Energy and Technology Review

ABOUT THE COVER

Four frames of the framing camera record of an electric gun experiment. The gun electrically explodes a metal foil that drives a plastic flyer up a barrel to strike a target. The camera is directly in line with the barrel but behind the target, a two-step plexiglass block. The flashes from foil explosion and target impact diffuse through the block. Clockwise from the upper left the frames record: (1) foil explosion, (2) flyer acceleration, (3) flyer impact on the first plexiglass step, and (4) flyer impact on the second step. For a description of the electric gun and its applications, see the article beginning on p. 1.

Scientific Editor: Robert W. Selden
General Editors: Richard B. Crawford
Kent L. Cummings
Judyth K. Prono

BRIEFS

ii

SCIENCE AND TECHNOLOGY

Electric Gun: A Versatile Tool for Studying Explosive Initiation

1

Our electric gun permits us to study explosive initiation and other shock-induced phenomena with a convenience and flexibility never before achieved.

Microcomputers and Computer Networks

4

Inexpensive modular microcomputers are taking over more and more routine chores in controlling operations on the Laboratory's Octopus network. The benefits include faster, more convenient computation and a large saving in user time.

Preferred Parts Concept: Making Metric Conversion Pay

9

Metric conversion is forcing a new look at the proliferated industrial standards for stock items; LLL's preferred parts strategy is helping to pinpoint duplication, streamline stocking and ordering, and save money.

NOTES AND REFERENCES

12

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Livermore, California 94550

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Briefs

The short items on these pages announce recent developments of importance. Some of these items may be amplified in future issues; none of this material is reported elsewhere in this issue.

PROGRESS IN GEOTHERMAL PROGRAM

Two significant experiments have been completed that verify our total flow concept for utilizing the high-temperature, high-salinity geothermal resources of California's Imperial Valley. The first laboratory test run of a total-flow impulse turbine has been completed; early results indicate a minimum engine efficiency of about 45%. This verifies the technical feasibility of our turbine concept and indicates that more advanced designs may achieve efficiencies in the 60 to 65% range. It also confirms the credibility of maintaining our research goal of 70% engine efficiency.

In field experiments during August, encouraging progress was also made toward solving a major problem: scale formation. Addition of hydrochloric acid to the brine before it was expanded through titanium-alloy nozzles prevented scale deposits over the 24-h test periods. Typical wells in the area produce brines hotter than 200°C with up to 30 wt% dissolved solids. Deposits from these dissolved solids have previously clogged pipes and equipment within a few hours of operation.

In these tests on a relatively shallow — 850 m — well, reducing pH to levels over the range of 5.0 to 1.6 eliminated scale in the nozzles used to expand the brine. Scale accumulation in downstream components — stationary wear blades and elbows that simulate turbine blades and chamber — was drastically reduced. Titration of the brine indicates that the cost of the hydrochloric acid needed for a brine pH of 4 would be about 0.5 mil/kWh, well within economic feasibility.

The titanium alloy (Ti-6Al-4V) used for the nozzles and wear blades showed no visible evidence of corrosion or erosion. Several titanium-alloy specimens stressed to their yield strength and exposed to the low-pH brine were found intact after the test with no evidence of stress corrosion cracking. These results indicate the titanium alloys, in particular Ti-6Al-4V, hold promise as candidates for brine-tolerant systems.

As expected, we also found that pH reduction stabilizes the colloidal suspension of mineral solids that form while the brine cools. This is expected to delay or prevent the destruction of a reinjection reservoir's porosity that would be expected if large quantities of precipitated solids were injected. This will be an important factor in establishing the long-term viability of disposing of spent fluids by reinjection.

These test results in experiments on scale control, materials evaluation, and the mechanical performance of a simple total flow turbine are encouraging. Together they indicate that complete brine-tolerant systems based on our total flow concept are realizable

for utilizing the hot, highly saline brines in the Imperial Valley. It is also evident that much of these results will be applicable to other conversion systems and other geothermal resources as well.

In the illustration on page 8 of the July issue, Figures 5c and 5d are transposed. The blackish solution is in the process of being oxidized, the green solution indicates complete oxidation.

LITHIUM-WATER-AIR BATTERY PROGRAM

LLL has been granted funds by the Energy Conservation and Storage Division of ERDA for a two-year study into the feasibility of using a lithium-water-air mechanically rechargeable battery in automotive propulsion. Pending signing of a contract, matching funds (\$300,000) will be given to Lockheed Missiles and Space Corporation, co-researchers in the project.

