TEST REPORT - BUILDING FREEZE ALARM SYSTEMS

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FOREWORD

Unintentional freeze-ups can cause a considerable amount of damage to a building's mechanical and architectural components resulting in costly repairs and the temporary loss of the facility's usage. The major complement of freeze-ups occur in unattended buildings as a result of heating unit failures. In many cases, buildings and content damage could be eliminated if simple alarm systems were available to give maintenance personnel advance warning of abnormally low temperatures.

This report, along with an earlier one entitled "Design Report -- Building Freeze Alarm System," describes design considerations of VHF radio alarm systems and tests performed on 3 prototype units. Assembled primarily from off-the-shelf components, these 2 to 25 watt units can be expected to provide reliable freeze protection under a wide variety of installation conditions. In addition to freeze protection, the units can be easily modified to be activated by any switch closure type sensor.

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1.0 SUMMARY

A radio-based freeze alarm device is being developed for installation in unattended state-owned buildings. The device is a self-contained, low temperature alarm capable of sending an alarm via low power VHF radio signal to small portable "beeper" receiving units.

As part of a Research and Development Program, three alarm units of varying power output have been fabricated by two communications firms (see Appendix IV for addresses). Each unit consists of a temperature alarm thermostat, radio transmitter enclosed in a cabinet, a rechargeable battery and charger, an antenna, and portable beepers. The units are designed to be easily mounted in existing or new buildings and pagers are small pocket type units to be carried by people monitoring building operation.

These units have been subjected to environmental and operational testing at the University of Alaska-Fairbanks campus. The units tested were:

* ACS 2-watt unit, manufactured by Automated Custom Systems.
* CSI 15-watt unit, manufactured by Communications Systems Inc.
* ACS 25-watt unit, manufactured by Automated Custom Systems.

Results of the testing program are as follows:

1. All units work as radio-based freeze alarm units, although performance between units varies widely.
   a. In terms of signal strength of the alarm transmitter and continued transmitting power at reduced temperatures, the 15-watt CSI unit out-performed the other two units tested.
   b. Encoding capabilities for ACS equipment was more flexible, making these units more applicable to multi-building facilities, where more than one zone must be annunciated. The ACS equipment, however, transmitted only five separate alarm signals when freeze alarm occurred. This sequencing should be changed to a continuously cycling alarm signal, to provide better coverage. The current sequence is not recommended.
2. The type of antenna used and its mounting location are two critical considerations for the system. Alarm signal strength varied significantly with size of antenna, for all three units.

3. Freeze alarm units could be made to work with small unit-mounted antennas that are within the building shell. Here, signals would actuate beeper units at significant distances from the test location, as long as the structure was made strictly of wood products. Where the building contained aluminum foil backed fiberglas insulation, for example, signal strengths were effectively blocked. Some attenuation was observed even with wood structures. Exterior roof-mounted antennas are recommended for the freeze alarm units.

4. With all the units, alarm signals were strong enough to activate the pager unit up to seven miles from the test structure. These activations were over generally flat areas with low rolling hills. Widely varying results can be expected at locations other than Fairbanks, due to terrain and signal transmission variations.

5. The systems generally operate satisfactorily, and can be expected to give a good reliable alarm protection under many installation circumstances. The three units were assembled from standard off-the-shelf modules and similar units should be able to be supplied by reputable building alarm and communication firms. Costs for a complete system in small unit quantities range from $2,000.00 to $3,000.00.

2.0 INTRODUCTION

This is a companion report to the **"Design Report - Building Freeze Alarm Systems"**, dated August 1982. In that report the concept of a radio-based freeze alarm system is advanced. This concept uses small scale Very High Frequency (VHF) radio equipment in a small, wall-mounted enclosure in conjunction with portable belt or pocket beepers to annunciate freeze alarms. Freeze sensing thermostats are located either in the enclosure, or at other locations within the building. The system is designed to transmit a warning signal to the pager at locations up to seven miles from the radio transmitter location.

Design requirements for the equipment are centered around providing a preassembled, pretested unit capable of sensing abnormal low temperatures and alerting maintenance personnel, in a timely manner, to the situation. Major considerations are listed as follows:

1. Resistance to false alarms.

2. Minimal maintenance requirements.

3. Minimal on-site installation labor.

4. Battery backup to allow operation under loss of main power.

5. User friendly.

6. Unobtrusive and vandal proof.

With these design conditions set forth by the State of Alaska's Energy and Buildings Group, two separate concepts were developed, entitled Option 1: **Hard Wired System** and Option 2: **Self-Contained System.**

The Option 1 system requires extensive in-building wiring, can accommodate more than one alarm zone, and includes an in-building local monitoring panel. This option is most applicable to large facilities and buildings yet in the design stage.

The Option 2 self-contained system is a less elaborate unit that contains a thermostat, battery backup, and transmitter package in one enclosure. This unit requires minimal installation labor, is a single zone unit, and is applicable to small buildings.

This report details the procurement of three Option 2 systems, and the testing performed on the units at the University of Alaska-Fairbanks campus. Conclusions are drawn from the testing to assist potential users in selection of units.

3.0 TESTING METHODOLOGY

3.1 Equipment Features

Each of the three freeze alarm units consist of a basic alarm thermostat, VHF radio transmitter, and a number of different system options to allow configuration to individual circumstances. The sequence of operation for alarming is as follows:

* When the alarm thermostat senses a temperature at or below set point, the thermostat contacts close and activate the transmitter circuit.

* After a time delay, the transmitter sends out an encoded signal at preset time intervals.

* The pager receiver senses the signal, and activates a tone progression.

The equipment is enclosed in a lockable wall-mounted enclosure. Power supply is via a standard battery trickle charger that connects into the building electrical system. The unit comes equipped with rechargeable batteries to allow for continued alarm annunciation after failure of building power.

The transmitter equipment operates at a frequency of 158.775 MHz, a State of Alaska communications test frequency.

Configuration options available include:

* Transmitter antennas range from small, flexible "rubber duckie" units mounted on the alarm enclosure, to large, high gain vertical units designed for mounting on a building roof.

* Remote alarm thermostats may be mounted at a number of locations within a building.

* "Beeper" units come with a unit charger that includes a ground plane antenna, amplifier, and speaker. This allows the beepers to sound a freeze alarm when being stored at night in the unit charger.

* Loss of power alarm.

* Automatic transmitter test features.

