STAR TPC Temperature Monitoring System

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Introduction

We have installed a temperature measurement system on the TPC in order to diagnose cooling (or heating) problems before any damage is done to the TPC electronics (or in extreme cases, damage to the TPC itself). A total of one hundred twenty temperature sensors are on the East and West sector mounting wheels and on the FEE and RDO cooling manifolds. These sensors are readout using an A/D card in a PC and the results (including periodic historical readings) are available on the WWW. The temperature measurements are also placed on a shared disk accessible by Slow Controls for storage in the data stream and the possibility of setting alarms.

Locations

The sector mounting wheels at the two ends of the TPC each have twelve temperature sensors. Each side has six located near the inner radius (referred to as the 'Inner Wheel') and six more located on the boundary between the inner and the outer sectors (referred to as the 'Outer Wheel'). See the picture below for the locations and numbering.

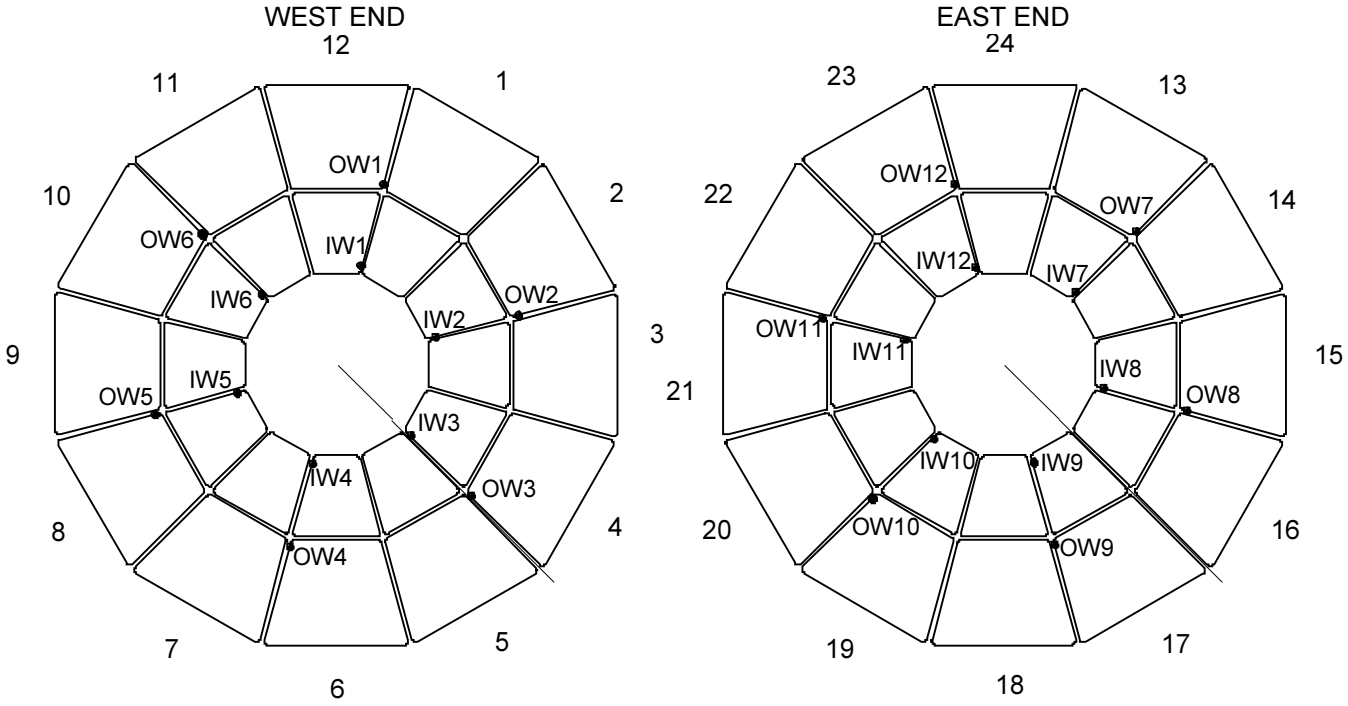

Figure 1. Mounting wheel temperature locations. Each end of the TPC has twelve temperature sensors in the locations shown in the figure.

Each FEE and RDO manifold has one sensor. The sensor locations were chosen to try to diagnose potential cooling (or heating) problems before they become serious. They have been placed in the region most likely to have reduced water flow in the event of particulate buildup in the manifolds (which unfortunately is usually not the same region in which any trapped air is likely to impede flow). The manifolds have water input and output on opposite sides. The sensors are placed on the same side of the manifold as the water exhaust but at the 'dead' end of that side. Figure 2 illustrates a typical layout.