LLL began fundamental research into the kinetics of the lithium electrode in February. Our initial studies show that high coulometric efficiency (greater than 90%) can be obtained over a wider range of system parameters (electrolyte temperature, concentration, and flow rate) than previously believed. In addition, early results suggest that a conventional plane-parallel electrode configuration may be used, rather than the novel cell configuration of the batteries studied. Currently, a new lithium production technique using a lithium-mercury amalgam separating an aqueous cell from a low-temperature (200°C) fused salt cell is being investigated.

OZONE DEPLETION: CONCLUSIONS UNCERTAIN

The uncertainties in predicting the effects of nitrogen oxides on the thickness of the ultraviolet screen provided by stratospheric ozone have been significantly underestimated. These uncertainties arise from the lack of precise measurements for the rates of many stratospheric chemical reactions.

By simultaneously assuming unlikely but possible rate constants for as few as five of the 42 major reactions, we can show computationally that nitrogen

oxides from a fleet of supersonic transports could increase rather than decrease the ozone screen. (The assumed rate constants are within the range of uncertainty estimated by the National Bureau of Standards.) We are not predicting such an increase, but rather taking note of the ambiguities that still exist in stratospheric analyses. Further research to measure these key reaction rates and hence to make more precise analyses possible is necessary.

These findings are a result of LLL involvement in the Federal Aviation Administration's High-Altitude Pollution Program designed to prevent unacceptable environmental effects due to stratospheric flight by quantitatively determining the requirements for reduced aircraft engine emissions. The program incorporates a number of related activities: modeling, field and laboratory measurements, engine and fuel assessment, and monitoring. We are contributing numerical modeling of the atmospheric response to airplane effluents, using both previously gathered data and data resulting from current monitoring.

Stratospheric chemistry is so complex that attempts to forecast the effects of introducing new chemicals (such as nitrogen oxides) must be done computationally. We have applied a variety of

computer models to this problem for several years, particularly with regard to the ozone depletion problem. In addition, we have used actual measurements of the stratosphere and its contents to evaluate the validity of models. Calculations done in our studies have produced results that fall within the ranges of measured ambient concentrations of chemical species in the stratosphere.

To test the uncertainty problem more directly, we have examined the effects of altering chemical reaction rates used in the model. The basic idea was to determine which rates would most strongly influence a computational prediction of the results of injecting nitrogen oxides into the stratosphere (for example, by supersonic transport flights).

Of the 42 main chemical reactions, 5 involving hydrogen oxides were found to have the greatest effect but the least well-known reaction rates. Hydrogen oxides exist naturally and are known to destroy ozone; however, they also interfere with the ozone-destroying effect of nitrogen oxides.

Precise measurements are needed to allow accurate estimates of ozone depletions. Meanwhile, our calculations underscore the range of effects that may result from present uncertainties.

Fig. 1. Schematic of the electric gun showing the placement of foil-flyer laminate, barrel, high-explosive target, and target holder.

SCIENCE AND TECHNOLOGY

THE ELECTRIC GUN: A VERSATILE TOOL FOR STUDYING EXPLOSIVE INITIATION

The convenience, flexibility, and low cost of our electric gun has made it possible to perform over 900 explosive-initiation experiments in the past year. We have achieved flyer velocities in excess of 14 km/s and peak pressures in the range 1 to 160 GPa (10 kbar to 1.6 Mbar) in the explosives studied. The system's simplicity and reproducibility make it attractive as standard shock-sensitivity test for explosives as well as a useful tool in diagnostics development and equation-of-state studies.

Over the past ten years we have developed a simple, inexpensive tool for studying initiation properties of explosives — the electric gun.¹ The gun operates by electrically exploding a metal foil that accelerates a plastic flyer plate or plastic-metal laminate to high velocity. Impact with a target produces a well-characterized shock.

Studies of explosive initiation require a pressure pulse of known amplitude and duration. This pressure pulse results in the detonation of the explosive, and the character of the pulse determines the character of the initiation — the promptness, the raggedness, the divergence, and so on. The two principal methods of producing these pulses are the gap test, in which a shock wave is driven through a barrier into an explosive, and the flyer-plate experiment, in which a flyer is driven to impact an explosive.

A disadvantage of the gap test is that it produces a rather complex pressure pulse. The hydrodynamic flow is divergent, and the fall in pressure behind the shock depends on the geometry of the barrier-explosive system rather than on the way the pulse is produced. Flyer impact methods, on the other hand, produce pressure pulses that are easily characterized. However, the traditional means of accelerating flyer plates — with gas guns or explosive plane-wave lenses — are time-consuming and require the use of expensive facilities.

Our electric gun combines the advantages of producing well-defined pressure pulses with experimental convenience and low cost. In performing over 900 shots this past year, we have achieved flyer

velocities of between 0.5 and 14 km/s with pulse widths of 5 ns to 1 μ s, producing peak impact pressures of 1 to 160 GPa (10 kbar to 1.6 Mbar). The wide ranges of pulse widths and impact pressures produced by the electric gun have enabled us to study a wide range of explosive shock sensitivities.