3.2 Description of Alarm Sequencing

The method by which the freeze alarm units transmit alarm signals is an important design consideration. A large number of radio message formats are possible with the availability of digital encoding equipment. Alarm sequencing for all units tested consists of a timed on/off cycle that will give alarms over a long time period with minimal power consumption. Sequencing for each of the units procured is as follows:

CSI 15-watt: This alarm consists of a commercially available mobile transmitter controlled by a custom designed module.

This unit provides two different alarm tone sequences based on two potentially serious conditions. The "freeze" alarm is a series of tones repeated for five seconds followed by a steady tone for an additional five seconds. The "loss of AC power" alarm, which alerts of possible freeze-up due to AC power loss, initiates a series of tones followed by receiver squelch.

In either case the alarm is repeated at five minute intervals while the condition exists and is reset to a non-alarm condition automatically when the initiating condition is corrected (i.e. the temperature rises above setpoint or AC power is restored).

ACS 2-watt & ACS 25-watt: A microprocessor accepts thermostat and low battery voltage contact closures to actuate a separate 2-watt RF transmitter module. An additional amplifier module is supplied to increase the power output to 25 watts.

This unit provides an encoded sequence to activate a specific pager receiver unit. The alert tone sequence is generated when either a low temperature or a low battery voltage contact closure is provided to the microprocessor. The alarm signal is transmitted at fifty-second intervals for a total of five transmissions as long as the contact closure remains, and then shuts off. Opening the contacts resets the unit to non-alarm condition. A reclosing of contacts initiates a new alarm sequence.

This unit includes a test timer module that will provide a test alarm signal every twenty-four hours at a preselected time.

3.3 Test Procedures

Tests were performed at the University of Alaska-Fairbanks campus in the Electrical Communications Laboratory and the Mechanical Engineering Department Environmental Laboratory. Testing was accomplished by Chris Merritt of J. S. Strandberg Consulting Engineers, and Professor Robert P. Merritt of the University of Alaska Experimental Station.

Three separate testing procedures were formulated to assess the performance of freeze alarm equipment. All these tests are laboratory procedures. Actual in-building testing was not performed.

Test Procedure 1: Cold Chamber

The unit was placed in a small environmental chamber with the thermostat disconnected, and the temperature in the chamber was slowly lowered to simulate a building slowly cooling down. The transmitter was manually keyed at preset time intervals, down to a temperature of -25 degrees F. The following data was collected for transmitter performance:

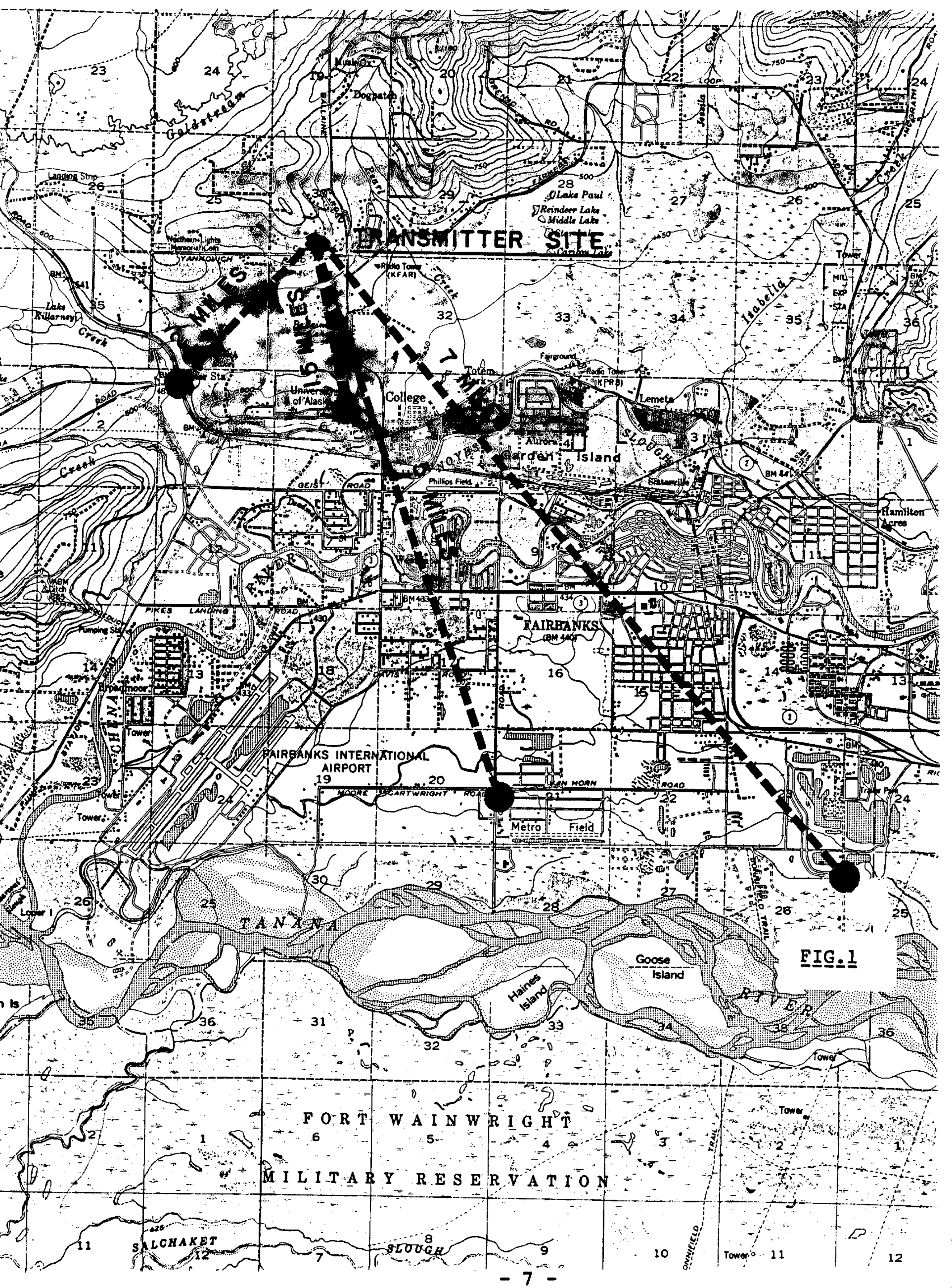
TABLE 1

	Parameter	Units
*	Time	Minutes
*	Ambient Temperature	Degrees F
*	Case Temperature	Degrees F
*	Battery Voltage	Volts
*	Battery Current	Amperes
*	Transmitter Output	Volts (RF)

These data were collected at one minute intervals using a combination of digital multimeters and a portable smart data logger. The data were dumped directly to a microcomputer, processed, analysed, and plotted. Tabulations of recorded data are included in Appendix 1.

