RCA Engineer

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The next step in manufacturing technology

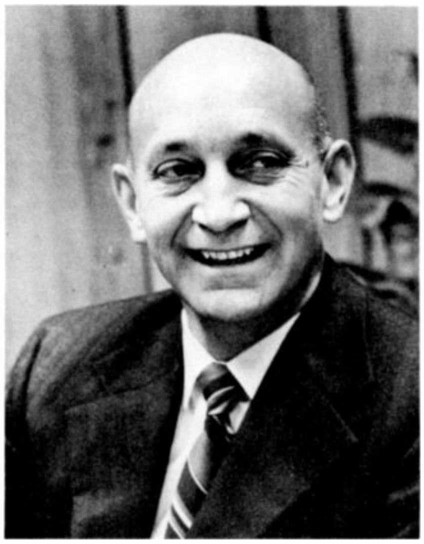
Inflation can be defined as an uncontrolled imbalance between changing productivity on the one hand and spiraling labor and material costs on the other. In our efforts to control inflation, we strive simultaneously to increase productivity and limit costs. In a sense, we live in a dichotomous environment, in that while limiting costs, we improve our standard of living through increased wages. That improved standard, of course, should derive from increased labor outputs. Solutions to such a complex problem exist, and our managerial responsibilities dictate that we constantly seek those solutions.

One such solution has been the development of custom equipment for specialized production applications. The demand for custom machinery, or at least customized adaptations of standard machines, led to another breed of engineers, the equipment technologists. Some of the equipment technologists' work is reflected in several papers in this issue of the *RCA Engineer*, which is themed around manufacturing productivity through automation. I'm pleased that we recognize these technologists' contributions in this issue, for we often shroud their work to preserve the competitive edge we realize from their innovativeness.

But we have another tool at hand, a tool that both supplements and expands custom-equipment approaches. The microprocessor is that tool, and its impact has two bases. First, it is a large-scale integration (LSI) device—and LSI means that more functions are available per unit of labor, whether that unit involves people or machines. Second, standard commercially available LSI designs such as the microprocessor have a multitude of applications, ideally suited to process control. The manpower efficiency required to develop one complex device is therefore applied to the solution of many problems and, in effect, improves the productivity of those highly skilled people who design and develop these devices.

Thus, we find an editorial subtlety in this issue by way of the inclusion of an article on COSMAC. Implications for the equipment technologist are immense, as indeed they are for all equipment and system design engineers.

B.V. Vonderschmitt



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Our Cover

. is a before-and-after look at part of the solid-state diffusion area at the Mountaintop plant. To accomplish this striking transition without curtailing production, a dedicated crew virtually had to perform "open heart surgery on a living factory" (p.39). In the "before" photo, Tom Ruskey (left) and Bob Guerin discuss the planned diffusion area rearrangement task (DART). The "after" photo shows the culmination of this planning and effort. In the photo, Carol Ann Piestrak and Tom Lyden are working at the left side of the aisle; Norah Smith is attending the furnaces at the far end; Helene Dobranski, Tom Ruskey, and Mildred Cerrito are at the right. MMes. Cerrito, Dobranski, Piestrak, and Smith are production workers; Messrs. Guerin, Lyden and Ruskey are members of the DART team.

Photo credit: John Semonish, Solid State Division, Clark, N.J.

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• To disseminate to RCA engineers technical information of professional value • To publish in an appropriate manner important technical developments at RCA, and the role of the engineer • To serve as a medium of interchange of technical information between various groups at RCA • To create a community of engineering interest within the company by stressing the interrelated nature of all technical contributions • To help publicize engineering achievements in a manner that will promote the interests and reputation of RCA in the engineering field • To provide a convenient means by which the RCA engineer may review his professional work before associates and engineering management • To announce outstanding and unusual achievements of RCA engineers in a manner most likely to enhance their prestige and professional status.

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Throughout RCA's 56-year history, efficient cost-effective production has been an important ingredient to success. But never before has productivity been as critical as it is today.

We are up against quality competitors in a marketplace characterized by decreased consumer spending and demands for lower costs and higher reliability. At the same time, many product lines have matured to the point where no one company can sustain a technological edge for any length of time. Obviously then, RCA must design and manufacture better products at lower cost.

Automated factory operations represent one way to meet this challenge. Some automated systems and techniques are described in this special issue of the *RCA Engineer*. Other ways will be examined in future issues, when the *RCA Engineer* addresses product design (next), manufacturing engineering, industrial engineering, resident engineering, and many other areas that represent the solid application of engineering know-how in the factory.

In this way, we hope to improve the professional dialog among factory operations as well as between the manufacturing and the design and development groups. *To make such dialog as productive as possible, we need more input from the technical staff in all our manufacturing operations.*

We invite your comments, your ideas, and your professional papers. Contact us directly, or through your Editorial Representative.

