Keyboard

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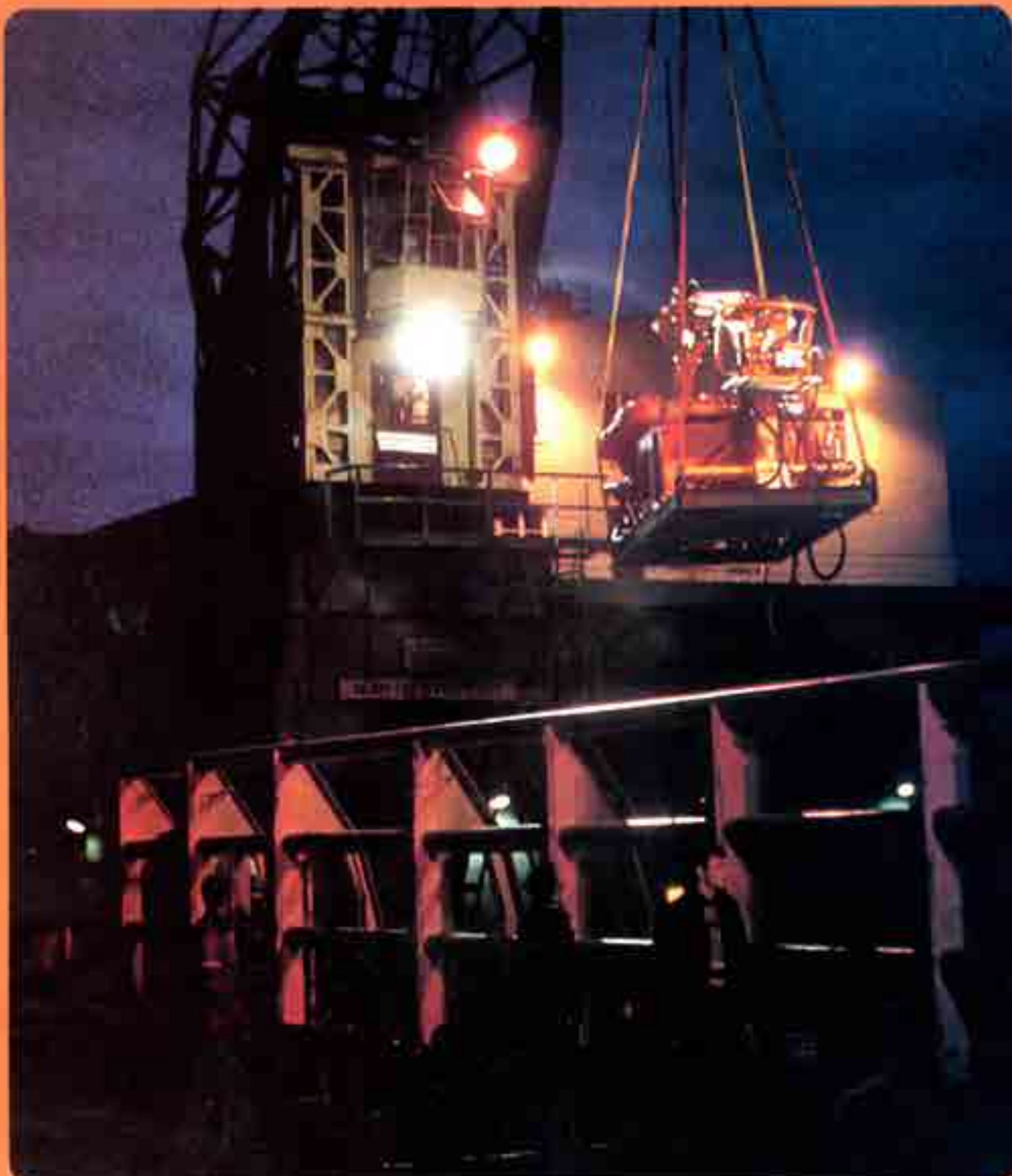


Contents

Cleaning up a North Sea BLOWOUT

by Arne Selle
with John Monahan

FRANK MOHN A/S har utviklet et automatisk analyse-system for prototype testing av sine pumper. Systemet som kalles FAPPA, har spart firmaet for store arbeidsmengder og betydelige beløp ved å gi raske og korrekte opplysninger om hvilke korrigeringer som er nødvendige på en prototype før den settes i produksjon.

The article that follows depicts the attention to quality the Frank Mohn company pays to the maritime pumps it manufactures. The reason is underscored by an event that occured April 24, 1977, when an oil well in the North Sea erupted, creating what became known as the Ecofisk Bravo blowout.

Frank Mohn

A Frank Mohn oil skimmer, the heart of which is a portable hydraulically operated submerged pump, was loaded aboard the supply vessel *Tender Carrier*. Most interesting was that the skimmer, called the ACM-400, had never been tested formally at sea; its shakedown, as it were, came in cleaning up an actual spill.

Attached to the deck of the *Tender Carrier*, and using an arm that extended down to the sea, the skimmer took up an estimated 1 500 to 1 800 tons of oil and water, pumping the liquid into storage tanks inside the ship. It worked so well that Norwegian authorities charged with protecting their nation's coastline immediately approved it.

Since then Frank Mohn has developed an automated system called FAPPA for testing prototype pumps of the kind associated with the oil skimmer. It provides in one day information engineers of 1977 might have waited a month to have. FAPPA, short for Framo Automated Pump Performance Analysis, is a data logging method designed for gathering and then analyzing data acquired as pumps and hydraulic mechanisms are tested. FAPPA can also be used for normal production testing.

The Frank Mohn automated system is built around two modules. The first, called the registration module, uses a Hottinger-Baldwin-Messtechnik 3200 Scanner for collecting data. The heart of number two, the analysis module, is the Hewlett-Packard 9845T Computer System. Software was written by the Norwegian company in enhanced Basic.

Although Frank Mohn makes emergency discharge and oil-gathering equipment (skimmers), its main product line is pump and hydraulic systems used in a variety of tanker ships and offshore oil installations. Last year seven percent of the firm's total sales was directed towards developing new products of this type, which are sold under the name Framo. The company's main manufacturing plants are in the Norwegian cities of Flatøy and Fusa. Mohn subsidiaries are located in other parts of Europe, the United States, and Japan.

It is in the Main Office Development Center in Bergen where most of the prototype systems are engineered, and where FAPPA is at work testing them. The results of the FAPPA analysis form the basis for deciding what design changes, such as the dimensions of a rotor, are needed to assure quality products when they are marketed.

The ability to produce reliable test results as soon as possible after the completion of a test sequence, and to eliminate redundancy, were two reasons why Frank Mohn wanted to automate the registration and analysis segments of its testing routine. A third reason was that the automated system provides the test engineer with accurate information as the test runs its course. Where once it took a month to produce a final report, FAPPA now provides it in a day.

To understand why the previous system, which was mostly manual, required so much of the engineers' time, consider the physical conditions that are measured during a pump test:

- Provided pressure from a pump
- Suction
- Hydraulic pressure for a motor

- Hydraulic oil volume
- Throughput volume
- Temperatures
- Number of revolutions
- Driving moment
- Stresses in the structure
- Others

The first results of an analysis will often be curves that, for a constant number of motor revolutions at a certain pump rotor diameter, describe the relationship between throughput volume/lifting heights and throughput volume/added effect. Taking into account different rotor diameters, revolutions, and different data sources, up to 12 000 manual readings could be required. This, needless to say, would consume an unsatisfactory amount of time.

Consequently, Frank Mohn devised the two-module FAPPA system. Registration, or collection, of data is accomplished by a HBM scanner. The scanner automatically measures from up to 50 different sources:

- Voltages (V, mV)
- Current (A, mA)
- Thermo elements (resistance thermometer)
- Straingauges (full-, half-, quarter-bridge connections)
- Inductive sources
- Other areas

The moment when data are registered at each measuring point is controlled by the test engineer. Ten separate measurement series are recorded. In this way it is possible to know what point was measured when, yielding a broader basis for analyzing the performance of that point. Data from the scanner are stored in an HP 9875 Cartridge Tape Unit. The machines are interfaced via an ICS Model 4880 coupler.

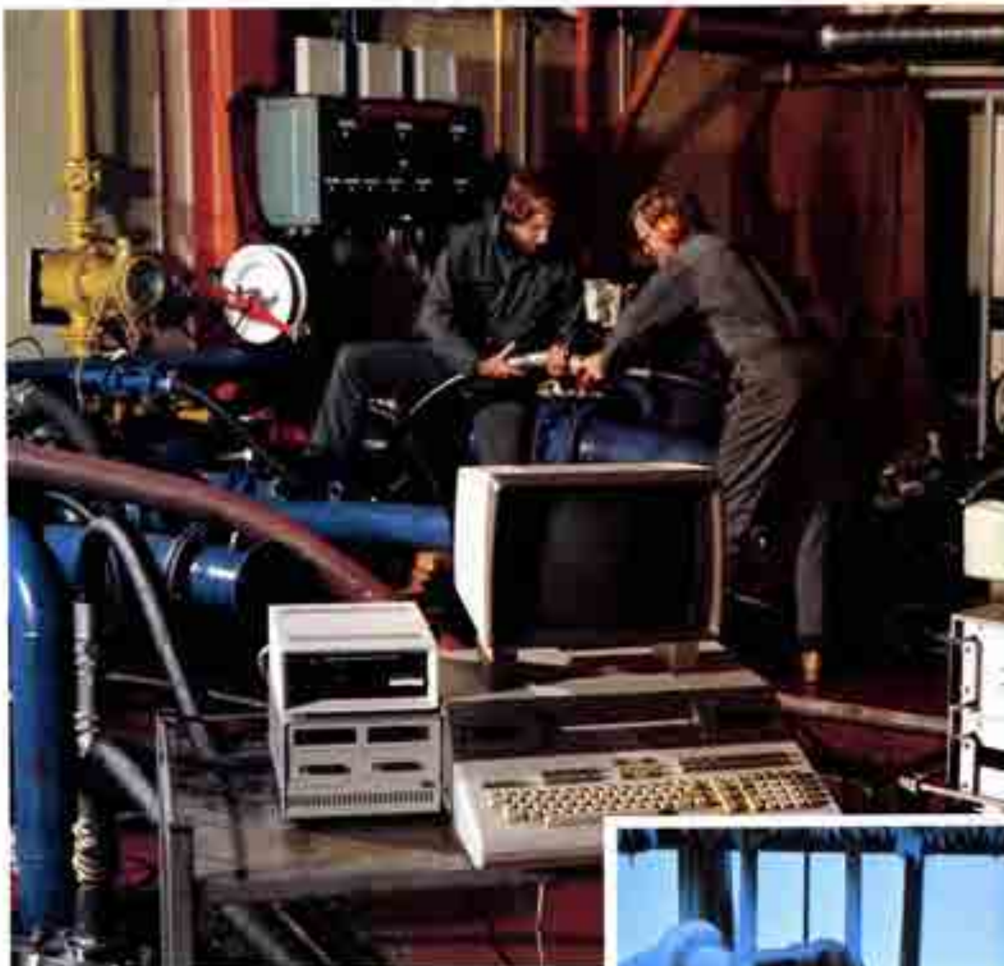
It is also possible to combine readings registered automatically with manually taken readings. This is helpful if some physical values cannot be measured with available resources. However, the system is designed to be fully automatic, without requiring registrations gathered by humans.