Test Procedure 2: Field Strength

In addition to cold chamber performance, the signal strength of the alarm signal from each of the three units was monitored as a function of distance from structure (See Figure 1). These field strength tests were accomplished in the following manner:



TRANSMITTER SITE
7 MILES
15 MILES
7 MILES
5 MILES
Goldstream
Dogpatch
Lake Paul
Reindeer Lake
Middle Lake
Radio Tower (KFAR)
University of Alaska
College
Totem Park
Fairground
Radio Tower (KFRB)
Lemeta
Aurora
Garden Island
Phillips Field
Isabella
Hamilton Acres
FAIRBANKS (BM 440)
PIKES LANDING ROAD
Pumping Sta
Broadmoor
CHENA
FAIRBANKS INTERNATIONAL AIRPORT
MOORE CARTWRIGHT ROAD
VAN HORN ROAD
Metro Field
TANANA RIVER
Goose Island
Haines Island
FORT WAINWRIGHT
MILITARY RESERVATION
SALCHAKET SLOUGH
Lake Killarney
Landing Strip
Northern Lights Memorial Cem
Noyes Slough
Tower

FIG.1

The alarm units were set up in two separate heated buildings, and signal strength and quality instrumentation was installed in a vehicle. Using two separate teams, and walkie-talkie communication equipment, RF output from transmitters was monitored at various locations in the Fairbanks area. Signal quality was monitored using an HP 141T Spectrum Analyzer, with 855A RF and 8552B IF sections. This device yields a signal strength versus frequency plot and effectively displays the transmitter bandwidth.

Readings were taken for five different configurations, as presented in the table below:

TABLE 2

Configuration	Antenna Size
ACS 25-watt	46 inch
CSI 15-watt	46 inch
CSI 15-watt	17 inch
ACS 2-watt	46 inch
ACS 2-watt	8 inch

Signal strengths from all transmitters and antennas located within the first building (with foil backed fiberglas insulation) were extremely weak, to the point that testing was discontinued after only a few data points were collected. The foil enclosure was an effective shield against the radio signals.

The remainder of this testing was confined to the second structure, a conventional wood framed structure located off Yankovich Road. This structure is a residence, and is located 50 - 75 feet above the river flood plain elevation.

Testing was accomplished with the transmitter located in front of a large picture window. The window looks out on the general area where signal strength measurements were taken. There are some low hills in the areas of testing and near-surface soils consisted of discontinuously frozen silts and gravels.

Test Procedure 3: Sequence Testing

The CSI 15-watt unit was configured to send an alarm transmission every five minutes on freeze thermostat contact closure. The RF power transmitted over a sixteen-hour period was measured and recorded while the unit was powered solely by a single 4.5 AH Gel-cell battery. The test was conducted at room temperature of approximately 70-75 degrees F.

4.0 DISCUSSION OF RESULTS

From the testing procedure, five major catagories of performance have been established, each of which is important to successful use of the system. These performance criteria are as follows:

- Cold Environment Performance
- RF Signal Strength
- Antenna Characteristics
- Alarm Sequence Conformance
- Pager Receiver Performance

4.1 Cold Environment Performance

From the analysis of this data it was found that the CSI 15-watt unit provided the best performance at lower temperatures. The ACS 2-watt unit provided the next best performance, while the ACS 25-watt unit suffered the greatest degradation at below zero temperatures. Figures 2 and 3 present cold chamber performance of the three tested units. It should be noted that all units performed satisfactorily when operating within the anticipated freeze warning temperature range.

4.2 RF Signal Strength

The second building was of wood construction and it was known that no aluminum or other type of metal that might shield RF signals was present in the building section used for the tests. The field data analyzed presented in this report was taken from this case. It was found that a curve plotted from the measured signal strength paralleled the "free space" attenuation loss curve (See Figure 4) with some additional attenuation due to local ground effects. The "beeper" receiver units proved to be very sensitive and were activated by the weakest transmitter with the smallest antenna at a distance of seven miles from the transmitter site.

These tests indicate that metal shielding of any type (aluminum foil, aluminum siding, metal walls, large metal cabinets) will severely affect the range of the transmitter units. It is thus recommended that an external antenna be used, where metal walls are present.

PLOT OF TRANSMITTER RF POWER (WATTS)

VS.

TRANSMITTER CASE TEMPERATURE (°F)

