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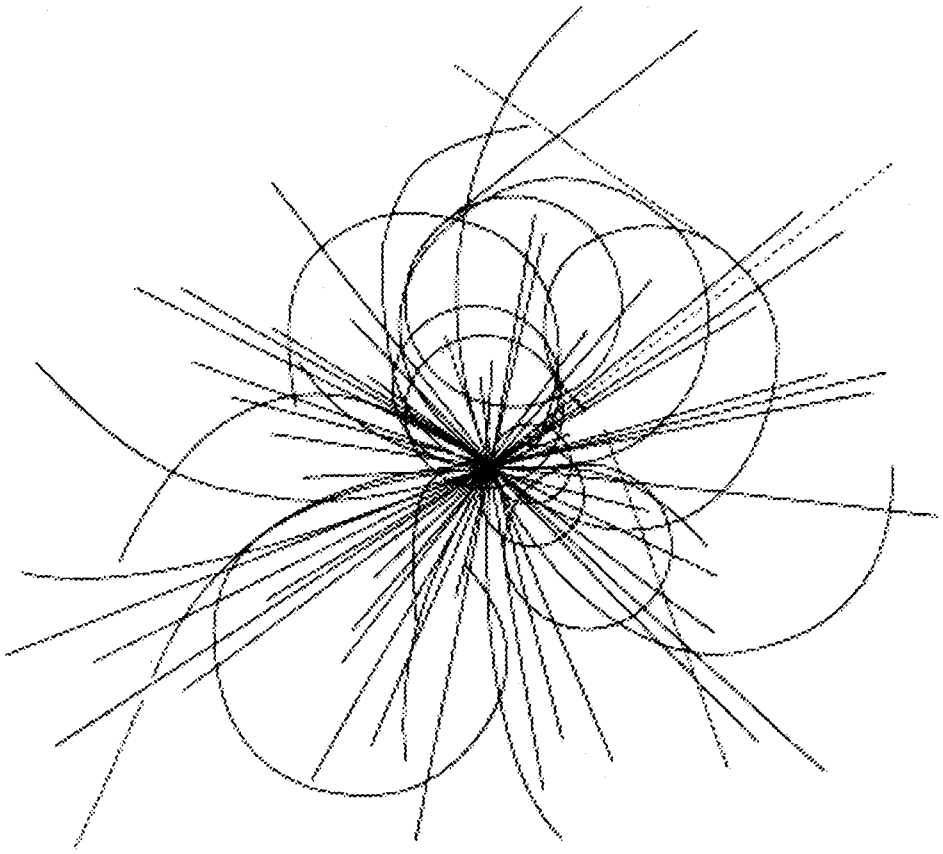

Superconducting Super Collider Laboratory

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Accelerator Design Using Databases and Graphical User Interfaces

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Accelerator Design Using Databases and Graphical User Interfaces

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Abstract

A description of the database and graphical user interfaces that support the design of the SSC Collider machine is presented below. An overview of the component data contained in the database is included, as well as a depiction of the high level view of the engineering systems that are described in the database. A general discussion of the database design is also given, as well as some examples of why this database is needed and how it is used.

1.0 SCOPE OF THE DATA CONTAINED IN THE COLLIDER COMPONENT DATABASE

There are more than 7500 instances of major components in just the top ring of the 87 kilometer SSCL Collider machine. Major components include main magnets (dipoles and quadrupoles), spool pieces, and utility components such as scrapers and collimators. In addition, there are more than 4000 corrector magnets and beam position monitors located inside the spool pieces. There are more than 200 distinct types of components. The bottom ring data doubles the instance numbers given above. Adding the HEB Transfer Lines, the Collider Abort and Utility Lines, and data from all the other Accelerators and Transfer Lines will add not only instances but data structure complexity.

The components of the Collider participate in the engineering systems which support the beam optics. Therefore, we are tracking the top level view of six major engineering systems:

1. Electrical—Main magnet power
2. Electrical—Corrector magnet power
3. Cryogenics
4. Quench Protection
5. Beam Instrumentation
6. Vacuum

Design parameters of the major components, especially magnets, are being collected and stored in the database. The database can aid in enforcing consistency of interrelationships between these parameters.

Another essential type of data collected in the database is infrastructure or geographic data, which enables the association of components to various groups which are of interest from an optics or engineering point of view. The four major sectioning mechanisms are:

1. Sector
2. Half Cell
3. Logical Section, *i.e.,* arcs, utility
4. Niche service regions

2.0 COLLIDER COMPONENT DATABASE DATA POPULATION

Figure 1 illustrates the manner in which data is captured to populate the Collider Component database. The component data is initially entered into a MAD input file.[1] The data is extracted from this physics design file and entered into the Lattice database. This extraction process orders the components and computes a starting position for each component based on lengths. The Lattice database is a controlled dataset that follows a formal release procedure. The Collider Component database is reloaded with every major Lattice release. The Collider Component database core tables contain the major components specified by the physicist responsible for the Collider design.

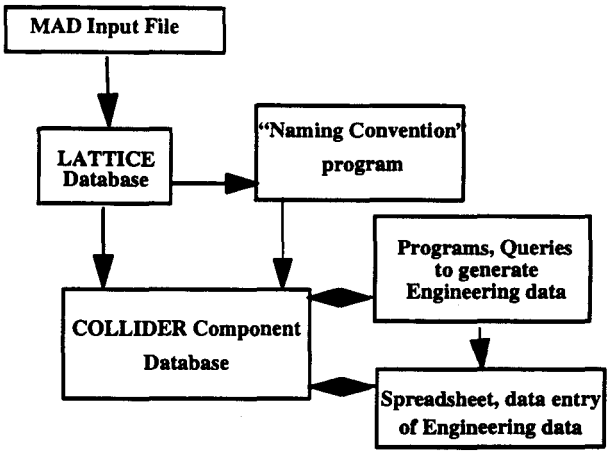

Figure 1. Collider Component Database Population Diagram.

A standard method of naming equipment in the SSC Laboratory has been devised to provide an unambiguous and compact method of referring to accelerator operations equipment. The Lattice database serves as input to a program that generates names for the Collider beamline components. This program is written following the guidelines proposed by the SSCL Naming Convention Committee.[2] The names generated by this program are also loaded into the database. These names are used to determine half cell and sector boundaries.

The major purpose of the Lattice database is to provide a basis for a consistent computation of the global 3-d geometry of the beam lines and derivatively the entire accelerator complex. As such, the 3-d lattice geometry is the basis for mechanical engineering and civil construction layouts. The Lattice database also supports optics simulation activities. It is unnecessary to orient a component with respect to sector or half cell position for this purpose, as the magnetic properties of the components and the geometry of the machine are of primary interest.

A major requirement for the Collider Component database is to describe the engineering systems and the physical aspects of the components and to orient the components with respect to each other and the major logistics points (for example shaft and niche locations). The component database also contains data such as detailed descriptions of spool pieces.

Data regarding engineering systems—such as electrical power, cryogenics, vacuum, beam instrumentation, and quench protection—are generated in a variety of ways. Some data can be derived by devising algorithms which take advantage of the repeating nature of the half cells in the arc sections of the Collider. This data may be augmented by manual data entry and data built in spreadsheets. Infrastructure data regarding niche locations, boundaries of sections of the Collider, and cryogenic sections are loaded into the database from spreadsheet files initially and then kept in synch with Lattice releases by updating the s coordinates of the begin and end of the sections.

The s coordinate is an essential element in the database. It is defined as the number of meters (to six decimal places) from an arbitrary point in the ring which is the 0.0 location. Each component in the beamline of the Collider ring, including drift spaces such as interconnect regions, is assigned a length in the MAD input file. The starting s coordinate of a component is the sum of the lengths of all the components which precede it in the beamline from point 0.0. The s coordinate serves as the ordering device for the component tables in the database.

3.0 FUNCTIONS PROVIDED BY A DATABASE

The data required to control the design of the Collider ring is highly structured, complex data which contains many interrelationships. A commercial database product can help tremendously in the organization, extension, and access of such data. The database provides us with the support required to store and preserve this data in a useful, accessible way. Also, databases provide the structure and tools to maintain a multi-user environment. Conventional relational databases provide the following capabilities:

1. Data access management. Data in a database can be accessed transparently without requiring the user to know the format or perhaps even the structure of the data. Relational databases, by definition, store such meta-data in catalog tables which are accessible by the same mechanisms as user data tables and support end-user tools such as query and reporting tools.

2. Data authorization. Keeping data secure on a user or group level is an essential property of multi-user environments. ANSI SQL provides a Data Control Language (DCL) to enable the granting and revoking of access privileges at an object level.

3. Backup and recovery. Efficient and usable backup and recovery utilities assure the reconstruction of the database in case of a disk crash or operator error where an entire table of data may be accidentally erased.

