Argonne Automatic Meteorological Data Processing System[1]

HARRY MOSES AND FRANK C. KULHANEK

Radiological Physics Division, Argonne National Laboratory, Argonne, Illinois

(Manuscript received 21 August 1961, in revised form 2 October 1961)

ABSTRACT

This paper describes a data processing system for recording automatically on paper punch tape and a teletypewriter 29 different meteorological variables measured at the Argonne National Laboratory.

The meteorological sensors are coupled to the data system either directly or through analog-to-digital converters attached to the recorders. Average values of the meteorological variables over periods of 2, 10, or 60 min are obtained by modified ball and disc integrators and pulse accumulators. Other characteristics of the data processing system and an enumeration of difficulties encountered and their solutions are discussed.

1. Introduction

The use of meteorological information for locating industrial plants which may emit toxic materials or for aiding in the alleviation of air pollution is on the increase. Many different observations are necessary for these purposes. At the Argonne National Laboratory, where investigations concerning the relation between weather elements and atmospheric diffusion are in progress, nearly 40 meteorological measurements are made hourly; at the other national laboratories supported by the Atomic Energy Commission such as at Hanford (Fuquay, 1960), Brookhaven (Brown, 1959), or Oak Ridge (Myers, 1956), a large number of measurements are also made. Since considerable time and cost are involved in reducing these data, one welcomes the saving which results from the use of automatic data processing equipment and electronic computers.

Manufactured by the Datex Corporation according to specifications furnished by the Argonne National Laboratory, a data processing system used to reduce large amounts of meteorological information is described in this paper, and the pitfalls and difficulties which may arise in the procurement and use of such equipment are discussed.

The system handles nearly 300,000 measurements annually and records these on a teletypewriter and 5-channel paper tape from which IBM cards are produced. Meteorological analyses are obtained with the aid of IBM 650 or 704 computers available at the Laboratory.

When meteorological measurements were begun in 1949, a number of conventions with respect to averaging times were adopted. For example, wind speed and direction data were averaged for 10 min each hour, beginning at 5 min before the hour. To maintain continuity in the records, the data processing system was designed to retain the conventions adopted previously.

[1] This work is performed under the auspices of the Atomic Energy Commission.

2. Description of meteorological data processed

Features of the meteorological equipment which are used in conjunction with the automatic data processing system are summarized in Tables 1 a–c. These tables give information pertinent to each of the measurements, such as type of sensor and recorder, elevation, averaging period, and method of tie-in to the data handling system. Details of the character of the site on which the Meteorology Laboratory is located are discussed elsewhere (Moses and Willett, 1957).

3. Components of the data processing system

Since the application of automatic techniques to meteorological measurements involves many unknowns, it was considered advisable to install a small part of the system first and to make use of the experience thus gained in specifying features of the complete system. A separate unit to process only the soil temperature data was put into operation in October 1957, and the complete system became operative in January 1961. A block diagram showing the essential components of the complete system is presented in Fig. 1. It may be seen from this diagram that there are four different types of data-handling schemes.

A. Type I—non-integrated variables

The dew point values, the temperature of the radiation flux plate, and the soil temperature measurements are recorded as instantaneous values. These data are obtained through the use of a Datex Disc Encoder (Fig. 2) attached to the slidewire shaft of the appro-

TABLE 1a. Features of meteorological measurements.

	Measurement of ambient air temperature	Measurement of temperature difference between two levels	Measurement of wind speed
Sensor	Thermopile (5 copper-constantan thermocouples made of #36 wire)	Copper-constantan thermocouples a. lower thermocouples made of #16 wire b. upper thermocouples made of #36 wire	3-cup anemometer with 1/60th mi contacts
Height above ground (in feet)	5.5	5.5–15.2 5.5–34.0 5.5–72.2 5.5–144	9.38, 18.75, 37.5, 75, and 150
Recorder	Minneapolis-Honeywell Strip Chart Electronik Potentiometer	Minneapolis-Honeywell Strip Chart Electronik Potentiometer	*None
Linearity	Nonlinear compensation applied	Nonlinear compensation applied	Linear
Scale of recorder	−20C to +20C and 0C to +40C	−5.0C to +20C (temperature of upper level minus temperature of lower level)	—
Character of trace	Fluctuating	Fluctuating	—
Integration period	10 min, beginning 5 min before the hour	2 min for each level. For sequence see Table 3	10 min, beginning 5 min before the hour
Method of integration	Contact closure type ball and disc integrator	Contact closure type ball and disc integrator	Contact closure count
Method of tie-in to data processing system	Cam mounted on recorder slidewire shaft actuates ball and disc integrator	Cam mounted on recorder slidewire shaft actuates ball and disc integrator	Direct count of contact closures

* Esterline-Angus recorders are used for wind speed, but these are not a part of the Automatic Meteorological Data Processing System.

TABLE 1b. Features of meteorological measurements.

	Measurement of wind direction	Measurement of net radiation flux	Measurement of temperature of radiation flux plate
Sensor	Aerovane actuating synchro transmitter	Beckman and Whitley radiometer	Copper-constantan thermocouple
Height above ground (in feet)	9.38,* 18.75, 37.5,* 75,* and 150	6	6
Recorder	Esterline-Angus	Minneapolis-Honeywell Strip Chart Electronik Potentiometer	Minneapolis-Honeywell Circular Chart Electronik Potentiometer
Linearity	Linear	Linear	Nonlinear
Scale of recorder	0–360 deg	−0.5 to 1.2 langleys	−20F to +100F
Character of trace	Fluctuating	Fluctuating	Nearly smooth
Integration period	10 min, beginning 5 min before the hour	One hour	Instantaneous reading
Method of integration	Contact closure type ball and disc integrator	Contact closure type ball and disc integrator	None
Method of tie-in to data processing system	Cam mounted on shaft of gear coupled to synchro repeater	Cam mounted on recorder slidewire shaft actuates ball and disc integrator	Datex disc encoder mounted on recorder slidewire shaft

* These levels have not yet been incorporated into the system.

TABLE 1c. Features of meteorological measurements.

