Leak Checker Data Acquisition System

John Payne, Jeffery Gannon
SSC Laboratory[1], Accelerator Systems Division
Electrical Engineering Department
2550 Beckleymeade Ave. MS 4004
Dallas, Texas U.S.A. 75237-3946

Abstract

A portable, high speed, computerized, data logging system. The primary function of this system is to collect 'Helium Readings' from mass spectrometers. This system monitors up to 14 mass spectrometers, operating from as far away as 1 kilometer, or clustered to isolate a helium leak within 20cm. Data logging enables technicians to witness the flight of the helium through the magnet string by a graphical plotting of every channel within microseconds of when the helium was released into the vacuum. The readings are used to locate vacuum leaks and provide acceptance testing of the vacuum system for a string of superconducting magnets. The secondary functions of this system are the documentation of test conditions, archiving data sets for future reference, and providing a real-time display of all channels as the string of magnets approach critical test conditions.

I. INTRODUCTION

By far the most time consuming aspect of magnet installation is leak hunting. In a completed machine (i.e. Tevatron[2]) there are 1,200 cryogenic interfaces. A typical interface consists of a beam tube seal, several liquid helium and nitrogen connections, and a room temperature insulating vacuum seal. Each of the cryogenic seals must be able to be verified at room temperature with sufficient sensitivity to assure that it will not leak liquid helium. On the average it takes only one-half hour to physically place a magnet, one hour to align it, and four man-hours to complete an interface. However, it takes a total of 40 to 50 man-hours to install and leak check each one. A pumpout port is supplied on each magnet, near the downstream interface of that magnet. A helium leak detector is put on each one of the four available interfaces and on the beam tube, and the cryostat is pumped down. The first pumpdown on a fresh cryostat typically takes 3 hours to reach a pressure sufficiently low so that the roughing pumps can be valved off and the leak detector opened fully to the cryostat. When the leak detector is able to be put on its most sensitive scale, leak hunting can proceed.

Previous systems used individual chart recorders to record the results of the leak check process. The scale of the SSC project required a computerized system for recording, analyzing, and documenting the leak check process. Existing commercial systems were not able to meet the requirements of this process.

This system utilizes digitizers daisy chained with a single twisted pair cable. A portable computer connects to this system and both controls and monitors the leak check process. The digitizers do not require special addressing, setup, or field adjustments as existing systems do. The system is user friendly and requires minimal training for use by technicians.

The computer used for this system, is a portable IBM-AT type clone. This PC is equipped with 4 Mb of RAM, 120 Mb hard disk, VGA color (flat screen) monitor, math co-processor, mouse, and 5 I/O expansion board slots. One of these I/O slots contains the data acquisition board custom designed for the Leak Checker System. The leak checker software can run on a PC without the I/O interface installed. This feature allows the engineers to examine the data files on a different computer, from the computer used in the test. For instance the data from a recent test can be up-loaded, from down in the accelerator tunnel, across a network, to an office computer. Analysis of the data can be done in an area where the archived files are located.

II. THEORY OF OPERATION

The 'Recorder Output' on the leak detector is an analog output that would typically be connected to a multichannel chart recorder. This output is a very small voltage (0 to -50mV) and the great distances between leak detectors means that leak detector data could be distorted or attenuated depending on the chart recorder location for each test. Since these chart recorder printouts have been archived as a permanent record for acceptance testing, retesting at a later date could indicate slightly different characteristics for a section of the machine. This new system for monitoring the leak detectors replaces the multichannel chart recorder with a computer. The 'Recorder Output' of the leak detector gets digitized right at the leak detector and is transmitted to the computer on a serial data bus. The digitizer module has a direct analog input for monitoring any make of leak detector. The leak detectors currently in use at the SSC Laboratory have an auto-ranging feature and have been modified for this new system, to transmit the range setting associated with the digitized 'Recorder Output'.