4. Multi-user facility. Locking mechanisms are provided so that an individual updating a row or series of rows in one or more tables may be assured that the entire transaction will be saved to the database in a consistent manner. This facility must be implemented in an intelligent fashion so that a minimum of data is locked by a particular user and others accessing the database can concurrently access the same tables.

5. Data distribution. The ability to transparently link databases which are logically and/or geographically distributed is necessary to organize and access organization-wide data.

6. Integrity support. Entity integrity stipulates that each table have a single primary key. Referential integrity requires that each foreign key is kept consistent with its corresponding primary key. Business rule integrity refers to the many underlying rules that apply to data within a database such as: all spool piece names must begin with the letters sp. Integrity constraints are enforced via triggers and stored procedures within the Sybase product.

7. Access utilities. Utilities are provided to load and copy data between the database and ancillary tools such as spreadsheets and text editors.

8. Application development tools. Most DBMS products provide a range of application development tools ranging from report writers and query generators to full blown menu and screen generator tools which can be used to build a custom application.

9. ANSI Standard Query Language (SQL). This standard query language provides a powerful interface to the database. There are three major components of SQL: Data Definition Language (DDL), *i.e.,* create, drop, Data Manipulation Language (DML), *i.e.,* select, insert, update, and delete, and Data Control Language (DCL), *i.e.,* grant, revoke, commit. These sub-languages provide powerful constructs to build data structures (DDL), view and update data in a powerful, concise way (DML) and control data access (DCL).

4.0 DATABASE IMPACT ON COLLIDER DESIGN

The many support features of a commercial relational database system described above have helped us in a number of ways to organize and extend our Collider design data. Some of the major general capabilities that are useful to us are enumerated below.

1. Extensibility. A Database Management System (DBMS) provides many alternative means to add data to the database. We use the load and copy utilities to move data between the database and tools such as spreadsheets as well as the data entry capabilities of the DBMS.
2. Accessibility. We use the powerful SQL query capability to access the data for ad hoc queries which might otherwise take programming time, if the data were even available in a reasonable pattern for a program to examine. Also, front end tools are available for most DBMS products so that access to the database is supported for non-computer people.
3. Counting of components. It is very important to be able to count components in various groupings easily and reliably. This information is important to the official design specification documents and is required for various contracts as well. The data organization properties of the database and the query language support have enabled us to provide the ability to count components as required.
4. Impose and communicate sectioning mechanisms. Sectioning mechanisms such as half cell, sector, and logical[3] section are reflected in database tables and can be used to group components accurately.
5. Documented and repeatable operations and data collection procedures. We are able to use the DBMS tools in conjunction with various UNIX system facilities to provide repeatable data loading and updating capabilities.
6. A single set of data for all users. Having a central repository for data encourages group members to improve data quality and add data to the database which is useful to others as well. The DBMS utilities and front end tools that support this effort are critical because these tools can reduce the drudgery associated with data management to a palatable level.
7. Consistent view of data. The database provides a repository of data from which consistent and reliable engineering schematics and high level graphical user interface displays can be drawn. Visualizing the data through graphical user interfaces whenever possible greatly improves individuals' abilities to identify inconsistencies and errors.
8. Automatic generation of engineering data. Much of engineering systems data which are covered in the next section was generated automatically from the main Collider component data already captured. This automation increases accuracy and consistency as well as reducing the amount of manual labor required.

Figure 2 shows a large scale view of the Collider (from the graphical user interface) by zooming out, until a sector of information is displayed on the screen. This, of course, obscures the detail view of the components but clarifies the patterns between the systems. This view reflects the consistency that was designed into the Collider systems and the further consistency that we can encourage by using standard data stored in a database. The labels 1 and 2 on the view point out the consistency of the sectioning of the Cryogenic system and the pattern of sector valves in the Vacuum system. Isolation spools contain this break in both systems. Another level of consistency which the database can help maintain is shown by labels 3 and 4. Label 4 points to the the tick marks below the instrumentation system. These tick marks indicate the scope of beam position monitor connections to a niche. Label 3 indicates the tick marks indicating which niche the heater firing units of the Quench Protection system will be powered from. The pattern is identical between the systems because we were able to use the instrumentation data in the database to generate niche connections for the Quench Protection system. This ability to generate data automatically is more efficient in terms of manpower as well as encouraging consistency.

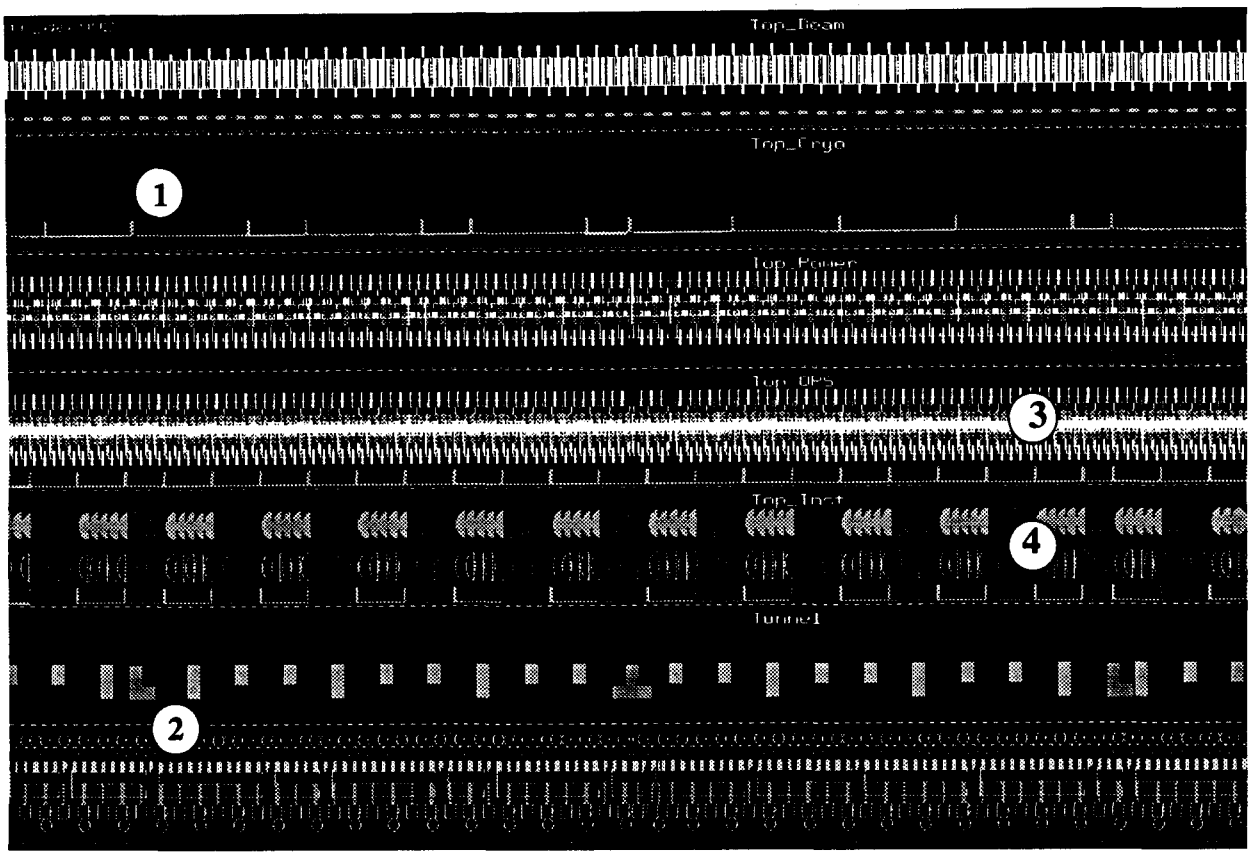

Figure 2. Graphical User Interface Screenprint Showing a Half Sector View of the Collider Engineering Systems.

5.0 DATABASE DESIGN

The next two sections outline the analysis and design models of the Collider Component database. The Object model discussed in the next section was created using the Object Modeling Technique (OMT) proposed by Rumbaugh, *et al.*,[4] an object oriented analysis methodology.

It is important to note the distinction between analysis and design, and implementation. While the analysis model here has been formed using object-oriented constructs, it is possible to implement this model in either an object oriented or a relational database. It would, in fact, be possible to implement this model using flat files, but we do not recommend this approach, because many of the general facilities that are provided with a database product would need to be custom built. This, of course, is not a cost effective solution. The Collider Component database is currently implemented in the relational database product Sybase.

The relations discussed in the Relationship Diagram of Collider Component Database section, are actual table definitions that are presently stored in Sybase. These relations could be modeled in an object oriented database. However, it would be prudent to redesign this data to take advantage of the structural support an object oriented database can provide.

Since our Collider Component data is composed of complex structural relationships discussed in the section describing the Object Model, we are investigating the practicality of storing this data in an object oriented database that would provide support for this highly structured data. However, our relational database has served us well with respect to its strong implementation of the ANSI Standard Query Language (SQL). In addition, some Sybase extensions such as stored procedures, Transact-SQL, and strong string manipulation capabilities, have helped us to efficiently maintain the database and generate engineering data.

