

FERMILAB-Conf-99/275

A Software System for Measurement of Accelerator Magnets Using a Relational Database

J.W. Sim et al.

Fermi National Accelerator Laboratory P.O. Box 500, Batavia, Illinois 60510

October 1999

Published Proceedings of the 16th International Conference on Magnet Technology, Tallahassee, Florida

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Distribution

Approved for public release; further dissemination unlimited.

Copyright Notification

This manuscript has been authored by Universities Research Association, Inc. under contract No. DE-AC02-76CH03000 with the U.S. Department of Energy. The United States Government and the publisher, by accepting the article for publication, acknowledges that the United States Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government Purposes.

A Software System for Measurement of Accelerator Magnets Using a Relational Database

J.W. Sim, B. C. Brown, E. Desavouret, H. D. Glass, D. J. Harding, J. M. Nogiec, J. E. Pachnik, K. Trombly-Freytag, D. G. C. Walbridge

*Abstract--*Two major upgrades to the Fermilab accelerator complex required the measurement of magnetic field strength and shape for a large number of electromagnets and permanent magnets. This paper describes the software system developed at Fermilab to measure these magnets. The data produced by this system was used to feed back information to the magnet design and fabrication process, as well as to help in determining magnet placement within the accelerator.

The central framework of the measurement software is a relational database management system (RDBMS). Tables within the RDBMS are designed to store magnet design and identification information, measurement prescriptions, magnetic field strength and shape data, comment text entered by measurement technicians, lists of instrumentation used during measurements, calibration constants used to convert data to appropriate engineering units, and quality control limits for measurement data.

The system employs a client-server architecture in which measurement computers, distributed at each of the magnet test stands, retrieved measurement prescriptions from the RDBMS server, controlled the data acquisition hardware used to run the measurement, and communicated measurement data back to the RDBMS. Additional client software was developed to apply analysis algorithms to the measurement data. These clients run either at the test stand, or from analysts' workstations. Standard tools provided by the RDBMS vendor facilitated report generation, *ad-hoc* queries, and manual data entry.

I. SYSTEM OBJECTIVES

The measurement system was designed to meet the following objectives:

- Provide feedback to magnet design and fabrication.
- Provide data for magnet placement in the accelerator.
- Allow quality control checks on magnets and on measurement data.

- Support different measurement techniques (rotating coil, flatcoil, stretched wire, NMR, Hall probe), and facilitate comparisons of data obtained by each technique.
- Allow flexibility to test magnets of various designs.
- Provide reproducible measurement conditions for magnets of the same design series, or for repeated measurements of the same magnet.
- Record all significant details concerning the measurement (data acquisition hardware used, calibration constants used, observations of measurement technicians, etc.) in a manner that allows correlation with measurement results.
- Support concurrent measurements of different subjects at different measurement stations.
- Facilitate retrieval of measurement data and comparisons of data for large populations of magnets of similar design.

The use of an RDBMS was essential in meeting these objectives. The tables designed for the measurement system allowed for straightforward correlation between test subjects, the measurement sequences used to test those subjects, the measurement station at which each subject was tested, the data obtained from the measurement sequences, and all important details related to the measurements.

II. SYSTEM ARCHITECTURE

The architecture of the measurement system is shown in Figure 1. At the center of the system is the RDBMS (Sybase), which employs a distributed client / server architecture. The RDBMS server, running on a Sun SPARCstation, responds to requests from clients running on distributed computers to store and retrieve data from the tables in the RDBMS.

Fermi National Accelerator Laboratory, Batavia, IL

System Architecture



Figure. 1 System Architecture

The principal client in the system is the data acquisition and control software, which runs on individual computers at each test stand. This client controls the measurement sequence according to one of the prescriptions stored in the database for each test subject and records measurement results into the database. The data acquisition hardware consists of VME, VXI and GPIB; the measurement computers vary from diskless VME SPARC computers at some test stands to SPARCstations with SBUS-to-VME adapters at other test stands. Concurrent measurement of individual subjects on different test stands is allowed.

The ability of the data acquisition client to follow measurement prescriptions provides two major benefits. First, measurement conditions are more repeatable, because they are very automated. Second, a wide variety of magnets are capable of being tested by developing measurement prescriptions that are tailored for each test subject. Rather than developing code to perform each new measurement, database table entries are made to drive the measurement.

Other clients that comprise the measurement system include:

• Data entry graphical user interfaces for entering test subject identities into the database and for identifying which subject is being tested at each test stand.

- A graphical user interface for selecting which measurement to run.
- Graphical user interfaces for controlling the data acquisition hardware.
- Software to apply standard analysis algorithms and quality control tests to measurement data.
- RDBMS vendor-supplied software to permit *ad-hoc* queries, report generation, and miscellaneous data entry.

All graphical user interfaces are developed using X-Windows / Motif. All programming is done in C.

III. DATABASE DESIGN

A. Table Grouping

The database consists of some 250 tables and 1700 columns. To facilitate understanding of the tables, they are grouped within the RDBMS according to function. Figure 2 lists the groups and their associated functions.

Group	Function
subjects	Identifies test subjects, categorizing them
-	by their design.
logbook	Stores measurement prescriptions,
-	historical record of measurement
	activities.
harmonics	Stores data acquired using the rotating
	coil harmonics technique.
flatcoil	Stores data acquired using the flatcoil or
	stretched wire techniques.
pointscan	Stores data acquired using NMR, hall
	field point measurements.
results	Stores results of analyzing data from
	harmonics, flatcoil and pointscan tables.
instruments	Stores information about data acquisition
	hardware used for each measurement.
calibrations	Stores information required to convert
	data to engineering units.
admin	Stores administrative information, such as
	personnel identification.
ramps	Stores magnet current ramping parameters
currents	Stores magnet current measurement data.
facilities	Stores inventory of available data
	acquisition hardware.
quality_control	Stores information used to perform
	quality control tests on measurements.

