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DESIGN REPORT FOR PS-105 DATA ACQUISITION SYSTEM FOR
BIOFOULING STUDIES OF HEAT EXCHANGERS IN SEAWATER

By
Robert W. Findley
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September 1, 1977

Work Performed Under Contract No. EY-76-S-02-4041

Carnegie-Mellon University
Pittsburgh, Pennsylvania

U.S. Department of Energy

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DESIGN REPORT FOR

PS-105

DATA ACQUISITION SYSTEM

FOR

BIOFOULING STUDIES

OF

HEAT EXCHANGERS IN SEAWATER

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September 1, 1977

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ABSTRACT

ADVERTISED TO ADVERT

An electronic system that is well-suited for acquiring OTEC heat exchanger fouling data from surface installations has been designed, constructed, laboratory-tested and field-proven. The CMU device for monitoring the degradation of heat transfer rates due to fouling is equipped with electrical transducers for measuring seawater temperature, flow velocity and heat transfer coefficient. The function of the electronics system described herein is to power the transducers, to boost the low-level output signals from the transducers and to transmit these amplified signals to a central control box where this raw data is sampled at precisely-defined intervals and transferred to a computer-compatible medium. In its present form the system can accommodate two CMU devices, but more could be added by external multiplexing. This system has performed well in acquiring fouling data from Caribbean waters near St. Croix.

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INTRODUCTION

The study of biofouling in heat exchangers through which ocean water is being pumped requires reliable instrumentation systems which can accurately measure temperature and flow velocity over long periods of time, with as little operator assistance as possible.

The system to be described here has been designed to provide such data acquisition, using modular concepts as much as possible, with some operator assistance, yet having the advantage of semi-automatic data gathering and storing.

The system has two separate parts: (a) the Pipe Unit, which contains, besides the pump and heater for the heat exchange functions, the electronics needed to convert the low-level voltages produced by the thermopile, thermistor, and flowmeter to high level signals which can be accurately multiplexed and read by a standard digital voltmeter, and (b) the control box, which has the operator controls for pumps and heaters, and the multiplexing of the signals for the DVM, and the timing circuits and interface circuits needed to connect a DVM to a Teletype.

BASIC SYSTEM DESCRIPTION

The system consists of a control box and two pipe units. The pipe units are identical, and contain the necessary amplifiers, with power supplies, to bring the low level signals from the flowmeters, thermopiles, and thermistors to a signal level (10 volts max.) which can be carried via long cables to the control box with sufficient signal-to-noise ratio that electromagnetic interference in the vicinity of the pipe units will not affect the data accuracy significantly. The signal

levels on the transmission cables are of low enough impedance that readings can be taken in an emergency with a standard digital voltmeter without the control box functioning.

The control box has the necessary circuitry to

- (a) Allow the operator to select either of the two pipe units to provide data.
- (b) Allow automatic data gathering, via a digital voltmeter, of the thermopile voltage, the flowmeter voltage, and the thermistor voltage, and type out (or punch out) the results on a Teletype.
- (c) Allow the operator to turn the pump on or off in each of the two pipe units, and to turn the heater on or off, and to run the heaters at high or low power.

THE PIPE UNITS

The electronics circuitry in each pipe unit has been designed to convert accurately the low-level signals produced by the thermopiles, which measure the heat exchanger temperature, the thermistors, which measure the seawater temperature, and the flowmeter, which measures the flow velocity of seawater thru the pipe, to high level signals which can be processed by a multiplexer and digital voltmeter.

Important in the design are reliability, so that the system may operate for long periods untended, and accuracy, so that drifts are minimized, and vibration and electrical noise have negligible effect. It is important to realize that once a pipe unit is assembled and put into operation, it must function continuously for the duration of the experiment (8 to 16 weeks). Disassembling a pipe unit to repair a

fault means terminating the experiment on that pipe.

Drawing #1 shows the three amplifiers in each of the pipe units. Overall description of the pipe units, including the pumps and heat exchanger has been published (see Ref. 1).

Each amplifier (Datel AM 490-2C) is a chopper stabilized amplifier with low noise, high open loop gain, and low drift. The amplifier for the thermocouple (thermopile) signal, is arranged to have a differential gain of about 10,000. The thermistor amplifier gets its signal from a bridge circuit which has the thermistor as one of its legs, and is connected to have a differential gain of about 150. The flowmeter amplifier (see other description in Ref. 1) for the flowmeter has a gain of about 2000, and gets its signal from the flowmeter strain gauge bridge circuit contained in the flowmeter. The jumper on the flowmeter circuit allows a 110 kilo-ohm resistor to be put in parallel with a 120 ohm bridge arm. This produces an artificial unbalance voltage at the input to the flowmeter amplifier and thus allows a calibration check of the flowmeter amplifier in the field.

The three amplifiers and their power supply are mounted on a small heat sink platform (see Drawing #11) attached to the pipe itself at a point downstream from the heat exchanger section. This gets rid of heat that is developed in the electronics circuitry into the water flow. Also mounted on this heat sink platform is the power supply for the flowmeter bridge.

The offset of each amplifier is trimmed to be off zero, so that minor changes in temperature will not change the sign of the thermopile

output voltage, and also to allow the flowmeter zero velocity signal to be accurately determined. Maintaining a single polarity on the output signals is expected to be a desirable feature in the event that these analog signals are converted to a digital form, as was done, in the Keahole Point operation and as will be done in the Gulf Buoy operation.

CLOCK DIVIDER

Drawing #5 shows the circuitry for producing precise time intervals from a crystal oscillator. The time intervals between data points must be accurately known to allow determination of the time constant of the thermopile decay.

A 100 kilohertz crystal oscillator is divided down by counters to produce two second, four second, and ten second periods, which can be switch selected from the front panel of the control box. In addition a "Manual" position of the switch allows the operator to take data each time a push button ("Manual Rate") is depressed.