6.0 OBJECT MODEL OF COLLIDER COMPONENT DATABASE

Figure 3 shows the object model of the core of the Collider Component database. This is an abstract data model which shows the major aspects of the database. Because this is an object model, we will refer here to classes within that model. Later, when discussing the relationship model of the existing database, we will refer to these objects as tables. The terms class and table are semantically equivalent, however, the term class is preferred in the object oriented paradigm and the term table is accepted in the relational database arena to describe the mechanism for the collection of related objects.

There is an inheritance hierarchy or generalization association between the class ELEMENT and the more refined versions such as MAGNET and SPOOL PIECE. A class such as ELEMENT may be referred to as a superclass in object oriented terminology and a class such as MAGNET would be referred to as a subclass. Attributes and methods common to a group of subclasses are attached to the superclass and shared by the subclasses. In the case of the ELEMENT class, attributes such as name and slot length are appropriate at the superclass level while attributes such as field strength are applicable to magnets but not to spool pieces. This is not a complete model of all the data that will be contained in the database, but simply the data which we are now in the process of collecting.

The association between COMPONENT_LIST and SUBCOMPONENT is labelled an aggregation hierarchy. An aggregation hierarchy is one where objects are bound by a whole to part relationship. This type of relationship is often referred to as a 'bill of materials' structure referring to a common manufacturing application. The association between the infrastructure classes (SECTOR, HALF_CELL, *etc.*) and the COMPONENT_LIST class is also an aggregation hierarchy because a sector or half cell contains a number of component instances.

The ELEMENT hierarchy structure contains type information. For example, the component 'b' (bender or dipole) is described once in the ELEMENT structure and all the parameters associated with this type of component are stored only once. The COMPONENT_LIST hierarchy, in contrast, contains the instantiation of all the benders (or dipoles) in the Collider macaine. For example, the COMPONENT_LIST class contains 3972 instances of 15 meter dipoles, a single instance of which describes, for example, the third bender in half cell N146.

The dotted line between ELEMENT and COMPONENT_LIST indicates a homomorphism. This is a common occurrence where links of two general associations are mapped as a one-to-many relationship between the associations. Each physical spool piece in the COMPONENT_LIST to SUBCOMPONENT instantiation set has the same form as the SPOOL_PIECE to SPOOL_PACKAGE explosion tree.

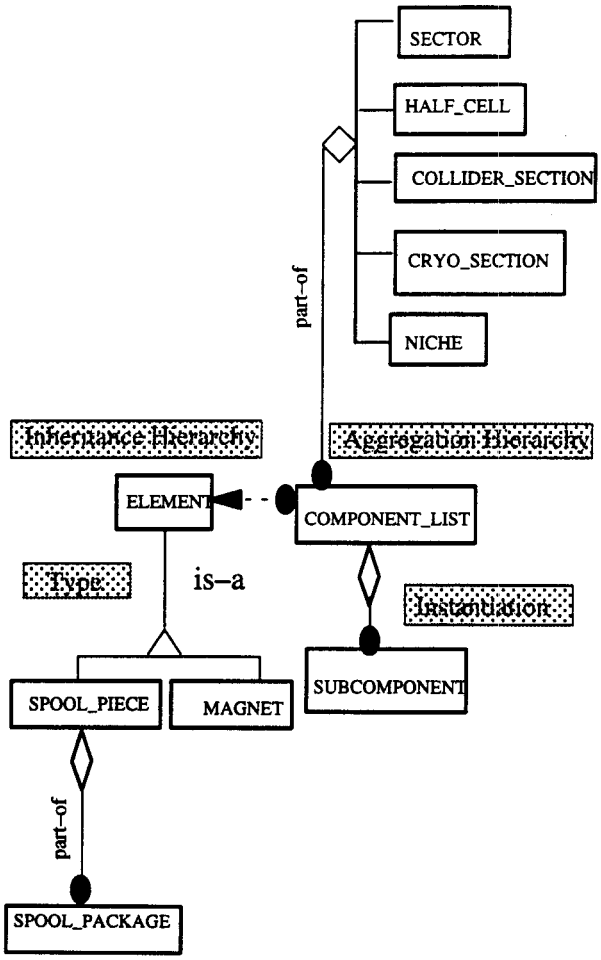

Figure 3. Object Model of Collider Component Database.

7.0 RELATIONSHIP DIAGRAM OF COLLIDER COMPONENT DATABASE

The following diagrams show relationship models of the Collider Component database. The next figure shows the core data which is loaded from the Lattice database. For a detailed discussion of how the data is restructured during the loading process, and also additional information on the data elements contained in the database and the general operational procedures associated with the database, please consult the document entitled 'Collider Component Database Documentation.'

In this diagram, the ELEMENT table lists the type information (which is extended in several ways as shown in Figure 4) and the COMPONENT_LIST table contains the instantiation data.

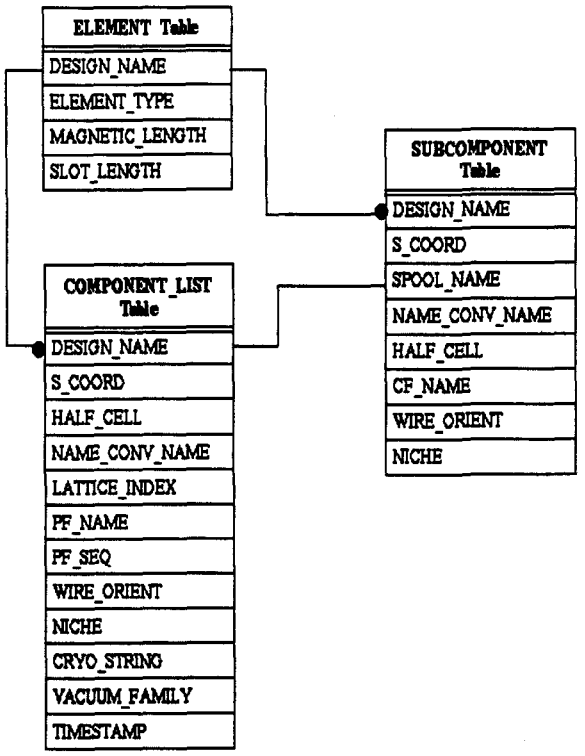

Figure 4. Core Database Component Tables.

Figure 5 shows the relationships between the instantiation tables of the components in the beam line to the tables containing data about the engineering systems. The data is highly denormalized (many data elements are duplicated in the various tables). This is because the core data in the COMPONENT_LIST table is reloaded with every official version of the Lattice. Therefore, we have tried to keep stable engineering data which can be related by its naming convention—name, in separate tables to facilitate the updating process.

This aspect of reloading the core database tables is unusual in database design. Normally, a database is loaded once (seeded) and then updated in an incremental fashion. The design environment that we are supporting, however, dictates that we must be able to reload the entire view of the Collider machine, which has been verified as a unit using physics design codes.

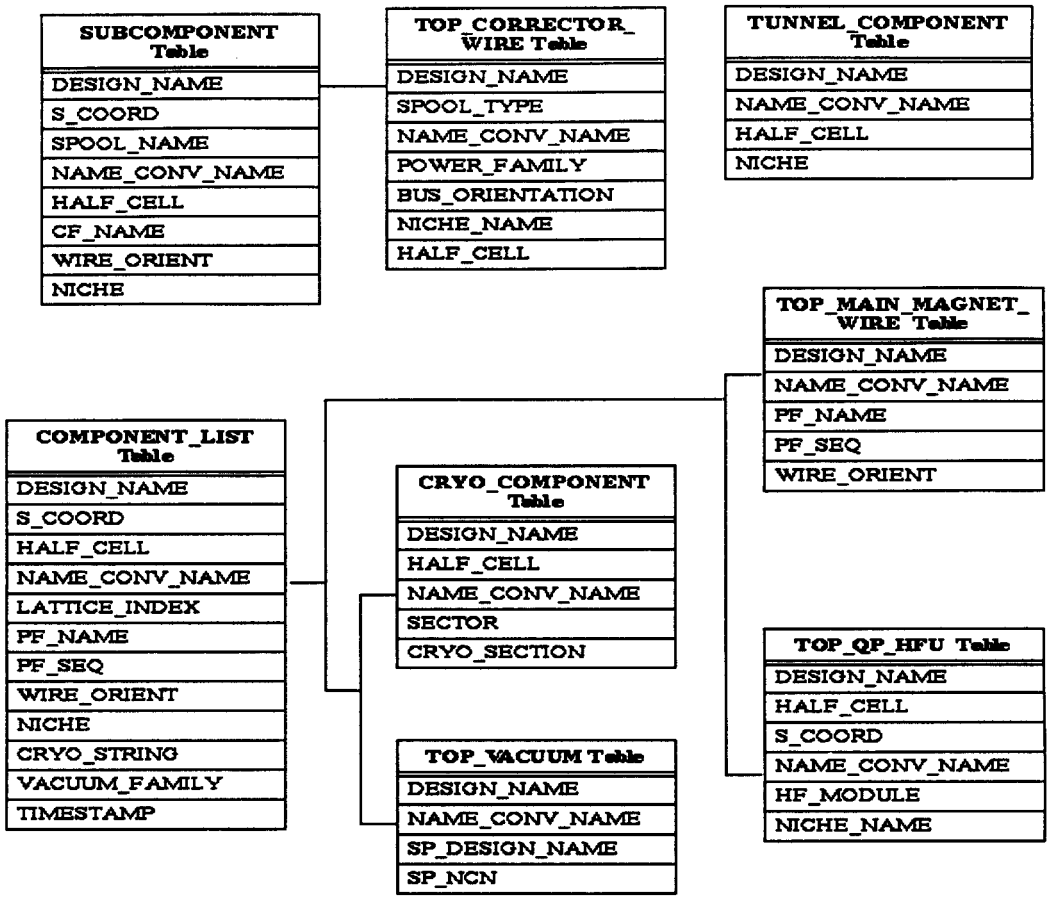

Figure 5. Component and Engineering System Connections.