The electric gun also has unique capabilities for other types of studies. We have used this system extensively for diagnostics development, including development of the VISAR² laser velocity interferometer and electrical and optical pin³ development. We also think it has excellent potential in equation-of-state studies.

The Electric Gun

A schematic of the gun is shown in Fig. 1. Its physical concept is simple. A capacitor bank discharges a high-current pulse through a foil bridge, causing it to explode. The burst pressure accelerates the flyer up the barrel to strike the target pellet.

There are many parameters involved in this simple procedure, leading to many possible ways of producing input pressure pulses in the target explosive. The pulse produced by flyer impact on an explosive target is a function of flyer velocity, mass, and geometry. Flyer velocity depends on its own mass, the pressure driving it created by the bursting foil, and the barrel length.

The exploding foil element used in our gun is aluminum and varies in area from 25 cm² down to 0.09 mm². Foil thickness varies from 2 to 51 μ m. The flyer plates are usually made from a film of Mylar (polyethylene terephthalate), which may have any thickness between 0.025 and 2.5 mm. The flyer film separates the exploding foil and the barrel. The foil's explosion punches out a section of the Mylar film, creating the flyer plate, and drives the plate up the barrel against the target. The exploding foil is made at least as wide as the barrel diameter to keep the pressure that accelerates the flyer as uniform as possible. We can vary both foil and flyer dimensions to achieve a specific impact area, pressure magnitude, or duration of the pressure pulse.

Figure 2 shows the gun in use as the foil bursts. The energy source is 56- μ F, 40-nH capacitor bank connected to the gun's foil-flyer laminate by a

✓
Contact Richard C. Weingart (Ext. 8381) for further information on this article.

flat-conductor transmission line. Charging voltages vary from 5 to 40 kV.

We make velocity measurements with a plexiglass impact block (step flasher) as the target. The two halves of block surface are parallel but at different heights. A streak camera records the flyer impact on both surfaces (steps), and we compute the flyer velocity from the difference in the two impact times.

Figure 3 shows a framing camera record of a typical step-flasher shot. The framing camera is mounted in the position normally occupied by the streak camera, that is, it views the face of the target directly opposite flyer impact. In frame 1 we see the back of the target at foil burst time. The flash at the left is burst gas jetting around the flyer. In frames 2 through 4 the flyer is accelerating. Frame 5 shows the impact flash when the flyer hits the closer step. Frame 6 shows the impact flash after the flyer hits the farther step.

Flyer velocity is dependent on burst current density, which creates the pressure that causes the acceleration. To a certain point, the greater the current density the

greater the burst pressure produced and the greater the acceleration for a particular foil and flyer.

Flyers continue to accelerate as they move up the barrel. Barrel length, therefore, can control the range of velocities obtained, but there are practical limits to maximum and minimum barrel lengths. Maximum length is limited by the instabilities that destroy flyer planarity. Minimum length is limited by two factors: the requisite impact pressure and the flyer velocity dependence on capacitor bank charging voltage. If the barrel is too short, the impact pressure is only slightly greater than the burst pressure pushing the flyer, producing a poorly defined pulse. Also, in a properly sized barrel, the capacitor bank charging voltage will control flyer velocity at higher voltages; making the barrel too short sacrifices this control.

Initiation Studies

In our electric gun initiation experiments, we impact thin flyers on high-explosive targets and determine the flyer velocity threshold required to initiate detonation.

Fig. 2. Electric gun in use as the foil bursts. Styrofoam blocks surround the gun. The streak camera is mounted out of view, above the gun. The green, boardlike structure through two-thirds of the picture is the flat-conductor transmission line.

Fig. 3. Framing camera record of a typical step-flasher shot. The flare at the left of each frame is burst gas jetting around the flyer. The notch in the upper right is caused by an obstruction in the light path. Frame 1 shows the back of the target at foil burst time; frames 2 through 4 show the interval when the flyer is accelerating along the barrel. In frame 5 the flash indicates that the flyer has struck the first step. By frame 6 the flyer has already struck the second step, and its flash is over.

To detect detonation breakout, we coat the target face seen by the streak camera with a thin coat of aluminum silicafluoride, a porous compound that gives a bright flash when shocked in air at about 20 GPa (200 kbar) or more.

