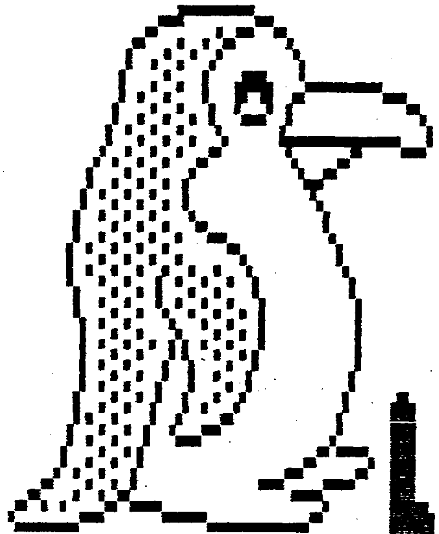
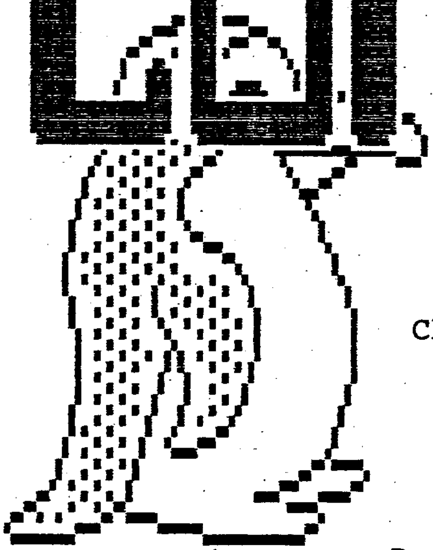
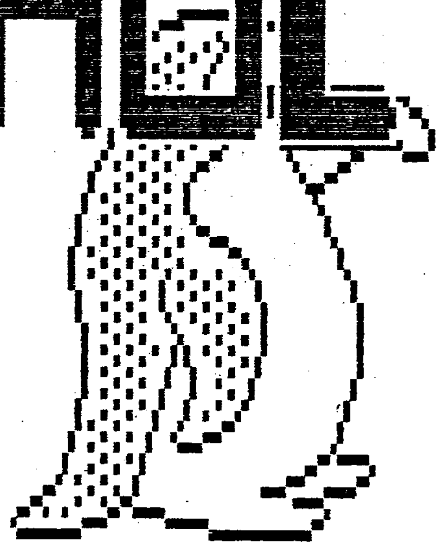
TM-1366
2600.900



IPF TEMP. CONTROL





Chuck Mangene

December 1985

TM-1366, 2600.900

THE IPF TEMPERATURE CONTROL SYSTEM

by Chuck Mangene
Sept. 1985

The Internal Picket Fence (IPF) is made of a set of proportional wire tube chambers which sit inside the outer vacuum vessel of the 15' Bubble Chamber. Though they are covered with layers of super-insulation, they are partially exposed to the cryogenic system of the Bubble Chamber and the Bubble Chamber magnet. The chambers are, therefore, equipped with heaters designed to maintain them at a reasonable temperature. As the operating conditions of the bubble chamber are changed, particularly during warm-up and cool-down, it is necessary to control the power to the heaters dynamically. Due to the adverse conditions in the area and the number of chambers (96 cans), we decided to operate the heaters remotely with a computer control system.

The IPF Temperature Control System consists of five (5) basic sub-systems. A STD bus Z80 microprocessor system, a serial communication link, a temperature monitor, a heater controller and heater driver card.(See Fig. 1). The separate sub-systems are described below. Each chamber has a 4-wire platinum resistor (RTD, R=100 ohms @ 0'C) and a 220 ohm resistance wire heater for temperature readback and control.

