The Organization and Collection of System's Data in Fusion

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I. INTRODUCTION

Future fusion power plants and experiments may have low availability due to complexity of equipment employed. This low availability translates into high cost of electricity (COE) for power plants and long mission times for experiments, i.e. low performance. In order to analyze the availability of systems, we have devised a Monte Carlo computer program that simulates plant operations and maintenance.[1-3] This enables us to predict the system's performance, run parametric and sensitivity studies and make recommendations as to the system design and criteria that must be met in reliability and maintenance downtimes. However, data (especially reliability data) is nonexistent for many subsystems of a fusion plant.[4] We've had to rely on experts' opinion and estimates published in some reports. With fusion experiments operating around the world, we can obtain some data from real experience. Before collecting this data, we need to know which data we need for our analysis and where that data can be stored, updated and easily accessed. This is accomplished by means of our Fusion Systems' Data Base (FUSEDATA). To collect raw data in the field, however, it is more convenient to use a component based collecting data base. For example, the CREDO framework, in use in the U.S. advanced reactor facilities has been used to collect data from the Tritium Systems Test Assembly (TSTA) at the Los Alamos National Laboratory.

II. FUSEDATA: FUSION SYSTEMS' DATA BASE FOR PERFORMANCE ANALYSIS[5]

We have designed a data base for storage of information pertinent to the performance analysis of fusion systems. There is a consensus that performance needs to be designed into the systems now, before expensive facilities are brought on line. Further impetus for this work is derived from the fact that fusion facilities would employ many complicated engineering systems that are not well understood at present; thus a need to analyze their performance and obtain appropriate data.

We have to know which data we need to collect for our performance analysis and how best to store it. In other words, we need a data framework that will enable us to systematically input and access the data we need. FUSEDATA is such a framework. It is a computerized data base, which allows the user to access and change the data, guided by menus that appear on the screen. At this time it is implemented on the IBM-PC personal computer; given enough resources we would like to put it on a VAX/VMS 11/780, which will make it more powerful and easier to access.

There are two types of data necessary for analysis of system's performance: performance data (reliability, cost, operations and maintenance data) and system's data (system's make-up, input/output information, operating and environmental conditions). The system's data constrain the performance data, i.e. define their range of conditions of applicability.

The data base contains information about systems and components. Systems are engineering units or parts which accomplish a certain task following a certain input/output functional dependence (e.g., magnets, turbines and the whole power plant can be systems). They are arranged in a hierarchical fashion in the data base, where the top system (e.g., the power plant) is successively broken down into systems (also called subsystems) comprising it, until the level of a component is reached. A component is an engineering unit which is not further broken down, for whatever reason (lack of data, manpower, interest). For instance, an electric motor is a component if it is treated as a black box which accomplishes a certain purpose (i.e., given inputs such as certain waveforms of electric voltage and current in certain amplitude ranges, there are outputs, in this case torque, in certain ranges). However, if the electric motor is further broken down into the armature, windings, ball bearings, etc., then it is no longer a component, but a system and we will be able to find information in the data base about its (sub)systems or components. In this sense, the data base is hierarchical from the top down.

The data base consists of 28 interconnected tables. A table is a data framework defining the data to be put in it, plus that data. Tables holding closely related information are associated in a table group. Thus, the 28 tables are arranged in 9 table groups. These are:

1) General group (one table). This table contains the concise, most asked for information about a system.

2) System's group (three tables). This group of tables has information on subsystems and their input/output connections, physical input and output of system and identification of other systems that the particular system is connected to.

3) Geometry and composition group (one table). This table gives physical dimensions, weight and material content of each system.

4) Reliability group (5 tables). Contains information on failure modes, rates, uncertainties, common mode failures, burn-in and wear-out failures and scaling laws.

5) Maintenance group (7 tables). Yields data on scheduled and unscheduled maintenance procedures, duration of each procedure, maintenance equipment and personnel used, spares needed.

6) Operations group (5 tables). Procedures during normal operation of system, start-up and shutdown procedures, equipment and personnel needed, environmental conditions of system operation.

7) Economic group (4 tables). This group tells us about the capital and installation costs of a system, labor costs, consumable supplies used in system operation and the scaling laws.

8) Reference group (one table). This table gives references by numbers that are referred to in other tables. The references may have more information on a particular piece of data.

9) Comments group (one table). This table gives comments by numbers referred to in other tables. The comments are used to amplify the information encountered in the tables.

