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# THE FUSION ENGINEERING DATA BASE

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## I. Introduction

Anticipated performance of a system is an important indicator of its feasibility and viability. There is a consensus that anticipated performance (in the form of availability and cost of electricity) of fusion experiments and power plants will need to be studied and improved in the near future before expensive systems are brought on line. This is due to employment of many complicated engineering systems. Many of these systems are not well understood and will need considerable development.

This computerized data base, called FUSEDATA, has been conceived in order to systematically present [1] the performance parameters of components and systems used in fusion plants and experiments. By putting together a framework where data could be systematically input, we have made it substantially easier to install the proper data when it becomes available (at first from the experimental facilities now operating). We do not claim that this framework is perfect or complete; some revisions may be necessary in the future to account for experience with using the data base. More "modules", i.e. tables, may be added that pertain to some other important aspects of designing a fusion system; ideally, a fusion systems data base would contain all the information needed to analyze and design such a system. At this stage, such a task would have been unmanageable for the group that undertook the project and in the time given (and also utilizing the computer software at our disposal).

The performance of a power plant is measured by its cost of electricity. The COE depends on the capital cost, operation and maintenance (O&M) cost (including major replacement costs), the cost of fuel, plant power level and availability. Availability also indirectly figures in the O&M cost and the fuel cost (the latter being a minor item). The performance of an experimental facility is measured by the duration of time it takes to obtain meaningful results, which is again tied to the availability. Therefore, the data base should contain the pertinent costs and the data from which availability can be computed. In addition to failure modes, rates and repair times (and a good description of the system and operating conditions) we will also need information on how the system is put together from which a fault tree or a success tree can be constructed.

The data base consists of different tables that contain information which defines the system, its operating and environmental conditions as well as the necessary performance data (reliability, maintenance, economics, etc.).

As of now, the data base is implemented on the IBM-PC utilizing the commercial data management program called Knowledge Manager (Kman) [2].

## II. Organization of The Data Base

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, neutral beam injectors or the whole power plant are 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 (sometimes 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 current and voltage 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 put in a table group. Thus, the 28 tables are arranged in 9 main groups. These are:

1) General group (one table: general table);
2) System's description group (3 tables: system's, functional and input/output transfer table);
3) Geometry and composition group (one table: geometry and composition table);
4) Reliability group (5 tables: reliability, common mode, burn-in, wear-out and scaling laws table);
5) Maintenance group (7 tables: maintenance, scheduled maintenance, unscheduled maintenance, timeline, equipment and personnel, testing, and spares table);
6) Operations group (5 tables: operations, environmental, startup, shutdown, and equipment and personnel table);
7) Economic group (4 tables: economic, labor cost, consumables, and scaling laws table);
8) Reference group (one table: reference table);
9) Comments group (one table: comments table).

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 the 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 (e.g., an ECRH gyrotron of certain power range for a mirror reactor or a TF coil of certain B-field range for a tokamak). 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 a system's 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 that are used to identify and find a particular record in the table and also cross-reference information in that record with information in another table's record for the same key field. In most tables, 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 component or a system (e.g., the component's weight, dimensions and material composition). Some tables have up to five key fields (see Section III). Some of the points in this paragraph are pictorially presented in Fig. 2. For discussion of data bases in general, the reader is referred to Ref. [3].

The need for cross-referencing information from different tables arises because information from one table may be used to more fully understand the 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.

## III. Description of the Contents of the Data Base

As previously mentioned, the data base consists of 9 groups of associated tables, with from 1 to 7 tables to a group. The records in different tables are cross-referenced by means of one or more key fields. Following is a brief description of each group and the tables within it.

Group 1 consists of only one table, the general table. This table gives a concise, general description of a system, for someone who wants to find important, most often asked information about the system (e.g., dimensions, weight, cost, input and output operating point). This table is also used in consistency checking [3] of the data base. Key field: system ID number.