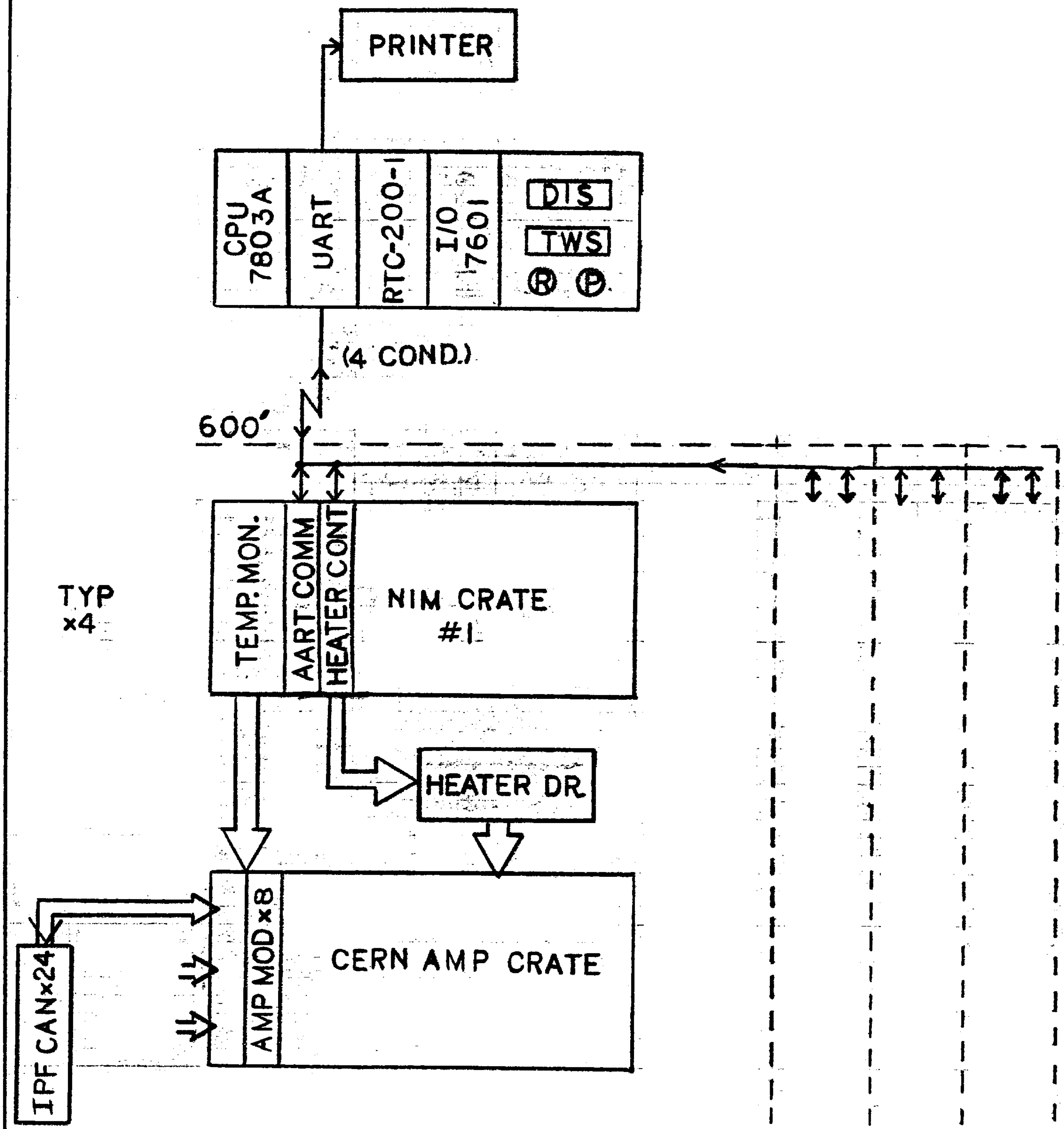
THE MICROPROCESSOR SYSTEM

The microprocessor system consists of a Pro-Log STD BUS back-plane, a Z80 CPU card (7803A), an I/O port card (7601), a Realtime clock (RTC 200-1 by Endlode Inc.), a serial I/O UART

SUBJECT
IPF TEMPERATURE CONTROL SYSTEM

NAME C. MANGENE
DATE
REVISION DATE

FIG #1



card, and an Axiom RS-232 serial printer (See Fig. 2).

The system has a visual display with thumbwheel switches that allows the temperature of any chamber to be displayed. It also produces, on request, a nicely formatted output giving the temperatures of all 96 chambers and the power being dissipated in each heating element.

The CPU card combines a buffered and fully expandable Z80 microprocessor with up to 4K bytes of onboard RAM (2114 type) and up to 8K bytes of onboard ROM (2716 type). 1K bytes of RAM and 4K bytes of ROM are used for the monitor-control program and data tables.