Figure 6 shows the type information tables as they exist today.

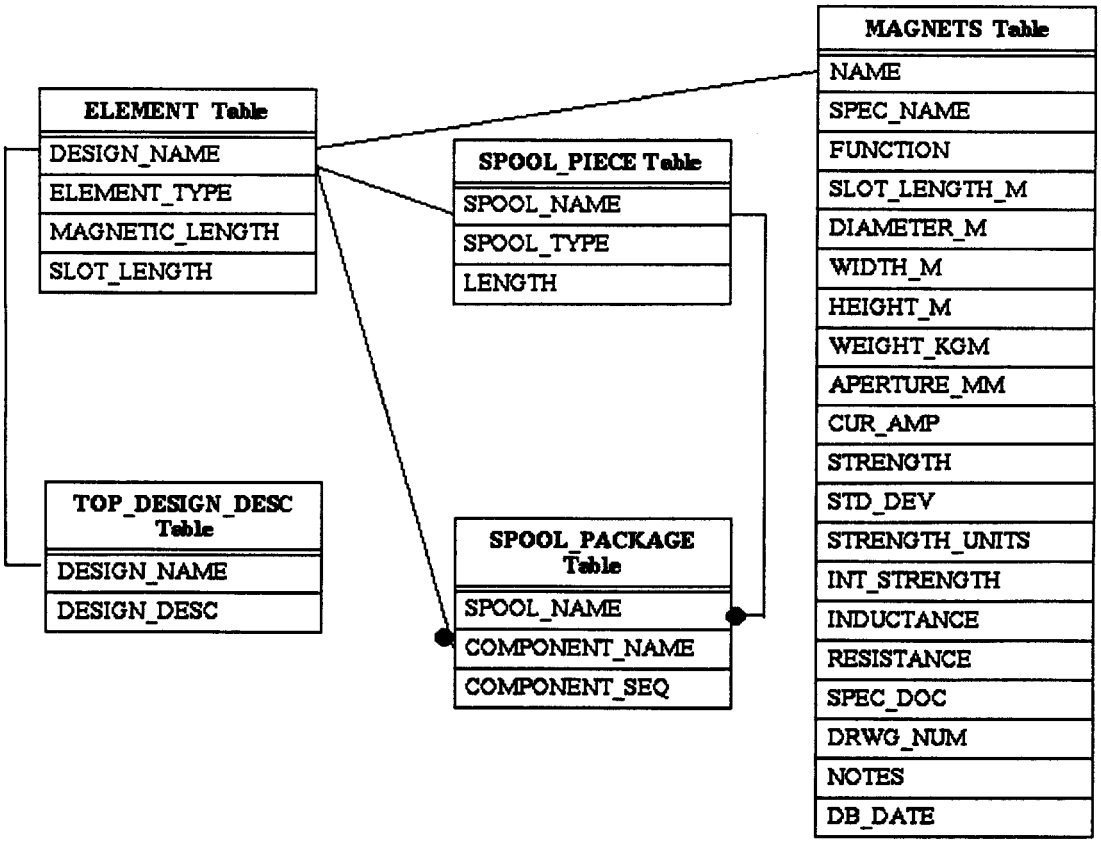

Figure 6. Type Tables Containing Data About the Component Type.

Figure 7 shows the data relationships between the infrastructure tables that contain the boundaries of various sectioning mechanisms, such as sector and half cells and the Component List table, that contains the instantiation of all the components in the beamline.

This design allows us to count components by the sectioning mechanisms contained in the HALF_CELL, SECTOR, and COLLIDER_SECTIONS tables. For example, we can count all components in the North Arc by ascertaining that the component's s coordinate lies within the begin and end s coordinates defined for the North Arc in the COLLIDER_SECTIONS table.

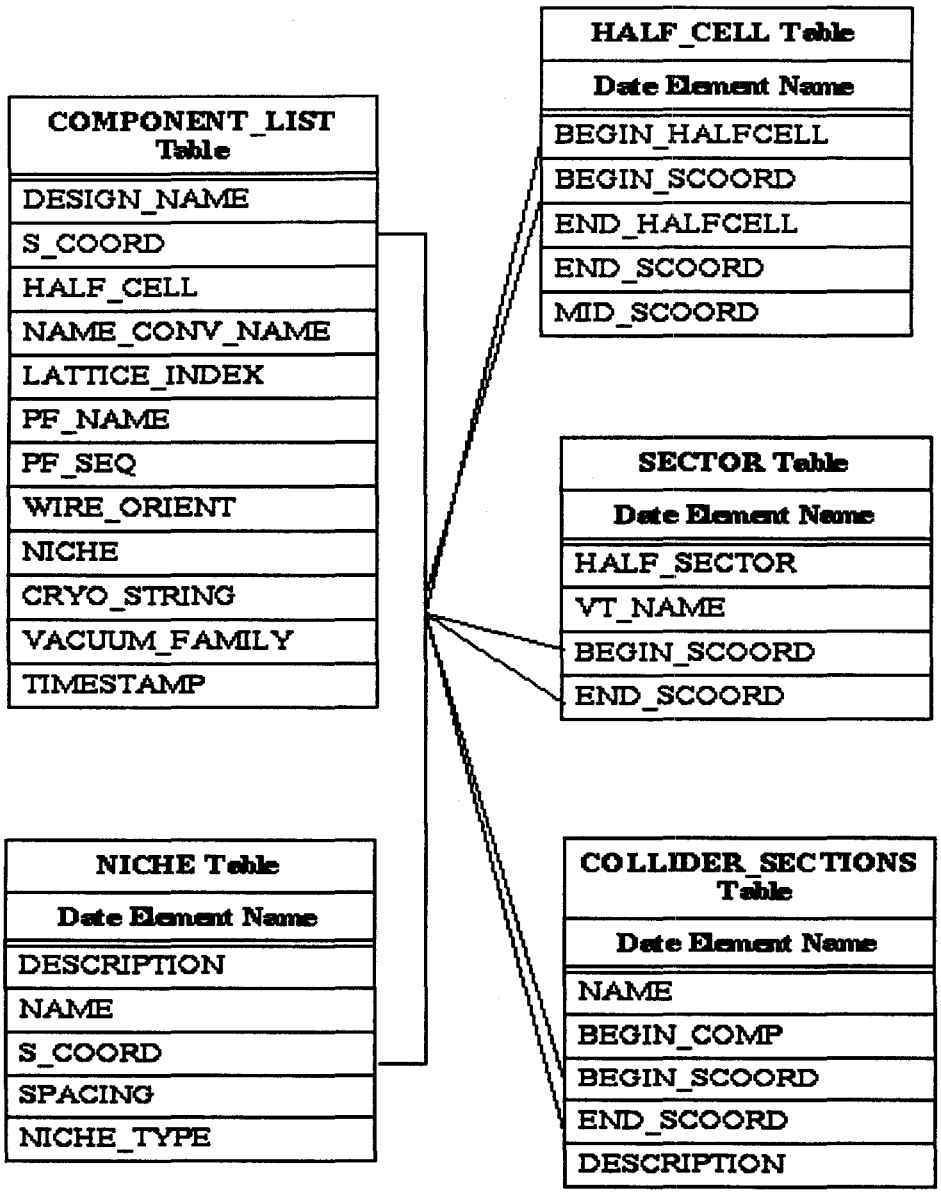

Figure 7. Infrastructure Tables Showing a Component's Location in Collider.

