INFRA-RED DETECTION AND ACOUSTIC DETERRENT STUDY CAPE CHURCHILL, MANITOBA, 1984

COMPLETED BY

COMPUHEAT SERVICES CANADA INC.
BOX G, 1103, STATION A
CALGARY, ALBERTA
T3A 3G3

FOR

DEPARTMENT OF RENEWABLE RESOURCES
GOVERNMENT OF THE NORTHWEST TERRITORIES
YELLOWKNIFE, NWT

1986

Northwest Territories Renewable Resources

File Report No. 55

ABSTRACT

A two part study was carried out by Compuheat Services Canada Inc. under the auspices of the Government of the Northwest Territories bear detection and deterrent research and training program at Cape Churchill, Manitoba in November, 1984. Part one was implemented to test the feasibility of using an infra-red system to detect (and also census) polar bears (Ursus maritimus) under natural arctic winter conditions, and to assess this system's usefulness as an early warning device. Part two consisted of a preliminary investigation into the feasibility of using an acoustic system as an effective and versatile deterrent system, which is physically harmless to polar bears. It was implemented to observe the effects of acoustic stimulation on bear behaviour and to determine any possible optimal frequencies for deterring these animals in their natural habitat. Results of part one indicate that the infra-red wavelength band of 8-14 microns is practical for use in detecting polar bears in their natural habitat, despite adverse weather conditions. The early warning device interfaced into the infra-red system proved to be 100% effective. The complete system was portable, simple to install and operate, and required little maintenance. Results of part two showed that most bears were sensitive to the 0.1 - 9.0 kHz range of frequencies, and were most effectively deterred at frequencies of 1.0 - 4.0 kHz. There was some indication that when this stimulus was presented in a pulsed mode it produced better results. Because of the small sample size and the limited testing period, further investigation is recommended to obtain conclusive results. A list of possible influencing factors is offered for consideration for further testing.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GENERAL INTRODUCTION

Since 1981, the Government of the Northwest Territories, in cooperation with industry and other government agencies, has conducted a research and training program designed to reduce bear-people conflicts and better manage bear problems. The goals of the program are:

1. to develop and test a variety of detection and deterrent systems that are effective and can be applied to each type of human installation whether it be a small exploration camp or a large industrial site or community; and
2. to develop and implement education and training programs for people who may have to deal with nuisance bears.

The results of work completed from 1981-1983 are reported elsewhere (Stenhouse 1982, 1983, Stenhouse and Cattet 1984).

The results described in this report were obtained in 1984 at Cape Churchill, Manitoba under the auspices of the bear detection and deterrent program. This study consists of two components. The first component was implemented to test the merits of an infra-red detection system. Polar bears (Ursus maritimus) were censused with this system under natural environmental conditions. The second component consisted of a series of preliminary experiments designed to test the effectiveness of an acoustic deterrent device.

STUDY 1:

A STUDY TO EVALUATE INFRA-RED THERMOGRAPHY TECHNIQUES FOR DETECTING POLAR BEARS (*Ursus maritimus*) AT CAPE CHURCHILL, MANITOBA

NOVEMBER, 1984

BY

RICHARD FITCH

COMPUHEAT SERVICES CANADA INC.

AND

LINDSAY M. HOOS

INDEPENDENT BIOLOGICAL CONSULTANT

INTRODUCTION

This study was designed and implemented under the auspices of the Government of the Northwest Territories' bear detection and deterrent project. The primary objective was to evaluate the feasibility of using an infra-red system to detect, and also census polar bears under natural conditions and then to evaluate the system's capabilities as a monitoring and warning device.

Polar bears inhabit remote areas and accurate population estimates are difficult to obtain. Normal photography (in the 400 to 700 microns wavelength) does not provide a picture with sufficient contrast to detect bears easily in an arctic environment where the reflection (albedo) of sunlight off snow and ice is significant. Ultra-violet (300 to 400 n.m.[1]) has proven useful in providing some additional contrast (Lavigne and Oritsland 1974a), although use of this wavelength is also limited by light conditions at the time of the filming.

Thermal infra-red imagery has been tested in past years to detect polar bears; but success was minimal for several reasons. First, the infra-red spectrum covers a wide band of frequencies and not all frequencies are useful for biological studies. Second, it is possible that, under some climatic conditions (e.g., cold and windy weather), the equipment was not sensitive enough to detect the temperature difference between the insulated

---

[1] n.m. = nano metres

animal and its habitat to facilitate detection by a thermal scanner (Lavigne and Oritsland 1974b). Consequently, the use of infra-red technology for wildlife studies has received little application.

In recent years, technological development of infra-red imagery has progressed to a level of specification and reliability unattainable at the time of previous polar bear studies. Early in 1984, Compuheat Services Canada Inc. (C.S.C.I.) acquired a portable infra-red detection and recording device thought capable of detecting polar bears in their natural environment. Because the system does not require liquid nitrogen, it is substantially smaller and lighter than many other types of infra-red units and, therefore, is easily portable. The C.S.C.I. infra-red unit is self-powered (using nicad batteries), extremely versatile, and records directly into a standard video cassette recorder. The unit employs a sensing tube which is a hard vacuum pyroelectric videcon (P.E.V.). Specifications of the unit are outlined in Appendix A.

A study conducted by C.S.C.I. (Fitch and Ward In press), at Resolute Bay and in the Beaufort Sea during the spring of 1984, to evaluate the system's ability to detect seals under a wide range of temperature and wind conditions, indicated that this system was capable of successfully detecting seals during all environmental conditions encountered. The results of this preliminary study provided the basis upon which the polar bear tests were undertaken.

Tests were conducted in November, 1984, at Cape Churchill, Manitoba. The primary objectives of the study were:

1. to evaluate the feasibility of using the infra-red detection system to detect (and also census) polar bears under cold, windy conditions;
2. to evaluate the range of detection and reliability of the system when exposed to severe weather conditions; and
3. to test an early warning technique from the camp under varying light conditions.

STUDY AREA

The study was undertaken at Cape Churchill, Manitoba from 3 to 8 November 1984 (Figure 1). A detailed description of the area can be found in Derocher and Miller (In prep.).

