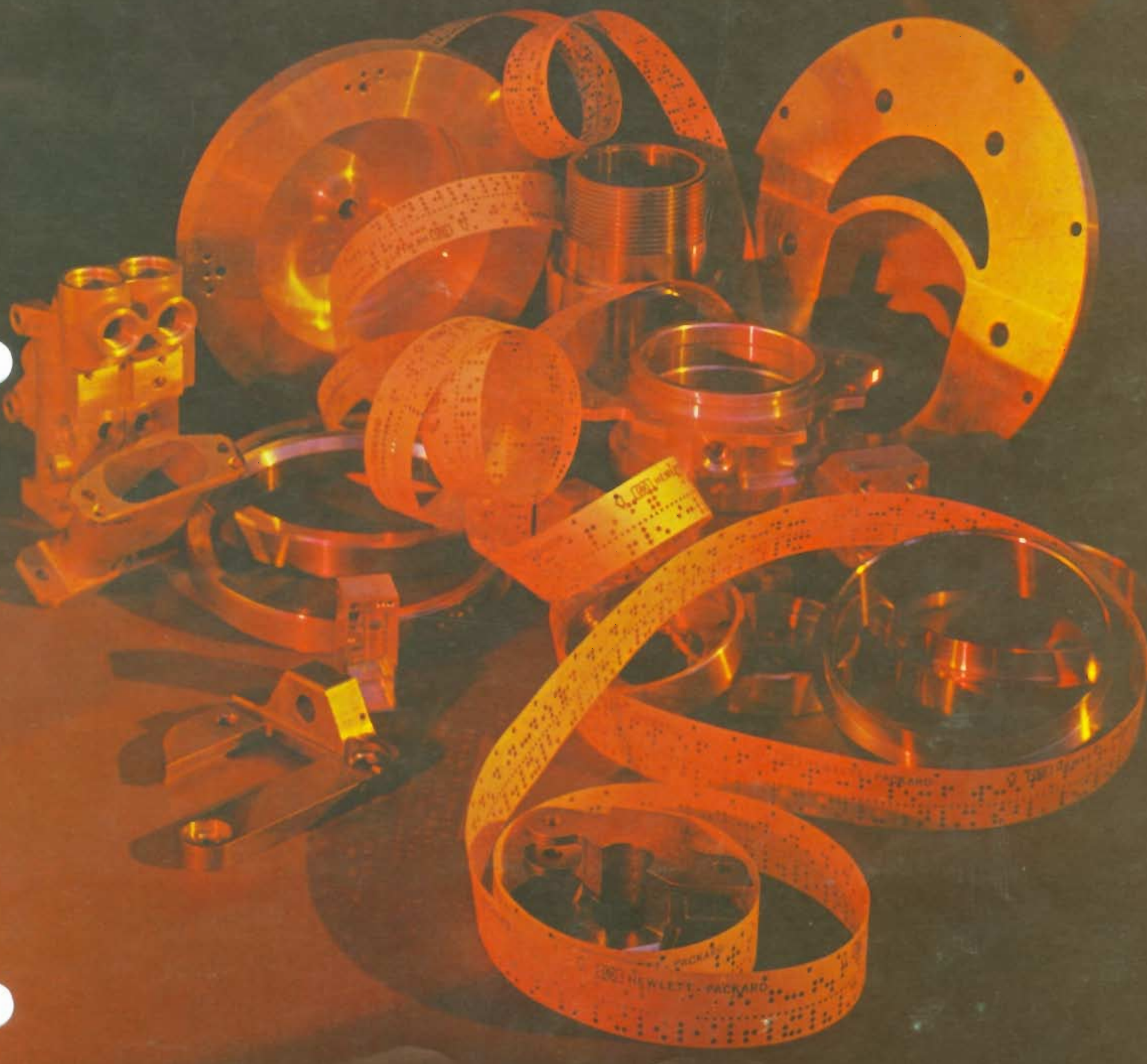
HEWLETT-PACKARD

KEYBOARD

VOL. 8 NO. 1



OVERVIEW

John Nairn's column, "The Crossroads," will not appear in this issue. John is a member of the team that worked on the HP 9825A Calculator, and as both product introduction time and *KEYBOARD* deadline time came nearer, it became obvious "The Crossroads" must go the way of all second priorities when first priorities are reaching zenith. John promises us his full attention when "The Crossroads" continues in the next issue.

For 1976 we hope to bring you a good, balanced magazine -- balanced between articles of high technical content and those of a more relaxed, let's-have-fun-for-a-change substance; among all the varied applications our calculators are used for; and among the several HP desktop programmable calculators you are using. If you have comments on the kind of magazine that would help you the most, please write. We're always happy to hear from you, and we'll give all suggestions serious consideration.

Nancy Sorensen

**APPLICATIONS INFORMATION
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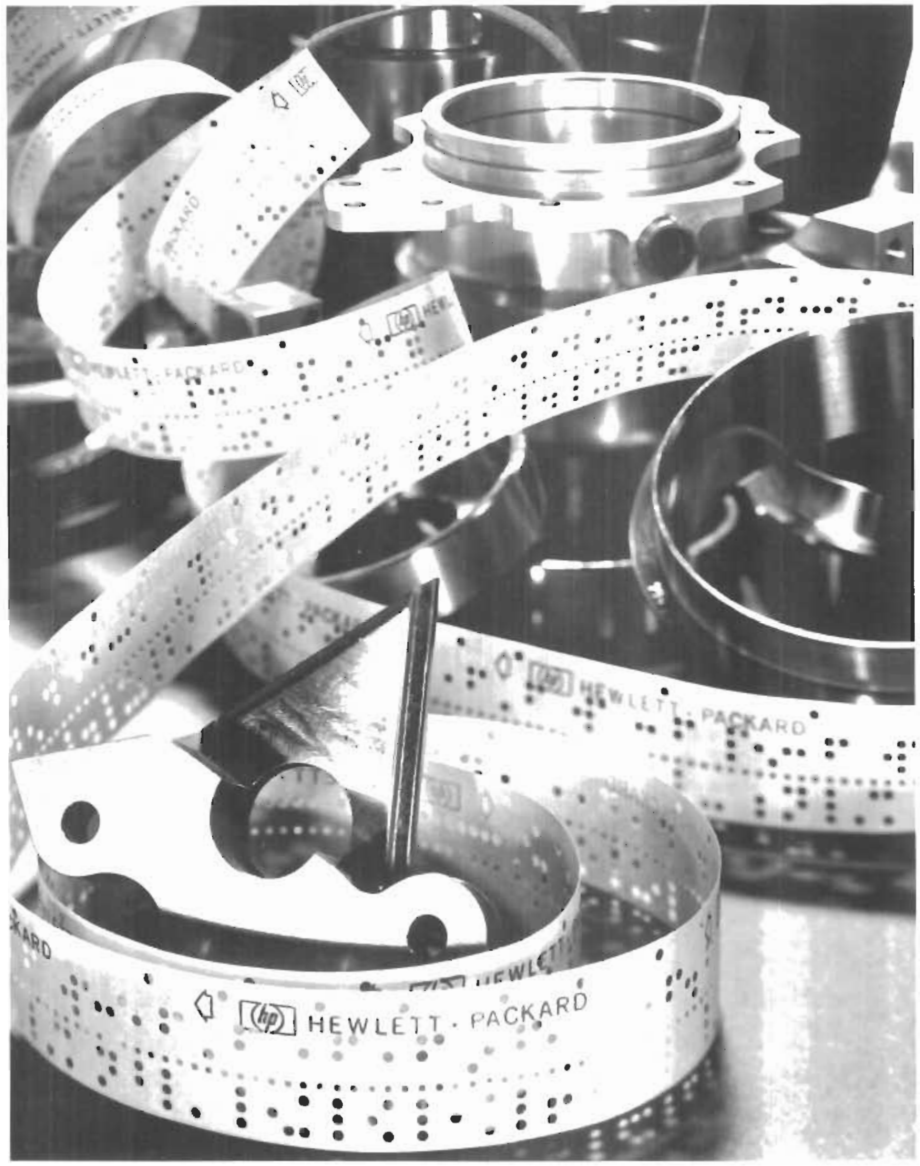
Low Cost CAD/CAM



CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) are usually thought of as being available only to those companies that own or have access to computers. But for the small-to-medium sized N/C machine tool shop dealing with small job lots and special designs, or custom fabricators working with unusual components, a computer may not be the most cost-effective answer. The following articles are by Richard Buerk and Mark Wallace who find the HP 9820A Calculator not only as good as, but better than, a computer for their use.

CURRICULUM VITAE

Dick Buerk admits to a "checkered" past. He holds an AB from Princeton (1956), an MA from Delaware (1958), both in physchology, and an MBA from the University of Buffalo (1967) in economics and marketing. He also is a Certified Manufacturing Engineer. He is a member of AAAS, SME, and NCS, and is a contributing member of the 9820/21 Calculator Users Club. He speaks a "weak" BASIC and once labored with FORTRAN for his MBA thesis. Dick is the General Manager and Programmer for Buerk Tool and also does electronic maintenance. And he finds time to advise the County Executive and his Commissioner on mental health matters.

Mark Wallace is a graduate of Bradley University where he received a BS and MS in Civil Engineering in 1967. He spent the next five years working as a project engineer for a prime contractor in the Naval Nuclear Program. In 1972 he joined Ionics, Incorporated as a design engineer and is now responsible for all ASME Code section III (nuclear) design work done by Ionics. Mark is a registered professional engineer in the state of Pennsylvania. He is the author of an article which appeared in the December/January 1975 issue of NC Commline on the use of the 9820 for direct preparation of N/C tapes.