Figure. 2 Table grouping within RDBMS

B. Keys – Serial Numbers

Data within the tables are correlated using numerical keys (serial numbers). These numerical keys are monotonically

increasing integers, automatically generated by stored procedures in the RDBMS whenever new data is inserted into a table. Storing the generated serial number as a foreign key in any table from which a relation is required correlates rows of data in different tables. A specific benefit of this design is that it facilitates correlating comments and data assessments with any entity in the system.

IV. MAGNET MEASUREMENT PROCEDURES

A typical sequence for measuring a magnet consists of the following steps:

- 1. Enter the measurement prescription into the database, if not already there.
- 2. Run the client to enter the magnet identity into the subjects table.
- 3. Run the client to identify which magnet is being tested at the given test stand.
- 4. Select a measurement prescription from the list of available prescriptions stored in the database for the selected magnet type.
- 5. Run the data acquisition client, which interprets the measurement prescription, acquires the measurement data according to the prescription, and stores measurement results into the database.
- 6. Run analysis clients, which extract measurement data from the database, perform analysis algorithms on the data, perform quality control tests on the results, and store analyzed results into the database.
- 7. Repeat items 4 through 6, as necessary, to complete all required measurements for a given magnet.

V. SYSTEM APPLICATION

The system originally was developed to provide the capability of measuring all of the magnets used in the Main Injector upgrade to the Fermilab accelerator complex. Before all Main Injector magnets were fabricated, however, the concept of using permanent magnets in a beam transfer line and in a storage ring was proposed, and the system was pressed into service measuring permanent magnets for those applications as well. The ability to create different measurement prescriptions for different types of magnets made the application of the system to the measurement prescriptions also proved invaluable in the fabrication of permanent magnets, which required repetitive measurement-rework-measurement iterations to obtain the correct field harmonics.

Throughout its history, the measurement system provided valuable information about a wide variety of magnets used in a several accelerators and accelerator subsystems. Examples include:

- 1. Feedback for the design of the end pack for Main Injector dipoles [1].
- 2. Effect of lamination steel production lots on Main Injector dipole field strength [2].
- 3. Feedback for the design of Main Injector Lambertson magnets [3].
- 4. Detection of fabrication errors in LQF magnets for the Antiproton source lattice upgrade.
- 5. Detailed measurements of old Antiproton source magnets, such as the SMA [4] and MDC, to help better understand the machine performance.
- 6. Determination of the time dependence and temperature stability of field quality of permanent magnets used in the Fermilab antiproton Recycler ring [5].
- 7. Determination of the temperature dependence of field strength of permanent gradient magnets for the 8 GeV transfer line [6].
- Determination of the longitudinal center of the field for permanent gradient magnets for the 8 GeV transfer line [6].
- 9. Measurement of the effect on field quality of adjacent Main Injector dipole magnets [7].
- 10. Measurement of magnets for deployment in the PET/RFQ linear accelerator of the Biomedical Research Foundation of Northwest Louisiana [8].
- 11. Measurement of magnets for the Loma Linda medical accelerator [9].

In total, approximately 2700 magnets of almost 180 different designs have been tested for about a dozen different accelerators or accelerator subsystems.

VI. CONCLUSIONS

The measurement system met the objectives for which it was designed. The use of a relational database was essential in meeting the objectives by providing a well-organized framework for capturing not only the measurement data, but also the important details required for interpretation of the measurement data. The system was flexible enough to accommodate both high-volume production testing of magnets with the same design, as well as one-of-a-kind measurements of one-of-a-kind test subjects.

VII. REFERENCES

- D. J. Harding, *et. al.*, "Design and Measurements of Prototype Fermilab Main Injector Dipole Endpacks", in Proceedings of the 1993 Particle Accelerator Conference, May 17-20, 1993, Washington, DC.
- [2] P. S. Martin, et. al., "Variations in the Steel Properties and the Excitation Characteristics of Fermilab Main Injector Dipoles", in Proceedings of the 1997 Particle Accelerator Conference, May 12-16, 1997, Vancouver, B. C., Canada.
- [3] D. E. Johnson, et. al., "Design and Magnetic Measurements of the Fermilab Main Injector Lambertson", in Proceedings of the 1997 Particle Accelerator Conference, May 12-16, 1997, Vancouver, B.C., Canada.
- [4] L. Oleksink, "Magnetic Field Design of the Accumulator Multipole Magnet", Fermilab/TM-1219, 1993.
- [5] B. C. Brown, et. al., "Time dependence and Temperature stability of the Permanent magnets for the Fermilab Antiproton Recycler Ring", these proceedings.
- [6] H. D. Glass, et. al., "Permanent Gradient Magnets for the 8 GeV Transfer Line at FNAL", in Proceedings of the 1997 Particle Accelerator Conference, May 12-16, 1997, Vancouver, B.C., Canada.
- [7] P. Martin, ed., "Fermilab Main Injector Technical Design Handbook".
- [8] N. Chester, et. al., "Magnet Development for the BRF Positron Emission Tomography Accelerator", in Proceedings of the 1997 Particle Accelerator Conference, May 12-16, 1997, Vancouver, B.C., Canada.
- [9] J. M. Slater, et. al., "Developing a Clinical Proton Accelerator Facility: Consortium-Assisted Technology Transfer", in Proceedings 1991 IEEE Particle Accelerator Conference, May 6-9, 1991, San Francisco.