Data, whether automatically or manually recorded, are converted from the cassettes by the 9845 into exact, named values. The computer registers what sources provided information during the scanner tests, and ascertains that sufficient data are available for further analyses. It does this as follows.

Each measuring point gathers data by taking ten separate readings. Using these data the computer determines the oscillation that has occured during the test sequence. The test engineer has the opportunity to set limits from the maximum allowed amount of oscillation. Such limits are stipulated during the scanning procedure.

Knowing the amount of oscillation enables the 9845 to decide whether the measuring point data can be accepted. If this amount exceeds limits, all data about the point are cancelled. If the point is accepted, the exact measured values are computed from the ten recordings.

The flexibility of the system is shown in the ensuing example. In some situations it is not possible to install a sensor that can register the number of revolu-



Frank Mohn

(Below left) author Selle; (above left) inside Frank Mohn; (below middle) FRAMMO onboard deck installation on oil tanker in freezing conditions; (below right) FRAMMO PB 12-Booster pump testing; (above middle) service and maintenance for a pump onboard an oil tanker; (above right) FRAMMO oil recovery system on Mexico Gulp blowout.

tions of an hydraulic motor integrated with a pump. However, this number can be computed by the 9845, based on specific motor data plus hydraulic oil volume and pressure. The software directs the machine to find the most convenient computing method according to those sources that supplied data.

Moreover, at times manually gathered data about the number of revolutions a motor makes is used to make analyses. These data are not as consistent or exact as scanner-obtained data. The 9845 will therefore analyze and adjust

such readings according to accepted affinity laws. Thus, it is only the computer-corrected data that are used for further computation of effects and efficiencies.

The final result of the analysis will be one data set for each measuring point. The set contains:

- Number of revolutions (rpm)
- Throughput volume (m^3/h)
- Lifting height (mlc)
- Added effect (kW)
- Efficiency (%)
- Decreased pressure over hydraulic motor (bar)

The data sets can then be used as a basis for more comprehensive analysis programs.

Corrected and computed test data are sent from the 9845 for storage on the HP 9885 Flexible Disc Drive. This information, along with data about the tested product and physical conditions during the test, form a data base of complete test records for all pump types developed by Frank Mohn. The data base is used for such things as composing specific curve clusters for a variety of applications, data listings, comparison of data registered during different test conditions, comparison of data with different products, or for viscosity correction.

The latter has important implications for the company. An application program under development will convert a pump's performance data, gathered using fresh water as a streaming medium, to corresponding data based on streaming media of different viscosities and specific weights. For projects in which hydraulic systems are installed onboard ships that carry a diversity of cargoes, such computations are of great value, in light of international pump performance standards. It will also be possible to devise viscosity and weight tests for hydraulicly driven pumps with a given moment limitation. Normally this involves extensive computation procedures that take a long time to complete when conducted without a computer.

Registered and computed data are presented in two ways. The 9845's internal printer lists tabulations and text, while simultaneously an HP 9872 Four-color Plotter graphs performance curves. Scales for plotting curves are computed by the 9845 using polynomic and exponential smoothing routines.

Such sophisticated routines underscore the value of FAPPA as an accurate, time-saving method for obtaining test results for pumps and hydraulic motors. It's another innovation from the engineering labs of Frank Mohn.

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MOSES of Mt. Sinai

by Irvin L. Bromberg, Alan Pollard, and Michael Rosenberg

An increasing number of medical laboratories are employing computers to manage demographic data, perform analytical calculations, and produce reports. Wide varieties of hardware approaches have been tried, ranging from single-board micro-processor systems to large mainframes. In the Biochemistry Division of the The Department of Laboratories at Mount Sinai Hospital in Toronto, Canada, two Hewlett-Packard desktop computers are used in a system affectionately known as MOSES (Mount Sinai On-line Serum Evaluation System).

The performance achieved by a unique software structure, written in BASIC and sprinkled with key Assembly language and binary modules, rivals, and in many aspects surpasses, that of much larger systems designed, like MOSES, to reduce paperwork and speed data acquisition.

By avoiding repeated manual transcriptions of results, MOSES reduces errors. Reports are legible because the are printed, not handwritten. Likewise, daily logs of lab work are printed as sorted lists. Workload statistics, once compiled manually, are now gathered by computer. The status of the tests requested for any sample or patient may be displayed on a terminal screen or printed anytime. Patients' files are automatically located by surname or hospital number.

Included in the system is the "Editor" task that supports word processing on multiple display screens. The text editor is mostly in BASIC, although line wrapping and righthand justification are in Assembly language. Text is printed in the background on any of the printers.

Another function of MOSES is radioimmunoassay (RIA) data reduction and result computation. Here data from scintillation counters are punched onto paper tapes by teletypes, then entered in the computer via a paper tape reader. The computer quickly collates the radioactivity counts, produces a standards report, plots the standards, fits a weighted Spline curve through the points, plots the curve and its derivatives, interpolates the unknowns on the curve, and produces a printed report of the results. Assay protocols can be defined, modified, or listed online.

MOSES includes a statistical graphics task that has data file management, data entry, basic statistics, scattergrams (with linear or non-linear regressions), histograms, probability plots, and Levey-Jennings plots (for quality control). The RIA and statistical graphics tasks evolved from HP software, although the similarity is now most remote.

How MOSES Does It

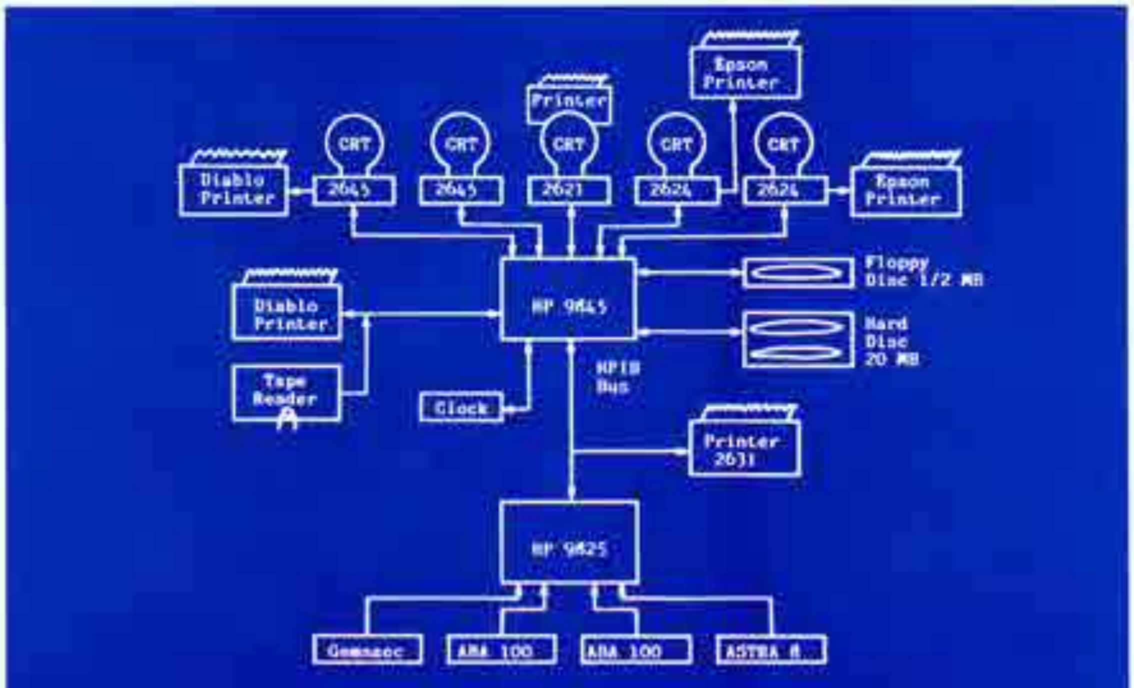
The hardware configuration of MOSES is shown in Figure 1. At the heart of the system is the 9845T Computer System with 320K of RAM, I/O expander, and ROMs for advanced programming and Assembly language execution. Mass storage devices connected to the 9845 include the HP 9885 Flexible Disc Drive and the HP 7906, a 20-megabyte dual hard disc. Five display terminals are linked to the 9845 via hardwired 9600 baud serial RS-232 links. Four of the terminals have external or internal printers.

Mount Sinai Hospital in Toronto, Canada.

