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Special Issue on Instrumentation

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COVER:

Kartchner Caverns in Arizona has been extensively studied with meteorological instrumentation. Diagram shows locations of sensors, cables and data-logging equipment in the Big Room. See articles in this issue by Bob Buecher and Dave Dalton.

NEWS AND ANNOUNCEMENTS

SPELEONICS IS ALIVE AND WELL, despite not having published an issue since May, 1991. Our goal is to publish quarterly, pending sufficient significant material. Delays seem to eventually strike all nonprofit cavers' newsletters produced by volunteer labor; we anticipated that it might happen when our group was organized, therefore, subscriptions are for a fixed number of issues rather than per year. Please don't blame Ian Drummond (editor is this issue): The delay is ALL MY FAULT; I do most of the mechanics of assembling and mailing each issue. Several problems have been solved, and the next issue is underway. -- Frank Reid

(Former) Soviet cavers join section

Lee Stevens contributed an Electronics Section membership and complete set of Speleonics back-issues to the Ukrainian cavers who attended the 1991 NSS convention. They presented fascinating slide-lectures about Soviet caving (see recent issues of NSS News), and brought Russian vodka and titanium carabiners. We are corresponding with cavers in Kiev, and hope to bring our readers news of their cave-related electronics. --

See you at Dayton!

Cavers and friends are invited to meet again this year at the world's largest hamfest in Dayton, Ohio. Same time and place as the last couple of years: Saturday, April 25 at 11 AM local time, outdoors on the narrow strip of grass between the lowest-numbered flea market spaces and the southwest corner of the arena, just inside the flea-market gate. Look for a SPELEONICS cover on the wall. You may not receive this in time; I'm sending letters to past participants at my own expense. -- FR

1992 NSS Convention Electronics Session

Our annual technical session and section meeting at the Salem, Indiana NSS Convention is scheduled for Monday afternoon, Aug. 3, from 1 to 5PM. Our meetings are quite informal. Bring your ideas and projects! --

## KARTCHNER CAVERNS CAVE METEOROLOGY SYSTEM

Bob Buecher and Dave Dalton \*

Two separate systems have been installed in Kartchner Caverns. In March, 1989 a data logger and seven air-temperature probes were installed in the entrance passages. Two of the probes measure unventilated wet-bulb temperatures. These allow an estimate of relative humidity to be made. Figure 9 displays the average daily temperature and relative humidity at the T1 and T2 probes in the LEM Room.

As can be seen from the graph, the annual temperature varies by; only 80F [4.40C]. The relative humidity shows the influence of dry air entering the cave during winter months. This system has now been in operation for 27 months and has proven very reliable; it has been operating 97.4% of the time. The most common problems have been failing to download before memory fills, battery failures, and probe failures.

A second, more elaborate computer data-logger system was installed deeper in the cave, in the Big Room, in May 1989. Initially, this system had 30 temperature probes. See Figure 10 [cover] for the system layout. Three temperature probes were connected to each of the ten environmental monitoring stations (EMS) around the Big Room. At each station a probe measures air temperature, wet-bulb temperature and soil temperature. The initial system had a resolution of 0.50F [0.28C]. In October and December 1989, the system was expanded to 40 probes and the temperature resolution increased to 0.10F [0.0560C]. Figure 12 illustrates the increased resolution of the results. In June, 1990, two additional probes were added to measure temperatures at bat roosts.

The second computer system has been in operation for 24 months. We have had more problems with this system as it is deeper in the cave and subjected to higher moisture levels. Relative humidity is 90 to 100% throughout the area.

Problems encountered fall into two categories. We first had problems with the temperature readings oscillating. This was apparently due to the length of wire from the computer to the multiplexer and from the multiplexer to the probe. For some of the remote stations this amounts to 400 feet [122m]. This problem was corrected by installing small capacitors at the multiplexers. We then found that some of these damping capacitors had failed. These were all disk capacitors. Where we have used bead capacitors there have been no problems.

The second problem has been failure of several probes. To dates, six probes have gone bad. These have usually been the wet-bulb probes. These are more susceptible to corrosion, as the lead wires were left exposed to aid in heat dissipation. We have since concluded that it is not necessary to expose the leads. There have been no problems with the wiring itself.

We also have a third computer/data-logger that we set up for special studies. Usually we use it to measure airflow. It is setup to record air temperature, wet-bulb temperature, air speed and direction, and air pressure. We take 11 measurements per minute and store the one-minute average. because of memory limitations we can only run the system for about 48 hours without having to download data.

### DESCRIPTION OF THE KARTCHNER LOGGING SYSTEM

The Owl Data Logger consists of four functional sections:

- 1) An eight-channel analog multiplexer.
- 2) An eight-bit analog-to-digital converter (ADC).
- 3) A Universal Asynchronous Receiver/Transmitter (UART).
- 4) A computer.

The system operates entirely under the control of the computer, which communicates with the logger via standard RS232 serial protocol. Use of this common serial interface allows the use of a large variety of computers as the system controller. For the Kartchner systems, Radio Shack model RS-102 computers were chosen because of low cost, ease of programming (BASIC in ROM), no mechanical storage components such as disk or tape drives, and low power consumption.

Eight temperature probes are connected to the eight analog inputs of the data logger. These input are multiplexed to the input of the ADC. The eight-bit data byte is converted to a serial bit-stream and sent through the connecting wires to the computer serial port.

A measurement is initiated by the computer sending a control character to the logger. Receipt of this character initiates a measurement of the requested temperature probe. After a delay of about 3 milliseconds, the UART transmits the measurement back to the computer for storage.

### SENSOR DESCRIPTION

The most common sensor used with this system is the National Semiconductor LM34, a solid-state temperature sensor producing a voltage output linearly proportional to temperature (10mV per 0F with no offset). These devices require very little power (typically 70 microamps) and are insensitive to power-supply fluctuations. These characteristics make them ideally suited for operation in portable, battery-operated equipment, and they can be operated over wire lengths in excess of 1000 feet [305m]. LM34 have a typical accuracy of  $\pm 10F$  [0.0560C] from the factory. In the OWL manual, Tracy Allen of EME Systems describes how to trim the accuracy to  $\pm 0.10F$ .

Humidity measurements are derived from a pair of these probes with one of the sensors covered with a wetted cotton wick. In the near-saturated environment of the cave, the very low natural air movement within the cave is sufficient to depress the the wet-bulb temperature for reasonably accurate relative humidity calculations in the 75-100% range.

Air-flow measurements are done with two sensors. A hot-wire anemometer is used for airspeed measurements. Because this type of device is not capable of detecting direction, an additional direction-sensing device was designed to work in conjunction with the velocity sensor. Because this direction-sensing device must be as sensitive as the minimum resolution of the anemometer, it was necessary to design an instrument that would respond to air velocities of as little as five feet/minute [1.5m/min]. The directional device developed was a wind vane of approximately one square foot [0.093m<sup>2</sup>]. This type of device can be made arbitrarily sensitive by adjusting the angle between the pendulum's axis of rotation and the gravity vector acting on the device. When this angle is zero, the pendulum's period is theoretically infinite, with the only restoring force being that of the stiffness of the hinge flexures. The wind vane's hinges were fabricated of light-gauge rigid plastic with just enough stiffness to support the weight of the pendulum. The

-----  
\* Arizona Conservation Projects, Inc.  
245 S. Plummer, suite 38  
Tucson, Arizona 85719  
(602) 620-0116

clear plastic found on "Pentaflex" file folders was found to be ideal material for the hinges. The period-determining angle mentioned above is adjusted with three screw/leveling feet. Opaque tabs attached to the free end of the vane occlude one or the other of two optical sensors, depending on the direction of movement of the wind vane.