	Measurements of solar radiation	Precipitation	Dew point	Soil temperature
Sensor	Eppley 50-Junction Pyrheliometer	Bendex Friez Tipping Bucket Precipitation Gauge	Foxboro Dewcels	Leeds & Northrup 100-ohm copper therm-ohms
Height or depth with regard to ground surface	6 ft above ground	3 ft above ground	*Above ground* 1.17 ft 2.34 ft 4.69 ft 9.38 ft 131.0 ft	*Below ground* 1, 10, 20, 50, 100*, 305, 884 cm
Recorder	Leeds & Northrup Micromax	Pips made by chronograph pen on margin of Esterline-Angus recorder	Minneapolis-Honeywell Strip Chart Electronik Potentiometer	Leeds & Northrup Micromax
Linearity	Linear	—	Nonlinear	Linear
Scale of recorder	0–2.00 langleys/min	Unlimited	−30F to +90F	−30C to +30C and 0C to +60C
Character of trace	Fluctuating	—	Steady	Steady
Integration period	One hour	One hour	Instantaneous reading	Instantaneous reading
Method of integration	Contact closure type ball and disc integrator	Contract closure count	None	None
Method of tie-in to data processing system	Cam mounted on recorder slidewire shaft actuates ball and disc integrator	Direct count of contact closures	Datex disc encoder mounted on recorder slidewire shaft	Datex disc encoder mounted on recorder slidewire shaft

* There are two sensors located about 40 ft apart at the 100-cm depth.

priate recorder to provide a modified binary-decimal digital output. The output is fed to a Datex K-106 translating unit containing a matrix of relays, diodes, and thyratrons to provide signals which activate the proper tape punch magnets for producing the paper tape.

B. Type II—integrated variables—ball and disc integrator coupled to recorder

Information on ambient air temperature, temperature difference between two levels, intensity of solar radiation on a horizontal surface, and net radiation flux is obtained through the use of a Librascope ball and disc pulse-counting integrator coupled to the slidewire shaft of a self-balancing potentiometer recorder (Fig. 3). The integrator provides a number of contact closures which is proportional to the value of the meteorological variable averaged over the desired time period. These pulses are accumulated in Datex Item Counters, type IC-101, which consist of a combination of stepping switches and relays, and are transmitted to the tape punch upon command from the programmer when interrogated.

(1) The pulse-counting ball and disc integrator

A schematic diagram of the ball and disc pulse counting integrator manufactured by Librascope, Inc., is shown in Fig. 4. In this unit the angle rotated by a spiral cam (A), attached to the slidewire shaft of the self-balancing potentiometer, is proportional to the recorder pen displacement. Cam (A) is coupled (through a linkage not shown in Fig. 4) to the ball carriage (E) and determines its displacement r from the center of the driving disc (D). Since the magnitude of r is a function of the angular position of cam (A), it is a measure of the instantaneous value of the meteorological variable. The balls in the carriage (E) transmit rotation from disc (D), which turns at a constant angular velocity, w, to the cylinder (C) which rotates at a speed depending on r. Attached to cylinder (C) is a disc-shaped 2-pole magnet (F) which actuates the contacts of a glass-enclosed switch (G).

By a proper selection of design parameters in the ball and disc integrator it is possible to make the number of contact closures within a chosen averaging period equal to the average value of the meteorological variable measured in appropriate units, i.e.

$$N=\frac{1}{T}\int_0^T Mdt+\epsilon,$$

where N is the number of contact closures, T is the averaging period, M is the magnitude of the meteorological variable in appropriate units (e.g., tenths deg F), t is time, ϵ is an error value representing the difference

