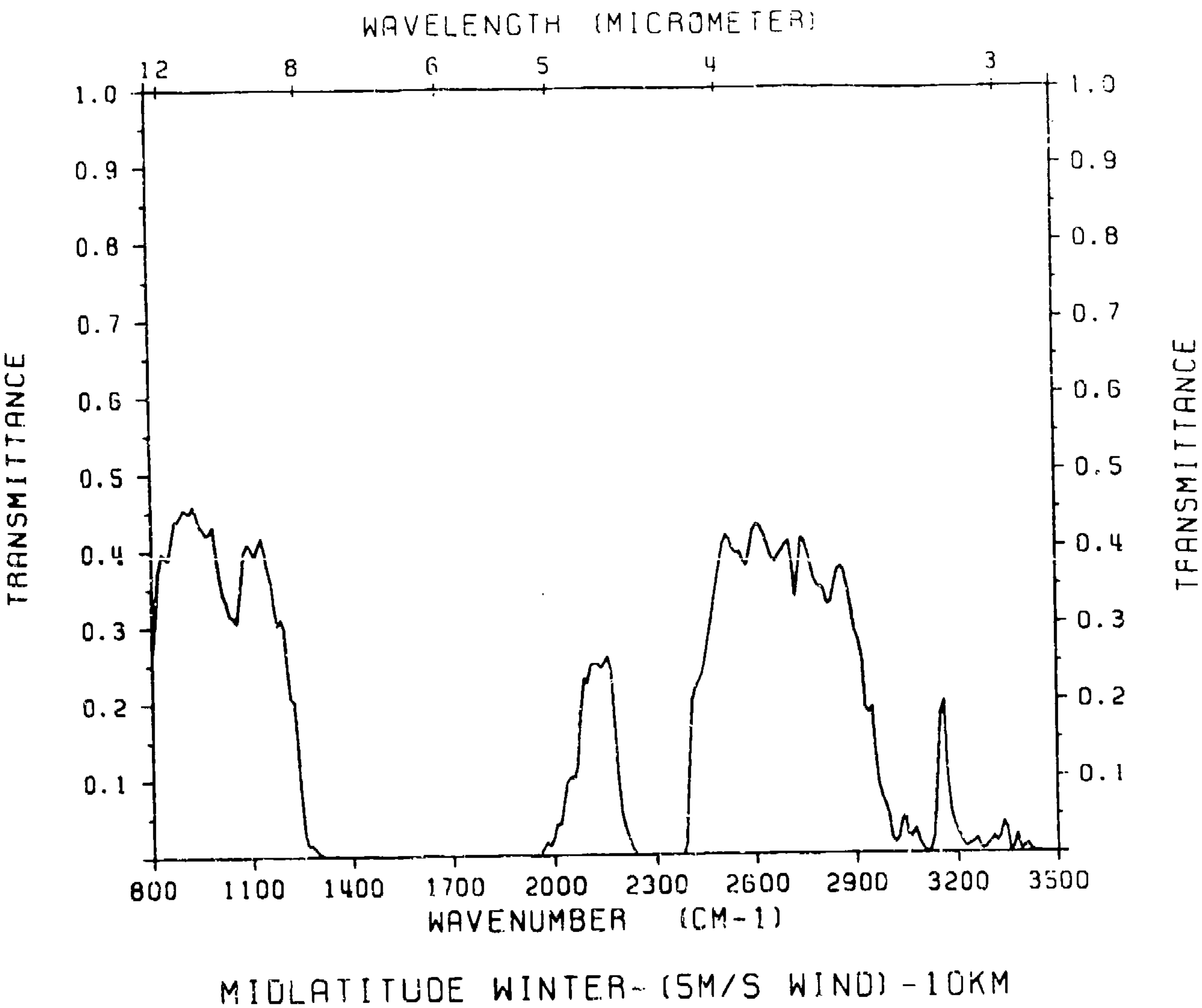
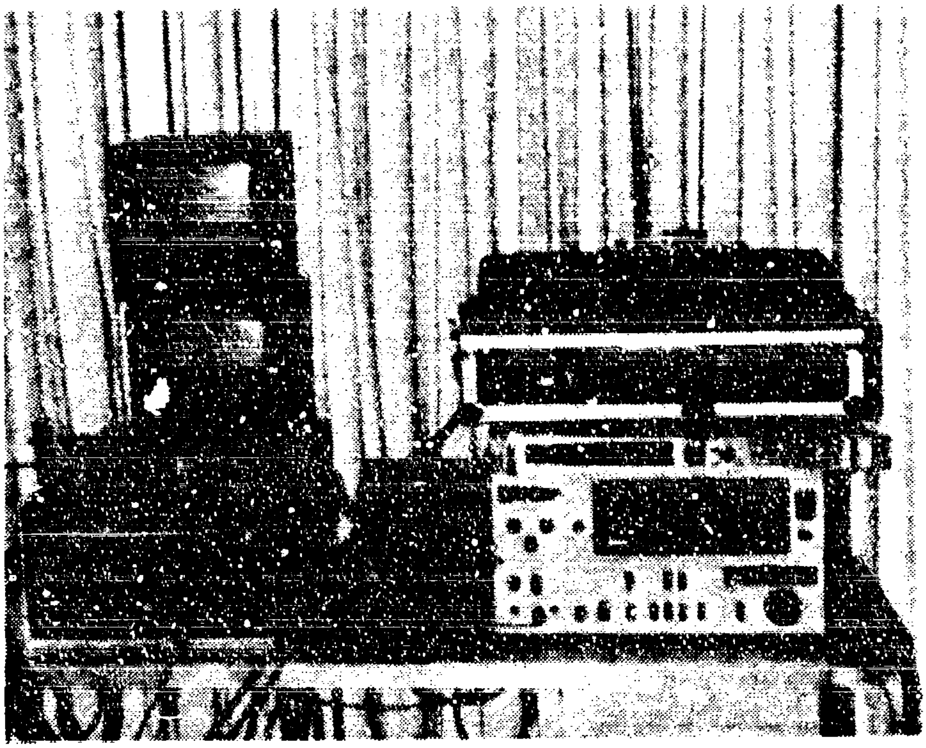


Figure 7. **LOWTRAN Transmission Windows for a 10km Path in a Midlatitude Winter Climate with a 5 m/s Wind.**



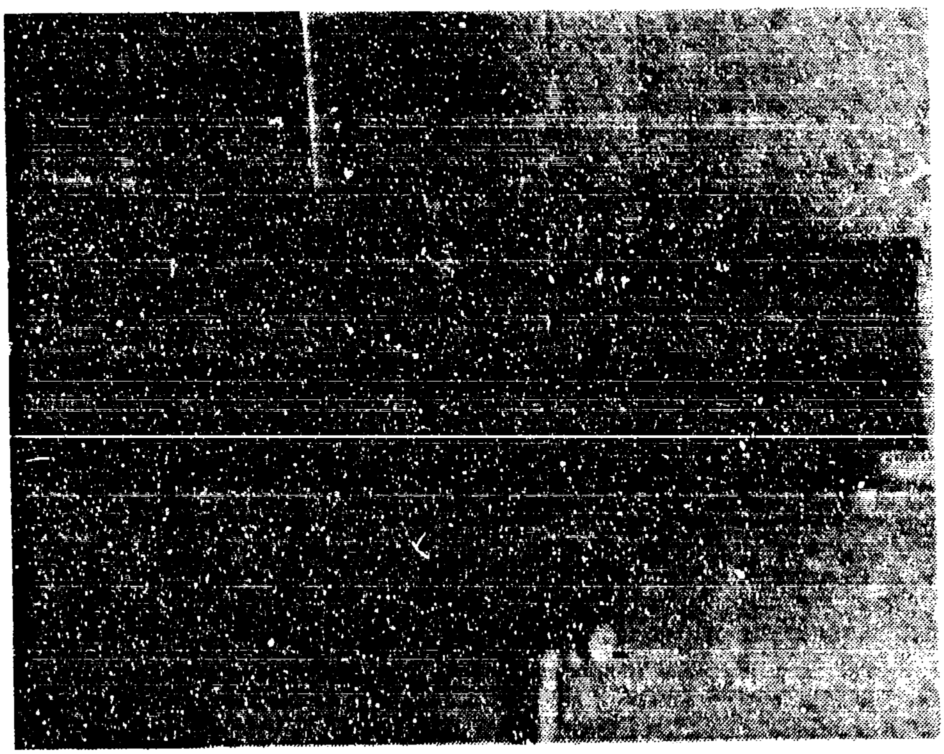


Figure 8.   Photos of Equipment Arrangement

TABLE I

CAMERA CHARACTERISTICS

Field of View	3 deg
Pixel Size	
Horizontal	80 μm
Vertical	40 μm
Angular Resolution	
Horizontal	0.26 mrad
Vertical	0.13 mrad
Horizontal Scan Lines	244
Lens Aperture	150 mm
Lens Focal Length	300 mm
Noise Equivalent Temperature Difference (measured independently at Wright-Patterson Air Force Base)	0.03°C
Detectors	
Array Size	160x244
Number of Detectors	39,040
System Weight	50 lbs.