The range of flyer velocities available from a given foil-flyer laminate determines which explosives can be studied. Most of our work has been with TATB (1,3,5-triamino; 2,4,6-trinitrobenzene), a relatively insensitive explosive requiring high impact pressures. TATB requires a high-energy laminate based on a 51- μ m-thick aluminum foil whose width and length are equal to the barrel diameter. With a 0.25-mm flyer thickness, the high-energy laminate gives flyer velocities in the range of 1.5 to 14 km/s.

The lowest flyer velocity attainable with the high-energy laminate, however, is too high to probe the initiation threshold of the more sensitive explosives. We therefore developed a low-energy laminate by using 13- μ m-thick aluminum foil and a

51- μ m-thick flyer. This laminate gives flyer velocities in the range of 0.5 to 2 km/s when used with a 0.25-mm-long barrel; with it we have studied the initiation threshold of the relatively sensitive PETN (pentaerythritol tetranitrate).

In practice, we can calibrate flyer impact velocity against either burst current density or capacitor bank charging voltage. Burst current density is more directly related to flyer velocity, but bank charging voltages are more easily and accurately measured. For routine experiments, therefore, we usually measure a bank charging voltage threshold for initiation, which we can convert to a velocity threshold by comparison to the step-flasher data. We routinely monitor current on each shot, however, so either a voltage or current calibration can be used. Experimental scatter is about the same with either.

During the past year we conducted over 900 initiation experiments with the electric gun. These experiments were conveniently performed in a small

steel tank in the laboratory. After an experiment, we had only to sweep out the debris before setting up for the next shot.

We impacted flyers on the relatively sensitive PETN to explore the upper range of electric gun shock sensitivities, and we observed flyer thickness and diameter effects on the relatively insensitive TATB. We studied flyer velocity effects on PBX-9404 and demonstrated the ease with which the electric gun can be used to study liquid explosives by impacting flyers on nitromethane.

Other Studies

The electric gun was very helpful in developing the VISAR laser velocity interferometer. In these experiments, we could view the flyers directly or monitor the jump-off of a thin target that had been struck by the flyer plate.

Electrically driven flyers have also been used to generate high-pressure, planar shocks for use in electrical and optical pin development.

As a third application, equation-of-state studies can be conducted conveniently with the electric gun. If the flyer's shock behavior (i.e., its Hugoniot) is known, the target Hugoniot can be determined by measuring the target's free-surface velocities at various flyer velocities. Mylar flyers have been accelerated to velocities in excess of 14 km/s, so equation-of-state studies can be conducted up into the 100-GPa (1-Mbar) range. For equation-of-state studies on hazardous materials, the entire system could be contained in a glovebox environment.

An intriguing area of current interest is modeling flyer acceleration with a one-dimensional hydrodynamics code to test the equation of state of the exploding foil material at low densities and high pressures. Electrical measurements of power delivered to the foil are input to the code. The validity of the calculation can be checked by comparing the code output with VISAR measurements of flyer velocity vs time.

Key Words: electric gun; explosive initiation; flyer plate tests; shock testing.

MICROCOMPUTERS AND COMPUTER NETWORKS

Computers, for all their speed and efficiency, have their foibles and failings. Until the advent of minicomputers, users often had to personally supervise their programs to make sure they executed correctly. Minicomputers could take over some of these chores, but they were too expensive to be dedicated to any but the most vital services. Inexpensive, easily programmed microcomputers are easing this limitation, permitting a flood of new applications.

For all their speed, computers can take a long time to finish a series of tasks in a time-sharing environment like the LLL Octopus network. Not only that, but they often need help in the form of operator responses. Sometimes they even get amnesia, forgetting a particular program and going off to another unrelated task. This can force computer users to stay at their terminals or to log in frequently to keep their programs running. It even became a standard, not very funny joke: "You're not waiting, you're time-sharing."

The original way to avoid this frequent, trivial

monitoring was to set up a controller program as a stand-in. Such controllers could perform all the command functions of a user at a terminal, and they became very complex and sophisticated. Being in the computer themselves, however, they were still at the mercy of the computer's lapses; they could themselves be ignored and forgotten.

The next step was to substitute an external minicomputer for the user. The minicomputer would log in every so often to check the status of problems under its supervision and restart them if need be. It could also be programmed to analyze the messages it received from the various programs and decide what to do next.

One of the first of these minicomputer applications at LLL was an operating system monitor called Lifeguard. It was designed to control a number of programs that gathered statistics and information on Octopus. Any little mechanical or electronic flaw in the computer can shut it down. This used to interrupt the continuity of these data until an operator could come around and restart the programs. With Lifeguard the restart could be instantaneous, maintaining continuity.

✓
Contact Jerry L. Owens (Ext. 7941) for further information on this article.