Group 2 consists of three tables: system's, functional and input/output transfer tables. The system's table provides information on subsystems of the particular system and their input and output connections. The key fields are the system ID number and the subsystem ID number (subsystem is a system in its own right; it is defined as a subsystem just in the course of hierarchically looking down from the vantage point of the top system). The functional table yields data on the physical input and output of the system in question (name of I/O quantity, its design value and the range). The key fields are the system ID number and the I/O ID number. The I/O transfer table tells us which other systems the inputs are coming from and the outputs are going to. Key fields: system ID number, I/O ID number.

Group 3 consists of one table, the geometry and composition table. This table tells us about the system's physical dimensions, weight and material content. In the future, it is possible that we will be able to put a reference to a CAD/CAM graphics output in this table, so that the user can see a 3-D picture of the system in question.

Group 4 consists of 5 tables: reliability, common mode, burn-in, wear-out and reliability scaling laws

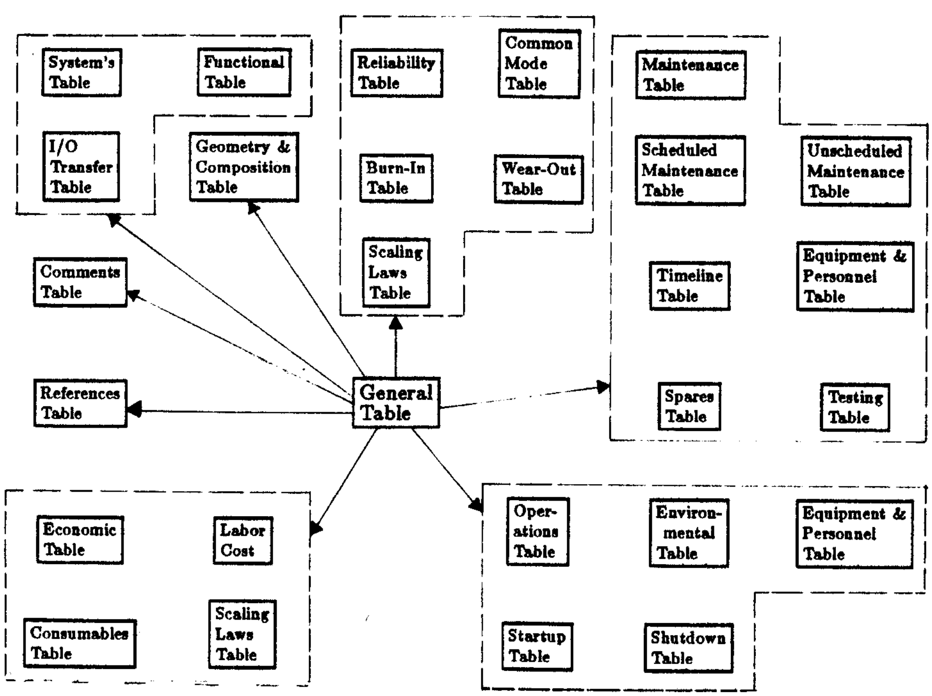


Figure 1. FUSEDATA Layout.

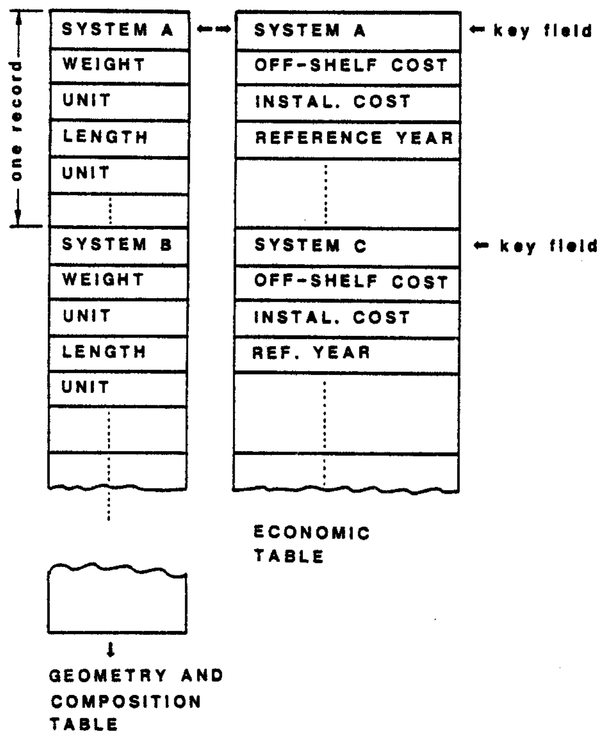


Figure 2. Tables, records and key fields.