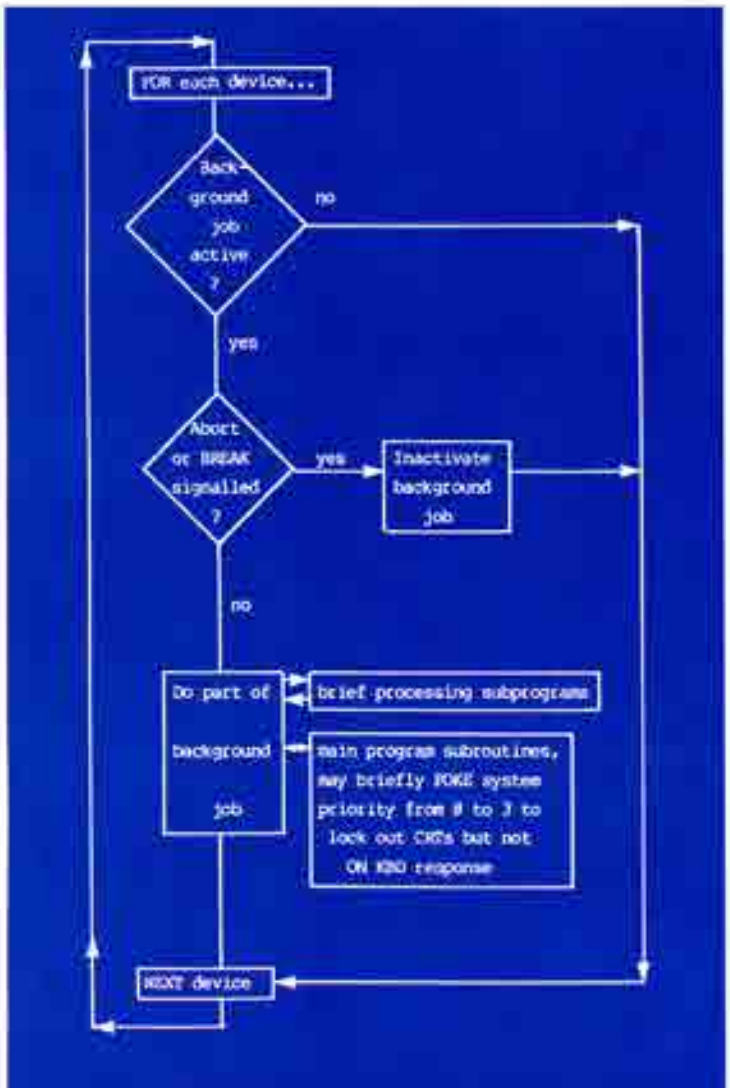
The keyboard and display screen of the 9845 serve as a sixth terminal by way of a full-screen terminal emulator subprogram. Printers directly joined to the desktop computer include the HP 2631 via the HPIB bus, a Diablo daisy-wheel-type printer via a serial RS-232 300 baud interface, and the 9845's internal thermal printer. The Diablo machine, which is a receive-only device, shares the HP 98036A Interface with an OKTronics (General Electric) paper tape reader (which is a parallel transmit-only device).

A custom-made parallel to serial converter transmits the paper tape data to the 9845 at a non-standard rate between 1200 and 2400 baud. The converter's transmitter clock output is wired to the receiver clock input of the 98036A card, and thus they communicate correctly. This sharing of interfaces saves not only the cost of one HP serial interface, but also reserves an essential I/O slot. The paper tapes originate from four scintillation counters used in radioimmunoassays (RIAs).

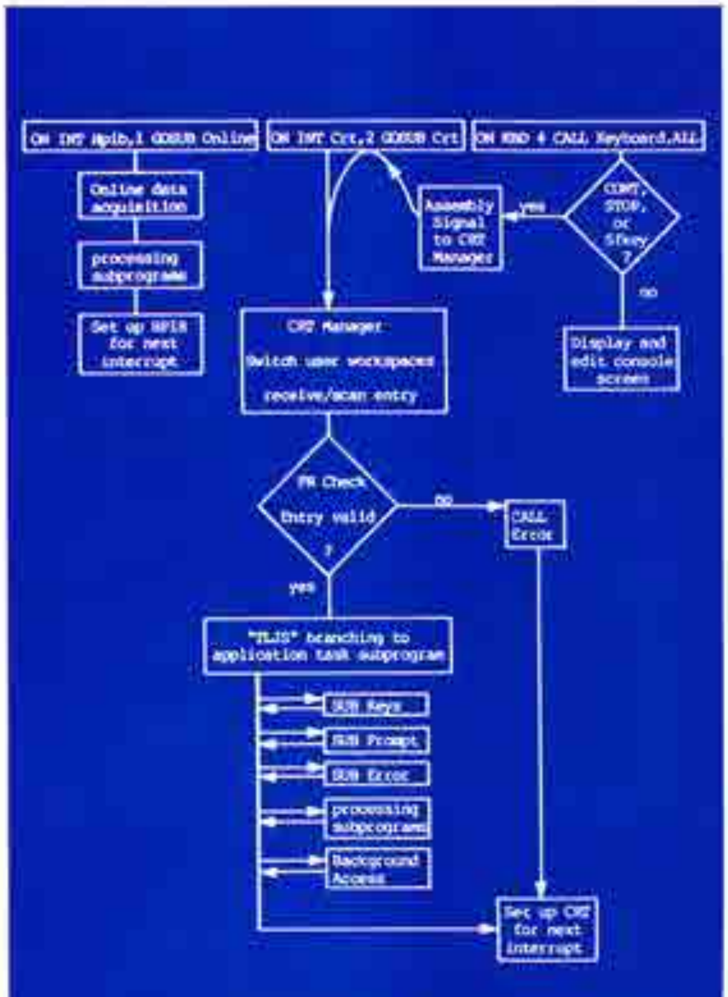
While the 9845 is the main HPIB controller, the smaller HP9825 desktop computer is also connected to the HPIB bus. The job of the 9825 is to acquire and "pre-process" data gathered from four online



Mount Sinai Biochemistry Computer System



Round-robin background manager



Interrupt servicing

biochemical analyzers. The burden of reliable data capture is too much for the 9845 alone, because the analyzers transmit data in rapid bursts at random intervals without first alerting the computer.

The 9825 easily handles this work because of its greater speed and its capability for simultaneous input buffer transfers at multiple I/O ports. The two ABA-100 bichromatic analyzers transmit current loop data at a teletype rate (110 baud), while the Gemsaec programmable centrifugal analyzer and Beckman Astra-8 analyzer transmit at 9600 baud.

The Astra-8 is the most difficult device to connect because it sends seven to nine linefeed-terminated strings at each burst. This requires the use of the continuous high-speed buffering capability provided in the programming ROM, using a *bred* statement at frequent intervals. Moreover, the 9825 must be programmed to buffer up to ten such sets of data strings and send them to the 9845 as it can accept them.

The other analyzers are handled by interrupt-driven, linefeed-terminated input transfers. When the 9825 receives an analytical result online, it reshapes it to suit the data base of the 9845, before passing it on to the bigger machine via HPIB. Under certain conditions, the 9845 will return acknowledgements or error messages to the 9825, which it logs using its own internal printer or another one situated near lab technologists. Actually, the power of the 9825 is quite under-used in this configuration (the entire HPL program is less than 4K bytes long), and the much less expensive HP-85 or 9815 probably could do the job.

Although the 9845 is a versatile machine, it was designed for single-user applications. It therefore lacks time sharing, swapping of user workspaces and program code, and automatic background operation. Using Assembly language, the Mount Sinai team developed a rapid method of switching between user workspaces within RAM; using IMAGE/45, they developed a method for rapidly swapping subprograms from the hard disc. It works as follows.

Infrequently used subprograms are stored together in a file on the hard disc. Commonly used subprograms for all tasks are kept in RAM at all times, with dummy subprograms appended to them. Before calling one of the infrequently used subprograms, the system checks whether that subprogram or function already exists (located after the dummy subprogram). If it is not present, *DEL SUB Dummy TO END* is executed to make room. Next, the required subprogram, preceded by a replacement dummy subprogram, is "swapped in" using the *LOAD SUB* statement.

Its job done, that subprogram remains in place unless a different subprogram is required, in which case the former is deleted. An Assembly language routine is used to test in advance for the presence of required subprograms by name, thereby avoiding the need to keep track explicitly of those subprograms that are or are not part of the core memory.

MOSES produces assorted reports on several printers, while simultaneously meeting the needs of technicians at the various terminals. To accomplish this, a round-robin background manager was devised (Figure 2). This generally operates in the main program and receives the lowest priority there. However, for certain jobs the background manager makes brief calls to the processing subprograms, and at other times its priority may be raised if operations involving critical data are occuring. (Accomplished using Assembly language.) Multiple printing tasks can be progressing for any number of the devices connected to the 9845; graphics plotting and paper tape reading also are done in the background.

The fact that significant Assembly-level operating information is protected by Hewlett-Packard proprietary policies was a constraint that slowed — but did not prevent — development of important Assembly modules. Seventeen-year-old Michael Rosenberg developed a variety of Assembly modules and binary programs that were essential in pushing the performance of the 9845 far beyond the limits imposed by BASIC.

Rosenberg initially used the HP Assembly Development and Execution ROM for this, but later wrote an assemble/binary program developer in BASIC. The hospital team now keeps only the Execution ROM, and does all other machine language development using Rosenberg's assembler. Some interesting binary programs add new or modified statements to the BASIC firmware.

The *PEEK* and *POKE* plus *WORD* and *WORD$* functions are two-byte versions of *NUM* and *CHR$*. *EDIT LINE* now allows any mix of upper- or lowercase spelling, regardless of the keyboard's mode. *REN* now permits the programmer to specify the particular line where renumbering should start, thus facilitating the insertion of multiple lines.

The *DO...THEN...THEN* statement, which is almost the same as *IF...THEN*, allows as many multiple statements as there is room for to be typed in and activated on the same program line. Finally, a *FIND* command expands on *EDIT LINE* by its ability to search specifically for a variety of program symbols (variable names, subprogram names, constants, etc.)

Another rather awakening feature of MOSES is this: a full-screen online program editing facility that operates in the background (allowing program modification or development to be done at the terminals), while the 9845 continues to service all the remote devices and perform other active background jobs. Assembly modules used by this editing facility perform several functions:

- Put the last item from the *RECALL* buffer into a string, *PEEK*, or *POKE*.
- Display a command or program line to be edited in the keyboard entry lines (unlike BASIC language's *TDISP* statement, this works even when *ON KBD* is *OFF*. Characters are actually shown — they are not "ghosts" — and the special video enhancements still work).
- Programmatically "press" the EXECUTE key (to cause a command displayed in the keyboard entry line under program control to be immediately carried out).

MOSES is unorthodox in that all the prompts, special function key labels (which are displayed on all the display screens), menus, and MOSES error messages are stored on the hard disc in the the "system workspace file" instead of in the program code. This vastly reduces RAM consumption. Speed is not adversely affected because the *ASSIGN*ments to all frequently used files are made only once at start-up. *ASSIGN*ments are retained and passed to all subprograms that need them, as a result of the speed of the hard disc and because the *OVERLAP* mode is always in effect. The data in the workspace file can be changed online at any terminal (after a password is given).

