BATTERY DATA FOR USE IN EXPERT SYSTEMS

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Summary

Expert systems, readily implemented by battery specialists on personal computers with programs such as "empty shells", can now perform complex comparisons of alternative battery choices. The applications being evaluated might be power supplies, solar energy storage, emergency power, or customer-side-of-the-meter load leveling. Each has unique requirements in voltage limits and delivered energy during discharge, over a range of temperatures. Batteries being compared need not be identical in performance. For example, in cycling service, two sets of $2000 batteries lasting three years each can be cheaper than a $4000 set lasting six years because of interest earned in the first four years by the unspent $2000.

Standardized performance data are a key to validity of these comparisons. A simple example is temperature at which the battery voltage and ampere hours are measured. The battery can be tested at any reasonable temperature, as long as a formula is available for converting test performance to performance at operating temperature. A more difficult but very important extrapolation is life in a charge–discharge service. Data from an accelerated test at a given temperature and depth of discharge might have to be extrapolated to another temperature with a varying depth of discharge.

Today, we have an opportunity to initiate the creation of a commonly useful expert system. Each of us can continue developing his own battery bank and his own ways to manipulate these data. Our present difficulties and ambiguities in comparing data and conclusions with each other will continue. Alternatively, we can adopt a standard way of defining, storing, and manipulating banks of battery data. In the ultimate we could exchange complex battery data by mailing computer disks to each other.

In this paper we try to identify the steps and effort that would be needed to achieve standard formats for organizing and presenting battery data. First, we illustrate the data and procedures vocabulary, with examples from our Boeing computer-based battery testing, data acquisition, and data analysis system.

Introduction

Personal workstations and personal computers are available to most engineers and scientific specialists. These offer to the battery specialist the opportunity to control a greater store of knowledge and to improve his productivity with the utilization of such knowledge. The normal workday requirements of each battery specialist may vary considerably in terms of data types, volume, and application. The data requirements of the manufacturer of a specific product line may be somewhat less than the requirements of the applications specialist who must consider many products in the course of a complete battery application trade study. The requirements also dictate in each case the amount of hardware storage and the complexity of the software needed.

It is the purpose of this paper to discuss and suggest a course of action which could be undertaken by the entire storage battery community to develop a sophisticated expert system useful to all interested in battery studies.

Definitions

Expert systems can commonly be called rule-based systems utilizing the IF-THEN, AND-OR rules of the computer language. Strategies developed using these rules, applied to a large Knowledge-Base or Data Base, can create a powerful computer tool in a specialty field. The logic used emulates the process that a technical specialist may use in the study or design of an end item or in a mental diagnostic process.

Background

In late 1979, we at Boeing had many aerospace programs requiring battery studies and specifications. We decided to buy a computerized data acquisition system which could automatically test batteries. Data supplied by manufacturers of batteries, while useful, did not always cover the required range of intended usage, environments, and duty cycles. As trade studies of alternative battery types progressed, sample cells were tested to support the studies. The accuracy and precision of the data acquisition system, as well as its ease of operation and record keeping capability, proved it to be an invaluable tool for battery testing. During the subsequent years of testing we accumulated valuable test records on magnetic tape or discs for later recall for plotting and reference. The Hewlett-Packard 9854B computer that controls the data acquisition system has a graphics option with which data can be displayed as curves on the CRT, and the curves can be printed by executing a "Graphic Dump" command. We have expanded the system to include dual 8 in. disc files, a Winchester 5 megabyte file, a 3 in. disc file and a graphics tablet (Fig. 1).

Database beginnings

While developing data acquisitions and control programs we recognized that the control computer could be used in a variety of other ways.