The 7601 I/O port card provides four 8-bit input ports and four 8-bit latched output ports (32 output and 32 input TTL lines). The 7601 card is mapped at ports 00 to 03 hex and can be mapped to any four sequential port addresses in the range 00 to FF hex via jumper wires. The input port 03(bits 0-7) is connected to two thumbwheel BCD switches which select a chamber to be monitored. The output port 03(bits 0-7) is connected to two BCD 7 segment displays to indicate the temperature in degrees centigrade of the selected chamber. If any chamber temperature deviates beyond predetermined limits, output port 02 (bit 1) turns on a sonalert for an alarm condition. Input port 02 (bit 0) is connected to a pushbutton switch which serves two functions. It initiates a printout of the temperatures and heater settings of all 96 chambers and resets the alarm via output port 02(bit 0).

The Realtime clock card contains a battery backed calendar and time-of-day circuit and delivers to a host computer the time data in BCD format. It is port addressed at EC to EF hex. The time and date information is printed out as part of the temperature printout.

The serial I/O UART card was developed by Mark Pauley of the Research Division Operations Department. It is compatible with both RS-232 and RS-422 data transmission standards. The serial transmission format is totally selectable in the asynchronous mode for the number of bits, even/odd parity, stop bits, etc. Three of its four serial channels have individually selectable baud-rates. The boards port addresses are 40 to 4F hex, and it is setup with channel B as RS-232 with a 1200 baud rate. This channel connects to the Axiom printer for data logging. Channel A is setup as RS-422 for communication with a Motorola MC14469 AART, which is the link between the experiment control room and the bubble chamber. (See drawing # 2300.000-ED-172119)

THE SERIAL LINK

The primary component of the communication system is the Motorola MC14469 AART integrated circuit. The advantages of the AART are threefold. It is serial which means the cable count is low, i.e., one four conductor cable is required. It's asynchronous which eliminats the need to transmit a system clock along with the data bit stream. Finally, it's main advantage is that it is addressable. With 7 address bits, 128 separate units may be interconnected for simplex or full duplex data transmission. After reception of either a valid address or both a valid address and valid command word the AART can be used to set up the necessary internal conditions for the transmission of two 8 bit data words. (See Motorola's application note AN-806.)

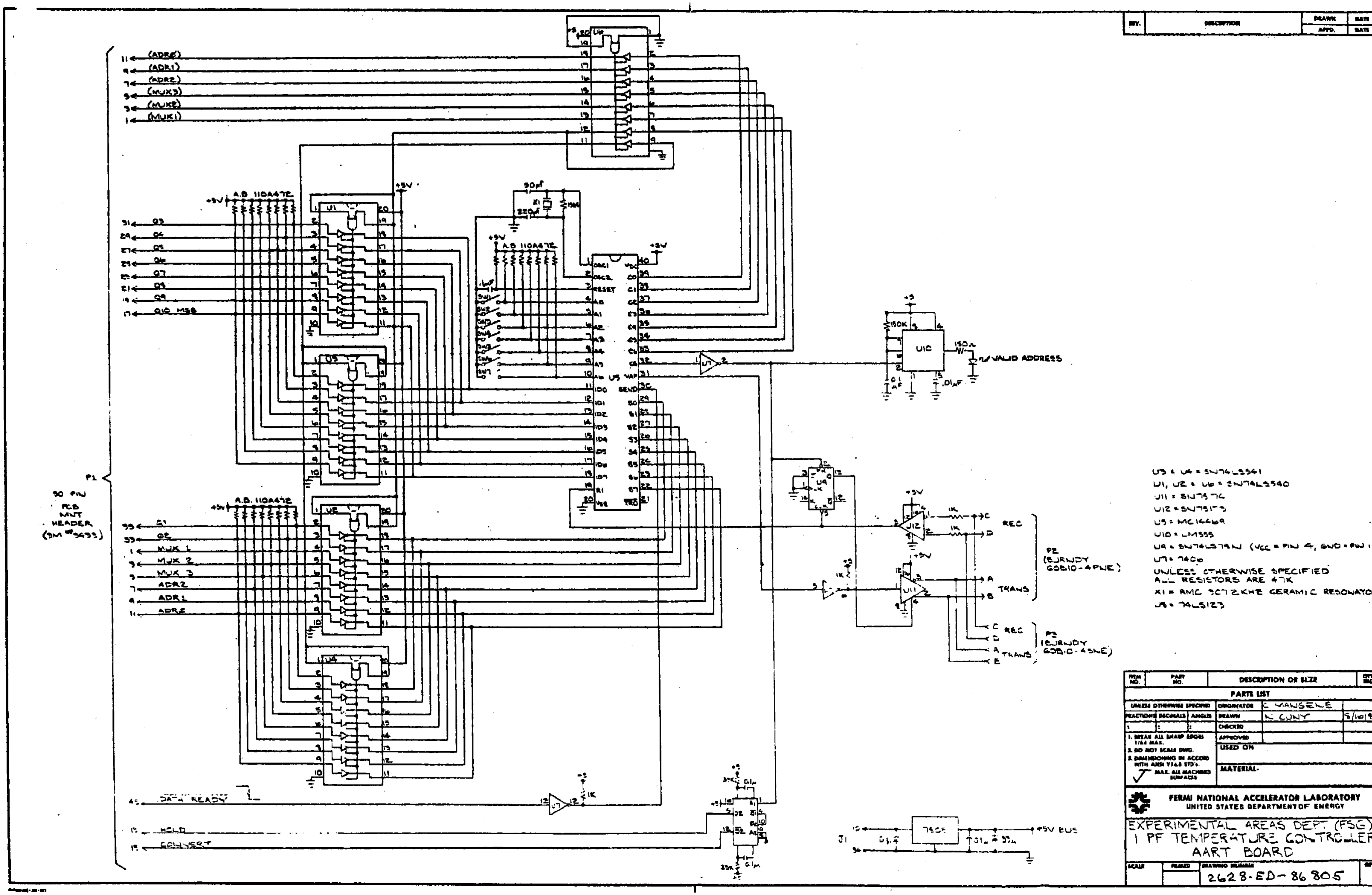
The AART Communication module was designed to interface the microprocessor system to the Temperature Monitor modules using the MC14469 AART. (See drawing # 2628-ED-86805)