MODULAR MICROCOMPUTERS

A microcomputer consists of a set of micrologic cards, each performing a single logical function, inserted into a common interconnection chassis. The modular design makes it possible to design each microcomputer for a specific job; low cost makes it feasible. Individual micrologic cards act as central processors, input/output interfaces, and memory units.

The heart of the microcomputer system, the processor, is a programmable, general-purpose integrated circuit equivalent to the central processing unit of a conventional computer. The integrated circuit is an inexpensive semiconductor chip a few millimetres on a side containing thousands of logic-function elements (gates).

The other major functional element of a computer system — memory — is also available on chips in two general types: random-access read/write memory (RAM) and read-only memory (ROM). Of particular importance is the PROM, a programmable read-only memory that can be erased and reprogrammed as required. The PROM is often credited with making microprocessors practical by providing this kind of semipermanent memory, thus allowing program modification after debugging.⁴

The modular design of these microcomputers makes them especially adaptable as auxiliaries to our Octopus network. It minimizes down time by reducing maintenance to a simple matter of replacing plug-in circuit cards. It also makes it possible to design each microcomputer for a specific job, and to order the basic modules in large enough quantities to make the price attractive. It even makes it possible to incorporate advanced components as they become available, upgrading performance at little cost.

Lifeguard has proved its value in more than three years of successful operation. It has unlimited patience, running the same sequence of programs over and over every few minutes or hours around the clock. It never needs coffee breaks or vacations, and seldom takes sick leave. However, such a dedicated minicomputer is too expensive for any but the most vital services.

The development of inexpensive microcomputers (see box above) opened up a wide range of new monitoring applications. Some are mere conveniences, others perform yeoman feats of endurance and vigilance. In one way or another, however, each

improves the reliability of computation, reduces the chances for error, and frees computer users for more creative tasks.

The microcomputer occupies about as much space as the standard teletypewriter input/output unit and connects directly to it (Fig. 4). The two operate as a unit, the microcomputer accepting instructions from the teletypewriter and relaying to it error messages and requests for information received from the Octopus network of computers. The microcomputer also substitutes for the teletypewriter, interacting directly with the network.

Fig. 4. Microcomputer installed beside a teletypewriter input/output terminal. The microcomputer's cover is opened to show the modular, interchangeable printed circuit cards. The flat ribbons are flexible multiconductor cables that permit portions of the circuitry to be swung out for trouble shooting while still in operation. Note the absence of controls on the microcomputer. The key switch controls the power. All other controls and commands are entered through the teletypewriter.

Microcomputer Services

The first microcomputer attached to an Octopus line was a dispatcher to operate a background production system. During time-sharing hours (8 a.m. to 5 p.m. weekdays), Octopus uses an auction bidding system to

determine user priority (see box below). To keep the machine busy during occasional slack periods, it allows background jobs to be bid in at a very low priority. There is no guarantee that these jobs will be run, but users willingly try it anyway to conserve their credit.

OCTOPUS: LLL TIME-SHARING SYSTEM

The Octopus network allows individual users at over a thousand input/output terminals to simultaneously enter programs on the four large 7600 computers and receive results. The highly simplified diagram below indicates the network's general arrangement. The interconnections are two-way communication links carrying commands, instructions, data, tables, graphs, and many other kinds of information.

With so many users entering programs simultaneously, it is essential to establish a system of priorities to expedite important jobs and yet give less important jobs at least a portion of the computer's attention. On Octopus this priority system takes the form of an auction. Each computer user receives a daily allotment of computer time. Every time he requests a computation he must give an estimate of the running time and state the rate at which time is to be charged. A person with an allotment of 10 minutes can run a 20-minute program by assigning a rate of 0.5. A user who is willing to spend a full minute from his allotment for every minute of running time (a rate of 1) would take precedence, however, and his program would be completed much more quickly. A user with a large allotment and an urgent need could assign an even higher rate, up to 3.

With individual users submitting background jobs to separate computers, each of the four CDC 7600 computers in Octopus was keeping its own list of background jobs. It could happen that one 7600 would be idle while the others still had a backlog. With the microcomputer Dispatcher coordinating all background jobs, the work load is shared. Dispatcher forms a common job list, keeps several jobs active on each machine, and starts up new jobs as others are completed.

After our success with Dispatcher, we programmed a second microcomputer (Dispatcher 2) to do the same thing for normal (priority 1) production. This has the advantage of making it easier for a production program to retrieve its files from the trillion-bit IBM mass storage (photostore) that forms the Octopus long-term memory. During production hours (5 p.m. to 8 a.m. weekdays and over the weekend), the photostore is often shut down for short intervals, especially during its daily maintenance period (4 a.m. to 7 a.m.). If a production code tries to read information while the photostore is down, it gets only an error message. Before Dispatcher 2, the program could either wait, holding up all other jobs in its batch stream, or suspend operation until an operator determined that the photostore was once again available. Either option wasted machine operating time.