Figure 3 shows the structure of the interrupt servicing software. The "Error", "Prompt", and "Keys" subprograms, along with the display screen manager, are generalized to handle the slight behavioral differences peculiar to the the screens interfaced to the system (9845, 2645, 2621, 2624.)

The software is organized to use a hierarchy of program branching corresponding to the eight special function keys on all the display screens. Thus, there are potentially eight Tasks, each of which may have eight Levels, each of which may have eight Jobs, each of which may have 99 Subjobs (this is called the "TLJS" structure).

TLJS, plus the fact that critical data are stored in COM memory, permits the operator to restart the system after an unexpected and grave error by simply pressing RUN. The program will resume from the point just prior to the error, without destruction of the information. After certain intervals, critical data are automatically stored on the hard disc, thereby minimizing the amount of information that would be lost if a power failure occured.

On all the display screens the ENTER, BREAK, and special function keys are supported in line block mode with DC1-DC2-DC1 handshaking. The "Keyboard" subprogram causes the console keyboard and display screen of the 9845 to emulate the remote display screens using the CONT, STOP, and special function keys k0 through k7.

Assembly modules used by the "Keyboard" subprogram perform these functions: *PEEK*; sense where the cursor is; input a line from the print out area of a display screen; signal an interrupt to BASIC on a specified select code; and cause the cursor to flash automatically. Any line in the print out area of the 9845's screen can be entered in response to a prompt. When keys k0-k7 are pressed, the same escape sequence is passed to the CRT manager as is sent by all the remote CRTs (that is, ESCp, ESCq, etc.) The lower row of special function keys gives access to other functions not available on the remote screens.

The CRT "Manager" subprogram is the key to the multi-user, multi-task operation of MOSES. Interrupts from CRTs are serviced on a first come, first served basis. Each entry is completely serviced before other pending or arriving interrupts are addressed. When it is expected that a certain operation will require processing or printing for longer than a few seconds, the program invokes the background manager operation.

Assembly language is used for reception handshaking, because BASIC is not fast enough at 9600 baud to go from a *WRITE BIN Crt;17* statement to an *ENTER Crt;Buffer$* statement, without sometimes missing the first few characters. Also, certain I/O errors can occur in the *OVERLAP* mode.

The "Check" function is invoked by the CRT manager to trap for out of range, improper length, improper characters, and other "primary" errors. This is accomplished by using control flags previously read from the disc by the "Prompt" subprogram. If any entry is found to be valid, it is repeated on the user's display screen and the Manager calls for the appropriate subprogram. If an entry is invalid, the Manager calls the "Error" subprogram and an error message is given.

Authors Rosenberg (left), Bromberg (sitting), and Pollard. For more information about MOSES, including purchase information, consult them.

With one display screen active, the system's response is virtually instantaneous. With several terminals active, the response time is somewhat longer, but still fast. There exist a few lengthy processing routines that are not written into the background because they are used infrequently. Long reponse delays occur when a weighted RIA Spline curve fit is being computed (which may take 10 to 30 seconds depending on the scatter of the points.) Delays may also occur when someone is using the Editor scans in several screens of text, or when long, multichannel biochemistry worklists are being dealt with.

With the *LOAD/DEL SUB/FN* statements, MOSES is almost a "virtual memory" system for extending the program code, and thus future plans call for the ongoing development of a variety of infrequently needed special functions. Intensive work for the development of binary programs is continuing. It is not practial to add more CRTs to the present system, mainly because there are no more I/O slots left, and also because response time would slow. The addition of more printers driven by the HPIB system is under consideration. Future additional automatic biochemistry analyzers can be connected to the present system, because the 9825 has plenty more power to handle additional data acquisition.

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Card test system suits STC

As stone tablets and styluses gave way to paper and pens, data storage became feasible, but not too practical, for today's volume of information. Paper gave way to punched cards, paper tape and microfiche – admittedly faster, more convenient methods still in use today.

Not until the emergence of computers, however, has storage technology advanced to a point where data storage retrieval is fast and convenient. Computer technology is quickly replacing punched cards and paper tape with magnetic media in the form of reel tapes, cassettes, hard and flexible disks, and cartridge or disk packs.

Working to meet the growing demands for disk drives specifically, is the Disk Division of Storage Technology Corporation (STC), Louisville, Colorado, U.S.A. The growth of this young company is indicative of the recent growth of the computer industry itself. While some businesses are experiencing the pain of worldwide recessions and cutbacks, STC is experiencing the pleasure of growth and expansion. The firm's net income for the second quarter of 1981, for example, was up 55% over the same period last year. How is STC handling this growth?

In the test engineering department of STC's Disk Division, engineers have developed and implemented a computer-controlled hybrid printed circuit board test system (commonly called an analog test system or ATS) to perform analog card functionality tests. The system, in use for about a year and a half, is boosting productivity by decreasing the time needed to check analog cards by 75%, with a simultaneous improvement in product quality. Since the construction of the computerized ATS, the unit test reject rate dropped from 32% to 8%. For a company that would like, within a year, to double its daily production rate of 1200 analog cards, these figures are encouraging, officials say.

The analog cards currently under test are servo cards and read/write cards, both of which are used in the disk drive units manufactured at STC. Servo cards control movement of the disk heads, while read/write cards read and write the data stored on the disks.

There are actually five ATS units at STC, devoted solely to testing these cards. Each ATS consists of many pieces of equipment, built into, or situated on top of, a combination cabinet-table unit. The manufacturing technician sits facing the majority of test instruments. The computer system, a Hewlett-Packard 9835A, sits on the right, within easy reach, and acts both as an instrument controller and as a test program monitor or prompter. The individual instruments in the system, besides the HP 9835, include an HP 9885M Disk Drive, an HP 5335A Universal Counter, an HP 3325A Function Generator/Frequency Synthesizer/Sweeper, an HP 8165A Programmable Signal Source, an HP 3455A Digital Voltmeter, an HP 1980B Oscilloscope, an HP 1602A 16 Bit Logic State Analyzer, and Electronic Measurements power source units. All instruments are connected to the 9835 via HP-IB.

The 9885M disk drive unit is built into the ATS frame, underneath the 9835. The software, developed in-house, is stored on a floppy disk in a test menu format. Written in Basic, the menu programming approach allows each technician to call up whichever reliability test is desired, out of a total of 13. The 9835 sets up the appropriate instrumentation for each test.

Although the menu format takes away some of the programmer's flexibility, it is very helpful in training new technicians. Through the use of "tech-tips", newcomers can understand the analog cards' construction, and how each section on the card works. A step-by-step procedure is followed to complete each of the 13 tests. Paul Zieschang, Senior Engineering Manager in disk test engineering, says that, "It takes probably half an hour for the technician to figure out how to use the computer," adding, "The system itself was very simple to put together.

"It took us not more than three weeks to do all the operating system software, like the drivers for the particular instruments."

The software's menu format also allows the manufacturing test technicians to examine a card in three minutes, compared with twelve when the reliability procedures were performed manually. This reduction in test time, along with a three-shifts-a-day, six-days-a-week work schedule, allows STC to increase production to meet demand.

From the 13 test programs in the menu format, technician Ron Bishop demonstrates a portion of one test, which allows him to locate any part on the analog card. Bishop admits that with approximately 350 parts on a board, a technician, even a good one, can't remember where all of that's located.

To locate part R-23 on the board, Bishop snaps the card into the unit test fixture, types R-23 on the keyboard of the 9835, and the location of R-23 flashes on the CRT. The software for this function is programmed to locate parts per section, or grid, and the computer focuses right down into the grid where R-23 is located.

In another test, Bishop demonstrates one use of the 9835's built-in strip printer. When a bad part is found, Bishop types in the location of that part. The 9835 automatically prints out the STC part number, the generic description and part number, the letter designation of the card being tested, and the appropriate product number. At this point, Bishop tears off the printer tape and places it on the board. The board is then taken away, the bad part replaced, and the board returned to complete testing.

Expansion has finally caught up with employees at the disc division, and a relocation to the new headquarters nearby is planned. Simultaneously, the test engineering department plans an expansion of their ATS facilities, which may include computer networking capabilities and the incorporation of a higher order programming language, such as Pascal.

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Eagle eyes and elusive beams

by John Monahan, Editor

Lee Elmore (right) and son Jeff at their fifth Cessna 337 Skymaster.

The father-and-son engineering firm of Lee and Jeff Elmore of Sarasota, Florida, U.S.A. offers a patented system for improving long-distance microwave communications that uses an aircraft full of electronics aptly dubbed "eagle eyes."

The system, 12 years in development, uses aircraft-contained radar to ascertain the terrestrial and atmospheric factors that affect reliability and fading of microwaves passing between pairs of towers that are situated an horizon apart in line-of-sight links. A realistic digital model of each path is recorded by an airborne computer, which is programmed to design automatically the heights of the towers to allow the microwaves to clear all obstructions.

The digital model is further used for computer simulation of the actual performance of the microwaves in order to protect against deep fades caused by surface reflections in a changing atomosphere. These innovations resulted in the granting, in 1977, of United States patent 4 050 067 – "Airborne Microwave Path Modeling System."

Engineering services using this technology are provided in the United States by Elmore Electronics, Inc., and internationally by Elmore Electronics, Ltd. Clients include long-distance telephone companies, specialized microwave networks, electric power utilities, oil and gas pipelines, and national telecommunications systems in developing countries. In their transcontinental lab, the Elmores have flown over a million miles to profile networks in America, as well as from the Artic to the equator and over unmapped, inaccessible parts of South America and Africa.

Prior to airborne path modeling, constructing microwave routes required that ground crews make surveys to check obstructions or erect temporary towers to test reflections, according to the Elmores. Moreover, they say, these crews often had limited access to areas because of rugged terrain, and the tests they performed were subject to unexplained atmospherical effects.

Son Jeff calls these methods "hoist and hope," and points out that half the Elmores' business involves improving existing routes. Heavy traffic and computer data sent over modern microwave systems – such as digital radar and single-band transmissions – require higher performance over each tandem path, the Elmores say. They believe their system can ensure such performance.