IONICS, INCORPORATED

by Mark P. Wallace

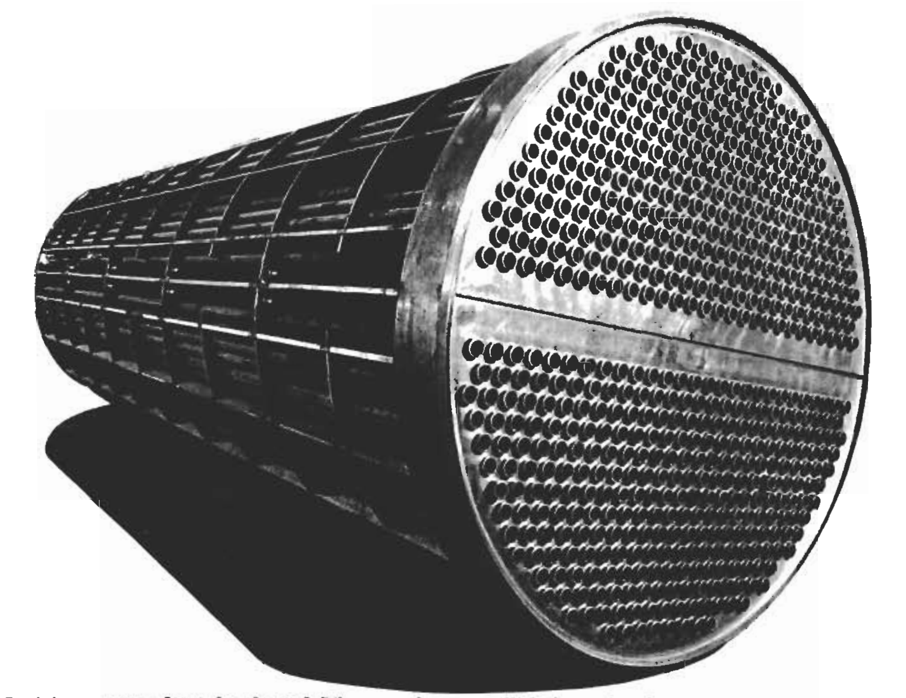
Ionics, Incorporated, located in Bridgeville, Pennsylvania, is a fabricator of custom weldments. Chief among these are nuclear grade components, specially designed heat transfer equipment such as recuperators, and fired heaters and out-of-the-ordinary products for commercial industries. This wide spectrum of activity dictates that productivity be optimized in all areas, since each order is unique and product standardization is impossible.

For the past three years, Ionics has utilized a 9820 in four basic areas; estimating, design, layout, and direct N/C tape preparation.

ESTIMATING

A recurring type of job at Ionics is the design and fabrication of special water demineralizers and makeup tanks for nuclear power plants. Because these items can be described by a series of well-defined parameters, it is possible, by a statistical analysis of past orders and the use of current work standards, to prepare a program to estimate costs. One of the spinoff advantages of this program occurs when the customer specifies performance requirements rather than physical dimensions. This allows Ionics to examine several alternate configurations and to offer the customer the best buy for his money.

Because the preparation of a typed estimate only takes 4 1/2 minutes, Ionics is also able to offer customers accurate figures they need for preparing budget proposals. Not only does the machine assist customer relations, it also frees estimating personnel so they have more time to devote to complicated proposals.



Ionic's program for tube sheet drilling requires very little input by the operator. The paper tape punched can be used directly by the N/C drill without being edited.

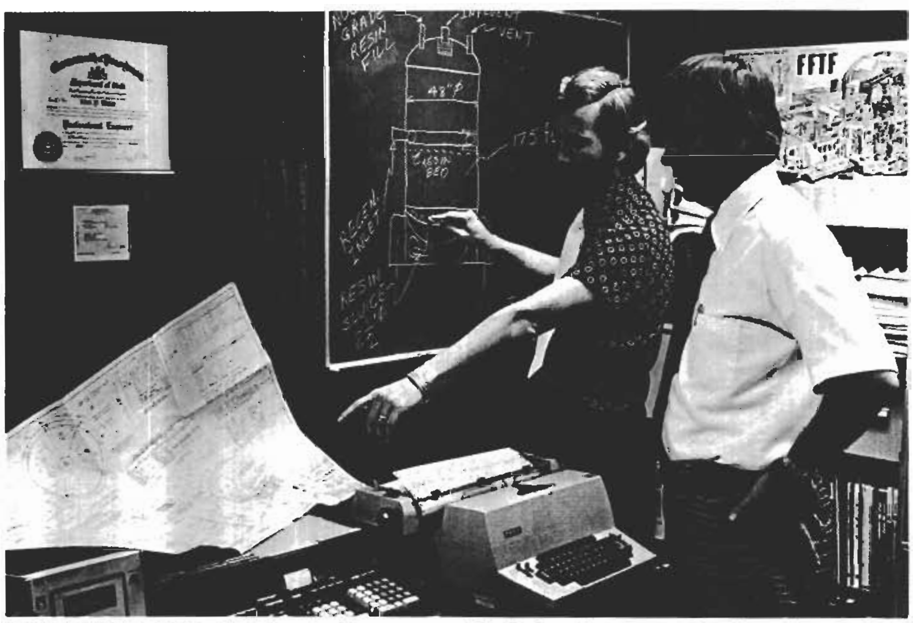
DESIGN

Many nuclear jobs require the manufacturer to perform design analyses to verify that the equipment furnished is capable of withstanding rigorous design conditions. Ionics has, therefore, prepared a series of programs to perform the required ASME Code calculations, seismic analyses of both vertical and horizontal tanks, and nozzle/head and nozzle/shell interaction analyses. In addition, structural optimization programs have been written for various support structures and TEMA Class heat exchanger tube sheets.

Since all custom heat transfer equipment design initiates as an indeterminate analysis, programs have been prepared to optimize the design of radiation recuperators and tubular heat exchangers.

All of these programs, including the optimization analyses, can be run in a matter of minutes. Outputs are fully formatted and typed and, if required, can be submitted directly to the customer for approval.

Although the time-saving advantages of the system of programs are obvious, one of the major benefits is that design engineers are freed from the normal drudgery of complex calculations. Thus more time is available to review the entire design and optimize it from the viewpoint of fabricability.



Mark Wallace, at the blackboard, discusses possible design changes to a demineralizer with Joe Zoftis, Manager of Industrial Water Conditioning Equipment. The 9820 System is used to determine the effect of these changes on the overall cost of the component.

LAYOUT

Since shop productivity is a key factor toward corporate profitability, another series of programs has been prepared to assist the shop in one of the more difficult tasks, layout.

These programs are:

- Ellipse generation for the intersection of a plate and cylinder
- X and Y coordinates of points on a bolt circle
- Tube sheet layout (used for non-critical applications)
- Bolt circle layout by arc length

- Cone geometry and layout by radii (nests multiple piece cones on one plate)
- Cone layout by offsets (used for large or shallow cones when the radii to be scribed are large)
- Hole template layout for any pipe/shell intersection
- Pipe cut template layout for any pipe/shell intersection

The program outputs used for layout are also fully formatted and typed so as to eliminate incorrect interpretation of the data.

DIRECT PREPARATION OF N/C TAPES

One of the more unusual uses to which the 9820 System is put by Ionics is the direct preparation of tapes for N/C mills. As an example, Ionics has written a program to make tapes for tube sheet drilling. The user need input only the following:

- The coordinates of the center of the item to be drilled relative to the origin of the machine table
- The maximum radius of the tube bundle
- The tube spacing (triangular pitch)

The program then computes:

- The maximum number of tube rows
- The correct number of tubes per row
- The exact coordinates, relative to the machine table of each hole

This N/C 2-axis machining center is drilling a template for a larger production part.

This information is then output onto the paper tape under such format controls that the tape can be used immediately with no editing required.

In order to make the program as flexible as possible, the following options are included in the program:

- The user can input the number of holes to be drilled before a programmed stop. This allows the machine operator to check tool wear on a planned basis.
- The user can input the number of the depth cam to be used as a drill stop.
- The user can specify a full spindle retract after each drilling operation. If this is not specified, the machine operator manually sets the retract gage height.
- The center hole can be skipped, if desired.
- The user can specify whether or not the positions of the holes are to be tabulated as typed output.
- The user can specify at what row he wishes the machine to stop if the full hole array is not required. In addition, the user can specify whether the last hole drilled under these conditions is to be an "end of block" or "end of program."
- The user can also specify X and Y limits such that only a portion (any portion) of the entire tube bundle configuration is output. If no special limits are specified, limits greater than the programmable area of the machine table are assumed.

The flexibility generated in the program makes it a simple matter to prepare a tape for a U-tube bundle configuration of any nonstandard array.

Aside from the obvious time savings associated with tape preparation (tapes can be made in minutes), there are other advantages. Because the machine does not make mistakes, preproduction piece inspection, debugging, and editing are eliminated and only spot inspection of production parts is required once a confidence level has been established.

Thus the minicomputer can be used in all phases of a technical operation. CAD/CAM is not limited only to those companies having access to large computer systems. The programs mentioned in this article are representative of the library of programs developed by Ionics, Incorporated. Many more are available for use, and others are constantly being added as new approaches are taken toward solving old problems.

BUERK TOOL AND MACHINE CORPORATION

by Richard K. Buerk

Buerk Tool and Machine Corporation was founded in 1918 to design and develop tooling for the Pierce-Arrow Motor Car Company and later for the "aeroplane" industry then centered in Buffalo, New York.

Today, Buerk Tool carries out five major overlapping functions:

- Tool making (jigs and fixtures)
- Contract machine building
- Job-lot machining
- Special development prototype building
- Casting and forging substitute machining

The 25-man precision manufacturer has no proprietary product. Its major markets are in air/space, graphic arts, health sciences, fluid and electronic controls, and recently, nuclear devices. Quantities run from 1 to 1500 per lot with many repeat orders.

