Hall Probe Polarity Checker

Polarity Testing the New Booster Corrector Magnets

Andrzej Makulski, Dana Walbridge
Fermilab

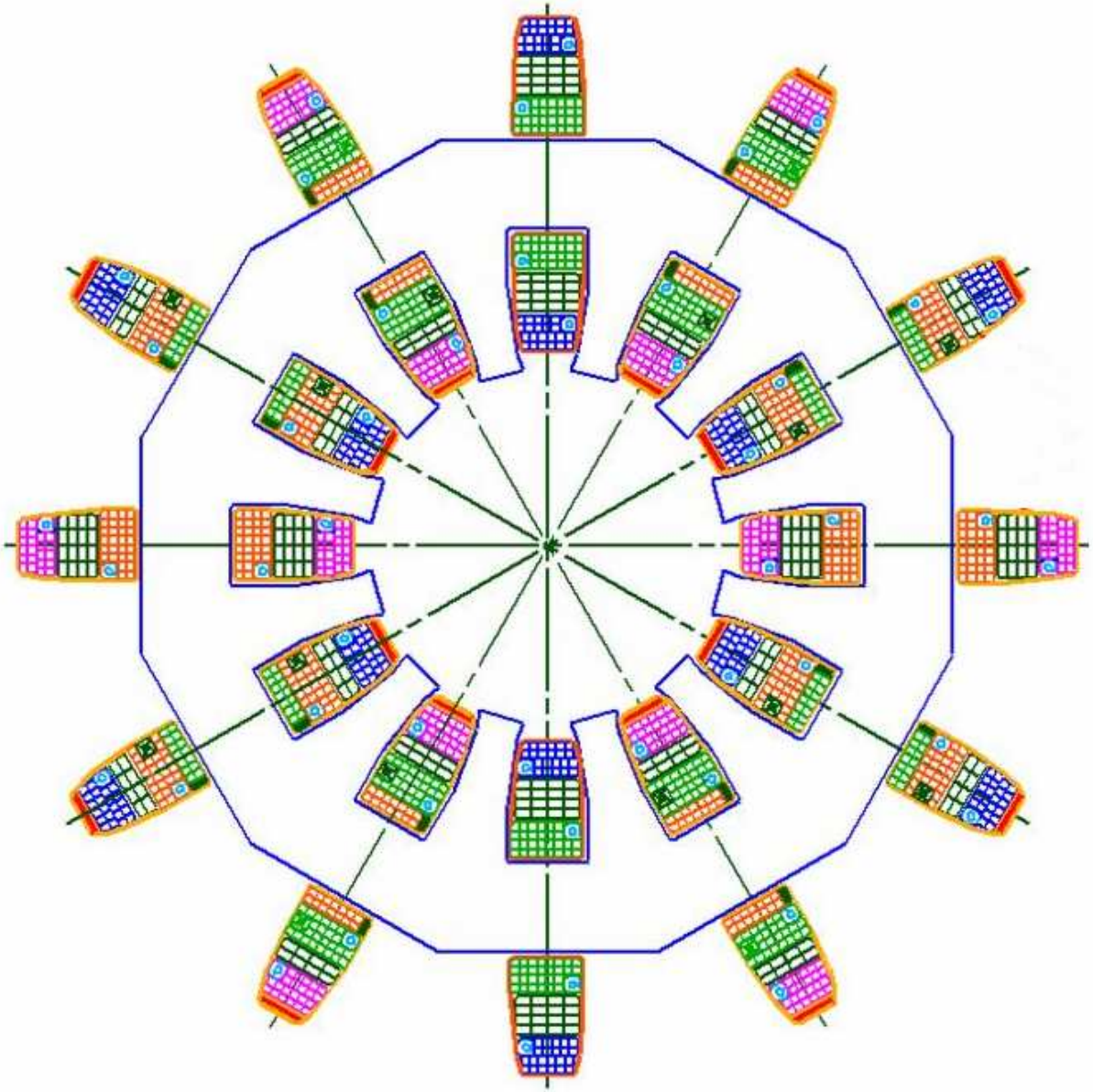
Introduction

- A new series of corrector magnets has been designed for the Fermilab Booster Synchrotron.
- Due to the wiring complexity of these new correctors, a polarity checker probe using low cost industrial Hall elements has been built to aid in the construction of the magnets by verifying that the polarities and wiring of the coils are correct.
- Before examining the polarity testing system, a better understanding of the magnets being tested should help to identify the issues behind the need for such a system.

Some Features of the Correctors

- Designed to provide correction over the range of energies from injection to extraction (control beam position, chromaticity, tune, resonances, and coupling)
- Multipole magnets consisting of a dozen racetrack coils containing:
  - 2 dipole coils, horizontal and vertical
  - Normal and skew quadrupole coils
  - Normal and skew sextupole coils