The layout of the data base is presented in Fig. 1. Each table in the data base consists of records, such that a record is the smallest unit of information laid out according to the framework of a particular table. For instance, each record in the geometry and composition table will present the weight, dimensions and material composition for a distinct system or component of a fusion plant. Therefore, there will be as many different records in this table as there are systems/components for which we have the data that can be put in this table. Each record consists of fields of information (in this case there will be a field for system ID number, another one for its weight, another for its dimensions, etc.). One or more of the fields in each table are designated as the key fields, which are used to identify and find a particular record in the table and also to cross-reference information in that record with information in another table's record for the same key field.[6] In most cases, one of the key fields is a system's or a component's ID number that denotes the information in other fields of the same record as pertaining to the particular compo-

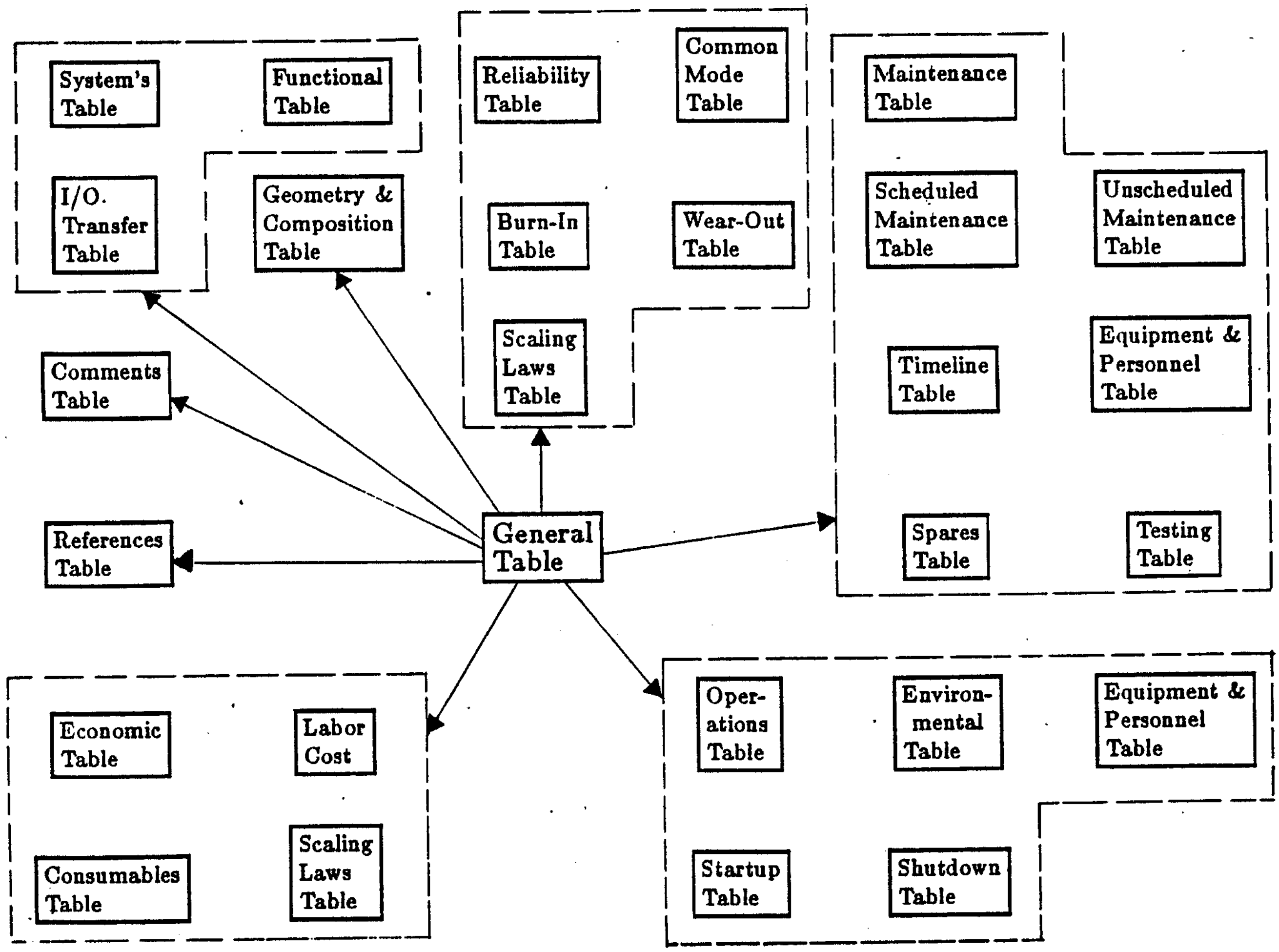

FIGURE 1. FUSEDATA Layout.

nent or system (e.g., the component's weight, dimensions and material composition). Some tables have up to five key fields.

