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THE MFTF SENSOR VERIFICATION COMPUTER PROGRAM

Harry K. Chow

November 9, 1984

Lawrence
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**THE MFTF SENSOR VERIFICATION
COMPUTER PROGRAM**

**HARRY CHOW
23-AUG-84**

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MASTER

ABSTRACT:

The design, requirements document and implementation of the MFE Sensor Verification System were accomplished by Bob Trusty and members of the Measurement Engineering Section (MES), a group which provides instrumentation for the MFTF magnet diagnostics. The hardware installation was the responsibility of Don Roach, a group member.

The sensors, installed on and around the magnets and solenoids, housed in a vacuum chamber, will supply information about the temperature, strain, pressure, liquid helium level and magnet voltage to the facility operator for evaluation. As the sensors are installed, records must be maintained as to their initial resistance values. Also, as the work progresses, monthly checks will be made to insure continued sensor health. Finally, after the MFTF-B demonstration, yearly checks will be performed as well as checks of sensors as problem develops.

The software to acquire and store the data was written by Harry Chow, Computations Department.

The acquired data will be transferred to the MFE data base computer system.

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0.0 INTRODUCTION:

This manual will describe the hardware, software relationship in the computer system and the software routine that acquire, verify and record the data.

There will eventually be approximately 1500 sensors installed onto the magnet system. The life expectance of the sensors are about 10 years.

The sensors are wired into a 61-pin connector. A maximum of 12 sensors can be configured into one connector. Each sensor will be assigned a block of 5 pins in the connector. The connectors are attached onto ports scattered along the magnet. Each port can have up to 6 connectors.

There are 7 different sensor types in the system. The sensors may or may not occupy all 5 pins assigned to it. All sensors in a connector are of the same variety.

There are a number of measurements associated with each type of sensor. The measurements are between assigned pins within the connector.

The hardware composition of the acquisition system are;

- 1 each HP-85B computer with 256k memory,
- 1 each HP-3497 scanner*,
- 3 each 20-channel low thermal relays*,
- 2 each 10-channel digital actuator card,

and

- 1 each Hp-4329A Hi-resistance meter.

The communications between the computer and the acquisition device will be over the HP1B.

- * The low thermal relay cards and the scanner decade address has been modified per DWG AAA84-108888-00.
(see Bob Trusty for more details)

1.0 SENSOR, PORT, CONNECTOR RELATION:

Twelve sensors max in one connector.

Six connectors per port.

Initial allotment of twenty port will accomodate 1440 sensors.

All sensors in a connector will be the same (type).

1.1 Sensor# assignments:

Type#	Type	
1	CLTS-3W	(Cryogenic Linear Temperature Sensors)
2	CLTS-4W	(as above, 4 wires instead of 3)
3	SG	(Strain Gages)
4	PRT	(Platinum Resistor Thermometers)
5	LS	(Liquid Helium Level sensors)
6	PT	(Pressure Transducers)
7	VT	(Voltage Taps)

1.2 Sensor, port, connector table:

A matrix of 20 ports, 6 connectors is set up for the table.
The #of ports can be expanded as the system grows.

```
Define,
    P0(20,6)      = Table array buffer
    S1            = Sensor type
    P             = port #
    C             = Connector #
and,
    S1            = P0(P,C)
then,
    S1            = the sensor type in port P, connector C
```

1.3 #Sensor, port, connector table:

A matrix of 20 ports, 6 connectors is set up for the table.

```
Define,
    S0(20,6)      = Table array buffer
    S2            = # of Sensor
    P             = port #
    C             = Connector #
and,
    S2            = P0(P,C)
then,
    S2            = # of sensor in port P, connector C
```

1.4 Signal measurement, connector pin assignment:

Measurement#	Pins
1	A-B
2	A-C
3	A-D
4	B-C
5	C-D
6	C-E
7	D-E
8	A-CL
9	A-CASE
10	E-CASE
11	E-PIPE

The first 9 measurements are taken with the scanner's integral voltmeter. The last 3, with the installation of the Hp-4329a Hi-resistance meter.

1.5 Extended measurements:

Some sensors will require extended measurements which might or might not require additional hardware.

Measurements	Exc	Sig
1. 4-wire ohm	A-B	B-C
2. Strain gage bridge	A-B	B-C
3. PT bridge	n/a	B-C

The 4-wire involves the CLTS-4W, LS, PRT sensors, while the strain gage bridge involve the SG sensor and the PT bridge involve the PT sensor.