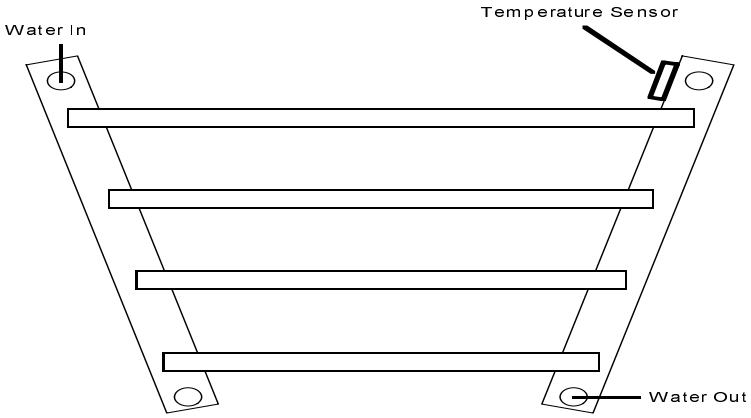

Figure 2. Temperature sensor locations on the TPC electronics manifolds. The sensors are positioned on the same side of the manifold as the water output, but on the far end. The brass mounting base (described later) is epoxied onto the water manifold.

Sensor Description and Readout System

The measurement system uses National Semiconductor LM34CAZ integrated circuit temperature sensors[1] in the circuit shown in Figure 3. The LM34, resistor and capacitor are all captured in an epoxy cast on a ⅛" thick brass 'sled' about 1½"x ⅝". One end of the sled is bent upwards at about 40º to allow for easy removal once it is epoxied to the manifold.

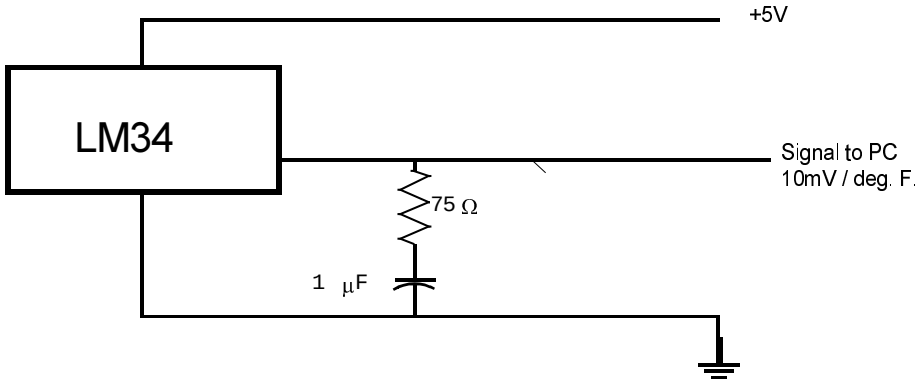

Figure 3. The circuit with an R-C damper used to measure the temperatures.

[1] More information on this device can be found at http://www.national.com/pf/LM/LM34.html

The low voltage, ground and temperature signal are carried on ribbon cables running between the endcaps and an interface box in Rack 2A4 on the South Platform. Five volts is supplied by a standard wall outlet transformer, which plugs directly into the interface box. The interface box has twenty-four DB-9 connectors, each of which serves five sensors (one pin for each signal plus a common ground and +5V). The 120 signal pins on the DB-9 connectors are connected inside the interface box to four DB-37 connectors, which in turn are cabled to the four computer A/D cards. The exact pin mapping is included in Attachment 1 in case there is need for troubleshooting or upgrades in the future.

The A/D cards are NuDAQ ACL-8113 units[2], each with 32 isolated 12-bit channels. The PC is a Pentium 90 running Microsoft Windows NT 4.0 (w/ Service Pack 5 as of this writing) which also sits on the second floor of the South Platform. Since physical access to this computer is subject to RHIC access controls, a remote desktop can be obtained using a VNC Viewer (requires the password). The readout is done by a C++ program that runs continuously and writes out the results to files. Several files hold information from the most recent measurements, and a history file holds a periodic sample of measurements indefinitely. Additionally, the C++ code invokes a Perl program that generates a new Temperature Homepage (described below) for each new set of temperatures. Routine access to the measurements is performed through the WWW in a manner described later. Several parameters of the readout code can be set at start time, such as the frequency of measurements (typically once per minute), how often to write an event to the history file (every 57 events, which is approximately one hour) and what temperature range should be considered normal (typically 68-78ºF). If any temperature is found to be outside of the specified range, a special event is written to the history file and the web page display clearly shows the out-of-bounds condition. At this time however, there are no automatic actions taken when an out-of-bounds temperature is detected other than updating the Web display. In the near term, it is expected that the temperature homepage will be checked sufficiently often to avoid any serious problems. At some point in the future, Slow Controls will include automatic monitoring of the temperatures and generate alerts when necessary.