This drawing also contains the one-shots which make up the timing circuits necessary to advance the channel counter for the data multiplexer (in Drawing #2) and to hold the digital voltmeter reading while print-out is occurring. A "Status" pulse is also generated to trigger the "Serdex" circuits (Drawings 3 and 4) to enable the Teletype printout. In effect, the "Status" pulse is a "Print Command" to the Teletype interface.

CHANNEL COUNTER AND SCANNER

In order to utilize a single digital voltmeter to read voltages from three different sources (thermopile, thermistor, and flowmeter) a

multiplexer was used to automatically scan through the three inputs. This multiplexer (Datel MM-16) is in modular form, with solid state switching and built-in address decoding. Its high transfer accuracy ($\pm 0.01\%$) allows multiplexing without degrading the accuracy of measurement.

In conjunction with the multiplexer in Drawing #2 is shown the channel counter which provides for sequential readings of data by the digital voltmeter of the three signal sources.

This channel counter is a three-state counter which is advanced by an "Advance Channel Counter" pulse from the clock divider, and is decoded by the address decoding in the MM-16 multiplexer to determine which of the three signal sources is applied to the digital voltmeter. The channel number is also decoded (Drawing #9) and displayed on the front-panel lamps (light emitting diodes) and denotes the signal source that is being measured at any time.

A front panel switch (Channel Select Switch) lets the operator stop the auto-scan feature and hold the voltmeter on any of the three signal sources (thermopile, thermistor, or flowmeter) for as long as is required, for multiple readings of the same sources.

P.C. INTERCONNECT GUIDE

The four printed circuit cards which make up the measuring electronics (Clock Divider, Channel Counter and Scanner, and the Serdex modules) are shown in block form on Drawing #6, along with the digital voltmeter. This voltmeter (Analogic Model 2546) is a 4-1/2 digit instrument capable of reading to ± 1.9999 volts with an absolute accuracy of .01 percent of reading, with one part in 20,000 resolution. It is complete with self-contained power supply and gas plasma display, and has a BCD output for interface to the Teletype.

Since full scale range on the DVM is ± 1.9999 volts, which is a factor of 10 better resolution than needed, a precision voltage divider was connected ahead of the DVM to give an output of one tenth the input to the divider, and the most significant digit is not used in the printout, making the range ± 9.999 volts.

A switch was mounted on the rear of the chassis of the control box, to let the DVM be used as a simple voltmeter for troubleshooting, using the "External" binding posts.

The power supplies for the control box are shown in Drawing #6. These are (1) +5 volts at two amperes (Acopian 5E200) for the TTL logic; (2) ± 15 volts at 50 milliamps (Analog Devices 904); (3) +17 volts at 20 milliamps (Drawing #8).

The four P.C. boards are mounted in a card cage (modified Vector-Pak, CCK-13 from Vector Mfg. Co.). The modification is merely a reduction in length of the cage to 8 inches, and utilization of wire-wrap card connectors (Douglas 72-125C-EL) (see Drawing #14).

The P.C. card connectors are wire wrapped according to the standard method of nomenclature for a two-level, double-side connector, where a particular pin is described by two letters and two numerals. For example, the pin A3F1 refers to a level A (where A is top, B is bottom) slot number 3 (there are a total of four slots), pin F (pins are lettered alphabetically A thru V, with G, I, O, and Q not used) and side 1 (where 1 is left side and 2 is right side viewed from the wire-wrap side).

SERDEX TELETYPE INTERFACE

The interface between the digital voltmeter and the Teletype has been simplified by the use of commercially available modules manufactured by Analog Devices. The modules, under the tradename Serdex, contain the circuitry needed to allow a particular data format, partly produced by the digital voltmeter, and partly by a channel counter, to be printed out by the Teletype, and to be punched on paper tape.

The two modules used are (1) a clock module (SCL-1006) and a transmitter module (STX-1003) which when used together allow conversion of BCD data from the digital voltmeter to serial ASCII (American Standard Code for Information Interchange) for operation of a Teletype with a 20 milliamperere current loop.

The clock module provides the proper clock frequency to the transmitter module to permit 110 baud rate communication with the Teletype, and also provides negative 15 volts D.C. for the integrated circuits in the transmitter module.

The transmitter module allows up to eight BCD digits to be converted from parallel to serial, and with the addition of external shift registers, can be used with more than eight digits per word.

The required data format to appear on the printed page consists of nine words (character groups) across the page, followed by a line feed and a carriage return to let the next line be printed exactly beneath the previous line. The format for each of the nine words starts with a channel number, where 0 = Thermopile, 1 = Thermistor, and 2 = Flowmeter, then the data is printed, with this format repeated for a total of 9 words, and finally a line feed and carriage return. The format then is:

Channel Number
 Space
 Polarity Sign
 Data (most significant digit)
 Data
 Data
 Data (least significant digit)
 Space
 Stop (or line feed)
 Stop (or carriage return)
 Stop

Drawing #3 shows the transmitter module, with the necessary inputs to give the first eight characters of the above format. Since the STX-1003 can handle only 8 characters in its internal shift registers, additional shift registers must be provided to allow the other characters in each printout to be stored. These additional shift registers are shown on Drawing #4.

Furthermore, certain of the characters as expressed in ASCII code, require bits 5 and 6 in the ASCII code to change when the character changes from a data character (numerals) to a function character (line feed or carriage return). To enable both types of characters to be handled by the Teletype, additional shift registers are added (Drawing #4) to store the bits 5 and 6.

Also, to allow nine words to be printed across the page, a counter must keep track of how many words are printed in each line, and after the ninth word provide a line feed and a carriage return. This counter is shown on Drawing #4.