8.0 ILLUSTRATION OF DATA STORED IN COLLIDER COMPONENT DATABASE

In the following sections, we will use screen prints from the Collider Component database graphical user interface (cdi—component database interface) to illustrate the data we have captured regarding the major engineering systems. We were able to construct much of this data automatically using a combination of programs, UNIX C Shell, awk, and sed macros, SQL queries, and manual data manipulation in spreadsheets. Most of the data that could be automatically generated is for the Collider Arc regions. These regions, however, comprise approximately 82% of the Collider beamline and therefore account for a substantial amount of the total data.

8.1 Top Ring Main Components

The North and South Arcs are composed of half cells that contain the following components is shown in Figure 8: five dipole magnets (benders), a quadrupole, and a spool piece. The quadrupoles may be focusing or defocusing and the spool pieces vary by corrector package and engineering system implications, as we will see in the following sections, that show the engineering systems.

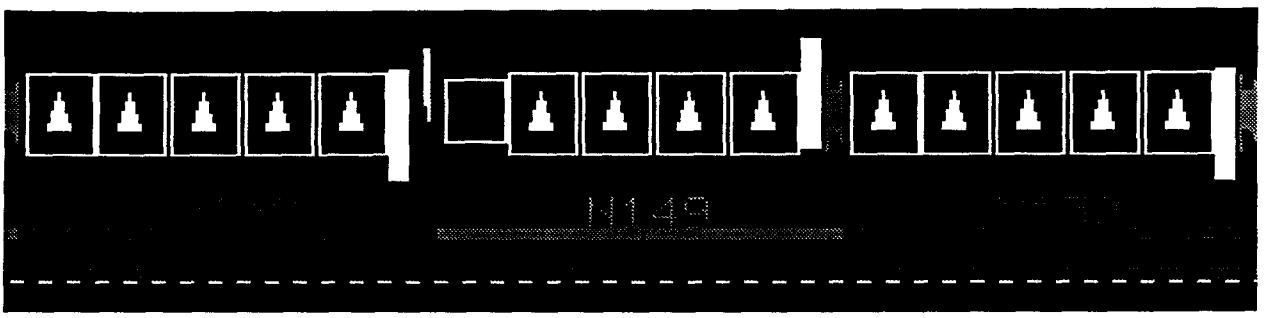

Figure 8. Two Collider Arc Half Cells.

The periodic, repeatable nature of the Arc half cells allow us to construct much engineering system data from the component data. For example, if we know a particular spool piece is an isolation spool piece, we can infer the Cryogenic sections based on the location of these isolation spools.

Figure 8 shows two half cells in the Collider North arc. This half cell pattern repeats throughout the arcs. It is sometimes useful to be able to look at the spool package (the corrector magnets and beam position monitor packaged into the spool pieces) while perusing the components. Using the graphical user interface, one can click on a spool piece and a graphic such as the one shown in Figure 9 will display the spool package contents description.

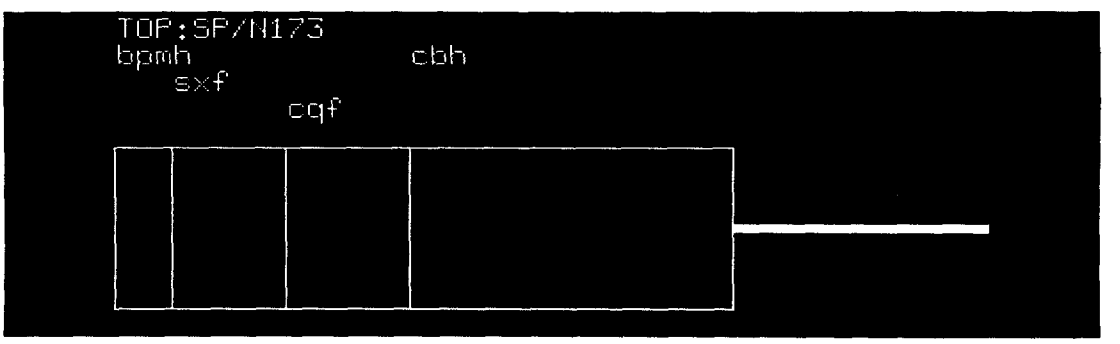

Figure 9. Spool Package.

Although the components in the Collider arcs are very repeatable, those in the straight sections are not. An example below shows a group of components in the West Utility Straight. A description and some characteristics about each component are stored in the database. The graphical user interface will display a small window showing some of this information for any component which the user clicks on.

Note the bottom line across Figure 10. It is labelled 'wustr' that indicates that these components are in the West Utility Straight. Again, this ability to ascertain at all times what section of the Collider you are viewing is an essential element of the database and graphical user interface.

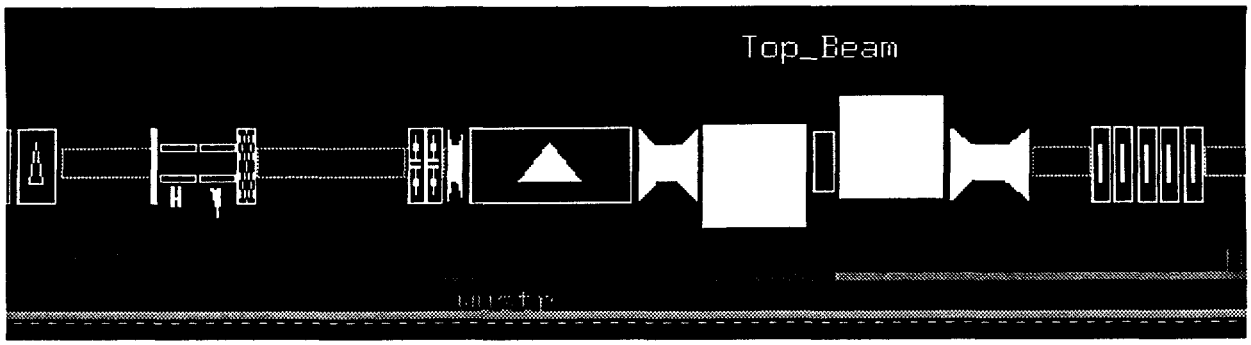

Figure 10. Section of Top Ring in the West Utility Straight.

8.2 Cryogenics System

The major sections of the Cryogenics system are bounded by isolation, feed, and end spools. Helium and nitrogen are fed into the system from the refrigerators situated at the sector houses having a suffix of 5, *i.e.*, N15, N25..N55 and S15, S25..S55. The Cryogenic isolation sections for each half sector are numbered in order (1–4) across the top and bottom Collider rings. This numbering sequence can be seen on the labels near the bottom of Figure 11 (the Cryogenic isolation section shown is section 3 in Collider Sector N2).

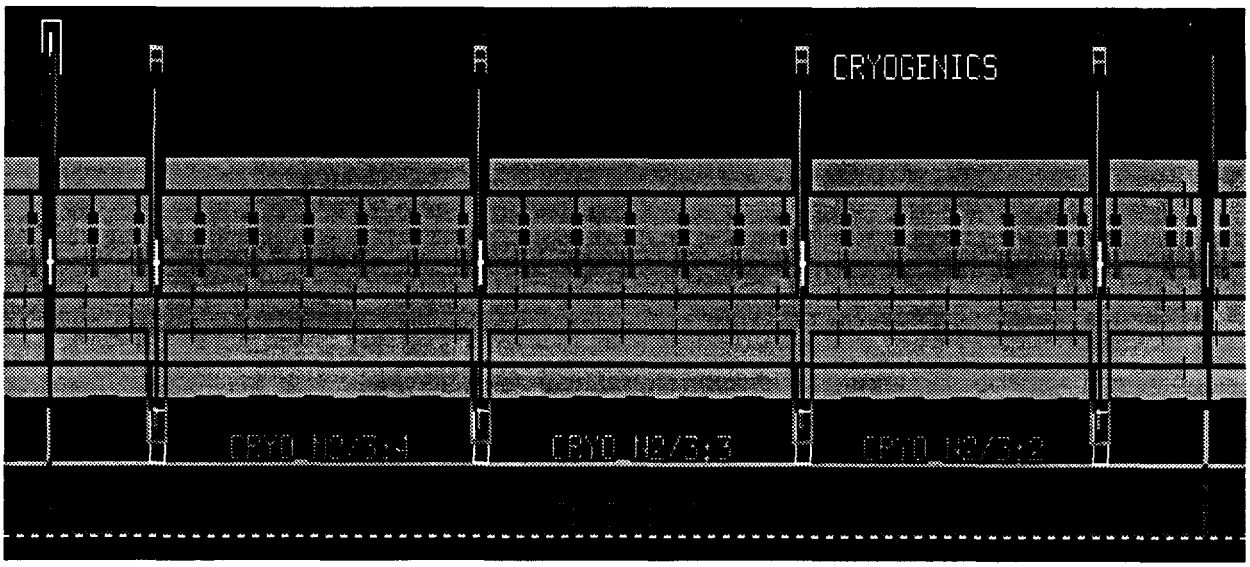

Figure 11. Cryogenic Isolation Subsection.