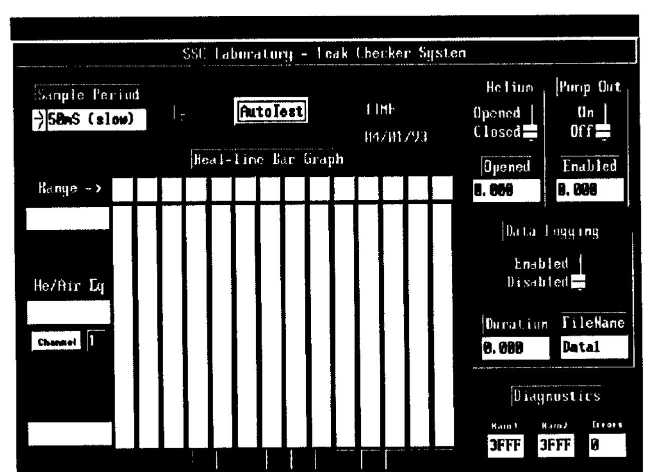

Figure 1

The application program uses three basic screens to work in. The main program screen will only be displayed if the I/O expansion board is present in the computer. Otherwise the program jumps right into the 'XYPlot' screen. The 'notes' screen can be launched from either the 'main' or the 'XYPlot' screen. Each of the three screens share a common menu selection bar along the top of the monitor. These menu items will display help messages, open other screens, exit from screens to previous screens, invoke screen dumps, and handle the chores of printing and copying the data files.

Leak Detector monitoring begins with the screen shown in figure 1. This is the main screen of the application program. From this screen the operators can monitor the status of all the leak detectors simultaneously with incoming data displayed in the thermometer like rectangular windows. These windows represent the 'fine' measurement of the leak detectors, and corresponds to an analog meter movement. As the magnitude of the signal from the leak detector increases, the shaded area of the corresponding window rises upward. Directly above each of the 'fine' windows is a 'Range' window that corresponds to the 'coarse' tune of the Mass Spectrometer. This 'coarse' tune is the power of ten multiplier, 0 to -10. To the left of channel 1 the upper and lower range limits are displayed along with the actual value of the selected channel, scaled in the engineering units of the leak detector 'Standard CC Helium per Air Equivalent'. Any active channel can be directly monitored by clicking the mouse on the 'Channel' button.

The FileName 'data1' is the default name for data logging. A unique file name should be selected before enabling the data logging, AutoTest, or ScreenDump features. The 'Files' option in the menu bar opens a window showing all the existing files. Select any one of these or create a new file by entering the new name to use. Any errors with opening 'FileName' results in opening the default 'data1' file. One of the safe guards used to protect archived data is to make them a 'read-only' file. The 'Duration' is an indicator showing the elapsed time while data logging is active.

The ScreenDump feature acts as a frame grabber. Operators can create up to 100 printable files of the computer screens. The files are in the format of the HP LaserJet III printer. An option in the 'Files' menu will sequentially send all these files to the printer.

The sample period control determines how often the leak detector digitizes its reading. The period of the start pulse ranges from 200µS (5Khz) to 50mS (20hz). When reading leak detectors spaced 90 meters apart, the suggested period is 50 milliseconds. This value is derived from the fact that helium travels close to the speed of sound in a vacuum, and the time of flight down 90 meters is ~250 milliseconds. The 50mS sample rate provides 5 times over sampling to better capture a difference between adjacent leak detectors. When isolating a leak within a 1/2 cell, if the shortest distance is ~1/3 meter, the time of flight will be 1 millisecond and the suggested sample rate should be 200 microseconds (x5).

The Auto-Test mode causes the system to automatically sequence through a pre-defined number of settings. The AutoTest sequence is as follows:

1.) Set the period for 50mSec (Slow).
2.) Enable data logging to 'FileName'.
3.) Save 20 seconds worth of data.
4.) Set the period for 200µSec (Fast)
5.) Open the Helium valve.
6.) Save 5 seconds worth of data.
7.) Close the Helium valve.
8.) Set the period for 50mSec (Slow).
9.) Save 5 seconds worth of data.
10.) Disable data logging.