2.0 MEASUREMENT ASSIGNMENTS:

There are 11 measurements involving the scanner's integral voltmeter (ohms) or the Hp-4239a meter (megohms). Each sensor can have up to 5 measurements. In addition, some sensor types require extended measurements, which involves a full bridge.

2.1 Number of measurements for sensor:

Sensor#	1	2	3	4	5	6	7
	-	-	-	-	-	-	-
#of measurements	5	4	5	4	4	4	3

2.2 Measurements flagged for sensor:

	measurement#										
	1	2	3	4	5	6	7	8	9	10	11
CLTS-3W	1	1	0	1	0	0	0	0	1	1	0
CLTS-4W	1	0	0	0	1	0	1	0	0	0	0
S	1	1	0	1	0	1	0	0	0	1	0
PRT	1	0	0	0	1	0	1	0	1	0	0
LS	1	0	0	0	1	0	1	0	0	1	0
PT	0	0	1	1	0	0	1	0	0	0	1
VT	1	1	0	0	0	0	0	0	1	0	0

2.3 Sensors flagged for extended measurement:

Sensor		Type#	Flagged measurement (#)
Type			
CLTS-4W	2		4-wire ohms (1)
SG	3		full bridge (2)
PRT	4		4-wire ohms (1)
LS	5		4-wire ohms (1)
PT	6		full bridge* (3)

*voltage excitation

3.0 MEASUREMENT, RELAY CLOSURE RELATION:

Each measurement necessitates a sequence of relays to be closed. It requires a series of relays for the excitation and another for the signal. The relays are structured so there is a common relay closure in the excitation series and the signal series for all sensors in a connector. Let a series be made up of a common relay (tree) and a relay set (2 or 5 relays). The relays for sensors 1 through 10 are located on the low thermal relay cards, while the digital actuator cards hold the relays for sensors 11 and 12.

3.1 Common relay (tree) closure for sensors 1 thru 12 (all) in connector (ohms and megohms).

Measurement#	1	2	3	4	5	6	7	8	9	10	11
Signal relay#	0	1	2	3	4	5	6	7	8	8	8
Excit relay#	10	11	12	13	14	15	16	17	18	19	19

3.2 Relay set (2) associated with sensors 1 thru 10, measurement #1 thru #8 (ohms).

Signal electrically triggered by excitation through scanner address
 Excitation $20+(n-1), 30+(n-1);$ $n=1$ thru 10

3.3 Relay set (5) associated with sensors 11 and 12 measurement #1 thru 8 (ohms).

Signal $4, 0+(n-11)*5; 4, 1+(n-11)*5; 4, 2+(n-11)*5;$
 $4, 3+(n-11)*5; 4, 4+(n-11)*5; n=11, 12$
 Excitation $3, 0+(n-11)*5; 3, 1+(n-11)*5; 3, 2+(n-11)*5;$
 $3, 3+(n-11)*5; 3, 4+(n-11)*5; n=11, 12$

* In $(4, 0+(n-11)*5)$, the 4 is the bin# in the digital actuator card and $0+(n-11)$ is the relay# on that bin.
 A call to the actuator card includes the bin# and selected relays.

3.4 Relay set associated with sensors 11 and 12, measurements #9, 10, 11 (megohms).

Signal relay set not needed. For $n=11, 12$.
 Excitation relay set, measure #9 $30+(n-11)$
 Excit relay set, measure #10, 11 $20+(n-11), 30+(n-11)$

3.5 Relay set associated with sensors 11 and 12, measurement
#9 10, 11 (megohms).

Signal	$4, 0 + (n-11) * 5;$	$4, 1 + (n-11) * 5;$	$4, 2 + (n-11) * 5;$
	$4, 3 + (n-11) * 5;$	$4, 4 + (n-11) * 5;$	$n=11, 12$
Exit	$3, 0 + (n-11) * 5;$	$3, 1 + (n-11) * 5;$	$3, 2 + (n-11) * 5;$
	$3, 3 + (n-11) * 5;$	$3, 4 + (n-11) * 5;$	$n=11, 12$

Examples:

Common relay (tree call) for all sensors in the connector remains the same. The relay set (channel calls) for each sensor in connector is incremented by 1 or 5.