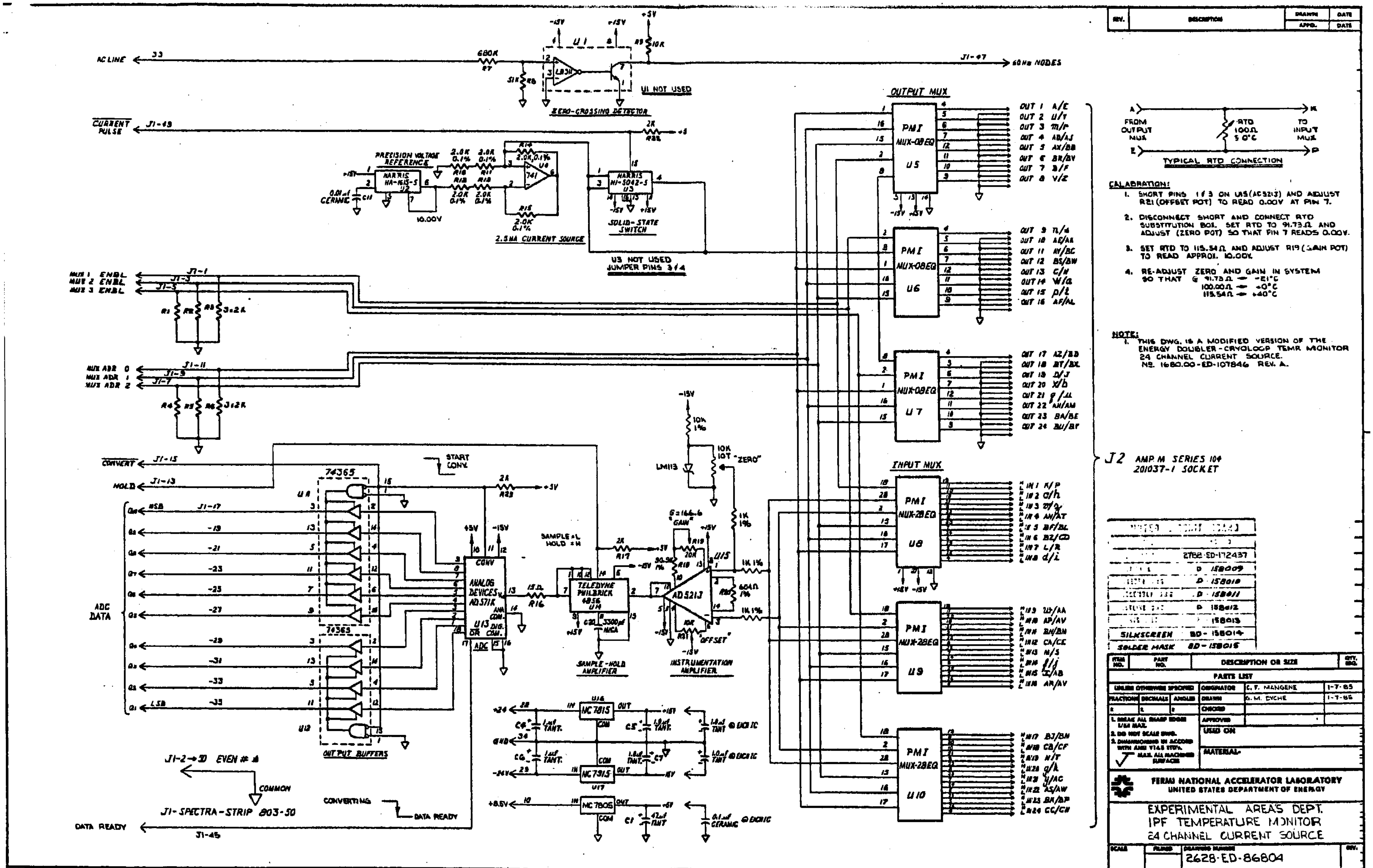
THE TEMPERATURE MONITOR

The IPF Temperature monitor is a modified design of the Energy Doubler "Cryoloop Temperature Monitor" by G. Pucci.(See drawing # 1680.00-ED-107846). It is a 24 channel multiplexed Current Source. It produces a voltage across the sensing resistor which is proportional to the temperature and converts it to a ten (10) bit digital signal which it sends to the computer via the AART. Since our operating range is room temperature rather than a few degrees Kelvin a different sensing element was used and circuit modifications of the analog portion were implemented in order to present an appropriate input to its ADC. One additional control line from the ADC was made available to the AART card to facilitate data transfer. The RTD's in the IPF system are platinum four wire resistors with a temperature coefficient of +0.385 ohms/'C. (100 ohms at 0'C) Modifications to the Temperature Monitor are to increase the gain and to add an offset voltage to the circuit. Also, the data ready line from the ADC was brought out to interface to the AART Communication card. (See drawing # 2628-ED-86804).

THE HEATER CONTROLLER

The IPF Heater Controller is a 24 channel latching DAC card. It consists of a RS422 receiver, transmitter, two AARTs and demultiplexers for 12 dual-latching DACs (AD7528). The receiver, transmitter, and two AARTs as configured act as two on-board