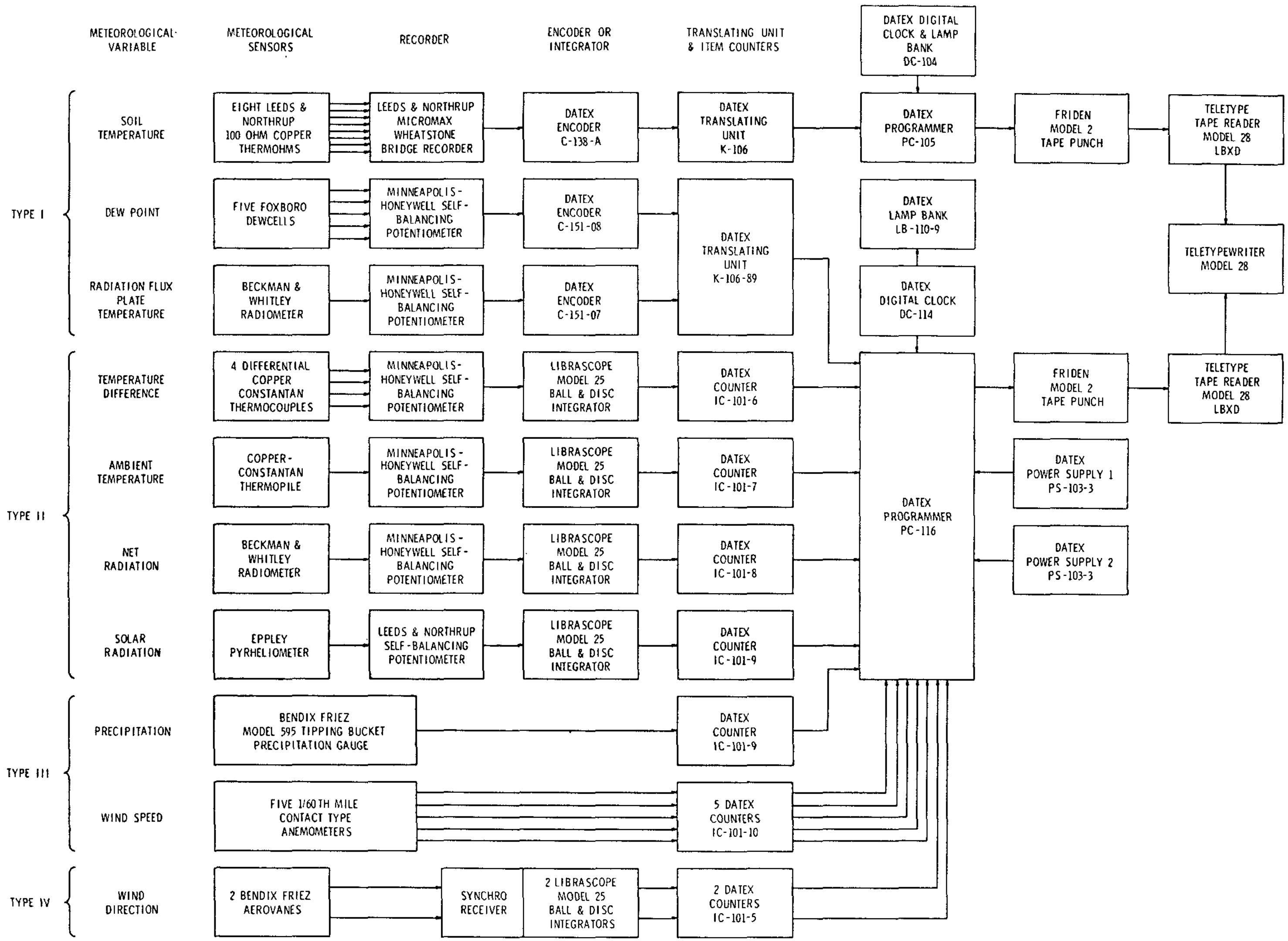


FIG. 1. Block diagram of Argonne meteorological and soil temperature data processing systems.

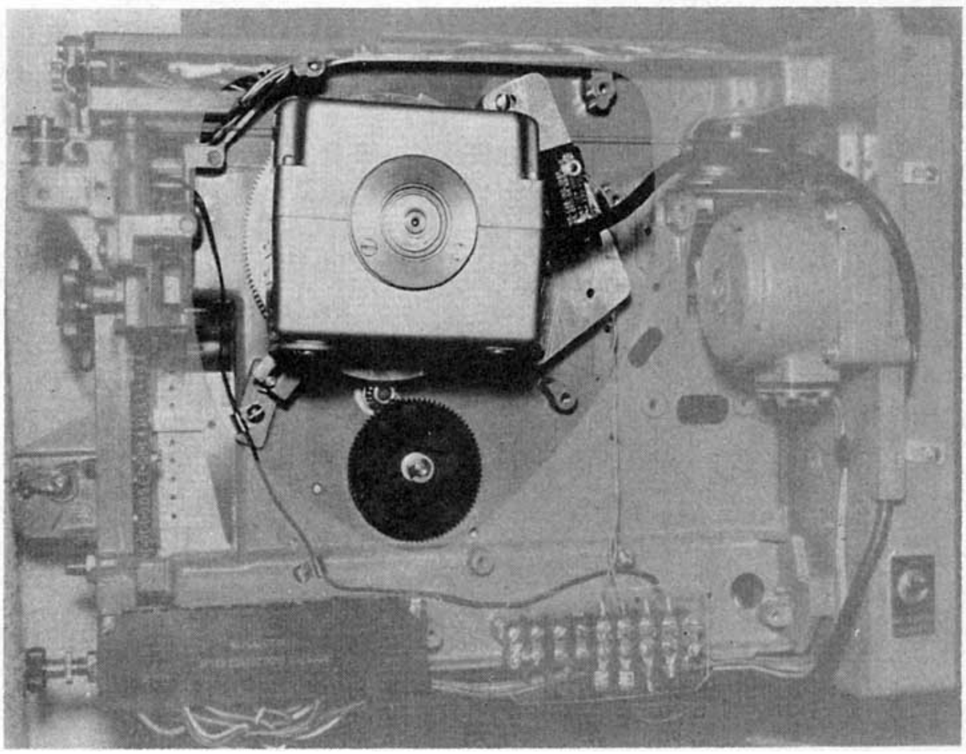


FIG. 2. Datex disc encoder coupled to Minneapolis-Honeywell recorder.

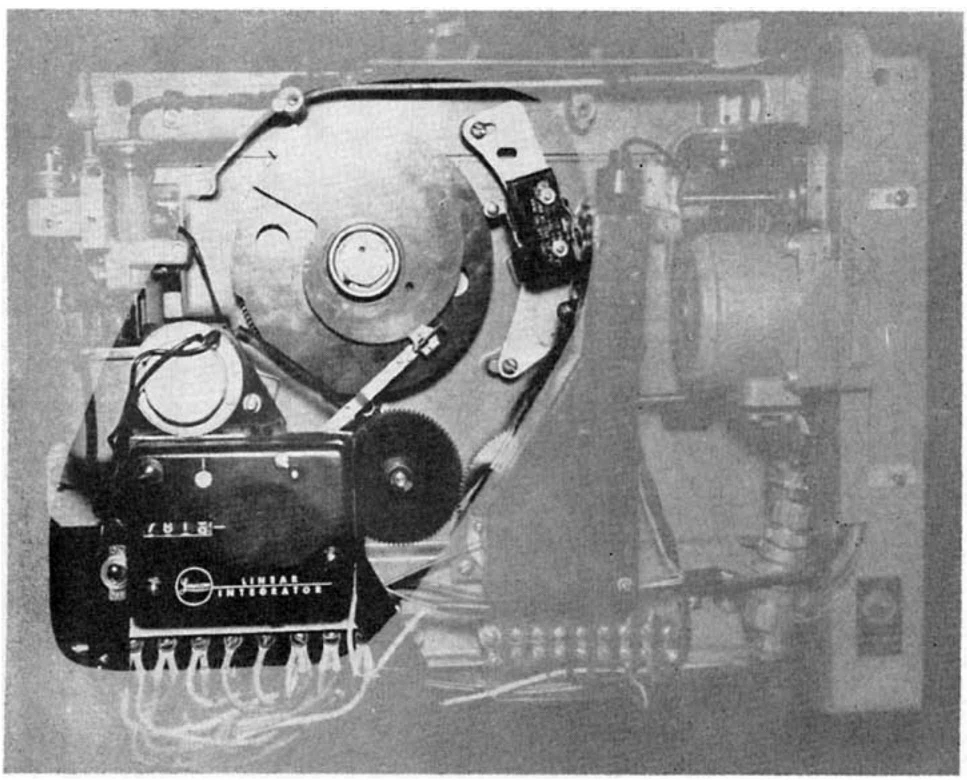
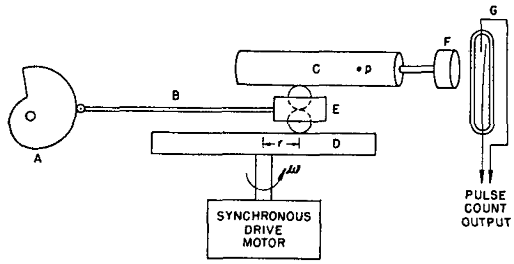


FIG. 3. Librascope ball and disc integrator coupled to Minneapolis-Honeywell recorder.