**OWL SYSTEM OPTIONS**

Seven of the eight input channels on the OWL logger may be expanded through the use of a secondary 8-channel multiplexer, thereby expanding the system capability to 57 channels (one main channel is dedicated to the battery

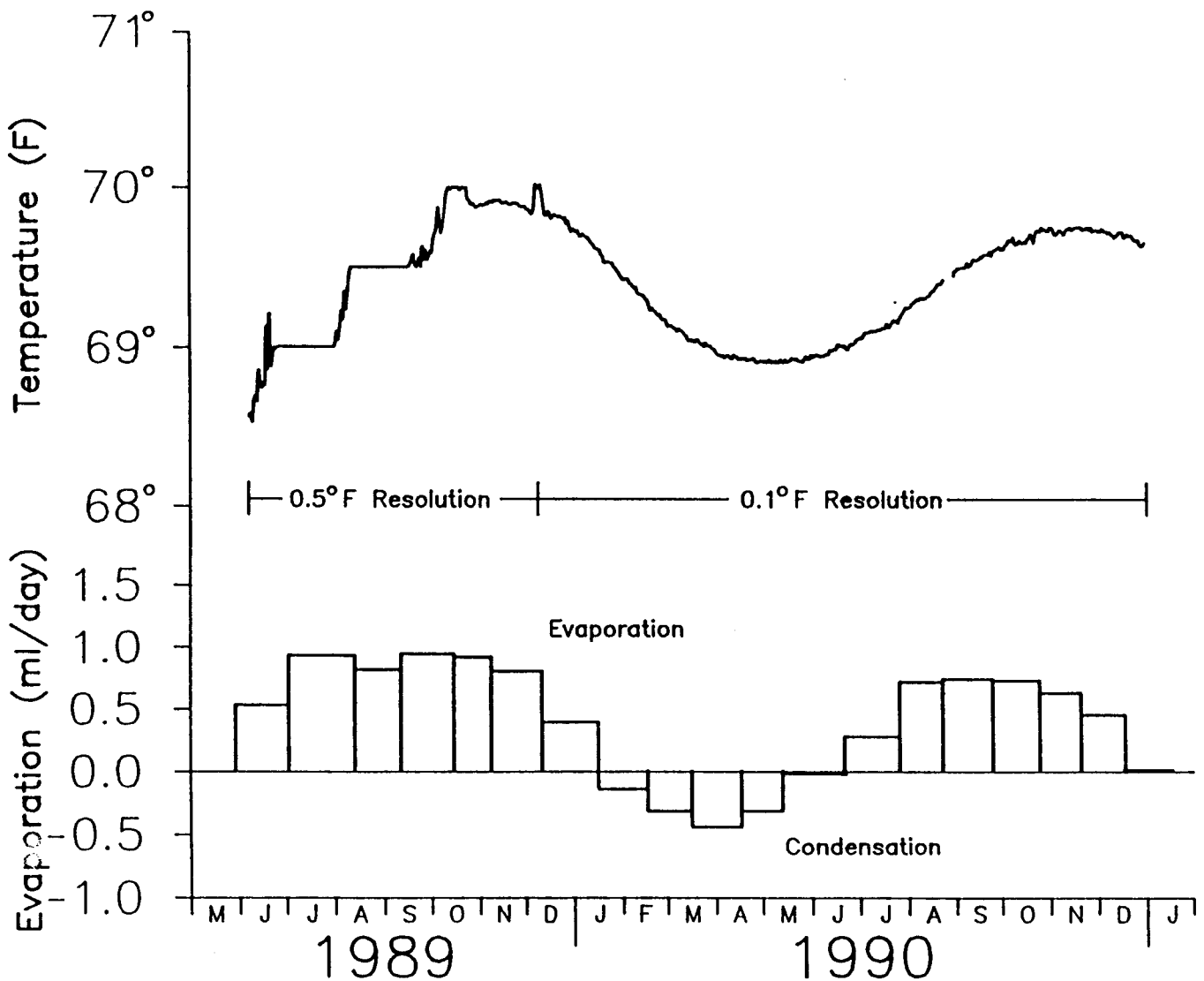
monitor). The secondary multiplexers require four electrical connections to the main logger: 5V power, ground, clock and analog signal. The channel to be read is selected by supplying the correct number of clock pulses to the multiplexer after a sufficiently long reset pulse.

With this arrangement, these secondary multiplexers may be located some distance from the main logger with only a four-conductor wire run to each. From each multiplexer, eight channel clusters may then be deployed. The Big Room logger is configured with five secondary multiplexers, each with a full compliment of probes, bringing the system to forty active probes.  
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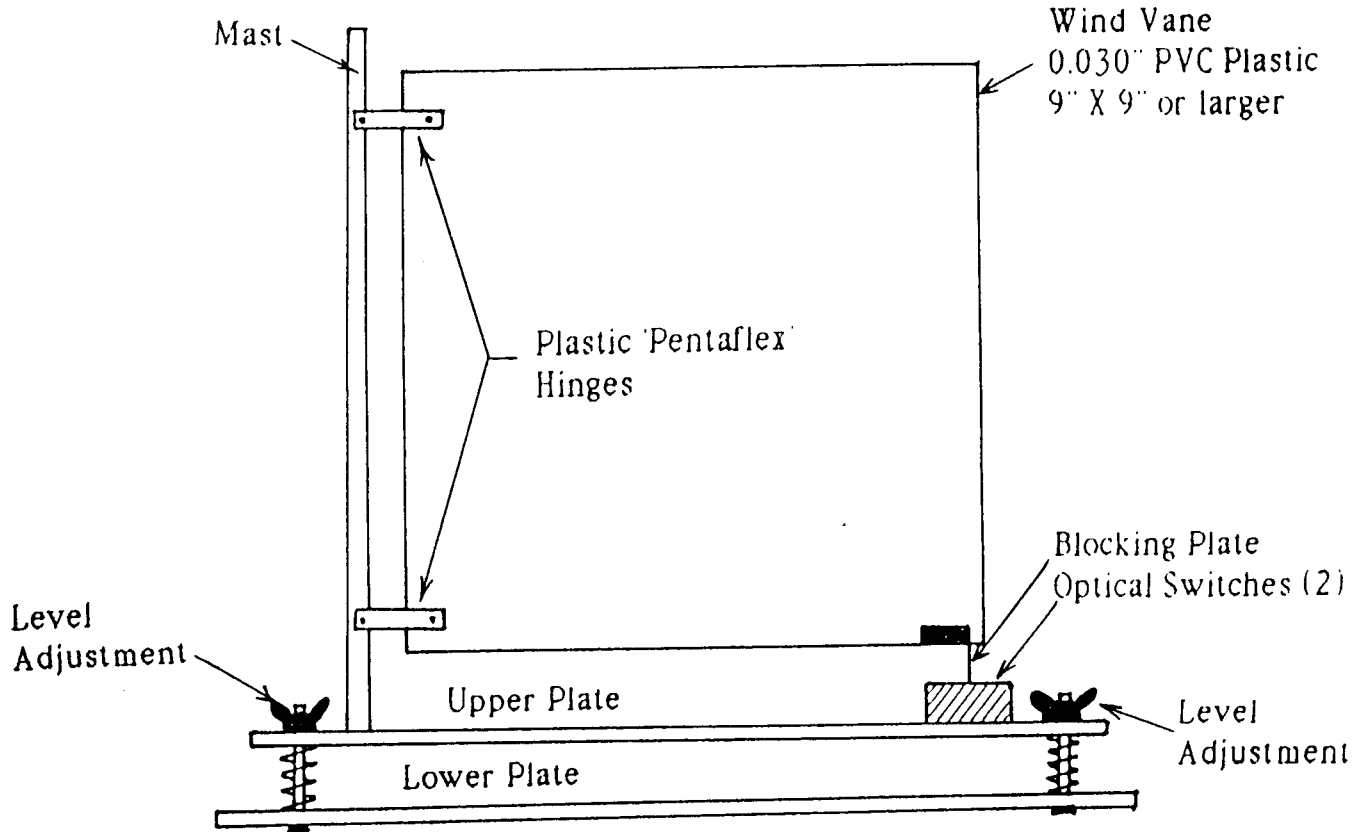
**FIGURE 12**