A Cohu television camera, which detects visual light, was also used during this experiment for comparison purposes. This camera provided the visual image signal which was recorded on a split screen with the infrared image signal.

3.2 TARGET

USCGC OCRACOKE (WPB 1307) served as the target for the test (see Figure 9). The OCRACOKE is a 110′ Coast Guard patrol boat. Initially, it was not known that a 110′ patrol boat was specifically designed to have a low infrared profile. Upon visiting the vessel, it was learned that the aluminum hull is insulated everywhere but in a small portion of the engine room. The interior spaces of the vessel are air conditioned. Two sets of main engine exhaust ports are on the vessel. The first is at the water line and is used during normal steaming (less than 18 knots). The second set of exhaust ports are located below the water line and are used for high speed operations (more than 18 knots). During the course of the experiment, the USCGC OCRACOKE was asked to measure the temperature of the engine compartment exterior bulkhead. The temperature was between 26°C and 29°C, only 1°C to 4°C higher than the surrounding ocean water temperature. Finally, with the seas running at about five to six feet, the OCRACOKE took large quantities of water over the bow.

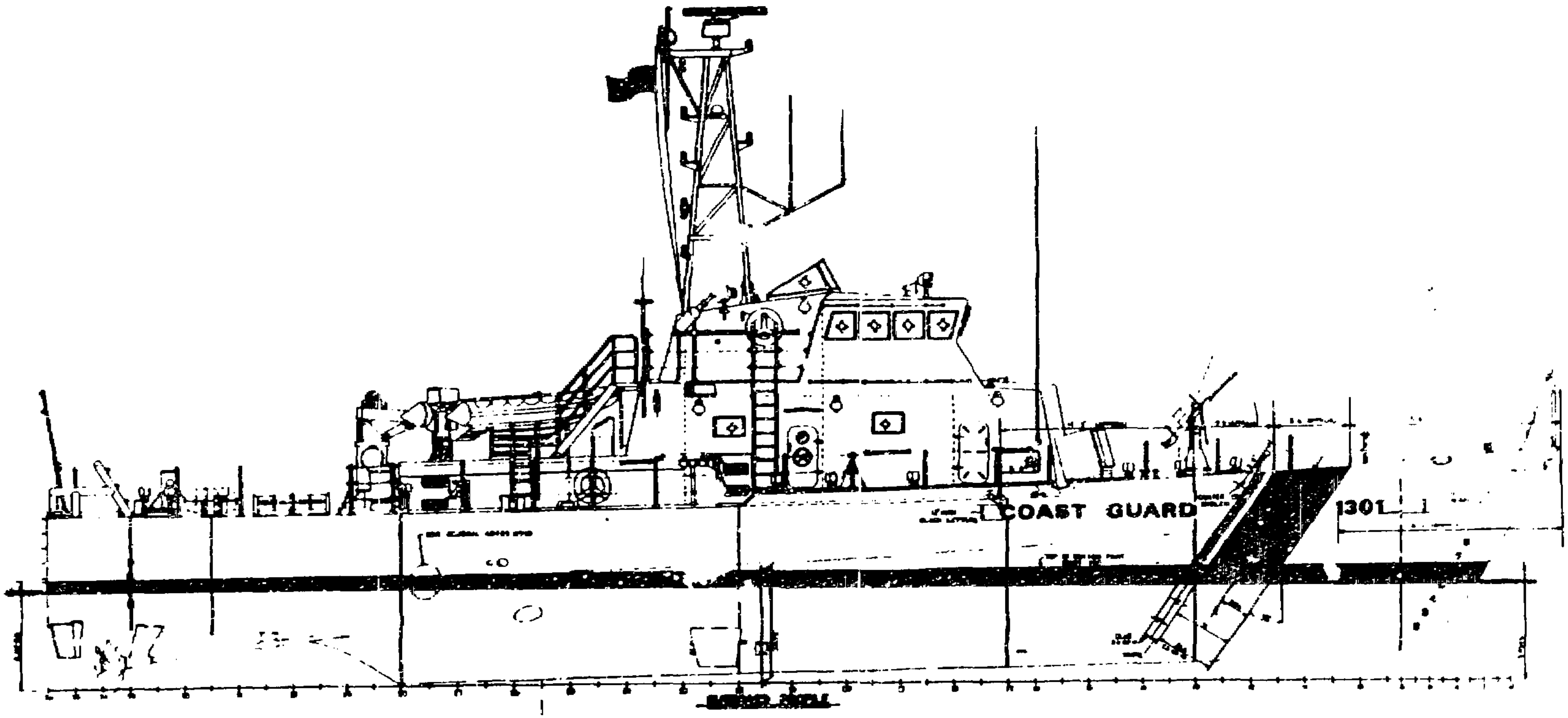


Figure 9. Profile View - Island Class Patrol Boat

The spray and green water left a water film on the decks and sides of the USCGC OCRACOKE. This film cooled the vessel down to the sea water temperature and destroyed the contrast between the vessel structure and the sea. Thus a severe test of the abilities of the mid-IR camera was conducted.

3.3 WEATHER

The experiment with the mid-IR camera was conducted for two days in the tropical climate of San Juan, Puerto Rico. Throughout this period, the temperatures and humidity were virtually unchanged. The majority of climatic changes were found in the amount of cloud cover, the wind velocity, and the wave height. Table II below lists the average conditions which were recorded at the target.

TABLE II

AVERAGE WEATHER CONDITIONS AT TARGET

Date / Time Wind Speed (kts)	Wave Height (ft)	Cloud Cover (%)	Visib. (nm)	Air Temp. (°C)	Water Temp. (°C)	Rel. Humidity (%)
24 Feb 88 / 0830 - 1030						
16-22	5-8	80	4-7	27.4	25.2	82
1330 - 1600						
13-15	6-8	60	7-8	28.2	25.5	73
1830 - 2000						
8-20	5-7	50	7-8	27.1	25.4	83
25 Feb 88 / 0830 - 1030						
3-9	3-5	20	6-7	27.3	25.3	77
1330 - 1530						
15-20	4-5	5	10	26.1	25.7	77
1830 - 2000						
10-17	3-4	10	8-10	27.3	25.5	80

Table III describes the conditions observed at the camera. Many of the conditions mentioned in Table II pertain to both the target and camera positions. Only those parameters which are most likely different are listed in Table III.

TABLE III

WEATHER CONDITIONS AT THE CAMERA LOCATION

Date / Time	Wet Bulb Temperature (°C)	Dry Bulb Temperature (°C)	Rel. Humidity (%)
24 Feb / 0800 - 1030	22.7	25.1	82
24 Feb / 1330 - 1530	23.2	25.5	83
24 Feb / 1830 - 2030	22.6	24.7	85
25 Feb / 0830 - 1030	22.9	25.1	83
25 Feb / 1330 - 1530	23.2	25.0	86
25 Feb / 1830 - 2030	22.9	25.0	84

The weather data can be further reduced to precipitable water per sea mile or millimeters of water per mile (mm/nmi). This term gives the thickness of the sheet of water produced if the entire moisture content of the air were condensed. The average mm/nmi are listed below in Table IV.

TABLE IV

AVERAGE PRECIPITABLE WATER PER SEA MILE (mm/nmi)
AT THE TARGET AND CAMERA

24 FEB 88			25 FEB 88		
0800-1030	1300-1600	1830-2000	0800-1030	1330-1600	1830-2000
TARGET					
41.47	40.05	40.88	39.63	40.46	40.31
CAMERA					
40.57	41.79	40.30	41.04	41.79	41.04

The weather conditions experienced were as hoped for. The warm atmospheric and oceanic temperatures coupled with the prevailing winds and high seas, gave us the high atmospheric humidity condition desired.