- a. Relay closure sequence for measurement# 1, sensor#1.

"AC0,10,20,30"

where,

AC = command to close thermal relays
0 = measure# 1, common sig relay
10 = measure# 1, common excit relay
20,30 = associated excit set

For measurement# $n=2,3,\dots,8$ and sensor #1

"AC",0,10,20+(n-1),30+(n-1)

- b. Relay closure sequence for measurement# 1, sensor# 11.

"DC3,0,1,2,3,4"

"DC4,0,1,2,3,4"

"AC0,10"

where,

DC = close cmdnd use w/actuator card
3 = bin# on card
0,1,2,3,4 = relays in bin# 4 sequence
DC = close cmdnd use w/actuator card
4 = bin# 4
0,1,2,3,4 = relays in bin
AC = close cmdnd use w/relay card
0 = common sig relay
10 = common excit relay for meas# 1

For meas# $n=12$, sensor# 1

"DC3",0+(n-11)*5,1+(n-11)*5,2+(n-11)*5,3+(n-11),
4+(n-11)*5

"DC4",0+(n-11)*5,1+(n-11)*5,2+(n-11)*5,3+(n-11)*5,
4+(n-11)*5

"AC0,10"

3.6 Relays associated with extended measurement:

Sensors type# 2,3,4 (4-wire bridge)

Common relays for sensors #1 thru 12

DC4,10,11,12,13

Sensors #1 thru 10 relays (exc, sig).

DC13,14

AC9,20+(n-1),30+(n-1) n=1,2,...10

Sensors #11 and 12 relays (exc, sig).

AC9

DC3,0+(n-11),1+(n-11),2+(n-11),
3+(n-11),4+(n-11) n=11,12

DC4,0+(n-11),1+(n-11),2+(n-11),
3+(n-11),4+(n-11) n=11,12

Sensor type# 5 (gauge bridge)

Common relays for sensors #1 thru #12

DC3,13,14

Sensors #1 to #10 relay set (excit, sig)

AC3,12,20+(n-1),30+(N-1) n=1,2,...,10

Sensors #11 and #12

DC3,0+(n-11)*5,1+(n-11)*5,2+(n-11)*5,
3+(n-1)*5,4+(n-1)*5 n=11,12

Sensor type# 6 (voltage bridge)

No common relays for sensors #11 thru 12

Sensors #1 thru 10 relays

AC3,20+(n-1),30(n-1) n=1,2,3,...,10

Sensors #11 and 12 relays

DC3,0+(N-11)*5,1+(N-1)*5,2+(N-1)*5,
3+(n-1)*5,4+(n-1)*5 n=11,12

Similiarly, the relay increments will follow the explanation as stated before. The AC prefix is for Analog relay closing as distinguished from DC, Digital actuator closing.

3.7 THE EXCITATION CURRENT SOURCE:

The current source is programmable via the HP-IB. For safety reasons, the source is separated from the sensors by a set of relays. These relays must be closed prior to turning on the current and open when turning it off.

The command to control the source is,

```
"VC"; n
      where n = 0   relays off
              = 1   10 micro-amps
              = 2   100 micro-amps
              = 3   1 milliamp
```

Example:

To turn on current of 1 milli-amp,

```
OUTPUT 709; "DC3,13,14"      close relay set, bin# 3
OUTPUT 709; "VC3"             on source
```

To turn off current source,

```
OUTPUT 709; "DC3,13,14"      open relays
OUTPUT 709; "VC0"             off source
```

4.0 SENSOR, MEASUREMENT, RELAY ASSIGNMENT TABLES:

The following tables apply only to the first sensor in each connector. The signal tree relays 10,11,12,13,14,15,16,17,18, 19 and the excitation tree relays 0,1,2,3,4,5,6,7,8,9 remain the same for all the sensors in the connector. The set, 20,30, increase with its sensor# (n-1) (9max). The sets for sensors 11 and 12 takes on another format and value.