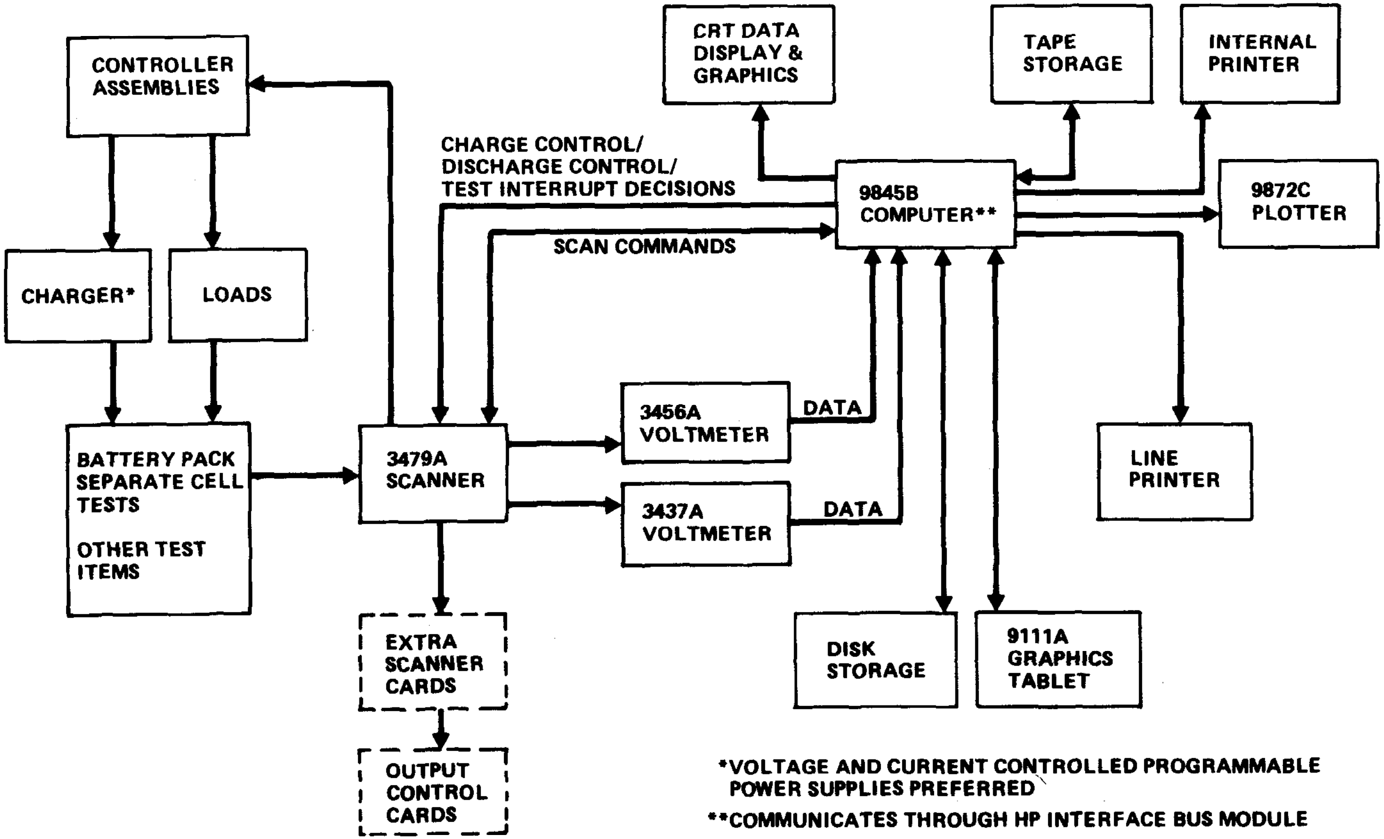

Fig. 1. Computer controlled battery test set-up.

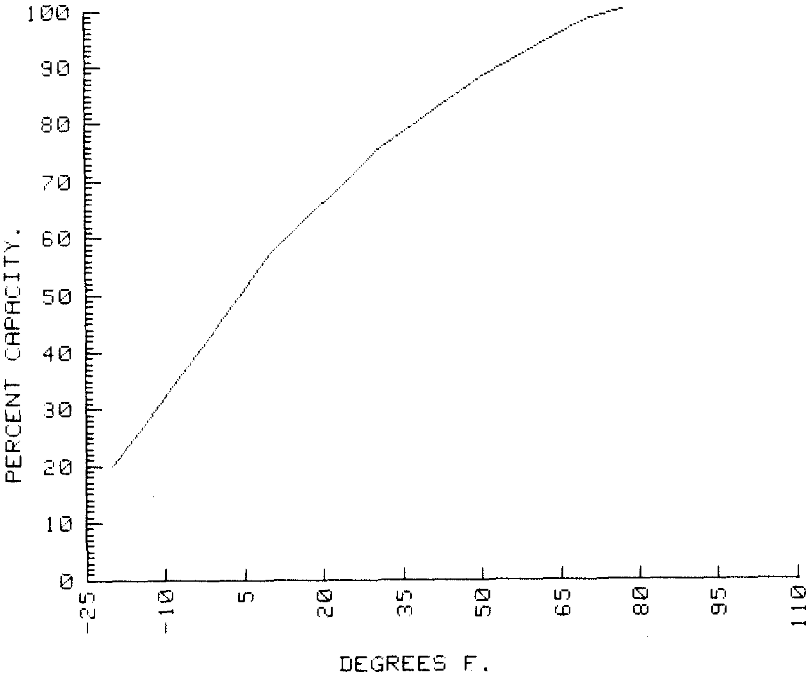

Fig. 2. Temperature/capacity effect stored as a program with a data line. Lead–acid battery, 6 h.