The other Serdex module (SCL-1006) is shown on Drawing #2, providing the clock signal for the STX-1003, as well as a 15 volt power source.

Since the transmitter module generates a 20 milliamperere current loop signal to drive the Teletype, the current regulator for the 20 milliamperes is shown on Drawing #3, with the current obtained from a 17 volt power supply (Drawing #8).

TELETYPE

A Teletype Corporation ASR-33 is used to print out and punch out the data. This Teletype must be wired for 20 milliamperes current loop operation. The printing format allows for nine data words (a data word being considered as a group of characters each having the same format, including polarity, data, and a line feed and carriage return on the ninth word) across the page. Each line starts with the data from channel zero (the Thermopile data), with succeeding lines falling in the same sequence as printing continues.

RELAY AND POWER CIRCUITS

Two pipe units are to be controlled with the control box, and provisions are made for a power cable and a separate signal cable for each unit. Drawing #7 shows the power circuits for control of two pipe units. It is necessary that the operator be able to start or stop the pump in each pipe unit, and to energize or de-energize the heater in each pipe unit. Solid state relays were used for the pumps and for the heater to insure long life operation with a minimum of radio frequency interference being generated.

In addition the heaters must be capable of being operated on "high" power (120 volts) or "low" power (84 volts) by operator switching. The relay for this function is electromagnetic, since solid state relays with single pole, double throw operation were difficult to obtain.

All relays are driven by TTL logic compatible relay drivers to allow change-over to computer operation if desired. Front panel lamps indicate the status of the heater and pump relays. The 12 volts D.C. needed for all relays is obtained from a zener regulator on the 17 volt power supply.

Also on Drawing #7 is shown the "Remote Unit" connector, which is provided to allow an extension of the number of units to more than two by adding an additional set of relays for each unit, external to the control box. Any measurements in the additional units must be done by replacing one of the existing signal cables with a cable from the additional pipe unit to be interrogated.

A 20 ampere circuit breaker protects the power circuitry, and fuses protect individual sections of the circuit. A convenience outlet is available to provide power to the Teletype or other peripheral equipment.

CABLES

Connections between the control box and the pipe units are made with two separate cables (see Drawing #13) for each unit, or a total of four cables. Each pipe unit has associated with it a signal cable and a power cable. The signal cable consists of six twisted shielded pairs (of which two pairs are not connected) with a PVC jacket, one end of which is attached by molding to a twelve pin connector. Only three shielded pairs are required in the present experiment, thus leaving a fourth shielded pair as a spare. Cables and connectors are submersible and can function at a depth as great as 15,000 feet in seawater. The cables are 93 feet long, with a standard AN type connector attached to the control box end.

The power cable consists of a 93 foot length of 4 conductor, 16 gauge wire with a neoprene jacket, again with a molded 4 pin connector capable of underwater operation up to 15,000 foot depths. On the control box end is attached a standard AN type connector.

A third cable in each pipe unit is used to supply power to the pump which is separate from the pipe. The cable is 20 feet in length, has two 16 gauge wires and a molded 2 pin connector on the end attached to the pipe unit, with the other end permanently attached to the pump. Pump power (120 volts a.c.) is fed from the control box thru the 4 conductor cable to the pipe unit, then via the two conductor cable to the pump itself.

For each of the three cables described above, a watertight feed-through is required to pass the conductors into the interior of the protective pipe unit housing. These bulkhead connector receptacles were supplied with 7 foot pigtails which matched the conductors in the mating cable plug. For example, the bulkhead connector receptacle for the power cable had four 16 gauge insulated wires as pigtails.

In addition to the cables, plugs, and receptacles, locking sleeves and protective dummy plugs were obtained for a complete cable system. The cable system was ordered from Enviro Con, Division of the Rochester Corporation, 5725 Hartsdale, Houston, Texas 77036. Complete ordering information is given in "Parts List for Cable System". Pin connections are given in Appendix 2.

SIGNAL AND POWER CONNECTORS

D.C. signal inputs to the control box are brought in on multi-twisted pair cables from the pipe units. These cables are separate from the power cables which carry power to the pumps and heaters in the pipe units. Each pipe unit then has a signal cable and a power cable associated with that unit. Connections to these cables are shown in Drawing #8.

In addition to the above cables, there are four additional connectors on the control box for use with a chart recorder, so that the thermistor and flowmeter voltages may be continuously monitored with a chart recorder without the necessity of print-out, if desired. These connectors are shown in Drawing #8.

TELETYPE AND RELAY POWER SUPPLY

Drawing #8 has the schematic for the power supply which delivers +17 volts to the 20 milliamperes loop circuit of the Teletype. This supply also provides the +12 volts needed for the relays in the power circuits.

RELAY DRIVER BOARD

Drawing #9 shows the relay drivers (75451B) which allow the front panel switches to operate the heater and pump relays. These drivers are TTL logic compatible, so that computer control of these relays could be easily implemented.

SCANNER DISPLAY LAMPS

The front panel lamps which indicate the current status of the multiplexer (scanner) are shown with the channel decoding circuits on Drawing #9.

COMMENTS ON FIELD OPERATION AND VERSATILITY

OF DATA ACQUISITION SYSTEM

At the time of this writing, the Data Acquisition System has been collecting biofouling data for six weeks aboard a barge moored 7 miles from the island of St. Croix. During this time field measurements of

the most critical parameter, the time constant of the thermopile decay curve, have been made with a typical precision of 0.6% (standard deviation on the mean of approximately 10 measurements). At the same time, measurement of temperature of the seawater passing inside the heat exchanger pipe have been made with a precision of 0.001°C , as well as flow velocity measurements with a precision of 0.02 ft/sec at 3 ft/sec and 0.01 ft/sec at 6 ft/sec. The system thus has been shown to perform to expectations.