CLTS-3W

#of measurments = 5

measurements

relay sequence

#	pin	signal	excitation	
1	A-B	0	10	20,30
2	A-C	1	11	20,30
4	B-C	3	13	20,30
9	A-CASE	8	18	20,30
10	E-CASE	8	19	20,30

CLTS-4W, PRT, LS

#of measurments = 5

measurements

relay sequence

#	pin	signal	excitation	
1	A-B	0	10	20,30
4	B-C	3	13	20,30
5	C-D	4	14	20,30
7	D-E	6	16	20,30
10	E-CASE	8	19	20,30

SG

#of measurments = 5

measurements

relay sequence

#	pin	signal	excitation	
1	A-B	0	10	20,30
2	A-C	1	11	20,30
4	B-C	3	13	20,30
6	C-E	5	15	20,30
10	E-CASE	8	19	20,30

PT		#of measurments = 4		
measurements		relay sequence		
#	pin	signal	excitation	
3	A-D	2	12	20,30
4	B-C	3	13	20,30
7	D-E	6	16	20,30
11	E-PIPE	8	19	20,30

VT		#of measurments = 3		
measurements		relay sequence		
#	pin	signal	excitation	
1	A-B	0	10	20,30
2	A-CL	7	17	20,30
9	A-CASE	8	18	20,30

Substitute 20,30 with DC3,0,1,2,3,4, for sensor# 11 and add DC4,0,1,2,3,4 to the sequence.
For sensors 2 thru 10, relay set 20,30,40,50 are incremented by (n-1), for n=2,3,...10. For sensor 12, the relay set are increment by 5 (i.e. DC3,5,6,7,8,9 and DC4,5,6,7,8,9).

Extended measurements:

The excitation current where applicable is 1 ma.

Sensor	Iex pins	sig pin
CLTS-4W	A-D	B-C
SG	A-D	B-C
LS	A-D	B-C
PRT	A-D	B-C
PT	N/A	B-C

5.0 DATA CONVERSION:

The measured data must be converted to its Engineering Units before it can be archived.

5.1 Resistance measurement conversion:

Volts to ohms ($R=E0/Iexc$)

where,

R = converted resistance
E0 = measured signal output
Iexc = excitation current

Sensor type#	Type	Iexc (amps)
1	CLTS-3W	0.001
2	CLTS-4W	0.001
3	SG	0.001
4	PRT	0.001
5	LS	0.001
6	PT	0.001
7	VT	0.00001

5.2 Extended measurement conversion:

Volts to ohms ($R=E0/Iexc$)

where,

R = converted resistance
E0 = measured signal output
Iexc = excitation current

Sensor type#	Type	Iexc (amps)
2	CLTS-4W	0.001
4	PRT	0.001
5	LS	0.001

PT sensor to mv/v ($V=E0/Eexc$)

where,

V = converted mv/v
E0 = measured signal output in mv
(1000* measured signal output)
Eexc = applied excitation volt
(10.0 volts)

SG sensor to micro-strain ($Q=4/(K(R*Iexc/E0-1))$)

where,

Q = converted micro-strain
K = gage factor (2.05)
E0 = measured signal output
Iexc = applied excitation current
(.001 amps)
R = nominal gage resistance
(350 ohm)

6.0 MEASUREMENT VERIFICATION VALUE TABLES:

The verification of the measured signal output is done in its Engineering Units.

6.1 Compare and deviation table value:

Sensor# 1		type CLTS-3W	
Measurement		Engineering units (ohm)	
#	pins	expected	deviation
1	A-B	280	30
2	A-C	280	30
4	B-C	10	3
9	A-CASE	20*10**9	not (2*10**9
10	E-CASE	20*10**9	not (2*10**9

Sensor# 2		type CLTS-4W	
Measurement		Engineering units (ohm)	
#	pins	expected	deviation
1	A-B	7	3
4	B-C	7	3
5	C-D	7	3
7	D-E	7	3
10	E-CASE	20*10**9	not (2*10**9
4-wire ohms		270	20

Sensor# 3		type SG	
Measurement		Engineering units (ohm)	
#	pins	expected	deviation
1	A-B	357	5
2	A-C	357	5
4	B-C	7	3
6	C-E	7	3
10	E-CASE	20*10**9	not (2*10**9
full bridge (strain)		15000	1000
@=units in micro strain			

Sensor# 4		type PRT	
Measurement		Engineering units (ohm)	
#	pins	expected	deviation
1	A-B	7	3
4	B-C	7	3
5	C-D	7	3
7	D-E	7	3
10	E-CASE	20*10**9	not (2*10**9
4-wire ohms		110	5

Sensor# 5		type LS	
Measurement		Engineering units (ohm)	
#	pins	expected	deviation
1	A-B	7	3
4	B-C	7	3
5	C-D	7	3
7	D-E	7	3
10	E-CASE	20*10**9	not (2*10**9
4-wire	ohms	35	3

