DATA ACQUISITION SYSTEM FOR MEASURING ENVIRONMENTAL VARIABLES WITHIN CONFINEMENT ANIMAL UNITS

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A data acquisition system developed to facilitate the instrumentation used in evaluating the environment within commercial animal housing greatly reduces the problems in instrumentation, data recording and processing. The data acquisition system converts the analogue signals generated by the instruments into a useable format compatible with a digital computer. This system minimizes the time lag between data acquisition and data processing. As well, monitoring of the various parameters can be left unattended for considerable periods of time. Hand keying of data by transcribing from strip charts and any manual recording has been eliminated. The data acquisition system, mounted permanently on a mobile equipment rack, can be transported easily to any site by means of an air-conditioned mobile trailer. At the site, the sampling lines and cables from the instrumentation in the trailer then are positioned within the animal facility.

INTRODUCTION

While laboratory studies involving environmental parameters in animal housing can provide valuable information, the question often arises as to whether such findings are valid in commercial-scale operations. Problems of instrumentation, data recording and lack of appropriate methods of processing the large quantitities of data generated in environmental studies in commercial facilities frequently have been a deterrent in the past to undertaking such projects. However, recent developments in instrumentation and recording equipment have reduced these problems very considerably. This report describes the components of a data acquisition system assembled by the Department of Agricultural Engineering, University of Alberta, for use in such studies.

SYSTEM COMPONENTS

There are four basic components in the data acquisition system (Fig. 1). The first component includes the instrumentation used to measure environmental parameters. The second component of the system is the signal conditioner which conditions the signals from the instruments to a 1-10 volt range. An automatic sampler becomes the third component which samples from different locations in sequential fashion. The last component of the data acquisition system is the analogue signal converter which converts the conditioned analogue signals to a digital format compatible with a paper tape punch and digital computer. The latter three components were assembled by the Department of Agricultural Engineering, and Technical Services, University of Alberta.

Instrumentation for Measuring Environmental Parameters

The following internal and external parameters, which would influence or account for the existing environmental conditions within the livestock building, are monitored:

(a) carbon dioxide (CO_2),
(b) ammonia (NH_3),
(c) hydrogen sulphide (H_2S),
(d) dew-point temperature,
(e) dry-bulb temperatures,
(f) static and velocity pressures,
(g) air speed,
(h) wind speed and direction, and
(i) direct and horizontal solar radiation.

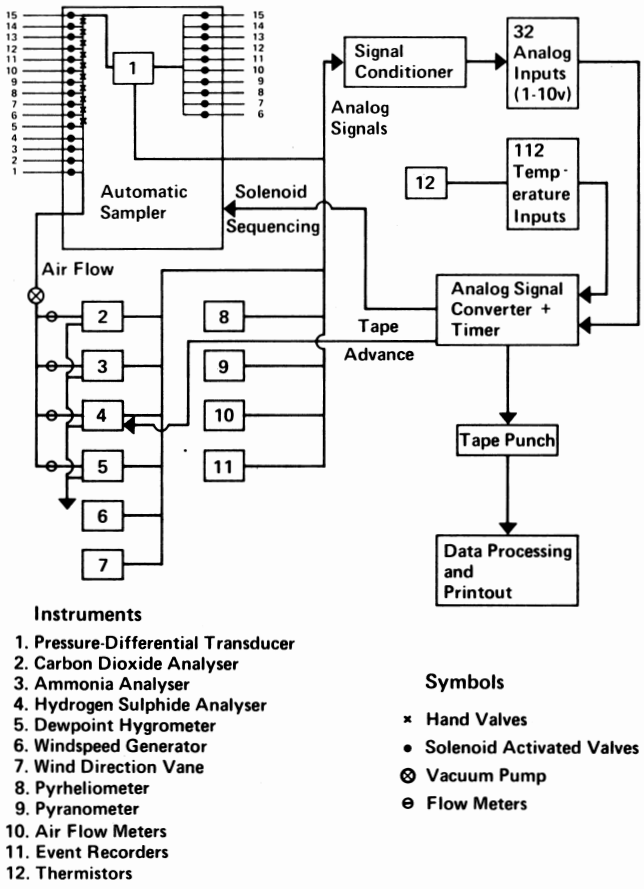

Figure 1. Components of data acquisition system.