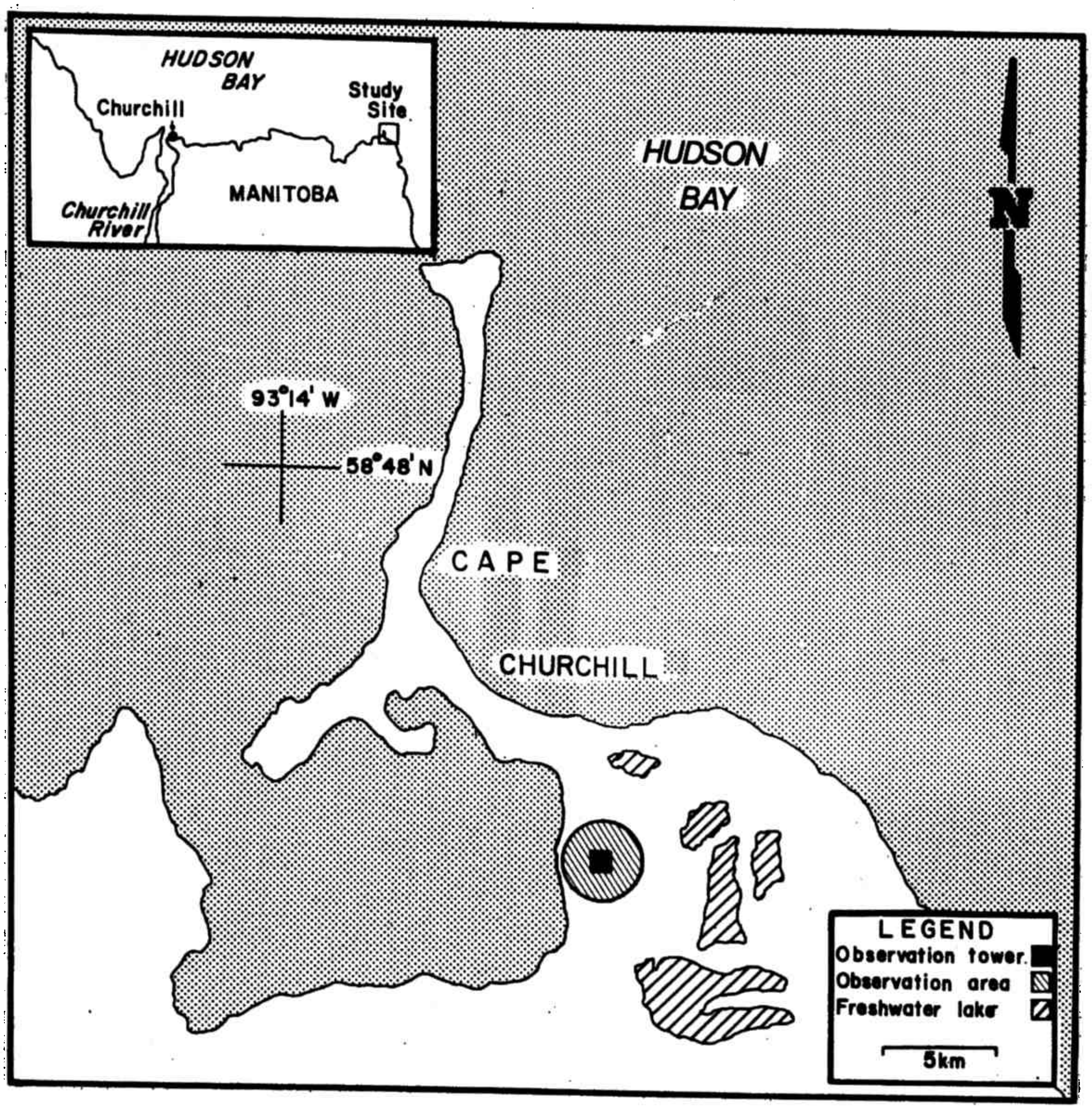

Figure 1. Location of the 1984 bear detection and deterrent study site at Cape Churchill, Manitoba.

METHODS

A complete description of the infra-red detection unit, its method of use and its modifications for an arctic environment, can be found in Appendices A and B. The unit was mounted outside the living quarters located at the top of the observation tower (Figure 2), in a location that would allow an open field of view.

Infra-red filming took place over a five-day period, under a wide range of temperature and weather conditions, during peak daylight hours, and at night under zero light conditions. An audible warning system was attached to the detection device, which allowed field workers to activate the VCR data recorder when bears approached. Although this function was completed manually during the tests, the system could easily be automated.

In order to attract bears to the camp site, whale meat immersed in furnace oil, was burned. The burning whale meat and oil had a strong odour which was carried by the wind. This technique (called "smudging") was implemented at various times throughout the day to attract as many bears as possible to the survey area. During the week of the study, blizzard conditions, incoming and outgoing aircraft, and failure of the 115V AC generator interrupted the continuity of the tests. However, these interruptions did not prevent researchers from recording bears and completing an assessment of the system.