The need for cross-referencing information in different tables arises because information from one table may be used to more fully understand information in another table, its proper application and limitations of such applications. For instance, the reliability table contains information on failure modes and rates of systems included in this table. However, we also need to know when these failure rates are applicable: we need to have a detailed description of the system in question (e.g., for magnets -- the type of magnet, superconducting or normal, application, e.g., central cell magnet, mass, magnetic field, electric current, where in the plant it is situated and its connection to other systems of the plant, its subsystems and components) as well as operating and environmental conditions under which these failure rates apply. All of this other information that completely defines the system and conditions is found in other tables of the data base. If we want to know the repair time for a certain system and a certain failure mode, we need to specify both the correct system ID number and the failure mode ID number. These should be identical to the corresponding ID numbers in the reliability table.

This data base has been put on an IBM-PC computer, utilizing a user-friendly program for interaction with the person who is entering, changing or accessing data. This program has been written employing a commercial data manager (Knowledgemanager or K-man). The user is guided by screen menus, which explain the contents of the data base, or a particular part thereof, and prompt him for action to be taken.

This setup is not ideal from the standpoint of ease of maintenance of the data base, multiple user environments and K-man limitations. We would like to put this data base on a VAX computer (preferably the 11/780 with the VMS operating system), utilizing a relational, concurrent (i.e., multiple user) data base management program called Ingres.

III. CREDO: DATA BASE FOR COLLECTING ADVANCED REACTOR DATA

Our data base for storage and accessing of data for performance analysis is not well suited for data taking purposes. The reason for that is that it's too large and complex for on-site work. The people taking the data may not want to fill out all the system information in detail, because it is repetitive, tedious and to them may seem unnecessary, since they already know the system. Traditionally, the people in charge of operations at facilities have been more interested in repairing what is broken and getting the plant on-line as soon as possible, without much ado about filling forms. Therefore, to obtain maximum cooperation in the process of data collection, we should strive to minimize the task that needs to be performed by operating personnel; for instance the system's data can be found in operating manuals and technical specifications for the plant. Data takers should be concerned only with obtaining the raw data (e.g., operating hours, number of failures, etc.). Everything else can be done separately. It should be pointed out, however, that our collaborators at the TSTA have been very cooperative and concerned about the data collection process, and would also like to use FUSEDATA for the data collection or at least contribute systems' data to insure te use of their results.

CREDO (Centralized Reliability Data Organization)[7] is a data base for collecting of reliability, operating and maintenance data from the advanced nuclear reactor facilities and test loops. It has been operating mainly in the United States since 1978, involving mostly liquid metal assemblies and fast reactors, including, among others, the EBR-II (experimental breeder reactor at the Argonne National Laboratory, Idaho) and the FFTF reactor (Fast Flux Test Facility for testing of fast reactor fuel elements). Recently, JOYO and 4 Japanese test loops have been added to the program. CREDO framework was implemented at the TSTA (Tritium Systems Test Assembly, at Los Alamos) in the summer of 1985. However, TSTA is not, at this time, part of the CREDO system, and the data collected are not yet shared with CREDO. TSTA is a fusion test facility for tritium handling systems.

While there are some system's data in CREDO, this is mostly a component-based data base. It is computerized and maintained at the Oak Ridge National Laboratory.

CREDO is organized into 3 basic types of information: engineering data, event data and operating data. Engineering data is reported once for each component, with updates as necessary, e.g., if a component is retired and replaced with a new component. Operating data is reported once for each agreed upon report period for each site/unit (e.g., each quarter for the TSTA facility). Event data is reported as events (i.e., failures) occur. For each of these types of data, there will be a separate form to fill out at the facility. The data from the forms are transferred onto the computer by CREDO personnel. In this manner, a centralized source is provided for accurate, up-to-date data and information for use in reliability/availability analysis of advanced reactors. Combining information from the engineering, event and operating data enables calculation of various availability parameters for components (failure rates, mean repair times, etc.).

There are 45 generic components in CREDO. Thus, every component in a reactor/test facility will fit into one of the 45 generic categories. Certain engineering data will be of a different kind for different generic components (explained below).

For the CREDO engineering file, there are two types of information requested, and they are given on two separate forms:

a) CREDO Base Engineering Form, containing general information that is of the same kind for all the component categories;

b) Engineering Data Supplement Form, containing specific information, different for each generic component.

The CREDO Base Engineering Form consists of 11 blocks of information. These identify the site, unit and the component, the component's use and general design information, operating factors and cycling rates, maintenance and inspection/test data, radiation exposure. The component's ID number contains an acronym for the generic class it belongs to, and a serial number in that class, along with any updates/replacements noted.

The Engineering Data Supplement contains component-specific information, divided up into three parts:

1) the engineering descriptor section;
2) the critical parts material section;
3) the design and operating parameters section.