U3 & U4 = SN74LS541
U1, U2 & U6 = SN74LS540
VALID ADDRESS
DATA READY
HOLD
CONVERT
+5V BUS
REC
TRANS
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
EXPERIMENTAL AREAS DEPT. (FSG)
AART BOARD
2628-ED-86805



OUTPUT MUX
INPUT MUX
ZERO-CROSSING DETECTOR
U1 NOT USED
PRECISION VOLTAGE REFERENCE
2.5mA CURRENT SOURCE
SOLID-STATE SWITCH
U3 NOT USED JUMPER PINS 3 & 4
OUTPUT BUFFERS
SAMPLE-HOLD AMPLIFIER
INSTRUMENTATION AMPLIFIER
ADC DATA
J2 AMP M SERIES 104 201037-1 SOCKET
TYPICAL RTD CONNECTION
CALABRATION:
1. SHORT PINS 1 & 3 ON U15(AD521J) AND ADJUST R21 (OFFSET POT) TO READ 0.00V AT PIN 7.
2. DISCONNECT SHORT AND CONNECT RTD SUBSTITUTION BOX. SET RTD TO 91.73Ω AND ADJUST (ZERO POT) SO THAT PIN 7 READS 0.00V.
3. SET RTD TO 115.54Ω AND ADJUST R19 (GAIN POT) TO READ APPROX. 10.00V.
4. RE-ADJUST ZERO AND GAIN IN SYSTEM SO THAT @ 91.73Ω → -21°C 100.00Ω → +0°C 115.54Ω → +40°C
NOTE:
1. THIS DWG. IS A MODIFIED VERSION OF THE ENERGY DOUBLER-CRYOLOOP TEMP. MONITOR 24 CHANNEL CURRENT SOURCE. NO. 1680.00-ED-107846 REV. A.
PARTS LIST
C. F. MANGENE 1-7-85
G. M. DYCHE 1-7-85
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
EXPERIMENTAL AREAS DEPT.
IPF TEMPERATURE MONITOR
24 CHANNEL CURRENT SOURCE
2628-ED-86804