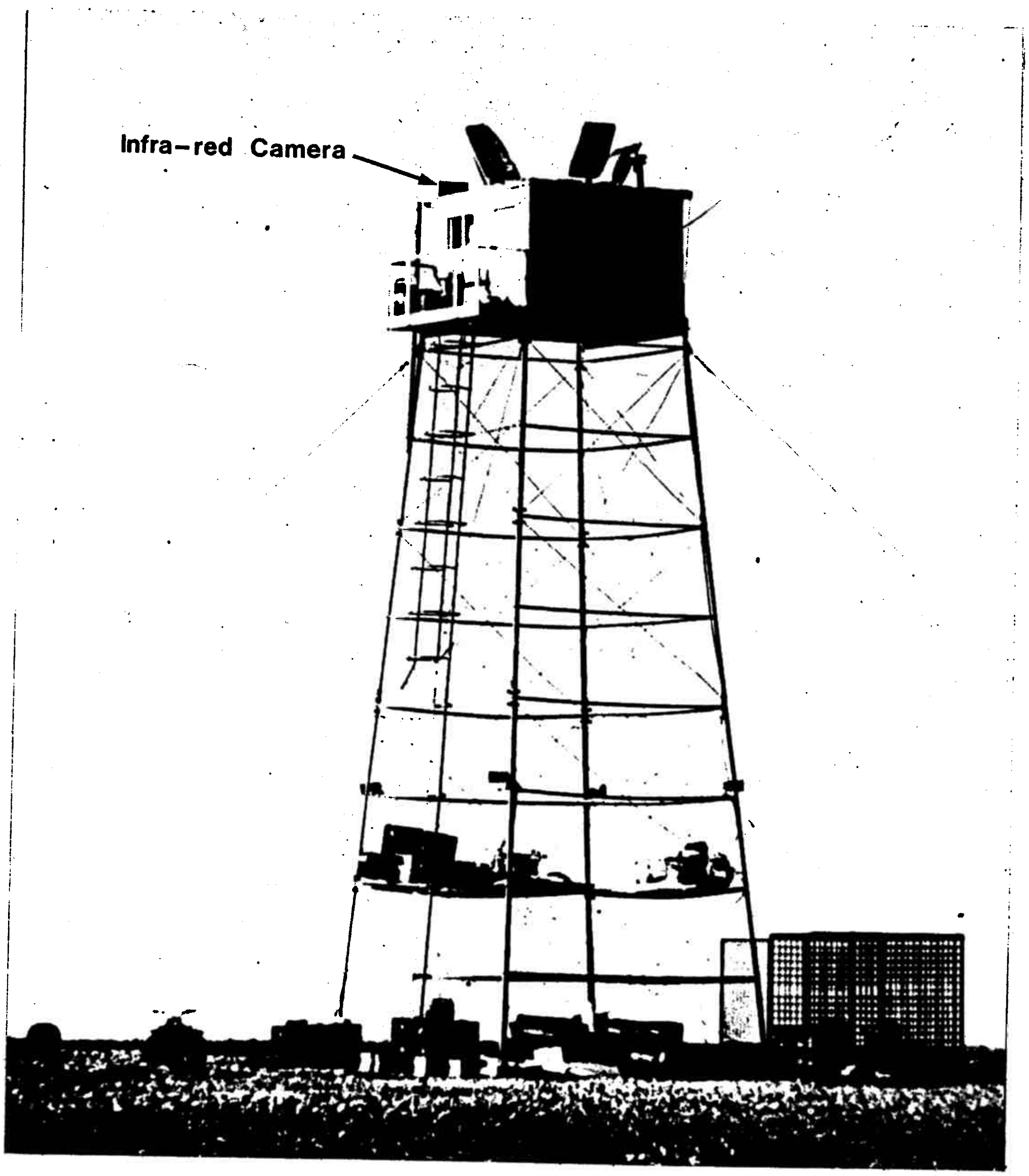

Figure 2. Observation tower/living quarters with infra-red detection unit mounted roof, Cape Churchill, Manitoba, 1984.

RESULTS

The results indicate that the infra-red wavelength of 8-14 microns is a practical band of frequencies for use in detecting polar bears. All recordings were similar in picture quality, and demonstrated that day, night, high wind and/or low temperatures, had little effect on the detector's ability to record the presence of polar bears.

The polar bears appeared on the monitor as sharply contrasting images on a dull grey background, owing to the very different emissivity characteristics of the bear and the snow (Figure 3). The motion detector triggered the alarm instantly and was 100% successful. The pre-set sensitivity adjustments completed in the laboratory prior to undertaking the field study did not have to be re-adjusted at the study site. The audible alarm activated the VCR and the image wave was recorded.

During the evening, bears were active and patrolled the site; their thermal images appearing brightly on the monitor at the pre-set distances of up to 400 m. During this period of the day, wind speeds were often reduced, which may have been coincidental with increased bear activity. It was clear that during the night solar energy was not a factor in the research. The infra-red detector only sensed energy emitted. During daylight hours the images were not noticeably brighter on the detector's monitor. Brightness is correlated to warmer temperature. Infra-red recordings during the evening

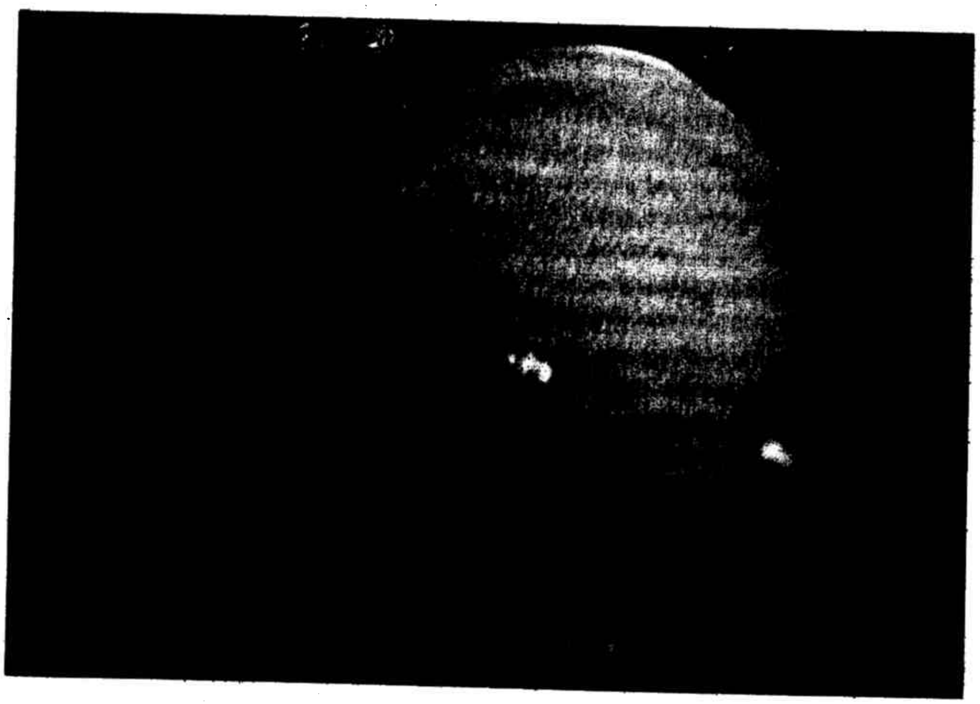

Figure 3. Infra-red plate showing a polar bear at Cape Churchill, Manitoba, 1984.

This plate is taken directly from an infra-red video recording of three polar bears. The recording was made from the top of the Cape Churchill observation tower. The estimated distance to the target was 100 m. Temperature: -15`C. Wind: 16-24 km/h. Date: November 7, 1984. Owing to a one-step processing of the plate, the quality of the picture definition is very degraded from that of the original video film.

illustrated the equipment's advantages over other units using different wavelengths. By detecting only the energy emitted as heat, the bear's image was the only picture on the monitor, and thus was easily detectable and recognizable. The analogue presentation facilitated easy recognition of bears versus other animals.

DISCUSSION

Before this study began, it was thought that the infra-red detection system might only detect bears under more favourable environmental conditions (e.g., low wind and mild temperatures) (Lavigne and Oritsland 1974b). However, the system's detection capabilities were not noticeably affected by temperatures as low as -17°C and winds up to 50 km/h during this study.

In the last decade, improved infra-red technology has resulted in the production of much more sensitive equipment. The germanium optical design has been improved, giving a flatter response across the waveband and, therefore, providing a maximum overall signal for the detector to process. Circuits, such as automatic gain control (AGC), increase effective sensitivity where temperature differences are small. The product is a brightly resolved image at all temperatures within the detector's range of specification. At Cape Churchill, all of the bears were easily detected and were displayed on the monitor as bright analogue images against a dull grey background.

Polar bears, having white pelts, are naturally camouflaged against a snow background, but there may also be thermal advantages to being white in a cold environment. However, the biological significance of pelt colouration with respect to solar energy transfer is not clear. Theoretical analyses and quantitative measurements suggest that some white pelts transfer solar energy more efficiently to the skin than do darker pelts

(Koravik 1964, Oritsland 1971). The results of this research suggest that white polar bear pelts do not absorb or emit a significant amount of solar energy. Infra-red recordings of lions (*Felix spp.*), black bears (*Ursus americanus*) and black labrador dogs (*Canis familiaris*) indicate that some dark pelts not only absorb solar energy, but also emit energy of similar value (C.S.C.I. video tape files).