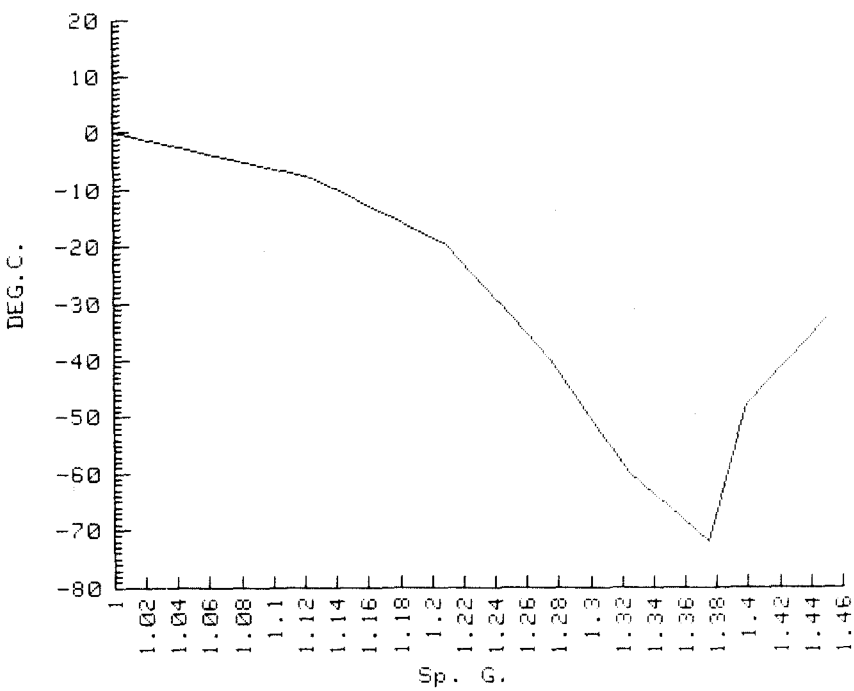

Fig. 3. Freezing points of H_2SO_4 stored as a data line in program.

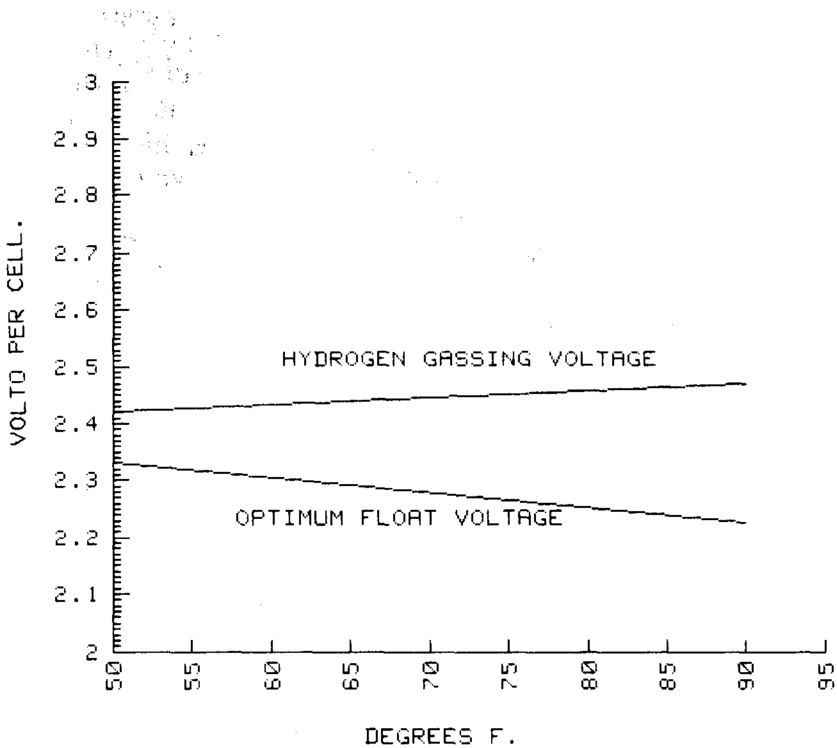

Fig. 4. Charge data stored as graphics.