The Cryogenic isolation section in Figure 11 shows the spool pieces with and without recoolers and the helium and nitrogen flow through the system. Feed and end spools bound section N2/3. This view covers the half sector N20–N25 and therefore much of the detail of the spool pieces is obscured. Figure 12 shows a much closer point of view, with the labeled helium and nitrogen flows and the direction of flow at the isolation spool.

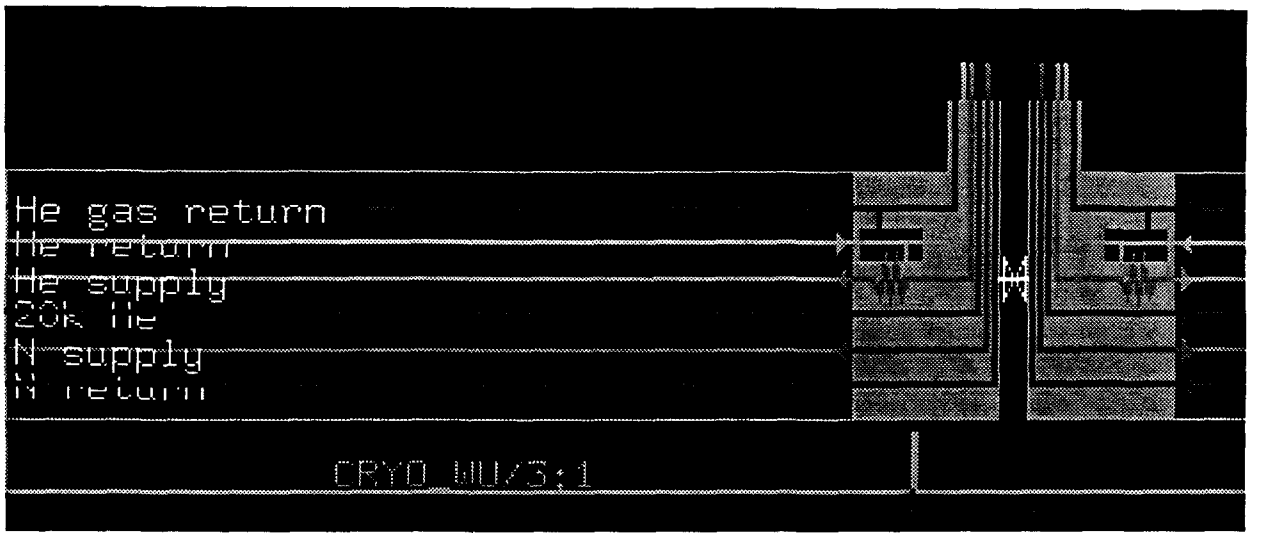

Figure 12. View of Cryogenic Isolation Spool and Description of Helium and Nitrogen Flows.

8.3 Main Magnet Power System

The main magnet power system is designed for all main magnets (main dipoles and quadrupoles) within a sector to be ganged on a single power bus. The magnets are situated in groups of six on either the upper or lower portion of the bus. This intertwining of the current direction of the magnets is required for voltage to ground distribution and because the current direction determines whether a particular quadrupole magnet is focusing or defocusing. The diode in Figure 13 indicates the direction of the current. The database enables us to track whether a given magnet is on the upper or lower bus.

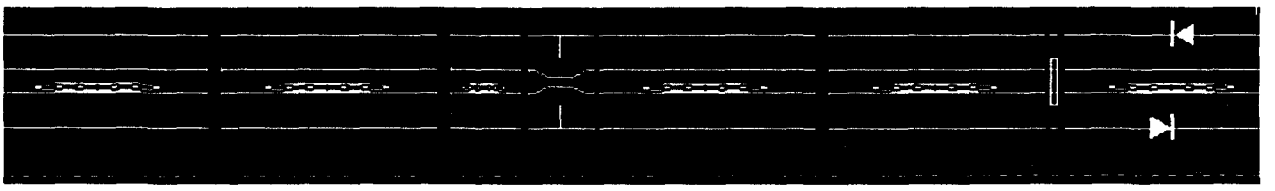

Figure 13. Section of Main Magnet Power System.

Figure 14 shows an entire half cell and the distribution of the magnets on the upper and lower buses.

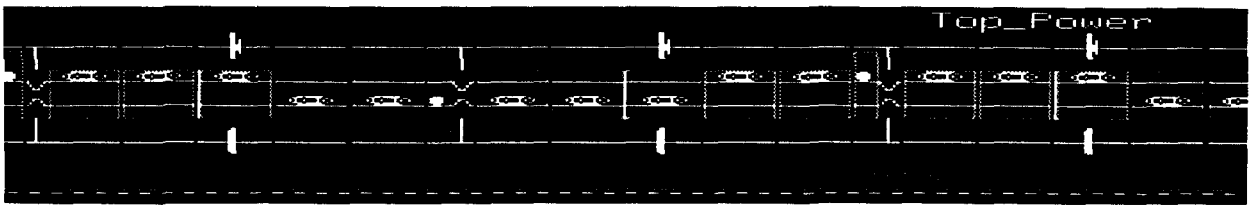

Figure 14. Main Magnet Power System Illustrating Magnet Placement on Upper and Lower Bus.

The feed and end spools shown in Figures 15 and 16 graphically illustrate the entry of the current at the feed spool and the turnaround at the end spools. Feed spools are located at the midsector (N15, S25, *etc.*) locations while end spools are located at the sector boundaries (N20, S40, *etc.*).

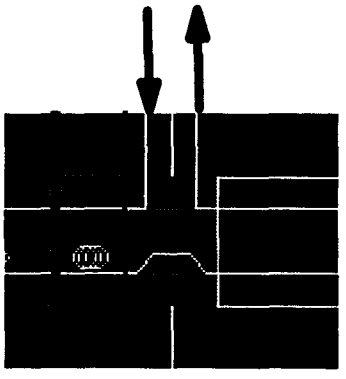

Figure 15. Feed Spool.

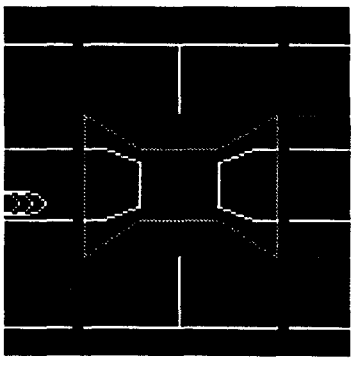

Figure 16. End Spool.

8.4 Quench Protection System

The data stored in the database regarding the Quench Protection system consists of the heater firing units in the spool pieces and the magnets that will be heated in case of a quench of any magnet in the heater firing unit family. A heater firing unit will heat three magnets on either side of the spool piece that contains it. This pattern is indicated by the turnaround wiring shown in the magnet farthest from the spool piece that it is associated with. The line along the bottom of Figure 17 indicates which niche a particular heater firing unit will be powered from.

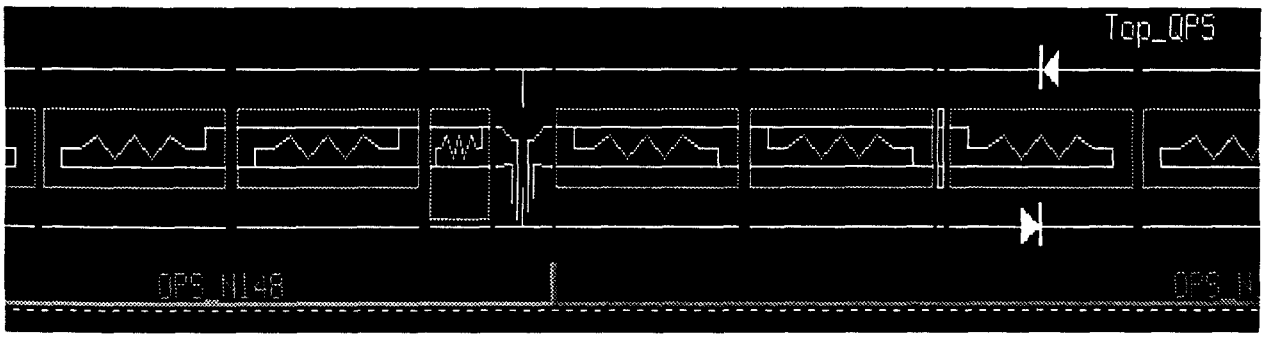

Figure 17. Quench Protection System—Heater Firing Unit and Associated Magnets.

The Quench Protection heater firing unit families, associated with each magnet, are named after the spool piece the heater firing unit resides in. As shown in Figure 18 (the cdi information window for the quench protection system components), the third bender magnet in half cell N149 (TOP:B/N149.3) is a member of the heater firing module located in the spool piece in half cell N148 (TOPQP:HFM/N148B). These component names are in the Naming Convention format.

Figure 18. Quench Protection System Naming Convention Names.