# Sharon's Saddle EMS-13

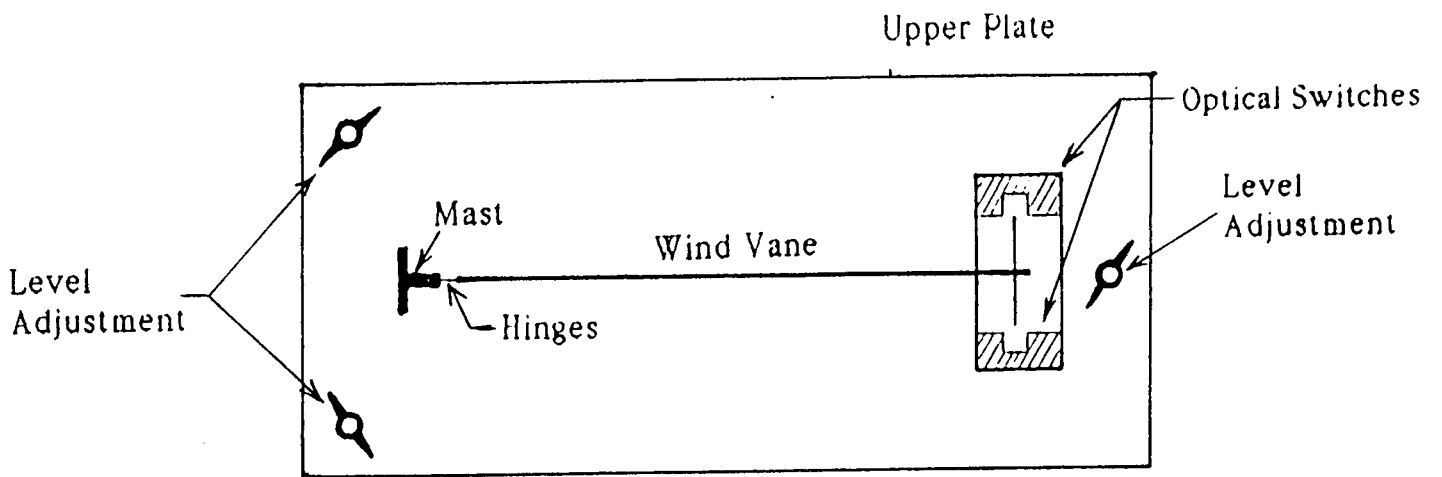
## Average Daily Air Temperature and Evaporation



# DALTON WIND VANE



PROFILE VIEW



PLAN VIEW

## THE USE OF DATA LOGGERS IN CAVE SCIENCE

Bob Buecher and Dave Dalton

### Advantages

- More data can be collected, either more quickly or over a longer period.
- Simultaneous measurements can be made at several locations or different parameters can be measured simultaneously.
- Recording the data in digital format aids in data reduction.
- There is no human presence to disturb the measurements.
- Measurements can be taken at very remote sites, or hazardous places such as areas which are subject to flooding.
- Equipment does not disturb bats.

### PARAMETERS that can be measured:

Temperature (air, soil, water)  
Water levels (and hence stream-flow rates)  
Water properties (conductivity, temperature, pH, turbidity, fluorescence for detection of tracers)  
Event Counts (drip rates, number of bats or people, presence of air tracers, presence of flood waters)  
Relative humidity  
Barometric pressure  
Air velocity  
Wind direction  
Radiation (radon and radon progeny)  
Air quality (CO<sub>2</sub>, gasoline contamination, tracer gasses)

### WHAT DO YOU WANT TO STUDY? What is the goal?

The cave environment can be very constant, with small temperature fluctuations, and usually very high relative humidity. There may be condensing atmosphere, with corrosive water.

In studies near entrances there will be larger fluctuations of parameters and more problems with animals and casual visitors. In deep caves studies (i.e., more than 200-300' [61-91m] from an entrance) very constant conditions require more sensitive instruments. Variations are usually more gradual and require several months or years of data to be collected. There will be fewer animal problems.

### Quality Control

There must be initial calibration and frequent cross-checks with independent methods and instruments (e.g., check relative humidity measurements made by the system against sling-psychrometer measurements).

### System Startup

**Wiring:** For a multi-probe setup the cost of the wire can be as great as that of the computer, data logger and probes. Cheap 4-conductor phone wire costs about \$50 per 1000' [305m]. High-quality 5 or 6-conductor wire can cost \$200 to \$300 per 1000 feet.

Wires must be placed out of the way. Avoid handling the wire with bare hands, as oils from the hands will attract critters and encourage them to nibble.

Making connections in a cave can be a problem, with poor lighting, lack of room, and presence of moisture. Small propane soldering-irons are useful. As many connections as possible should be made before entering the cave. Sensors should have modular design so that spares can be constructed prior to need.

Keep records on how the system is wired; if possible, package a wiring diagram with the equipment in the cave.

Leave extra wire in coils, to allow for adjustment in position and possible expansion.

### Power requirements

Continuous operation of the data logger and computer will use more energy. If possible, use computers with a "sleep" mode that "wake up" only long enough to take the measurements.

### Batteries

Gel cells are reliable and cost-effective but heavy and bulky. Lead-acid car and motorcycle batteries are readily available but very awkward, with a danger of acid spills. Alkaline batteries have high capacity, small size, and are expensive.

### Radio Shack model 102 computers

At Kartchner we have used the Model 102's exclusively. They have several advantages for work in caves: They are small, approximately notebook-sized and lightweight. The list price for a Model 102 is \$599 but they are frequently on sale for \$350 to \$399. They operate on very little power (1 watt), have built-in BASIC, RS232 port, cassette output, and 300-baud modem. Also included are several built-in programs to handle rudimentary communication and text-file manipulation. The BASIC version also has a feature that allows it to resume a program after powering down. This allows for a sleep mode to conserve battery power. The BASIC is also highly compatible with GWBASIC on IBM PC's. (editor's note - the Tandy BASIC only recognizes the first two letters of a variable name, so it cannot distinguish "VAR1" from "VAR2", for example. This can give interesting results when transferring programs written for an IBM PC to the Tandy.)

The Model 102 does not have an internal disk drive; This is not a disadvantage in a cave where condensation and dirt would soon destroy a disk drive.

The greatest drawback of the Model 102 is lack of memory; maximum memory is only 32K and less than 29K is available to the user. After a small data-logging program is installed, there is only 25K left for data storage. For short runs, the data can be stored as ASCII text, allowing the data to be reviewed in the field. However, only about 4000 data points can be stored in this way. For a 7-channel system taking hourly measurements this would allow 23 days of operation.

If multiplexers are added or more frequent measurements taken, then the data must be compressed with bit encoding. With this method approximately 20,000 data points can be stored. Our 7-channel system could now run approximately 4 months between downloads. A separate program is needed to decode the data after it is sent to another computer.

The next higher (Model 200) computer has not been satisfactory. While the additional memory available in the Model 200 (two banks of 32K) is attractive, the hassles of utilizing it creates more problems than they solve. Additionally, the sleep feature does not work in quite the same manner.