The flying lab is a Cessna 337 Skymaster II with twin push-pull engines, an airplane specially equipped for stabilized flight over straight-line microwave paths. Their current Skymaster is the fifth the Elmores have owned since 1967.

They have similarly stuck with Hewlett-Packard equipment, beginning with a handheld calculator and moving up to their first desk-top computer system purchased in the mid 1970s.

Jeff Elmore

The Elmore staff and instruments at home base.

As new desktops were added to HP's line, the Elmores added them to their offices in Sarasota. There they use the 9815, 9825T, 9845T, 9845C, plus assorted peripheral devices. HP's newest desktop, the 9826, finds service inside the airplane as controller for the HP 3497A data acquisition system. The machine with the propellers and the machines with the IC chips work as follows.

During a single day, the Elmores typically fly five, one-hour paths, for a total of 150 route miles. Until recently, the microwave path data they gathered were recorded on magnetic tape for processing in Sarasota. This analog method was cumbersome, relative to how fast information could be collected, and so the 9826-controlled digital data acquisition system was installed.

Now the 9826 produces in-flight models of each path and tower design, so that they are available upon landing. The all-digital system permits the Elmores to handle all of their clients' network expansions or modernizing of heavy traffic routes with just one aircraft, they say.

Of course, possessing all this hardware, without having something to tell it what to do, is like having a body without a brain. The key to Elmore Electronics is the proprietary software the owners wrote.

The Elmores' microwave software is organized into four groups, which are used sequentially to accomplish map route planning, airborne radar modeling, atmospheric analysis, and performance testing. Both HPL and Basic languages are used here. MAP-ART is the first group of programs.

MAP-ART...is a pre-flight software used for planning new paths. Geodetic and contour data are entered from topographic maps into the 9845T via the HP 9874A Digitizer. The computer then orders the 9872S Four-color Plotter to profile the new paths, taking into account the various topographic data. These profiles indicate what path-tower configurations are the most feasible. (These predictions are later confirmed by actual flight over the path).

Scaling and tower design are automatic. Graphic results can be sent by dataphone to licensed clients. Producing a complete profile and design takes one operator less than an hour.

RAD-ART...is the radar software for processing measurements taken in the air to produce a digital model of the path and the reflectivity of the terrain. From a dome below the fuselage of the airplane, two vertical radars scan the microwave path. The measured radar range is corrected to account for variations in the airplane's altitude, thereby yielding a true profile. The radar echo is calibrated to measure terrain reflectivity. Landmarks are photographed by an exterior camera at the push of a button.

The 3497 data acquisition system converts the radar and other measurement signals into digital data and sends them to the 9826. As the Cessna flies over the microwave route, the data are processed; at the end of each path, the resultant digital model is stored on the five-inch flexible disc in the 9826. The Elmores like to call this quick turnaround "instant replay."

The radar-based profile is depicted on the display screen of the 9826. The format of the radar profile is identical to the MAP-ART plots for direct comparison of these pre-flight plots with the real-world findings of RAD-ART.

MET-ART...is the meteorological software used to process atmospheric measurements made by sensors during flight. The temperature of the air, humidity, pressure, and height of the aircraft are used to compute the refractivity gradient. This gradient determines the bending that occurs as the microwave beam passes between towers. Meteorological data are later stored in the HP 7906 hard disc for statistical accounting of geographical and seasonal changes in atmospheric conditions.

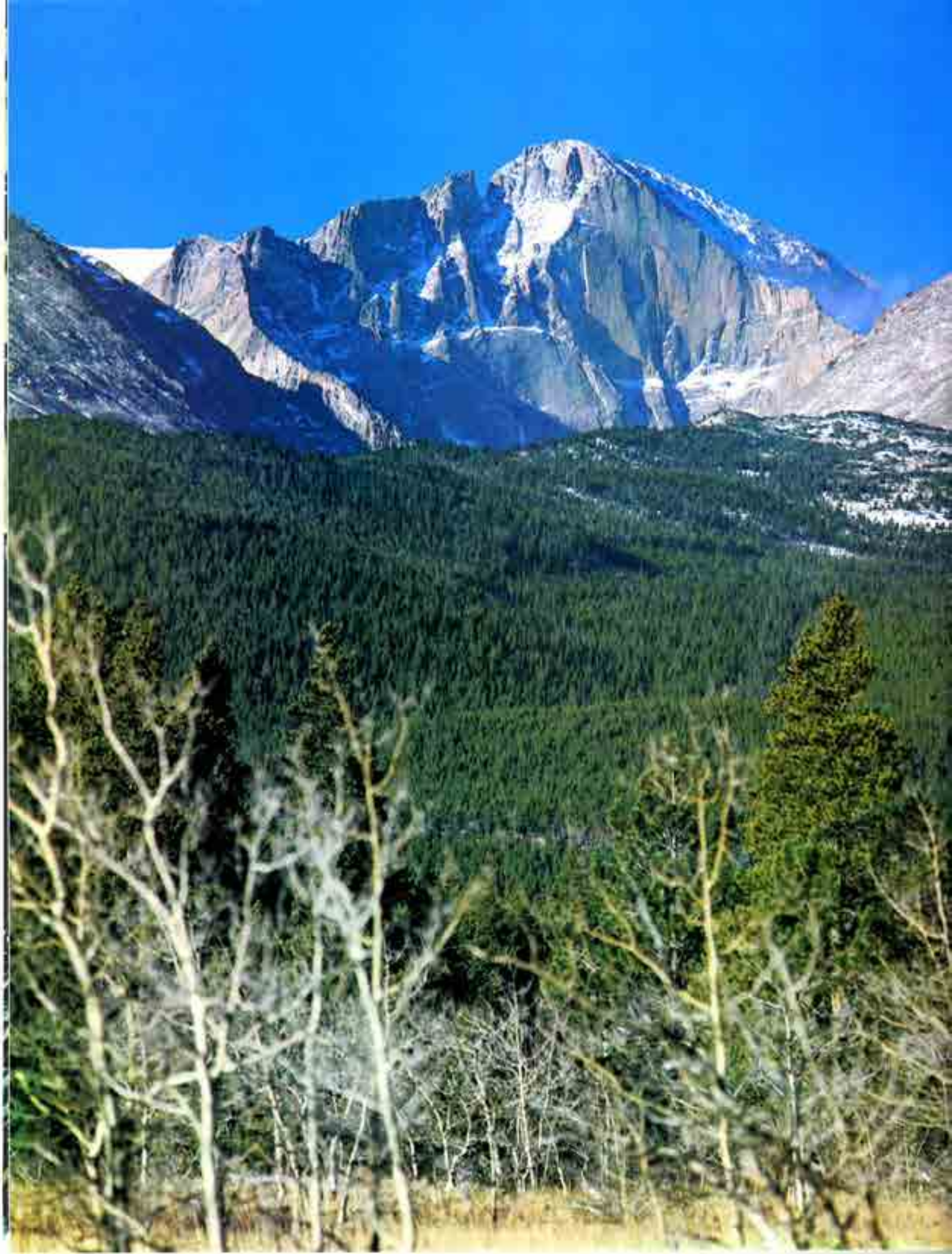
(In order to produce more locally valid statistics, MET-ART can also run an HP 85 personal computer/3497 data logger configuration where probes are attached to the microwave towers, according to the Elmores).

SIM-ART...is the simulation software for testing microwave path performance and fade-protection designs. This technology employs the digital path models and meteorological data to determine fade sources and predict the reliability of a propagated beam.

Path loss tests are simulated by plotting path transmissions against antennae heights, with atmospheric bending fixed at various static conditions (such as normal or extreme temperatures for summer or winter.) A dynamic simulation of a path's performance is achieved by plotting the transmission throughout the range of atmospheric variations. Protection against reflective fades is also tested by simulating the operation of the microwave combiner, a black box on the microwave equipment that looks at signals from two antennae and switches to that antenna giving the best signal.

Licensed and properly equipped Elmore clients can receive map profiles, flight results, and simulations via the telephone, thanks to the data communications capabilities of the 9845T and the 9845C located in Sarasota, or those of the 9826 located in the Cessna. The 9845C computer, with its 4 913 colors, is further used to demonstrate Elmore technology at symposia, where the message is likely to be, in Lee Elmore's words, that "our technology is being used for expedited expansion of microwave networks, and for enhancing performance of existing routes to greatly increase capacity."

In other words, Elmore Electronics provides an eagle's eye view (for the electrical engineer) of that sometimes elusive energy called microwaves. ☐



Keyboard to cease publication.

This is the last issue of *Keyboard* that you will receive. The magazine was published from the spring of 1969 until now, the winter.

The decision to cease publication went beyond the staff's means of preventing it. It was, we are told, a matter of the mind that won out over the heart: for no one close to the magazine wanted it to die. Apparently something called "Computer Advances" is to suffice for *Keyboard*.

The staff remains somewhat embarrassed, because in the previous issue, we invited you to send in article ideas and programming tips. We were, please believe, under the assumption that *Keyboard's* position within Hewlett-Packard was unquestioned. That expression of exuberance was as genuine then as our surprise and disappointment are now.

Still, speaking for the many people who've been associated with *Keyboard* over the last 13 years, we are satisfied, if not proud in some instances, that we have actually communicated with men and women whom we've never met... communicated with them across continents, cultures, politics. Of late, it has not been our intention to tout Hewlett-Packard, so much as to impart useful information in the most objective manner possible. We wouldn't change a thing.

It is in this spirit that we leave you with this photograph of the Colorado mountains, near to where *Keyboard* was published. To us the photo depicts the solidarity of goodwill we hope the magazine has fostered. Goodwill, we maintain, that lasts longer than journalistic endeavors – because, like the mountains, it works effects that are no less real for being merely mute.

Farewell.

John Monahan,	Editor
Hal Andersen,	Art Director
Paula Dennee,	Layout Artist
Rene'e Adams,	Staff Assistant
Linda Bingham,	Typography

Alpine glow ... Long's Peak, elevation 14 255 feet, located in Colorado's Rocky Mountain National Park. The photo was shot by art director Hal Andersen last October 20 from a clearing 9 000 feet high.