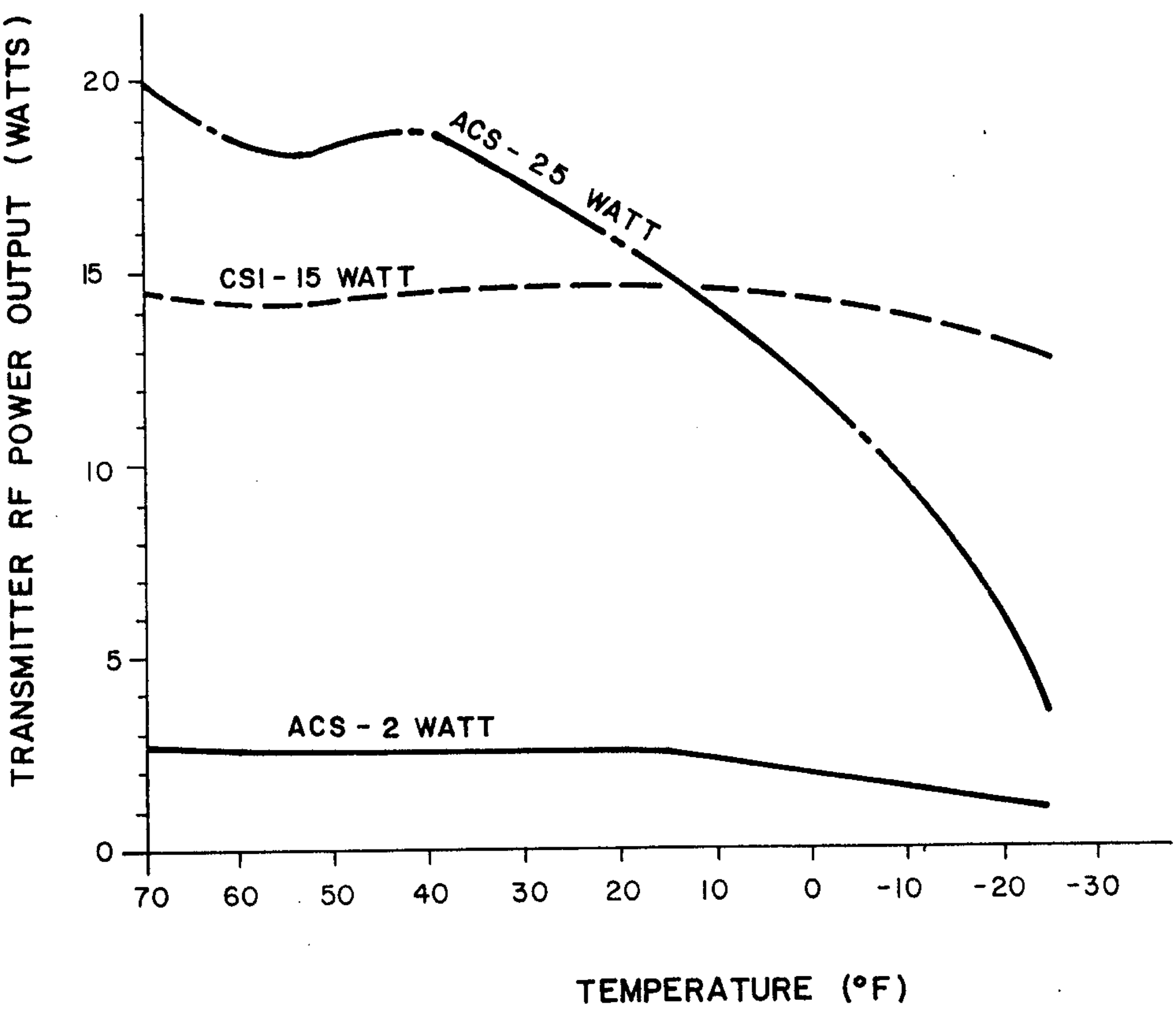


FIG.2

PLOT OF % OF INITIAL TRANSMITTER RF POWER OUTPUT

VS.

TRANSMITTER CASE TEMPERATURE (°F)

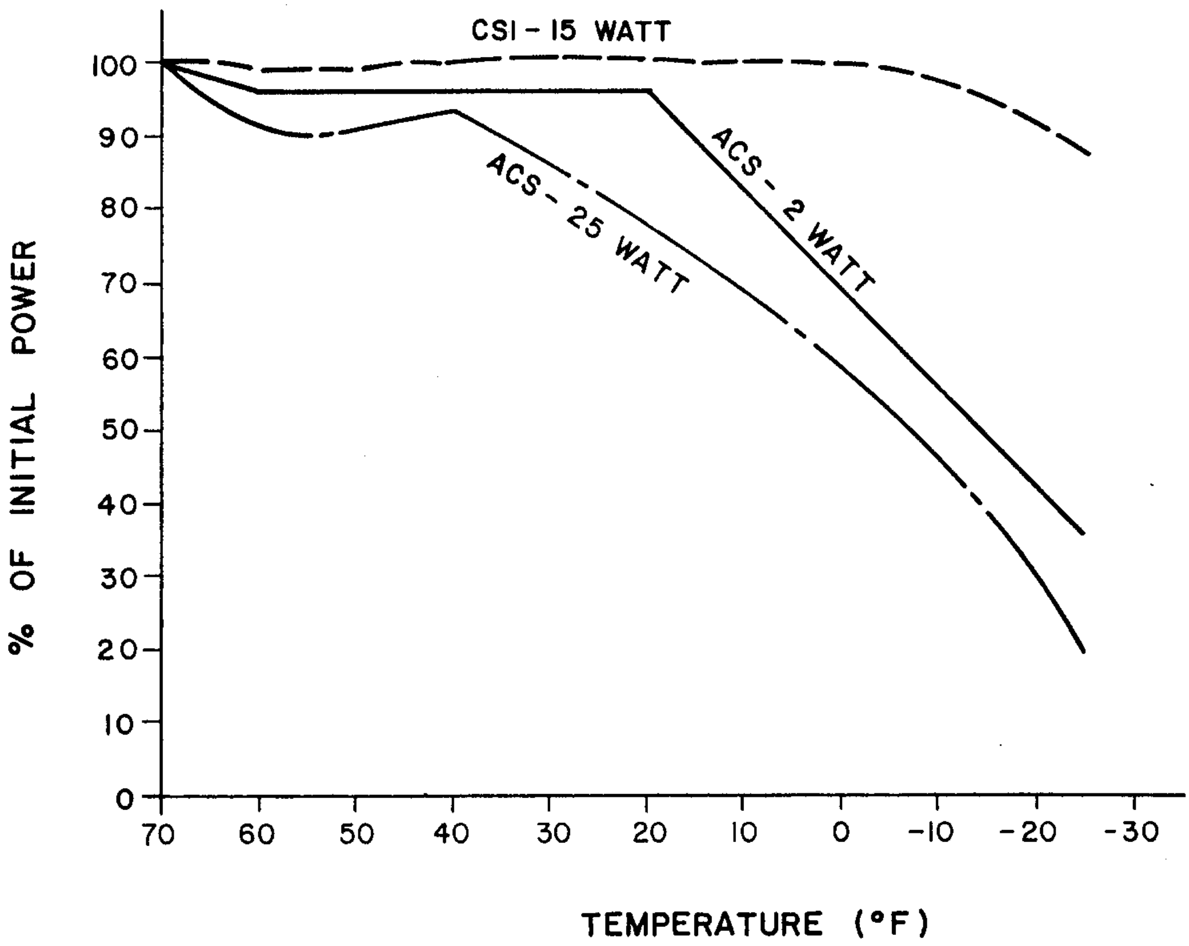


FIG.3

PLOT OF SIGNAL STRENGTH

VS.