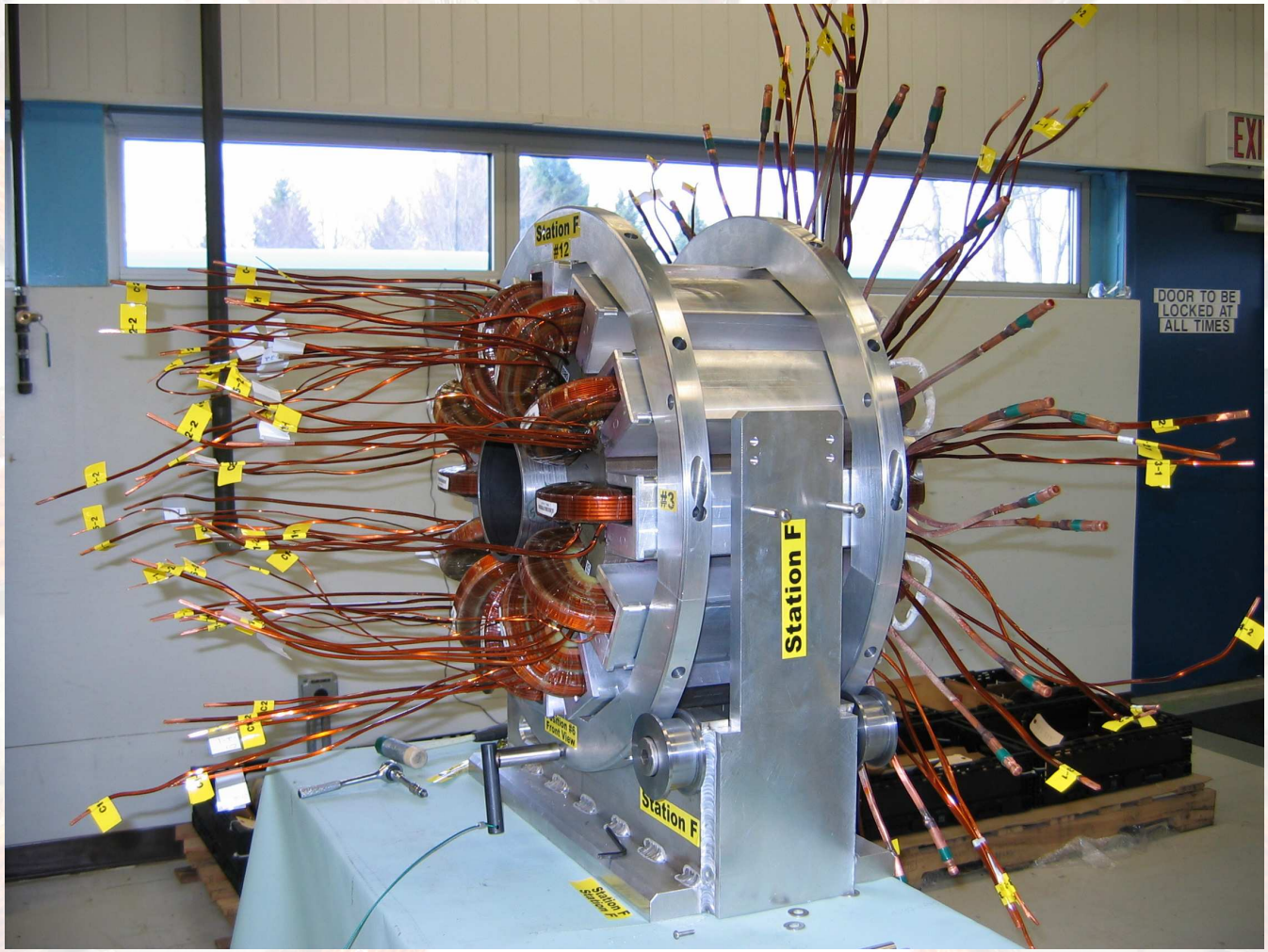
Corrector Cross Section



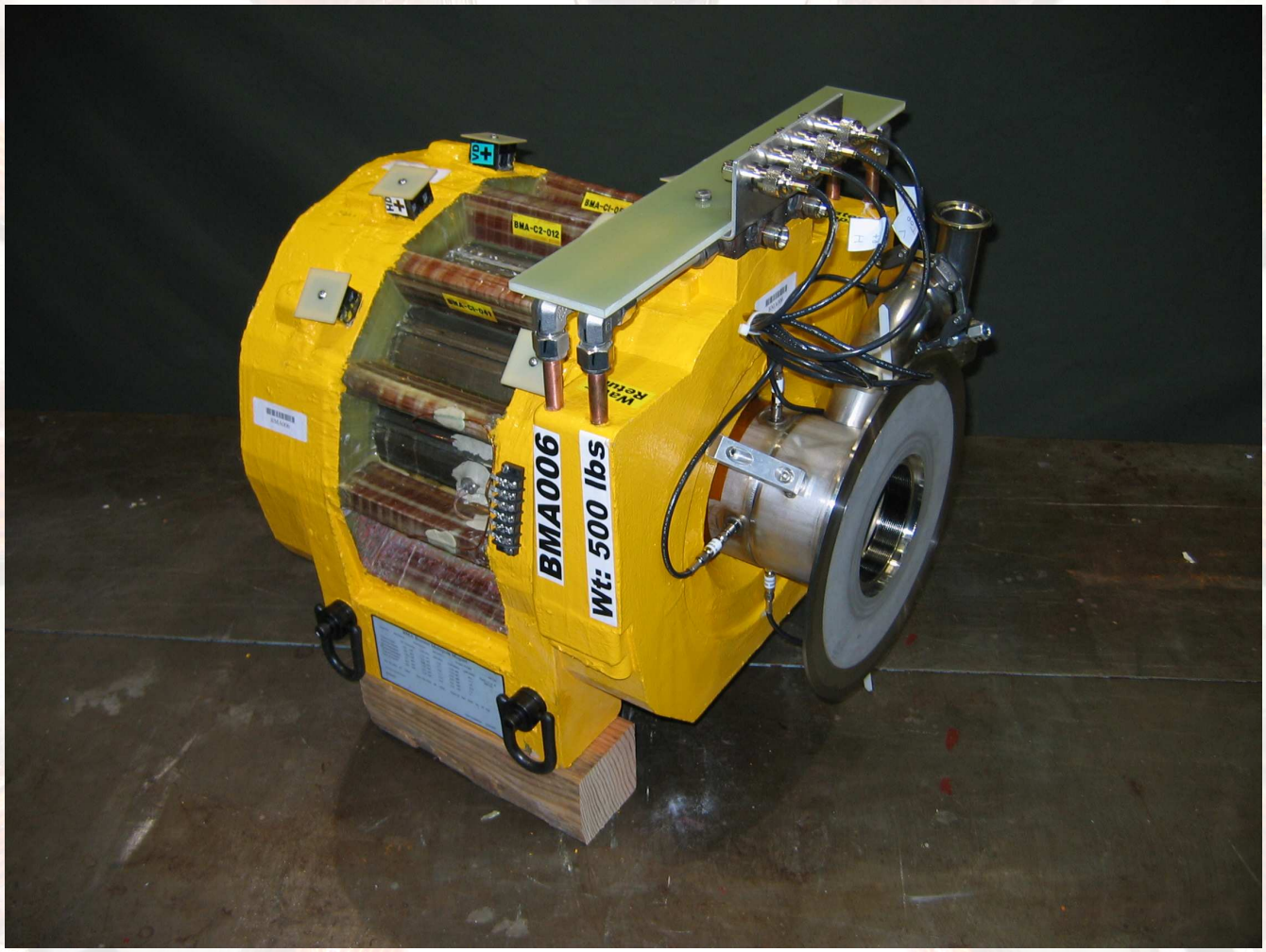
Coil Construction

Coil with Lamination

Magnet Construction



Completed Magnet

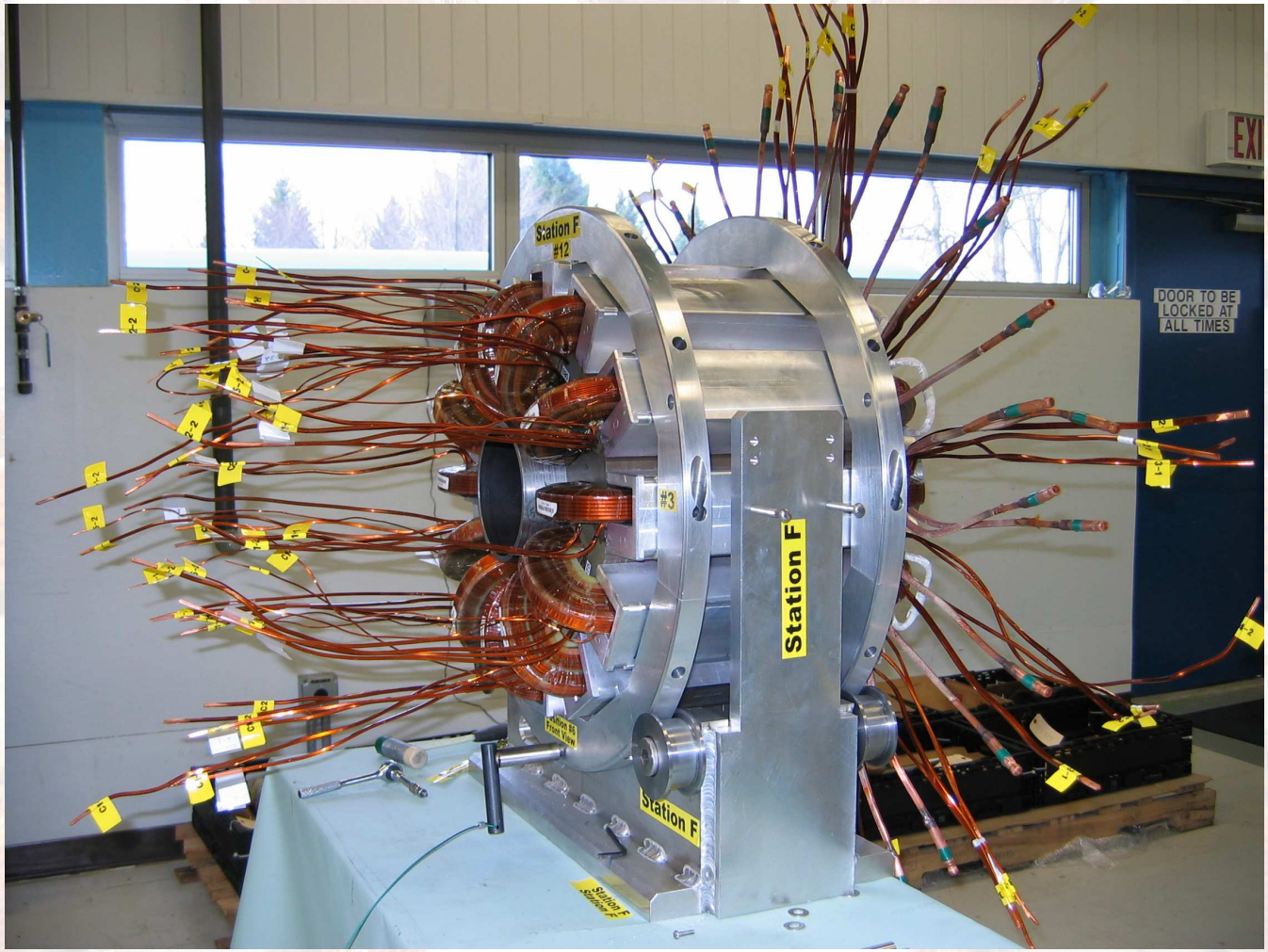


Installed Magnet

Project Status

- 48 correctors will be installed in the Booster
- 2 prototype magnets have been built
- 60 correctors in total are to be built
- To date, not quite half of the magnets have been or are being constructed. The polarity checker has been used to test those built or in the process of being built.

Why is a Polarity Checker Needed?



Polarity Checker

- A request was made to the Test and Instrumentation Department in the Technical Division of Fermilab to provide a means for testing magnet coil polarities in order to verify correct wiring during the magnet construction process.
- Andrzej Makulski of the T&I Department designed and built the polarity checker in response to this request.