Some pictures are included in order to provide an idea of the physical construction of the devices. In Picture 1 is shown the insert of the pipe unit which consists of the heat exchanger pipe and the instrumentation mounted on it. In operation, this insert is surrounded by a protective PVC housing. The Pipe Electronics is shown to the right of the 3 heater cylinders and their 2 support disks. Also shown are the Control Box and the cables. Picture 2 provides a view of the amplifier board of the Pipe Electronics and Picture 3 shows the cables,

Picture 1

Picture 2

Picture 3

Picture 4

Picture 5

Picture 6

plugs and bulkhead connectors. The front panel of the control box is shown in Picture 4. Picture 5 illustrates the rear panel connectors and printed circuit boards in their card cage. A bottom view of the control box is given in Picture 6 with solid state relays, power supplies, fan and card cage being shown.

The ability of the Control Box to sample analog voltages at precise intervals and to record these voltages on a computer compatible medium (paper tape) makes the instrument much more versatile than simply a bio-fouling monitoring device. In our laboratory we have used a forerunner of this instrument to determine leak rates by periodically measuring and recording the output of a thermocouple pressure gauge. We have also used it to measure the relative thermal time constant of the heater and reference cylinders in the biofouling monitoring device, and the thermal response time of thermopiles and potted thermistors. In addition, the external binding posts allow the instrument to function as a precision 4-1/2 digit DVM. With serial data output from the SERDEX module and TTL-compatible relay drivers, the Data Acquisition System could easily be interfaced to a microprocessor or minicomputer where programmed logic would allow for nearly operator-free control of experiment and on-site analysis of data.

Reference: (1) Fetkovich, J. G. et al., "A Novel Method of Measuring Heat Transfer Coefficients with High Precision" and "Heat Transfer Problems in an Ocean Thermal Power Plant", Proceedings, Twelfth Southeastern Seminar on Thermal Science, Charlottesville, 1976, pp. 1-6, 81-86.

APPENDIX 1Special Components

Digital Voltmeter - Analogic 2546-P-60-2
 Analogic Corp., Audubon Road, Wakefield, Mass. 01880

Pipe Amplifiers - Datel AM-490-2C
 Datel Systems, Inc., 1020 Turnpike Street, Canton, Mass. 02021

Power Supplies - Acopian 5#25, Acopian 5E200
 Acopian Corp., Easton, Pa. 18042

Power Supplies - Analog Devices 904
 Analog Devices, Inc., Norwood, Mass. 02062

Multiplexer - Datel MM-16
 Datel Systems, Inc., 1020 Turnpike Street, Canton, Mass. 02021

Teletype - Teletype ASR-33
 Teletype Corp., 5555 Touhy Avenue, Skokie, Ill.

Serdex Modules - Analog Devices STX-1003 and SCL-1006
 Analog Devices, Inc., Norwood, Mass. 02062

1% Metal Film Resistors - Dale Electronics, Inc., Box 609, Columbus,
 Neb. 68601

Solid State Relays - Teledyne Relays, 3155 W. El Segundo Blvd.,
 Hawthorne, Calif. 90250

Fan - Boxer WS-2107-FL
 IMC Magnetics Corp., Rochester, New Hampshire 03867

Card Cage - Vector-Pak CCK-13
 Vector Electronic Co., Inc., 12460 Gladstone Avenue, Sylmar,
 Calif. 91342

P.C. Board Connectors - Douglas 72-125C-EL
 Douglas Electronics, Inc., 718 Marina Blvd., San leaudor, Calif.
 94577

Cables and Connectors - Enviro Con, Div. of Rochester Corp., 5725
 Hartsdale, Houston, Texas 77036

Cabinet - Bud CR-1739 Hammertone Gray
 Bud Radio, Inc., 4605 E. 355th Street, Willoughby, Ohio 44094

APPENDIX 2Transducer Connections to Pipe Amplifier Board and Connector Pin Designations

<u>Transducer Leads</u>		<u>Pipe Amplifier Board Inputs</u>
white (iron)	} Thermopile	TC Input +
red (constantan)		TC Input -
shield		S
one lead	} Thermistor	TH In.
other lead		TH In.
shield		S
lead 1 (green)	} Ramapo flowmeter	FM Input 1
lead 2 (white)		FM Input 2
lead 3 (red)		FM Input 3
lead 4 (black)		FM Input 4
lead 5 (shield)		S

Signals from Pipe Amplifier Board

<u>Pipe Amplifier Board Outputs</u>		<u>Enviro Con Conn.</u> (Pipe Unit Housing)	<u>Amphenol Conn.</u> (Control Box)
All + terminals are common on Pipe Amplifier Board	TC Out +	1 (red)	A
	TC Out -	2 (black)	B
	shield	3 (shield)	C
	TH Out +	4 (white)	D
	TH Out -	5 black)	E
	shield	6 (shield)	F
	FM Out +	7 (green)	G
	FM Out -	8 (black)	H
	shield	9 (shield)	J
	Not Connected	10 (blue)	Not Connected
	Not Connected	11 (black)	Not Connected
	Not Connected	12 (shield)	Not Connected

Power from Control BoxAmphenol (Control Box)

A (AC high)
B (AC low)
C (heater)
D (120 V. to pump)

Enviro Con
(Pipe Unit Housing)

1 (to pipe electronics power supplies)
2 (to pipe electronics, to heater, to pump)
3 (to heater)
4 (to pump)