### Resolution of the data logger

A voltage or current is converted into a binary number. The cheapest analog-to-digital (A/D) converters are 8-bit, giving a resolution of 1 in 256. More sophisticated A/D give 12 bit (1 part in 4096). Higher resolution means more memory is required to store data.

Eight-bit resolution can be sufficient if the ranges of measurements is small. For instance, with the OWL data logger and LM34 temperature probes the range is 0 to 128F [-18 to 53C] with a resolution of 0.5°F [0.28°C]. For use in a cave, the span can be expanded and offset to cover the range of 50 to 75.5F [10-24C] with 0.1°F resolution [0.56°C].

### COMMERCIALY-AVAILABLE DATA LOGGERS

#### OWL Data logger by EMES

Cost \$275, includes sturdy case, 8-bit A/D board, software for RS100 computer. 7 channels of 8 bits, and 4 switch inputs. Requires a separate computer (Radio Shack Model 102 preferred). Manual covers numerous examples of possible inputs to the data logger. With the supplied program and a 32K RS-102 computer it is possible to store approx. 15,000 to 20,000 data points. It is possible to expand the 7 channels up to 49 channels with the addition of 7-channel multiplexers (\$75 each).

Electronically Monitored Ecosystems  
2018 Parker St.  
Berkeley CA 94704 ph: (415) 848-5725

#### Campbell Scientific CR10 Data Logger

12 channels configurable as 6 differential channels, 3 switched excitation outputs. 8 digital I/O ports. 13-bit analog resolution of five voltage ranges +2.5 to +2.5mV. 16K RAM (5300 data values) expandable to 64K (29900 data values). Low power: Will operate for one year on 7 A-hr of unregulated 12V power, with one-minute scan rates. Size 7.8 x 3.5 x 1.5" [19.7 x 8.9 x 3.8cm] stainless steel module. Needs separate computer to download data and upload programs.  
Cost: \$990 (CR10 16K). \$75 64K RAM. \$105 9-pin serial interface.

Campbell Scientific  
P.O. Box 551  
Logan UT 84321f ph: (801) 753-2342

#### Squirrel Data logger

8-bit and 12-bit models available; models available with 4 and 16 inputs. Data storage 1836 readings, up to 32000 readings. Data logger inputs can be customized when ordering. Cost: \$1757 (8 bit, 1836 data points); \$2295 (8 bit, 32000 data points); \$2943 (12 bit, 20000 data points).

Science / Electronics  
P.O. Box 986  
Dayton OH 45401 ph: (800) 543-9930

#### Rustrak Ranger II

12 channels (4 analog, 4 digital, 4 math channels). 16 bit resolution, 64K RAM stores 28800 data points. \$895 for data logger with software. \$145 for temperature input module (temperature sensor not included).

Rustrak Instruments  
2101 Oxford Road  
DesPlaines IL 60018 ph: (708) 803-5390

**Telog Series 2100 Data Recorders.** One channel (2 on some models); 10 bit resolution, built-in RS232 interface. Lithium batteries will operate the recorder for 18 months. Unit will save average, minimum or maximum of one-second measurements over a computation interval of 1

second to 18 hours. Up to 2000 values can be stored. Small size 6.2 x 4.5 x 1.1" [33 x 33 x 33cm], water resistant. \$465 (single channel), \$695 (2 channel). Units are customized for voltage, temperature, pressure, and water-level measurements.

Telog Instruments  
P.O. Box 240  
West Henrietta NY 14586 ph: (716) 359-1110

**Omnidata Easy Logger.** 12 analog inputs (6 differential), 4 digital outputs, 4 digital inputs, two 16-bit event counters, one frequency counter. Easy Logger \$1890; 64K EPROM \$170; EPROM reader \$600.

Omnidata  
P.O. Box 3489  
Logan UT 84321 ph: (801) 753-7760

#### Build your own data logger?

Article in Radio Electronics (October 1991) describes an altimeter/data-logger that records 1000 values at 0.25 second intervals. Cost of the kit is \$135. It may be possible to change the program (in EPROM) to make readings at other intervals. It may also be possible to modify the design for other types of inputs such as temperature probes.

### SENSORS

#### Temperature

OMEGA has just about every type of sensor, and great manuals (free) on temperature, RH, pressure measurement, theory of operation, etc.

OMEGA  
One Omega Drive  
Box 4047  
Stamford, CT 06907 (800) 826-6342

YSI (thermistor temperature probes)  
Yellow Springs Instrument Co.  
Yellow Springs, OH 45387 (513) 767-7241

Physitemp (thermocouple probes)  
154 Huron Ave.  
Clifton, NJ 07013 (201) 779-5577

LM34 are available for approx. \$1.70 each from:

Hamilton/Avnet  
6822 Oak Hall Lane  
Columbia, MD (301) 995-3500

or call National Semiconductor (408-562-5900) for a closer supplier...

#### Pressure

Micro Switch (Catalog 15)  
Freeport, IL 61032 (815) 235-6600

Sensors 162PC01D (69 mb range) and 163PC01D36 (12.4 mb range) are differential pressure sensors suitable for cave use. They will operate from a 5.12v source.

Nova Sensor (low-cost pressure transducers)  
1055 Mission Court  
Fremont, CA 94539-9978

#### Passive IR Detectors

Heathkit Infrared Motion Sensor (Kit SK-116)\$25  
P.O. Box 8589  
Benton Harbor, MI 49022-8589  
(ed. note: Heathkit Co. is no longer in business.)

Interruptible-beam counter

Radio Shack Infrared photorelay sensor (49-551)  
\$37.95. Operates on 12vdc @ 60 mA.

Modern Electronics, June 1990, p 44. "Infrared  
Event Counter"

Relative Humidity

Hy-Cal Engineering (small RH sensors, \$65 each)  
P.O. Box 5488  
El Monte, CA 91731-1488 (818) 444-4000

Relative Humidity/temperature transmitter (model HX93V),  
0 to 1v output, input 6v to 30v. Cost \$180.

OMEGA (see address above)

Ohmic Instruments Co. (resistive RH sensors \$25 up)  
St. Michaels, MR 21663 (800) 626-7713

Radiation

Radalert, a small digital Geiger counter. Described in  
Radio-Electronics, July 1988, p 51. Interfacing to a PC  
is described in the June 1989 issue, p 51. Cost is  
aprox. \$275.

International Medcom  
7497 Kennedy Rd.  
Sebastopol, CA 95472 (707) 823-0336

PC Geiger counter hooks up to serial port, includes  
software. Cost \$149.

Personal Computing Tools  
17419 Farley Road  
Los Gatos, CA 95030 (408) 395-6600

Wind Speed

Hot-Wire Anemometer 435DC-PC series are suitable for cave  
use. They require a 12vdc supply, output is 0 to 5v,  
power requirements vary with air velocity but will work  
for several days with moderate size batteries. Different  
models have different ranges, lowest is 0 to 100 feet per  
minute (0 to 1 mph), highest is 0 to 12000 fpm (0 to 120  
mph). Cost is aprox. \$500.

Kurtz Instruments  
2411 Garden Road  
Monterey, CA 93940 (800) 424-7356

Ultrasonic measurement of air velocity

Reference: Campbell, G.S. and Unsworth, M.H. "An Inex-  
pensive Sonic Anemometer for Eddy Correlation" Journal  
of Applied Meteorology, Vol. 18, Aug. 1979. Article in-  
cludes construction details of an ultrasonic anemometer  
for very low velocities. It can be built for aprox. \$25  
worth of readily-available components. A copy of the  
article available from Frank Reid for SASE.