A. SPIRAL CAM
B. TRANSMITTING ARM (COUPLED BY A LINKAGE NOT SHOWN)
C. CYLINDER
D. DISC
E. BALLS AND BALL CARRIAGE
F. 2-POLE DISC MAGNET
G. MAGNET OPERATED SWITCH

FIG. 4. Schematic diagram of ball and disc integrator.

between N and the average value of the meteorological variable. The value, ϵ, arises from the possibility that a contact closure does not occur exactly at the beginning or end of the averaging period. To obtain the desired accuracy the ball and disc integrator is designed to yield sufficiently small values of ϵ.

C. *Type III—integrated variables and direct coupling of meteorological sensor to item counter of data processing system*

Data on precipitation and wind speed are obtained by coupling the sensors directly to the data handling system. Precipitation is recorded by a tipping bucket precipitation gauge, which provides a contact closure whenever 0.01 inch of precipitation has fallen into the gauge. The contact closures create impulses which are counted for one hour beginning on the hour by an item counter. Similarly the anemometers for measuring wind speed at five different levels above ground provide contact closures when 1/60th of a mile of wind has passed. These impulses go directly to item counters and are counted for 10 min to provide an output suitable for actuating the proper punch magnets on the tape punch. With a 10-min averaging period and anemometer contacts occurring every 1/60th of a mile, the number of counts accumulated represents the speed in tenths of a mile per hour. For example, a 1-mph wind speed accumulates 60 counts in one hour and 10 counts in 10 min. Therefore, the ten counts represent ten tenths or a 1-mph speed averaged over 10 min.

D. *Type IV—integrated wind direction values*

The determination of average wind direction is beset with difficulties. For example, if one wanted to obtain the average of two wind directions, 30° and 350°, it would be incorrect to add the values and divide by two since this would result in a value of 190°. Of course, the average direction is 10°. The difficulty arises from the fact that our numbering system corresponds to points on a line while direction corresponds to points on a circle. To make the transformation of the points on a circle to points on a line, the circle must be broken at some point, i.e., north or 360° in the case of direction. Averaging about this break point leads to erroneous results.

In the design of this data processing system the difficulty has been partially avoided by the scheme shown in Figs. 5 and 6.

In the Aerovane system the wind vane is attached to the shaft of a synchro transmitter. A synchro receiver is coupled to the pen of an Esterline-Angus Recorder through a heart-shaped cam linkage to provide the wind direction record. In the data processing system a second synchro receiver is connected to the Aerovane transmitter. The shaft rotation of this synchro is coupled to the spiral cam of a ball and disc integrator through a 3:1 gear reduction so that three complete revolutions of the Aerovane wind vane correspond to one revolution of the spiral cam. The rapidity of pulsing of the ball and disc integrator has been designed as shown in Fig. 6. An average wind direction corresponding to the first rotation will result in a number of impulses ranging from 0 to 36; the second rotation, from 36 to 72; and the third, from 72 to 108. Since wind direction to the nearest 10° is desired, direction is indicated to 36 points.

Just before the 10-min averaging period begins, the programmer control unit energizes a Ledex reset mechanism, which places the cam in the middle third of its rotation, and then the second synchro receiver is connected into the Aerovane system. This synchro will drive the cam to the correct angular position corresponding to the wind direction at the moment. If during the 10-min averaging interval the wind direction varies from, let us say, 340° to 030° through the smaller arc of the circle with a mean direction of 020° (see A–B in Fig. 6), the ball and disc integrator will provide 74 counts but the item counter will store only two counts corresponding to the correct average of 20°. This is accomplished by resetting the item counter to zero whenever a count of 36 has accumulated. Thus the difficulty of averaging about the 360° break point is obviated.

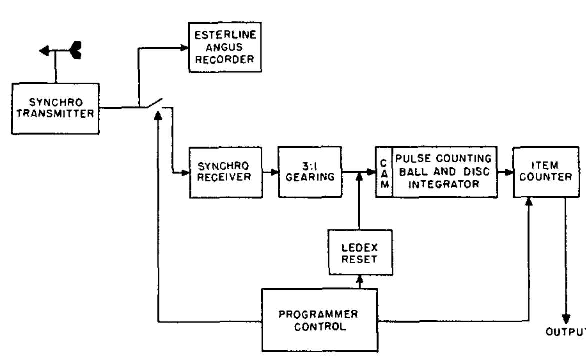


FIG. 5. Technique for averaging wind direction in Argonne meteorological data processing system.