3.4 SYNOPSIS OF EVENTS

A summary of the viewing events of the USCGC OCRACOKE with the mid-IR device is included in Appendix B. These events were recorded on video tape and are being stored at the R&D Center for future reference. A short video of the highlights of the experiment was made and has been included with this report. The viewing of this tape should answer many of the questions generated by this report and should give the viewer a better understanding of what an IR imaging device is and does.

4.0 RESULTS

4.1 PERFORMANCE OF THE MID-IR CAMERA

The mid-IR device worked well during this two day experiment. The following Figures (Figs. 10 through 17) exhibit the output viewed at various times and distances. Notice should be taken of the clarity of the commercial freighters at what is believed to be 4 nmi, and of the barge at 6 nmi. The differences between the recognition distances of these vessels and the Coast Guard cutter is attributed to the designed low infrared profile of the 110′ cutter.

An observation was made during the experiment that the operators of the IR equipment continually adjusted the gain and offset of the detector. These variables are nothing more than adjustments of the brightness and contrast of a television picture. Any current system chosen will have these adjustments and the operator will need to know how to use them. As these adjustments seemed somewhat trivial, no problem should be expected with the imaging adjustments on the IR device, especially when compared to the task of adjusting a radar. RADC is presently developing an automated adjustment system to relieve the operator of this task.

4.2 COMPARISON OF THE FAR-IR AND MID-IR DEVICES

The performance exhibited by the mid-IR camera was encouraging, especially when compared against the results of the far-IR FLIR as outlined in Reference 2. Under similar conditions of temperature and humidity, the far-IR device was not capable of detecting vessels beyond 5 nmi, and recognition distances were severely reduced for large vessels, down to less than 3 nmi. The mid-IR device was capable of detecting vessels well past 8.5 nmi and the recognition range for typical commercial vessels exceeded 4 to 6 nmi (see Figures 16 and 17). For smaller vessels, such as the 110′[1] Coast Guard Cutter, the recognition range was about 3 nmi.

---

[1] It is important to keep in mind that this small, 110′ vessel, the USCGC OCRACOKE, is a low infra-red profile vessel. Any other vessel, such as the various targets of opportunity sighted, would have an increased detection range and recognition range.

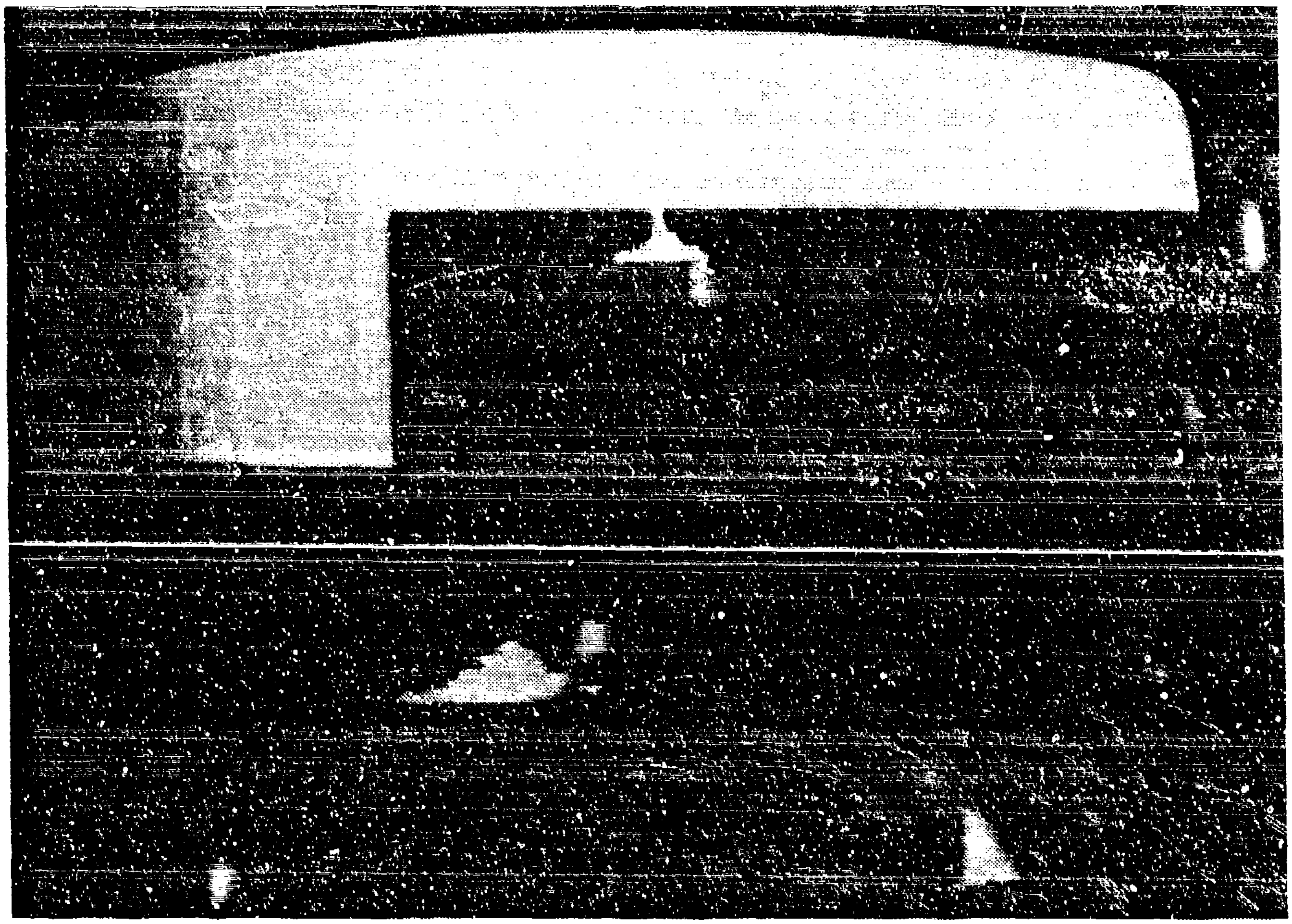


Figure 10. Photo - USCGC OCRACOKE, Starboard Side at 2 nmi, Afternoon of 24 February 1988.

NOTE - Figures 10 through 17 are photographs of the video output produced during the experiment. The lower half of the photo is the Infrared picture which has only a 3° field of view. The upper half of the photo is a visual picture of the same scene as seen by a Vidicon TV camera with ~8° field of view. The objects on the lower right side of the Infrared and visual photos of Figures 10, 11, 12, 14, 15 and 16 are palm trees. The white wall on the left side of the visual photo in Figures 10, 12 and 16 is the wall of the hotel.