Tranquilized polar bears may overheat, which suggests that heat transfer from the skin to the air is not efficient. From the infra-red pictures taken during this study, the areas of maximum heat loss from the polar bear appear to be the head and the paws. By way of contrast, previous studies on ringed seals (*Phoca hispida*) (Fitch and Ward In press) indicate that these animals exhibit uniform heat absorption and loss over the entire body. Although infra-red filming of ringed seals was not attempted during night conditions, a significantly brighter target is resolved from ringed seals than is obtained from polar bears during daylight hours. It is, therefore, suggested that seals absorb solar heat more efficiently than do polar bears. However, this statement should be qualified, since it is not clear how total heat dissipation can be measured from a polar bear, when only certain parts of the body appear to conduct heat efficiently.

An interesting observation was made during the course of this study. Polar bears did not patrol the survey areas during periods of high wind conditions. Bait left around the site over night was always taken on calm days. Bears were observed to visit the area and inspect bait sites where they had previously been rewarded, but during blizzard conditions (estimated to be 80 km/h) the bait was left untouched throughout the night and the following day. The evening after the winds had dropped (estimated to be 50 km/h), the bears resumed activity and consumed the bait that had been left from the previous evening. The reason for this behaviour was not determined, but it was thought that perhaps the strong winds dissipated the odour of the bait before the bears detected it.

CONCLUSIONS

Based on the results of this study, the following conclusions can be drawn:

1. The C.S.C.I. infra-red system was highly effective in detecting polar bears in their natural habitat.
2. Adverse weather conditions (winds up to 80 km/h and temperatures as low as -17°C) had no effect on the 8020 infra-red equipment's ability to detect polar bears.
3. The C.S.C.I. infra-red system is easily portable, simple to install, and simple to operate.
4. The incorporation of a motion detection warning device was 100% effective in detecting moving polar bears.
5. Once installed, the C.S.C.I. infra-red system required little maintenance or tuning adjustments.
6. With only slight modification, the C.S.C.I. infra-red system could provide a totally automated polar bear detection warning system.
7. No conclusions regarding the efficiency of solar heat conduction by polar bears could be made from these tests.
8. Polar bears did not patrol baited man-inhabitated areas during periods of adverse weather conditions.

STUDY 2:

A STUDY TO EVALUATE THE APPLICABILITY OF ACOUSTIC STIMULI AS AN EFFECTIVE POLAR BEAR (*Ursus maritimus*) DETERRENT, CAPE CHURCHILL, MANITOBA, 1984

BY

RICHARD FITCH

AND

KATE FITCH

COMPUHEAT SERVICES CANADA INC.

INTRODUCTION

This study was run in conjunction with the infra-red detection tests described in study 1 of this report. It was a preliminary study to investigate the feasibility of using acoustic stimulation as an effective polar bear (*Ursus maritimus*) deterrent. An acoustic system is a technique that has the potential of deterring polar bears without causing them physical harm. Furthermore, it is a versatile system which is easily compatible with an early warning system such as the infra-red detection technique.

In this study, a number of frequencies were investigated for the following two reasons:

1. to observe the overt effects that this kind of stimulus would have on bear behaviour, and
2. to attempt to determine the frequencies (if any) that most effectively deter polar bears.

Literature Review

There is a distinct lack of research on the behavioural effects of acoustic stimuli on wildlife and, in particular, on bears. However, it is known that different kinds of noise can produce distinct behavioural reactions. For example, in Canada's Mountain Parks, gunshots (loud, short duration sounds) have been used to frighten Big-horn sheep (*Ovis canadensis*) away from highways. Similarly, large elk (Cervus canadensis) herds have been deterred from highways in Wyoming by discharging firearms (Ward et al. 1976). Strong individual reactions were recorded with grizzly bears (Ursus arctos) to the noise of small, fixed-wing aircraft (McCourt et al. 1974). In a summary of the behavioural effects of noise on wildlife, Dufour (1980) noted that an unexpected noise almost always elicited a frightened or startled response. Moreover, some animals tend to avoid the area near an unpleasant noise source: avoidance behaviour has been observed in geese (Branta spp.), caribou (Rangifer spp.), Dall's sheep (Ovis dalli), and deer (Odocoileus spp.). Stenhouse (1983) found that recordings of barking dogs did not deter polar bears, and in some instances elicited agressive responses. Dufour (1980) cautions that research completed to date has not clearly determined whether it is the actual noise to which the animals have reacted, or the human presence associated with it (e.g., the person firing the gun).

It is a well established fact that rats (Rattus spp.) tested in a laboratory display avoidance behaviour when presented with an electrical shock (Sprock et al. 1967). Ultrasonic radiation also appears to act as an effective negative stimulus. Sprock et al. (1967), in experiments conducted with laboratory rats, reported that the animals were effectively repelled when presented with intermittent tones of varied frequencies or with previously recorded rat distress calls. Greaves and Rowe (1969) exposed confined colonies of rats to pulsed ultrasonic frequencies and reported that the test animals refused to enter the testing area because of a strong aversion to the sonic field. Therefore, it is likely that an appropriate radiated tone could act as an irritating stimulus to an approaching polar bear, and result in the retreat of the bear from the area of the sound's source. Carefully controlled to radiate as the bear approached, and terminated as the animal retreated, it has the potential of being an effective deterrent.

The peak sensitivity for humans is generally considered to be 1 - 4 kHz, although some people can hear up to and beyond 16 kHz. Rats respond to frequencies well above the human hearing range (21 - 29 kHz) and will flee when subjected to a sound stimulus in this range (24 - 28kHz) (Greaves and Rowe 1969). Viol (1980 as cited in Damas and Smith 1984, p. 243) suggested that moose in Sweden responded to the 15 - 18kHz band. Masterton et al. (1969) indicated that animals of greater body weight are less able to hear sounds generated at higher frequencies; however, it is more likely that larger animals have larger ear diaphragms and, therefore, are sensitive to lower frequencies. It was, therefore, reasonable to expect that, although ultrasound would be ideal as a stimulus in terms of its inaudibility to humans and its effectiveness as a unique sound in the natural environment, it would probably not be heard by polar bears.

Habituation response was reported by Sprock et al. (1967) and Greaves and Rowe (1969) from their work with laboratory rats. This refers to the behavioural response of animals that become accustomed to, and eventually ignore, continuously present monotone frequencies. Polar bears may also become habituated to monotone frequencies if continually subjected to the sound.

STUDY AREA

Tests were completed at Cape Churchill, Manitoba from 8 to 9 November 1984. A detailed description of the study area is provided by Derocher and Miller (In prep.).

METHODS

Test Equipment

The test equipment used in this study is described in Appendix D. Two transducers, a low-to-mid range horn and a mid-to-high range tweeter, were used. The transducers maintained a flat response throughout the range of frequenices tested. They were placed in a forty-five gallon drum, which was partially opened at one end to protect the equipment from weather and curious bears. The drum was then placed inside an observation cage 1 m from the bait site with the open end directed at the bait. A two-pair conductor cable was routed from the transducers to the power amplifier and the frequency generator located in the living quarters approximately 30 m above the bait site. To ensure that all bears received the auditory stimuli at a constant distance (1 m) from the transducers, the bait drum was chained in position. Bears were attracted to the site by smudging whale meat (Stenhouse and Cattet 1984).