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Adieu

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auf Wiedersehen für immer

Sláin Agus Grurmiabh Maith Agut

Data Base: The heart of battery tests

by William Fairchild
with John Monahan

Some of you reading this may now owe your life to Wilson Greatbatch. One day some of you will.

Mr. Wilson Greatbatch is the inventor of the implantable cardiac pacemaker, the device that uses a pulsed current to steady the beat or reestablish the rhythm of an arrested heart.

Just as it is the heart that keeps the body alive, so it is a battery that keeps the pacemaker working. The imperative is thus to build a battery that is reliable, because the situation can be one of life and death.

In 1970, roughly a decade since the patenting of its first pacemaker, Wilson Greatbatch Ltd. (WGL) developed a trustworthy lithium iodine battery. It provided power for a minimum of six years, compared with the one or two years previous batteries lasted. In order to achieve the quality demanded in such a critical component, the company devised a comprehensive system for quality control.

This system tests every battery at body temperature under simulated pacemaker load. The number of batteries tested, the nature of the tests, and the volume of data require the aid of a computer, and WGL uses the Hewlett-Packard 9845T, along with other HP gear.

Technician and HP 9845 at Greatbatch site in Ireland.

The huge herd of data accumulated during battery testing calls for a few cowboys to kind of keep it in line, which is why the company opted for the IMAGE/45 and QUERY/45 data base management package. IMAGE/45 consists of programs for manipulating the data base (define, restructure, recover, etc.), plus ROMs for enhancing the 9845's BASIC language. QUERY/45 is a program that allows a person to add new data, perform sorts and searches, and check ranges.

The system is not used in Clarence, New York, U.S.A., the firm's headquarters, but in Galway, Ireland, at the laboratories of a subsidiary company called Gwydd Ltd. The Galway battery testing facility has no computer experts, so technicians there are trained to use the system, most learning within two weeks. Such production testing is called burn-in, and is conducted in the Warm Room.

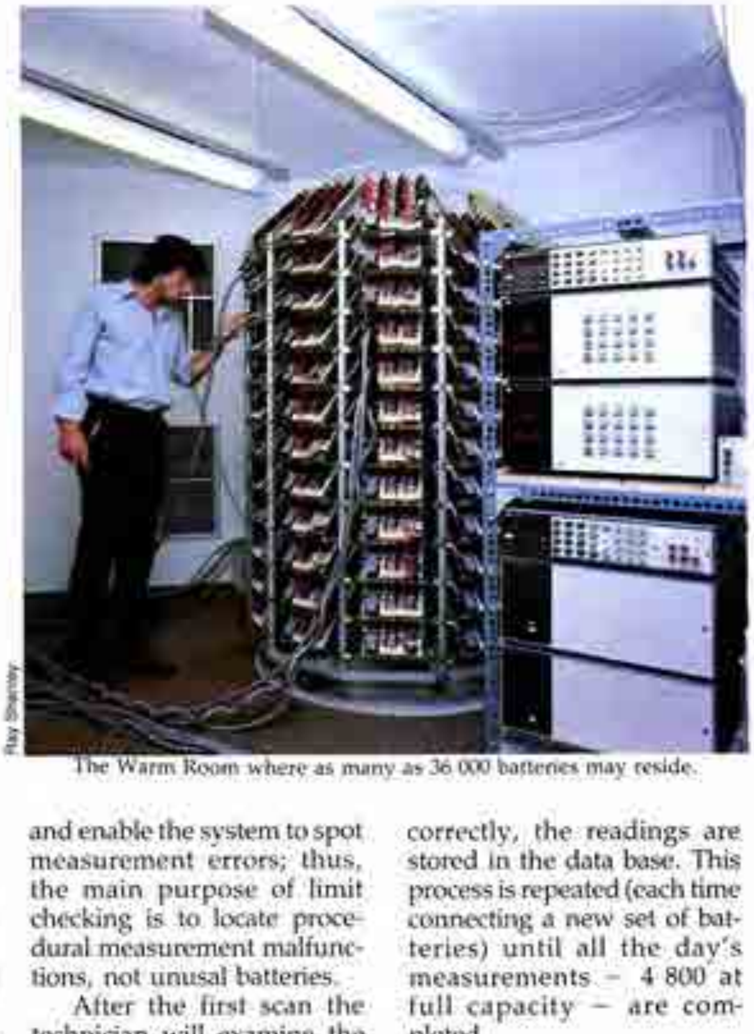
During burn-in each battery is tested under simulated pacemaker load and at body temperature for 63 days. The dc voltage and ac impedance (at 1 000Hz) of each battery are measured. Also recorded are the date and temperature, which must be maintained at 37°C (plus or minus 0.5°C). Batteries are placed in 50-unit test racks that are stored in carousels. Each of the five rotating carousels holds 144 racks, meaning the room may contain 36 000 batteries, of which 400 may be tested at once. Every battery is tested six times over the 63 days.

The WGL-written software for accomplishing all this on the 9845T consists of several programs. ONTEST is a pre-measurement program, SMLIST is for scheduling and sorting, and BATMAN performs the actual testing. Other post-test programs are also employed.

Each rack is referred to as a GROUP and given a unique code name by ONTEST. The code name consists of the current date (kept by a real-time clock) and the rack number, obtained by 9845 after reading two resistors and using a table look-up procedure to calculate a number between 1 and 3 025. ONTEST next requests the battery's mode number and checks it agains another table to ensure it's correct, then determines the measurement schedule fo the batteries and displays i on the 9845's CRT screen fo the technician.

Further, ONTEST automatically checks to make sure each battery in the rack is properly clipped to leads that are connected to a 100 000-ohm resistor. Once a battery is properly connected, ONTEST asks the operator to type into the computer's memory the nine-digit serial number etched on the battery's stainless steel case. ONTEST then verifies that the correct number has been entered. The digit-checking algorithm it employs is so precise that typically just one typing error in 100 000 goes undetected.

Prepatory to actual battery testing, the technician runs SMLIST every morning. SMLIST prints a list of the GROUPS scheduled for measurement that day. It also lists any unmeasured groups that need testing. In addition, SMLIST provides a measurement schedule for any past or future date.


The Warm Room where as many as 36 000 batteries may reside.

Now it's time for BATMAN (for BATtery MeAsuremeNt) to perform scheduled measurements. After checking to see whether rack connections are correct and the room is at the proper temperature, BATMAN reads each battery for voltage and impedance. It then refers to a table entry unique to the age and model of the batteries under test to see whether the readings are within acceptable limits. These limits are compiled from historical data and enable the system to spot measurement errors; thus, the main purpose of limit checking is to locate procedural measurement malfunctions, not unusal batteries.

After the first scan the technician will examine the printout of voltage and impedance for failed units. Using this information he takes corrective action, such as rechecking connections. BATMAN can then remeasure all of the connected units or only those that failed initially. When all measurements have been performed correctly, the readings are stored in the data base. This process is repeated (each time connecting a new set of batteries) until all the day's measurements – 4 800 at full capacity – are completed.

With this information now rounded up for all six measurements, SMLIST works through the data base and points out those batteries that should be rejected because of impedance or voltage problems. It does this by referring to a table that tells it acceptable limits for voltage and impedance, based on the model of battery it's looking at. Because the technique, that is, the measuring, was done correctly, WGL can be certain that an out-of-tolerance reading is indeed caused by some abnormality in the battery itself, and is not an artifact of the testing.

With burn-in completed, final processing occurs. Batteries pass through several inspections, and rejected units are physically segregated from good ones along the way. Some batteries are modified (cutting and tinning terminal pins) to suit a customer's specific order. These batteries, along with rejected ones, receive a special code that identifies the alteration or reason for failure. Another WGL program, called FIRES (Final Inspection RESults program), facilitates entering this last information into the data base. It also gives counts of shippable batteries based on model and part number.

The final step in the process is selecting and packaging batteries for individual orders and printing a report for the customer. A program called BOXER relates the number of batteries to put in a box, along with the model and part numbers. BOXER then prints a report that contains the serial numbers of the batteries for that box and their final voltage and impedance readings.

The beauty of the Ireland-based system cannot be fully appreciated until one understands some of the advantages it holds over the older system used in Clarence, New York. In Ireland, the machine checks for incorrectly entered digits; in New York, two people must do it. Specifying electrical rejects, scheduling measurements, recording temperatures, and reading dates are done quickly by computer in Ireland; in New York, they're done by hand.

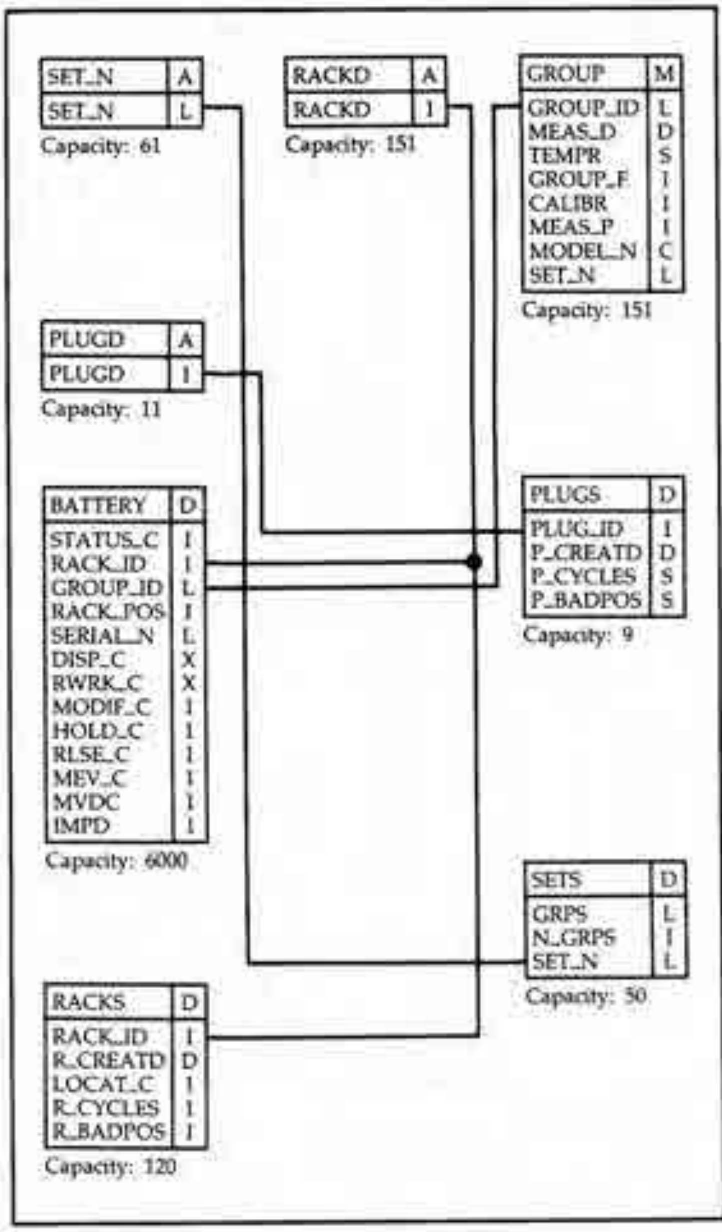
Under the New York system the measurement process must be continually monitored, but in Ireland it's done by BATMAN. The old system measures 192 batteries at once, the new system 400. Also, the selection of batteries for shipment is a manual operation in New York, and the customer does not receive a unique report. The BOXER program offers both.