DISTANCE FROM TRANSMITTER

(WOOD STRUCTURE)

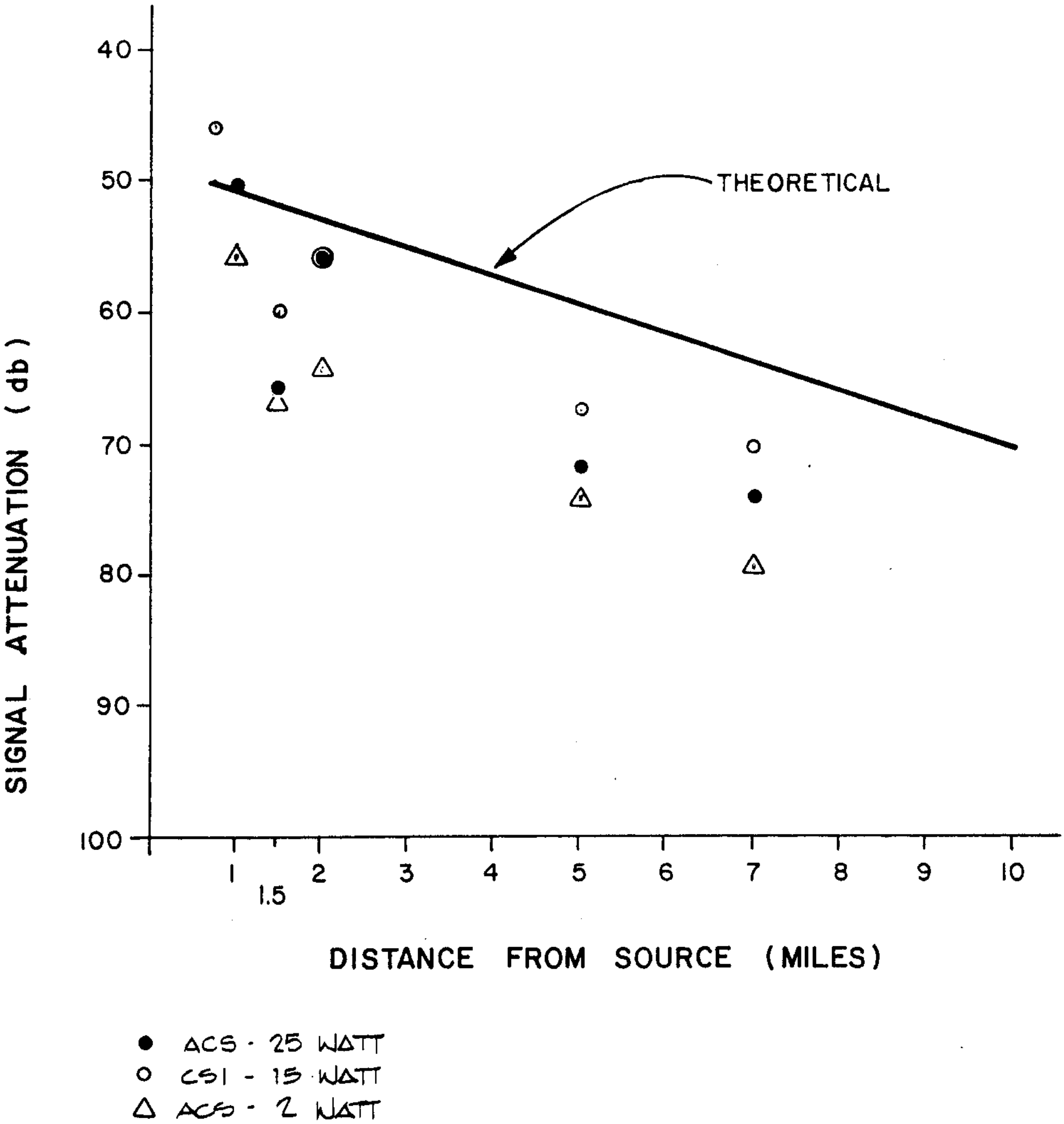


FIG.4

4.3 Antenna Characteristics Measurements

The field strength results allowed evaluation of antenna-transmitter combinations (See Appendix II). It was found that the ACS 2-watt unit with the 46" antenna provided the best ratio of power received to power transmitted. The 8" "rubber duckie" antenna showed the worst performance, significantly below all other antennas. It was also found that the ACS 25-watt unit would not work properly with the 8" "rubber duckie" antenna. The mismatch between the 25-watt unit and the 8" antenna was so great that it endangered the continued operation of the transmitter.

It was found that none of the antennas were specifically cut to the operating frequency of 158.775 MHz when tested on the alarm boxes. The 46" antenna mounted on the 2-watt unit came the closest to a proper match. Transmission and reception efficiency are improved by having a properly matched antenna. The size of the mounting box and nearby conducting materials may significantly affect the matching of a particular antenna to its transmitter. To optimize performance, a selection of antennas should be available, each suited to meet a particular mounting environment.

4.4 Alarm Sequence Testing

The sequence testing was confined to the 15-watt CSI unit (see Appendix III). This test was performed under conditions where the building power was assumed to have failed, requiring the battery alone to supply all power needed by the transmitter. It was found that the RF power output dropped to one half the original value after twelve hours and effectively dropped to zero at the end of sixteen hours.

The battery was substantially discharged while testing due to large power requirements during transmission and continued small power drain between transmissions.

4.5 Pager Receiver Performance

The "beeper" receiver units were activated by the ACS 2-watt transmitter with the 8" "rubber duckie" antenna at a distance of seven miles from the transmitter site. In the laboratory the signal required to provide quieting of the FM receiver was measured at 4 microvolts per meter. This indicates state-of-the-art receiver sensitivity in accordance with the pager specifications. It should be noted, as confirmed during testing, that Nicad batteries used in the pager receivers should be recharged daily and not allowed to experience a deep discharge. One of the batteries in a pager has failed, due to deep discharge, and has not recovered. Battery chargers provided for the pagers are unregulated and do not provide a tapered charging rate. Pagers should not be left in them longer than recommended by the manufacturer.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The testing program for the three freeze alarm units yielded some surprising performance characteristics. All three units provide good alarm sequencing. In regard to other features, each unit has its strong points. As one might expect, selection based on application is required to optimize performance.

As the purpose of this report is to give potential users evaluation information for the three prototype alarm units, tests were devised to indicate potential effectiveness.

Table 3 presents an evaluation of the units on the basis of five major operating characteristics. These criteria are determining factors that define expected performance.

TABLE 3

EVALUATION SUMMARY

Performance Criteria	ACS 2-Watt	CSI 15-Watt	ACS 25-Watt
Cold (below zero) Environment Performance	poor	good	poor
RF Signal Strength	fair	good	good
Antenna Characteristics	good *	fair	fair
Alarm Sequencing	poor	good	poor
Pager Receiver Performance	good	good	good

* The weakest powered unit performed best with the largest antenna ordered for the project, a 46" unit. Better performance with the higher powered units will require larger antennas.