serial links. The two seven bit outputs of the AARTs combined make up the necessary five lines for 1 of 24 demultiplexing and eight data input lines for the latched input DACs. The outputs of the DACs are buffered by op amps to drive the Heater Driver Board's power transistor which regulates the current to the IPF Heaters. The Heater Driver generates a 0 to 4.5v output voltage which translates to 0 to 45 volts on the heaters. (See drawing # 2628-EE-86803).

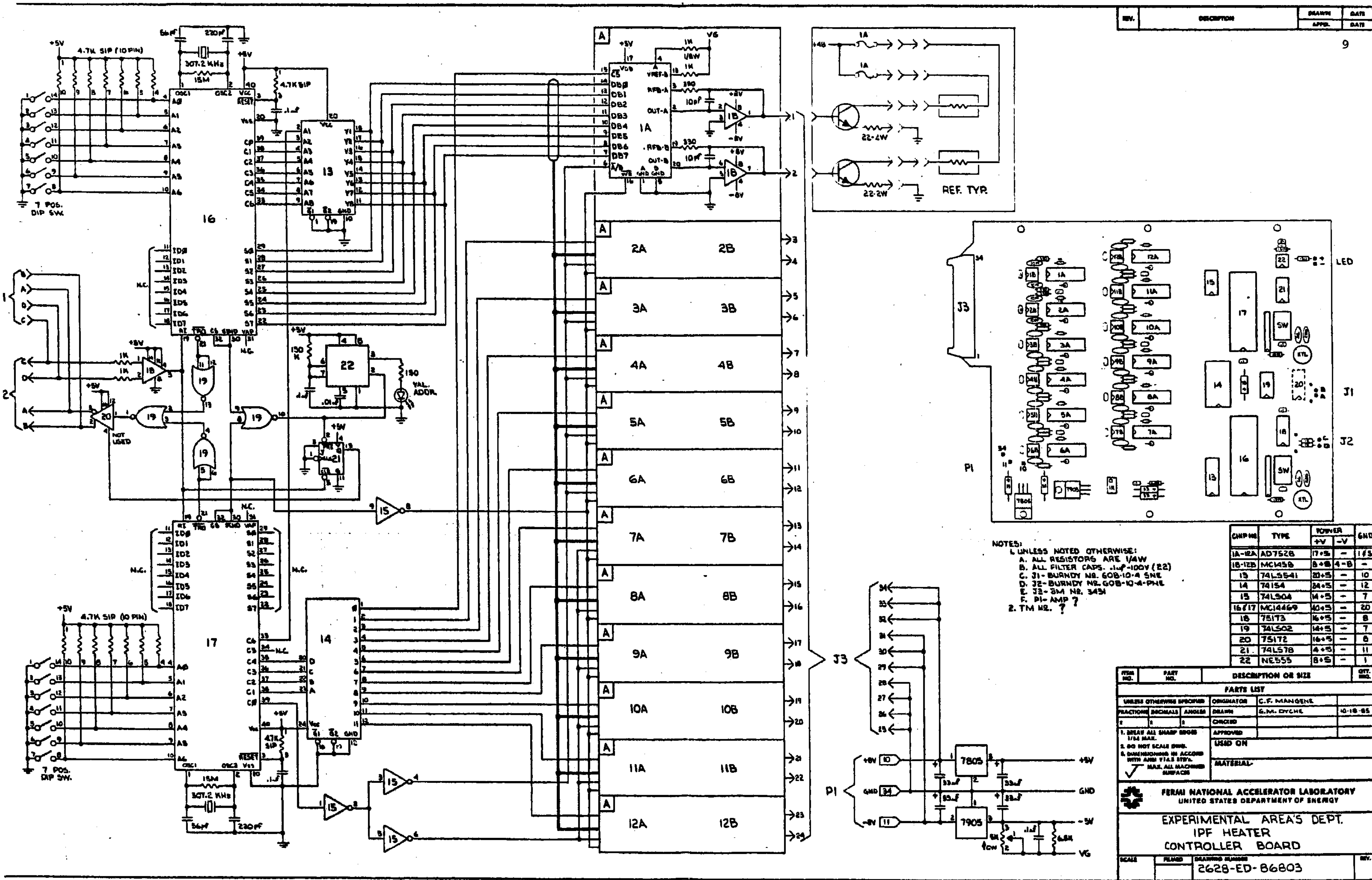
THE HEATER DRIVER

The raw power for the heaters is provided by a "BRUTE" 45 volt, 25 amp unregulated supply. The Heater Driver board consists of 24 power transistors and fuses, and connects the "BRUTE" power supply and the Heater Controller to the individual heaters. (See drawing # 2628-ED-86806).

PROGRAM ALGORITHM

The algorithm used to control the IPF heaters is quite straight forward in principle. The system cycles through and reads the temperature of each tube. If the temperature of a particular tube lies within a pre-defined range (18'C to 22'C) the corresponding heater setting is left unchanged. If the temperature of a tube is too low,the heater setting is raised one step; if it is too high, the setting is reduced one step. Notice that there is no attempt to match the heater setting to the temperature. In practice, the temperature read-back on several tubes is missing (broken wires or intermittent) and the program has to recognize this and deal with it explicitly.

The system on power up first initallizes the I/O devices and



NOTES:
1. UNLESS NOTED OTHERWISE:
   A. ALL RESISTORS ARE 1/4W
   B. ALL FILTER CAPS. .1uf-100V (22)
   C. J1-BURNDY NO. GOB-10-4 SNE
   D. J2-BURNDY NO. GOB-10-4-PNE
   E. J3-3M NO. 3431
   F. P1-AMP ?
2. TM NO. ?

CHIP NO.	TYPE	POWER +V	POWER -V	GND
1A-12A	AD7528	17+5	–	1 & 5
1B-12B	MC1458	8+8	4-8	–
13	74LS541	20+5	–	10
14	74154	24+5	–	12
15	74LS04	14+5	–	7
16 & 17	MC14469	40+5	–	20
18	75173	16+5	–	8
19	74LS02	14+5	–	7
20	75172	16+5	–	8
21	74LS78	4+5	–	11
22	NE555	8+5	–	1

PARTS LIST

ORIGINATOR: C.F. MANGENE
DRAWN: G.M. DYCHE 10-18-85