Wind Direction

Most commercial wind-direction sensors will not respond  
well to the low velocities normally found in caves. See  
the attached description of the "Dalton Wind Vane" which  
will sense wind direction at velocities as low as 5 to 10  
feet per minute [1.5 - 3m/min].

An alternative approach, if you are near an entrance  
is to measure the relative humidity. Airflow out of the  
cave should be higher than outside air. Air flow into the  
cave should have lower relative humidity.

Air Tracing

I have seen ads for several Freon gas detectors. All of  
which produce a variable rate of beeping to indicate the  
concentration of Freon. It should be possible to hook up  
the speaker to a data logger and count the beeps. Freon  
appears to be an ideal gas to use in air-tracing experi-  
ments (as long as we don't consider the effects on the  
ozone layer).

Other Projects

Bat Counters

Either by breaking a grid of IR beams or by passive IR in  
a small passages. I have tried doing this with the  
Heathkit passive IR sensor hooked up to a computer. The  
sensitivity of the detector can be changed so that it  
will respond to a fast-moving object such as a bat.  
However, all field tests so far have been negative, as  
the sensor appears to lose sensitivity within a few  
minutes of being set up. May want to obtain additional  
information such as time and direction of bat.

Precise Relative Humidity

Caves usually have very high relative humidity. In some  
cases the RH is 100% and we see condensation. Usually it  
is slightly less but usually in the 98-100% range. This  
is higher than most solid-state sensors go. Also because  
we are dealing with a range of only a few percent we need  
great accuracy, typically 0.1%. Solid-state sensors do  
not usually cover the range up to 100%; most go only up  
to 95% and are quite inaccurate at that level. They may  
be suitable for use near an entrance where the RH fluctu-  
ates over a large range. They can also be used as an  
airflow direction indicator if outside air is dry in  
comparison to cave air.

An unventilated wet-bulb thermometer paired with a  
dry-bulb probe can give reliable RH in the 75% to 100% RH  
range. A suitable water reservoir can be made from a 35mm  
film can (the transparent ones are best, as the water  
level can be easily monitored). RH can be calculated  
from the difference between wet and dry-bulb tempera-  
tures. With 0.5°F of temperature resolution, the RH has  
a precision of about 0.5%.

\*\*\*\*\*

WET NOODLE PASSES FIELD TEST

Paul Johnston NSS 15988

The Wet Noodle Field Phone (Speleonics 15) successful-  
ly passed its first extended field trial. In November,  
1991 Jim Bowden (NSS 25545), cave diver/explorer, used  
the Wet Noodle system in Sotano de las Calenturas in  
Mexico. It was strung through the long underwater sumps  
to provide communication. It was set up for seven days  
continuously, and provided reliable service as intended.  
The Wet Noodle was even used in helping to photograph the  
entrance pit. One unit was placed just below the lip of  
the pit so that the caver on the rope could get  
instructions from Jim who was on the bottom taking pic-  
tures. Another extended trial is planned for the Wet  
Noodle the first half of 1992 in Belize.



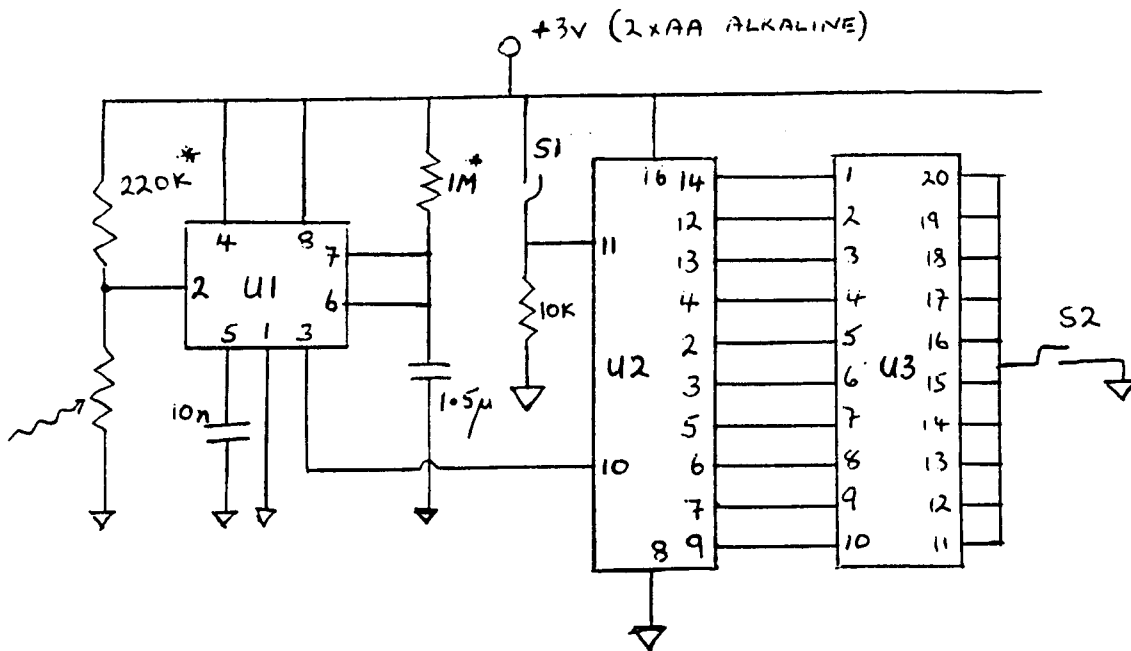
PHOTOELECTRIC CAVER-COUNTER

Ian Drummond

Cave conservationists often need to monitor traffic through a cave. This inexpensive electronic counter (in appropriate housing) can be buried in mud with only a tiny photocell exposed, to record a count each time it detects a caver's light. The count is inexact, of course, but will indicate relative traffic. A calibration factor can be determined empirically.

When S2 is closed, the LEDs indicate the count in binary. As shown, maximum count is 210, or 1024. The counting register can be expanded indefinitely with additional 4040B chips and LEDs.

The same circuit, with suitable sensors, could count stalactite water drops, crawling crickets, flying bats, or other underground events. The electronics must be protected from moisture which can damage the components or short-circuit the high-impedance CMOS devices.



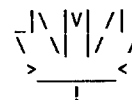
Notes

1. S1 is "reset" button to zero counter. Mount inside and operates by a pin through a small hole. Magnetic reed-switches could probably be used for S1 and S2.
2. Closing S2 displays the count in binary code on the bar graph. Display is normally off to conserve battery.
3. 1M resistor adjusts the delay to avoid multiple counts from one caver. Increase to 10M for delays to 12 seconds.
4. 220k resistor adjusts the sensitivity of the unit, which depends upon its location in the cave. The 555 triggers when the voltage at pin 2 drops to 1/3 of the supply voltage, so a workshop test with the LDR will allow setting of this resistor.
5. Mount the LDR at the bottom of a long tube (3" [7.5cm]) so it has a narrow field of view. Mount it off-axis so light from a caver's light is not reflected back to him. A black cap is required to cover the LDR when servicing and reading the unit.
6. Coat all electronics with conformal coating for moisture resistance. Make boxes water-resistant.