Table 4 shows the options that were included on each of the test freeze-up alarm units.

TABLE 4

OPTION SUMMARY

Option	ACS 2-Watt	CSI 15-Watt	ACS 25-Watt
Low Battery Radio Alarm	Yes	No	Yes
Loss of AC Radio Alarm	No	Yes	No
Low Battery LED	Yes	No	Yes
Loss of AC LED	Yes	Yes	Yes
Power on LED	Yes	Yes	Yes
Transmitter On LED	Yes	No	Yes
Multiple Units per Frequency	Yes	No	Yes
Low Power Consumption	Yes	No	No
Test Timer	Yes	No	Yes
AC Charger	Yes	Yes	Yes

How are the units to be used? The following recommendations give guidelines for the potential user.

1. All units come with a serviceable enclosure that is reasonably heavy duty. Adequate annunciator lights are mounted in the door of the units to indicate operation.

2. All units appear capable of being placed into operation. Given the widely varying results from signal strength tests, however, antenna size, type, and location appear to be major considerations for an effective installation. Utilization of a roof top antenna of a larger size than those tested is recommended if ranges greater than five miles are required.

3. An interior unit mounted antenna may be used only if the building is constructed entirely of wood, without any metal foil, siding or structure. It was found that metallic components will seriously degrade signal strength levels outside the building.

4. The CSI 15-watt alarm unit had by far the best extreme cold temperature transmitting power. Where temperatures can be expected to fall fast and alarm conditions are necessary under below zero temperatures, the CSI unit is recommended over the two ACS units. Test results showed that the CSI equipment was better designed to operate in colder temperatures than the ACS units.

5. However, where cold temperatures are not a problem with respect to transmitter output, the ACS equipment offers significant advantages. The 2-watt ACS unit has an extremely low power drain. It is possible to provide the unit with a moderate sized Gel-cell battery which would permit operation totally independent from building power. Further, with the 25-watt unit, a flexible encoder is included in the unit to allow more than one single zone alarm system to operate per frequency. Here, each alarm transmitter uniquely encodes the alarm signal to activate only one beeper unit. Alarm/beeper units from other buildings would operate independently.

6. Currently, the alarm sequence for the ACS equipment consists of five alarm tone groups distributed over a twenty-five minute time period. After this time, even though the alarm condition may still exist, the alarm unit will not annunciate. This should be changed to allow continuous broadcast of alarms.

7. Installation of a freeze alarm unit in a given building will require some site evaluation to determine the optimum unit characteristics:

   - For a very small facility where all personnel will be in the vicinity of the building, and where terrain is generally flat, the 2-watt unit could be used.

   - For a larger multi-room facility, a larger unit should probably be employed to guarantee alarm transmission. This is especially true where a number of buildings are grouped in one area or larger distances require coverage.

8. The ability of the units to sense not only a freezing condition but also loss of power conditions is useful. It is possible to have the 25-watt ACS unit encoder send out a different signal for loss of power alarm than freeze alarm. Additionally, where an internal alarm panel is already in operation, it is possible to interface the radio-based alarm to the alarm panel, and thus remotely annunciate the entire building.

6.0 PHOTOS OF FREEZE ALARM UNITS

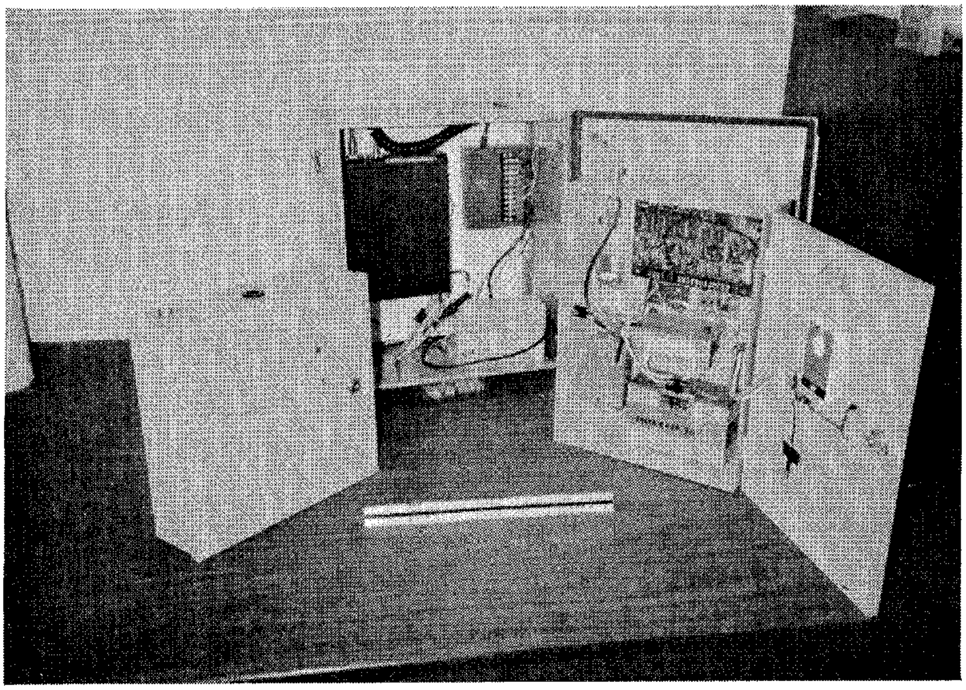


Photo 1: Three Freeze Alarm Units. ACS 15-Watt
Unit is in Background.