Now, Dispatcher 2 starts to retrieve the needed files as soon as it gets the job. Spreading these requests over a long time makes the photostore, from a user's point of view, 100% reliable.

Another advantage of Dispatcher 2 is that it processes error messages according to the needs and desires of each user group. This places responsibility for providing the most graceful mode of recovery on the person programming the microcomputer rather than on the computer operator. The alternative would be to teach each of LLL's 150 computer operators all the different error recovery procedures necessary for each of our production programs.

Production programs also write files and send them to the photostore. This could create a problem when the latter is down; the files may have nowhere to go. To solve this problem we created Filing Clerk, a microcomputer with its own user number. Filing Clerk accepts files from the production programs, together with instructions on where and how to file them. It holds the files in temporary storage, keeps a close watch on the photostore, and transfers files to long-term memory whenever it gets the chance.

This procedure has greatly simplified the logic in production programs. Each program formerly contained its own version of a filing clerk, and there were occasional conflicts. Now we have only one Filing Clerk, quietly and efficiently serving all.

There are, however, potential problems with the Filing Clerk approach. For one, a long shutdown of the photostore might make too many files accumulate under Filing Clerk's user number. Defensive programming takes care of this problem; the microcomputer checks the number of files under its care, how much space they occupy, and how long the photostore has been down. If any of these numbers exceeds its present limit, it transfers the files onto tape and erases them from disc. Later, when the photostore recovers, it reverses the process.

Another potential problem is the possibility of losing files temporarily entrusted to Filing Clerk. In one and a half years of operation, this has only happened during a "dead start without files" — an event that wipes out all temporary storage. Now, in the usual case of an intentional dead start without files, the operations staff can command Filing Clerk to transfer all waiting files onto tape beforehand.

Figure 5 indicates how Filing Clerk's services have been put to use. The annual volume of files transferred has shown a steadily accelerating increase from 15 000

Fig. 5. User acceptance of the microcomputer Filing Clerk, showing annual volume of files transferred as a function of time. Evidently neither the demand for nor the capacity of the system is approaching a limit.

at the beginning to over 25 000 so far this year, and demand shows no sign of leveling off.

In still another application, we have designed a microcomputer policeman, or Micro Cop. Like most operating systems, Octopus has a set of rules for allocating computer time, made more complex in our case by bidding. As in most auctions, the bidders sometimes get carried away, using up their credit early in the day. Although the operating system itself has always had rules restricting access to the machines and setting time limits on certain uses, it had no procedures for controlling bidding levels.

We are now using Micro Cop to monitor the bidding process and enforce sanctions against rule breakers, e.g., by setting their bank accounts to zero for a short time to remind them that they have been violating agreed-upon rules. Micro Cop is currently monitoring only the 7600-S machine that specializes in large production jobs and very large time-sharing problems. This approach to priority rule enforcement appears to be working well.

A Language for Microcomputers

If a microcomputer is to take over some of the functions of a person at a terminal, it needs an easy method, i.e., a command language, in which to receive instructions. Our answer to this need is OWL (Octopus working language). OWL reduces by a factor of twenty the time to implement one of the new microcomputer programs.

In designing OWL, we were constrained by the limited memory of the microcomputer. This forced us to use very short commands, consisting of just two characters apiece. Such short commands are sometimes hard to remember; the characters chosen may bear scant relationship to the message. On the other hand, they make for a very short dictionary. In practice the two-character commands have caused little real hardship.

Among its other advantages, OWL makes debugging and modifying programs easy and direct. Its primitive commands direct surprisingly complex actions: searching a large string of characters for a smaller string of characters and branching to a new instruction if the string is or is not found, calling in subroutines, breaking a string at a specified character or joining strings, and moving strings from place to place in the memory or off to a working computer. The versatility

provided by this type of command language is one of the best ways to keep our microcomputers flexible.

Future Directions

As we review current microcomputer applications, it is easy to see many possibilities for further improvements. Some of these have already been through preliminary testing, others are now being designed, still others are just ideas.

For example, we now have one microcomputer whose function is to make sure the jobs assigned to other microcomputers are being accomplished and to notify an operator if for any reason they are not. Thus we have a primitive three-level task group: a microsupervisor who reports to a human supervisor when one of its subordinates is malfunctioning. We plan to upgrade the performance of this system by programming the microsupervisor to take over from the failing microcomputer in most cases, and to call in human help only when absolutely necessary.