Numerically controlled machine tools were first introduced in 1954, but it was not until the early 1960's that the use of N/C machines gained wide acceptance. Although computer-aided tape generating, verifying and editing came along a few years after N/C machine introduction, the great majority of tapes were generated in longhand. The tapes were manually punched, manually verified or tried out on each machine line for line, and manually edited. It was a slow and costly procedure.

Although Buerk Tool purchased its first N/C machine tool (a simple, two-dimensional, point-to-point model) in 1963, it was in 1973 that they received its first continuous-path machine tool - a lathe. Manual programming became so complicated it was obvious another method must be found.

With 25 men and only four N/C machines, neither the purchase of a large computer nor the rental of a computer terminal (time-share) to develop the needed control tapes could be justified. Buerk Tool is too small for computers and too large for the pencil-and-paper approach.

Tapes are edited and verified on the 9820 instead of tying up an expensive N/C machine tool such as this 3-axis machining center at Buerk.

Dick Buerk is shown preparing a program for one of the shop,s N/C machine tools. He appreciates the 9820's algebraic language, which makes software development an easy job.

By this time, HP had assembled its 9820 with the HP 9862A Plotter, HP 2895B Paper Tape Punch, HP 9863A Paper Tape Reader, and some straightforward software to high-speed verify N/C tapes and high-speed edit existing N/C tapes. Buerk Tool found the 9820 System to be a sound alternative.

With some coaching from HP's field and factory personnel, Buerk Tool developed the next step - a basic N/C tape generation program. Then came specific programs to generate tapes for each individual machine tool.

Because the language is algebraic, and therefore familiar to anyone who knows algebra, "doing business" with the 9820 is easy - one of the primary reasons Buerk Tool bought the system.

Now, by striking designated keys, given "words" can be programmed onto a tape. To call for a drill function, a single assigned alpha key is pressed to produce G81; another key is pressed to encode "end of program," or M02. Geometric positions or moves can be encoded by pressing X, Y, or Z, and then either the given value or the calculations leading to that quantity. Decimal points and required zeros are automatically located. Each line is printed, and if approved, one key is struck and the line is punched.

In addition to this single-line entry mode, various canned-cycle programs have been developed. One complicated lathe function is cutting threads. Buerk Tool has developed a program to make a complete thread cycle, requiring only the starting and finishing sizes to be input for both straight and taper threads. They also have developed a canned-cycle program to mill rectangular holes in grid patterns for pushbutton and other control details for the communications and electronic industries. And, like the Ionics software, another program automatically produces hole patterns for heat exchanger tube sheets.

Once tapes are generated, they are verified to insure proper moves and locations and to insure against collisions between the machine and the fixtures holding the part or the part itself - some of the machines cost more than $100,000. If errors are found, corrections are edited long before the tape reaches the shop. Costs are reduced because tryouts are done on the calculator system, not on the expensive and expensive-to-run machine tool.

The next area of cost benefit is in estimating. All N/C machines, plus additional standard machine tools, have 9820 programs to estimate machine times and costs. Buerk Tool has cut its turnaround time for estimating, which means better service for its customers and time saved by management.

Buerk Tool is considering the addition of some general ledger programs (available through HP); even higher speed tape preparation, verification, and editing with HP's 9865A External Tape Cassette; and moving into job costing, controls, and work status reports.

The flexibility of the 9820 System seems to match the flexibility of a "service type" manufacturer such as Buerk Tool.

One interesting note: 85% of N/C machine tools sold today are two-axis. Of these, most go into the medium-to-small firms, many too small to buy or rent (time-share) computers, but these firms could justify a 9800 System.

The finalized tape is loaded into the controller for an N/C machine.

The operator of a numerically controlled lathe inspects a part to see if it is within tolerance. Since the use of N/C machine tools eliminates human error, occasional spot checking for out-of-tolerance measurements due to tool wear is all that is needed.

Forum

Dear Editor:

The announcement of "Forum" as a new *KEYBOARD* feature came at the right moment for me. I think this column will be of great interest to your readers and may become as popular as the "Programming Tips" section.

Here is my question:

When the 9830A is used for work involving a choice of different options, the calculator usually displays a series of questions, each of which must be answered by the operator in order to allow program execution to continue. With programs of this type (for example, our "Textman" Editing/Bookkeeping System), similar sequences of questions may appear again and again, depending on the actual application. To avoid the impression of monotonous work, it would be nice if the calculator could be told to wait for input only a limited length of time (say 3 seconds), after which it should choose itself the most probable answer and immediately continue program execution. A program statement like "WAIT 3000 INPUT X" would be a boon to anyone concerned with conversational data input. For example, in evaluating a multiparameter function, an engineer may want to set parameter values by manual input from the keyboard; after each run of calculation, he would have to pay attention only to those parameters he wants to change at a time, since the machine could be programmed to continue automatically using the previously assigned numerical value for each parameter for which the respective question did not get a prompt reply.

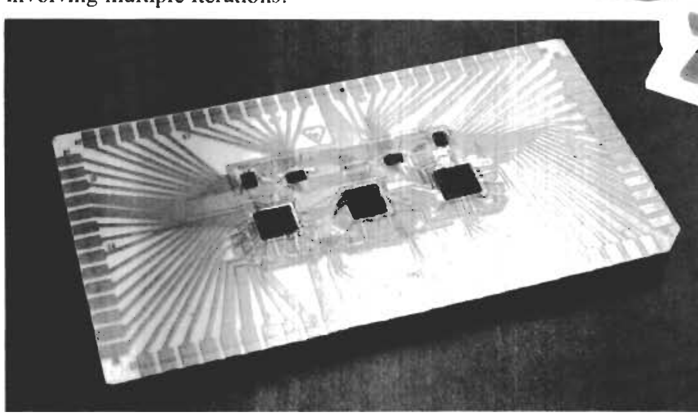
Has anyone found a method to make the 9830 react this way? The use of auxiliary questions such as "AUTO REPLY OK?" is not considered as a valid solution to the problem, because the operator would then be faced with even more routine questions than originally. If no actual 9830A user has a good solution, I would suggest that HP engineers note my question as a challenge for a future AP ROM.

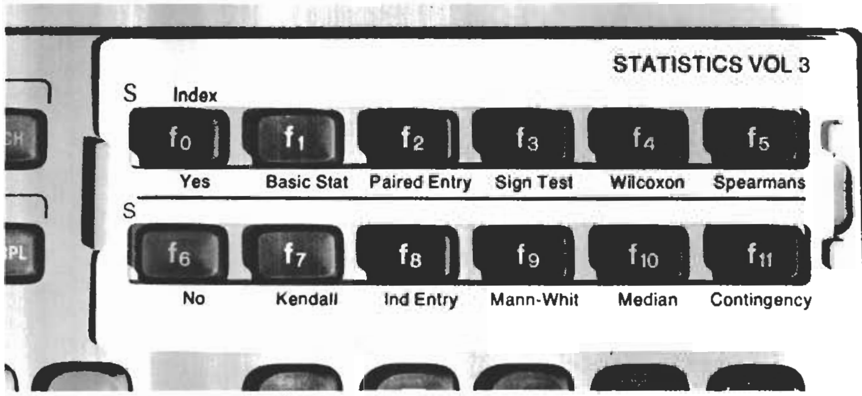
Prof. D. G. Maeder
22, Av. Louis Yung
Geneve, Suisse (Geneva, Switzerland)

Introducing the Hewlett-Packard 9825A

Hewlett-Packard announces a new programmable desktop calculator, the HP 9825A. This calculator is designed for a broad range of applications in the scientific and engineering fields and has particularly strong interfacing capabilities.

The 9825 is small and fast, two features made possible by state-of-the-art LSI circuits especially developed by Hewlett-Packard for this product. Weighing only 26 pounds and about the size of an attache case, it easily fits on a desk and is light enough to take on business trips. The problem solving speed of the 9825 is impressive. Compared to currently available calculators, it is from 2 to 20 times faster with an average speed increase of approximately 10 times. This increased speed allows the user to see results faster and is especially significant in solving problems involving multiple iterations.





The 9825 incorporates many new and unique features, but still maintains the friendliness and ease of use that we feel is important in the design of our calculators. It has a full alphanumeric keyboard with both upper- and lower-case characters, 12 Special Function keys, a number pad, and a set of line and character editing keys. Upper- and lower-case alphanumerics appear in the 32-character LED display and print on the built-in, 16-character thermal printer. Some Greek characters have been added for scientific notation, and some Europeam characters have been added for multilingual prompts and messages.

The 9825 uses a high-speed bidirectional data cartridge similar to that used in the 9815. However, speed and packing density are improved. The cartridge holds 250,000 bytes of information and has an average access time of about 6 seconds to any place on the tape. There is nearly instantaneous access to both programs and data; bidirectional search speed is 90 inches a second, and read/write memory is 22 inches a second.

The internal read/write memory starts at 6844 bytes and can be expanded up to a total of 31,420 bytes in 8192-byte steps. The entire memory of the calculator can be stored on a data cartridge, should it be needed for a higher priority project, and reloaded into the machine. Execution continues where it left off; there is no need to restart the program from the beginning.