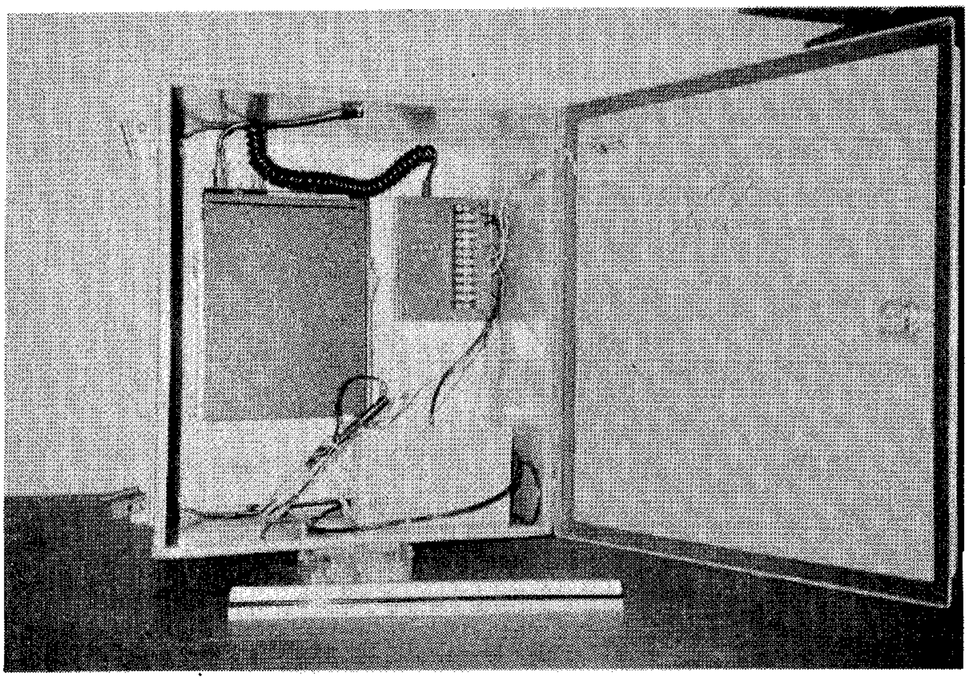


Photo 2: ACS 15-Watt Freeze Alarm.

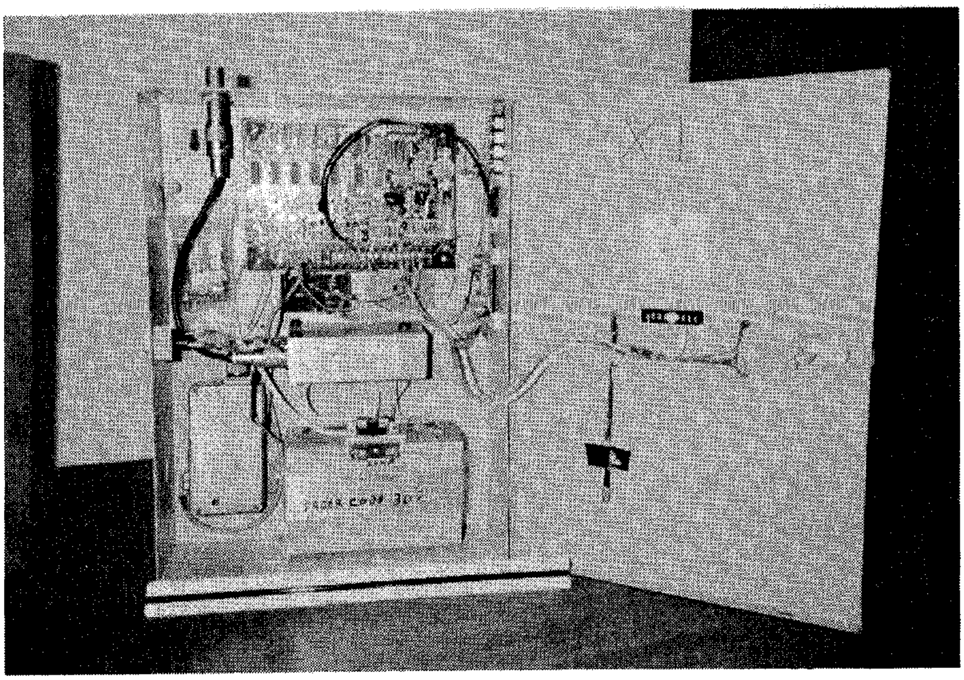


Photo 3: CSI 25-Watt Freeze Alarm.

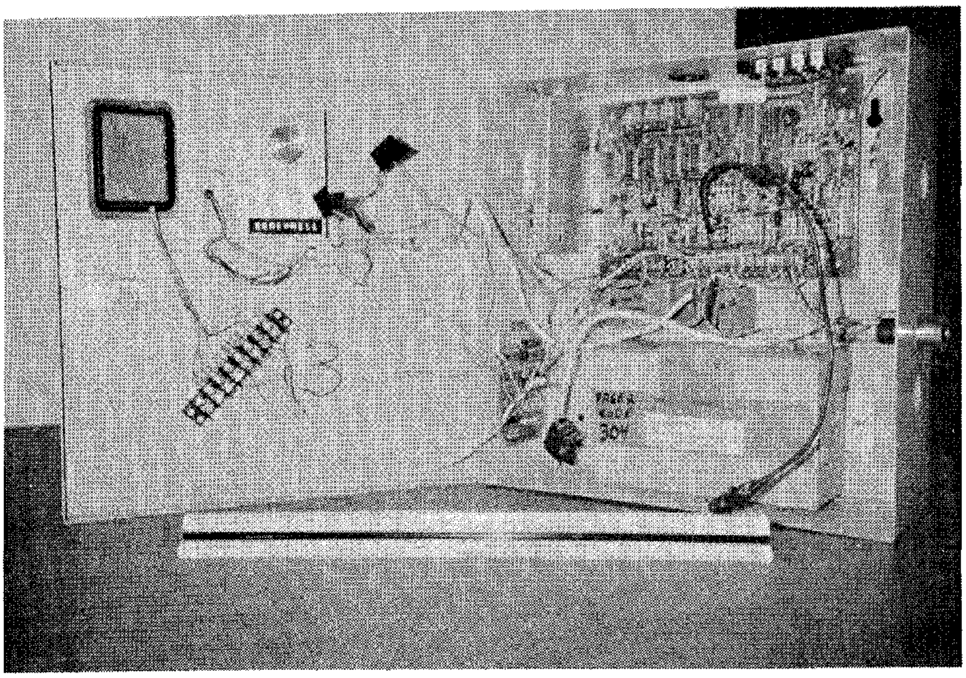


Photo 4: CSI 2-Watt Freeze Alarm.

