

Specialized Instrumentation Packages for Radon Field Research

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ABSTRACT

Small research efforts into specific areas can sometimes be better served with small special instrumentation packages rather than multipurpose units. Two such systems have been used to support EPA field test activities. One is for monitoring multiple pressure and temperature points when investigating pressure field extensions in problem houses. The second is a small system designed for long term monitoring of a residence either prior to or after installation of a mitigation system.

The pressure field extension unit can monitor up to 12 differential pressures of +/-12 Pa sequentially, flow through the vacuum system as delta P across a laminar flow element, and four temperatures. The system has been used to map the pressure field extension along three rays from the central vacuum point and to locate a major discontinuity in flow propagation under the slab. The speed of data acquisition allowed the entire slab mapping to be done in less than 1 day for multiple vacuum strengths.

The long term data package uses separate remote sensors with data transmitted to the data acquisition system over the house wiring. Relatively low transmission rates using the 60 Hz AC as the carrier allow little interference from normal electrical dirt found within a house. The central unit appears to be a large digital clock to the residents with no connections other than the power cord. Data are saved on a small read only memory (ROM) package clipped to the side of the "clock." During long term monitoring, the ROM can be retrieved by a visiting member of the research team or the resident can swap the cartridge at the same time alpha track detectors are swapped.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

INTRODUCTION

EPA's research and development program includes a major development and demonstration of radon mitigation techniques. By the end of 1988, over 200 mitigation techniques will have been installed as a part of field projects in 9 states, and at least 100 additional installations are planned for 1989. These projects are conducted jointly with local and state agencies using local contractors to expand available mitigation knowledge. Additional houses have been intensely studied to better understand the processes present when radon invades a house.

All of these projects characterize the houses sufficiently for proper mitigation installations to be designed. The characterization process can require differing levels of data collection and measurements which provide the necessary data for designing a system (1, 2). Much of the data are common among the investigators, but different collection techniques or rates make comparisons difficult.

A core set of measurements has been chosen by EPA to provide a common data set for comparisons and future data analysis. These measurements are to be collected for each installation in each field project conducted under EPA sponsorship to allow a common data base to be compiled. Most of these are currently being collected along with additional site specific data.

Most of the data are collected manually from direct reading instruments used to provide the diagnostician on-site information while a few of the instruments print out their results. The detailed house studies rely on computer collection of the data from many sophisticated sensors around the house. A prototype microprocessor-based data acquisition system has been developed which may bring some of the technology used in the research houses reasonably to the demonstration house.

CORE MEASUREMENTS

The core measurements have been organized by four mitigation phases and five mitigation operational principles as described below. The matrix of the specific measurements used for a specific mitigation phase and techniques is shown in Table 1.

Phase 1: Screening/Selection

House screening determines if a house has the necessary characteristics to be included in the project (e.g., radon level, substructure type). Field project houses are screened by analyzing the data available for a given area, by on-site examination, or by a combination of both.

Selection requires on-site examination of the house and the collection of necessary data to determine if the house meets the needs of the study. Baseline data (Phase 2) may be collected during the house selection visit.

Phase 2: Baseline Data

A complete characterization of the house prior to the installation of mitigation is done to provide necessary diagnostic information for that design and to provide a base for comparing the performance of the system.

Phase 3: Short-Term Performance

Following the installation of a mitigation system, a short-term performance test is conducted for 48 to 96 hours. These data are compared to those collected during the baseline phase to assess the effectiveness of the system.

Phase 4: Long-Term Performance

Once the final installation is made in a house (sometimes more than one method is applied to a house), system performance will be tested for 2 to 5 years. This is the real proof of the reduction of radon exposure to the occupants of the house.

MITIGATION METHODS

Soil Gas Ventilation: Draws radon-containing soil gas from beneath slabs and plastic films or within hollow block walls and drain tiles and exhausts it away from the building.

Soil Gas Barrier: Prevents radon-containing soil gas from penetrating the structure by sealing entry routes or by maintaining a positive pressure in the portion of the house in contact with the soil.

Indoor Air: Increased ventilation rates or air treatment (e.g. air cleaners) removes the radon already inside the house.

Well Water: Removes radon from well water to prevent it from escaping into the indoor air.

Building Materials: Removes or seals radon-emitting building materials.