Parts List (all resistors 1/8 watt)

- U1 CMOS-555 (8-pin DIP)  
Do not substitute bipolar 555.
- U2 CMOS 4040B 12-bit ripple counter
- U3 10-element LED bargraph
- 1 light-dependent resistor
- 1 10 nF ceramic capacitor
- 1 1M resistor (see note 3)
- 1 220k resistor (see note 4)
- 1 10k 1/8w resistor
- 1 1.0 uF tantalum capacitor
- 2 normally-open momentary switch
- 1 Battery holder for two AA cells
- 1 box (waterproof)
- 1 p-c board
- 3 16-pin sockets
- black matte paint
- conformal coating

	Radio Shack #	
276-83	\$5.49	
276-116A	\$2.19	
270-257		
276-150		



**FLUORESCENT LIGHTS FOR CAVING?**

Ian Drummond

Fluorescent lights are more efficient than incandescent bulbs at converting electrical energy to light, and yet they are rarely used for caving. Perhaps the reasons include the large size of most tubes, and the requirement for high operating voltages. Both these objections seem to be overcome by products now available on the market.

I obtained a power supply chip and tube from Absopulse Electronics Ltd. (See side panel for specs) and ran some tests. The chip and tube would normally cost about \$30-35 Canadian. I compared light output for electrical input for the fluorescent tube, a standard incandescent bulb (FNG), and a halogen bulb (Osram 862). These are both bulbs used in my Petzl Zoom caving lamp. In addition I measured the intensity of light from a carbide lamp for comparison.

First the chip and tube were very easy to use, just connect 12 volt power, and the output pins to the tube using a couple of test leads, and things were all lit up. The tube is a mercury vapour unit, and light intensity increased for the first minute or two as the tube warmed up. (More later on temperature effects). The tube supplied was rated at 5 watts, and was 12 cm long by 0.5 cm diameter (5" x 0.2"). Absopulse indicated they could supply custom designed tubes, coils or u-bends, which would be more suited to a caving light.

As I was interested only in light output and not in the efficiency of reflectors, I arranged for the bare tube or bulb to be suspended in mid-air, 64 cm (25") from my light meter.

Bulb	Power (watts)	Light intensity (lux at 63cm)	Lux/watt
FNG (standard)	1.0	3.0	3.0
862 (Halogen)	1.87	10	5.3
Carbide (3 cm (1.2") flame)		11	-
Fluorescent tube	4.3	44	10
	3.3	35	11
	0.54	3.5	6

These results support the common claim that fluorescent lamps are 4 or 5 times as efficient as incandescent bulbs (and twice as efficient as halogen bulbs) even with the inefficiency of the power supply.

The power to the tube was varied by changing the input voltage from 11 v to 9.5, to 9.0 volts. The change from 9.5 to 9.0 volts changed the light intensity by a factor of 10, and only slight changes in ambient temperature (about 20 C) caused significant variations in both power consumption and light output at these very low power levels.

I did try putting the whole unit in my deep freeze (approx -18 C) and with a 12 volt power supply the tube would just light and warm-up to give a light output of 5 lux at 63 cm.

These chips and tubes are a long way from being a practical caving light, but certainly the potential is there for construction of some interesting experimental designs.

While preparing this article, I noted a classified advertisement in the National Speleological Society News (NSS News) for a Helmet-mounted fluorescent Headlamp. I wrote to the address and received an interesting 8 page letter from Doug Strait, 17 Pinehurst Dr., Caswell Beach, NC 28465 USA. Doug has been experimenting with various prototype units in the field and has reached the stage where he wishes to build a batch of 15 to 20 units. He is looking for people interested in purchasing one of his units. If this catches your fancy, I would suggest you write to Doug to receive a copy of his proposal.

**DC to AC Fluorescent Light Inverters**  
Series SWI 2868

The SWI 2868 inverter series is specially designed for driving cold cathode discharge lamps for a wide range of applications. The design can be easily customized for various output voltages and currents.

The converters have very high conversion efficiency and reflect a minimum amount of noise back to the power line.

**Features:**

- No minimum load requirement
- Short circuit protection
- PCB mounted or wire leads
- Constant current output
- Output for two lamps
- Epoxy encapsulated package

**Technical Description:**

Input Voltage: 12VDC +/- 10%  
Output Voltage: 100VAC (typical) no load  
150VAC (typical) with fluorescent lamp load  
Designed to drive two 2.5W fluorescent lamps  
5 x 250mm (0.2" x 10") OR ONE 5W LAMP (502525mm)

Input Current: 420mA at 12V input  
Output Current: 2 x 5mA

Temperature: 0 to 60 deg. C operating; -30 to +85 deg. C storage

Efficiency: minimum 80% at full load

Frequency: 30KHz +/- 5KHz (tighter tolerance available)

**Dimensions:**

0.85" x 1.50" x 0.65"

**ABSOPULSE**

2.

**Connection Diagram:**

**Note 1:** Input 0V and output C are connected internally. (Floating output version available)

**Note 2:** L1 and L2 outputs can be parallel connected to one lamp to obtain twice the single output current.

**Available Options:**

- Input/output to suit customer requirements
- Wide temperature range
- Custom sized
- Flexible flying wires on input/output

ABSOPULSE designs and manufactures a broad range of other inverters for virtually all lamp types.

**Other ABSOPULSE products include:**

- Switching Power Supplies
- DC/DC Converters
- Inverters
- Eurocard Power Supplies
- Battery Chargers
- N + 1 Redundant Systems
- Miniature Converter Modules
- Modular Building-Block Converter Systems
- Complete Power Supply Systems in 19" Racks
- UPS Systems with DC Output

**ABSOPULSE**  
ELECTRONICS LTD.  
110 Walgreen Road,  
CARP, ONTARIO  
K0A 1L0 CANADA

Phone (613)336-3511 Fax (613)336-7488

**ABSOPULSE**

## MAGLITE(™) FLASHLIGHT FIELD-REPAIR

Anmar Mirza, N91SY

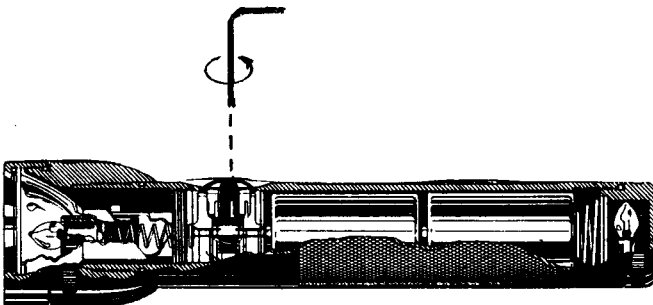
[Abridged from article posted on cavers' electronic mailing list, 26 August 1991. Reproduced by author's permission.]

Maglite(™)\* flashlights are of highest quality construction and have all-silver contacts. They are ubiquitous among professional emergency-service personnel, and are highly caveworthy. However, the switch and upper battery contact are very difficult to clean; cave gear should be field-repairable. The manufacturer will repair the switch free of charge, an excellent service but not much help in a cave. (Shipping costs \$5-10.)

The switch is supposed to be self-cleaning, and probably is in normal environments. The engineers certainly didn't design it to be regularly immersed, dragged through mud, dropped down pits, and then left in the bottom of a cave pack until the next trip.

The switch in my three-D-cell Maglite died, and no amount of fiddling would save it. I had previously failed to discover how to extract the switch mechanism. The switch was already bad, so why not go all the way? A new Maglite wouldn't cost a fortune, and I might learn something. I had already removed the retaining ring (gold or silver-colored ring in the bulb end of the switch assembly). I used the rounded end of my 20-pound, 5-foot long [9kg, 1.5m] rock-destruction tool to pound the switch out. It came out with a minimum of fuss. Thus I learned the secret.

### HOW TO REMOVE THE MAGLITE SWITCH:



Do not use a wrecking bar! Unsnap the retaining ring from the bulb side of the switch mechanism, as described above. Remove the rubber cover from the switch. Insert a 5/64" hex (Allen) wrench into the hole in the switch. Turn counterclockwise 3-4 turns. The switch assembly will slide out of the forward end of the flashlight. Disassembly and cleaning are simple. Assembly is straightforward with no difficult springs, etc. I am going to see if the company will send me a new switch mechanism. I feel better about caving with the Maglite now that I know how to field-strip it. A 5/64" hex wrench fits nicely inside the head assembly.