7.0 APPENDICES

Appendix 1: Cold Chamber Test Results

a. 2-Watt ACS Unit
b. 15-Watt CSI Unit
c. 25-Watt ACS Unit

Appendix II: Field Strength Tests

Appendix III: Alarm Sequencing Testing

Appendix IV: Technical Representatives

APPENDIX I

Cold Chamber Test Results

a. 2-Watt ACS Unit

b. 15-Watt CSI Unit

c. 25-Watt ACS Unit

ACS 2-WATT COLD CHAMBER TESTS

POWER vs. TEMPERATURE NORMALIZED DATA

Temperature (Degrees F)	RF Power (Watts)	% Of Initial Power
70	2.80	100
65	2.75	98
60	2.70	96
55	2.70	96
50	2.70	96
45	2.70	96
40	2.70	96
35	2.70	96
30	2.70	96
25	2.70	96
20	2.70	96
15	2.55	91
10	2.26	81
5	2.12	76
0	1.94	69
-5	1.75	62
-10	1.58	56
-15	1.42	51
-20	1.20	43
-25	.98	35

CSI 15-WATT COLD CHAMBER TESTS

POWER vs. TEMPERATURE NORMALIZED DATA

Temperature (Degrees F)	RF Power (Watts)	% Of Initial Power
70	14.57	100
65	14.51	100
60	14.45	99
55	14.41	99
50	14.47	99
45	14.54	100
40	14.61	100
35	14.68	101
30	14.70	101
25	14.70	101
20	14.70	101
15	14.64	100
10	14.57	100
5	14.50	100
0	14.42	99
-5	14.29	98
-10	14.05	96
-15	13.67	94
-20	13.19	91
-25	12.64	87

ACS 25-WATT COLD CHAMBER TESTS

POWER vs. TEMPERATURE NORMALIZED DATA

Temperature (Degrees F)	RF Power (Watts)	% Of Initial Power
70	* 20.05	100
65	19.27	96
60	18.49	92
55	18.07	90
50	18.25	91
45	18.48	92
40	18.65	93
35	18.06	90
30	17.44	87
25	16.72	83
20	15.86	79
15	15.05	75
10	14.07	70
5	12.93	64
0	11.79	59
-5	10.62	53
-10	9.25	46
-15	7.65	38
-20	6.30	31
-25	3.88	19

* RF power output ratings assume 13.8 VDC with a large battery power supply. Under test conditions reduced battery power made a corresponding reduction in available RF power output.

APPENDIX II

FIELD STRENGTH TESTS

FIELD STRENGTH LEVELS (dB)

FROM FIELD TEST DATA

TRANSMITTER LOCATED AT THE SPECTRUM BUILDING	25-WATT ACS 46"	15-WATT CSI 46"	15-WATT CSI 17"	2-WATT ACS 46"	2-WATT ACS 8"
SPECTRUM BUILDING	-24	-29	-33	-34	-48
REPEAT TEST (0.0 MILES)	-40	-30	-40	-42	-42
WEEK'S FIELD (0.5 MILES)	-80	-78	-90	-82	-

* It was found that this building was built with foil backed insulation. The field tests were discontinued due to the extreme weakness of received signals.

TRANSMITTER LOCATED AT THE MERRITT'S RESIDENCE	25-WATT ACS 46"	15-WATT CSI 46"	15-WATT CSI 17"	2-WATT ACS 46"	2-WATT ACS 8"
BOB MERRITT'S RESIDENCE (0.0 MILES)	0	-4	-8	-5	-20
1.1-MILE UNIVERSITY NORTH ENT (SKI TR)	-46	-51	-75	-56	-70
1.5 MILE UNIVERSITY BEHIND FIREHALL	-60	-66	-57	-67	-73
2-MILE OLD NEN & SHP CRK	-56	-56	-59	-64	-72
5-MILE VAN HORN & PEGER RDS	-67	-72	-70	-74	-84
7-MILE BOROUGH SANITATION FACILITY	-70	-74	-75	-79	-85

TRANSMITTER-ANTENNA COMBINATION FIELD STRENGTH COMPARISONS (dB)

FROM FIELD TEST DATA

USED TO COMPUTE COMPARATIVE GAIN BETWEEN ANTENNAS

XMTR 1	ANT 1	XMTR 2	ANT 2	MEASURED FIELD STRENGTH DIFFERENCE (dB)	COMPUTED XMTR POWER RATIO (dB)	COMPUTED ANTENNA COMPARATIVE GAIN (dB)
ACS 25-W	46" ANT	ACS 2-W	8" ANT	17.5	11.0	6.5
CSI 15-W	46" ANT	ACS 2-W	8" ANT	13.5	8.8	4.8
CSI 15-W	17" ANT	ACS 2-W	8" ANT	13.0	8.8	4.3
ACS 2-W	46" ANT	ACS 2-W	8" ANT	9.8	0.0	9.8
ACS 25-W	46" ANT	ACS 2-W	46" ANT	7.7	11.0	-3.3
CSI 15-W	17" ANT	ACS 2-W	46" ANT	5.8	8.8	-3.0
ACS 25-W	46" ANT	CSI 15-W	17" ANT	4.8	2.2	2.5
ACS 25-W	46" ANT	CSI 15-W	46" ANT	4.0	2.2	1.8
CSI 15-W	46" ANT	ACS 2-W	46" ANT	3.7	8.8	-5.1
CSI 15-W	46" ANT	CSI 15-W	17" ANT	2.7	0.0	2.7

APPENDIX III

ALARM SEQUENCING TESTING

CSI 15-WATT REPEAT ALARM TESTS

% OF ORIGINAL POWER (%)	CHART RECORD (millimeters)	MEASURED POWER (watts)	TRANSMISSION NUMBER	TIME SINCE START OF ALARM (hours)
100	88	14.6	1	0.08
95	84	13.9	35	2.33
90	79	13.1	70	4.66
85	75	12.4	95	6.33
80	71	11.8	117	7.8
75	66	10.9	138	9.20
70	62	10.3	152	10.13
65	57	9.4	167	11.13
60	53	8.8	178	11.87
55	48	8.0	182	12.13
50	44	7.3	189	12.60
40	35	5.8	206	13.73
30	26	4.3	212	14.13
20	18	3.0	217	14.47
10	9	1.5	224	14.93
5	4	0.7	229	15.27

* The test was conducted at room temperatures varying between 70-75 degrees F.

** As a result of the testing conditions, the values recorded in this table are conservative.

APPENDIX IV

Technical Representatives

CSI 15-watt Freeze-up Alarm Unit Vendor:

Don Munro
Communications Systems Incorporated
1165 Harrison Street
Seattle, Wa. 98109
(206) 622-7477

ACS 2-watt & ACS 25-watt Freeze-up Alarm Vendor:

Gary Santee
Automated Custom Systems
P.O. Box 88342
Seattle, Wa. 98188
(206) 852-5614 (206) 763-1988