The CO_2, and NH_3 concentrations are measured by nondispersive infrared gas analyzers (Beckman, Model 315A, California). The concentration of H_2S is measured by a tape sampler (A.I.S.I., Model F-2-SER, Research Appliance Company, Pennsylvania) in which the sampled air passes through a tape impregnated with lead acetate. Upon contact with H_2S, the tape darkens. The tape is positioned between a

densitometer light source and a photocell which evaluates the amount of H_2S present in the sample by means of a voltage output.

Dew-point temperatures are measured by a Dew Point Hygrometer (Model 880, Cambridge Systems, Massachusetts). This instrument utilizes the dew-point condensation principle to determine the water vapor concentration in an air sample. Dry-bulb temperatures are measured by thermistors (Fenwal Electronics, Framingham, Mass.) which are semi-conductors exhibiting a change in electrical resistance with a change in temperature.

Static and velocity pressures are measured by a low range differential pressure transducer (Validyne, Model DP45, Sierra Instruments, California). This instrument monitors differential static pressures between the inside and outside of the livestock building and also the velocity pressures within ducts downstream from the exhaust fans for the purpose of measuring fan capacities. Air speeds within the zone of animal occupancy are measured with air-meters utilizing horizontally positioned, omni-directional probes (Model B-27, Hastings Raydist Inc., Virginia).

Wind speed and direction are measured by a three-cup wind anemometer and wind direction vane mounted on a 10-m pole (Sierra Instruments, California). The intensity of solar radiation is measured by a pair of pyrheliometers (EPPLEY Laboratories, Newport, Rhode Island): one measures the direct radiation normal to the sun's rays, while the other measures the total horizontal radiation.

Relay switches also are incorporated into the system to monitor such events as when an electric motor or set of lights is on or off. When switched on, the relay switches would allow a signal to be transmitted. Therefore, when an electric motor is operating, a signal is generated; when there is no signal the motor is not operating. This is particularly useful in determining, for example, the periods of operation for fans and furnaces, and when lights are in use. The operating time-periods can be correlated with the data obtained for the various environmental parameters.

Signal Conditioner

The signals generated by the above instruments are either amplified or integrated by a signal conditioner. The amplifiers condition the signals to a 1-10 volt range compatible with the analogue signal converter. The amplified signals and their respective gains, are as follows:

(a) carbon dioxide X 2,
(b) ammonia X 2,
(c) hydrogen sulphide X 100,
(d) dewpoint X 200,
(e) differential pressure transducer X 2,
(f) air flow X 1000,
(g) wind direction X 2,
(h) pyrheliometers X 1000, and
(i) event signals X 1.

The integrators accumulate the signals over a 4-min time interval. This time period is specified by the clock in the analogue signal converter. After each 4-min time interval, the integrators are reset to zero and integration resumes. Immediately prior to resetting the integrators, the integrated signals are scanned by the analogue signal converter. The maximum allowable voltage accumulated is 5 volts, the integrators having been found to operate linearly in the 0-5 volt range.

The integrated signals together with their integration constants are as follows:

(a) differential pressure transducer, 10.2; and;
(b) wind speed anemometer, 11.5.

The integrated signal divided by the integration constant provides the mean signal for the designated time period. The reason for using this integration system was because of the appreciable signal fluctuations that were found to occur for these parameters during a relatively short sampling period. The signals generated from the other instruments were found to be relatively stable. For some signals, filters are used to attenuate undesirable noise or signal components that have a different frequency content from that of the signal of interest.

Temperature signals are obtained by incorporating the thermistors into a voltage divider circuit. The voltage outputs range between 9.06 and 2.42 volts corresponding to -40C to 40C, respectively.

Automatic Sampler

In order to sample air from more than one location within an animal facility, an automatic sampler is incorporated into the data acquisition system which permits sequential sampling from a total of 15 locations. This is carried out by solenoid-activated valves placed on each sampling line which are sequenced by a time-clock in the analogue signal converter. Each sampling location is monitored for 4 min; therefore, all of 15 locations can be sampled in 1 h, at which time the sequencing order again is initiated.