This latest addition to our line of scientific and engineering calculators uses HPL. A high-level, formula-oriented language HPL offers you more power and efficiency for handling equations, data manipulation, and input/output operations. Although more powerful, much of HPL is compatible with the language of the 9820/9821. If you have programs for either the 9820 or 9821, you can upgrade them to the 9825 with little effort. Other HPL language features include:

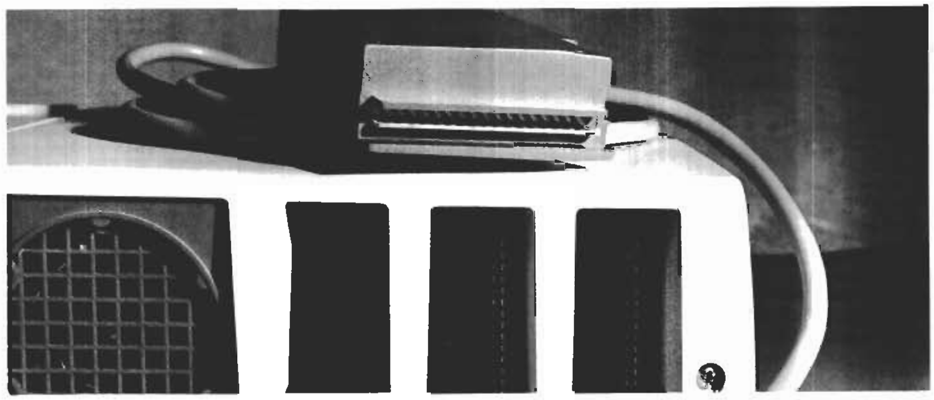
- Branching to either line numbers or labels, as defined by the user,
- Arrays of any dimension - one, two, or as many as the memory allows with dynamic dimensions, and user-defined upper and lower bounds,
- String handling to "humanize" programs by allowing alphanumeric input and output in addition to numbers,
- 26 simple variables from A to Z.

Program error correction is greatly simplified. When the 9825 detects an error, the appropriate error message is displayed, and when the RECALL key is pressed, the erroneous line is displayed with a flashing cursor at the point where the error occurred. With such a striaighforward indication of the problem, it is easy to correct the error and enter the proper syntax.

A completely new feature is the live keyboard; it is usable even while a program is running for calculations, to examine variables, or to change variables in the running program. For example, to find the log of 26 while the calculator is running a program, key in LOG 26, press EXECUTE, and 1.41 is displayed. Any problem that will fit in one 80-character line can be executed with the live keyboard.

A complete set of ROM's is available for the 9825: the String ROM, which provides strings and string arrays; the Advanced Programming ROM, which includes FOR-NEXT loops, parameter passing functions and subroutines, and a cross-reference generator; the Matrix ROM, which provides all the standard matrix operators plus a set of multidimensional array operators. The 9825's LSI processor allows a 40 x 40 matrix to be inverted in about 80 seconds, which is much faster than can be done on our previous 9800 Series calculators.

The Plotter ROM adds plotting capabilities for the HP 9862A Plotter, and the General I/O ROM adds complete fomatted read and write capabilities for all other external devices. The General I/O ROM permits data to be transferred at speeds of up to 16,000 bytes per second.

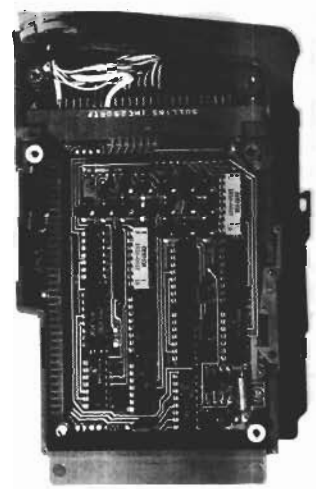


The Extended I/O ROM is the ultimate in flexibility and capability for interfacing to external devices. This ROM offers two levels of priority interrupt, buffered I/O for increasing throughput to external devices, complete HP-IB (conforms to IEEE Standard 488-1975) control, and a series of bit manipulation commands. It can transfer data via Direct Memory Access (DMA) at rates of up to 400k words per second. The Extended I/O ROM contains additional key features, such as a table for code conversion, auto restart, and error trapping.

The Plotter, General I/O, and Extended I/O ROM's are available in three combinations; Plotter - General I/O, General I/O - Extended I/O, and Plotter - General I/O, - Extended I/O.

There are three interface cards available for the 9825. The general-purpose, 16-bit parallel interface card connects to most of our standard peripherals and gives the user the option of interfacing to other devices. A BCD input card is available for connection to digital voltmeters and counters. The HP-IB interface card connects to HP-IB instruments and devices.

The 9825A Data Sheet, 5952-9017 (40), and the 9825A Brochure, 5952-9028(40), are available upon request. For literature, information, or a demonstration, please contact your local Hewlett-Packard sales office or check the reply card in this issue of *KEYBOARD*.



Coast Guard Uses 9830 in Harbor Study

by Marlene Disney, Hewlett-Packard Calculator Products Division

"Our job is to keep ships from hitting each other. . ."

. . . A somewhat oversimplified statement when applied to the task of maintaining safety and order in New York Harbor - the largest, busiest, and most complex port in the United States.

Until recently, ship-to-ship and ship-to-harbor communication and cooperation was the only regulatory aspect of traffic flow. Despite the best efforts of mariners and harbor personnel, accidents occurred at the rate of nearly 100 per year, and it was apparent that many could have been prevented if a controlled system existed.

In 1972, the U.S. Coast Guard stationed a staff of eleven on Governors Island to acquire data needed to design and implement a Vessel Traffic System (VTS) for the harbor.

First, they determined what data is needed to plan a system and what is required to generate traffic management techniques. At present, they are monitoring the harbor, gathering information on traffic density, conflict areas, arrival rates, communication density, and the physical and behavioral characteristics of 50 vessel types. The comprehensive data base also includes all the geographic, hydrographic, and environmental factors for each section of the harbor.

A Hewlett-Packard 9830A Calculator System assists in collecting and assimilating the data needed to establish safe and efficient traffic flow.

A U.S. Coast Guard spokesman has described the project as a building process beginning with the acquisition of the 9830 and development of simple programs by inexperienced operators. Today, the system includes the 9830 (8k memory), HP 9866A Printer, HP 9880B Mass Memory, and HP 9882A CRT Subsystem. The system has been used primarily as a data reduction device and as an aid in analyzing and presenting the data. The staff has become more confident and competent in operating the system and is using the massive data base in many ways.

Typical of any U.S. port is the above procedure for assisting large tankers. Efficient and safe traffic movement is also a common concern of the ports. The Vessel Traffic System being devised for New York Harbor will serve as a prototype for a National Traffic data base to assist each port in implementing its own VTS.

ACCIDENT ANALYSIS

Preventing marine accidents is a major concern to the Coast Guard. Since certain types of accidents are preventable by a VTS, an analysis of the 700 which have occurred in New York since mid-1968 was an initial use for the 9830. Information on each accident and whether it was determined preventable was compiled and stored, using the Practical File System. The program has since been rewritten using the Advanced Programming II ROM, which has greatly increased sorting speed and flexibility in the use of the data.

TV DATA RECORD

A time-lapse video recorder on a TV camera records 24 hours actual time onto an hour tape. The vessel count derived from the tape is divided into 11 categories, cross divided into one-hour increments, and stored (along with environmental data including tidal current, height of tide, general weather condition, wind, visibility, etc.) for use in calculating mean vessel densities at various sites and hours.

COMMUNICATIONS DATA ANALYSIS

Similar to the TV data analysis application is the storage of radio communications data. Transmissions are recorded, counted, timed, and separated into categories of users of a frequency. The data is used to determine the utility factor of the frequencies and project possible overloading of a channel.

SIMULATIONS

Routines have been written which simulate the present traffic at various channel junctions around the harbor, complete with random arrival times and various tracklines and vessel speeds. The output of this simulation is a listing of the number of "encounters" -meetings, crossings, and overtakings - that occur with a given traffic density.

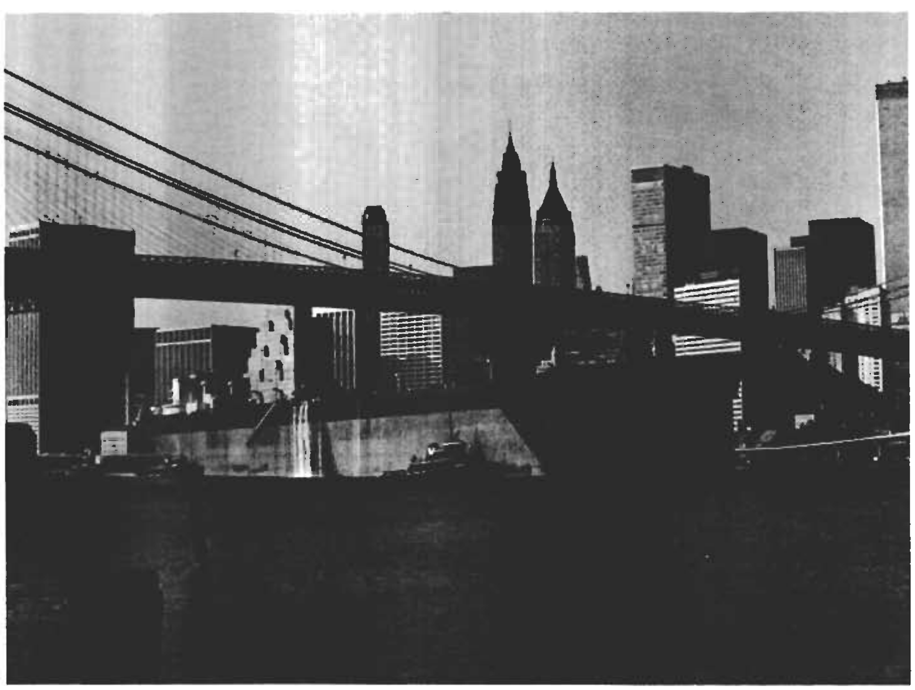
The next step will be to expand this system using the 9882 CRT to simulate what the actual console picture will look like to help determine operator loading factors and refine operating procedures.

HISTOGRAMS AND GRAPHS

Visual aids are helpful in studying or presenting data of any type. The U.S. Coast Guard uses histograms and graphs extensively to compare functional relations and variations of the data they are accumulating. For example:

- A modified polynomial regression program has been interfaced with the TV data so that graphs can be plotted by entering date and vessel type only.
- A modified histogram program plots histograms.
- The plotter produces graphs of mean traffic density versus hour of the day for each sector of the harbor.

Graphs and histograms are produced and used similarly with the communication data.