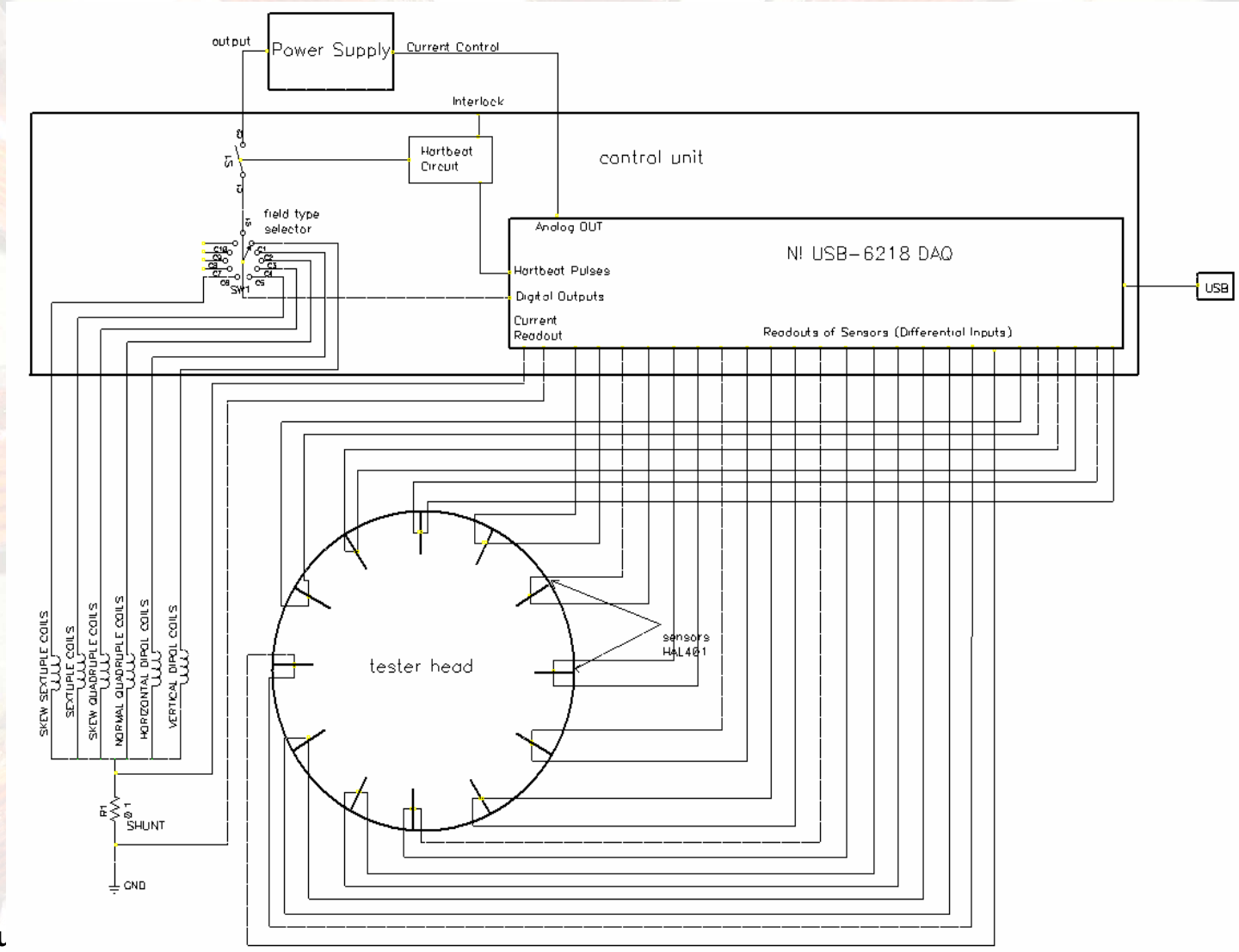
Polarity Checker - Primary Hardware Components

- Consists of 12 linear Hall Effect Sensors (HAL401) evenly spaced around a 112 mm diameter circular head
- A National Instruments NI USB-6218 DAQ reads data from the sensors and transfers the data to a PC via the PC's USB bus

Other Features

- The DAQ controls the setting of current and switching to the correct coil
- Compatible with commercial power supplies which are voltage controled and capable of providing up to 12 volts and 10 ampere output
- Includes and interlock system for safety