PARTS LISTPipe Amplifiers
Drawing #1

A-1	Chopper Stabilized Operational Amplifier Datel AM-490-2
A-2	Chopper Stabilized Operational Amplifier Datel AM-490-2
A-3	Chopper Stabilized Operational Amplifier Datel AM-490-2
C-1	Capacitor - Ceramic .0015 mfd. - 50 v.
C-2	Capacitor - Ceramic .1 mfd. - 50 v.
C-3	Capacitor - Ceramic monolythic 1.0 mfd. - 50 v.
C-4	Capacitor - Ceramic .1 mfd. - 50 v.
C-5	Capacitor - Ceramic .1 mfd. - 50 v.
C-6	Capacitor - Ceramic .1 mfd. - 50 v.
C-7	Capacitor - Ceramic .0015 mfd. - 50 v.
C-8	Capacitor - Ceramic .1 mfd. - 50 v.
C-9	Capacitor - Ceramic .1 mfd. - 50 v.
C-10	Capacitor - Ceramic .1 mfd. - 50 v.
C-11	Capacitor - Ceramic .1 mfd. - 50 v.
C-12	Capacitor - Ceramic .1 mfd. - 50 v.
C-13	Capacitor - Ceramic .0015 mfd. - 50 v.
C-14	Capacitor - Ceramic .1 mfd. - 50 v.
C-15	Capacitor - Ceramic .1 mfd. - 50 v.
C-16	Capacitor - Ceramic .1 mfd. - 50 v.
C-17	Capacitor - Ceramic .1 mfd. - 50 v.
C-18	Capacitor - Ceramic .1 mfd. - 50 v.
R-1	Resistor - metal film 100 ohms - 1% - 1/4 watt
R-2	Resistor - metal film 100 ohms - 1% - 1/4 watt
R-3	Resistor - metal film 1 megohm - 1% - 1/4 watt
R-4	Resistor - metal film 1 megohm - 1% - 1/4 watt
R-5	Resistor - metal film 13.7 k - 1% - 1/4 watt
R-6	Resistor - metal film 13.7 k - 1% - 1/4 watt
R-7	Resistor - composition 120 k - 5% - 1/4 watt
R-8	Resistor - metal film 1.1 k - 1% - 1/4 watt
R-9	Resistor - metal film 1.1 k - 1% - 1/4 watt
R-10	Resistor - metal film 1.1 k - 1% - 1/4 watt
R-11	Resistor - metal film 1 k - 1% - 1/4 watt
R-12	Resistor - metal film 1 k - 1% - 1/4 watt
R-13	Resistor - metal film 150 k - 1% - 1/4 watt
R-14	Resistor - metal film 150 k - 1% - 1/4 watt
R-15	Resistor - metal film 13.7 k - 1% - 1/4 watt
R-16	Resistor - metal film 13.7 k - 1% - 1/4 watt
R-17	Resistor - composition 43 k - 5% - 1/4 watt
R-18	} in flowmeter
R-19	
R-20	
R-21	
R-22	Resistor - metal film 110 k - 1% - 1/4 watt
R-23	Resistor - metal film 1 k - 1% - 1/4 watt
R-24	Resistor - metal film 1 k - 1% - 1/4 watt
R-25	Resistor - metal film 2 megohm - 1% - 1/4 watt
R-26	Resistor - metal film 13.7 k - 1% - 1/4 watt
R-27	Resistor - metal film 2 megohm - 1% - 1/4 watt
R-28	Resistor - metal film 13.7 k - 1% - 1/4 watt
R-29	Resistor composition 100 k - 5% - 1/4 watt
R-30	Resistor composition 510 ohms - 5% - 1/4 watt
R-31	Resistor composition 510 ohms - 5% - 1/4 watt

R-32 Resistor composition 100 ohms - 5% - 1/4 watt
Z-1 Diode-Zener IN429 6 volts
PS-1 Power Supply ± 15 volts, 50 ma. Analog Devices 904
PS-2 Power Supply -5 volts, 250 ma. Acopian 5E25

PARTS LIST

P.C. Card #4

Drawing #2

S-1	Switch-Rotary - 3 pole - 2 position Centralab PA-2007
S-2	Switch-Rotary - 2 pole - 4 position Centralab PA-2001
R-33	Resistor - Composition 3.3 k - 5% - 1/4 watt
R-34	Resistor - Composition 3.3 k - 5% - 1/4 watt
R-35	Resistor - Composition 3.3 k - 5% - 1/4 watt
R-36	Resistor - Composition 5.1 k - 5% - 1/4 watt
R-37	Resistor - Composition 5.1 k - 5% - 1/4 watt
R-38	Resistor - Composition 5.1 k - 5% - 1/4 watt
R-39	Resistor - Composition 5.1 k - 5% - 1/4 watt
R-40	Resistor - Composition 5.1 k - 5% - 1/4 watt
R-41	Resistor - Composition 5.1 k - 5% - 1/4 watt
D-1	Diode 1N270
D-2	Diode 1N270
D-3	Diode 1N270
D-4	Diode 1N270
D-5	Diode 1N270
D-6	Diode 1N270
C-19	Capacitor Electrolytic 10 mfd - 25 volts
C-20	Capacitor - Ceramic .1 mfd - 50 volts
C-21	Capacitor - Ceramic .1 mfd - 50 volts
C-22	Capacitor - Ceramic .1 mfd - 50 volts
IC-1	Integrated Circuit DM7405N Hex Inverter
IC-2	Integrated Circuit DM7476N Dual J-K Flip-flop
M-1	Module - Analog Multiplexor - Datel MM-16
M-2	Module - Serdex Clock - Analog Devices SCL-1006

PARTS LIST

P.C. Card #1

Drawing #3

M-3	Module-Serdex Transmitter - Analog Devices STX-1003
IC-3	Integrated Circuit DM 7404N Nex Inverter
Q-1	Transistor - 2N3641
Z-2	Diode-Zener - 3.3 volts Schauer SZ-3.3
R-42	Resistor - Composition 1 k - 5% - 1/4 watt
R-43	Resistor - Composition 1 k - 5% - 1/4 watt
R-44	Resistor - Composition 120 ohms - 5% - 1/4 watt
R-45	Resistor - Composition 3.3 k - 5% - 1/4 watt
J-1	Connector - Amphenol AN-3102-14S-6S
D-7	Diode 1N270
D08	Diode 1N270