Test Procedure

Two experiments were implemented, each approximately 4-5 hours in length on 8-9 November 1985. Experiment 1 was completed to determine the bandwidth at which bears were most sensitive. Experiment 2 was completed to observe the behaviour of each bear when presented with a sound stimulus from the bandwidth chosen as a result of experiment 1. Presentation of the stimulus in experiment 2 was done in both a continuous and a pulsed mode to identify any observable differences in the resulting behaviour of the bears.

Experiment 1 was carried out over two sessions. During session 1 (November 8), the bears were presented with auditory stimuli in a stepped order from 0.1 kHz to 30.0 kHz. During session 2 (November 9), the bears were presented with the same auditory frequencies, but in a random order.

Like experiment 1, experiment 2 was implemented over two sessions. During the first session (November 8), stimuli of 1 - 2kHz were emitted as the experimental bears arrived at the bait site. Each stimulus was presented as a continuous 15 second tone. In the second session (November 9), frequencies from the same range (1 - 2kHz) were again presented, but in a pulsed mode.

Individual bears were identified by markings that had been previously put on the bears. Unmarked bears were recorded as such (U/M). Certain recognition was attempted through size, age and noticeable morphological traits, but only occasionally were the observers able to confidently record the identification of an unmarked bear. These bears were designated on the tables by number (e.g., U/M#1). Bear behaviour is described in each table. All attempts were made to keep behavioural descriptions consistent and objective (Table 1).

Table 1. Behavioural catalogue of polar bears subjected to auditory stimuli at Cape Churchill, Manitoba, 1984.

Behavioural Description	Definition
Ran Away	Immediate retreat at high speed
Walked Away	Immediate retreat at a walk
Head Shaking	Movement of head back and forth
Agitated	Uneasy, restless, nervous
Startled	Alert behaviour
Backed Off	Walked backwards away from site
No Reaction	Continued original behaviour (e.g., feeding)
Jumped Back	A quick jump backwards

Testing procedures were limited in number and duration due to unsuitable weather conditions and time restraints. More bears were tested during experiment 1 because fewer bears were present at the test site during experiment 2.

RESULTS

Experiment 1. Tests to Determine Effective Bandwidth

The results of experiment 1 are outlined in Tables 2 and 3, in which the observations of each bear's behavioural response to a particular tone are described. The results from session 1 able 2) indicate that polar bears responded to a bandwidth of 1 - 9kHz. In session 2, only three bears were tested, and the results indicate inconsistent responses - bears responded to a selected frequency at one time, but not at another. Of the three experimental bears, one bear responded to the 1.5 kHz and 3 kHz tones, while the other two bears showed no reaction to any stimuli presented.

During experiment 1, no bears reacted to the ultrasonic stimuli, nor was there any apparent reaction to the frequencies immediately below the ultrasonic band (10-20kHz). The polar bears were most agitated when subjected to sounds in the 1 - 4kHz range of frequencies (all behavioural responses were more exaggerated). Most bears subjected to this band of tones retreated without hesitation. Therefore, it was decided to use 1 kHz and 2 kHz as the auditory tones for experiment 2.

Table 2. Experiment 1, session 1: response of polar bears to stepped auditory stimuli in the 0.1 - 30.0 kHz frequency range, Cape Churchill, Manitoba, 1984.

Time[1]	Frequency[2] (kHz)	Observed Behaviour	Bear[3]
18:20	0.1	ran away 40 m, lay down	U/M
nr	0.1	agitated, walked 20 m, stopped, remained at this distance	C Z
nr	0.1	startled, jumped back, backed off, walked away	U/M
nr	1.0	grabbed bait, ran away	U/M
nr	1.0	ran 20 m, shook head, walked away	U/M
nr	1.0	ran away after 5 seconds	A Q
nr	1.0	agitated	C Z
nr	1.5	ran for about 40 m	C Z
nr	2.0	agitated shook head, ran about 40 m	A Q
		shook head, ran 40 m	C Z
nr	3.0	shook head, ran about 40 m	A Q
		shook head, ran away	C Z
nr	4.0	shook head, ran away	A Q
		shook head, ran away	C Z
nr	5.0	ran 20 m	A Q
		ran away	C Z
nr	7.0	ran away, returned when tone stopped	A Q
		ran away, returned when tone stopped	C Z
nr	8.0	walked away	A Q
		walked away	C Z
nr	9.0	agitated, walked 10 m	A Q, C Z
nr	10.0	no reaction	A Q, C Z

Table 2. Continued

Time	Frequency (kHz)	Observed Behaviour	Bear
nr	13.0	no reaction	A Q, C Z
nr	14.0	no reaction	U/M, C Z
20:25	15.0	no reaction	U/M, C Z
	15.0	no reaction	U/M
nr	20.0	no reaction	U/M
nr	20.0	no reaction	U/M
nr	25.0	no reaction	U/M
nr	25.0	no reaction	U/M, C Z
nr	30.0	no reaction	U/M, C Z
nr	30.0	no reaction	U/M, C Z

---

1 Times in minutes:seconds. nr - not recorded.

2 Frequencies: various, range from 0.1 - 30 kHz.
Signal: continuous, 15 s duration, stepped presentation from low (0.1kHz) to high (30kHz).
Distance: tone emitted 1 m from bait site.
Conditions: wind 20km/h in same direction as signal.
Temperature: -15°C.

3 U/M - Unmarked bears.
Letters indicate marked bears.

Table 3. Experiment 1, session 2: response of polar bears to random auditory stimuli in the 0.1 - 30.0 kHz frequency range, Cape Churchill, Manitoba, 1984.

Time[1]	Frequency[2] (kHz)	Observed Behaviour	Bear[3]
10:35	2.0	no reaction no reaction	U/M#1 C Z
10:35	1.0	no reaction no reaction	U/M#1 C Z
10:38	14.0	no reaction no reaction	U/M#1 C Z
	20.0	no reaction no reaction	U/M#1 C Z
10:40	25.0	no reaction no reaction	U/M#1 C Z
	30.0	no reaction no reaction	U/M#1 C Z
10:42	1.5	backed off	C Z
10:48	3.0	backed off, ran away	C Z
11:15	20.0	no reaction	U/M#2
11:16	2.0	no reaction	U/M#2
11:17	1.0	no reaction	U/M#2
11:20	3.0	no reaction	U/M#2
11:21	4.0	no reaction	U/M#2

[1]Time in minutes:seconds.
[2]Frequencies: Range from 0.1 - 30.0 kHz.
Signal: continuous, 15 s duration, random presentation.
Distance: tone emitted 1 m from bait site
Conditions wind 25km/h in opposite direction (against) signal.
Temperature: -6`C.
[3]U/M - Unmarked bears, only designated with a number when recognized by special characteristics. Letters indicate marked bears

Experiment 2: Tests To Determine The Effectiveness Of Continuous and Pulsed Auditory Stimuli

The results of experiment 2 (sessions 1 and 2) are outlined in Tables 4 and 5. All bears were deterred by the continuous (15 seconds) tones presented in all tests (n=17) of session 1. Similarly, during session 2, the pulsed stimuli (n=5) deterred all bears.