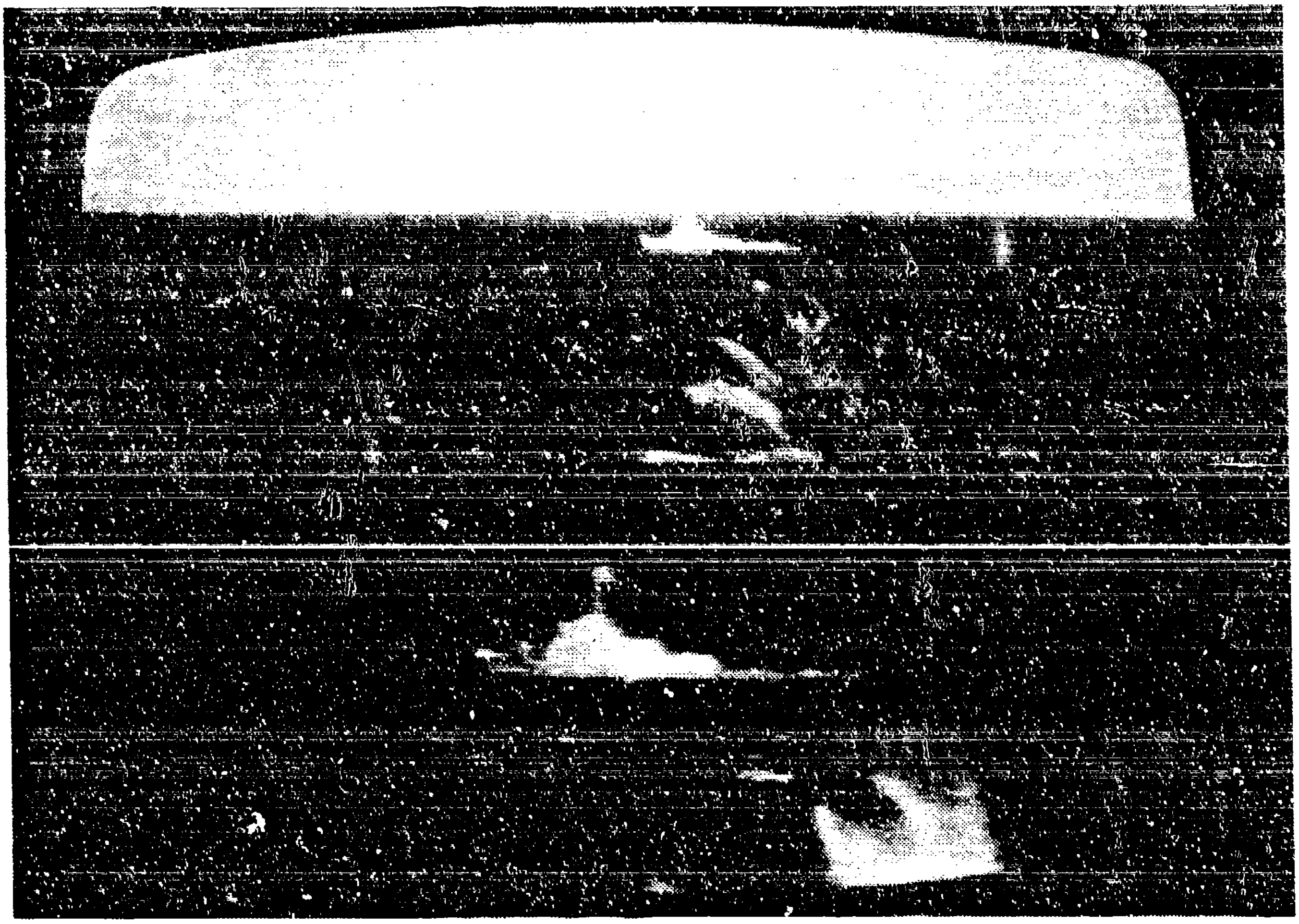


Figure 11. Photo - USCGC OCRACOKE, Port Side at 2 nmi, Afternoon of 25 February 1988.

SEE NOTE ON PAGE 17

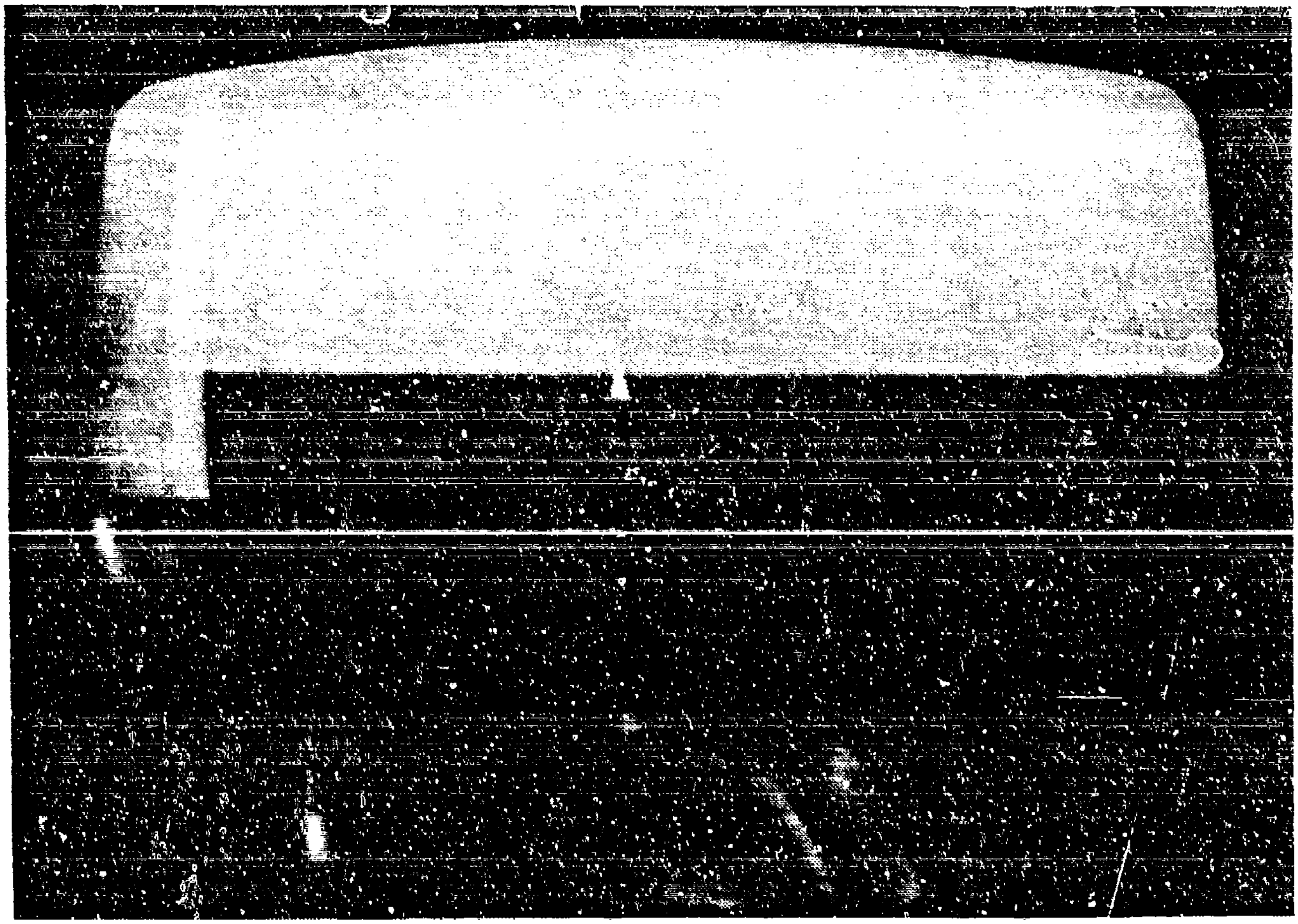


Figure 12. Photo - USCGC OCRACOKE, Bow Aspect at 2 nmi, Afternoon of 25 February 1988.