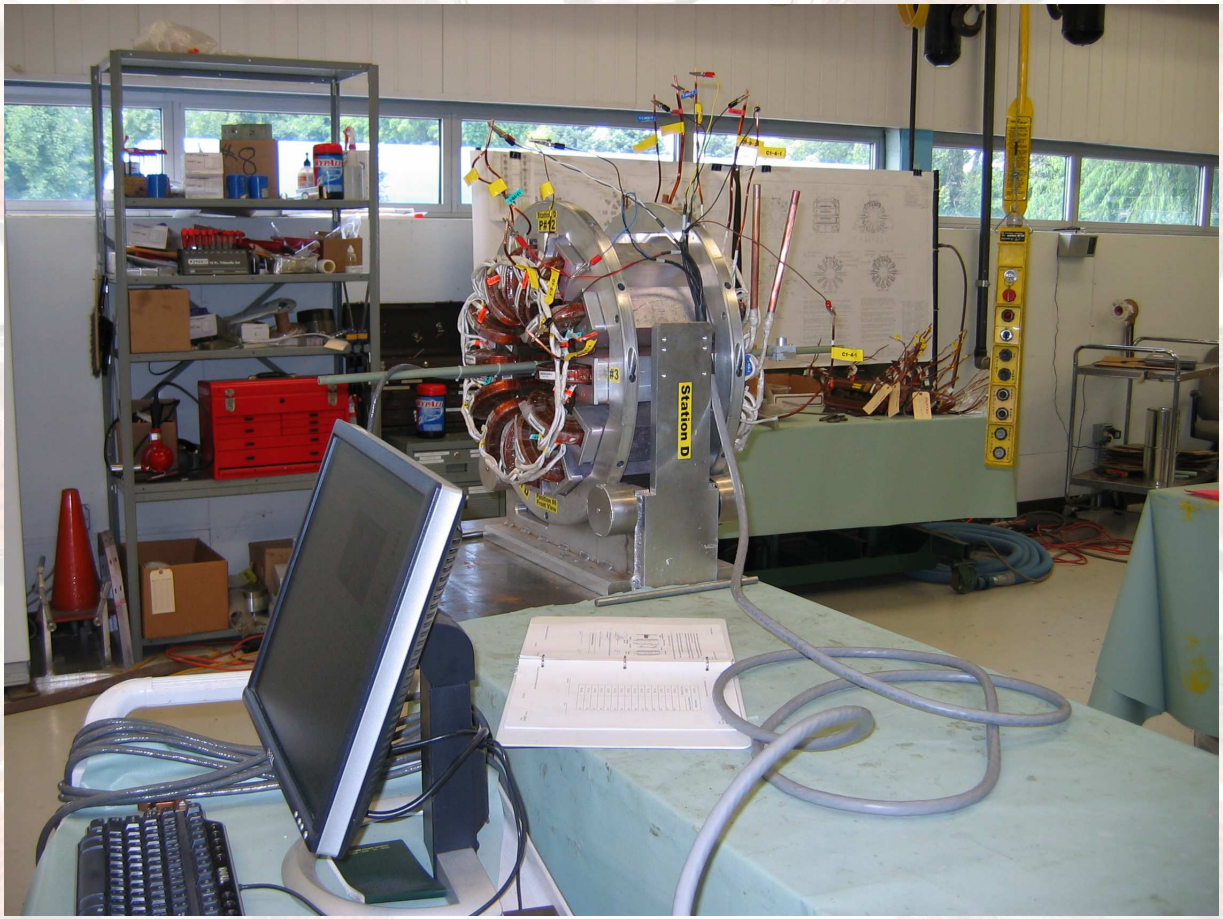
System Diagram



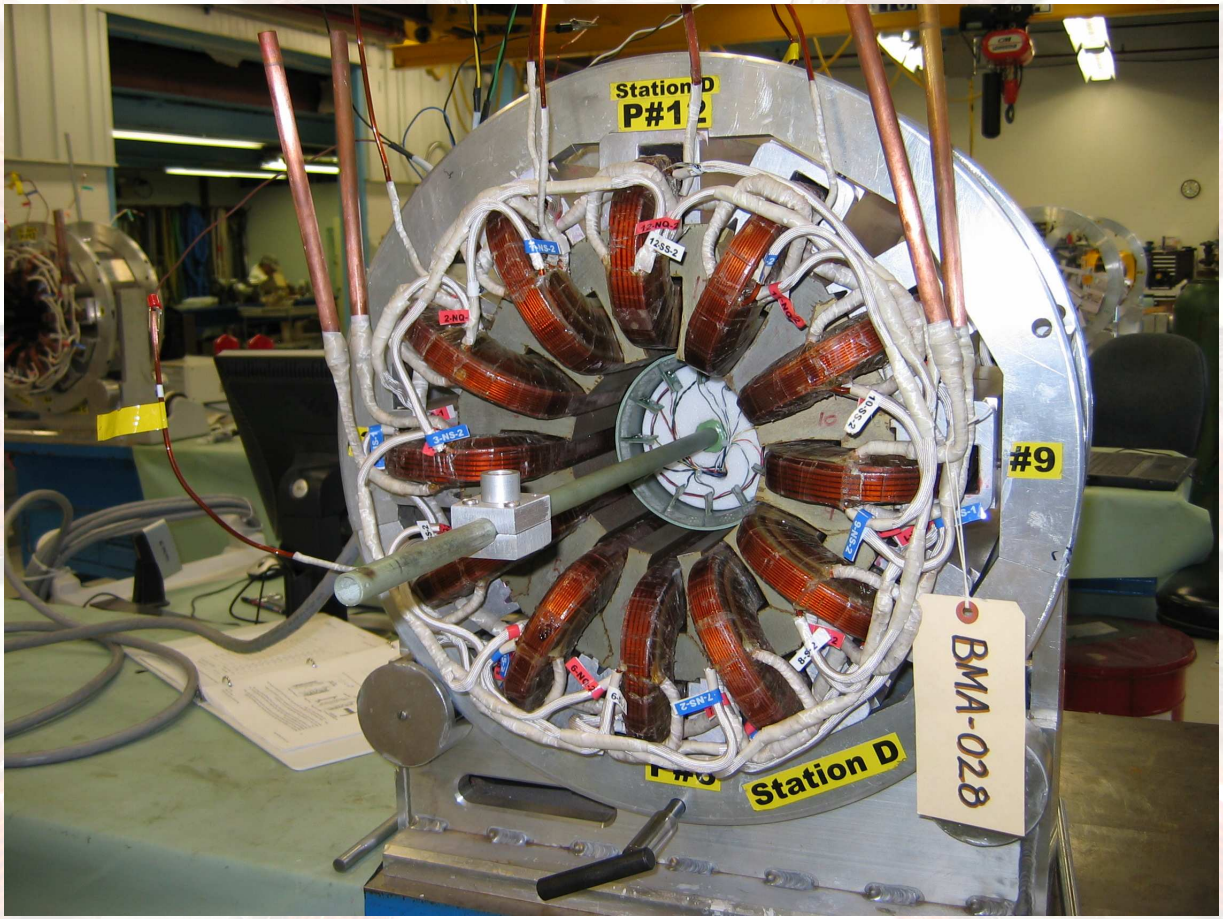
Hall Sensors

- 12 Micronas HAL 401 linear Hall effect sensor IC's
  - Temperature compensated Hall plate
  - Choppered offset compensation
  - 2 linear output stages
  - Differential voltage output is proportional to the magnetic field passing vertically through the sensitive area
  - Robust: can be used in mechanically and electrically hostile environments
  - Designed for industrial and automotive applications
  - Magnetic field range of -50 to +50 mT
  - Low cost, approximately $1 per sensor