The engineering descriptor section has several categories, containing check-off items, depending on the generic component class. For instance, the valves will have the following categories: type, functional/application, functional/characteristics, medium processed, seal, operator type, valve to pipe/equipment connection. Listed under each category are appropriate items for that category. The one corresponding to the component in question is checked off by the person filling out this form. For instance, under "type", we have ball, diaphragm, gate, globe, etc. Under "medium processed", we have air, inert gas, liquid gas, sodium, steam, etc. Each item to be checked off will have an appropriate acronym, called keyword, to be entered in the CREDO computer to represent that item.

The critical parts material section lists the critical parts of the component, with a keyword to be filled in by the person completing the form. The keywords in this case are appropriate acronyms for the material of which the critical part is built (e.g., type of stainless steel, concrete, etc.). In the case of valves, the critical parts listed on the form are the seal, the body, the pipe and the seat.

The design and operating parameters section lists the parameters for the component and the unit to be used for each parameter. The data taker needs to fill in the correct values of these parameters. In the case of valves, the parameters include design pressure, design temperature, nominal operating temperature, nominal operating pressure, nominal pipe size, operator actuation force, operator actuation time, operator actuation torque, etc.

The engineering data described above are reported once for each component or its update. The operating data are reported for the whole facility usually several times per year. The form for reporting these data identifies the site and the facility and the operating period for which the report is made. It requests the operating times for the facility in each of the three modes of operation (facility dependent, e.g., power operation, hot standby and cold standby); number of CREDO event reports for the facility in the reporting period; availability data including number of scheduled and unscheduled maintenance operations and total time expended in either, design and reported output of the facility, number of transients and total time spent in transients.

The event data are reported for each abnormal event occurring at the facility. The Event Data Reporting Form consists of nine blocks of information. The facility and the component in question are identified. Information is required on how the event was detected, its effect on related systems, the corrective action taken, data on human interaction and most recent maintenance. Several of the items require a keyworded response. Other keyworded entries include event type, event mode and event cause. Narrative sections have also been included in the form in order to gain a more complete insight into the circumstances of the failure.

IV. CREDO IMPLEMENTATION AT THE TSTA

The TSTA is a facility to prove the tritium handling and processing technology for the large scale fusion experiments before the demonstration reactor step.[8,9] Tritium operation began in mid-1984 with 10.5 g of tritium introduced into the system. The TWT (Tritium Waste Treatment) plant is the part of the system where the CREDO framework for reliability/availability data taking has been implemented. Refer to Ref. 9 for description of the TSTA and the TWT. About 200 components have been identified in the TWT. These fall into 12 generic CREDO categories. Components such as wiring and piping have been ignored.

The interface between the data reporter and the CREDO data base has been accomplished by a K-man based program on the IBM-PC, which converts the user-supplied data into the CREDO format.[10] The data can be written onto floppy disks and shipped to the CREDO headquarters, to be put on their computer. Statistics from these data can also be derived there. Currently the data is used by the onsite personnel at the TSTA to monitor and improve performance. It is probable that eventually the CREDO organization will also have the data.

The base engineering data has been organized into 7 tables. Each table has 200 records (one for each component). The records from different tables and for the same component are related by means of the CREDO ID number for that component. The engineering data supplement is represented by 12 tables (for each of the 12 identified generic component categories). An additional table contains the key as to which is the appropriate category for each of the 200 components.

The operating data consists of one table. Each quarterly report will be put in a separate record of this table.

The event data have been organized into 8 tables containing related information. Each table contains one record for each event (25 records so far). Records from the 8 tables are tied together by the TSTA Event Report Number.

This is an ongoing project. We would like to expand this framework to some other fusion experiments as well.

The data from the TSTA (converted into the failure rates, etc.), which are in the CREDO format, can be used, with additional data to fill some records in the FUSEDATA. The additional data will include the system's and operating conditions data.

V. CONCLUSIONS

We have described two data bases for performance data and their computerized implementations. One of the data bases (FUSEDATA) is to be used for storage, accessing and entering the data necessary for analysis of performance of a fusion (or any other) system. Besides the reliability, maintenance and cost data, we need a description of the system and operating and environmental conditions. These are all encoded into our tables, which are tied together employing key fields, one of which is usually the system's/component's ID number. The other data base (CREDO) is to be used for collecting raw performance data from the field and has been used as such in advanced reactor facilities and test loops in the United States, and, lately, in Japan. This data base was implemented last summer to gather the event and operating data at the TSTA, a fusion test facility for tritium handling and processing systems. This makes the job of event data collector easier, because it is interactive and oriented to collecting the event and operating data, once all the components have been identified. This data can be converted to useful form offsite.

VI. ACKNOWLEDGEMENTS

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