SEE NOTE ON PAGE 17

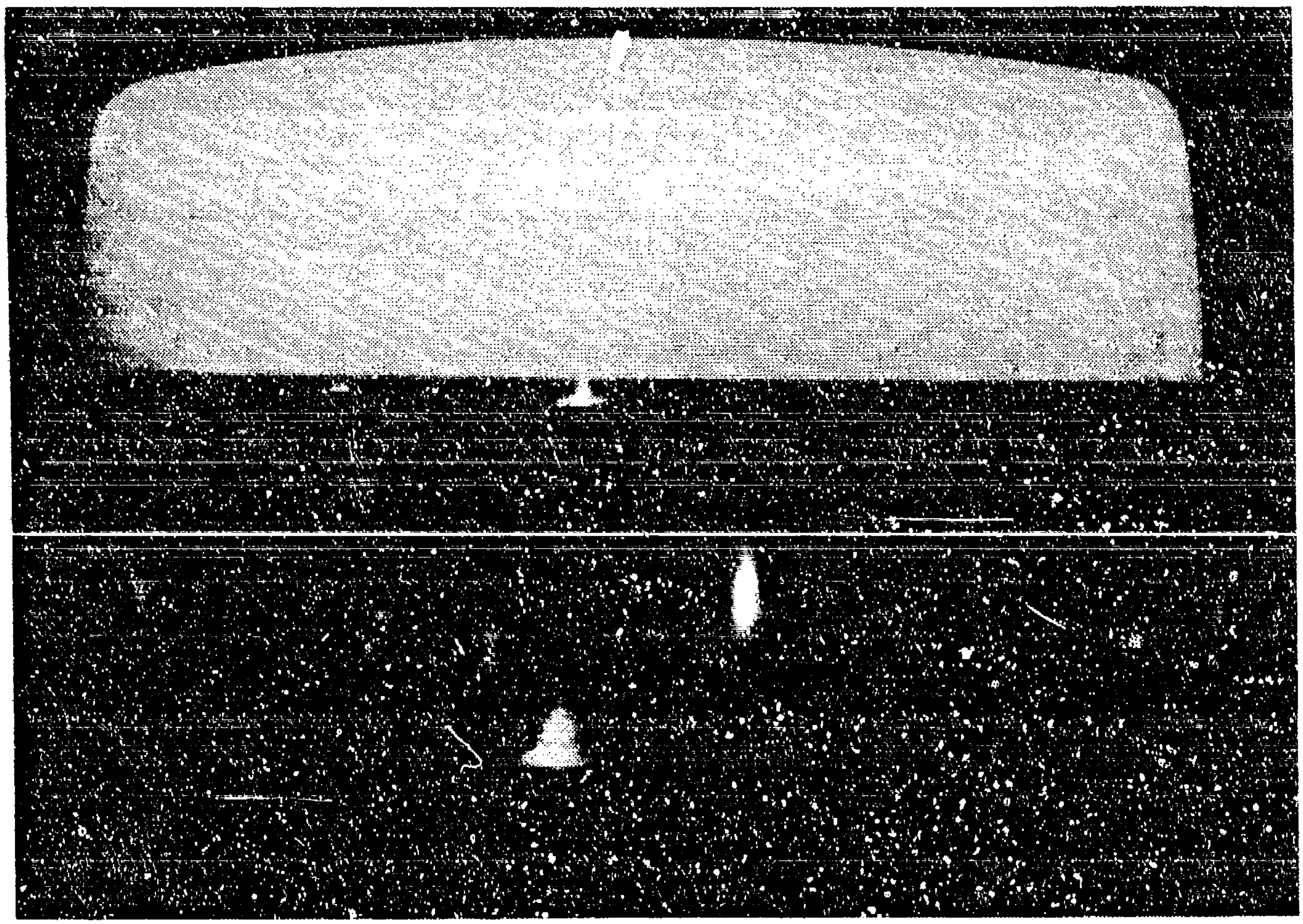


Figure 13. Photo - USCGC OCRACOKE, Stern Aspect at 2 nmi, Afternoon of 25 February 1988.

SEE NOTE ON PAGE 17

Figure 14. Photo - USCGC OCRACOKE, Starboard Side at 4 nmi, Afternoon of 25 February 1988.

SEE NOTE ON PAGE 17

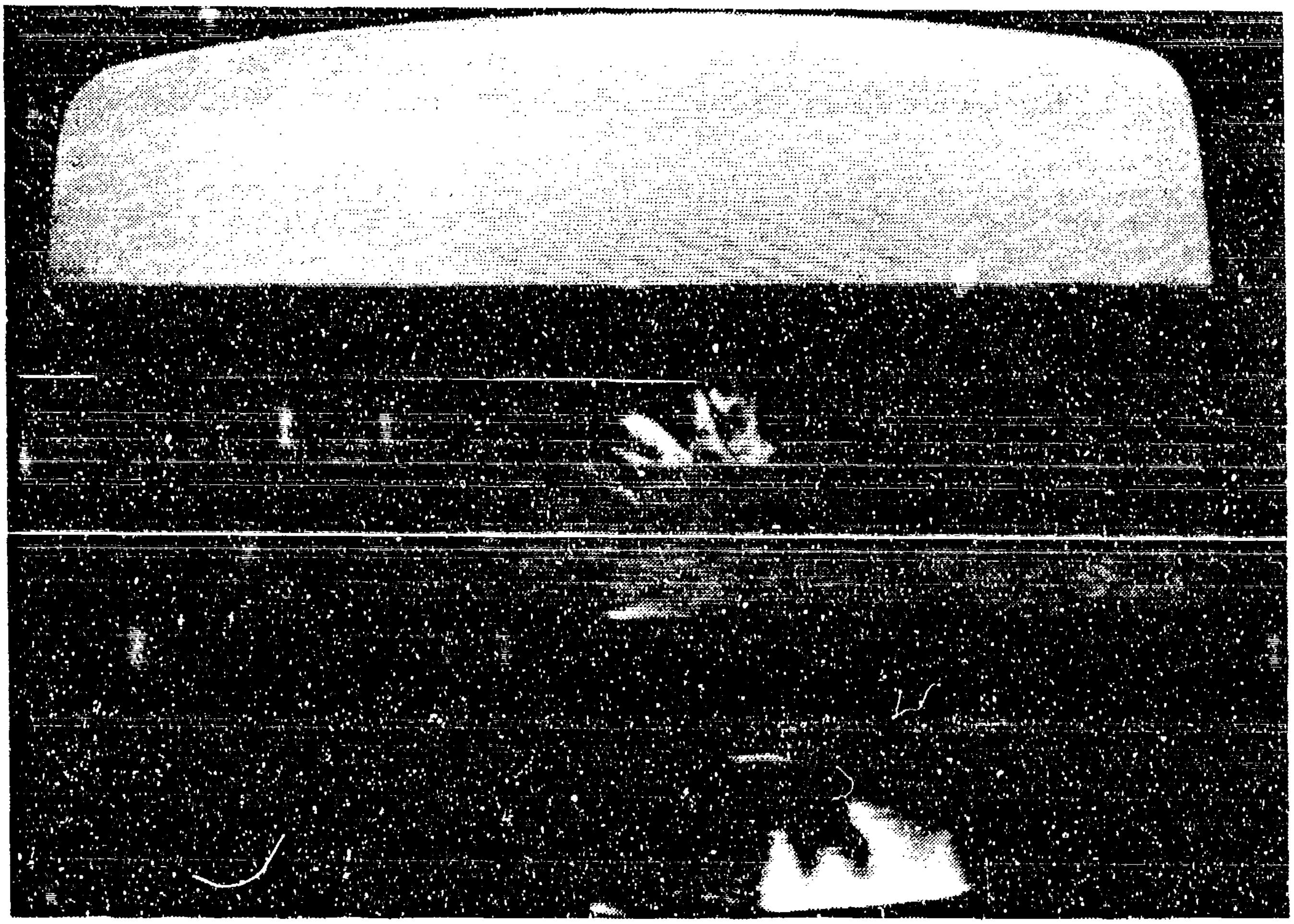


Figure 15. Photo - USCGC OCRACOKE, Starboard Side at 6 nmi, Afternoon of 25 February 1988.