8.5 Beam Instrumentation System

The Beam Instrumentation system shows the beam position monitors which are located in each spool piece. The bpms contain electronics to measure only one coordinate (alternating horizontal and vertical) except at each niche location, where electronics for both planes will be placed. The icons associated with each of these types are self describing. At this time, we are showing a single beam loss monitor per half cell. This may change if there is a requirement for more instrumentation. The line beneath the Beam Position Monitors (BPM) shown in Figure 19, illustrates the niche to which a particular BPM is wired. The niches are shown in the tunnel area below.

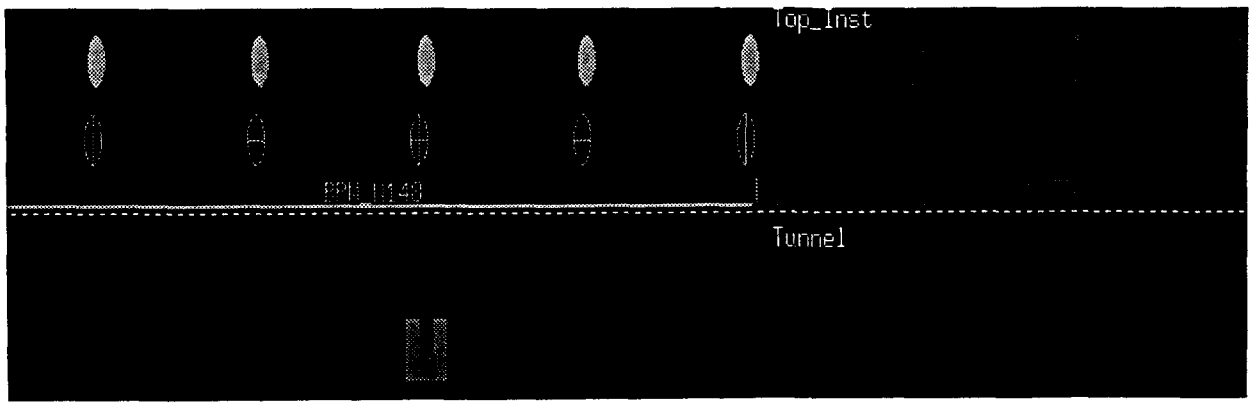

Figure 19. Beam Instrumentation System and Connection to Niche.

8.6 Vacuum System

The Vacuum system components which are stored in the database include pumps, gauges, and valves. Figure 20 shows the vacuum components.

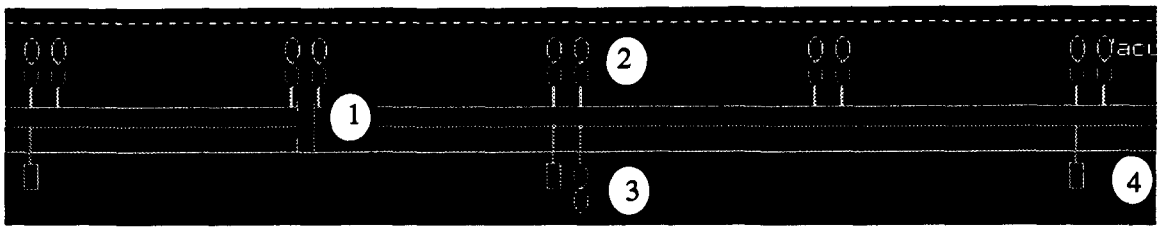

Figure 20. Vacuum System.

In Figure 20, the caption 1 points to a beam tube sector valve. There is one of these inside every isolation spool. Caption 2 indicates cold cathode and convectron (pirani) gauges which occur two-per-half cell. These gauges are connected to the insulating vacuum tube. Caption 3 shows an ion gauge and a convectron gauge which occur every two cells and are attached to the beam tube. Caption 4 points to an ion pump, also attached to the beam tube. Ion pumps occur once per-cell.

8.7 Corrector Magnet Power System

The data base contains the information listed in Table 1 which pertains to the Corrector Magnet Power system. In addition, for each corrector magnet, an entry exists for either the family per sector on which this magnet is ganged, or the niche it is powered from. In the case of magnets connected to a bus, the bus sequence alternates singly between upper and lower bus. Each magnet is assigned to either the upper or lower bus.

TABLE 1. CORRECTOR MAGNETS.

CORRECTOR TYPE	NUMBER IN COLLIDER ARCS	NICHE OR BUS CONNECTION
Dipole horizontal	392	Niche
Dipole vertical	392	Niche
Quad defocus	392	Both
Quad focus	392	Both
Sextupole defocus	392	Bus
Sextupole focus	392	Bus
Octupole defocus	78	Bus
Octupole focus	78	Bus
Multipole defocus	78	Bus
Multipole focus	78	Bus

8.8 Niches

There are niches along the Collider tunnel wall, occurring approximately every 450 meters. The niche is located opposite the spool piece in the half cell in which it is located. There are three kinds of niches in the Collider arcs: small niches, large niches, and niches at the base of each utility shaft. The database contains locations of all these niches. In addition, the rack assignments are stored in the database. Figure 21 shows a screenprint from the graphical user interface to indicate the spacing of the niche types.

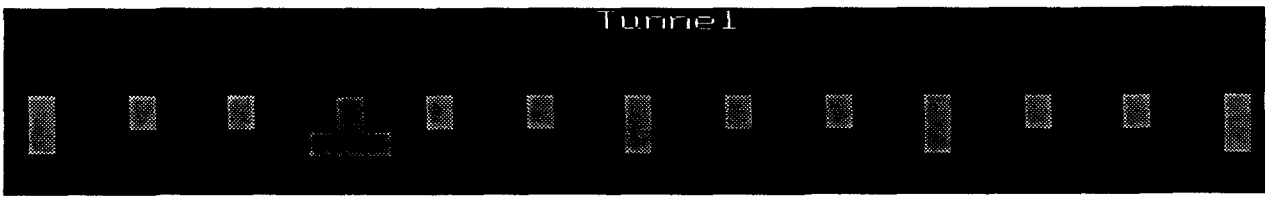

Figure 21. Niches in Collider Tunnel.

Figure 22 shows the graphical user interface icon for a large niche. The boxes within the icon indicate the racks. The database carries rack assignments for the niches as well as rack assignments for the surface buildings. We plan to connect the Collider Component database to the databases being built in the various systems groups so that one could click on a rack in the Collider component graphical user interface and be automatically connected to the appropriate database, for example Controls. One could then navigate through that database to find detailed information on the electronics.

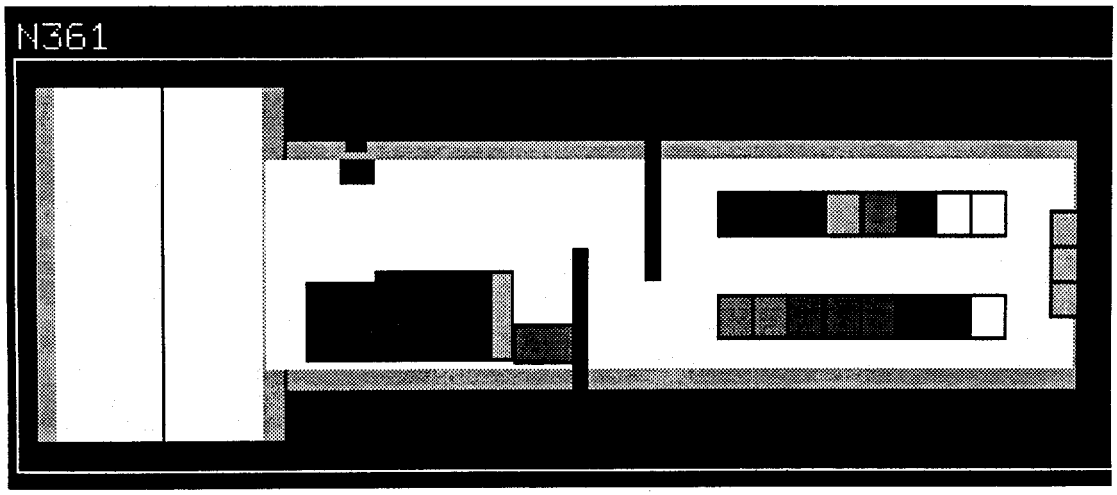

Figure 22. Large Niche Showing Racks.

9.0 GRAPHICAL USER INTERFACES

There are essentially three ways in which we provide a graphic view of the data in the Collider Component database. The first way is the generation of mechanical drawing schematics. These schematics are printed on 11" by 14" paper once with every new version of the Lattice/Component database. They show the components and their placement with respect to the cryogenic sections, half cells, and logical sections of the Collider and to the niches.

The second type of interface is with a commercial query generation tool. We are in the process of procuring such a product and plan to make canned queries of common database searches such as counts by logical section and component listings. Results for these queries will be made available at the push of a button on the main screen.