Developing all this software, including documentation, took a little more than a year. Over 7 000 lines of code were written by author Fairchild. Such an investment was well worth it, because one key word keeps popping up: productivity. And when you can increase productivity, while maintaining vital quality, your heart is in the right place. ☐

Notes on the Data Base

It should be evident that the burn-in test processing requires a fair amount of information. The QUERY/45 and IMAGE/45 data base package provides a mechanism for logically structuring, storing, and retrieving this information. The battery data can be broken down into two subsets. Some data are unique to an individual battery (serial number, for instance). The remaining data (measurement temperatures are an example) are the same for all batteries in a given GROUP. The data base can be organized so that information unique to a battery is stored for just that battery, while information unique to each GROUP is stored solely for that GROUP. Figure 1 shows the QUERY/45 structure for the battery data base.

The box labeled BATTERY represents its namesake's data set. The items in that box are stored once for each entry in the BATTERY data set. There is one entry in the BATTERY data set for each battery in the data base. The box labeled GROUP represents the GROUP data set. There is one entry (containing the items listed in the box) for each GROUP of batteries in the data base. The line drawn



from GROUP_ID in the GROUP data set to GROUP_ID in the BATTERY data set indicates that the GROUP data set acts as an index to the BATTERY data set.

Think about how you could find all batteries in a particular GROUP (for example, when you need to measure them). One way would be to search the entire BATTERY data set for each serial number in the GROUP. This method isn't bad if the BATTERY data set is small, but in this case the data set can contain 24 000 entries. Using IMAGE/45 and the indexing structure, one may gain direct access to all the BATTERY data set entries for a particular GROUP. If one wants to work with the batteries in a particular set, he can gain access to the SETS data set to ascertain what GROUPS are in that SET. The previously described method is then used to obtain the desired BATTERY entries.

Most the programs described in the accompanying article are extensions to QUERY/45. The mechanism for implementing a QUERY/45 extension is to write the main program as a subroutine that follows certain QUERY/45 strictures. Such extensions do not have to open or close the data base, because that is done by QUERY/45 automatically. QUERY/45 also possesses a search capability that allows selection of a subset of data prior to activating the extension.

Extension programs have access to a set of utility subroutines. These routines permit WGL to write measurement software that is entirely menu-driven, with full screen editing capabilities. This is especially important when writing routines for people not technically oriented. For example, program BOXER handles BATTERY shipments and requires only four inputs from the user. Without screen editing, one is forced to ask each question in sequence – and superfluous dialog between man and machine may be required.

All input screens and menus appear on the display screen as the result of three programs. The first, written by WGL, puts a character string anywhere on the screen and offers highlighting features (underlining, blinking, or inverse video). The second, provided by QUERY/45, displays the menu options. The third, also from QUERY/45, reads a field anywhere on the screen. Continuity is maintained because each extension uses the same subroutines that QUERY/45 uses.

There is one program written without QUERY/45 that should be noted. BARC (Battery data ARChival) opens two data bases at once and is used to transfer data between them. The program was developed because of a need to remove periodically batteries from the active data base to make room for new batteries about to be tested. The solution was to create archive data bases, indentical in structure to active data bases, and then transfer batteries that have completed processing to the archive base. An advantage of this method is that QUERY/45 or WGL programs can still be used to manipulate this second base – no new programming is required. □

THE WORLD'S SMALLEST WATCH

Japanese watch quality in ICs

by Hisahide Nakagawa
with John Monahan

この記事はシチズン時計株式会社に於ける水晶腕時計用ICの電気的特性測定の測定からデータ処理を自動的に行なうシステムの一例を紹介します。

中川寿英

The fact that one of the world's biggest manufacturers of wristwatches also makes perhaps the world's smallest watch is attributable to one of the all-time electronic marvels.

The Citizen Watch Company of Tokyo, Japan, manufactures about 28 million wristwatches a year, 47% of which are quartz watches. Among this staggering number is a watch staggeringly small: the "Exceed Gold" model – a midget compared with one thin American dime – is the smallest wristwatch in the world, says its maker.

The keys to such huge production levels, as well as to such a diminutive size, are the integrated circuit (IC) chips that control the operation of the quartz watches. For this reason, the Quality Measurement Section of Citizen is centrally important, because it is charged with testing samples of ICs developed for new products to determine whether they are satisfatory. If the ICs do not meet Citizen's quality standards, the section must analyze the causes for failure and find a solution.

The section's quality efforts don't stop there, however. Its third job is studying the properties of ICs used in watches sold by other companies in order to compare the quality of those chips to that the Tokyo firm.

A desktop computer system is indispensible to the section's efforts for one important reason: it saves time. And time eventually converts into money, because using properly working ICs in the first place circumvents the need for design alterations and prevents the production of watches that possess inferior ICs and cannot be sold.

The Quality Measurement Section evaluates 20 or more properties from five samples of each IC type. On the face of it, this doesn't sound like such a lengthy process, until one understands that the temperature and humidity test takes an average 40 hours when performed by humans. Under the manual system, one technician completed just three to four evaluations a month.

Another problem stemming from the manual system was that it took a long time to find the cause of a failure. Production methods had to be re-evaluated and revised, and once a "fix" was found, numerous trial-and-error procedures were needed to verify that the solution really worked. For these reasons, the decision was made to convert to automated measurement and data processing. The question then became: what kind of computer to buy?

After an intense investigation, Citizen decided on a desktop computer; specifically, the Hewlett-Packard 9845T Computer System. The reasons are probably well-known to regular *Keyboard* readers. First, the 9845T is easy to program in BASIC language, according to company workers, who opine that even a non-professional can create a program on it. Similarly, they say, the I/O control on the 9845 makes it easy to connect measurement devices to the computer.

The company was also attracted to the 9845 for its graphics capability. Graphics, it was felt, would speed up data processing by providing information in the form of charts and graphs — and as you will see, automatic data processing dropped evaluation time from 35 to 45 hours down to one-half to five hours.

The 9845's function is two-part: to control the test environment, and then to make measurements. For temperature or humidity controlling, a thermostatic oven that can be operated directly by varying voltages of two power sources is used: +1.00V input = −40°C, and +5.00V input = +80°C. Similarly, the humidity can be changed continuously: +1.00V input = 20%, and +5.00V input = 100%.

For measuring, the 9845 operates the HP 6130C power source that is connected to a test socket of the IC. The minimum operating voltage Ven (V) of the IC is calculated by inputting voltage and reading — through the use of the HP 5370A Universal Counter — the resultant frequency. Start voltage or Vst (V) is calculated from this data.

Other calculations require somewhat different methods. Current consumption IDD(μA) is calculated by sending voltage across a datum resistor at 1.55 (V). The frequency deviation ∂F/F (ppm) from a standard reference frequency is calculated by the 9845 using the output of the 5370A counter. This value shows how much the frequency of the IC deviates from the reference frequency. The value of ∂F/∂V (ppm) is calculated by the ∂F/F (ppm) both at 1.45V and 1.55V.

The values Ven(V), Vst(V), Idd(μA), ∂F/F (ppm), and ∂F/∂V, which are fundamental values of the IC, are measured automatically for the five samples by the HP 3495A Scanner, controlled by the 9845. For temperature tests, these measurements are taken at five-degree intervals between −20°C and 80°C, and stored in the HP 9895A Flexible Disc. Next, these values are graphed and plotted for each IC (volts on the Y axis, temperature on the X.) A report is also provided.

The five-degree temperature sweep from −20°C to 80°C is completed in 10 hours (overnight), although these parameters may be changed freely. Humidity tests are conducted the same way that temperature tests are.

Since the full implementation of the system, evaluation capability has increased by a factor of 10. More reliable evaluations are now made, which contributes to enhanced quality in Citizen watches, in the opinion of the company. Moreover, the system enables the Quality Measurement Section to analyze products of other companies, in order to determine the veracity of their claims.

Software development occurred in two steps. A summary of the process is provided in this table:

	Before Introduction	1st Step	2nd Step
Outline of Measurement	• Manual Measurement • Manual Data Processing	• Manual Measurement • Automatic Data Processing	• Automatic Measurement • Automatic Data Processing
Implementation of the System		1 to 3 months after introduction	7 to 8 months after introduction
Data Evaluating Time (Measurement & Data Processing)	35 to 45 hours	17 to 21 hours	0.5 to 5 hours
Number of Measurements	3 to 4	[illegible]	[illegible]

Nakagawa-san had no experience writing software, and so he attended a three-day BASIC programming course about the 9845 offered by Yokogawa Hewlett-Packard (YHP). He also studied the rudiments of the system while at home. His first step was to automate the processing of data; the 50 programs he eventually wrote were completed within three months after his first course.

He now seems to possess the kind of quiet pride peculiar to persons who learn by doing. He says, for instance, that the first graphic representations he produced were full size (frame-size), but later he reduced them 30% to a demure size more befitting official reports. He even joined a guild of other craftsmen: he became a member of the YHP Basic User's Club, where he obtained the least-squares polynominal curve fitting software and curve construction programs he incorporated into his own work.

These, he says, plus indexing and tabling techniques, enabled him to reduce report generation time by 50%. He used these stitches in time to make the data acquisition system, step two.