SEE NOTE ON PAGE 17

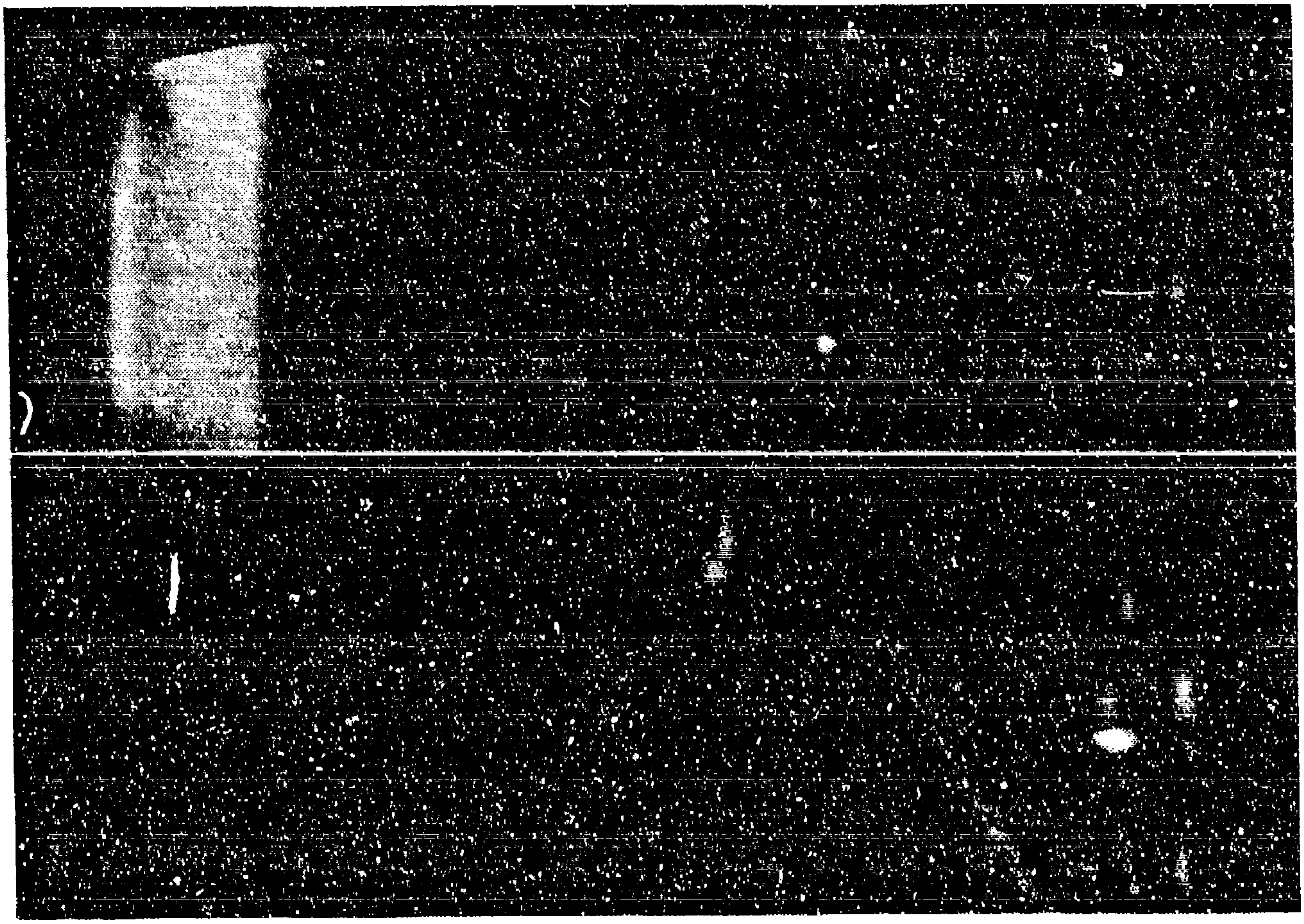


Figure 16. Photo - Tug and Tow at 6 nmi, 1930, 24 February 1988.

SEE NOTE ON PAGE 17

Figure 17. Photo - Two Large Commercial Vessels at an Approximate Range of 4 nmi, Early Evening of 24 February 1988.

SEE NOTE ON PAGE 17

It is difficult to accurately compare the performances of the two devices without an adequate supply of tropical data taken with the far-IR FLIR. The data in Table V below were obtained from the "Trend Line" in Figure 6 of reference 2 which is included in this report as Figure 18. To compare device performances, the data in Table IV indicates that 39 to 42 mm/nmi of precipitable water should be used on Figure 18. The "Trend Line" on Figure 18 is a compilation of data taken in multiple climates including the northern Atlantic, the mid-Atlantic and tropical regions by the USCGC VIGOROUS and the USCGC DECISIVE. The existence of the "Trend Line" is expected from the mathematics and inferred by this data. There are, however, other factors involved which are important in the determination of detection and recognition ranges. Nowhere on the "Trend Line" is there any distinction for the vessel size, the winds, or the sea conditions, all of which can affect the recognition range. For these reasons, deviations from the "Trend Line" should be expected and are indeed evident on Figure 18.

TABLE V

PERFORMANCE COMPARISON OF DEVICES IN A TROPICAL CLIMATE

VESSEL SIZES (approx.)	OBSERVED RECOGNITION RANGES (nmi) MID-IR	FAR-IR*
110′ OCRACOKE	3.0	1.0
300′ barge	6.0**	3.0
300′ tanker	4.0**	3.0

* Obtained from "Trend Line" mean values (see Figure 18)
** Observed Range - not evidently maximum range because of good image quality

5.0 CONCLUSIONS

It is obvious that neither of these IR technologies meet the full operational requirements compiled by the Coast Guard. However, the mid-IR device out performed the far-IR FLIR by far in the tropical climate of San Juan, PR. A detection range on the order of 8 nmi and a recognition range of 3 nmi was achieved on a low IR profile vessel with approximately 40 mm/nmi of atmospheric water vapor. In these same conditions, the far-IR FLIR was found to be inadequate for any detection or classification tasks desired.

Secondly, the mid-IR device can and did perform better when the target of interest was not an infrared camouflaged military vessel. All the commercial vessels examined by the mid-IR camera

NOTE - This Figure is taken from Reference 2, Results of FY87 Tests of Shipboard Electro-Optical Apparatus.

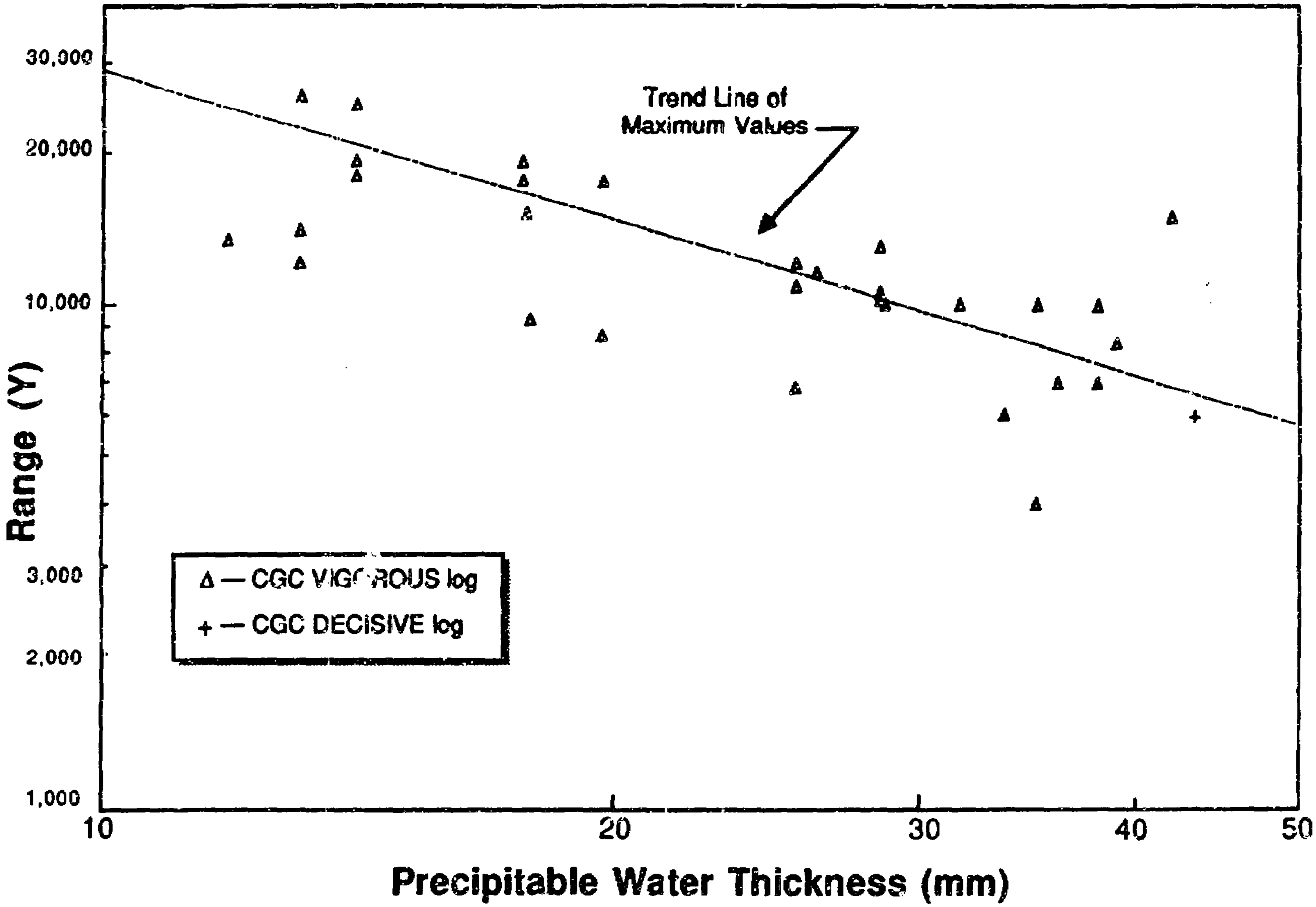


Figure 18. Maximum Observation Ranges for Freighters.

exhibited better imaging qualities than the USCGC OCRACOKE. It was easier to recognize the image of a barge at night at 6 nmi than it was to detect the aluminum, insulated OCRACOKE at the same range.