tables. The reliability table presents system's failure modes, rates and distributions, and has references to common mode and reliability scaling laws tables. Key fields: system ID number and failure mode ID number. The common mode table has information on conditional probability of system common mode failure. Key fields: system ID, causing system ID, failure mode ID of causing system and common mode failure ID number. The burn-in and wear-out tables have the same format. They present parameters for the time varying failure rate (decreasing due to elimination of infant mortalities for burn-in and increasing due to wear-out for the wear-out table). Key field: system ID number. The reliability scaling laws table provides information on scaling laws for failure rates with respect to two unspecified key variables (e.g., failure rate may vary with the system mass and ambient temperature). Two forms of the laws are given: binomial and multiplication of powers. The table gives parameter values and applicable ranges of the two variables. Key fields: system ID and failure mode ID.

Group 5 consists of 7 tables: maintenance, scheduled maintenance, unscheduled maintenance, timeline, equipment and personnel, testing and spares tables. The maintenance table just contains flags pointing to other tables in which information exists for a particular system. Key field: system ID. The scheduled maintenance table contains data on duration and frequency of a particular scheduled maintenance operation, as well as the effect on other systems (up or down) during maintenance. Key fields: system ID, maintenance mode ID. Unscheduled maintenance table contains the same type of data in case of failure. Key fields: system ID, failure mode ID. The timeline table contains a step by step description of each maintenance operation, including its duration. Key fields: system ID, type of maintenance ID (scheduled or unscheduled), maintenance/failure mode ID and procedure (i.e., maintenance step) ID. The equipment and personnel table tells us which maintenance equipment/type of personnel is needed in each maintenance step described in the timeline table. Key fields: system ID, type ID (operation, startup, shutdown, scheduled/unscheduled maintenance, testing), mode ID (maintenance mode/failure mode), procedure ID from timeline table and equipment/personnel ID. The testing table tells us which procedures are performed upon failure, and their duration, in order to determine the correct failure mode and therefore maintenance action. Key fields: system ID, testing type ID and procedure ID within that type. The spares table tells us which spare parts and how many are kept for a particular system. Key fields: system ID, spare part ID.

Group 6 contains 5 tables: operations, startup, shutdown, environmental and equipment and personnel table. The operations table describes the system operation procedures that are covered in more detail elsewhere in the tables. Key fields: system ID, procedure ID. The startup and shutdown tables have the same format and describe the startup and shutdown procedures and their duration. Key fields: system ID, procedure ID. The environmental table describes the environmental quantity and range that the system operates in. Key field: system ID. The equipment and personnel table is shared with the maintenance group of tables (group 5) and describes the quantity and type of equipment/personnel used in a particular operation/startup/shutdown procedure.

Group 7 contains 4 tables: economic, labor cost, consumables and scaling laws table. The economic table contains the capital cost, type of costing and reference year. Key field: system ID. The labor cost table contains the cost of labor and range for each personnel ID. Key field: personnel ID. The consumables table contains the cost of consumable materials used up in the plant operation and ranges. Key field: material ID. The cost scaling laws table is the same in format as the reliability scaling laws table described above.

Group 8 consists of one table: reference table. This table contains the list of references (i.e., bibliography) mentioned by number in other tables of the data base. Key field: reference ID number.

Group 9 contains one table: comments table. This table contains comments referred to in other tables by number that more fully explain the data in a certain table. Key fields: system ID, table group ID, table ID and comment ID.