—J.C.P.

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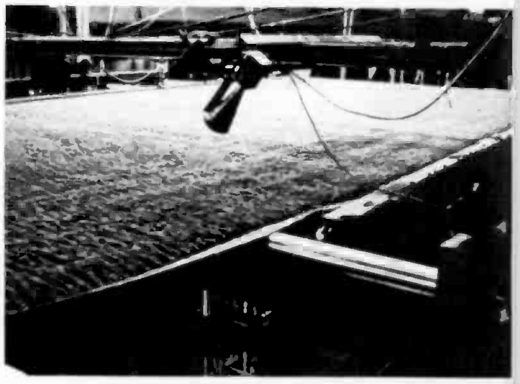
Editorial Representatives are listed on the inside back cover of each issue.

Right: Automatic component insertion equipment in action at Juarez. Consumer Electronic's mechanization program encompasses domestic and offshore operations with the objective of improved quality and cost performance.

Below: Process control monitoring at Coronet in carpet manufacturing. Sensing equipment measures bonding material thickness to assure quality and minimize power consumption.

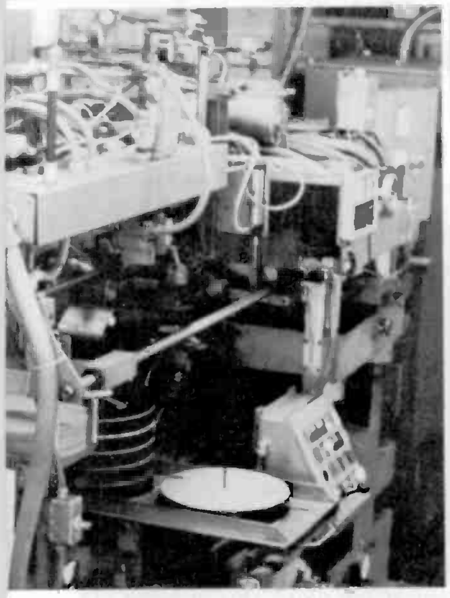


Far right: A recent development in diffusion furnace technology in operation in the Solid State Division. This equipment incorporates microprocessor control and provides a major improvement in manufacturing efficiency. J. Kau, Design Engineer, is loading a process card into the reader. This view shows one half of an 8-tube module.

Right: Automatic record production in Indianapolis. This mechanized press system is being evaluated along with other equipment approaches as the Record Division improves its productivity.

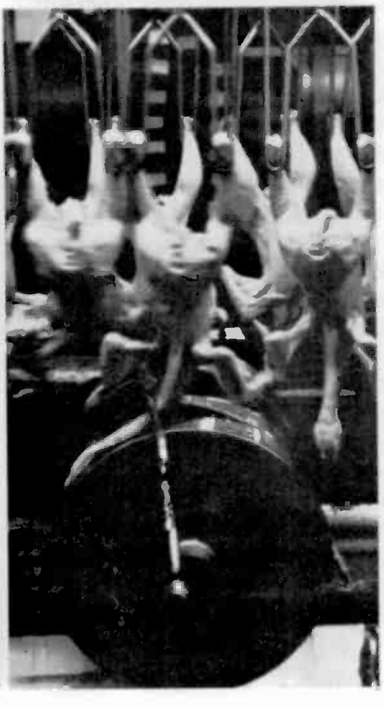
Below: Automatic wire wrap has provided a major productivity improvement in G&CS operations. The unit shown is presently in operation in the Camden plant.

Right: These two photos show integrated circuit assembly mechanization now in operation in the Solid State Divison.



Right: Chickens are processed through clever mechanization at high rates in Banquet facilities. This simple unit removes heads.

Below: Densely-packed conveyors carry chickens at rates exceeding 5,000 an hour through a carefully monitored series of automatic and manual steps.



Productivity and manufacturing at RCA

R.T. Vaughan

Manufacturing is, and will continue to be, a major contributor to product cost for the majority of RCA's products. Productivity improvements are therefore essential to business success. This paper reviews some recent productivity improvements in several operating units and provides general guidelines for across-the-board improvements.

THE WORD *productivity* has many meanings that generally match the interests or specialty of the particular user. Although the term seems only partially defined in the dictionary as the production of goods or services having exchange value its meaning has become accepted generally as the ratio of output compared with input. For example, the development and use of automatic screw machines as compared with the earlier technique of an individual operator painstakingly turning out pieces one by one on a simple lathe clearly improved productivity. There seems to be little disagreement on the general meaning of the term, but there are definite differences of opinion as to the specific measurement to use and the various factors to be included in the definition, such as inflation and others.