The third type of user interface to the database is a graphical user interface tool called cdi (component database interface) which was designed and implemented here at the SSCL. This user interface is programmed in C and uses the Xwindows toolkit as a graphical medium. The screenprints throughout this document have been generated using cdi.

The two figures below show screenprints of the full cdi screen and a blowup of the engineering systems. The graphical user interface allows the user to navigate through the Collider using slider bars or clicking on the particular point of interest in the bitmap display on the upper right.

ACKNOWLEDGEMENTS

Rainer Meinke, Machine Leader of the SSCL Collider Group sponsored and guided the database effort described in this document. Dale Orth made significant contributions to the design of the graphical user interface, in particular, crafting the icons and designing the engineering systems displayed in this document. Keith Rich is responsible for generalized software architecture, design, and implementation. Jigang Yang provided programming support. YunHai Cai and Brett Parker helped define the scope of the data in the database and assisted in the collection of some of the physics data. Many other individuals from organizations throughout the lab supported this effort as well.

COLOR REPRINTS AVAILABLE

If the subject of this paper is of particular interest to you, you may contact the author for a color copy. The illustrations are more informative in color, however, the cost of mass color production is still prohibitive.

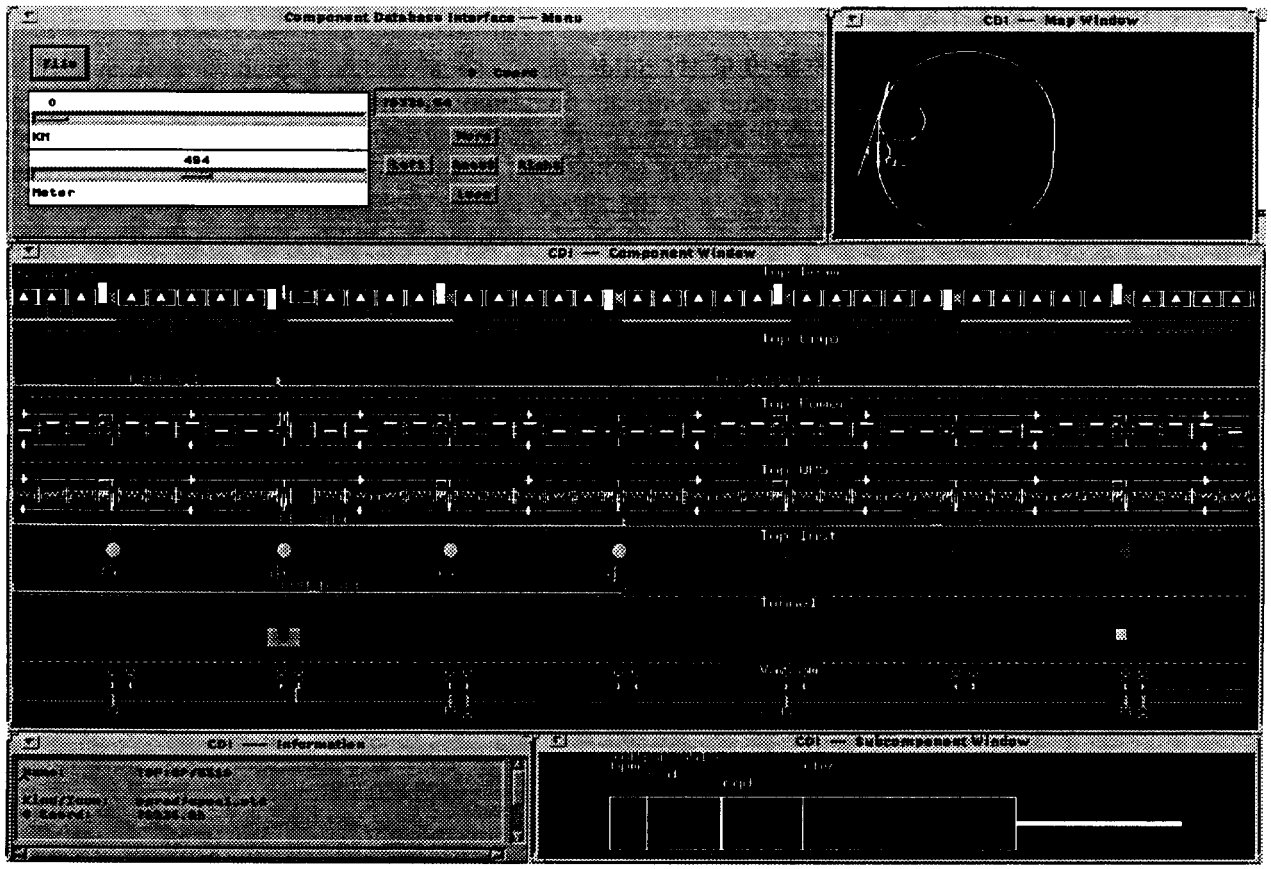

Figure 23. Full Screen Display or CDI (Component Database Interface)—Graphical User Interface to Collider Component Database.

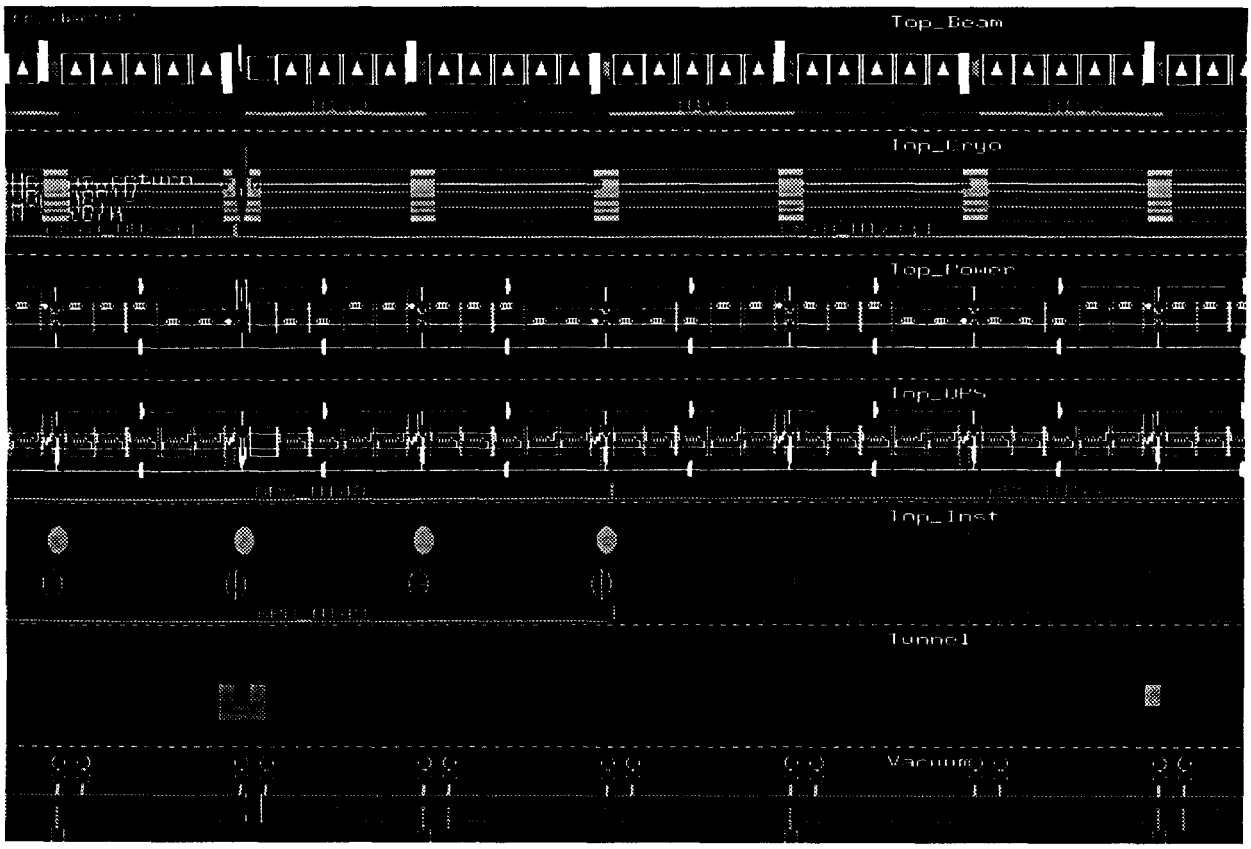

Figure 24. Full Screen Display (CDI) of Engineering Systems.

REFERENCES

1. Methodical Accelerator Design program developed at CERN by H. Grote and F.C. Iselin.
2. SSC Laboratory Standard document P40-000151 entitled "Mnemonic Device Naming Convention."
3. Logical Sections refer to sections of components int he Collider which together form related groups such as the North and South Arc regions, functional groups such as the Dispersion Suppressor regions, or practical units such as the East and West Utility sections.
4. Object-Oriented Modeling and Design, J. Rumbaugh, *et al.*, Prentice Hall, 1991.