A Hewlett-Packard 9830 calculator system stores the geographic, hydrographic and environmental data which aids mariners in maneuvering a 238,000 ton super tanker safely through a narrow section of the East River.

The staff has found numerous miscellaneous applications for the system, all of which save time, money, and labor:

- Small monthly mailings are addressed by the typewriter.
- Draft document writing is made easier by a text assembler and editor that allows copy to be changed instead of rewritten.
- Rotational watch lists are prepared by the calculator.
- Operator loading evaluation can be done to determine how much time is spent on services to vessels, how busy an operator will be, how many vessels one operator can handle, and eventually, how many operators will be needed at specific times.
- Personnel status and staff hours monitor files, which are updated regularly, provide current records of numbers and ranks of personnel, various tasks and projects, and hours associated with each. This data also allows projections of people needed to complete tasks, or the impact on the rest of the system if a project dies or one is added.

The Coast Guard's first goal is to establish a system whereby an operator, aided by two radar sets and several low light level television cameras, inputs into a computer system vessel identification and speed. From that point, the equipment will dead reckon the vessels along their courses. The step beyond that will be to interface the radar to the computer - thus eliminating the operator except for the purpose of vessel identification. These simulations will enable the Coast Guard personnel to act in a preventive and advisory capability to facilitate traffic.

Their desire is to make as few changes as possible in the present mode of operation and still strengthen the safety factor. Although they expect to have the capability and authority to control ships, the staff prefers to define their task as controlling space. They hope to accomplish this by establishing some limited traffic and precautionary areas, and determining safe vessel speeds and spacing for certain sectors of the harbor rather than by controlling vessels and changing traffic patterns.

"Our long-range goal is a fully-automated National Traffic Data Base based on our New York Harbor prototype," stated Coast Guard spokesman, LT Stewart Sutherland. "One of the advantages of using the 9830 System is that if we do go to national planning and use the HP 3000, all our groundwork - programs and data - is perfectly compatible with that system."

The Stereographic Projection

by J. N. Shapiro and Patricia Grothouse

The problems of projecting a sphere onto a plane and describing a spatial direction by means of coordinates on a plane are very similar. Cartographers have looked at the former in great detail, while crystallographers, geologists, and geophysicists, among others, have great interest in the latter. As anyone who has spent any time looking at world maps knows, there are many ways of projecting the globe onto a two-dimensional map. Mercator and polar projections are familiar to all of us.

Any projection, by its very nature, distorts the global sphere. For example, a Mercator projection tends to exaggerate regions distant from the equator. The exaggeration increases nonlinearly with latitude with both poles projecting at infinity. Such maps do not serve people living in the Arctic or Antarctic very well, but since their number is small, the Mercator projection has found wide application.

Polar projections, on the other hand, exaggerate those areas most distant from the center of the projection . Many Texans, for example, approve of the North Polar projection because it exaggerates Texas to such an extent that it appears almost as large as Alaska.

What is the best projection? There is no one answer to this question. The most suitable projection for one problem may be quite unsuitable for another. Let's look at one in particular, the stereographic projection. This projection is not particularly good for world maps because it distorts and expands the low latitudes, but it has some exceptional properties that make it very useful for determining distances between cities.

The method for projecting a point stereographically is illustrated in Figure 1. One connects the point to be projected to the pole in the opposite hemisphere by a straight line. The projected point is the intersection of the line and the equatorial plane. Note that with θ as the polar angle (colatitude) measured from the vertical direction and ϕ as azimuth, the two points (θ,ϕ) and $(180^{\circ}\theta,\phi)$ project onto the same point. This is a minor drawback, however, and can be compensated for by marking all points projected from the upper hemisphere with one symbol and those from the lower hemisphere with another. The interested reader should be able to show that if the radius of the circle of projection is R, the point on the sphere at (θ, ϕ) projects onto the plane at the same azimuth ϕ at a distance R tan $(\theta/2)$ from the center, if the point is in the Northern Hemisphere. For points from the Southern Hemisphere the longitude is again preserved and the radial distance is R tan $(90-\theta/2)$ = R cot $(\theta/2)$.

$$(\theta, \phi) \rightarrow \begin{cases} R \tan \theta/2, \phi & \text{Northern Hemisphere} \\ R \cot \theta/2, \phi & \text{Southern Hemisphere} \end{cases} \qquad \text{Eq. 1}$$

The stereonet, or Wulff net, shown in Figure 2 allows one to project points and measure angles without doing any of the calculations otherwise required. The stereonet is actually constructed by projecting great circles onto the plane of the net. The arcs which merge at the center of the top and bottom of the net are such projections. Great circles are projected at 2-degree intervals from the equator (a true circle in projection) to the circle (a straight line in projection) which is parallel to a line connected to the poles. The other arcs, the so-called small circles, are the locus of the projections of a point on a great circle as it is rotated from the equator, to vertical, and back to the equator once again. These are also separated by 2-degree increments.

Given its longitude and latitude, it is quite easy to project a point or a few points stereographically. A thumbtack is used to form a spindle in the center of the net and a piece of tracing paper is placed over the net and pierced by the thumbtack. All latitudes are measured from the equator along the horizontal straight line. The tracing paper is rotated on the thumbtack a number of degrees equal to the longitude, and the latitude is counted in from the edge along the horizontal line. By rotating the tracing paper until two points overlie the projection of a common great circle, it is possible to draw the projection of the great circle connecting any two points and to determine the angle subtended at the earth's center by the points. The great circle distance is proportional to the angular separation. It is possible to rotate groups of points also, using the small circles, and even to project circles from the globe stereographically.

Figure 3 is a stereographic projection of the Northern Hemisphere. It was made by first storing the latitudes and longitudes of the margins of all land masses in the North-

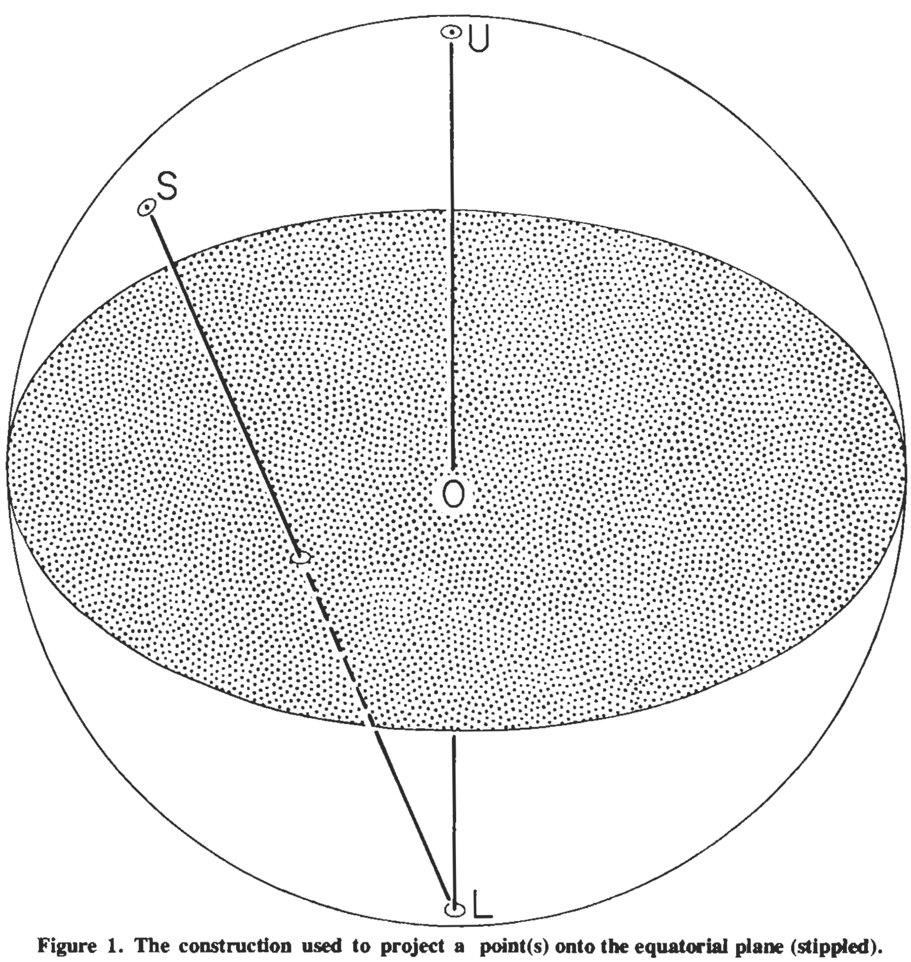


Figure 1. The construction used to project a point(s) onto the equatorial plane (stippled).