PARTS LIST

P.C. Card #2

Drawing #4

R-46	Resistor - Composition 2 k - 5% - 1/4 watt
C-23	Capacitor - Electrolytic 10 mfd - 50 volts
C-24	Capacitor - Ceramic .1 mfd - 50 volts
C-25	Capacitor - Ceramic .01 mfd - 50 volts
IC-4	Integrated Circuit - DM 74165N Shift Register
IC-5	Integrated Circuit - DM 74165N Shift Register
IC-6	Integrated Circuit - DM 74165N Shift Register
IC-7	Integrated Circuit - DM 74165N Shift Register
IC-8	Integrated Circuit - DM 74165N Shift Register
IC-9	Integrated Circuit - DM 74165N Shift Register
IC-10	Integrated Circuit - DM 74165N Shift Register
IC-11	Integrated Circuit - DM 74165N Shift Register
IC-12	Integrated Circuit - DM 74165N Shift Register
IC-13	Integrated Circuit - DM 7410N Gate

PARTS LIST

P.C. Card #3

Drawing #5

IC-14	Integrated Circuit - CD 4049 AE CMOS Hex Inverter
IC-15	Integrated Circuit - SN74390 Dual Decade Counter
IC-16	Integrated Circuit - SN74390 Dual Decade Counter
IC-17	Integrated Circuit - SN74390 Dual Decade Counter
IC-18	Integrated Circuit - DM7474N Dual Flip-flop
IC-19	Integrated Circuit - DM7474N Dual Flip-flop
IC-20	Integrated Circuit - DM74123N Dual One-shot
IC-21	Integrated Circuit - DM74123N Dual One-shot
IC-22	Integrated Circuit - 555 Timer
IC-23	Integrated Circuit - 555 Timer
R-47	Resistor - Composition 22 Megohm - 5% - 1/4 watt
R-48	Resistor - Composition 33 k - 5% - 1/4 watt
R-49	Resistor - Composition 1 k - 5% - 1/4 watt
R-50	Resistor - Composition 20 k - 5% - 1/4 watt
R-51	Resistor - Composition 10 k - 5% - 1/4 watt
R-52	Resistor - Composition 10 k - 5% - 1/4 watt
R-53	Resistor - Composition 1 megohm - 5% - 1/4 watt
R-54	Resistor - Composition 1 megohm - 5% - 1/4 watt
R-55	Resistor - Composition 10 k - 5% - 1/4 watt
R-56	Resistor - Composition 10 k - 5% - 1/4 watt
R-57	Resistor - Composition 10 k - 5% - 1/4 watt
R-58	Resistor - Composition 100 ohm - 5% - 1/4 watt
R-59	Resistor - Composition 100 ohm - 5% - 1/4 watt
R-60	Resistor - Composition 10 k - 5% - 1/4 watt
R-61	Resistor - Composition 100 k - 5% - 1/4 watt
R-62	Resistor - Composition 1 k - 5% - 1/4 watt
C-26	Capacitor Dipped Mylar - 20 pf - 5% - 50 volts
C-27	Capacitor Dipped Mylar - 10 pf - 5% - 50 volts
C-28	Capacitor Electrolytic 10 mfd - 50 volts
C-29	Capacitor Ceramic .1 mfd - 50 volts
C-30	Capacitor Ceramic .01 mfd - 50 volts
C-31	Capacitor Ceramic .1 mfd - 50 volts
C-32	Capacitor Ceramic .001 mfd - 50 volts
C-33	Capacitor Ceramic Monolythic 1.0 mfd - 50 volts
C-34	Capacitor Ceramic .001 mfd - 50 volts
C-35	Capacitor Ceramic Monolythic 1.0 mfd - 50 volts
C-36	Capacitor Ceramic .01 mfd - 50 volts
C-37	Capacitor Ceramic .01 mfd - 50 volts
C-38	Capacitor Ceramic .01 mfd - 50 volts
C-39	Capacitor Ceramic .001 mfd - 50 volts
S-3	Switch-Push Button SPDT Grayhill 46-05-05
S-4	Switch-Rotary-Single Pole - 4 position Centralab PA-2001
X-1	Quartz Crystal - 100 kh _z - JAN HC-13U

PARTS LIST

Drawing #6

DVM Digital Voltmeter - Analogic 2546
R-67 Resistor-Metal Film 1 megohm 1% - 1/4 watt
R-68 Resistor-Metal Film 111.1 k selected 1/4 watt
BP-1 Binding Post - Dual
S-11 Switch-Toggle SPDT - JBT-JMT-123
TTY Teletype - ASR-33 Teletype Corporation
Cabinet Bud CR-1739
Chassis Bud AC-428
Card Cage Vector Vector-Pak CCK-13
P.C. Board Connectors Douglas 72-125C-EL