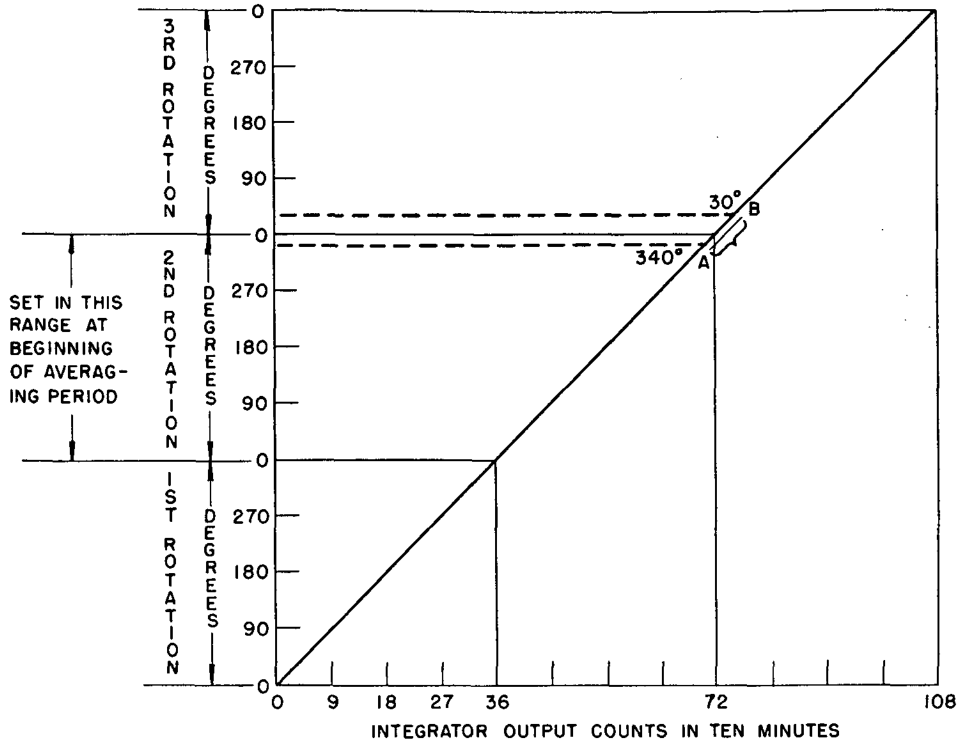


FIG. 6. Relation between Aerovane angle and output of ball and disc integrator.

The system has the shortcoming of providing an average which may be dependent on the direction of rotation. For example, if the wind blew from a direction of 280° for 5 min and 360° for the following 5 min, the average would be recorded as 320° if the wind veered through the smaller arc, but 140° if the wind backed through the larger arc. During a thunderstorm or a severe frontal passage, this ambiguity may arise. The difficulty may be eliminated by an indicator punch on the tape to show that the wind direction variation exceeded 180° during the 10-min averaging period.

E. Digital clocks and programmers

In an automatic data processing system of the type discussed in this paper, it is necessary to have a timing device to energize the equipment at selected times so that the desired information is punched on paper tape and printed out by the teletypewriter. The timing device contains a synchronous motor and is often called a digital clock because it has an associated lamp bank to indicate the date and time in decimal digits. The cam and microswitch driven by this motor operate sequentially a bank of stepping switches which, in turn, control a matrix of relays, switches, and diodes. This arrangement of electronic hardware controlled by a synchronous motor is called the programmer.

(1) The soil temperature system

Soil temperature is measured at each of the depths, 1, 10, 20, 50, 100, 305, and 884 cm for 2-min periods in the order indicated; the soil temperature at a second 100-cm level, 40 ft from the first, is also measured. The sequence of measurement, which is controlled by a synchronous motor, cam-driven switch, and a stepping switch, begins on the hour; thus the 1-cm temperature is measured from 0 to 2 min past the hour, the 10-cm temperature from 2 to 4 min past the hour, etc. At the odd minutes past the hour, i.e., in the middle of each 2-min measuring period, a short pulse is produced to energize the appropriate portion of the system to punch on tape the value of the soil temperature currently recorded. Table 2 lists the schedule of soil temperature readings and punch-out times. A second synchronous motor, which forms part of the digital clock, sets up the circuits through a cam-driven switch controlling several stepping switches and a diode matrix to punch out the date and hour prior to the recording of the soil temperature information.

(2) The meteorological data processing system

In the soil temperature system the temperature at a given level is recorded on a Micromax recorder and paper tape within the same 2-min interval. There is no need to average the data because the temperature in the soil changes slowly, therefore, instantaneous readings are taken and data storage is unnecessary. In the meteorological data system, storage is required since variables are averaged over periods of 2, 10, or 60 min (see Table 3).

In the meteorological data system, which has a basic time period of 30 sec controlled by the digital clock, the programmer performs the following functions:

(1) It turns the ball and disc integrators on or off and commands the item counters (see Fig. 1) to start or stop storing impulses generated by the integrators and the wind speed or precipitation equipment. At the end of the averaging period it resets the item counters to zero to be ready for the next cycle.

(2) It controls the operation of the unit which translates the digital output corresponding to the dew point temperature and net radiation flux plate temperature. This digital output is transformed into 5-channel teletype code for punching the paper tape.

(3) It controls the sequence in which the digital clock, the item counters, and translating unit are interrogated. (See Table 3.)

(4) It commands the tape punch to produce the paper tape.

(5) It energizes the tape reader which in turn commands the teletypewriter to print out the information which has accumulated on the paper tape during the previous hour.

The programmer of the meteorological system converts the parallel output of meteorological information (since the data are measured simultaneously) into a series output by sequential interrogation. The programmer of the soil temperature system interrogates as the temperature is being measured; thus the conversion from parallel to series output is not needed.

TABLE 2. Soil temperature punch-out schedule.

	Instantaneous reading (min:sec)	Punch-out time (min:sec)
Code date time	—	01:00
Soil temp. 1 cm	01:00	01:00+
Soil temp. 10 cm	03:00	03:00
Soil temp. 20 cm	05:00	05:00
Soil temp. 50 cm	07:00	07:00
Soil temp. 100 cm #1	09:00	09:00
Soil temp. 305 cm	11:00	11:00
Soil temp. 884 cm	13:00	13:00
Soil temp. 100 cm #2	15:00	15:00
Reference	17:00	17:00
End of line and stop code	—	17:00+

TABLE 3. Meteorological data punch-out schedule.