It is important to note that wind conditions were different for the two sessions. In sessions 1 of experiments 1 and 2 (November 8), the wind was blowing in the same direction as the sound was being emitted, while in sessions 2 of experiments 1 and 2 (November 9), the wind was blowing in the opposite direction.

It is also significant to note that some of the experimental bears may have previously visited the test site and were aware of human presence. Bears may also have detected human scent; however, during the testing sessions the bears appeared to be neither visibly nor audibly aware of human presence.

Table 4. Experiment 2, session 1: response of polar bears to continuous auditory stimuli[1] at a frequency of 2 kHz, Cape Churchill, Manitoba, 1984.

Time	Observed Behaviour	Bear[2]
20:25[3]	backed off, shook head walked away	A Q
	ran away	U/M
	ran away	C Z
	ran away	U/M
	ran away	U/M
	ran away	C Z
	ran away	U/M
	hesitated for 3 seconds and ran away	U/M#1 U/M
	ran away	C Z
	ran away	U/M
	backed off and ran away	U/M
	walked away	U/M
	ran away	U/M
	walked away	U/M
21:35	ran away	U/M

[1] Frequency: 2khz @ 30 watts.
Signal: continuous, 15 s. duration.
Distance tone emitted 1 m from bait site.
Conditions wind 20 km/h, in same direction as radiated signal.
Temperature: -17`C.

[2] U/M - Unmarked bears, only designated with a number when recognized by special characteristics. Letters indicate marked bears.

[3] Time in minutes:seconds.

Table 5. Experiment 2, session 2: response of polar bears to pulsed auditory stimuli[1] at a frequency of 1 kHz, Cape Churchill, Manitoba, 1984.

Time[2]	Observed Behaviour	Bear
11:23	shook head, backed off	U/M[3]
11:25	backed off walked away	U/M
11:26	backed off, walked away	U/M
11:32	ran away	U/M
12:10	ran away	U/M

1 Frequency: 1kHz @ 30 watts.
Signal: pulsed 0.5 s on/0.5 s off.
Distance: tone emitted 1 m from bait site.
Conditions: wind 20 km/h in same direction as radiated signal.
Temperature: -6°C.
2 Time in minutes:seconds.
3 U/M - Unmarked bear.

DISCUSSION

All bears exhibited a strong aversive reaction to the acoustic stimuli generated during experiment 2. It is the opinion of the observers that the aversive response was more exaggerated with the use of the pulsed mode during experiment 2, session 2. This is further supported when a comparison is made between the results of experiment 1, session 2 and experiment 2, session 2 (November 9) when the same environmental conditions prevailed (the wind conditions being of particular significance). All experimental bears were deterred by the pulsed mode stimuli (experiment 2, session 2); however, only one of three subjects was deterred by the continuous mode stimuli (experiment 1, session 2).

The results of this study suggest that most of the polar bears were sensitive to the sonic bandwidth of 0.1 - 9 kHz. The majority of subjects reacted to the 1 - 4kHz frequencies. The bears did not appear to detect ultrasonic radiation, nor did they react to frequencies of 10 - 30kHz.

Because of the small number of bears tested during this study, and the limited testing time, more auditory stimuli research is needed before final conclusions can be drawn.

The results of this preliminary study warrant further testing of the acoustic deterrent system. Using a 1 or 2 kHz frequency as a negative stimulus in a pulsed mode appears to have potential as an effective technique for deterring bears. In keeping with the goals of the Government of the Northwest Territories' bear detection and deterrent program, this system is physically harmless to the animals, is versatile, and could easily be installed and maintained in a variety of locations. Used with an early warning detection system it could prove to be an effective method of deterring bears.

CONSIDERATIONS FOR FURTHER TESTING

Additional testing should be initiated to address the following issues:

1. The effect of background noise (e.g., generator) on a polar bear's ability to detect the tones clearly is not well understood. Perhaps the tones would have been more easily distinguished if background noise had not existed.
2. The baited test site had been available for approximately 2 weeks prior to testing. Any, or all, of the subjects may have encountered it, been positively reinforced by the whale meat and, therefore, may have learned an approach behaviour. This fact may have rendered the sound deterrent less effective for those bears. A bear approaching a site for the first time may react differently.
3. Any of the bears may have been subjected to other deterrent tests (e.g., rubber batons and 12 gauge plastic slugs).
4. In this study, the limitations restricted:
   (a) the size of the test sample,
   (b) the testing of alternative amplitudes (e.g., louder and softer noise),
   (c) extensive testing with the pulsed mode presentation,
   (d) the control and variation of background noise, and
   (e) the recording of the behaviour patterns of a control

group of bears (receiving only the whale meat and no sound), which could have been used for comparison purposes with the test group to establish statistically significant behaviour patterns.

ACKNOWLEDGEMENTS

Special thanks are extended to the following members of the Northwest Territories Department of Renewable Resources: Paul Gray, for his scientific input and help in co-ordinating the study and reviewing the final report; Steve Miller, for his tremendous help on the survey site and companionship during the study; Andy Derocher, for his co-operation and scientific advice prior to the study; Peter Clarkson and Alison Welch for reviewing this report; and Elizabeth MacDonald and Jackie Bell for their patience and word processing skills.

We also greatly appreciate the help and advice given by Jim McComiskey of Gulf Canada Resources and John Ward of Dome Petroleum Ltd.

LITERATURE CITED

Damas and Smith. 1984. Wildlife mortality in transportation corridors in Canada's national parks, impact and mitigation. Division of DSL Consultants Ltd., Ottawa, Ontario. 397 pp.

Derocher, A. and S. Miller. (In prep.) Bear deterrent study (twelve gauge ferret shell tests), Cape Churchill, Manitoba, 1984. NWT Dept. of Renewable Resources File Rep. No. 54.

Dufour, P.A. 1980. Effects of noise on wildlife and other animals, review of research since 1971. Informatics Inc., Rockville, MD. 106 pp.

Fitch, R. and J.G. Ward. (In press). Field evaluation of an infra-red detection technique for surveying Arctic marine mammals. Prepared for: Dome Petroleum Limited, Gulf Canada Resources Inc., Department of Fisheries and Oceans, Department of Indian and Northern Affairs Canada, and Petro-Canada Inc.

Greaves, J.H. and F.P. Rowe. 1969. Responses of confined rodent populations to an ultrasound generator. J. Wildl. Manage. 33(2):409-417.

Kovarik, M. 1964. Flow of heat in an irradiated protective cover. Nature 201:1085-1087.

Lavigne, D.M. and N.A. Oritsland. 1974a. Black polar bears. Nature 251(5472):218-219.

Lavigne, D.M. and N.A. Oritsland. 1974b. Ultra-violet photography: a new application for remote sensing of mammals. Can. J. Zool. 52:939-941.