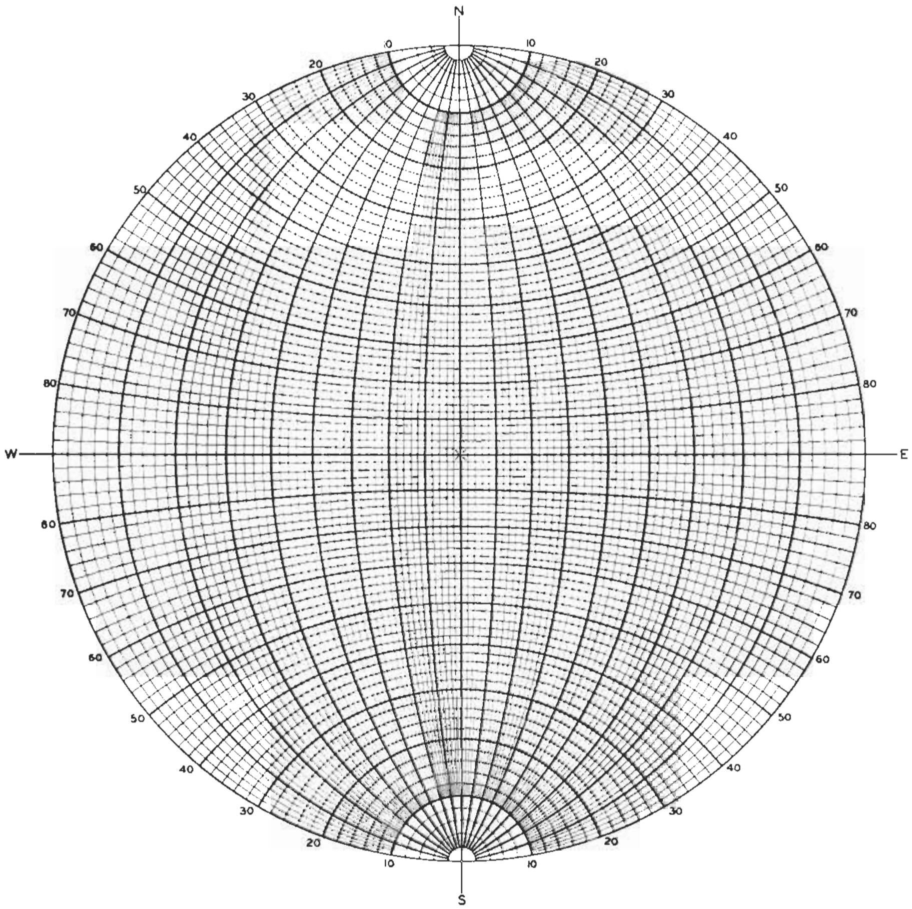


Figure 2. The Wulff Net or Stereonet.

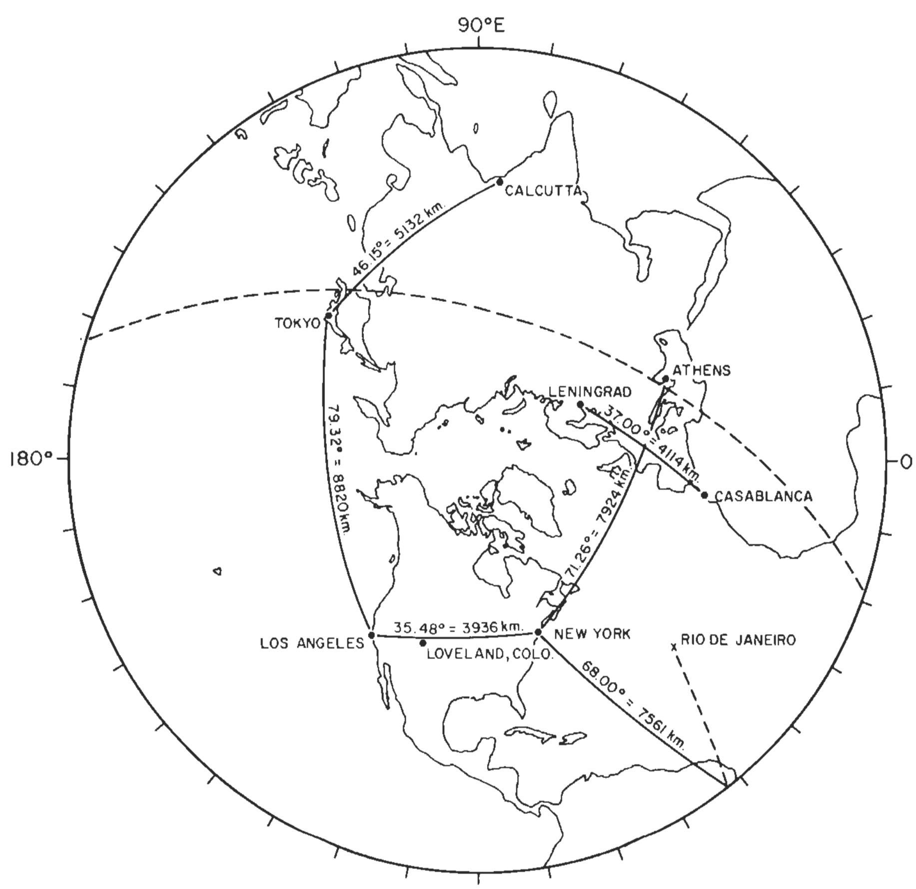


Figure 3. Stereographic projection of the Northern Hemisphere.

ern Hemisphere. The detail in this figure required a fairly close spacing; several thousand points, in fact. The stored points are projected one by one using Equation 1, and adjacent points for each separate land mass are connected by straight lines.

Eight cities in the Northern Hemisphere and one in the Southern Hemisphere have been indicated on this projection. The cities and their locations are:

	Latitude	Longitude
Athens	38°00'N	23°44'E
Calcutta	22°35'N	88°21'E
Casablanca	33°39'N	7°35'W
Leningrad	59°55'N	30°25'E
Los Angeles	34°3.5'N	118°15'W
Loveland	40°24'N	105°4.6'W
New York	40°42.5'N	74°00'W
Rio De Janeiro (Southern Hemisphere)	22°53'S	43°17'W
Tokyo	35°40'N	139°40'E

Rio De Janeiro is indicated by a cross because it is in the Southern Hemisphere. The other cities are marked with dots. The five continuous arcs are the projections of the great circles connecting some of the pairs of Northern Hemisphere cities. Each is labeled with the angular distance and distance in kilometers separating the cities. Each degree is 111.2 km.

The disjointed line connecting New York and Rio De Janeiro is the projection of the great circle connecting these two cities, also. The continuous line is the part of the projected circle in the Northern Hemisphere. Also indicated on the map is something called a reciprocal projection. In this case the reciprocal projection is that of Loveland, Colorado. It is the projection of the great circle that is normal to the radius connecting Loveland and the earth's center. This projection is useful because all points on it are the same distance, 90°, or a quarter of the way around the world, from Loveland.

All of the above constructions - the cities, the great circles, and the reciprocal projection - can be done with the aid of a stereonet. However, they are somewhat tedious and subject to errors in reading, the latter often amounting to one or two degrees in measurements of angular distances. A programmable calculator and plotter is an ideal combination for performing the same operations without the tedium or error. The net becomes superfluous - the equations of projection are sufficient.

We have written a package of four programs which perform most of the operations stereonets are used for. The Calculator Users Club Program Number 832, Generalized Stereonet Plotting Program, will automatically project and plot pairs of points, project and plot the great circle connecting them, and print out the angle between them. It will also project and plot the reciprocal projection of any point.

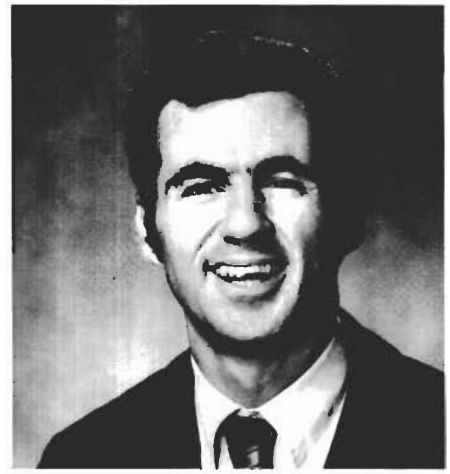
Program Number 830, Rotation of Points on a Stereonet, automatically rotates any point to the center of the net, rotating other points to their correct positions. Rotations are of limited application for cartography but are very useful when one projects spatial directions onto a stereonet. The calculations are substantially more complicated than those required to simply project a point and we will not go into them here. Let us instead consider the second problem mentioned at the beginning of this article, that of describing a spatial direction by Planar coordinates.

It is often the case that only the direction of a vector, and not its magnitude, is important. For example, in paleomagnetic studies the rotation and shift in latitude of the giant plates that make up the surface of the earth can be inferred from the direction of the magnetic field that has been preserved in igneous crustal rocks composing the plates. The orientation and dip of a geologic bed can also be described by a direction in space. In crystallography the orientation of crystal faces is of paramount importance. A face is described by a vector normal to it. In all of these examples only the direction of the vector, not its length, is important.

The scheme for projecting a direction is fairly simple. First, translate the vector so that its tail is at the center of a sphere whose radius is equal to the stereonet's. Then, extending the vector if necessary, the vector direction is represented by the point where it pierces the sphere. Its projection is the projection of the point. Program Number 831, Stereographic and Cyclographic Plot of Crystal Faces, allows the user to project a crystal face onto a stereonet using the face's Miller Indices and the axial ratios of the crystal. Again, the mathematics required in this program are quite involved and will not be repeated here. The interested reader might consult a crystallography text such as Bloss, *Crystallography and Crystal Chemistry*, (Holt, Rinehart and Winston, 1971) for a presentation of some of the formulas involved. Derivations are harder to find. I have not been able to locate any other than my own.

The final program in this package, Number 829, Stereographic Projection of a Circle, allows the user to project a circle onto a stereonet. Anyone who tries this program will be surprised at the results. Any circle on a sphere projects onto a stereonet as a circle! I leave the reader with the following brain teaser: If a circle on a sphere is projected stereographically, the center of the projected circle is not generally coincident with the projection of the center of the original circle.

CURRICULUM VITAE



James N. Shapiro is Assistant Professor of Geophysics at Texas A&M University. He hold a BS degree from M.I.T. and MS and PhD degrees from U.C.L.A., all in physics. His research interests include the theory of generalized inverses, digital filter theory, and other applied mathematical techniques in geophysics. Dr. Shapiro "relaxes" by playing handball and racketball and also has a most unusual hobby - he is fascinated by anything mechanical and enjoys finding out how all mechanical devices operate.

Dr. Shapiro is a member of The Society of Exploration Geophysicists, The American Geophysical Union, and Sigma Xi.

CURRICULUM VITAE

Patricia A. Grothouse is a junior majoring in Geophysics at Texas A&M University. She became interested in stereographic projections while taking an undergraduate course under Dr. J. N. Shapiro. She enjoys music, jogging and tennis.