WWW Display Setup

The TPC Temperature Homepage is accessed at http://tpctemp.star.bnl.gov/. This page displays the most recent measurements, including the highest and lowest temperature, the overall average temperature and the time the measurements were made. Temperature values that fall outside the acceptable range are displayed in bold and color coded (red for high temperatures, blue for cold temperatures). Special events are recorded whenever the temperature service is started, or when a temperature crosses the normal temperature limits. The most recent special event is displayed by clicking on the appropriately labeled button. Additionally, the six most recent special events can be accessed by name as 'AlertX.txt' where X=1,2,3,4,5 or 6 (one being the most recent). Below the textual information, each of the six sensor location types (such as Inner Wheel or Outer FEE Manifold) has a graph with the most recent measurement from each sensor. These graphs display out-of-bound temperatures in different colors as well. This front page updates itself automatically, if the browser is sufficiently modern. It has been shown to work with MS Internet Explorer 4 and 5 and with Netscape Communicator 4.6 on PCs with Windows. Several Unix

systems with various versions of Netscape Navigator 4.xx have been shown to have problems updating the graphs. This appears to be a Navigator feature/bug, for which there may be no solution.

The user can click any of the six graphs in the vicinity of a point (or somewhere in a vertical region around a point) to request a generic history graph for that sensor (50 events starting with the most recent). Alternatively, the user can fill out a form near the bottom of the page to request a history graph. (Hopefully the available parameters are self-explanatory on the web page.) When either method is used to select a history graph, another Perl script (with a CGI interaction to pass the parameters) generates the desired GIF image, displays it in a new window and returns the main browser window back to the Temperature Homepage. This makes it possible to have multiple history graphs open at once, while still looking at the main page. Each history graph is also color-coded and marks special events. The individual history graphs attempt to update themselves every ten minutes. Under normal circumstances, the history file is only updated once an hour, but the history can be updated more frequently in the case of a special event (as defined previously). To prevent historical graphs from clogging the server's disk space, a separate Perl script is automatically started that deletes any GIF images that are more than 2 hours old.

[2] More information on this device can be found at http://www.web-tronics.com/webtronics/32se12bitisa.html

Attachment 1. Cable and Interface Descriptions

Sensor Location	DB-9 Location (Connector Number - Pin Number)	DB-37 Location (Connector Number - Pin Number - ACL9113 Analog Input Number)
Inner Wheel 1 (Sectors 12&1)	1-3	I - 3 - 4
IW2 (S. 2&3)	3-3	I - 13 - 20
IW3 (S. 4&5)	5-3	I - 23 - 7
IW4 (S. 6&7)	7-3	II - 3 - 4
IW5 (S. 8&9)	9-3	II - 13 - 20
IW6 (S. 10&11)	11-3	II - 23 - 7
IW7 (S. 13&14)	13-3	III - 3 - 4
IW8 (S. 15&16)	15-3	III - 13 - 20
IW9 (S. 17&18)	17-3	III - 23 - 7
IW10 (S. 19&20)	19-3	IV - 3 - 4
IW11 (S. 21&22)	21-3	IV - 13 - 20
IW12 (S. 23&24)	23-3	IV - 23 - 7
Outer Wheel 1 (Sectors 12&1)	2-3	I - 8 - 14
OW2 (S. 2&3)	4-3	I - 35 - 27
OW3 (S. 4&5)	6-3	I - 33 - 23
OW4 (S. 6&7)	8-3	II - 8 - 14
OW5 (S. 8&9)	10-3	II - 35 - 27
OW6 (S. 10&11)	12-3	II - 33 - 23
OW7 (S. 13&14)	14-3	III - 8 - 14
OW8 (S. 15&16)	16-3	III - 35 - 27
OW9 (S. 17&18)	18-3	III - 33 - 23
OW10 (S. 19&20)	20-3	IV - 8 - 14
OW11 (S. 21&22)	22-3	IV - 36 - 29
OW12 (S. 23&24)	24-3	IV - 34 - 25
Inner Sector 1 RDO	1-5	I - 5 - 8
IR2	3-1	I - 11 - 16
IR3	3-5	I - 15 - 24
IR4	5-1	I - 21 - 3
IR5	5-5	I - 25 - 11
IR6	7-1	II - 1 - 0
IR7	7-5	II - 5 - 8
IR8	9-1	II - 11 - 16
IR9	9-5	II - 15 - 24
IR10	11-1	II - 21 - 3
IR11	11-5	II - 25 - 11
IR12	1-1	I - 1 - 0
IR13	13-1	III - 1 - 0
IR14	13-5	III - 5 - 8
IR15	15-1	III - 11 - 16
IR16	15-5	III - 15 - 24
IR17	17-1	III - 21 - 3