Masterton, B., H. Heffner and R. Ravizza. 1969. The evolution of human hearing. J. Acoust. Soc. Amer. 45:966-982.

McCourt, K.H., J.J. Russel, D. Doll, J.D. Feist, and W. McCrory. 1974. Distribution and movements of the Porcupine caribou herd in the Yukon, 1972. Chp. 2 In: R.D. Jakimchuk (ed.). The Porcupine caribou herd, Canada. Arctic Gas Biological Report Series Vol. 4. Canadian Arctic Gas Study Ltd., Calgary.

Oritsland, N.A. 1971. Wavelength-dependent solar heating of harp seals (*Pagephilas groenlandicus*). Comp. Biochem. Physiol. 40A:359-361.

Sprock, C., R.E. Howard and C. Jacob. 1967. Sound as a deterrent to rats and mice. J. Wildlife Manage. 31(4):729-740.

Stenhouse, G.B. 1982. Bear detection and deterrent study; Cape Churchill, Manitoba, 1981. NWT Wildl. Serv. File Rep. No. 23. 64 pp.

Stenhouse, G. 1983. Bear detection and deterrent study, Cape Churchill, Manitoba, 1982. NWT Wildl. Serv. File Rep. No. 37. 58 pp.

Stenhouse, G. and M. Cattet. 1984. Bear detection and deterrent study, Cape Churchill, Manitoba, 1983. NWT Wildl. Serv. File Rep. No. 44. 62 pp.

Ward, A.L., J.J. Cupal, G.A. Goodwin and H.D. Morris. 1976. Effects on highway construction and use on big game populations. Rep. FHWA RD-76-174. 92 pp.

APPENDIX A. COMPONENTS OF THE INFRA-RED DETECTION SYSTEM

The infra-red system was comprised of the following equipment:

a) One model 8020 portable (self-powered, supplied with a 115V AC power source) infra-red detector, receiving and displaying emitted electromagnetic energy in the spectrum of 8 - 14 microns. Included were 25 mm and 50 mm focal heads.

b) Two Canon VR20 portable video cassette recorders for storing data from the 8020 and video camera.

c) One microprocessed thermal printer to produce immediate hard copy plates of any frame in real time or of the recorded data.

d) One RCA motion detector that will warn researchers of new data appearing in the 8020 detector's field of view (this device had not been used in this configuration before by C.S.C.I.).

e) One RCA scanner to revolve and step the 8020 detector.

f) One composite video camera (400 to 700 nm) for additional support information.

g) One custom-made thermally insulated and heated housing for the 8020 detector and electronics unit.

h) One custom-made germanium "window", with a spectral response of 8 - 14 microns.

i) One video monitor (both the 8020 and the video camera had built-in monitors but they were too small for constant viewing).

j) One universal 115V AC to 12V DC power supply (at 3 amps continuous duty) for the operation of the detection equipment.

k) Two 12V DC battery power sources as back-up to the 115V AC supply in case of generator failure.

l) One variable output sine wave generator to cover frequencies ranging from 30Hz to 30kHz.

m) Two transducers.

n) One power supply.

o) Miscellaneous equipment, such as spare parts, test equipment, tools, and hardware for installation.

APPENDIX B. TECHNICAL DESCRIPTION OF THE EQUIPMENT USED

The infra-red equipment used by C.S.C.I. during the study was a model 8020 man-portable detector. It utilizes the pyroelectric videcon principle (P.E.V.), which does not require liquid nitrogen commonly used in other detection systems. The equipment is suitable for use in any land, sea, or air vehicle with no danger of spillage.

The detector accepts infra-red radiation through a germanium lens, which converts the information to a monochromatic tone on a built-in video monitor. The analogue presentation appears in scales of grey tone, similar to the picture produced on a black and white television. The tones denote differences in the surface temperature of all objects in view. Black or white tones correspond to cold or warm, respectively. A wide range of easily fitted focal lengths are available in increments from 18-130mm, and the detector can resolve temperature differences to 0.2`C. During this study, the two focal lengths of 25 mm and 50 mm were available and used. The standard lens for the detector is a 50 mm f/0.8 germanium optic. This lens has a 20` field of view, which produces a swath width of approximately 100 m at a distance of 305 m. The 25 mm lens has a 40` field of view, and provides a swath width of approximately 220 m at 305 m. Since a scanner was used, the swath of the 50 mm lens was not important. However, it was more desireable to use this focal length owing to the higher resolution charactertistics at the distances tested.

The infra-red system detects and records electromagnetic energy in the wavelength of 8 - 14 microns. However, other frequencies can be detected at reduced efficiency. The spectral response is largely dictated by the transparency of the input material, and can be altered through the use of selective filters. The infra-red detection and recording system can be used to survey large areas quickly to determine the presense of polar bears under any light conditions. Detectability is a function of the infra-red energy emitted. A unit can also be used as an automated census device.

The 8020 detector operates in two modes:

1. a chopped mode (designed for still or tripod operation); and,
2. a panned mode (used when the target and the detector are moving relative to each other).

The panned mode is desireable in most cases because it is more sensitive. This mode is always used in aerial surveys, for example, owing to the movement of the aircraft relative to the target. In the chopped mode, the function of the chopper is to ensure that at any point on the target, the reading beam permits the detection of temperature variation between two successive scans. Consequently, a still object at a constant temperature cannot be detected when the target has reached its equilibrium. In this case it is necessary to "chop" the infra-red flux by continuously displacing the image on the target (panning). Both methods were tested in this study.

APPENDIX C. MODIFICATIONS OF THE INFRA-RED DETECTION SYSTEM

The 8020 detector is not designed to withstand contact with precipitation or prolonged temperatures below -15`C. In order to accommodate these limitations, a special thermally-insulated and heated housing was constructed (Figure 4). In addition, because the detection system was fully sealed, the focal head was also encased. In this configuration, a germanium-glazed window was placed at one end of the housing, abutted to the face of the detector. Germanium will not impede the spectral response of the infra-red band emitted.

The housing was custom-made and designed to fit an RCA scanner, which is comprised of a servo-controlled motor, remotely operated by a separate controller unit. The controller unit was positioned within the living quarters at the top of the tower and was designed to allow the operator to stop, rotate and pre-set a desired arc of up to 350`. The system allowed automatic scanning, stepped scanning, or manual control. The scanning and control units were simple to construct and operate. The units were supplied with a power source of 115V AC and a built-in DC converter for the motor. Once the detector was installed on the roof, three cables were routed into the living quarters; two carried power and the third the video information.