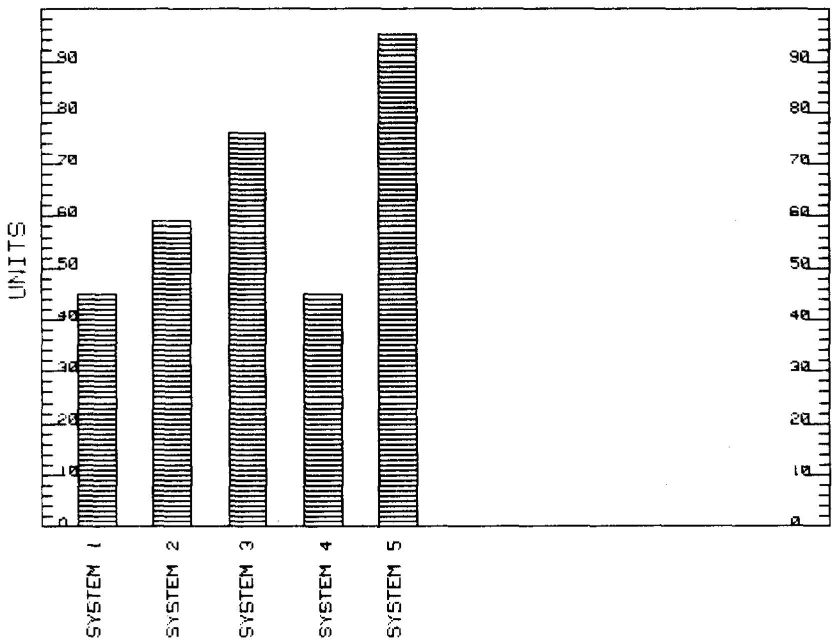

Fig. 5. Bar chart interactive graphics program.

Frequently-used battery constants, performance data, and physical characteristics of batteries were simply typed into the computer or entered with the graphics tablet, and stored on discs under descriptive names. Graphics were stored in the form of data lines which recreate the graphics when the program is run. Alternatively, graphics arrays can be entered from the graphics tablet. Typical data in storage are shown in Figs. 2 - 4.

Another form of our data storage created is bar chart programs. This program, which is interactive with the user, either prints previously stored data or provides the base for creating a new chart. A typical chart is shown in Fig. 5.

A third method of graphics storage uses slightly modified standard curve fitting programs which print out the equation of best fit for the data as well as a plot. A typical plot is shown in Fig. 6. With the equation derived,

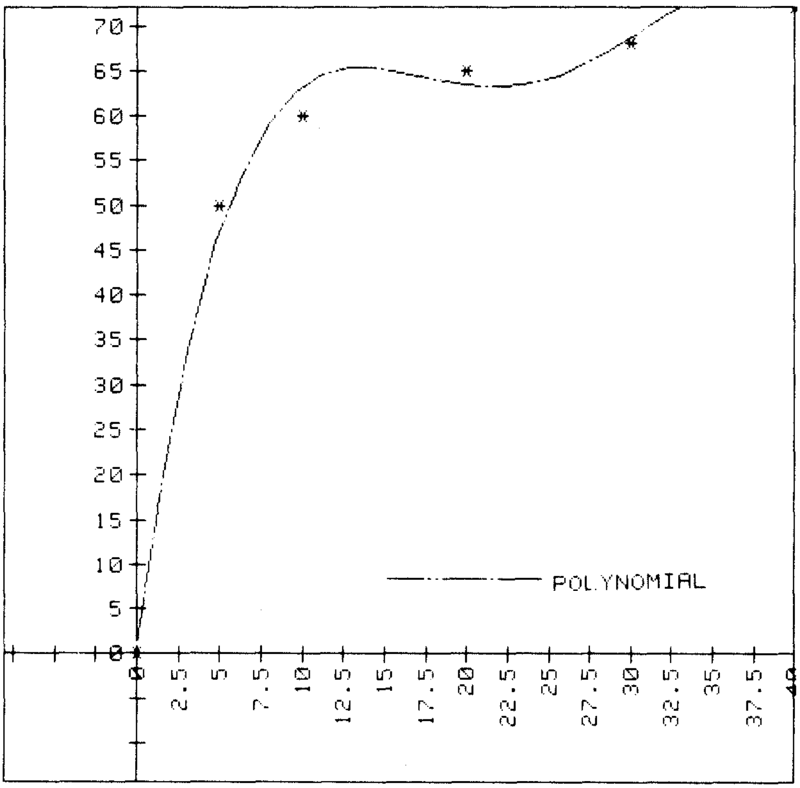

Fig. 6. Interactive program fitting curve to data-stored or manual input.
Polynomial model: $Y = A + BX + CX^2 + DX^3 + EX^4$.
Coefficients:

$A =$ 0.820 402 16
$B =$ 13.491 072 47
$C =$ 0.993 194 877
$D =$ 0.029 990 522 3
$E =$ 0.000 312 955 518

the best fit equation is transferred to another program, using the "Define Function" (DEF FN) statement, which then creates tables for interpolation.

We soon found that the catalog of data was becoming unwieldy in terms of retrieval , so a better form of logical organization of the data was required. In the end we wrote a menu type program in which the data were "stacked" according to battery type, manufacturer, data category or battery attributes. We are still working on making the whole system interactive and more "user friendly". Typical displays as the program begins are shown in Figs. 7 and 8. When the cursor is placed in the selected box of Fig. 7 and the

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[ ]Poc_plate_nicad

[ ]Sin_plate_nicad

[ ]Nickel_hydrogen

[ ]Lead_acid

[ ]Lithium
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Fig. 7. First page of menu type program.

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[ ]Gen_electric

[ ]Nife

[ ]Magraw_edison

[ ]Varta

[ ]Saft
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Fig. 8. Second page of menu type program when Nicad selected from first page.

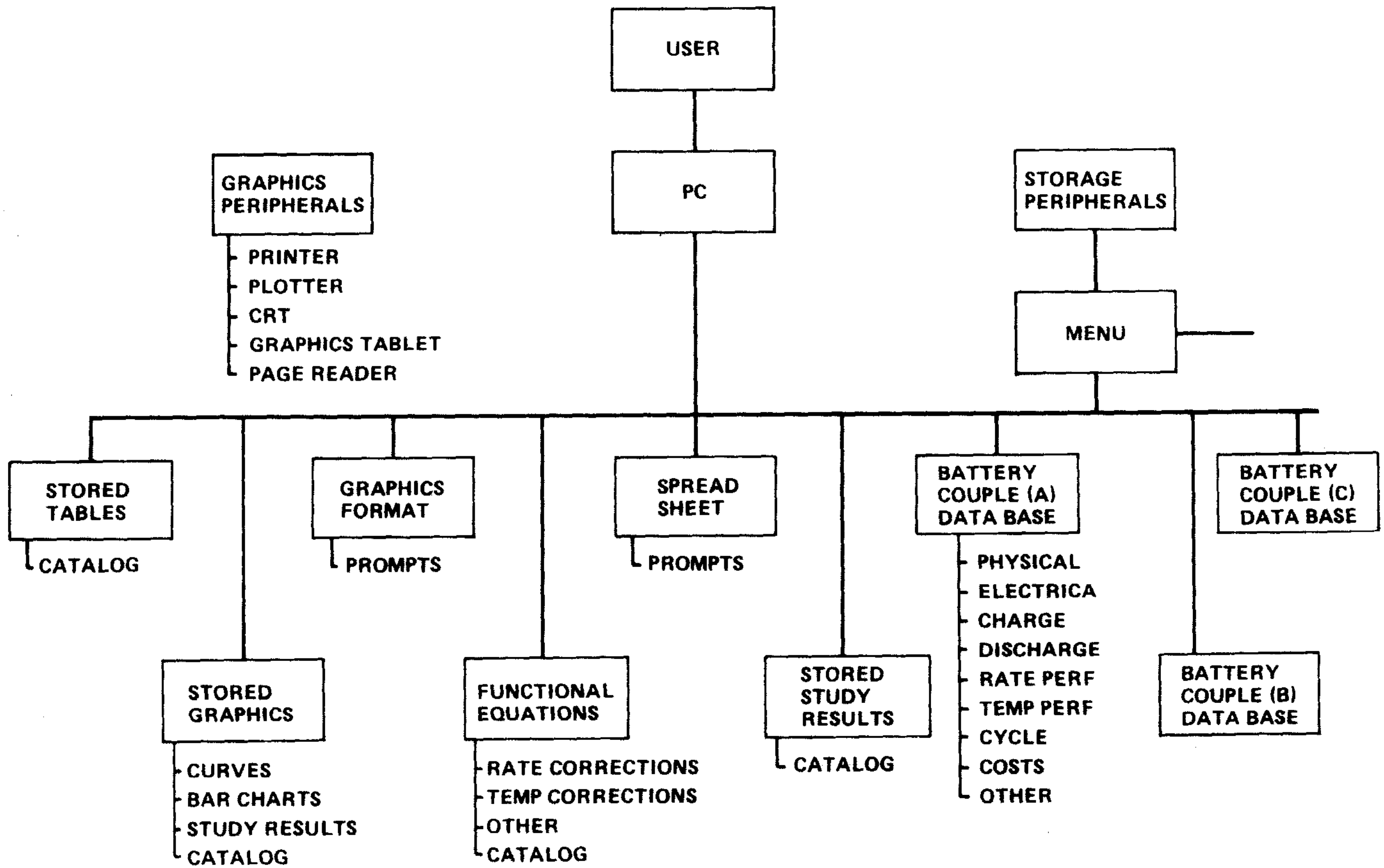

Fig. 9. Menu system with knowledge-base and data-base.

"Continue" key is pressed, the display in Fig. 8 appears, showing the names of manufacturers of the type of battery couple selected. Selection of a manufacturer calls up a selection of data types for that particular manufacturer. Selecting from subsequent branches brings more specific stored data. Sophisticated interactive programming will ultimately allow the user to direct the assembly of data in storage and select the routine for the data. Figure 9 is a preliminary concept of a system structure. A "Help" subroutine will eventually be incorporated.

Future development

The present data and programs can be coded so that a master program can eventually be written. A coded task description, entered from the keyboard or with light pen or cursor, would initiate an automatic computer assembly of data which will be delivered in some standardized or predetermined format. This program would include logic which commands battery options for trade studies.

It is our intent to continue to expand the knowledge-base and the utility of the Boeing expert battery system which, for the present at least, we refer to as BEBATS. The development is, however, not a large concerted effort but rather a fallout of the normal workday study, test, and design efforts. An all encompassing computer program may quite naturally require many months or even years to develop, debug, and make user friendly. Others in the field of batteries are most certainly developing such programs as they pertain to their particular interests. Many such systems have already been developed in other technical areas [1, 