INSTRUMENTATION PACKAGES

The manual method of data acquisition has been the mainstay of radon mitigation efforts and has been detailed in several training manuals produced by various agencies and mitigators (3). Special measurement and data acquisition units have been assembled by mitigation teams for special purposes. An example is shown in Figure 1. This system allowed several differential pressures across a slab to be monitored sequentially to determine the extent of the pressure field extension which could indicate possible use of sub-slab suction as a control strategy.

The intensively monitored research houses have applied computer technology to continuously acquire many sensor inputs for extended time periods. These systems have been connected with computers at the research laboratory allowing investigators to follow events without visiting the houses. These installations are few in number and expensive, but produce valuable data that would not be available with less sophisticated data collection schemes.

It would be desirable to have a system which could monitor many sensors for a long time, but still be reasonable enough for many houses to be followed simultaneously. The EPA Field Evaluation Package (FEP) has been designed to fill that need. The system is based on a proven industrial computer (STD Z80) with sensors placed near the measuring point, transmitting their data over household wiring. The data collected are stored on a battery powered memory card which can be returned to the laboratory for analysis. The system is shown functionally in Figure 2.

The system is based upon wireless intercoms used in many houses for example to monitor sleeping babies or call someone working in the garage to dinner. One intercom is located near a sensor which is placed at the point of interest. This method eliminates most of the cabling needed for system instrumentation and only requires access to the AC power line. All the remote transducers and the control computer must be connected to the same AC power line, a condition met in almost every house.

The control computer is used to receive the data from the remote transducers, compute averages, save the data in permanent memory modules, and permit sending the data over serial data lines to a checkout computer or over the telephone lines. The present system is based on the STD bus and consists of the Central Processing board, a parallel port board, a special interface board, and a power supply. The communications link to the transducer is provided by a modified FM Wireless Intercom.

The remote transducer unit is made up of the intercom and an A/D converter and control board. The system uses MOS technology to limit power requirements. Any type of transducer which generates an adequate voltage output can be used. Types under consideration include pressure, temperature, relative humidity, and radon concentration.

System installation consists of placing the removed transducers in the desired locations and connecting them to the AC power line. Because the power requirement is less than 5 W. light duty extension cords may be used if needed. The control computer is placed where access may be gained for replacing the memory module and checking out the installation, yet is secure enough for long term unattended operation. Since low frequency radio signals are used, some interference may be experienced either by the system or by devices in the house. System checkout includes determining if any objectionable interference takes place.

Operation of the remote transducers is shown in Figure 3. The remote units are controlled by the type 2716 PROMs connected as "Sequential State Controllers." Each PROM has eight output lines which control the

various functions in the system (trigger conversion, turn on transmitter, reset, etc.). The lines are programmed to have the correct state for each sequential address in the PROM. An address generator starts at location 0 and steps through the permitted values in order. As the system steps through the addresses, the control lines cause the correct operation to take place. The frequency of the AC on the power line is used to pace the system. Each zero-crossing of the AC starts a clock period. These are 8.3 msec long (frequency is 120 Hz). Since all the devices see the same frequency, they are synchronized with each other. The zero-crossing produces a pulse which steps the address generator to its next value. The control lines then produce the action which is correct for that sequential state of the system.

The voltage signal output by the transducer in the remote device is applied to an A/D converter. The full scale value is determined by selecting a resistor and can range from 5 mV to 5 V. After conversion of the input value, the data are presented in digital form on 12 output lines. A digital data multiplexer connects to each data line in turn. The data are applied to an oscillator which produces an output of 2 kHz for a digital "0" and 1 kHz for a digital "1." These tones are applied to the FM wireless intercom and sent to the control computer for detection and decoding.

There can be several remote transducers in a system and more than one of them can be ready to send their data at the same time. Special steps must be taken to prevent overlap of data transmission. When the remote unit has completed the A/D conversion, it listens to see if any other unit is transmitting. If none is, it sends a tone for one clock period then listens again for a number of clock periods assigned uniquely to it. If no tone is heard after the waiting period, it then begins to transmit its data. Each unit has a different delay period so that no conflicts should take place. The data from each remote unit have an identifier prefixed to them. When the unit is cleared to send, the control PROM places the digits of the identifier onto the oscillator input line one after another, producing the audio tones for the "0s" and "1s" which are sent out. When the complete identifier has been sent, the data multiplexer connects each digital data line to the oscillator input in turn until all the data bits and two parity bits have been sent. If more than one transducer shares the transmitter intercom, the second transducer is connected to the input of the A/D converter, conversion is triggered, and data are sent. After the data have been sent from a transducer, the remote unit enters a waiting period of about 17 sec before trying to send another data value. At start-up, all the units will try to send data at the same time. They should arrange themselves in order of their delay times, and then should send all the system data in bursts spaced 17 sec apart.