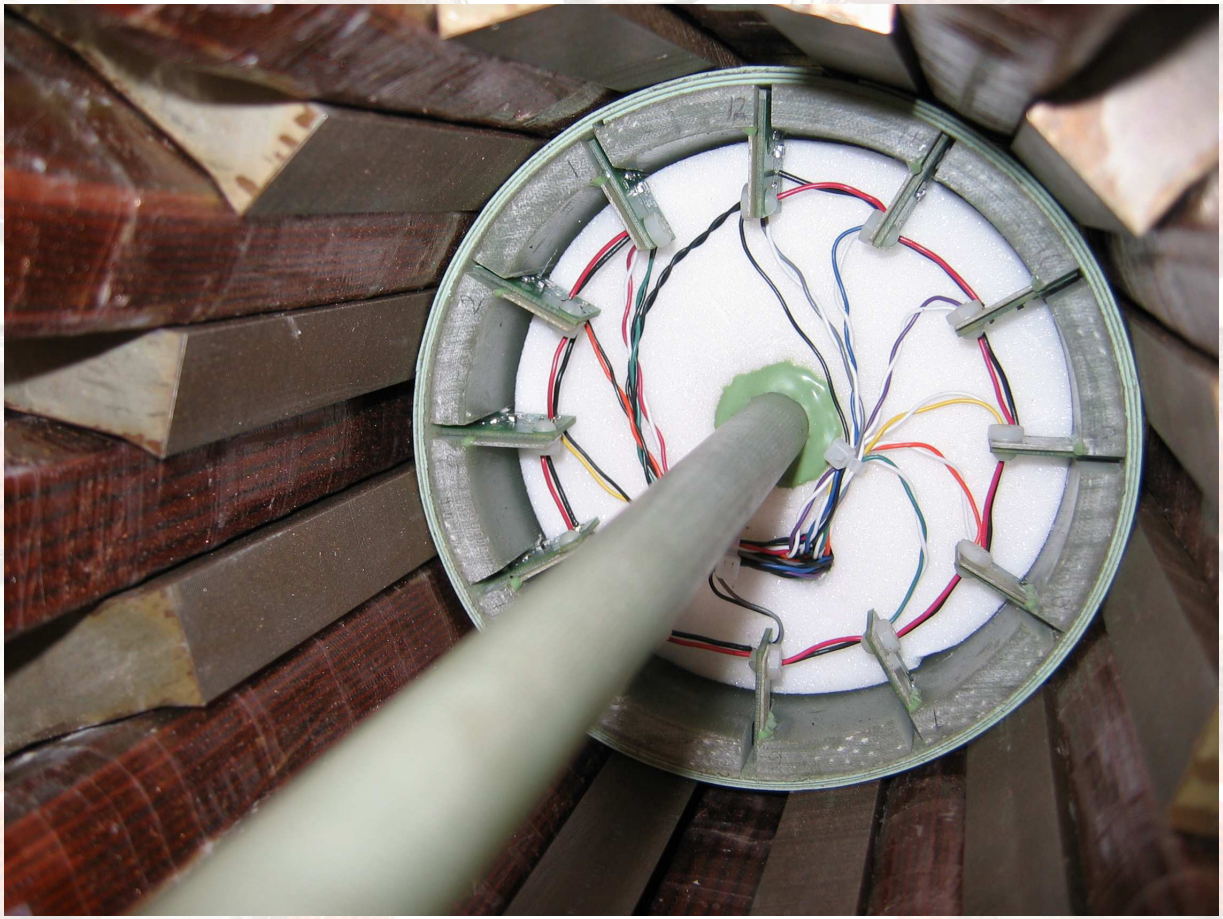
Polarity Testing Setup



Probe Mounted in the Magnet



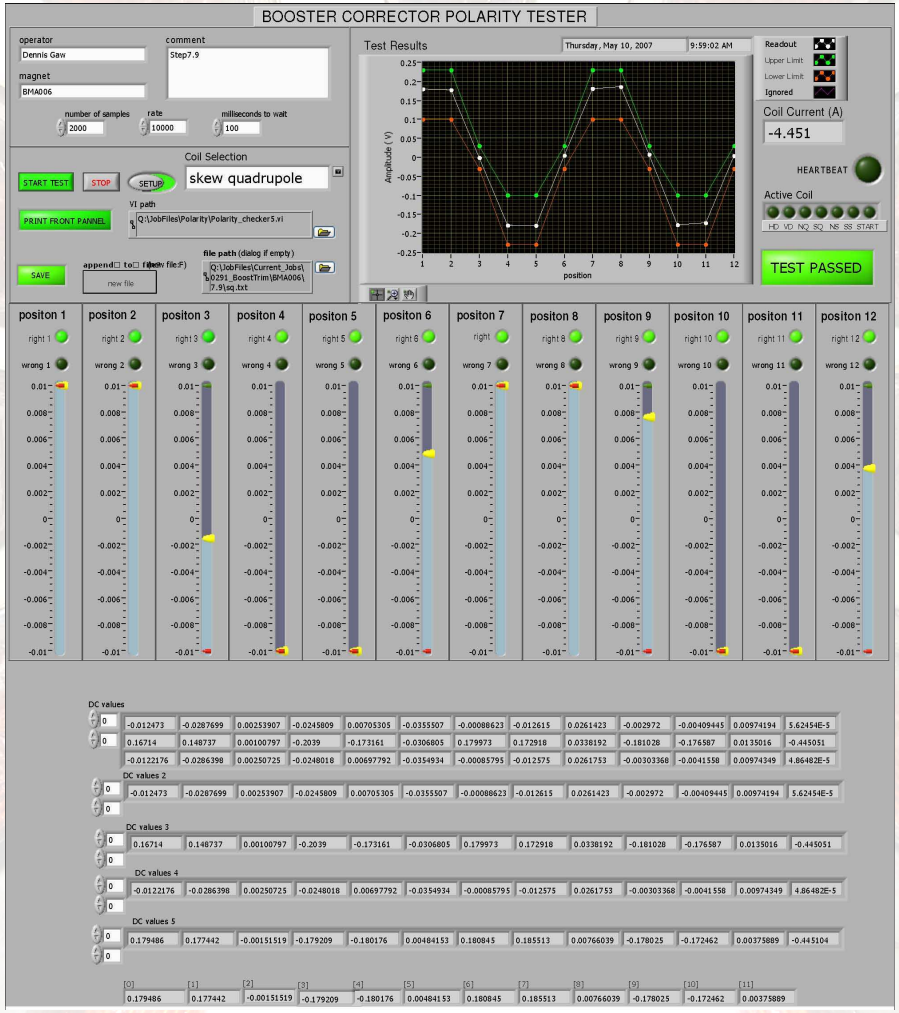
Close-Up



Software Package

- The controlling program for the Polarity Checker was developed using LabVIEW 8.2.
- It provides a graphical user interface which lets the user select the coil to be tested, start the test, and save the results as a text file and/or screen capture of the GUI.
- Data sampling parameters are setable, but default settings reject all harmonics of 5Hz, (particularly 15Hz, 60Hz, 120Hz, etc. which are observed in our environment).
- The heartbeat mechanism, which is implemented through hardware and software, provides a level of protection in the case where the program ceases to function. In this case, the failure of the program is detected and our system of interlocks shuts of the power supply and de-energizes the magnet.