As another example, we plan to use a microcomputer to improve communication between our CDC Star-100 computer and the rest of the Octopus network. Eventually we expect to purchase file transport hardware to exchange files back and forth. In the meantime, we can program a microcomputer to transfer Star files onto tape and transmit them to the 7600 computers, or vice versa. When the commercial file-transport system arrives, this microcomputer system can be switched over to make use of it without any changes in our production programs.

As a final example, we plan to add a voice to our microcomputers to facilitate communication with program originators. We already have microcomputers that signal for help from an operator when they encounter an abnormal situation beyond their capabilities. Sometimes the operator is also unable to deal with the situation and must consult with the program originator. Programming the microcomputer to dial the originator's phone number and to deliver a direct verbal report would relieve the computer operators of this time-consuming chore.

Key Words: integrated circuits; microcomputers; minicomputers; multiple-access computer systems; Octopus system; time sharing.

PREFERRED PARTS CONCEPT: MAKING METRIC CONVERSION PAY

Stocking unnecessary standard components costs this country uncounted millions of dollars annually. Metric conversion is forcing a new look at these proliferated industrial standards, which typically contain two to ten times more varieties than necessary. The preferred parts concept, which grew out of an LLL effort to make an orderly metric changeover, gives engineering design groups a systematic way to pinpoint duplication, weed out unnecessary varieties, and streamline ordering and stocking procedures. The prospective savings from applying our preferred-parts strategy could pay for the costs of metricizing many times over.

When General Motors decided to develop a new in-house metric standard for fan belts a few years ago, it discovered that its engine designers were selecting from over 500 different fan belt sizes. The company immediately cut all but 150 sizes and limited its new standard to no more than 50. The direct and indirect savings from these changes were more than enough to finance the conversion to a metric standard.

This GM story illustrates an increasingly common experience within American industry. One business after another is discovering that it has been working with two to ten times too many standard varieties of stock items. How has this proliferation come about? One answer lies in our private, voluntary, full-consensus system for creating industrial standards.

Committees of volunteer experts meet infrequently to establish these standards. No one is in a position to completely overhaul his committee's work; there is barely enough time to consider the minor changes (almost always additions) that come up. Any proposal to delete standards risks antagonizing the manufacturers on whom consensus depends. Thus, although it has the advantage of ensuring industrial acceptance, this system by its very nature results in a piecemeal effort, with no overall perspective.

The need for design freedom at the project level is another source of proliferation. Individual designers can be depended upon to make rational selections from the variety of stock items available to them, but no two sets of selections will be the same. When hundreds of designers are selecting independently, even the less-popular items will be used occasionally, thereby "justifying" keeping them in stock.

These conflicting needs — for design freedom and for avoiding irrational proliferation of design specifications — create a dilemma. We need to take a hard look at existing standards; someone must take charge, resolve conflicting viewpoints, and provide rational direction. No one wants to create a central authority to arbitrarily dictate industrial standards, but some form of control during the application process is indispensable to avoid excessive stock inventories.

One solution to this dilemma is the preferred parts approach, a concept developed at LLL in support of an orderly metric changeover and now gaining acceptance in many other design laboratories. It goes back some years to a study into the best way to ease the transition from conventional to metric standard parts. At the time, we were stocking 27 sizes of nuts and bolts, which were to be replaced by about 14 metric sizes.

Twenty-seven different sizes may not sound like much of a problem until you realize that each size has an average of 40 variations (Fig. 6). Brass, steel, stainless steel, cadmium-plated steel, hex head, round head, Phillips head, socket head, all with their own range of lengths — this variety added up to well over a thousand bins for nonmetric nuts and bolts. During the transition we would need to stock both metric and nonmetric parts; that would mean another 600 bins. Where could we find the room?

The answer was that we could make room by throwing out all sizes not really needed. Careful study and consultation with representatives of engineering, design, technician, and shop groups convinced the proponents of this solution that 16 sizes would adequately cover all the Laboratory's normal needs. The other 11 were superfluous.

To demonstrate the redundancy of these 11 "nonpreferred" sizes, we asked four Mechanical Engineering design groups to continue to select whatever fastener was best for their designs but to consider the preferred list first. Each group was given a notebook and asked to record any nonpreferred selection and why it was appropriate. One year later, not one of the four notebooks contained a single entry.

The beauty of the LLL preferred parts approach is that it allows everyone concerned to work with about as much freedom as before. Nonpreferred parts are not abolished by fiat, they are placed on probation. Those that experience shows to be superfluous can then be dropped with minimal fuss.

✓
Contact Jack W. Pearson (Ext. 8573) for further information about this article.

Fig. 6. Sampling of the variations available for a single bolt, here a 1/4-20. Differences in head geometry, fabrication material, and length result in a multiplicity of stock items.