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

EXPERIMENTAL AREA'S DEPT.
IPF HEATER
CONTROLLER BOARD

DRAWING NUMBER: 2628-ED-86803

zeros the memory area for heater settings and the error table. Then it cycles through and reads all the RTD's and stores the data in a data table. After all the data has been read, it checks each reading for error conditions; was it within the good range (18'C to 22'C), was the reading valid (5'C to 30'C), was it bad or good previously, or are they all invalid? With this information it generates a table of which tubes have valid/ invalid read-backs, and a table for valid tubes which gives how far the tube is from the desired temperature (20'C), and the average heater setting value of all valid tubes. It now updates the heater value table. If below the good range but within the valid range it increments the heater setting by one. If at the desired value, it adds zero to its setting. If above the good range, but within the valid data range, it decrements the setting by one. If, on power up, the tubes all read out of the valid range, then it sets all heaters on full until at least one tube warms up. When there is at least one good chamber reading then a heater setting average can be calculated and all chambers with invalid read-backs are set to this value. There are 256 steps to a heater setting from zero to full ON. Once the heater setting table is complete the values are all output to the latching DAC's. If a tube has gone from good to bad, an alarm is generated. Finally the front panel is read; the thumbwheel switches for chamber number, the alarm silence push button, and the print push button. The chamber addressed temperature is displayed in degrees Celsius, converted from a lookup table. If the print button was pushed then all the temperatures and heater settings are printed out along with the date and time. (See sample printout). After updating the front panel the program loops back to read temperatures and update heater settings and continues looping. The program listing (IPF.Z80 V3.00) is available upon request.