EDITOR'S NOTE: The programs mentioned in this article are included in the 9820A/9821A Calculator Users Club's Program Library. They are available from the Club on an exchange basis according to the policies of C.U.C. For further information please contact:

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Werk Böblingen
Herrenberger Strasse 110
D-703 Böblingen, Württemberg
Germany

programming tips

READING 5-HOLE TELEX TAPE (9830A)

Lloyd Stott of the Service Section in the Hewlett-Packard, Melbourne, Australia office submits this programming tip.

This short program enables the 9830 to read 5-hole telex tape. Equipment required is the HP 9863A Paper Tape Reader, HP 11272B Extended I/O ROM, and HP 11274B String Variables ROM. Decimal equivalent codes for each shift mode can be worked out from Lines 30 and 40, where "T" and "5" are 1 in each case (not 2). Shift mode change characters are not included in the line or output (hence, Lines 160 and 190 to restore the actual character count). Line 70 logically ends a byte from tape with the expected 5 bits ($31_{10}=37_8=11111_2$). I.e., the unwanted 3 holes of the 8-hole system are masked out. One is added to the masked character to give X.

```
1 REM:  PROGRAM TO READ 5 HOLE TELEX TAPE (L.STOTT/1.75)
10 DIM A$[75],N$[40],L$[40],T$[10]
20 T$="LETTERS"
30 L$=" T O HNM LRGIPCVEZDBSYFXAWJ UQK "
40 N$=" 5 9 #,. )4$80:=3+ ?'6%-2 71(  "
50 A$=""
60 FOR I=1 TO 72
70 X=BIAND(RBYTE7,31)+1
80 IF X=28 THEN 150
90 IF X=32 THEN 180
100 IF X=9 THEN 130
110 IF T$="LETTERS" THEN 210
120 IF T$="NUMERALS" THEN 230
130 PRINT A$
140 GOTO 50
150 T$="NUMERALS"
160 I=I-1
170 NEXT I
180 T$="LETTERS"
190 I=I-1
200 NEXT I
210 A$[I,I]=L$[X,X]
220 NEXT I
230 A$[I,I]=N$[X,X]
240 NEXT I
250 END
```

USE OF DUMMY VARIABLES TO CONTROL 9830A PROGRAMS FROM THE 9864A

Our thanks to Dr. P. A. Burrough, School of Geography, University of New South Wales, Kensington, N.S.W., Australia, for this programming tip.

A common use of the digitizer is to measure lengths of curved lines on maps or charts, etc. Usually this is programmed in the form of a simple loop, with the digitizer in continuous mode:

```
10 D=0
20 ENTER (9,*)X,Y
30 ENTER (9,*)X1,Y1
40 D=D+SQR((X-X1)↑2+(Y-Y1)↑2)
50 X=X1
60 Y=Y1
70 GOTO 30
80 PRINT "DISTANCE="D
90 END
```

There are disadvantages to this method. To print out the result at the completion of the line, the continuous mode is switched off, the program must be stopped and recommenced by CONT 80, EXECUTE to print the result. This is time consuming and unnecessary, because by simple programming, the digitizer can be made to control the calculator. This is a great advantage if much digitizing is to be done.

Consider the following program:

```
10 D=0
20 ENTER (9,*)X,Y
30 ENTER (9,*)X1,Y1
40 IF X1<0 AND Y1<0 THEN 90
50 D=D+SQR((X-X1)↑2+(Y-Y1)↑2)
60 X=X1
70 Y=Y1
80 GOTO 30
90 PRINT "DISTANCE ="D
100 GOTO 10
110 END
```

The line is digitized in continuous mode. At the end the continuous mode is switched off and a single double negative X, Y value is entered. This causes the line length, stored in D, to be printed via statements 40 and 90. After this the program returns to the beginning to measure the next line, all without need for control via the 9830 keyboard.

By varying the nature of the IF-THEN conditions, a whole range of controls over program operation may be obtained using only data from the digitizer, thus providing simple and flexible operation.

ON THE EFFICIENCY OF THE POS FUNCTION

Donna Kimble of Calculator Products Marketing at Hewlett-Packard in Loveland, Colorado, submits this programming tip.

Is September the ninth month? That question may surprise some people, because it seems universal that January is the first month, February the second, and so on. But the answer depends on who you ask. In the context of the fiscal year, September might be the third month or the eleventh month.

I came across a problem of this type recently, and I thought at the time that my solution was routine. But, being a fairly avid reader of other people's programs, I came across three lines buried in the middle of one program which put the entire situation in a new light. Here are those lines:

```
120 FOR P=1 TO 10
130 IF C$(P,P)=A$(1,1) THEN 180
140 NEXT P
```

To make this situation a little clearer, Iwill quote other portions of the same program. 50 C$="0123456789" established ahead of this section a set of allowable numeric digits. And 180 V=VAL(A$) comes after.

A certain string, called A$, contains unknown data. The above section of the program was designed to avoid a nonnumeric argument during conversion of the string to a numeric type data.

Consider the following line:

```
120 IF POS (C$,A$(1,1)) THEN 180
```

I believe this alternative line can replace the three lines previously used with no change in the function of the program except for a significant improvement in speed, as well as an improvement in the amount of memory used by the program.

All this brings me to that problem I had recently, in which there was quite a bit of confusion possible in referring to months by number. It seemed to me to be too risky in matters pertaining to dollars to arbitrarily decide that the user of my program should change his ways to conform to my standard. And no matter whether I decided to call January or November month one, I would be making such a demand on at least some of the managers in my department.

Using the String Variables ROM, I allowed instead that the answer to the questions pertaining to months could be the month name. In the program I could then with a clear conscience use whatever month number to refer to the month that I chose by using the POS function.

Because I had to include this facility in a number of programs, I have "optimized" it. You may find that with little modification it can be incorporated into your own programs. Here it is:

```
10 DIM M$(39)
20 M$="NOVDECJANFEBMARAPRMAYJUN-
   JULAUGSEPOCT"
30 DISP "MONTH"
40 INPUT M$ (37,39)
50 M=(POS(M$ (1,36),M$(37,39))+2)/3
60 IF NOT M THEN 30
```

This program is optimized so that it requires only one string and takes the least amount of memory possible for variable storage. Also, it includes some protection against ambiguous answers from the keyboard. If a month is not recognized, the question is repeated.

It would have taken an incredible amount of programming steps to accomplish this translation from month by name to month by number if the approach had been similar to that taken in the three lines at the beginning - but I have seen this done.

Just for fun, it would be interesting to see by how many steps the program could be expanded if Line 50 were replaced by some group of statements including a FOR and NEXT loop. Just for fun, of course.

RANDOM NUMBER GENERATION (9830A)

We appreciate receiving the following programming tip from Philip Dawdy, Science Department, Lansing Community College, Lansing, Michigan.

I have discovered a technique for "continual randomization" of random numbers generated from the 9830. Normally, the 9830 will generate a sequence of random numbers (via the RND(0) function) from a calculated seed ($2-\pi/2$) or another seed if specified by the user.

When programs are run, they are initialized before execution. This initializing process causes the random sequence to begin from the 9830's seed unless the program changes the seed. If the program uses the 9830's seed, or changes it using the same negative number within the parentheses of the function, the sequence will be the same every time the program is run.

The following method eliminates any need for an extra dummy entry and automatically generates a new sequence of random numbers each time the program is restarted. The only way the same sequence will result is from calculator turn-on restarts. When the calculator is first turned on, the sequence will begin at the same point, but each time the program is rerun a new sequence begins.

Lead the program with the following statement:

```
20 DISP RND(-0.123745367989-ABSRES 0.01)
or
20 DISP TAB32;RND(. . .
```

The above statement generates a seed for the random sequence and produces a new seed when the program is rerun. The reason is that the seed is calculated from the RESULT register, and it is the only register in the 9830 that is not made undefined when the program is initialized. In fact, the RESULT register is unaltered except during keyboard calculations and when SCRATCHA is executed. Another most unusual situation where RESULT is altered is in programs. Since the 9830 will not allow, for example 30 RES =5×A. I was forced to find another method for storing values in RESULT via the program.

Experimentation told me that printing or displaying values are all stored in RESULT. The reason for the display of the random seed in the above statement should be clear to you now. RESULT will contain a different value each time the program is executed. If the calculator is used for keyboard calculations between runs, this alters the random sequence also, since the seed is then altered (another form of randomization).

To assure that RESULT does not contain a number from a print or display statement, a final random number is generated at the end of the program and placed in RESULT. The following statement should be placed before the program END (or STOP):

```
190 DISP RND0
200 END
or
190 DISP TAB32;RND0
200 END
```

To keep the program from starting with the same sequence every time the program is first loaded into memory, the user can do an arbitrary calculation prior to running the program (or just key in any random number and press EXECUTE).

ERRATA

The short program mentioned in Bob Huston's programming tip, "Use of READ BYTE Key," published in *Keyboard* Vol. 7, No 4 was accidentally omitted. Here is Mr. Huston's programming tip for the 9820A again, and this time, complete.

If FMT "AD"; WRT 1 is executed, and then RDB1→R( ), a decimal code will be returned to the register that is the decimal equivalent of the ASCII. For instance, a space returns a 32, C is 40, 48 through 57 are digits 0 through 9, 65 through 90 are A through Z, and so forth. A 10 is found at the end of a card. By looping back to the RDB command and not the FMT, an entire card can be read in and decoded. This feature can be used to sort cards with the select hopper option on the card reader and will work on alpha or numeric data.

In our application we use the card reader and plotter to produce report-quality plots. In order to make the lettering of plots automatic, we use the routine mentioned above. All plot heading data and plot points are put on cards by a computer. The plots are done completely by the 9820, including lettering. Heading data is read into the calculator one column at a time. It is decoded using the short program given below and plotted using the plot commands of the PC I ROM.