With the success of this demonstration, the larger implications of part redundancy began to be apparent. The LLL/LBL General Stores stocks about 28 000 different items, ranging from tiny set screws to massive transformers, from paperclips to computers. How many of these are really needed? How many could we do without and how much would we save?

No one knows, and it will take years to find out, but there are encouraging signs along the way. The new national metric standard for metal raw stock contains 200 varieties instead of the former 2000, a 90% reduction. National committees on metric conversion have brought about similar reductions for other industrial stock items. "O" rings, a common elastomer seal, have gone from 368 to 148 varieties, a 60% reduction. Self-tapping screws have been reduced 90%.

One of the big reasons for these reductions is that the new standards are rationalized. The old standards were frequently based on a simple arithmetic series of sizes: 1, 2, 3, 4 in., for example. The problem is that there is a much bigger proportional step between one and two than there is between nine and ten. It is more rational to have sizes increase by a regular proportion: $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, 4, 8, etc. Then each size can be twice as strong (or stiff, or heavy, or some other characteristic) as the one before.

In practice, however, factor-of-two steps are sometimes too large. For metal raw stocks, LLL has adopted a basic number series that provides steps of about 60% between members. It runs 1, 1.6, 2.5, 4, 6, 10, 16, 25, 40, etc., and can be extended indefinitely in either direction. If still smaller steps are

required, they can be interpolated between the basic number series' steps.

Another reason for the reduction in metric stock items is that the new standards are unified. The old standards often consist of two or more families or series — independent sets of standards covering overlapping size ranges. Some series are tied to existing measurement systems; for example, a 1/4-20 brass screw has a 1/4-in. diameter and 20 threads to the inch. Other series are more arbitrary, being designated by numbers or letters that, by themselves, give no size information. A 10-24 brass screw, for instance, is essentially the same size as a 1/4-20 but has 24 threads to the inch; the 10 has no dimensional significance. Some series are even numbered backward with zero or double zero for the largest size, progressing to larger numbers for the small sizes.

Metric conversion offers an opportunity to replace this hodgepodge of standards with a single, unified, rational system. When other laboratories heard about our success with nuts and bolts, they started similar programs of their own. Along with the kinds of savings we experienced, they turned up additional sources of waste and confusion. Some of these are even more striking.

For example, Sandia Laboratories, Albuquerque, chose to study electrical resistors because they are widely used, readily separated into families, and covered by several redundant specifications. Furthermore, Bendix Corporation and other suppliers identify resistors with their own numbers. In one resistor family, Sandia investigators found 14 duplicates. In all, they had some 15 000 individual

specifications, of which 11 000 were duplications; there were really only 4000 different resistors.

As a result of this study, Sandia now has an interactive computer search program keeping track of parts specifications and ordering. This program is producing six-figure savings annually on resistors alone, and Sandia is beginning to apply it to capacitors and other standard parts. The field is wide open; at last count some 80 000 commercial parts had been defined, and no one knows how many are duplicates.

Meanwhile, an Ad Hoc Preferred Parts Committee consisting of representatives of Sandia Livermore, Lawrence Berkeley Laboratory, Stanford Linear Accelerator, and LLL is working to extend the preferred parts concept to other areas. Its work with the recently adopted B32 national metric raw-stock metals standard resulted in large reductions of raw metals stock variety at both LBL and LLL. The

committee has also been able to eliminate several raw materials that were hardly ever used and to find substitutes for others. It is now looking into ways to coordinate purchasing among the various ERDA laboratories — based on a common, agreed-upon list of preferred parts — for even greater savings.

The Preferred Parts Committee's main work, however, is still managing the introduction of metric industrial standards, which are coming with or without all of our cooperation. What seems to some an onerous burden, to be resisted tooth and claw, is to the committee a golden opportunity: a chance for a new look at old ways, a clean slate on which to write rules that make sense.

Key Words: metric conversion; preferred parts concept; specifications — design; standards — industrial.

Notes and References

1. R. Weingart, R. Lee, R. Jackson, and N. Parker, *Acceleration of Thin Flyers by Exploding Metal Foils: Application to Initiation Studies*, Lawrence Livermore Laboratory, Rept. UCRL-77610 (1976).
2. N. Parker, *Velocity Measurement of Mylar Flyers Using the VISAR*, Lawrence Livermore Laboratory, Rept. UCID-16846 (1975).
3. L. Shaw, R. Donaldson, J. Murchie, and T. Ramos, "Nanosecond Hydrodynamics Diagnostics Using Fiber Optic Probes and a Streaking Camera," to be printed in *Proceedings 12th International Congress on High-Speed Photography, Toronto, 1976*.
4. For a more complete description of modular microcomputers, see the March 1976 *Energy and Technology Review* (52000-76-3), p. 12.