The Helium Valve selection opens or closes the mass flow control valve. This feature is currently not functional until more information is available on the type of valve to be used for testing. This feature still serves a useful purpose if the valve is controlled manually at or about the time the computer selection is toggled. If data logging is active, an 'OPENED" time stamp is saved every time the switch is toggled, for reference during an XY PLOT.

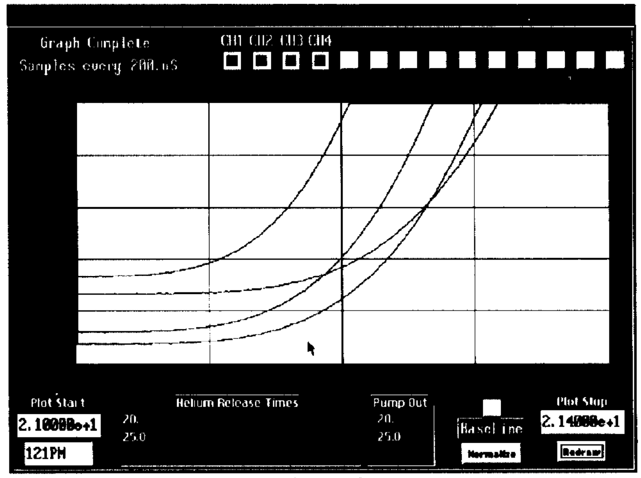

Figure 2

After a leak hunt test, with data logging, evaluating the data begins. The XYPlot selection in the menu bar, will launch a new screen (figure 2) and read the data file named. In this case the FileName is '121pm'. The plot will start at time zero and continue to the end of the data file. The operator can zoom in to any point in time during the plot by manually entering the desired start / stop times. As the plot is expanded the data points will be represented as stars to differentiate between actual data and the connecting lines between points. Along the top of the plot are channel numbers in a color that corresponds to the trace color for that channel. Individual channels can be de-selected in a plot if the data is obscuring other channels, or just want to make screen dumps of some of the channels. The 'Files' option brings up a choice of different files to plot. Operators can view the latest test data or data from previous tests. The 'Helium Valve Status', indicates all the times that the helium was released into the system. The 'Pump Out' display shows all the times that a pump out took place. Each channel can be plotted along with a 'flat base line'. This line helps to determine when the helium reading starts to rise above this point of reference. A rising trend indicates the presence of helium at that point in time. The 'Normalize Point' is the point in time to be used for normalization and for drawing the 'baseline' shown with each channel. By clicking on the 'Normalize' button, the 'Reading' at the 'Normalized Point' in time is subtracted from every 'Reading' in the block (for each channel).

The last program feature is the 'Note Book'. Selecting this launches a new window to display a text file for general purpose documentation. When the data file is re-examined at a later date, observations noted here will be used as a reminder of configurations, and the circumstances of this particular test.

III. HARDWARE DESCRIPTION

The PC initiates an analog to digital conversion by transmitting a START pulse to all leak detectors simultaneously. The leak detectors send their own data, and all data from the leak detectors further away from the leak detector. Data can travel great distances without degradation. Each leak detector module starts its A/D conversion at the same time (+2μS propagation delays), and it takes 13 microseconds to convert (using an ADC912 12 bit A/D converter). Every interface module takes 8 microseconds, plus 1.5 to 2 μS delay between interface transmissions, to send the data back to the PC. Therefore 13+(number of modules * 10) = maximum sample rate. The present application program limits the sample period to 200μS, so all 14 channels can be monitored, at this rate, without concern of losing data. The transmitted serial data consists of 12 bits of digitized analog input and 4 bits of range setting.