During the running the heater supplies were repeatedly turned on and off to investigate noise problems with the IPF amplifiers and problems with the EMI system. It was satisfying to see that the program never showed any signs of being confused. It consistently maintained the IPF tubes at 20'C (+/- 2'C) without the need for operator intervention, thereby eliminating many of the possibilities for human error one of which had caused the demise of the previous system.

ACKNOWLEDGMENT

I would like to thank Cecil Needles and Paul Czarapata both for their continuing help in debugging both the hardware and the software. Thereby making it all happen and in time.

IPF TEMPERATURE READINGS

date: 03/21/85 time: 20:18

1	14°C	2	-21°C	3	-21°C	4	-21°C	5	-21°C	6	-21°C	7	-21°C	8	-21°C
9	10°C	10	-21°C	11	-21°C	12	-21°C	13	-21°C	14	-21°C	15	-21°C	16	24°C
17	13°C	18	-21°C	19	-21°C	20	-21°C	21	-21°C	22	-21°C	23	-21°C	24	-21°C
25	-7?°C	26	-7?°C	27	-7?°C	28	-7?°C	29	-7?°C	30	-7?°C	31	-7?°C	32	-7?°C
33	-7?°C	34	-7?°C	35	-7?°C	36	-7?°C	37	-7?°C	38	-7?°C	39	-7?°C	40	-7?°C
41	-7?°C	42	-7?°C	43	-7?°C	44	-7?°C	45	-7?°C	46	-7?°C	47	-7?°C	48	-7?°C
49	-7?°C	50	-7?°C	51	-7?°C	52	-7?°C	53	-7?°C	54	-7?°C	55	-7?°C	56	-7?°C
57	-7?°C	58	-7?°C	59	-7?°C	60	-7?°C	61	-7?°C	62	-7?°C	63	-7?°C	64	-7?°C
65	-7?°C	66	-7?°C	67	-7?°C	68	-7?°C	69	-7?°C	70	-7?°C	71	-7?°C	72	-7?°C
73	-7?°C	74	-7?°C	75	-7?°C	76	-7?°C	77	-7?°C	78	-7?°C	79	-7?°C	80	-7?°C
81	-7?°C	82	-7?°C	83	-7?°C	84	-7?°C	85	-7?°C	86	-7?°C	87	-7?°C	88	-7?°C
89	-7?°C	90	-7?°C	91	-7?°C	92	-7?°C	93	-7?°C	94	-7?°C	95	-7?°C	96	-7?°C

-7? = CHAMBER NOT CONNECTED

IPF HEATER SETTINGS

1	18 HV	2	10 HV	3	10 HV	4	10 HV	5	10 HV	6	10 HV	7	10 HV	8	10 HV
9	18 HV	10	10 HV	11	10 HV	12	10 HV	13	10 HV	14	10 HV	15	10 HV	16	00 HV
17	18 HV	18	10 HV	19	10 HV	20	10 HV	21	10 HV	22	10 HV	23	10 HV	24	10 HV
25	10 HV	26	10 HV	27	10 HV	28	10 HV	29	10 HV	30	10 HV	31	10 HV	32	10 HV
33	10 HV	34	10 HV	35	10 HV	36	10 HV	37	10 HV	38	10 HV	39	10 HV	40	10 HV
41	10 HV	42	10 HV	43	10 HV	44	10 HV	45	10 HV	46	10 HV	47	10 HV	48	10 HV
49	10 HV	50	10 HV	51	10 HV	52	10 HV	53	10 HV	54	10 HV	55	10 HV	56	10 HV
57	10 HV	58	10 HV	59	10 HV	60	10 HV	61	10 HV	62	10 HV	63	10 HV	64	10 HV
65	10 HV	66	10 HV	67	10 HV	68	10 HV	69	10 HV	70	10 HV	71	10 HV	72	10 HV
73	10 HV	74	10 HV	75	10 HV	76	10 HV	77	10 HV	78	10 HV	79	10 HV	80	10 HV
81	10 HV	82	10 HV	83	10 HV	84	10 HV	85	10 HV	86	10 HV	87	10 HV	88	10 HV
89	10 HV	90	10 HV	91	10 HV	92	10 HV	93	10 HV	94	10 HV	95	10 HV	96	10 HV

VHT~30mv x (HVAL)

HTAVE=