\* Manufactured by Mag Instrument Inc., 1635 S. Sacramento Ave., Ontario CA 91761 ph: (714) 947-1006 FAX: (714) 947-3116

## A PECULIAR BATTERY PROBLEM

Bob Sergesketter NSS 17602

[Abridged reprint from Petroglyph (Evansville Metropolitan Grotto newsletter), Jan-July 1991 (v.7 no.1).]

A pair of alkaline cells (Eveready Energizers) suddenly stopped working in a flashlight. Both tested good with a voltmeter; under load, one tested good but the other appeared completely dead.

In a carbon-zinc cell, the outer shell is negative and the post on top is positive. Under the post is a carbon rod that extends into the chemical paste inside the can. Alkaline cells look the same from the outside but are different internally. The can of an alkaline cell is positive and the rod extending into the electrolyte is negative. To make them have the same polarity as carbon-zinc cells, the manufacturer must use adapter plates at both ends of the cell. This means that there are internal surfaces that must maintain good electrical contact if the cell is to work. This is true of all alkaline cells, not just Eveready(™).

In the case of my suddenly-dead cell, I figured that there must be a bad connection on one of those internal plates. When I gave the base of the dead cell a good rap with the handle of a screwdriver, it came back to life and tested as good as the other one. If your cave light suddenly dies or goes dim, and you don't think that your battery should have run down so quickly, you may have a cell with the internal-contact problem described above. Try smacking the ends of each cell. It can't hurt, and it might restore your light, at least long enough so that you can get your carbide lamp out of your pack and have a real light!

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Rane Curl [NSS 2247] notes in an article posted to the cavers' electronic-mailing list\* that his dissection of a Duracell(™) C-cell reveals that it is not waterproof, and can self-destruct after immersion.

\* To join, send internet e-mail to cavers-request@m2c.org

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## BRITISH CAVE-RESEARCH ASSOCIATION CAVE RADIO AND ELECTRONICS GROUP

BCRA CREG publishes a most excellent cave-electronics newsletter. The following is from the masthead of their seventh issue (March 1992):

**Objectives of the group:** The group aims, by means of a regular newsletter, other publications and meetings, to encourage the development and use of radio communications and other electronic and computer equipment in caving and related activities.

**Subscription rate** is 7.50 British Pounds (5 pounds for BCRA members), worldwide airmail postage paid. Subscriptions should be sent to the secretary. Please send payment by cheques drawn on a British bank in UK currency. Do not send foreign cheques or Eurocheques. At your own risk, you may send UK bank notes, or US dollars (rates \$14 / \$9). Please do not send any other foreign currency. If you still have difficulty with payment, please contact the secretary.

Secretary: **David Gibson**  
12 Well House Drive  
Leeds, LS8 4BX ENGLAND

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### BCRA PUBLISHES EASILY-BUILT CAVE RADIO

"Making a Simple Radio-Location Device" by **Stuart France** and **Bob Mackin** appears in the British Cave Research Association's magazine, *Caves & Caving* (issue 52, Summer 1991, p 7). The article has full details of a radiolocator which appears an excellent combination of performance and reproducibility.

The 874Hz operating frequency derives from a 3.58MHz crystal oscillator (the American television color-burst frequency) and binary dividers. Conveniently, 874 Hz is nearly halfway between harmonics of both 50 and 60Hz power lines. (See *Speleonics 2* p.11.)

The article describes a beacon transmitter and separate receiver. Transceivers could be constructed, but the system is intended primarily for surveying, where two-way communication is not essential.

The transmitter output stage is a Harris Semiconductor RFP15N05L, an inexpensive N-channel power MOSFET with on-resistance of only 0.14 ohm. It has variable class-C sinusoidal drive, and feeds either a resonant loop antenna via a primary winding, or a larger nonresonant loop for 150m [-500 ft] maximum range. The driver transistor is a BC107 (equivalent to 2N2222).

The receiver input amplifier is a 7611 CMOS op-amp in Q-multiplier configuration (resonant loop antenna connected in negative feedback) followed by active filters and audio amplifier. The authors recommend Sony Walkman(™) earphones, which are more sensitive than similar types.

The printed-circuit diagrams are not actual size, perhaps a publisher's oversight. It should be easy to build the circuits on "universal" p-c boards, or to adjust the published diagrams with an enlarging photocopier. Test equipment is necessary for precisely resonating the antennas. Otherwise, construction appears noncritical except for an admonition to keep active-filter component leads short.

Transmitter and receiver use 12-volt batteries. **Stuart France** says (personal correspondence) that the transmitter can use 18 volts for more power output if the CMOS circuits are limited to 12 volts maximum.

Stuart has used his equipment to establish accurate relative locations in a large cave system in Wales where a geologic fault has offset passages by 50-130m [164-427ft] horizontally. The cave's 600-700ft [183-213m] depth made cave-to-cave methods preferable to conventional surface locations and depth measurements.

The article tells how to obtain the British license required for all cave radios not of type-approved design. The license costs 50 British pounds per year. (The U.S. Federal Communications Commission does not regulate operations below 9kHz, and allows limited unlicensed operation above. Stuart hopes that the British government may someday deregulate very low frequencies.

--Frank Reid

### 1991 CAVE-RESCUE COMMUNICATION NOTES

Frank Reid, W9MKV

*Speleonics 16* described a simple phone-patch for connecting radio transceivers to field or commercial telephones, and mentioned its use during the rescue of Emily D. Mobley at Lechuguilla Cave in April 1991. At the 1991 NCRRC seminar in New York, I got further details from participants in that rescue.

Logistics and geography dictated that the incident-command and staging area (where rescuers assembled and equipment was amassed) be at Carlsbad Caverns National Park headquarters, several miles from the Lechuguilla entrance. Rescue organizers experienced significant delays and misunderstandings when radio traffic was passed

through a relay operator into the underground field-phones, until the hastily-improvised phone patch provided direct conversations with underground leaders.

The national park's Motorola VHF radios, on a fixed and well-known frequency, were used throughout the operation. The news media doubtlessly monitored transmissions, and radio traffic may have initially attracted outside attention.

This year's final mock-rescue exercise of NCRRC week lasted 19 hours. Phone patch was not necessary because incident command was located near the cave entrance and had direct telephone contact with underground operations. There was a surface radio link to the parking area/field kitchen. Rescue students used 2m ham transceivers under the supervision of license holders, who periodically announced callsigns and that a simulated emergency exercise was in progress. Several cavers have become interested in amateur radio after using the equipment in rescue training.

I connected a 2-meter transmitter with VOX to the cave phone line so that students and instructors could monitor communications (See *Speleonics 3* p.7) I disconnected it after a few hours to conserve radio batteries. The exercise drained all available rechargeable batteries; a pack of alkaline AA-cells on an Icom IC-2AT transceiver failed at the very end, having previously lasted through one real rescue and two weekend training events. (Alkaline AA-cell capacity is approximately 2250 mA-hours. See *Speleonics 12*, p. 9.)

Rechargeable radio batteries are most economical for casual use, but alkaline-cell packs are recommended for emergency service: Alkaline cells have considerably higher capacity than nickel-cadmium cells of the same size, alkaline cells are widely available, and depleted battery packs can be immediately "recharged" with new cells.