The Graphical User Interface



Setup and Start

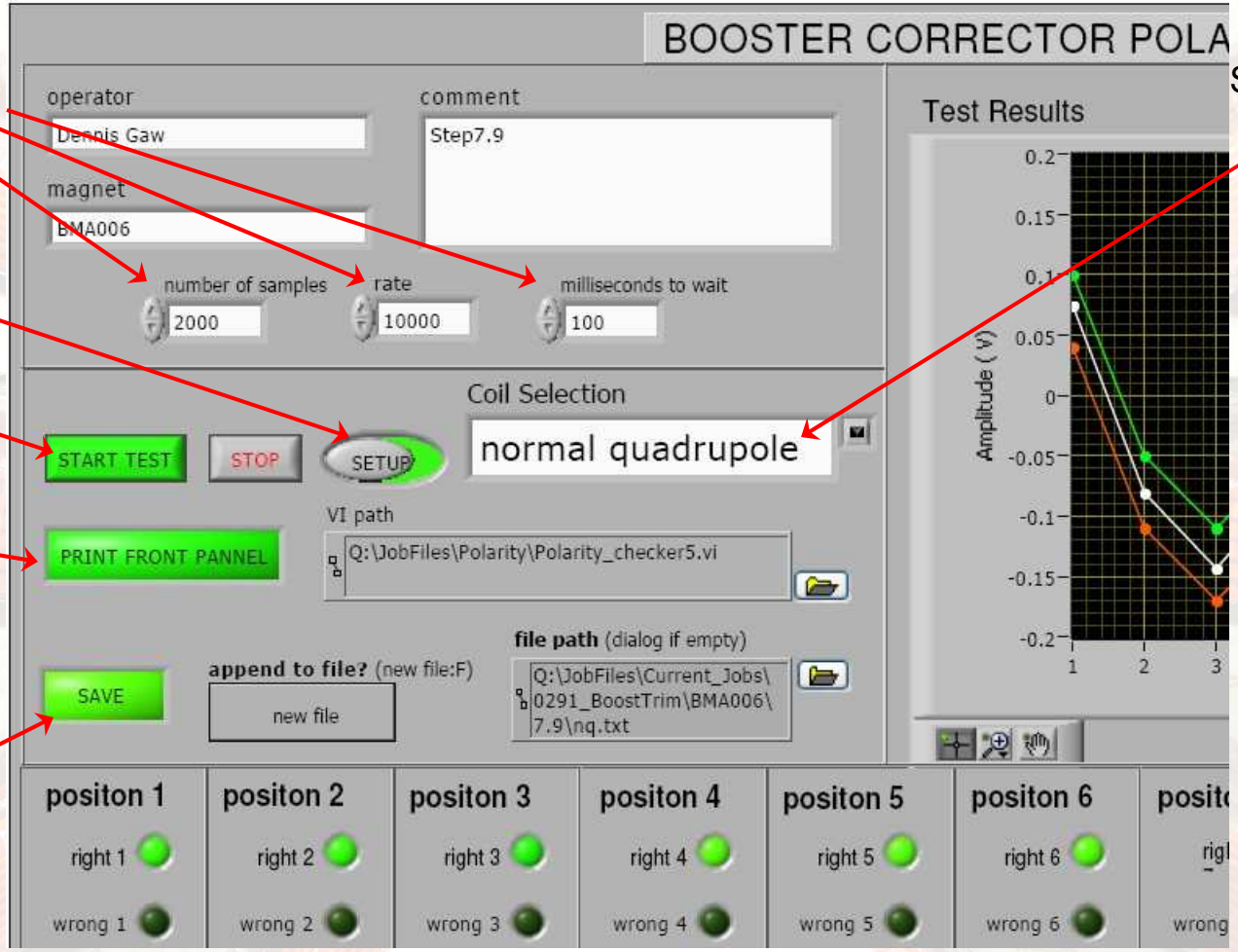
Data Sampling Parameters

Select Setup Mode

Start the Test

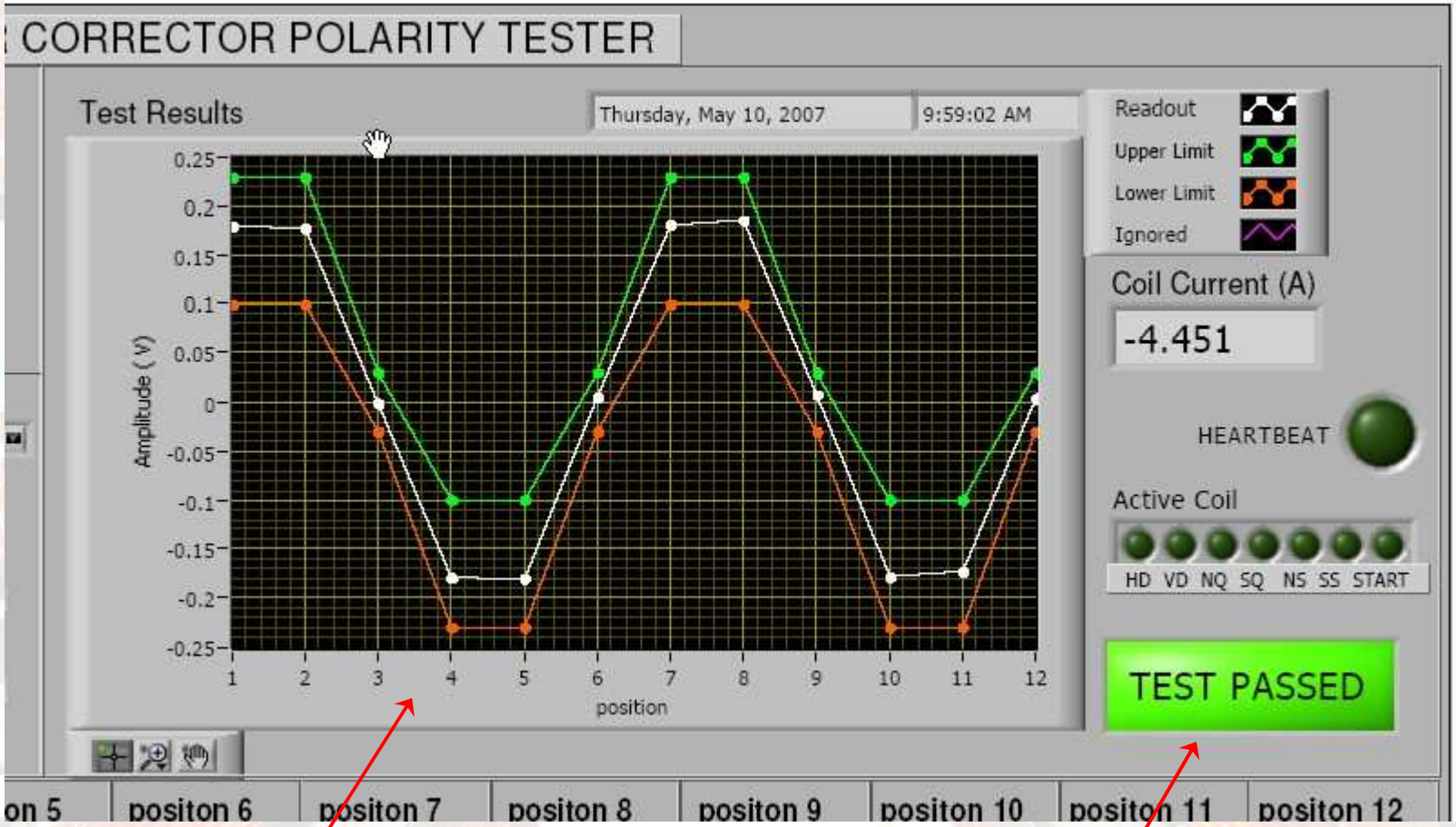
Save the Window as a PDF

Save the results in a Text File



Select Magnet Coil to Power and Test

Monitoring and Plots



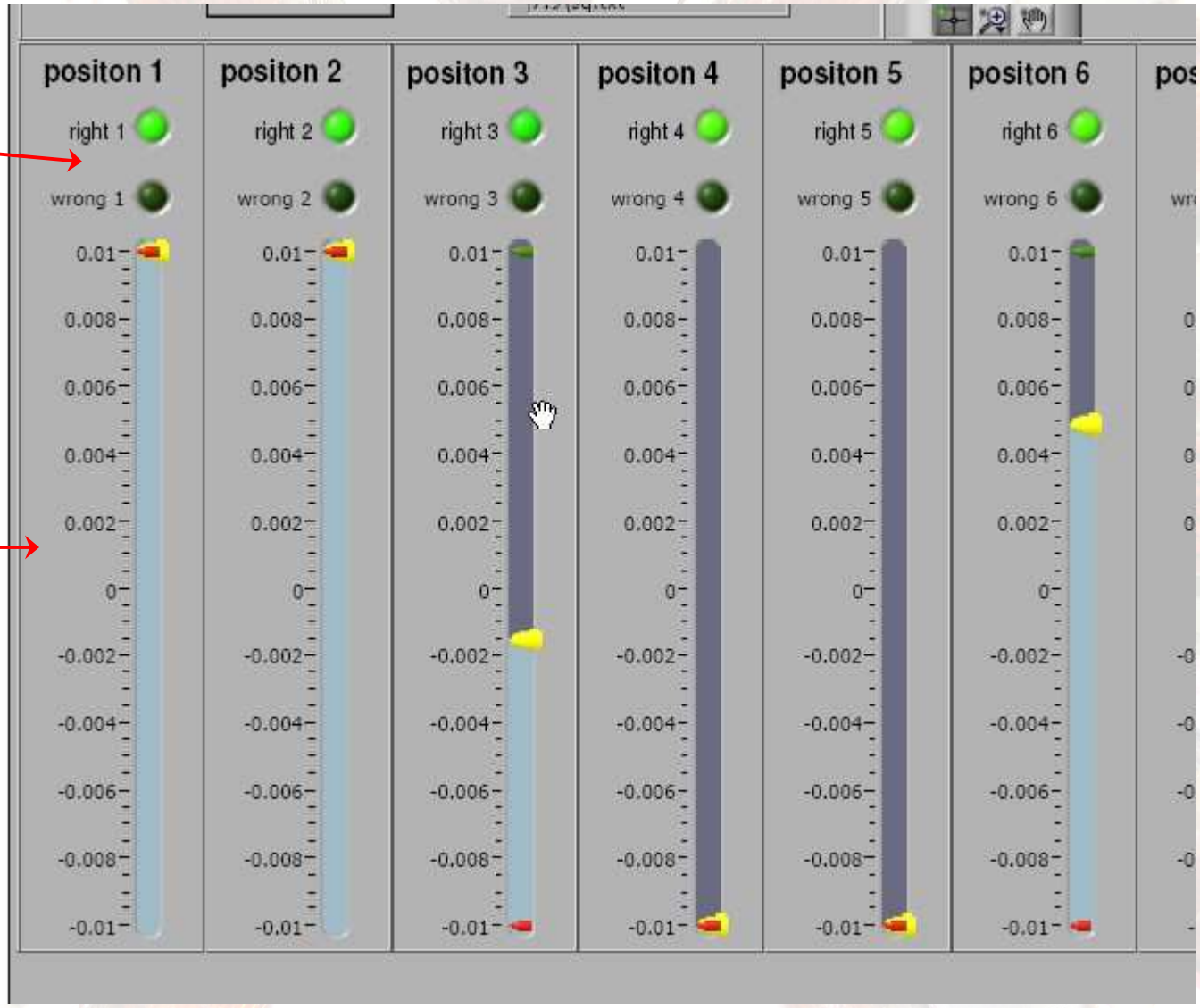
Plot of the Test Results

Test Assessment

Position Monitors

Position Assessment

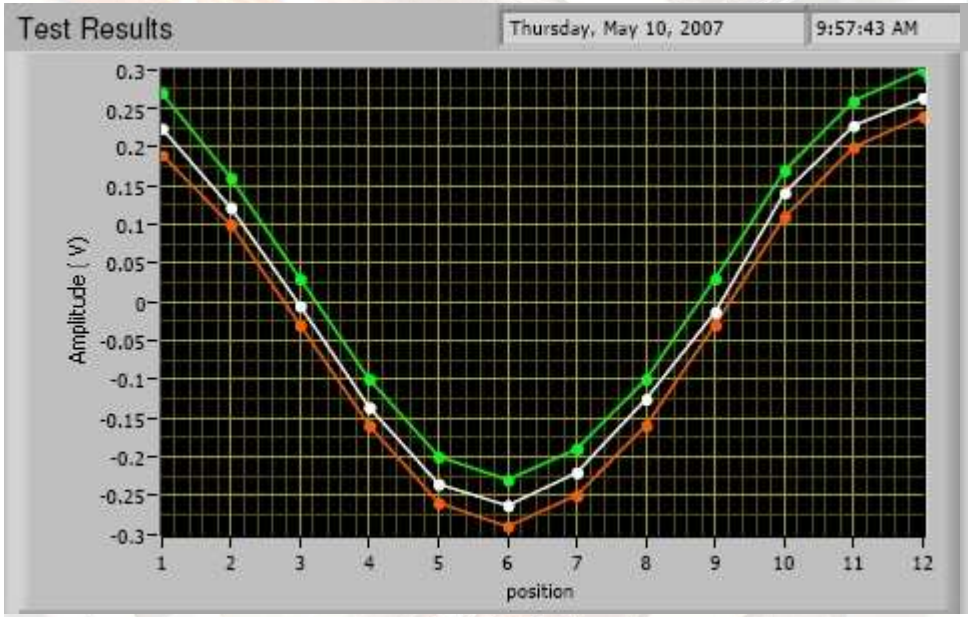
Test Results



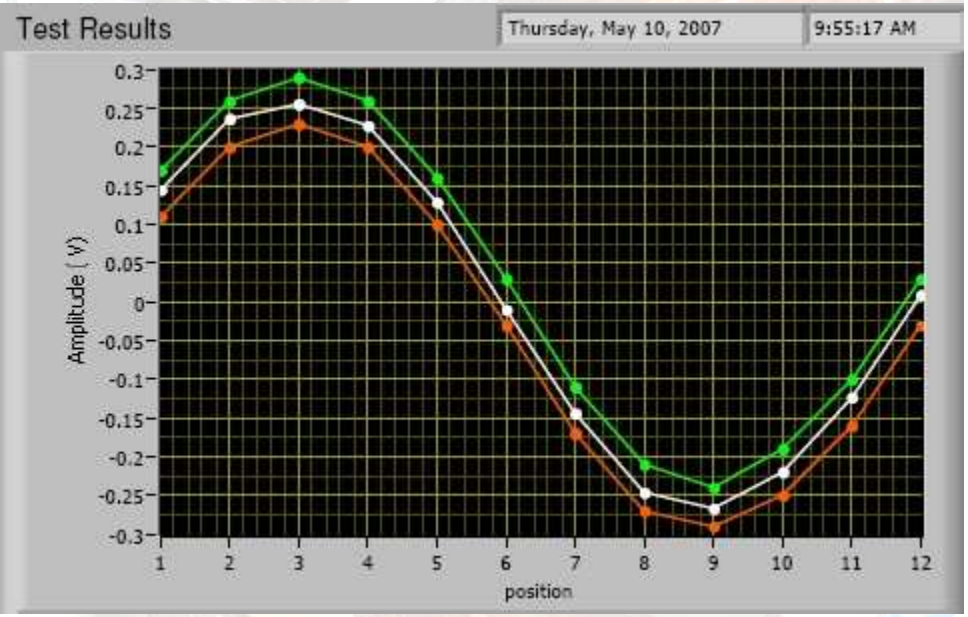
Saved Test Results

- Actual tests are done several times per magnet as specified in the Magnet Assembly Traveler procedures.
- As seen on the GUI, test results can be saved in text files or a screen dump of the GUI.
- Actual tests are done saving both.
- Screen dumps are saved as PDF files.
- Both are viewable online via the electronic version of the traveler.