The control computer in the current configuration collects the data, computes appropriate averages, and stores the data permanently in a battery backed-up ROM cartridge. The data cartridge can be replaced easily by the homeowner and the unit returned to the laboratory be downloaded to a PC for analysis. Three months of data can easily be stored, so long term alpha tracks and the ROM could be picked up at the same time.

SUMMARY

EPA has developed a set of core diagnostics which will produce a common data base for system comparison and analysis. To facilitate the acquisition of long term data an easily installed set of sensors and a control computer have been developed. Using 12 A/D converters which provide 0.024% resolution, the sensor data are transmitted over the household wiring using a wireless FM intercom. The intercom eliminates most of the cabling normally associated with remote sensor operation. The data are permanently stored in a RAM cartridge which can be changed by the homeowner and returned to EPA for analysis.

REFERENCES

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TABLE 1. CORE MEASUREMENTS.

- 1 SOIL VENT (SUBSLAB, FGLY, WALL, TILE)
- 2 BARRIER (SEALING, PRESSURIZATION)
- 3 INDOOR AIR (VENTILATE, TREAT)
- 4 WATER (REMOVE)
- 5 BLDG MATLS (TREAT, REMOVE)

4/16/82

| PHASE | INDOOR RADON | SUBSLAB [Rn] | SUBSLAB COMMUNICATION | HOUSE DYNAMICS | WEATHER | HOMEOWNER SURVEY | ENTRY ROUTES | GAMMA SURVEY | WATER (WELL) |
|---------------------------|-----------------------|-------------------|-----------------------|----------------|--------------------|------------------|--------------|--------------|--------------|
| SCREENING/ SELECTION | 1 GRAB SAMPLE | OPT GRAB SAMP | OPT PFE | OPT BD, DP | QUAL WB | STD FORM | VISUAL | OPT MAP | OPT MEAS |
| | 2 GRAB SAMPLE | OPT GRAB SAMP | NONE | OPT BD, DP | QUAL WB | STD FORM | VISUAL | OPT MAP | OPT MEAS |
| | 3 GRAB SAMPLE | NONE | NONE | OPT BD, DP | QUAL WB | STD FORM | VISUAL | OPT MAP | OPT MEAS |
| | 4 GRAB SAMPLE | NONE | NONE | OPT BD, DP | QUAL WB | STD FORM | NONE | OPT MAP | MEAS |
| | 5 GRAB SAMPLE | NONE | NONE | OPT BD, DP | QUAL WB | STD FORM | NONE | MAP | OPT MEAS |
| BASELINE | 1 48HR PYLON, ATD, WL | GRAB SAMPLE | PFE | BD, DP | T(I/O), P, QUAL WB | STD FORM | DET VISUAL | MAP | MEAS |
| | 2 48HR PYLON, ATD, WL | GRAB SAMPLE | OPT PFE | BD, DP, TG | T(I/O), P, QUAL WB | STD FORM | DET VISUAL | MAP | MEAS |
| | 3 48HR PYLON, ATD, WL | GRAB SAMPLE | NONE | BD, DP, TG | T(I/O), P, QUAL WB | STD FORM | DET VISUAL | MAP | MEAS |
| | 4 48HR PYLON, ATD, WL | GRAB SAMPLE | NONE | BD, DP | T(I/O), P, QUAL WB | STD FORM | NONE | MAP | MEAS |
| | 5 48HR PYLON, ATD, WL | GRAB SAMPLE | NONE | BD, DP | T(I/O), P, QUAL WB | STD FORM | NONE | MAP | MEAS |
| SHORT-TERM PERFORMANCE | 1 48HR PYLON, WL | GRAB SAMPLE, PIPE | PFE | DP | T(I/O), P, QUAL WB | NONE | OPT VISUAL | NONE | NONE |
| | 2 48HR PYLON, WL | GRAB SAMPLE | OPT PFE | DP, TG | T(I/O), P, QUAL WB | NONE | VISUAL | NONE | NONE |
| | 3 48HR PYLON, WL | GRAB SAMPLE | NONE | DP, TG | T(I/O), P, QUAL WB | NONE | OPT VISUAL | NONE | NONE |
| | 4 48HR PYLON, WL | GRAB SAMPLE | NONE | NONE | T(I/O), P, QUAL WB | NONE | NONE | NONE | MEAS |
| | 5 48HR PYLON, WL | GRAB SAMPLE | NONE | NONE | T(I/O), P, QUAL WB | NONE | NONE | MAP | NONE |
| LONG-TERM PERFORMANCE | 1 QUARTERLY ATD | OPT GRAB SAMP | NONE | NONE | QUAL WB | PROBLEMS | OPT VISUAL | NONE | OPT MEAS |
| | 2 QUARTERLY ATD | OPT GRAB SAMP | NONE | NONE | QUAL WB | PROBLEMS | VISUAL | NONE | OPT MEAS |
| | 3 QUARTERLY ATD | OPT GRAB SAMP | NONE | NONE | QUAL WB | PROBLEMS | OPT VISUAL | NONE | OPT MEAS |
| | 4 QUARTERLY ATD | OPT GRAB SAMP | NONE | NONE | QUAL WB | PROBLEMS | NONE | NONE | MEAS |
| | 5 QUARTERLY ATD | OPT GRAB SAMP | NONE | NONE | QUAL WB | PROBLEMS | NONE | MAP | OPT MEAS |