PARTS LIST

Drawing #7

F-1	Fuse - 6 Ampere 3AG in Bussman HkP Holder
F-2	Fuse - 6 Ampere MDL in Bussman HkP Holder
F-3	Fuse - 3 Ampere 3AG in Bussman HkP Holder
L-1	Panel Lamp - Leecraft 3200
L-2	Panel Lamp - Leecraft 3600
L-3	Panel Lamp - Leecraft 3600
L-4	Panel Lamp - Leecraft 3200
L-5	Panel Lamp - Leecraft 3200
RLY-1	Relay - Solid State - Teledyne 601-1402
RLY-2	Relay - Solid State - Teledyne 601-1402
RLY-3	Relay - Solid State - Teledyne 611-8H
RLY-4	Relay - Solid State - Teledyne 611-8H
RLY-5	Relay - Potter-Brumfield KRP-11D in Amphenol MIP-8 Socket
W-1	Fan - Boxer W52107FL
PS-3	Power Supply ± 15 volts - 50 ma. Analog Devices 904
PS-4	Power Supply 5 volts - 2 Amperes - Acopian 5E200
T-2	Transformer 120 volt primary - 36 volt - 4 Amp secondary - Signal 36-4
S-5	Circuit Breaker - 20 Amperes - Potter-Brumfield 190-220-101
S-6	Switch - Toggle SPDT - JBT - JMT - 123
S-7	Switch - Toggle SPDT - JBT - JMT - 123
S-8	Switch - Toggle SPDT - JBT - JMT - 123
S-9	Switch - Toggle SPDT - JBT - JMT - 123
S-10	Switch - Toggle SPDT - JBT - JMT - 123
J-11	Power Receptacle - 3 Pole - Amphenol 160-10N
J-12	Connector - Amphenol AN-3102-16S-1S
IC-24	} See Drawing #9
IC-25	
IC-26	
R-64	Resistor - Composition 33 k - 1 watt - 10%
R-65	Resistor - Composition 33 k - 1 watt - 10%
R-66	Resistor - Composition 33 k - 1 watt - 10%

PARTS LIST

Drawing #8

J-2	Connector - Amphenol AN-3102 A - 20-29P
J-3	Connector - Amphenol AN-3102 A - 20-29P
J-4	Connector - Amphenol AN-3102 A - 18-10S
J-5	Connector - Amphenol AN-3102 A - 18-10S
J-6	Connector - Amphenol 126-217 Minihex
J-7	Connector - Amphenol 126-217 Minihex
J-8	Connector - Amphenol 126-217 Minihex
J-9	Connector - Amphenol 126-217 Minihex
B-1	Bridge Rectifier - Motorola MDA - 942A2
T-1	Transformer - 120 volt primary - 12 volt sec. Triad F-25X
Z-3	Zener Diode 1N1605 - 12 volts
R-64	Resistor - Wirewound 35 ohms - 10 watts
R-65	Resistor - Composition 3 k - 5% - 1/4 watt
R-66	Resistor - Composition 3 k - 5% - 1/4 watt
R-67	Resistor - Composition 3 k - 5% - 1/4 watt
R-68	Resistor - Composition 3 k - 5% - 1/4 watt

PARTS LIST

Drawing #9

IC-24	Integrated Circuit SN75451B Dual Driver
IC-25	Integrated Circuit SN75451B Dual Driver
IC-26	Integrated Circuit SN75451B Dual Driver
IC-27	Integrated Circuit SN75451B Dual Driver
IC-28	Integrated Circuit SN75451B Dual Driver
IC-29	Integrated Circuit SN7400N Gate
D-9	Diode - Light Emitting - Monsanto MV-5054
D-10	Diode - Light Emitting - Monsanto MV-5054
D-11	Diode - Light Emitting - Monsanto MV-5054
R-63	Resistor - Composition - 200 ohms - 5% - 1/4 watt
C-40	Capacitor - Ceramic .1 mfd - 50 volts
C-41	Capacitor - Electrolytic - 100 mfd - 25 volts

PARTS LIST FOR CABLE SYSTEM

(Excluding Amphenol Connectors for Control Box)

A. Signal Cable and Connectors:

1. Cable: 93 foot length of 6 twisted, shielded pairs (only 4 pairs of which are connected) of #20 wire; cable jacket is PVC.
2. Cable Connector Plug: XSL-12-CCP; plug is molded onto cable with pin connections as shown below.
3. Bulkhead Connector Receptacle: XSL-12-BCR; for pigtails, a 7 foot length of signal cable is attached with the jacket remaining on according to the following scheme:

<u>Pin</u>	<u>Color</u>	
1	red	pair 1
2	black	
3	shield	
4	white	pair 2
5	black	
6	shield	
7	green	pair 3
8	black	
9	shield	
10	blue	pair 4
11	black	
12	shield	

4. Dummy for Bulkhead Connector Receptacle: L-12-SCP.
5. Dummy for Cable Connector Plug: L-SCR.

B. Main Power Cable and Connectors:

1. Cable: 93 foot length of 16/4 SO with a neoprene jacket.
2. Cable Connector Plug: RMK-4-FS; plug is molded onto cable.
3. Bulkhead Connector Receptacle: XSK-4-BCL; for pigtails, a 7 foot length of 4 #16 stranded wires is attached.
4. Dummy for Bulkhead Connector Receptacle: RMK-4-FSD (LP).
5. Dummy for Cable Connector Plug: RMK-4-MPO (LP).

6. Locking Sleeve: K-FLS-P

C. Pump Power Cable and Connector:

1. Cable: 20 foot length of 16/2 SO with a neoprene jacket.
2. Cable Connector Plug: RMG-2-FS, plug is molded onto cable.
3. Bulkhead Connector Receptacle: XSG-2-BCL; pigtails, a 7 foot length of 2 #16 stranded wires is attached.
4. Dummy for overhead connector receptacle: RMG-2-FSD (LP).
5. Dummy for Cable Connector Plug: RMG-2-MPD (LP).
6. Locking Sleeve: G-FLS-P.

NOTE: Part numbers are those of Enviro Con, Division of the Rochester Corporation, 5725 Hartsdale, Houston, Texas 77036. Phone: (713)-782-5350.

PIPE AMP. PARTS LAYOUT. FOR
SCHEMATIC, REFER TO DWG #1

BOTTOM (FOIL SIDE) VIEW

BOTTOM (FOIL SIDE) VIEW REFER TO DWG. 2

BOTTOM (FOIL SIDE) VIEW

REFER TO DWG. 3

BOTTOM (FOIL SIDE) VIEW REFER TO DWG. 4.