## IV. The Data Base Setup on the Computer

The data base has been implemented on the IBM-PC computer with a hard disk, employing the commercial data handling software Knowledge Manager (Kman). A program was written employing Kman commands to interface the user to the data base and enable record addition, deletion, changing and viewing. The program is user friendly and menu driven such that instructions for using it appear on the screen as needed.

Upon signing on, the user will be asked to supply his choice of a table group, a table within the group and an action (add, delete, view, change). Then, the key field values are supplied by the user to find the proper record or start a new one. Consistency checking is done to insure that no duplicate key field value records exist and that any changes in the data base are self-consistent.

For the add option, after supplying the key fields values, the user will be given a blank record (except for the key fields) of the appropriate table to fill out. If the key fields values specified already exist, there will be a warning message and an option to quit to a previous menu or supply different values of the key fields.

For the delete option, the appropriate record is deleted from the data base and appropriate changes made in the rest of the data base (for instance some other tables may have been referencing that record). If a record in the general table is deleted, all the records for that system number are deleted from the data base.

For the change option, the appropriate record is displayed and the user can move the cursor to the field to be changed. Appropriate changes are done in the rest of the data base.

For the view option, the appropriate record is simply displayed for the user to see.

At the end of each action, the user can either quit to the previous menu or repeat the action for another record.

The Kman software used presents some limitations that we hope to circumvent in the future. Under certain conditions there is a waiting period of several seconds between screens. This is due to the fact that the C compiler employed in Kman can access only 64K of memory of which only about 48K can be accessed by the user, i.e. our program. This necessitates complex procedures for releasing the files in memory in the order they were loaded in, and loading in the new batch of files that are needed; hence the abovementioned time delay. It is possible that in the future a new version of Kman will come out utilizing a C compiler without this limitation.

## V. Conclusions and Recommendations

We have designed and implemented on the computer a data base to fill the needs of the fusion community in the area of availability and cost data, which can be used in design and analysis procedures. The data base consists of 28 tables (arranged in 9 table groups) that contain information describing each system, its operating and environmental conditions, and its performance parameters, such as failure rates, repair times and cost, as well as its connection to other systems and the parts comprising it. This then gives us complete data for analyzing system performance.

The data base has been implemented on the IBM-PC computer by writing a user friendly interface program based on commercial data handling software (Kman). As of now, there is not much data in this data base. We envisage use of this data base at several sites around the country; the framework bearing computer program described above can be transported on diskettes. Each site would independently contribute and retrieve data from the data base, with occasional "synchronization" of data. For more convenient access and more control over input, it would seem desirable to put this framework on a mainframe computer (e.g., on the MFE network) with write protect passwords instituted. Unfortunately, at this time MFE does not have a supported data base manager program that one could use to write this type of program.

Although the data base currently performs adequately, an upgrade of Kman capabilities seems desirable in view of the time delays encountered. There is a possibility that this new version of Kman will come out in a year.

Before this data base can be used by more than one site, there should be some consensus on a method for generating system ID numbers. For speed of processing an ID number should have at most 10 alphanumeric characters. There is a limited amount of information conveyed by 10 characters, so the question is how much information is enough. We decided against using the standard fusion cost of accounts numbers because they are based on generic components and systems (e.g., any magnet will have the same ID number, as will any ECRH gyrotron regardless of power, etc.). We need to work with systems and components that are well described with respect to their application. Perhaps we can incorporate some information from the tables in coding the ID numbers.

The above described data base is useful for storage and access of processed data that can be applied in the analysis of fusion systems. However, for collection of raw data from the field (e.g., number of failures of particular system in a given time) this data base is too cumbersome. We decided that the CREDO [4] data base, used in advanced fission reactor work, will work well for this purpose. The reason for this choice is that standardized forms have been made out that can be filled out with minimum effort and time by people who know their facility well. We have helped in setting this CREDO data collection system up at the TSTA (Tritium Systems Test Assembly) in Los Alamos; this will be the subject of another report [5].

FUSEDATA will be described in more detail in an upcoming report [6].

## VI. Acknowledgement

This work has been sponsored by the U.S. Department of Energy.

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