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### ELECTRONIC THERMOMETERS TESTED AT PRACTICE CAVE-RESCUES

Frank Reid

Inexpensive electronic digital thermometers (from Radio Shack and other sources) with remote probes have been evaluated in practice cave-rescues to monitor the patient's body temperature. In tests at several NCRRC seminars, a sensor was placed in the mock-patient's armpit, with the indicator protected by a plastic bag and attached to the outside of the patient packaging.

Resolution of most such instruments is 0.1° C or F. Absolute accuracy is questionable, but they do cover the hypothermic temperature range (down to 75°F [24°C]), unlike ordinary medical "fever" thermometers not specially designed for hypothermia use. In cases of possible hypothermia during transport through the cave, the trend of the patient's temperature is extremely important information for monitoring his condition. Some instruments have maximum/minimum memories.

Bodily core temperature defines state of hypothermia, and may not be accurately indicated by axillary (armpit) temperature measurements. A suitably-configured electronic temperature probe could be used rectally, a better method for measuring core temperature (but seldom practicable with glass thermometers in the cave-rescue context). Oral temperature usually can only be taken if the patient is conscious, alert and not in motion. The electronic thermometer is a very convenient instrument, subject to the limitations discussed above. It must be well-protected from the cave environment.

Reference: Manual of U.S. Cave Rescue Techniques (2nd edition) S. Hudson, ed. NSS 1988.

**INSTANT CAVE PHONE**

Paul Johnston KA5FY1

Finding some device that could be instantly used for cave communication has been a constant interest. Seeing the TA-1/PT field phones advertised in the Fair Radio Sales catalog piqued my interest. These were ordered and tested.

TA-1/PT phones are sound powered, and have both visible and audible (adjustable volume) call indicators. A palm lever actuates a generator that puts out approx. 100 volts to sound a buzzer. The visible indicator operates independently of the ringer volume-control. Each phone has a coiled cord with push-type binding posts for the transmission wires. Each phone comes with a fibre carrying-case, weighs approx. 3.5 pounds [1.6kg] including case, and measures 8.5 x 3.5 x 3.5 inches [21.6 x 8.9 x 8.9cm]. According to a military field-manual<sup>2</sup>, the transmission and signalling range is 6-10 miles [9.6-16km]. The TA-1/PT is compatible with battery-powered military field phones for point-to-point operation or with a local-battery switchboard.

Voice sound energy strikes the diaphragm, and a permanent magnet and coil convert it into electric current which is converted back to sound at the receiver. Interestingly, this phone will work with reduced range if either the transmitting or receiving transducer becomes inoperative. If the mouthpiece does not work, speak into the earpiece and listen in the earpiece; do not press the push-to-talk switch in this situation. If the earpiece does not work, press and hold the push-to-talk switch and speak and listen through the mouthpiece. These capabilities are useful in emergencies.

The audio of my phones was loud and clear. When the hand generator is squeezed and the volume is turned on, the other phone will make a "knocking" sound and the visual indicator flag will appear and remain in view until reset by the push-to-talk switch. If you are absent when the phone rings, the flag will indicate that someone has called.

I quickly learned to turn the ringer volume off when answering the phone, otherwise the other party may ring again, which is painful to the ear.

I tried the phones as a single-wire system, using earth ground for the return path. I was using 24-gauge [0.573mm dia.] stranded two-conductor speaker wire. After disconnecting one wire from each phone, I stuck a 6 inch [15.3cm] piece of aluminum wire into the ground at each location, wrapped a piece of bare wire around each of the grounds, connected to the second wire terminal of each phone. To my surprise, I could make the other phone ring about 75 feet [23m] away. I could hear my wife's voice, but it was difficult because of the 60 Hz hum caused by nearby power lines. My curiosity was now rally intrigued! How would these phones work at extended distances and without the intense AC hum? A few days later I took the phones to large nearby vacant lots. My first 1000 feet [305m] of 24-ga. wire was rolled out; one side was connected as a single wire and ground stakes were connected to the second phone terminal. The audio was loud and clear and the buzzer worked as it should. For comparison, I disconnected the ground stakes and connected the second wire as it was designed and could notice no difference in the audio.

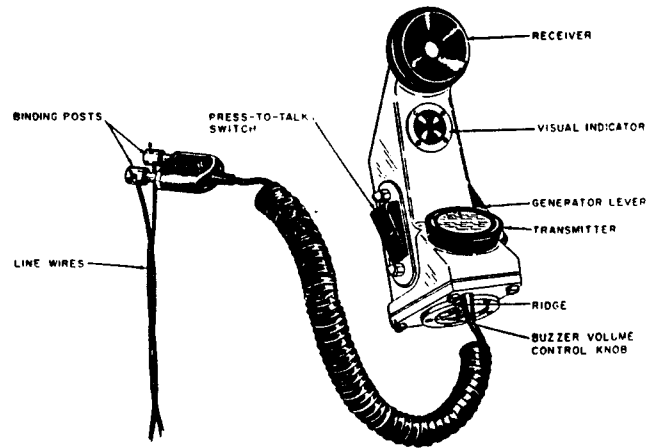
It continued to work fine as a single-wire system when I added my last 1000 feet of wire.

TA-1/PT phones are a potential ready-to-go cave phone system, either as a dual-wire or a single-wire system. The conductivity of the soil would be an important factor in the ultimate limits for the single-wire system. My ground stakes were made from 8-inch aluminum tent stakes with holes drilled in the tops for attaching the wires with nuts and bolts. The stakes were driven about 6 inches into the ground. It may have rained within a couple of weeks of when I tested the system.

Underground communication experimenters may want to consider military-surplus gear if it may fit the requirements because it is rugged and inexpensive for the quality that you get.

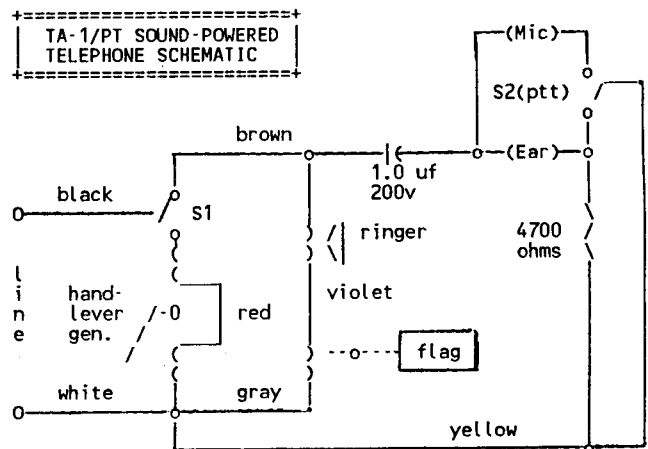
1. Fair Radio Sales Co., P.O. Box 1105, Lima, Ohio 45802. ph: (419)223-2196 or 227-6573.
2. U.S. Army Armour Communication Electronic Data, ST-2418-1; U.S. Army Armour School, July 1973.

**TELEPHONE SET TA-1/PT**



**TA-1/PT SOUND-POWERED TELEPHONE NOTES**

Frank Reid



S1 and S2 are shown in normal (receive) positions. S1 is an internal switch which automatically engages when the hand-powered ring generator is active. The generator has two coils connected by red wire. The annunciator flag latches each time the phone rings; S2 (push-to-talk) mechanically resets the flag.

Light, durable TA-1/PT U.S. military sound-powered field telephones have proven highly desirable in cave rescue. A single sound-powered transducer at each end of a line could make a rudimentary phone. Telephone ringers have proven important in cave-rescue operations.

Newer TA-1's have plastic cases; others are metal. The transducers are somewhat delicate and can be damaged by impact. Transmitter and receiver elements are electrically equivalent but not mechanically interchangeable.