KEY

- ATD - ALPHA TRACK DETECTOR
- BD - BLOWER DOOR TEST
- DET - DETAILED
- DP - DELTA PRESSURE BETWEEN FLOOR/SLAB & SHELL/OUTDOORS, INCL HVAC OPERATION & WIND GAUGE (NEED ENTIRE PACKAGE)
- OPT - OPTIONAL
- P - BAROMETRIC PRESSURE
- PFE - PRESSURE FIELD EXTENSION (ORNL METHOD)
- QUAL WB - QUALITATIVE WEATHER BUREAU DATA (TEMPERATURE, PRESSURE, RAIN, ETC.)
- STD FORM - STANDARD FORM, TO BE DEVELOPED
- TG - TRACER GAS
- T(I/O) - TEMPERATURE, ALL INDOOR LEVELS & OUTDOORS
- VISUAL - VISUAL INSPECTION INCL SMOKE STICKS
- WL - WORKING LEVELS

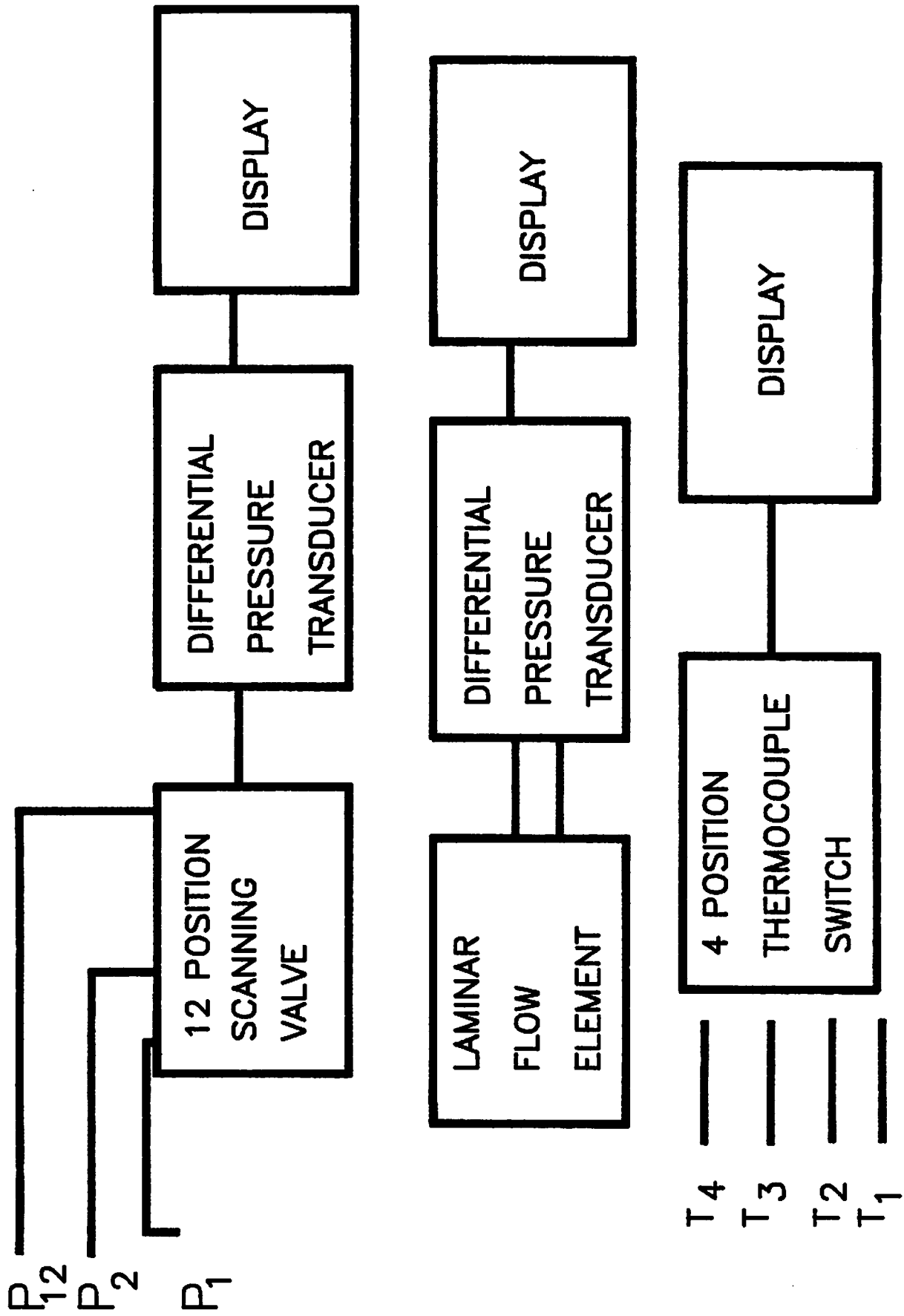


FIGURE 1. PRESSURE FIELD EXTENSION UNIT

AC POWER LINE

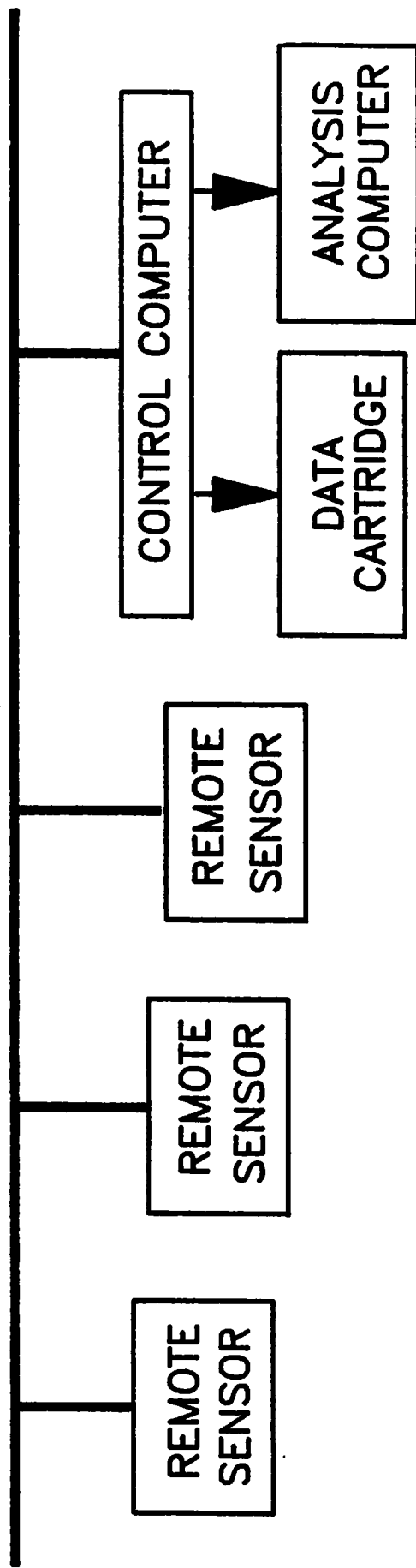


FIGURE 2. FIELD EVALUATION PACKAGE

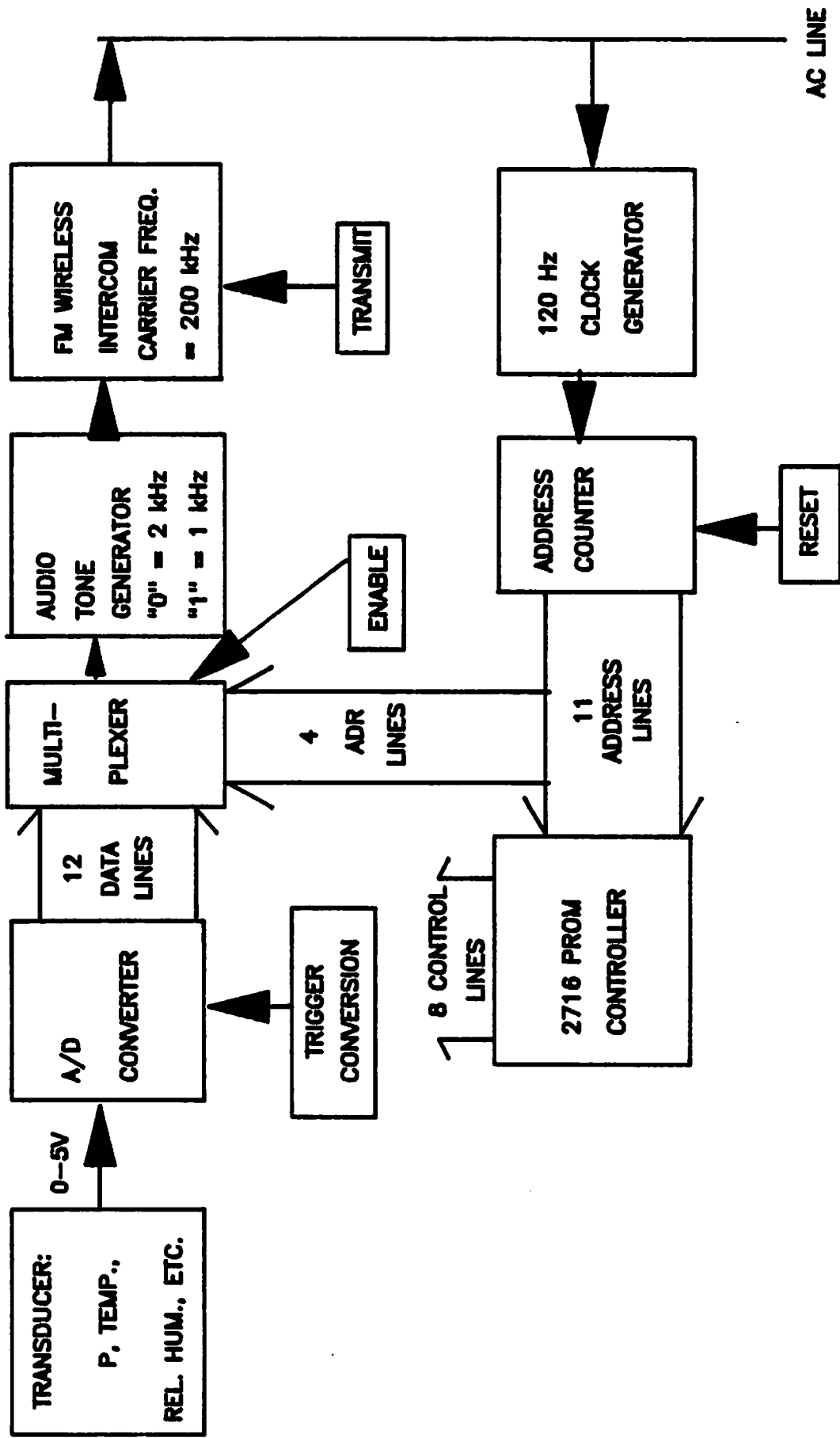


FIGURE 3. REMOTE TRANSDUCER/TRANSMITTER