Finally, it must be noted that even this IR technology has been improved recently by the manufacturer of the detector, RCA. A new detector assembly with twice as many individual detectors has been produced. This improvement will increase the resolution capabilities of the IR device which will in turn increase the recognition range of the system.

6.0 RECOMMENDATIONS

It is recommended that the Coast Guard consider a mid-IR device as the best possible choice for meeting its operational requirements for electro-optical sensors.

7.0 REFERENCES

1. Itakure, I., Tsutsumi, S., and Takagi, T., "Statistical Properties of the Background Noise for the Atmospheric Windows in the Intermediate Infrared Region", Selected Papers on Infrared Design, SPIE Vol. 513, Part 1, p. 205, 1985.

2. Replogle, F Jr., Results of FY87 Tests of Shipboard Electro-Optical Apparatus, United States Coast Guard Research & Development Center, Report No. CG-D-07-88, October 1987.

APPENDIX A

COMMENTS ON FAR-IR FLIR TESTS

A copy of the After Action Report from the Commanding Officer of the USCGC DECISIVE is reproduced in this Appendix. The source of this document is Appendix E of the report on the evaluation of the far-IR device, Reference 2.

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U.S. Department of Transportation
United States Coast Guard

Commanding Officer
USCGC DECISIVE(WMEC 629)

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3980
17 Jun 87

From: Commanding Officer, USCGC DECISIVE (WMEC 629)
To: Commanding Officer, USCG Research & Development Center

Subj: EVALUATION OF SHIPBOARD MOUNTED FLIR

1. The FLIR (Texas Instruments Lightweight Shipboard Electro-Optical Sensor) was installed prior to our departure on 18 May 1987. The location selected for the most unobstructed view was the flying bridge adjacent to the lookout station. The nine-inch monitor was placed conveniently in an open cabinet, forward on the port side of the bridge and the power pack/video gear was oriented athwartships against the after bulkhead under the starboard window. All cables were led through the overhead and out a side window to the FLIR. Once underway, R&D technician, Mr. Bob Berry, conducted a briefing on the operation and capabilities of the FLIR with all the non-watchstanding petty officers who would be operators.

2. Our first night at sea was the clearest night in about three years. Outside Tampa Bay were many ships and small vessels with which to test the FLIR capabilities. The first ship observed was a 600 foot cruise liner that was visually confirmed at about six nautical miles. At about five miles, the stack became visible through the FLIR, and at about three miles the overboard discharge was identified. Not until a range of approximately two miles was the ship identified by type with the FLIR.

3. The FLIR was manned, in the beginning, from 2100 to 0500, and was used as a normal, scanning lookout watch. The first two nights of watch revealed that this would be counter-productive since our regular, flying bridge lookout was reporting contacts as usual at six to fifteen miles while the FLIR watch saw nothing. We rarely closed vessels to less than two nautical miles and small vessels of 100 feet or less were not visible beyond two miles. Continuous scanning tended to cause some eye strain, so scanning was done for five to ten minutes followed by a brief rest. In addition, the range/size reticle within the device proved to be distracting to the lookout. Night vision was not seriously impacted by the green light of the FLIR so the red filter was not used. The lack of contacts seen by the FLIR watchstander proved taxing, so we shifted the FLIR watch to an on-call basis, activated when we wanted to get a close-up view of contacts of interest.

4. We were unable to completely evaluate far, intermediate and near distances since FLIR's range ability was so limited. On the

occasions that we closed a vessel for LE purposes, the device did make available another window for details. It allowed us to observe vessel type and construction, monitor crew movement, and examine possible heat sources prior to illumination and boarding. Once the boarding was in progress, the FLIR became insignificant for that vessel. As comparison between the FLIR and the NVS-500 night vision scope, the NVS-500 is a more capable detector at a distance greater than two miles, but for close in detail, the FLIR is a better choice.

5. During our investigation of the F/V CLARIBEL, which contained over 30,000 pounds of marijuana, no particular heat was observed that could be identified as decomposing marijuana. However, if the vessel had been of fiberglass construction, that might have been different. The engine space and exhaust were clearly identifiable and, in another case, we were able to confirm that a vessel had been at anchor for some time due to the lack of heat detection.

6. Throughout the patrol, we had opportunities to encounter many types of vessels ranging from 800' tankers to 29' sailboats. Only on a very few occasions were any vessels visible through the FLIR at a range of over three miles. FLIR clarity became progressively worse the farther south we travelled. Between the latitudes of 15 and 12 degrees north we were not generally able to detect contacts farther than one mile, and there was considerable "fogginess" in the field of vision when scanning out from the ship beyond 1,000 yards. Within 1,000 yards the sea was clearly visible. Of particular note, during our patrol time between 12 and 13 degrees north latitude, our visibility was reduced to a maximum of eight miles as a result of red-brown Sahara dust blown west by the tradewinds.

7. After ten days of operation, the FLIR developed a full ground. Mr. Berry and DECISIVE's EMC attempted to identify and correct the problem, but a full ground remained in its power source. The equipment was secured until mid-patrol break arrival in Martinique where a Texas Instruments repair representative flew to meet us. The technician replaced the power source and the FLIR was again operational.

8. The FLIR in its present state of development is useful only as a supporting device and not as primary search equipment. Given the acquisition costs, technical maintenance and support required to keep the equipment operational and useful, its benefits do not appear to outweigh using familiar and reliable methods like a high powered spotlight and portable video camera. The pedestal mount, nine-inch monitor (with red filter), and yoke performed quite well, but resolution was a problem and the video

Subj: EVALUATION OF SHIPBOARD MOUNTED FLIR

capabilities were peripheral to our procedures and require too much space. If the reticle was removed, and resolution was clarified considerably, the FLIR might be a fine addition to the fleet.

9. Having evaluated various lowlight level televisions in the past, I find them to have more capability than this FLIR and at a much lower cost. A WMEC needs a detection device that can sense targets at a range of five to ten miles and identify them at three to five miles. This allows for effective covert surveillance. Additionally, this device must be on a stabilized platform due to the movements inherent in a ship. The manning level on a WMEC 210' is insufficient to man a second lookout so remote control would allow the bridge watch to effectively use it.

10. DECISIVE was pleased to have been chosen as a testing platform for the FLIR equipment. It was a pleasure working with the R&D representative (Mr Frank Replogle) and technician (Mr Bob Berry) and having them aboard. I look forward to further results and developments in infrared technology and offer to provide any further assistance as a testing facility.

L. E. PARKIN

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CG LANTAREA (oc)
CGD 7 (ole)

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APPENDIX B

SUMMARY OF EXPERIMENT

1. 0800-1030 24 FEB 1988

We began our first test of the mid-IR device at 0800 by viewing a calibration box brought from the R&D Center, (see Figure B-1). Initially, the temperature differences were too small to be distinguishable on the thermometer but were easily seen in the infrared. The temperatures were adjusted until differences of 0.5°C, 0.9°C and 1.4°C were achieved between the three different elements. These temperatures were easily distinguishable on the IR camera.

Our first sighting of the USCGC OCRACOKE was at 0835. The vessel was at 4.4 miles, very cold, and appeared dark against the sea background. The vessel started to circle but was lost in the rain. As the rainfall decreased, the vessel was re-acquired on the television camera but was not acquired on the IR camera until it was out of the rain. The vessel circled at 4 nmi and the exhaust ports were clearly visible when exposed. As the vessel turned, it was found that the bow on aspect was the worst for imaging.

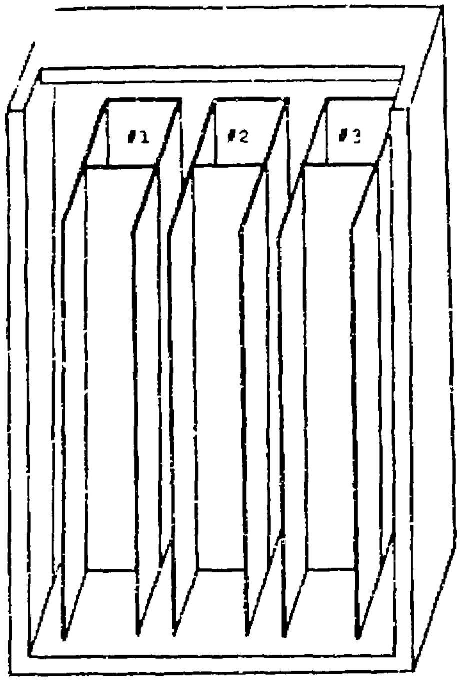
Finally, after about 45 minutes, the skies began to break and some sun came through. We asked the vessel to come toward us and found that the closest approach possible was 1.5 nautical miles. At this distance it was possible to make out some hull detail in the IR due to: a) the short distance, and b) the vessel was warming up. After circling, the vessel was sent out to determine our maximum range.