Here he encountered some trouble with noise and data transfer, but managed to solve the problems in four months. This was when the current system actually became effective, although another four months were needed to collect enough data for testing it. During this period he further improved his original programs.

Technician at IC test system checks quality.

As for the future, Nakagawa-san says there is still a lot more software he wants to create. However, he's not so concerned with being 'on the leading edge of technology,' as the line goes. Rather, he says, "I think that the most important thing is to do my job effectively, so I intend to create software useful to me, rather than highly sophisticated software."

One may finally point out that the better he does his job, the better his company (and country) prospers. Perhaps a lesson about quality resides there — one made in Japan.

Hisahide Nakagawa is chief engineer in the Development Division of Citizen Watch Company, Ltd. He wishes to express his thanks for help received from Yasue-san and Kin-san, as well as the sales and service departments, of YHP.

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Tanashi City
Tokyo, 188 Japan

□

U.S. team skiis without

SNOW

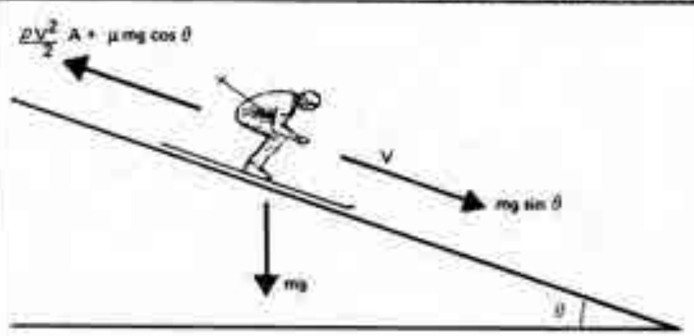
by Dr. George Skinner

For the past two years, as part of their pre-season training, the downhillers on the United States ski team have been improving their form by "skiing" in a wind tunnel. Supported on a drag balance in a 55 mph wind, the athletes study the effects of their body positions on aerodynamic drag. In this way they can fine-tune the aerodynamics of not only their basic "tuck" positions, but those positions taken on turns and bumpy terrain to attain higher speeds — thereby shaving off those few hundredths of a second absolutely critical to an Olympic competitor.

The originator of the wind tunnel workshop is Dr. Michael Holden, principal aerodynamicist with the Calspan Corporation of Buffalo, New York, U.S.A., and a certified skiing instructor (among other accomplishments). The workshop takes place in a facility designed to study atmospheric boundary-layer phenomena such as dispersal of pollutants, wind effects on high-rise buildings, and pedestrian-level winds in the vicinity of such buildings.

For the workshop, certain devices are removed from the tunnel, and it is operated at full speed. This speed, about 55 mph, is close to the average speed of a downhill run and typical of the speeds at which the tuck position can be held with relative ease.

The experiments are set up so that the skiers themselves can directly observe and evaluate their performance. Information, both verbal and visual, has to be passed to the skier standing on the wind tunnel balance. First a cable is run under the skier's suit from one ankle to the helmet, which is equipped with headphones and a microscope, so that Dr. Holden can communicate with the skier once he or she steps into the bindings and the wind begins.



V = SKIER'S SPEED ≈ WIND VELOCITY
m = SKIER'S MASS
g = ACCN. OF GRAVITY
θ = SKI-SLOPE ANGLE (=0 IN THE TUNNEL)
μ = COEFFICIENT OF FRICTION
ρ = AIR DENSITY
A = EFFECTIVE DRAG AREA (WIND DRAG = $\frac{\rho V^2}{2} A$)

IN THE EQUATIONS:

β = $\rho A/m$
V_0 = INITIAL SPEED AT START OF SIMULATED "RUN"
V_t^2 = $2g(\sin\theta - \mu\cos\theta)/\beta$
x = DISTANCE FROM START OF SIMULATED "RUN"
t = TIME TO COVER THE DISTANCE x

Secondly, the skier's drag in pounds is displayed on a digital voltmeter (DVM) mounted in a fairing some small distance ahead of the athlete. With his head in the usual racing position, the skier can thus see the effects of small bodily changes.

Thirdly, two television cameras are set up, one to show a head-on view, the other a side view. Either view can be shown to the skier inside the tunnel or an adviser outside it. Another DVM, visible from the side, shows drag in pounds. The DVM's readings, plus of course the skier's performance, are recorded on video tape.

Fourthly, the skier's stance is documented by three automatic Hasselblad cameras that photograph from the front (with a long-focus lens located far upstream in the wind tunnel), from the side, and from overhead. The resultant pictures are valuable references throughout the World Cup season.

This year a new feature was added, one that the skiers find invaluable: a display that shows just how much time they are picking up when they improve their tuck position. The HP 9825 Computer System does the computation every half second, then sends the result to a DVM beside a television monitor beneath the tunnel's floor. To better grasp how this is done, it is necessary to examine briefly what might be called the theory of the accelerating skier.

The skier leaves the gate or turn with a speed V_0. He goes into a tuck to reduce aerodynamic drag and pick up speed as quickly as possible. The differential equation of the motion is:

$$m\frac{dv}{dt} = mg\sin\Theta - (\rho V^2 A/2 + \mu\, mg\cos\Theta) \qquad (1)$$

It is assumed that the skier holds his stance throughout the acceleration run, so that his effective drag area remains constant. The differential equation for his velocity at any distance from the initial point where his speed was V_0 can be solved as:

$$V^2 = (V_0^2 - V_t^2)\exp(-\beta x) + V_t^2 \qquad (2)$$

The quantity V_0 is the terminal velocity he would ultimately reach.

One can now relate elapsed time to distance run by noting that $dt = dx/V$. Equation (2) gives V in terms of x. Integrating from 0 to x, one gets this result:

$$t = (2/\beta V_t)\left[\tanh^{-1}\sqrt{1 - (1 - V_0^2/V_t^2)\exp(-\beta x)} - \tanh^{-1}(V_0/V_t)\right] \qquad (3)$$

which one can readily solve for x as a function of t. The hyperbolic functions must be written in terms of exponentials, and the inverse hyperbolic functions in terms of natural logarithms for programming on the 9825.

The tunnel wind speed is not necessarily related to the skier's speed. Together with the drag measurement, it yields the skier's effective drag area with which to calculate β. To compare two tuck positions, one first measures β_1, in the poorer position. When the skier settles into an improved tuck, β_2 is measured and the calculation is started on the 9825.

First entered into the computer are the parameters relevant to the case under study. The 9825 then watches the DVM that reads the output of the drag balance that supports the skier. A running average, with a suitable time constant, is continually calculated and displayed.

When a skier is settled on his first position, the stop key (on the 9825) is hit, saving the averaged drag reading. Dr. Holden then discusses improvements with the athlete. When a lower drag has been established, another special function key is hit. The skier then sees, alongside his television monitor, a DVM showing the time he is gaining, updated every half second.

For each half-second interval, the computer calculates how far the skier would have gone in his original tuck position. It then calculates how long it would take in the improved position. The time difference is the gain in time accomplished by the skier.

The skier's drag is not actually read throughout the run. His average drag in the first half second is used for the calculation.

The result is an evaluation that is much more meaningful to the skier than simply a measurement of drag, although he does have that displayed before him as well. He studies the drag as he works with his position; the system gives him a reasonably realistic appraisal of what it really means in time. All the skiers relate well to this procedure, one reason being, perhaps, the straightforward nature of the hardware.

The drag balance supporting the platform on which the skier places his skis is a conventional wind tunnel strain-gauge balance, oriented to use its most sensitive direction to measure drag. The skier's drag, which at 55 mph may run in the neighborhood of 40 lbs when he stands up, drops into the 10 to 15 lb range when he adopts a good tuck position. Some skiers can even get below 10 lbs at 55 mph.

The strain-gauge output is conditioned by a solid-state amplifier that includes an analog filter to remove fluctuations caused by the skier's movements. Some experienced athletes are very steady and cause little fluctuation on the balance output. Other skiers move about quite a bit, and it has been found that a time constant of about five seconds works best for reducing fluctuations.

The processed drag signal, still in analog form, goes to a DVM (placed in front of one of the television cameras), to another DVM on the wind tunnel floor (where the skier can see it), and finally to another DVM connected to the 9825 through a BCD interface. To output data from the computer to the skier's display, an HP 98032A 16-bit Parallel Interface is used.

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Because a display that would decode a binary output was not available, a DAC-02 seven-bit D/A converter is used to send back an analog signal to the DVM mounted alongside the skier's television monitor beneath the floor of the tunnel. None of this represents an ideal system, but one must take into account that it is all done with the donated time of a couple of engineers and a few technicians, a small contribution from the U.S. Ski Team, and the donated use of the Arvin/Calspan Atmospheric Simulation facility. The skiers seem to appreciate this appropriate use of advanced technology, and that is all that counts.

The 9825 is, of course, used in other kinds of investigations. It was originally purchased to acquire and plot data in the Calspan Atmospheric Simulation Facility when the capabilities of previous equipment, the HP 65 and HP 67, were exceeded. It is normally used to acquire data from a mass spectrometer (actually a modified helium leak detector) used as a gas analyzer to study the dispersal of pollutants from industrial plants.

Dispersal of SO_2 from large power plants, steel-making facilities, and other industrial operations has been investigated, as has the dispersal of CO from cars on highways, and the re-ingestion of exhaust gases in gas-turbine power plants. The 9825 was the principal component of a digital, three-dimensional, constant-temperature, hot-wire anemometer used to chart the wind field around a model of the Trestle Facility at Kirtland Air Force Base, Albuquerque, New Mexico, where multi-million dollar aircraft are rolled out on a wooden trestle and subjected to electromagnetic impulses.

The same anemometer arrangement has been used to explore the velocity fields in aircraft gas-turbine compressors operating in, or near, rotating stall conditions. The computer has also acquired calibration data for balances used to mount models in hypersonic shock tunnels, where, for example, a lot of work on the Space Shuttle has been done. Most recently, the 9825 was interfaced with the NAVCOR data system used on these shock tunnels, to relieve peak loads on the regular data-reduction system.

Completing these kinds of applications provided the expertise needed for the U.S. Ski Team project. It has been a pleasure to see the enthusiasm in these athletes when they experience the results that come about when serious research engineers turn their talents and equipment to the skiers' special needs.

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