A motion detector, manufactured by RCA and commonly used for security systems, was incorporated into the system to allow warning of incoming data. The motion detector works on a

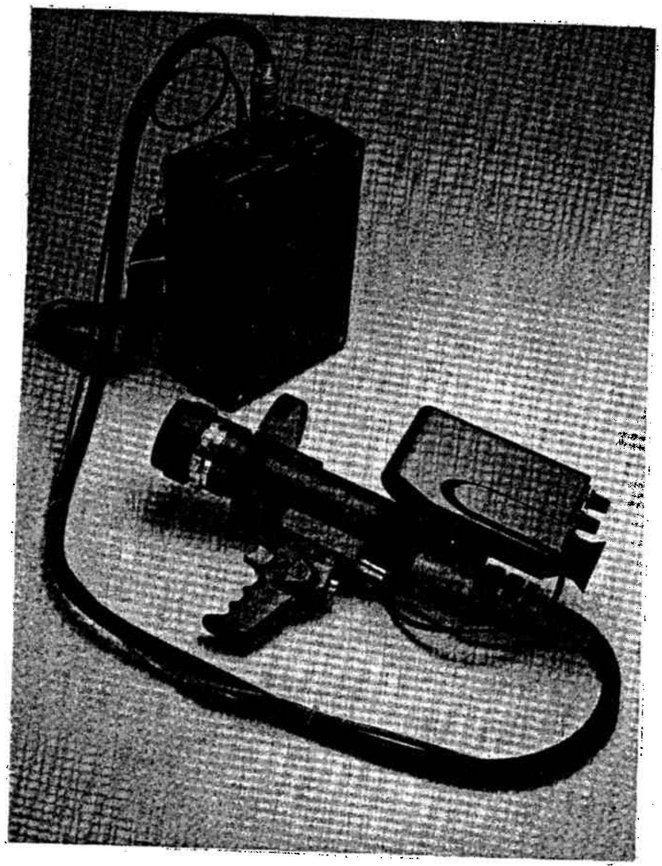

Figure 4. Infra-red detection system used for polar bear detection at Cape Churchill, Manitoba, 1984.

The detection unit was placed in a special thermally-insulted and heated housing and placed on top of the observation tower.

"change-of-contrast" principle, which produces an alarm. While this type of detector cannot discriminate between data, it allowed the operator some freedom from constant monitor viewing. Ultimately, a computerized motion detector would be desirable. However, at this point in time the costs were prohibitive.

In addition, a microprocessed hard copy thermal printer was included. This machine produced plates of any frame of any part of the film at 1/60th of a second. The machine will "grab" data from either recorded or real-time information. The printer digitizes the analogue waveform and stores it in the memory and, therefore, any number of copies can be produced. The memory is cleared by entering new information. As a support feature, a second video camera (400-700 n.m.) was utilized within the accommodation room for collecting data for purposes of comparison.

The entire system (a solid state design partially self-powered by batteries) consumed approximately 4 amps DC at peak production. A suitable 115V AC generator was necessary to meet power demands. The batteries were charged during off-peak periods. In practice, the operator was able to observe a 360° area day or night, and view the monitor only when alerted by the motion detector.

A flow chart of the system is illustrated in Figure 5. Except for the special germanium window, all of the equipment used is available commercially.

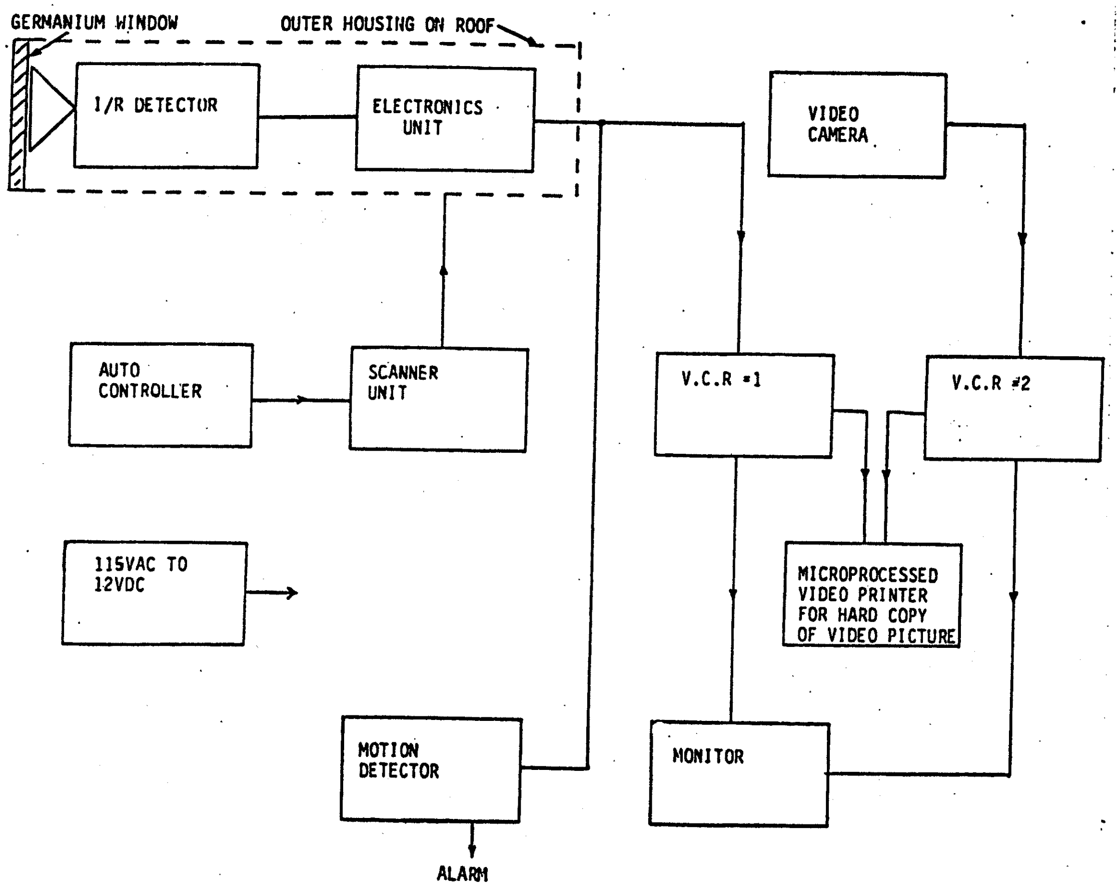

Figure 5. Flow chart of infra-red system used at Cape Churchill, Manitoba, 1984.

Following equipment installation, initial recordings of bears under various weather, temperature, and light conditions were obtained. During this period, the equipment was adjusted to provide optimal focus and scanning motion for the distances of interest. These pre-set positions were then fixed for the remainder of the study.

APPENDIX D. COMPONENTS USED IN SONIC AND ULTRA-SONIC TESTS

Description	Model
Audio generator 5-60 X1 to X10K	200CD (Hewlett Pakard)
Power amplifier, dynamic power o/p 38 watts @ 8 ohms. Frequency response: 20 - 5 hz +- 2db.	KA-2002A (Kenwood)
Horn transducer #1, Frequency response: 20 - 15kHz @ 30 watts	Norske Hoyttaler Fabrikk
Leaf transducer #2, Frequency response: 5 - 50kHz @ 30 watts	Realistic

Twin pair shielded 16 gauge cable was used to couple the transducers to the power amplifier at a distance of approximately 20 m.