As often as possible, targets of opportunity were viewed with the camera and, generally speaking, all the targets of opportunity were easier to view than the USCGC OCRACOKE.

As the USCGC OCRACOKE headed out, we used a scan method to determine if it was still detectable. The camera was taken off the target and a scan of the horizon was made. If the camera operator could re-acquire the target, it was still considered to be in range. The USCGC OCRACOKE was detected out to 7.6 nautical miles.

2. 1250-1530 24 FEB 1988

Various scans of the horizon were attempted prior to the arrival of the USCGC OCRACOKE. We were able to view three targets of opportunity during the scans but their ranges were unknown. At this time, the sun was out and the cloud cover was estimated at only 10% but there was heavy coverage at the horizon. When the USCGC OCRACOKE arrived at 1330, we obtained a very good beam shot at a range of 1.5 nmi. It was evident that



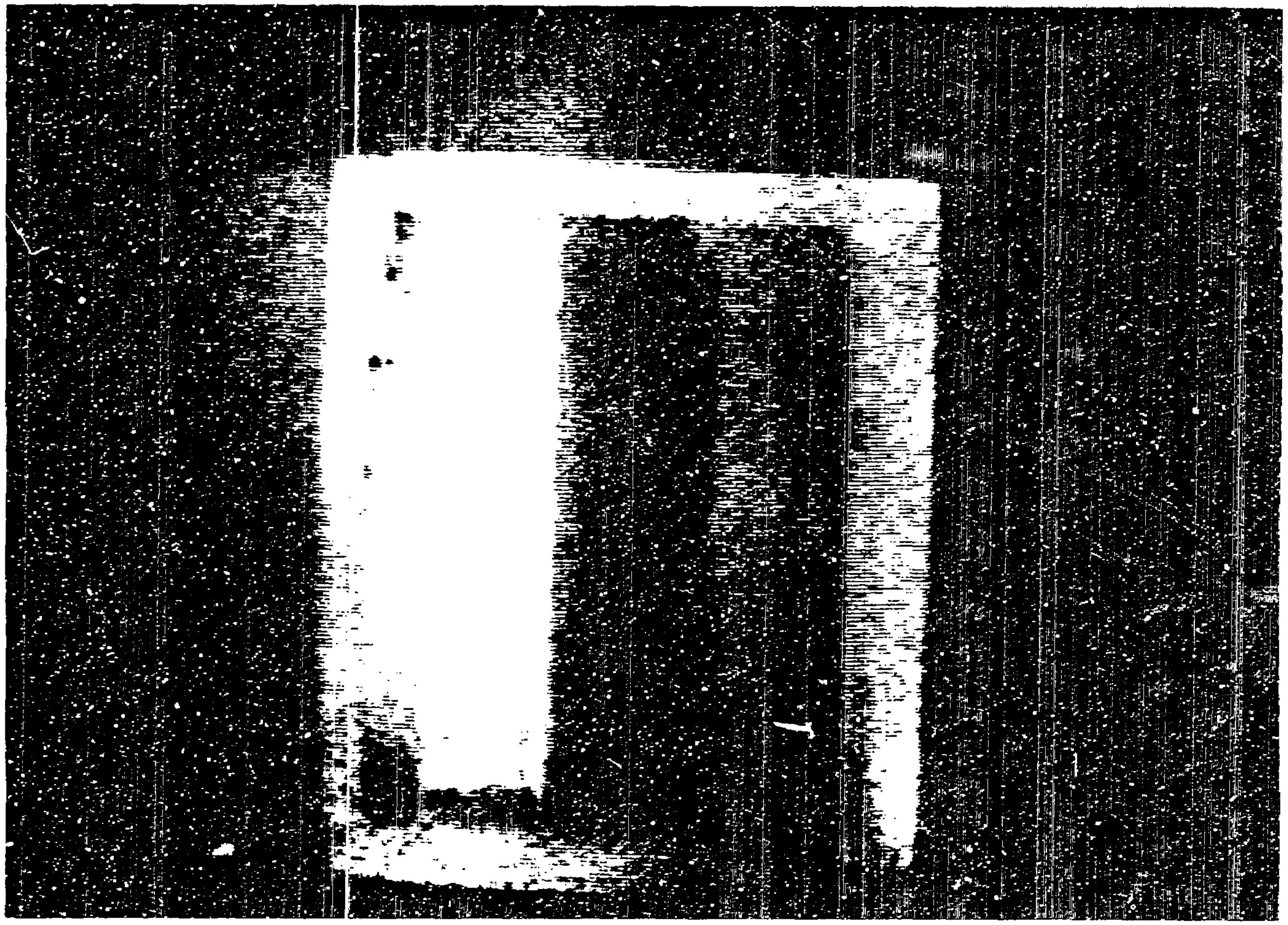


Figure B-1. FLIR Sensitivity Tester - Schematic and Photo.

Reservoirs 1, 2, and 3 are nearly filled with water at three different temperatures. Three aluminum "U" channels are thermally connected to the reservoirs so they perform as IR black bodies of bar shape.

the vessel had been warmed up by the sun and as it turned to present its port side, we could make out the bridge windows which were black because of the air conditioning. A man was put out on the after deck but at 1.5 nmi, it was very hard to detect him.

Again, the vessel headed out and was lost on the visual camera at 6.0 nmi. At 8.0 nmi the vessel was at the limit of detection in the IR and turned around at 10 nmi. Now, with a bow on aspect, the vessel was very difficult to detect. At 6.0 nmi, the vessel increased speed to 30 knots but was still hard to detect since the bow was so cold from the sea spray. Finally, at 4.5 nmi, the vessel was detectable and a good image of the cold bow and the warm superstructure was obtained.

Later, two targets of opportunity were viewed after the USCGC OCRACOKE left our field of view. The vessels were easily recognized as a tanker and a freighter passing. The range to these vessels was estimated at 3.7 to 4.2 nmi by guessing that their length was on the order of 250-300 feet and solving for a distance by simple geometry. The ease of recognition of these two vessels at a range of 4 nmi reinforces the fact that the USCGC OCRACOKE's low infrared profile decreased its recognition range significantly.

3. 1830-2030 24 FEB 1988

We noticed that the USCGC OCRACOKE was much cooler this evening as compared to the afternoon operation. The vessel performed the same tasks as in the previous runs and was finally lost at 8 nmi. During the return trip, a tug and tow was encountered at 6 nmi. While it was difficult to make out the USCGC OCRACOKE at this range as anything other than a blur, the tug was a radiant white spot and even the barge could be recognized at this range. By simple geometry, the size of the barge was calculated to be 300 feet long and yet could be recognized on this system 6 nmi away.

4. 0830-1030 25 FEB 1988

The wind and seas had abated from the previous day. The USCGC OCRACOKE was again cool and the picture on the camera was quite poor. We could detect the USCGC OCRACOKE out to about 7 nmi and had the vessel turn about. Upon arrival back at 2 nmi, the vessel circled and produced a good image. We could easily see the cold bow and warm after sections of the vessel during this mornings run.

5. 1330-1530 25 FEB 1988

The run on this afternoon seems to be the best so far. The

USCGC OCRACOKE made several circles at 1.58, 4, 6, and 8 nmi. In this run, the limit of recognition was estimated to be roughly 3 nmi. The vessel was detected out past the 10 nmi point and after turning around at 12 nmi, the vessel was re-acquired because of solar reflection. On the return trip, the USCGC OCRACOKE circled at 5, 3 and 1.8 nmi. The images were very clear. A man was put on deck at 1.8 nmi and he was detectable; partially because we knew what to look for.

Later, another target of opportunity was sighted. This tanker was estimated to be outside of 4 nmi, and probably much further, but recognition was still no problem.

6. 1830-2000 25 FEB 1988

On this last run, the vessel had again cooled appreciably from the afternoon. The vessel was detectable out to 8 nmi.