2]. An option to accelerate the development of a Battery Expert System would be to ask the entire battery community, and more specially participants of this battery workshop, to develop guidelines, requirements, standardized nomenclature and standardized test data formats such that, in the future, individual contributions of subroutines and data subsets to a global program can be compatible. Such subroutines, perhaps being developed concurrently by specialists, could create an expert system of great utility to all.

Recommendations

The computerized data acquisition system used by The Boeing Company for battery evaluations, data reduction, and data storage has thus far proved itself an invaluable tool in the specification of reliable power systems. All major programming for the closed loop battery test functions have essentially been accomplished; however, much remains to be done in the areas of creating what may be classed as an expert system for battery technology. It is the intent of the authors to continue to pursue the development of such a system which, at times, appears to be a monumental task. It is suggested, however, that a more useful tool for all interested parties may be a system which is jointly created and contributed to by battery manufacturers and users alike, and that some standardized data formats, programming, and programming nomenclature be developed. The expert system thus developed would be universally usable by all specialists in the field and would be compatible with most of the commonly available personal computer systems.

The important question is this: Do we create our own unique system or work in cooperation with others? We would prefer the cooperative approach that produces data in a standard format, so that all can use data collected by others in the battery community. This would avoid, for all, the costly duplication of tests already done by others. We recognize that most participants in standardization programs have to make changes. We would probably have to delete some of our favorite software routines to become compatible with programs developed by others. We might even have to change computer hardware. To us, and to others, however, we believe the results would be worth the cost.

Only if this conference supports the standardization of battery data handling as a desired objective can such a standardization program be realized. We believe that a valid recommendation is that a Steering Committee be formed and a contributors list be compiled as a result of this conference. Intermediate committee meetings prior to the next International Battery Workshop should be scheduled to insure progress toward the common goal.

References

1 L. C. Butterbaugh and Capt. John K. McBride, Computer based tools for cockpit design, *IEEE Nat. Aerospace Electronics Conf. Proc.*, Volume 2, May, 1985.

2 William B. Gevarter, Expert systems: limited but powerful, *IEEE Spectrum, 20* (8) (1983).