Meteorological variable	Integration period (min:sec)	Instantaneous reading (min:sec)	Punch-out time (min:sec)
Code date time	—	—	30:00
Flux plate temp.	—	30:00	30:00+
Dew point ref.	—	55:00	55:00
Temp. diff. ref.	53:00–55:00	—	55:00+
Dew point 1.17 ft	—	57:30	57:30
Temp. diff. 15.2–5.5 ft	55:30–57:30	—	57:30+
Dew point 2.34 ft	—	59:00	59:00
Precipitation	00:00–60:00	—	00:00
Solar radiation	00:00–60:00	—	00:00+
Radiation flux	00:00–60:00	—	00:00+
Temp. diff. 34.0–5.5 ft	58:00–60:00	—	00:00+
Dew point 4.69 ft	—	01:00	01:00
Dew point 9.38 ft	—	02:30	02:30
Temp. diff. 72.2–5.5 ft	00:30–02:30	—	02:30+
Dew point 131 ft	—	05:00	05:00
Temp. diff. 144–5.5 ft	03:00–05:00	—	05:00+
Ambient temp.	55:00–05:00	—	05:00+
End of card code	—	—	05:00+
Code date time	—	—	05:00+
Wind speed 9.38 ft	55:00–05:00	—	05:00+
Wind speed 18.75 ft	55:00–05:00	—	05:00+
Wind speed 75 ft	55:00–05:00	—	05:00+
Wind speed 150 ft	55:00–05:00	—	05:00+
Wind direction 18.75 ft	55:00–05:00	—	05:00+
Wind direction 150 ft	55:00–05:00	—	05:00+
End of line and transfer code	—	—	05:00+

F. Tape punches, tape readers, and teletypewriter

Since the soil temperature system and the meteorological system were purchased at different times, it was more economical to have a separate Friden Model 2 tape punch and teletype Model 28 LBXD tape reader for each system. The two systems are combined only in producing a printout by a single teletypewriter Model 28.

At 30 min past each hour, the programmer energizes the tape reader and teletype for printout from the meteorological system. Printout continues until a "bell code" signal is read by the tape reader which effects a switch-over to begin reading and printing information on the soil temperature tape. When a "k" code is observed, the teletypewriter and tape reader circuits are then automatically de-energized. The punches, readers, and teletypewriter are designed to operate only about 3 min during each hour and remain de-energized during the remainder of the hourly cycle.

A sample of the printout format is shown in Fig. 7. Measurements for one hour are represented by a 3-line group. The IBM card layouts are shown in Table 4.

G. Additional features

A number of additional features were incorporated into the system.

(1) "Subtract" circuits

Some of the meteorological variables have negative values. For example, the ambient air temperature recorder has two ranges: −20C to +20C, and 0 to +40C. When the temperatures are in the −20 to +20C range

10361051109 65 400 00 399-09 378 000 585 065-07 363 360-11 359-12 141
14161051109 080 086 092 099 104 14 15
12061051109 130 113 111 105 090 078 108 092 250

10361051110 72 399 00 427-07 400 000 563 078-11 396 363-10 356-11 171
14161051110 073 076 082 086 088 14 15
12061051110 147 119 111 105 090 078 107 093 251

10361051111 76 399 00 422-09 396 000 792 098-11 380 360-08 354-11 185
14161051111 065 069 079 082 089 11 13
12061051111 161 129 113 105 090 079 107 093 251

Explanation of above format

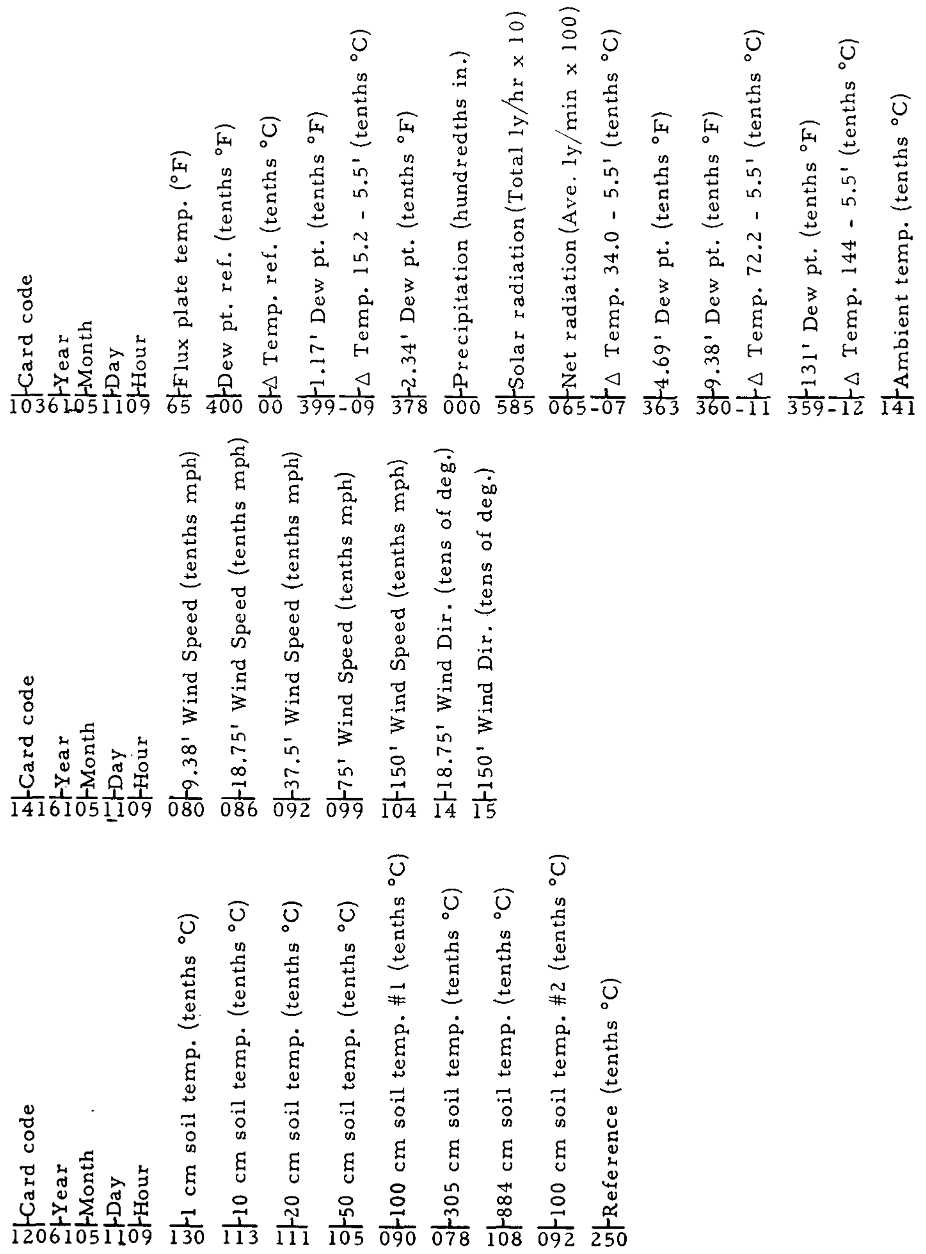


FIG. 7. Teletype printout format.