Sensor# 6		type PT	
Measurement		Engineering units (ohm)	
#	pins	expected	deviation
3	A-D	262	5
4	B-C	262	5
7	D-E	7	3
11	E-PIPE	20*10**9	not (2*10**9
bridge	measurement	0.20	not (0.40
		0=units 0 mv/V	

Sensor# 7		type VT	
Measurement		Engineering units (ohm)	
#	pins	expected	deviation
1	A-B	530*10**3	50*10**3
9	A-CASE	20*10**9	not (2*10**9

The deviation is the amount the measured readings can vary from the expected readings. Any readings greater than the allowed value will be print as an alarm to the user. Bear in mind the expected measurements are initially determined to be those values and can be expected to change with age and experience.

7.0 DATA TAPE STRUCTURE:

The data tape is composed of two files, a control file and a data file. The control file is to keep track of the data records written to the data file.

7.1 Control file:

filename : CONTRL
record size : 30 integer words (240 bytes)
filesize : 1 record
contents : word 1 = # of records written to data file.
 word 2 = # of transfers to RT-11.
 word 3 = last record # transferred to RT-11.
Words 4-30 are reserved for later additions.

7.2 Data file:

filename : DATAFIL
recordsize : 278 bytes
filesize : 762 records
contents : date = MM/DD/YY (18 bytes)
 : time = HH:MM:SS (18 bytes)
 : user initials (12 bytes)
 : port # (12 bytes)
 : connector # (12 bytes)
 : sensor id (10 bytes)
 : comments (80 bytes)
 : data block (17 readings- reals)

7.3 Data block structure:

Readings
1. Res A-B
2. Res A-C
3. Res A-D
4. Res B-C
5. Res C-D
6. Res C-E
7. Res D-E
8. Res A-CL
9. Res A-CASE
10. Res E-CASE
11. Res E-PIPE
12. mv/Volt
13. Micro-Strain
14. Res 4-wire ohms
15. Spare
16. Spare
17. Spare

8.0 PROGRAM PROFILE:

MODULE : Autotest (MFESEN)

PURPOSE : Verify output signals from various sensor types attached to the MFE Verification System.

FUNCTION : Given the port#, connector#, routine selects the proper sensor, performs relay closures, measures the signal output, flag improper readings and records the data for all sensors in connector.

LANGUAGE : HP-85 BASIC

SOURCE : Autotest (MFESEN.BAS)

DESCRIPTION : 1. Check mounted data tape for storage space.
2. Create control, data files if new tape or full.
3. Ask for and set system date and time.
4. Ask for user initials, port#, connector #.
5. Set up proper tables relative to sensor type, relay closures, measurements, compare values.
6. Do readings for selected sensor type.
7. Compare values to expected, flag improper readings.
8. Ask for comments on sensor.
9. Record readings along with test info.
10. Summary printout of sensor if prompted.
11. Repeat til all sensors read in connector.
12. Enter next port#, connector# to continue, else quit for the day.

9.0 VARIABLES and ARRAY ASSIGNMENTS:

Integer

```

PC(20)      = control file data buffer
N0          = # records written to data file
P1          = port #
C1          = connector #
S1          = sensor type selected
S2          = # sensors in selected connector
X           = temporary store variable (indexing)
K0          = temporary store variable (counter)
M0(7)       = # of measurements for sensor type
S0(20,5)    = sensor type table buffer
G0(20,5)    = # sensors in connector table buffer
T2(11)      = excitation relay (tree) assignment table
T3(11)      = signal relay (tree) assignment table
F2          = flag for extended measurement for sensor
P3(17)      = flag for resistance measurements for sensor

```

String

```

D0101      = date storage MM/DD/YY
T0101      = time storage HH:MM:SS
P0101      = character input port #
C0101      = character input, connector #
U0101      = character input, user initials
C0101001   = comments input buffer
N75071     = sensor id buffer
I0101     = sensor id, write buffer

```

Real

```

P           = temporary output storage
S0(17)      = extended measurements data buffer
R2(5)       = expected reading values for sensor buffer
DS(5)       = allowed deviation from expected reading
B7(17)      = data write to disk storage buffer
V0(12,17)   = signal output data buffer
              (12 sensors, 17 readings)

```

MODULE: AUTOST