The diagnostics area is useful in troubleshooting hardware problems. The computer I/O board has two storage buffers, each buffer is 32k by 8bits, for the incoming data. One buffer is filled with incoming 16 bit data while the other is transferred to the PC main memory by the DMA controller. After the transfer, the role of buffers is switched. The A/D conversions can take place with a precise frequency, while only the average frequency matters when the buffer is transferred. The 'Buff1' and 'Buff2' windows are references to the two memory buffers in the acquisition hardware. The hex values displayed are the number of voltage readings accumulated before they get transferred to the IBM main memory. As the value displayed approaches '0x3FFF' (16k words), an overflow may occur causing a loss of data. The system has been successfully bench tested in the fastest mode (100μS) with 7 input channels, and Data Logging enabled, without the loss of data. This 100μS mode should never be necessary, it serves only to demonstrate the limits of this system. A screen dump during high speed (200μS) transfers of 7 leak detectors showed an average of '0x1730' values accumulated before being transferred to the PC main memory. This indicates the system can easily read 7 leak detectors for isolating a vacuum leak within inches. The 'Errors' window displays the running total of the number of times the number of input channels is not equal to the same number of input channels of the previous block of readings. This can occur if digitizing modules are added or removed while the system is running, or if one of the digitizing modules becomes faulty.

The A/D module dimensions are 12"x7"x4" and sits on top of the Mass Spectrometer. The future plans are to mount the digitizer modules inside the Mass Spectrometers to eliminate the extra power requirements and reduce the number of interface cables. Digitizing modules may be configured many ways depending on the test desired. Two bus ports are provided on each digitizing module. Connection must always be made to the 'Primary Bus' port of any sending module. Connection to the 'Secondary Bus' port is an option, for 'close proximity' applications. Any combination of sending modules is allowable, providing that the 'Primary' port of each A/D module is used. For instance if six digitizing modules were operating, each 90 meters apart, and an additional A/D module was connected to the 'Secondary' port of the 3rd module. That new A/D module would become #4, and what was 4th, 5th, and 6th, would then become 5th, 6th, and 7th modules on the computer monitor.

The asynchronous data transmission on the differential twisted pair is accomplished by sending a synchronizing bit with every data bit. The suggested cable for this system is 'shielded twisted pair' (Belden DataLene), although 'ribbon' cable can be used for short (<10ft) runs. The cable is driven in a differential mode terminated in 100 ohms, with 1500 ohm pull-up and pull-down resistors to compensate for the capacitance of long cable lengths. The bit rate is 4Mhz, and was successfully tested at 8Mhz on 500' (150 meters) of cable. The PC uses a programmable clock timer to transmit the START signal, at a regular interval. After transmitting the START the PC listens for responding leak detectors. Each leak detector module monitors the data bus. If no data is moving in the bus, the module will switch to the receiver mode to wait for the START signal from the PC. The leak detector module looks for the rising edge of the START pulse to start a conversion, and transmits data after the falling edge of the START pulse. When the Leak Detector module is listening and waiting for a start pulse, it is standing ready to transmit a START pulse to the next Leak Detector module further away from the computer. The leading edge of the start pulse from the PC initiates a data conversion in all Leak Detector modules. The falling edge of the start pulse is the signal for a Leak Detector to transmit its data. After a Leak Detector module transmits its data, it will drop the start pulse to the next leak detector, and act as a repeater to relay the data from leak detectors further away from the PC, back to the PC. The computer determines how many channels to display, by how many leak detectors respond to the start pulse. Errors will be indicated in the diagnostic window if the number of leak detectors changes during operation.

IV. DOCUMENTATION

The software for this application is written in ANSI C, with some IBM assembly code. Procedures for modifying and compiling the code are documented within the code.

Data files created and associated with each test:

<FileName>.dat -> raw block of 16 bit data.

<>.ctl -> block sizes, # of channels, and sample rate

<>.txt -> documentation file

<>.val -> helium valve log file

<>.lpo -> pump out log file

<>.pxx -> ScreenDump files (up to 100 may exist)

V. CONCLUSIONS

This system could have applications in other areas where a simple, low cost, portable data acquisition system is required. Battery operation could be used for systems requiring complete portability.

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[1] Operated by Universities Research Association, Inc., for the US Department of Energy under contract No. DE-AC35-89ER40486.

[2] The Fermilab Tevatron: Vacuum for a superconducting storage ring (1983) C.L. Bartelson, H. Jostlein, G.M. Lee, P.J. Limon, and L.D. Sauer