BOTTOM (FOIL SIDE) VIEW REFER TO DWG 5.

BOTTOM (FOIL SIDE) VIEW REFER TO DWG 9

DRAWING INDEX

<u>Drawing No.</u>	<u>Title</u>
1	Pipe Amplifiers
2	Channel Counter and Scanner (P.C. Card #4)
3	Serdex Teletype Interface (P.C. Card #1)
4	Serdex Shift Register (P.C. Card #2)
5	Clock Divider (P.C. Card #3)
6	P.C. Interconnect Guide
7	Relay and Power Circuits
8	I/O Connectors - Relay Power Supply
9	Relay Drive and Scanner Display Ckts.
10	O.T.E.C. Heat Monitor Mfg. Plate
11	Heat Monitor Assembly
12	Pictorial Front and Rear Views
13	System Cabling
14	Card Cage Layout

~NOTE~

USE SILICON GREASE ON ALL
METAL TO METAL CONTACTS
ON ASSEMBLY.USE VECTOR T-19 MINIATURE
TERMINALS AT ALL INPUT &
OUTPUT CONNECTIONS.

CARNEGIE-MELLON UNIVERSITY PGH. PA.			
PIPE AMPLIFIERS			
REVISION	DATE 8/10/77	DRAWN JFD	CHARGE NO.
REF. DWGS.	SCALE	CHECKED	APPROVED
DWG. NO. 1

CARNEGIE-MELLON UNIVERSITY PGH. PA.			
SERDEX TELETYPE INTERFACE CARD #1			
REVISION	DATE 8/11/77	DRAWN #423	CHARGE NO.
REF. DWGS.	SCALE	CHECKED	APPROVED
DWG. NO. 3

CARNEGIE-MELLON UNIVERSITY PGH. PA.			
REVISION		INPUT & OUTPUT (PWR & SIGNAL CONN.)	
REF. DWGS.		TTY & RELAY DRIVE POWER SUPPLY	
DWG. NO. 8		DATE 8/17/77	DRAWN 9215
		SCALE	CHECKED
		CHARGE NO. APPROVED

RELAY DRIVER BOARD

ALL IC'S = 75451B

(Connections shown
on
Dwg. #7)

FROM
CARD #4
SCANNER

SCANNER DISPLAY LAMPS.
THIS CKT. BOARD MOUNTED ON
CHASSIS NEAR "CHANNEL SELECT" SWITCH

TC = THERMOPILE
TH = THERMISTOR
FM = FLOWMETER

CARNEGIE-MELLON UNIVERSITY PGH. PA.			
RELAY DRIVE CIRCUITS SCANNER DISPLAY CIRCUITRY.			
REVISION	DATE 8/17/77	DRAWN 9/4/77	CHARGE NO.
REF. DWGS.	SCALE	CHECKED	APPROVED
DWG. NO. 9

ITEM-43

MATERIAL- $\frac{1}{8}$ " ALUM. PLATE
ONE REQD. PER UNIT.

O.T.E.C. HEAT
MONITOR MTG. PLATE
FOR PWR. SUPPLIES,
2 REQD.

CLEARANCE HOLES
4-40 3 PLACES.

CLEARANCE HOLES
FOR PWR SUPPLY PINS
10 PLACES $\frac{1}{4}$ " DIA.

$\frac{1}{4}$ " HOLE 2 PLACES
FOR AC TERMINALS
USECO 4442 B

CLEARANCE HOLES
10-32 4 PLACES

CLEARANCE HOLES
6-32 6 PLACES

O.T.E.C. HEAT MONITOR FLOW
PIPE CLAMPS. SUPPORT FOR
ELECTRONICS & TWO POWER SUPPLIES.
2 PER UNIT. 2 UNITS REQD.

REVISION		CARNEGIE-MELLON UNIVERSITY PGH. PA.		
REF. DWGS.		O.T.E.C. HEAT MONITOR MTG. PLATE & PIPE CLAMPS		
DWG. NO. 10		DATE 8/22/77	DRAWN JLB	CHARGE NO.
		SCALE	CHECKED	APPROVED

REFER TO DWG 10 FOR
DETAILS & DIMENSIONS OF
ALUM. PIECES.

○ SILVERED COPPER ○	$\frac{1}{16}''$ $\frac{1}{4}''$
PIPE AMPLIFIER P/C BOARD ITEM "D"	
SILVERED COPPER ETCHED CIRCUITRY P/C BOARD COPPER CLAD (ONE SIDE) COPPER IS 1 MIL. THICK. BOARD IS $\frac{1}{16}''$ G-10 EPOXY RESIN FIBREGLASS.	$\frac{7}{16}''$
○ SILVERED COPPER ○	$\frac{1}{16}''$ $\frac{1}{4}''$
$\frac{7}{16}''$ $1\frac{3}{4}''$ $\frac{9}{16}''$ $1\frac{3}{4}''$	

47

MELLON INSTITUTE, PITTSBURGH, PA.			
HEAT MONITOR ASSY. & P/C BOARD SPECS.			
REVISION	DATE 8/23/77	DRAWN JHB	CHARGE NO.
REF. DWGS.	SCALE	CHECKED	APPROVED
DWG. NO. 11

CARNEGIE-MELLON UNIVERSITY PGH. PA.			
PICTORIAL OF FRONT PANEL & REAR OF CHASSIS.			
REVISION	DATE 8/24/77	DRAWN JLB	CHARGE NO.
REF. DWGS.	SCALE	CHECKED	APPROVED
DWG. NO. 12

CARNegie-MELLON UNIVERSITY PGH, PA.			
SYSTEM CABLING REQUIREMENTS			
REVISION	DATE 8/24/77	DRAWN JJB	CHARGE NO.
REF. DWGS.	SCALE	CHECKED	APPROVED
DWG. NO. 13