IR18	17-5	III - 25 - 11
IR19	19-1	IV - 1 - 0
IR20	19-5	IV - 5 - 8
IR21	21-1	IV - 11 - 16
IR22	21-5	IV - 15 - 24
IR23	23-1	IV - 21 - 3
IR24	23-5	IV - 25 - 11
Outer Sector 1 RDO	2-5	I - 32 - 21
OR2	4-1	I - 16 - 26
OR3	4-5	I - 20 - 1
OR4	6-1	I - 26 - 13
OR5	6-5	I - 30 - 17
OR6	8-1	II - 6 - 10
OR7	8-5	II - 32 - 21
OR8	10-1	II - 16 - 26
OR9	10-5	II - 20 - 1
OR10	12-1	II - 26 - 13
OR11	12-5	II - 30 - 17
OR12	2-1	I - 6 - 10
OR13	14-1	III - 6 - 10
OR14	14-5	III - 32 - 21
OR15	16-1	III - 16 - 26
OR16	16-5	III - 20 - 1
OR17	18-1	III - 26 - 13
OR18	18-5	III - 30 - 17
OR19	20-1	IV - 6 - 10
OR20	20-5	IV - 33 - 23
OR21	22-1	IV - 16 - 26
OR22	22-5	IV - 20 - 1
OR23	24-1	IV - 26 - 13
OR24	24-5	IV - 30 - 17
Inner Sector 1 FEE	1-4	I - 4 - 6
IF2	3-2	I - 18 - 30
IF3	3-4	I - 14 - 22
IF4	5-2	I - 22 - 5
IF5	5-4	I - 24 - 9
IF6	7-2	II - 2 - 2
IF7	7-4	II - 4 - 6
IF8	9-2	II - 12 - 18
IF9	9-4	II - 14 - 22
IF10	11-2	II - 22 - 5
IF11	11-4	II - 24 - 9
IF12	1-2	I - 2 - 2
IF13	13-2	III - 2 - 2
IF14	13-4	III - 4 - 6
IF15	15-2	III - 12 - 18
IF16	15-4	III - 14 - 22
IF17	17-2	III - 22 - 5
IF18	17-4	III - 24 - 9
IF19	19-2	IV - 2 - 2
IF20	19-4	IV - 4 - 6
IF21	21-2	IV - 12 - 18

IF22	21-4	IV - 14 - 22
IF23	23-2	IV - 22 - 5
IF24	23-4	IV - 24 - 9
Outer Sector 1 FEE	2-4	I - 31 - 19
OF2	4-2	I - 17 - 28
OF3	4-4	I - 36 - 29
OF4	6-2	I - 27 - 15
OF5	6-4	I - 34 - 25
OF6	8-2	II - 7 - 12
OF7	8-4	II - 31 - 19
OF8	10-2	II - 17 - 28
OF9	10-4	II - 36 - 29
OF10	12-2	II - 27 - 15
OF11	12-4	II - 34 - 25
OF12	2-2	I - 7 - 12
OF13	14-2	III - 7 - 12
OF14	14-4	III - 31 - 19
OF15	16-2	III - 17 - 28
OF16	16-4	III - 36 - 29
OF17	18-2	III - 27 - 15
OF18	18-4	III - 34 - 25
OF19	20-2	IV - 7 - 12
OF20	20-4	IV - 31 - 19
OF21	22-2	IV - 17 - 28
OF22	22-4	IV - 37 - 31
OF23	24-2	IV - 27 - 15
OF24	24-4	IV - 18 - 30

The wire colors connected to the sensors outside of the interface box are described below (some colors are repeated):

Pin/Sensor Number	Signal Color	Ground Color	+5V Color
1	Green	Yellow	Orange
2	Red	Black	Brown
3	Violet	Gray	White
4	Blue	Yellow	Green
5	Orange	Red	Brown

Inside the interface box, the DB-9 pins are connected to the DB-37 in the following colors:

Pin Number	Wire Color
1	Red
2	Orange
3	Yellow
4	Green
5	Blue

For the DB-9 connectors, pin 6 connects to +5V (white wire) and pin 9 is for ground (black wire).