Example Test Results

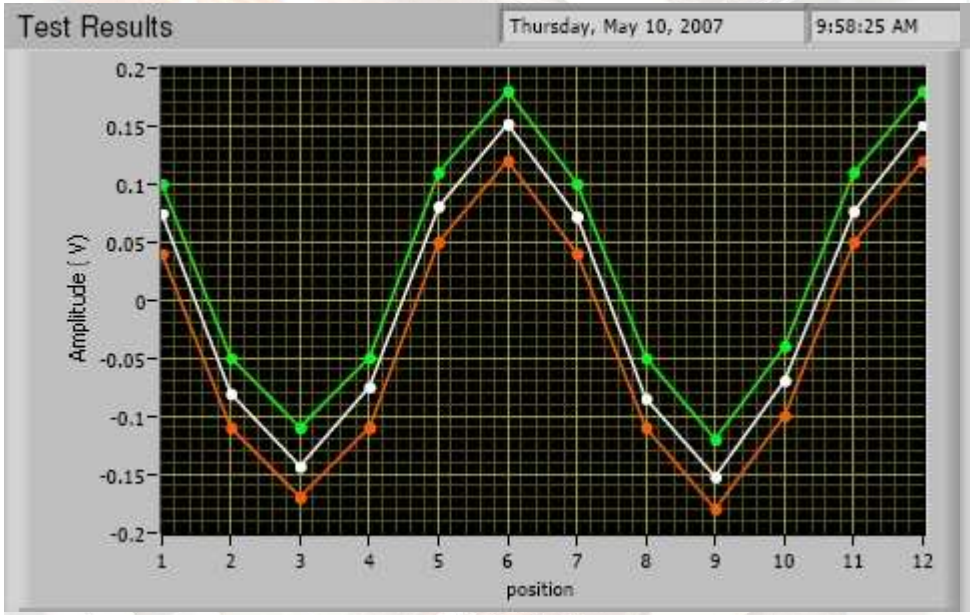


Vertical Dipole

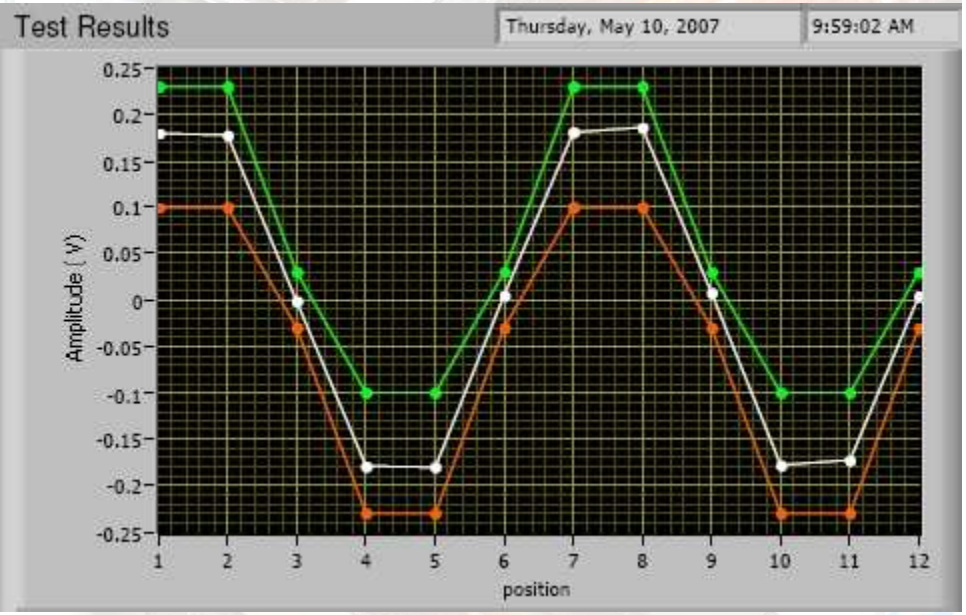


Horizontal Dipole

Example Test Results

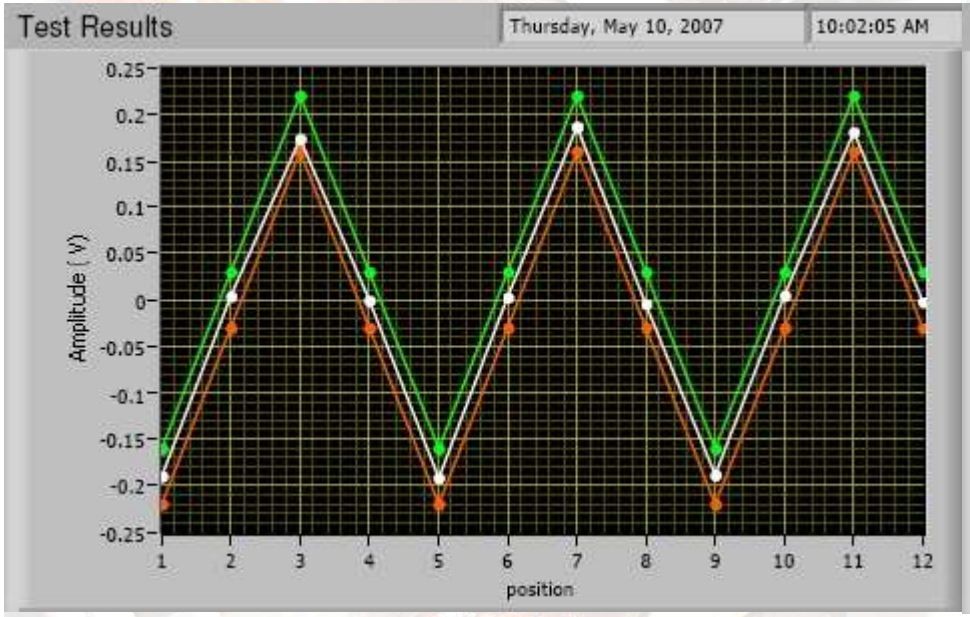


Normal Quadrupole

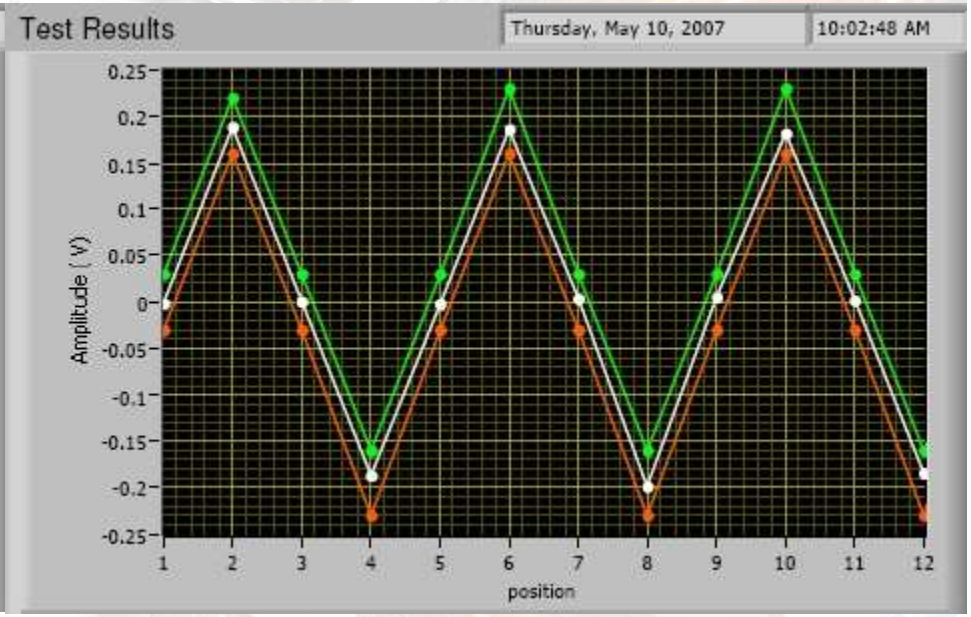


Skew Quadrupole

Example Test Results

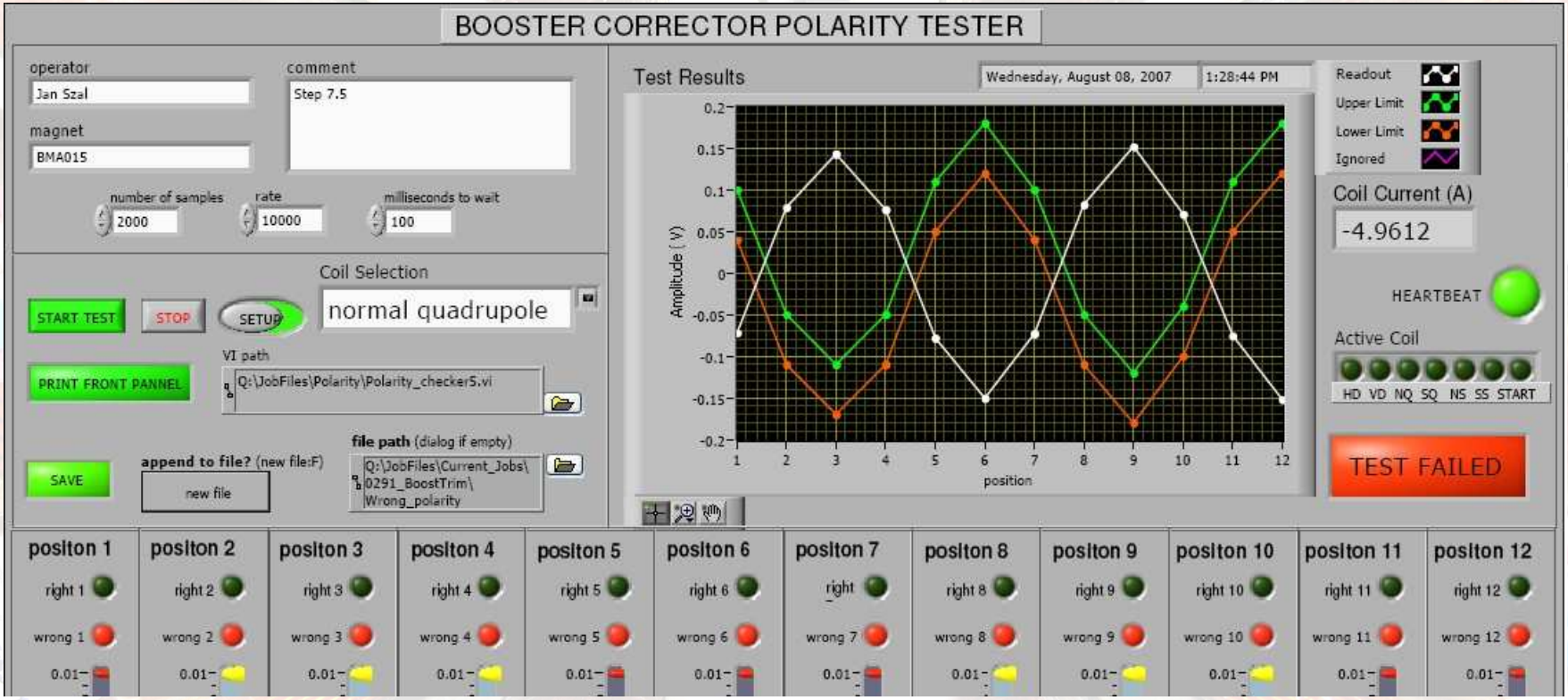


Normal Sextupole

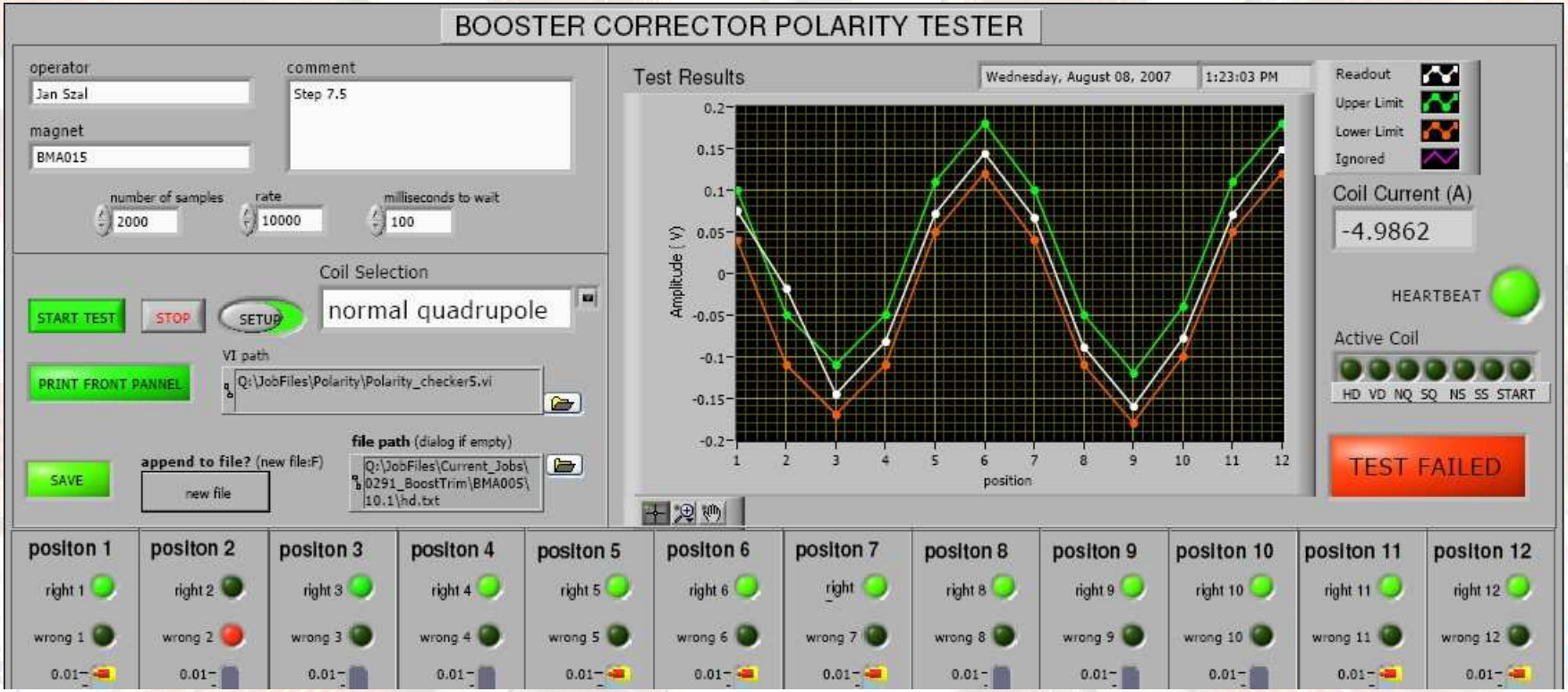


Skew Sextupole

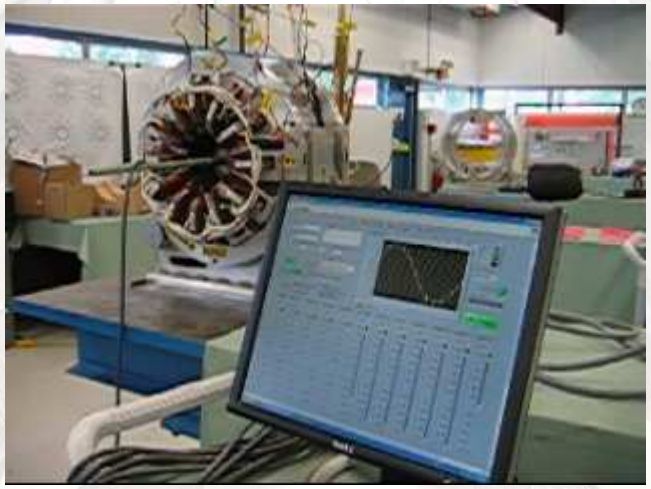
Test Failed – Reverse Polarity



Test Failed – Mis-wired



Sample Test



Conclusion

- A set of multi-pole, multi-element corrector magnets is being built for the Fermilab Booster.
- A polarity checking system using Hall probes has been created to assure quality control in the wiring of these magnets.
- This polarity checker has been successfully used to verify the correct wiring of each of the magnets built to date.

References

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