TABLE 4. IBM card formats.

Card column	Information	Card column	Information
		Card #1	
1, 2	Blank	35	Blank
3–5	Station code	36–38	Precipitation
6, 7	Year	39	Blank
8, 9	Month	40–42	Solar radiation
10, 11	Day	43–46	Radiation flux
12, 13	Hour	47–49	Temp. diff. 34.0–5.5′
14–16	Flux plate temp.	50–53	Dew point 4.69′
17–20	Dew point ref.	54–57	Dew point 9.38′
21–23	Temp. diff. ref.	58–60	Temp. diff. 72.2–5.5′
24–27	Dew point 1.17′	61–64	Dew point 131′
28–30	Temp. diff. 15.2–5.5′	65–67	Temp. diff. 144–5.5′
31–34	Dew point 2.34′	68–71	Ambient temp.
		Card #2	
Card column	Information	Card column	Information
1, 2	Blank	22	Blank
3–5	Station code	23–25	Wind speed 37.5′
6, 7	Year	26	Blank
8, 9	Month	27–29	Wind speed 75′
10, 11	Day	30	Blank
12, 13	Hour	31–33	Wind speed 150′
14	Blank	34–37	Blank
15–17	Wind speed 9.38′	38, 39	Wind direction 18.75′
18	Blank	40–46	Blank
19–21	Wind speed 18.75′	47, 48	Wind direction 150′
		Card #3	
Card column	Information	Card column	Information
1,2	Blank	22–25	Soil temperature 20 cm
3–5	Station code	26–29	Soil temperature 50 cm
6, 7	Year	30–33	Soil temperature 100 cm #1
8, 9	Month	34–37	Soil temperature 305 cm
10, 11	Day	38–41	Soil temperature 884 cm
12, 13	Hour	42–45	Soil temperature 100 cm #2
14–17	Soil temperature 1 cm	46–49	Reference
18–21	Soil temperature 10 cm		

the ball and disc integrator will provide zero counts for −20C and 400 counts for +20C, that is, 1 count for every 0.1C. If the average temperature were −10 deg then 100 counts would be sent to the item counter by the ball and disc integrator. When temperatures are in the −20 to +20 deg range a "subtract 200" circuit is energized so that the value of −10.0 instead of +10.0 is punched on the tape. Other variables such as soil temperature, dew point temperature, net radiation flux plate temperature, and the temperature difference between two levels have appropriate "subtract" circuits.

(2) Missing data code

Should the sensors using thermocouples develop a break, the pen on the recorder is driven to the upper limit on the scale. Similarly, the pen is driven to the lower limit of the scale when the temperature falls below −20C, or when the net radiation flux sensor becomes wet due to rain. If the recorder pen has reached its maximum or minimum position, a limit switch, attached to a second cam on the slidewire shaft, is actuated to provide space codes on the paper tape which in turn show up as blanks on the teletypewriter and IBM cards indicating that the information is missing.

(3) Power failure light

When power is resumed after a failure, an indicator lights up on the front panel signifying that data-logging is off schedule.

(4) Date-time light bank and manual reset buttons

Illuminated numbers (part of the digital clock) indicating day of the month, hour, and minute on the meteorological system, and day of the month and hour on the other system, appear on the consoles. With these it is possible to reset each system to the correct time once a power failure has occurred. Also provided are manual rotary switches for inserting the month and year. These may be seen in Figs. 8 and 9.

Switches are also provided on the meteorological system to readout the information which is being recorded by each of the sensors. However, only instantaneous values are read out. If the item counters have been operating for a smaller period than the selected averaging period, the readings are spurious. A "data-log"