We also use this method for special lettering of plots. It allows us to keypunch lettering and have the plotter produce high quality, finished work.

```
0:
"ONE";CFG 1;RDB
1→R9;IF R9≠10;
LTR R30,R33,211;
GSB "PRT"⊢
1:
IF FLG 1;GTO "ON
E"⊢
2:
GTO "NXT"⊢
3:
"PRT";SFG 1;IF R
9=42;32→R9⊢
4:
IF R9≤31;32→R9⊢
5:
IF R9>32;IF R9≤3
9;32→R9⊢
6:
IF R9>57;GTO "L"
⊢
7:
"R";IF R9=32;
PLT "";GTO "N"⊢
8:
IF R9=40;PLT "("
;GTO "N"⊢
9:
IF R9=41;PLT ")"
;GTO "N"⊢
10:
R9-42→R9;JMP R9⊢
11:
PLT "+";JMP 15⊢
12:
PLT ",";JMP 14⊢
13:
PLT "-";JMP 13⊢
14:
PLT ".";JMP 12⊢
15:
PLT "/";JMP 11⊢
16:
PLT "0";JMP 10⊢
17:
PLT "1";JMP 9⊢
18:
PLT "2";JMP 8⊢
19:
PLT "3";JMP 7⊢
20:
PLT "4";JMP 6⊢
21:
PLT "5";JMP 5⊢
22:
PLT "6";JMP 4⊢
23:
PLT "7";JMP 3⊢
24:
PLT "8";JMP 2⊢
25:
PLT "9"⊢
26:
GTO "N"⊢
27:
"L";IF R9≤64;32→
R9;GTO "R"⊢
28:
IF R9>90;32→R9;
GTO "R"⊢
29:
R9-64→R9;JMP R9⊢
30:
PLT "A";JMP 26⊢
31:
PLT "B";JMP 25⊢
32:
PLT "C";JMP 24⊢
33:
PLT "D";JMP 23⊢
34:
PLT "E";JMP 22⊢
35:
PLT "F";JMP 21⊢
36:
PLT "G";JMP 20⊢
37:
PLT "H";JMP 19⊢
38:
PLT "I";JMP 18⊢
39:
PLT "J";JMP 17⊢
40:
PLT "K";JMP 16⊢
41:
PLT "L";JMP 15⊢
42:
PLT "M";JMP 14⊢
43:
PLT "N";JMP 13⊢
44:
PLT "O";JMP 12⊢
45:
PLT "P";JMP 11⊢
46:
PLT "Q";JMP 10⊢
47:
PLT "R";JMP 9⊢
48:
PLT "S";JMP 8⊢
49:
PLT "T";JMP 7⊢
50:
PLT "U";JMP 6⊢
51:
PLT "V";JMP 5⊢
52:
PLT "W";JMP 4⊢
53:
PLT "X";JMP 3⊢
54:
PLT "Y";JMP 2⊢
55:
PLT "Z"⊢
56:
"N";R30+1.25→R30
;RET ⊢
R324
```

RECOVERING A "LOST" PROGRAM FROM A TAPE FILE (9821A)

Our thanks to Arthur F. Graf, San Antonio, Texas for this programming tip.

The other day I "lost" a very long, complicated program. The wrong file identifier appeared at the heading of program file 20, and I did not want to spend several hours re-entering and editing. Here is a method to recover such a "lost" program.

Clear calculator.

Load in about 10 lines of GTO +1.

Then stack other programs in the memory until this new "program" is slightly longer than the "lost" program.

GTO 0

RCF 20

The instant the new heading has been recorded on the tape, open the cassette door. Remove the tape and shut off the calculator.

Restart and initialize.

LDF 20

When the machine detects an error in loading and starts to rewind, press STOP and hold until operations cease.

CLEAR

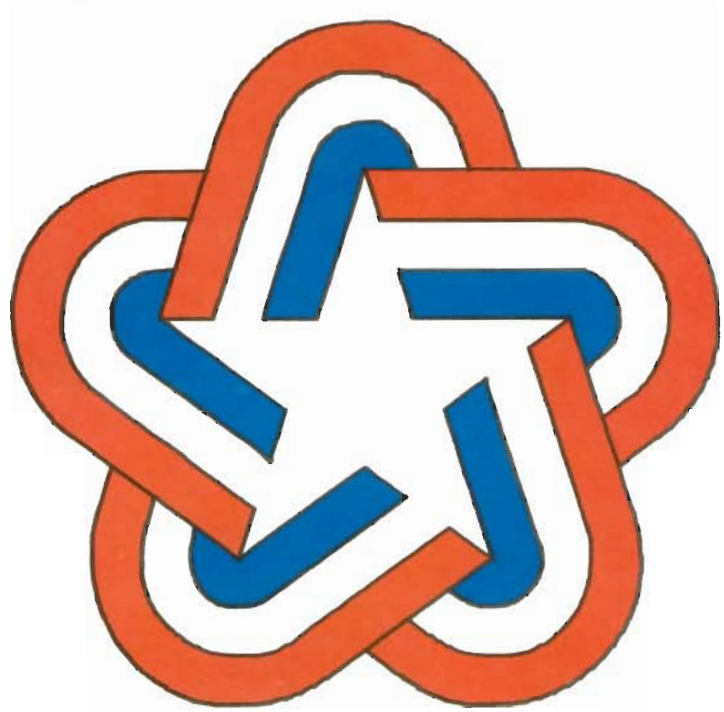
GTO 0

LIST

The first few lines will be GTO +1 and other irrelevant data. The end of the program also may contain irrelevant data. Edit out this data and replace missing lines. The bulk of the program should have been loaded intact.

Bicentennial Symbol Program

by Sarah McLucas, Hewlett-Packard
Calculator Products Division



Mr. André E. Samson, a computer science teacher from W. T. Woodson High School in Fairfax, Virginia, submitted the following Bicentennial Symbol program. Since it's so timely, we thought you might like the program listing. Mr. Samson created the program on the HP 9830A Calculator and HP 9862A Plotter at Mary Washington College in Fredericksburg, Virginia, while he was there last summer teaching computer science for the Governor's School (for gifted students).

Besides the beauty and patriotic qualities of the design produced by the the plotter, Mr. Samson feels that this program incorporates many mathematical skills that cannot be fully explored in a regular analytical geometry class. It lets the student see a realistic application of theories or concepts that involve complex computation. Plotting illustrates polar coordinates in action; the Law of Sines is used to calculate the points of the star; the translation of coordinates --offset statements-- is used to repeat the five distinct divisions of the symbol; and the point-of-division formula, by which the distance from the inner to outer points of the star is divided into thirds, creates the "striping" effect of the symbol.

Mr. Samson challenges you to devise a maze based on this Bicentennial symbol program or to adapt the program to create other mazes and original designs.

He provides the following user instructions: use square paper and insert the red pen first. When the red portion of the plot is finished, there is a 30-second delay during which you can insert a blue pen for the remainder of the plot. (We tried this and it is easily accomplished.) The program requires no additional interaction. After the symbol has been drawn, you may wish to finish it off by coloring in the lines with felt-tip markers--and you will have the makings of a fine poster or greeting card format for next Fourth of July.

```
10 DIM X[11],Y[11]
20 SCALE -2,2,-2,2
30 DEG
40 FOR I=1 TO 11
50 IF I/2=INT(I/2) THEN 90
60 X[I]=COS(90-36*(I-1))
70 Y[I]=SIN(90-36*(I-1))
80 GOTO 110
90 X[I]=SIN(18)/SIN(54)*COS(90-36*(I-1))
100 Y[I]=SIN(18)/SIN(54)*SIN(90-36*(I-1))
110 NEXT I
115 W=1-Y[2]
120 FOR D=1 TO 9 STEP 2
130 PLOT X[D],Y[D]
140 OFFSET X[D+2],Y[D+2]
150 FOR D1=90-36*(D-1) TO 90-36*(D-1)-144 STEP -6
160 PLOT (W)*COS(D1),(W)*SIN(D1)
170 NEXT D1
180 OFFSET X[D+2]+(W)*COS(D1+6),Y[D+2]+(W)*SIN(D1+6)
190 PLOT X[2]*COS(D1+6-90),X[2]*SIN(D1+6-90),-1
200 OFFSET X[D+2],Y[D+2]
210 S=2/3*SQR(X[2]↑2+(W)↑2)
220 PLOT S*COS(D1+6-18),S*SIN(D1+6-18),-2
230 FOR D2=D1+3 TO 90-36*(D-1) STEP 6
240 PLOT (W)*2/3*COS(D2),(W)*2/3*SIN(D2)
250 NEXT D2
260 OFFSET 0,0
270 PLOT (2*X[D]+X[D+1])/3,(2*Y[D]+Y[D+1])/3
280 PLOT X[D],Y[D]
290 PEN
300 NEXT D
310 WAIT 30000
320 FOR D=1 TO 9 STEP 2
330 PLOT (X[D]+2*X[D+1])/3,(Y[D]+2*Y[D+1])/3
340 OFFSET X[D+2],Y[D+2]
350 FOR D1=90-36*(D-1) TO 90-36*(D-1)-144 STEP -6
360 PLOT 1/3*(W)*COS(D1),1/3*(W)*SIN(D1)
370 NEXT D1
380 D1=D1+6
390 OFFSET X[D+2]+1/3*(W)*COS(D1),Y[D+2]+1/3*(W)*SIN(D1)
400 PLOT 1/3*X[2]*COS(D1+6-90),1/3*X[2]*SIN(D1+6-90),-1
410 OFFSET 0,0
420 PLOT X[D+2],Y[D+2]
430 PLOT X[D+1],Y[D+1]
440 PLOT (X[D]+2*X[D+1])/3,(Y[D]+2*Y[D+1])/3
450 PEN
460 NEXT D
470 END
```

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