This unit has the capability of either drawing air samples or measuring pressure differentials. To draw air samples, one solenoid-activated valve is required per sampling location, while monitoring pressure differentials requires two solenoid-activated valves, one for each side of the pressure gradient. To measure velocity pressures within a duct, one sampling line is connected to the total pressure port and the other to the static pressure port of a pitot-static tube. To measure differential static pressures, one line is placed on each side of a pressure gradient.

The sampler was constructed to allow the number of air samples and pressure monitoring sites to be interchangeable. The sampler either can draw air from 15 sample sites with no provision for sampling differential pressures or it can accommodate up to 10 sites for monitoring pressures leaving the remaining 5 sites for air sampling only. Hand valves are placed in the unit to isolate the solenoids used for air sampling from those used for pressure sampling, since the air-sampling pump would affect the transducer.

Analogue Signal Converter

The analogue signal converter consists basically of an input board, multiplexer, time clock and analogue-to-digital converter. The input board accommodates 144 inputs of which 32 are allocated for analogue inputs from the signal conditioner, the remaining 112 being reserved for thermistors only.

The multiplexor scans the analogue signals every 4 min in groups of 16 and relays the signals one at a time to the analogue-to-digital converter which converts the analogue signal to a three-digit format. This output is transmitted to a paper tape punch.

Immediately subsequent to the scanning, the integrators are reset to zero and the solenoid-activated valves are sequenced to sample the next site. In addition, the paper tape in the H_2S analyzer is advanced automatically to the next 4-min sampling. Hence, 15 groups of analogue signals are scanned in 1 h. The thermistors, which occupy the input locations 33-144, are scanned in 4-min multiples as specified by the manually adjusted time clock. For example, if the time specified is 20 min, the thermistors will be scanned immediately after each fifth analogue scanning. If only one analogue group is to be scanned, the remaining group can be masked. The total number of input locations in use can be specified by a selector switch. This prevents

TABLE I RESPECTIVE UNITS FOR THE MONITORED PARAMETERS

Carbon dioxide	mg/liter
Ammonia	mg/liter
Hydrogen sulphide	mg/liter
Dew point	°C
Thermistors	°C
Pressure transducer (velocity pressure)	m^3/sec (ft^3/min)
Pressure transducer (static pressure)	cm water (inches water)
Air speed	m/sec (ft/min)
Wind speed	km/h (mi/h)
Wind direction	degrees from South
Direct radiation	watts/m^2 (BTU/h/ft^2)
Diffuse radiation	watts/m^2 (BTU/h/ft^2)

the multiplexer from scanning the input locations not in use, thus minimizing the quantity of punched tape used. Each instrument was calibrated to account for any discrepancy occurring between the output of the instrument and that recorded by the paper tape.

DATA PROCESSING

The paper tape is read by an IBM paper-tape reader at the University of Alberta Computing Services Centre. The output of the tape reader is stored on a temporary disc file. A Fortran IV computer program has been developed to convert these raw data, which are expressed in voltages, to their respective units. Each instrument has a calibration curve or conversion formula such that each signal can be converted to its corresponding measurement. For example, a voltage signal from the CO_2 analyzer is converted directly to concentration in terms of milligrams per liter. Table 1 shows the transformation of each signal to its respective unit expression. The processed data are stored in a permanent disc file for further analyses, either statistical or graphical.

DISCUSSION

The data acquisition system and instrumentation described provide a capability for undertaking heat and moisture balance studies in commercial animal housing and for studying concentrations of the three gaseous contaminants of significance in such units. This system offers a potential usefulness in environmental studies, since interactions between the environmental parameters may be investigated in addition to studying a simple parameter. This system also enables an assessment of the effects of non-environmental factors on the animal environment. These factors might include management techniques and the design criteria used in the facility. The influence of external environmental parameters such as wind, solar radiation, temperatures, and building design also may be investigated. The system has the capacity to gather quickly and economically large volumes of data over specified sampling periods. The output from the system has a computer-compatible format that eliminates the manual transposing of data. In addition, the data may be sampled to conform to statistically designed experiments.

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