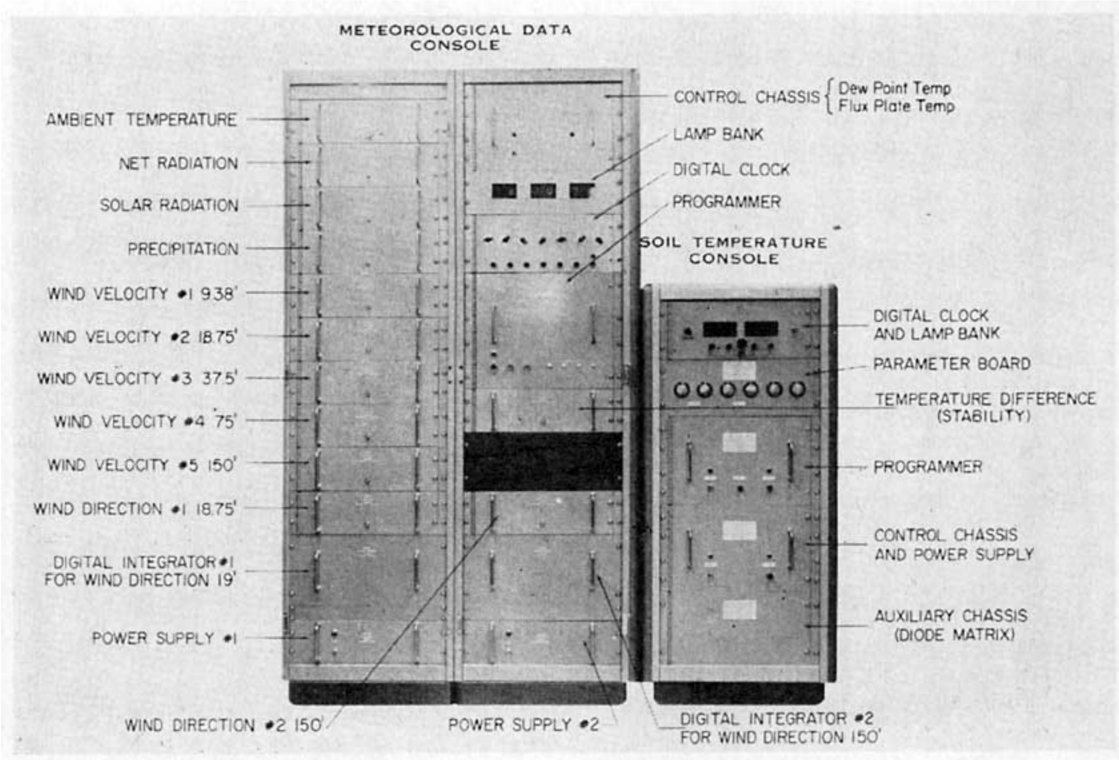


FIG. 8. Argonne meteorological and soil temperature consoles with chassis identification.

switch is also provided to punch out the information accumulated on the tapes at any instant without waiting for the scheduled printout time which occurs at 30 min past the hour.

4. General comments

The soil temperature system has been working satisfactorily for over three years. Satisfactory operation of the meteorological system began on 1 January 1961. Based on the experience gained in the use of this type of equipment, the following comments are made:

(1) It is advisable to retain recorder pen and ink traces in order to provide a simultaneous record. This is especially desirable to avoid the loss of data during the first year of operation when difficulties might be expected.

(2) A printout device such as a teletypewriter, a Datex Data Log, or a Flexowriter is a necessity to minimize the loss of data, especially in the cases where intermittent difficulties arise. A printout device will pay for itself in avoiding the time spent correcting spurious data or avoiding the actual loss of measurement.

(3) Experience has shown that a manual tape perforator for punching new tape to replace sections that are faulty or when the system becomes inoperative is highly desirable.

(4) In drawing up the specifications for a system where both printout and paper tape are obtained, one may choose a parallel system where separate impulses are sent to the tape punch and typewriter, or a series system where the tape is produced first and then used to produce the printout. The series system has the advantage of providing a check on the correctness of the printout since it is produced from the tape. However, a time lag will result between the printout and tape punching. Where a time lag is tolerable, the series system is preferred.

FIG. 9. Argonne meteorological and soil temperature data processing equipment.

(5) In the soil temperature and meteorological data systems the day, hour and minute are advanced automatically, but only in the meteorological data system is the month advanced automatically. Experience has shown that the additional cost of an automatic monthly advance is justified.

(6) When tape punches, tape readers, and teletypewriters are used for only small fractions of each hour, it is desirable to incorporate timing devices to de-energize them during periods of disuse, thus reducing wear and noise.

(7) In designing an automatic data processing system one must consider the type of computer on which the data will be handled and select a compatible tape code, for example, one must decide on whether to use 5-, 6-, 7-, or 8-channel tape.

(8) Although maximum versatility is desirable, one must balance the cost of incorporating flexibility against his future needs. In most cases it is desirable to specify that a pinboard be included which will allow a change in the sequence of readout and the addition of new measured variables, i.e., a system with room for expansion. If the system is to be used for research as well as for the gathering of climatological data, provision for varying the length of the integration period or the portion of the hour during which integration takes place should be made. A well designed pinboard will also allow variation in the number of digits for specifying data.

(9) It is well to caution that specifications must clearly spell out what is wanted. If specifications are loosely drawn, misunderstandings are likely to arise unless the vendor has a thorough appreciation of the uses of the data.

(10) One may wonder whether it is desirable to purchase an automatic data processing system in parts such as we have done. This has both advantages and disadvantages. In general, it may be said that the purchase of equipment in parts raises the cost. For example, it was cheaper to have two tape readers and two tape punches to avoid the engineering and fabrication costs of incorporating the two systems into one. Further, a dual system requires the use of more than one controlling timer thus increasing synchronization difficulties, especially after a power failure. Nevertheless, the experience gained through the use of a pilot system may well pay for itself by aiding in the selection of the most suitable design for the final system.

(11) In selecting a vendor, in addition to the usual considerations such as capability, reliability, and experience with this type of system, one must carefully consider the location of the service group. Regardless of what data processing system one might purchase, it is reasonable to expect malfunctions during the first year. The location of the service group within reasonable distance may result in a substantial saving.

5. Conclusions

The automatic data system described here represents a tool for processing large amounts of meteorological data. Since it was necessary to buy the equipment in pieces—first the meteorological sensors and recorders, then the two sections of the data processing system—the unit described here is not the most efficient one possible. Nevertheless, the system is reliable and has worked for long periods without down time and represents a satisfactory solution to our data handling problems. There are many pitfalls associated with the purchase and selection of a data processing system, a few of which have been enumerated above. Careful consideration must be given to many points along the way to avoid a data processing system which becomes a white elephant. After experiencing a saving of time and money in handling of large amounts of data, one is inclined to recommend the use of such equipment with enthusiasm.

Acknowledgments. The authors are grateful for the helpful comments and suggestions provided by Dr. John E. Rose and Mr. L. D. Marinelli of the Radiological Physics Division of Argonne National Laboratory, and by Dr. Horace R. Byers of the University of Chicago. The assistance of Gunther A. Zerbe and Janet G. Daccardo in preparing the figures is sincerely appreciated.

The wide knowledge of Kenneth W. Clarke of the Datex Corporation in automation techniques has contributed materially to the design of the equipment.

REFERENCES

Brown, R. M., 1959: An automatic meteorological data system. *J. geophys. Res.*, **64**, 2369–2372.

Fuquay, J. J., 1960: Personal communication.

Moses, H., and J. H. Willett, 1957: *Argonne National Laboratory five-year climatological summary, July 1949–June 1954.* ANL-5592, 383–384,

Myers, R. F., 1956: A weather information telemeter system. *Bull. Amer. meteor. Soc.*, **37**, 108–117.