On a large scale, economists think in terms of gross national product as a total, including all industries and many activities. At the other end of the range, a supervisor is concerned about the output of his employee group and the absentee problem he has to contend with. At yet another level, a production superintendent looks at his department, including the personnel and facilities, and considers individual efforts and output as well as machine performance and maintenance problems with their total impact on production. He compares his current output with last year or last month

A manager responsible for a particular product must continually evaluate his output with respect to the people and equipment resources utilized. He is interested in his own trends and progress and also his performance within the industry. His product must be designed for competitive performance and producibility. He must equip his operation with efficient facilities and control systems; maintain practical labor standards; and keep scrap, inventory, and variances to a minimum. In addition, he must maintain high employee morale for its important effect on productivity.

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Robert T. Vaughn, Staff Vice President, Manufacturing, Cherry Hill, N.J., joined RCA in 1973 from the post of Director of Manufacturing for the International Division of Philco-Ford Corporation. Mr. Vaughan received the BSME from the University of Pennsylvania in 1949 and received the MS in 1952. After several years of electronic component and process development experience, Mr. Vaughan joined Philco in 1952 as a Senior Engineer and was appointed Chief Engineer, Equipment Operations in 1959 and General Manager in 1962. Two years later he was named Manager of Manufacturing for Television Pictures Tubes, and in 1969 was appointed Manager Tube Operations. He is a member of Tau Beta Pi and has been awarded eight U.S. Patents.

Thus, the application of the term *productivity* to our business activities as a practical measurement is desirable and important as one of a number of calibrating means for operating management.

In practice, productivity is used to compare product value produced with the labor, or possibly total personnel, involved in the operations. This is a useful ratio, but if too vigorously used as a measurement of management effectiveness, could theoretically lead long-term manufacturing planning in the wrong direction. For example, in the case of television, if productivity is defined as product value compared with labor cost, the ratio would be improved by reducing component integration and its labor cost contribution by increasing purchased content. Conversely, the manufacturing integration of additional components involves adding labor and therefore adversely affects a productivity index that simply compares product value with head count. In spite of these technicalities, one practical and obtainable index is the ratio of manufactured product value in constant dollars divided by the total personnel involved in the operation or division to which it is applied.

Productivity in television manufacturing

Any review of productivity in television manufacturing would be incomplete without considering the effects of the color tube, solid state, and other major components at the same time — although some of these products will also be discussed individually. While the chassis assembly process has been undergoing simplification and mechanization via printed circuit boards and automatic insertion equipment, the color tube has simultaneously become more difficult to produce as brightness performance and other design features have reduced process yields and increased labor. The real task in television manufacturing has been to find ways of improving efficiency to compensate for the additional functional complexity that has developed as a result of competitive pressure. The development of integrated circuits has already simplified the television assembly task by incorporating functions and reducing the total component count. Additional assembly benefits can be anticipated as further IC developments are utilized.

Since the emergence of television in the 40's, industry manufacturing and product design trends have followed generally parallel paths among the many manufacturers. Some have naturally moved faster than others into new manufacturing techniques and have chosen to use low-cost labor resources in various parts of the world. It should be recognized that there is probably no single best way and the outlook five or ten years ago was substantially different than that of the current period.

Today, in television manufacturing as in most other areas, the name of the game is efficiency or productivity. Manufacturing must do a thorough job of planning, controlling, and economizing in the use of all its resources — including facilities, personnel, materials and utilities. It must be producing a product designed not only for excellent performance but also for manufacturing cost effectiveness and reliability.

Mechanization

To review some specifics, television assembly technology adopted the printed-circuit board quite a few years ago with a surge toward mechanization of component insertion. This included the development of the long, many-stationed automatic insertion machines of the United Shoe Machinery Company. These appeared to be the answer to one of the major needs — getting the vast number of discrete components into the circuit reliably and inexpensively. These machines were reasonably effective in this application but required relatively long model runs for effective utilization. The large variety of chassis and relatively frequent new developments the industry experienced since their acquisition put them in the role of handling the "common denominator" assemblies and demonstrated the need for something more versatile and flexible. This gap has been filled by a related development, covered thoroughly by previous issues of this publication: the variable-center-distance, pre-sequenced component inserter with its accompanying sequencing equipment.

There has been a tendency to consider the television assembly mechanization task as very well along via the automatic inserters with their capability of handling axial-leaded components. However, quite a few other components, including a large number of disc capacitors, have only recently begun to become insertable from a practical viewpoint. Interestingly, this component had already undergone an excellent job of productivity development, but its manufacturing process and design did not fit readily into the dual-taped configuration of the newer insertion machinery. However, this problem is being solved and the industry can count on mechanized insertion of a large proportion of the individual components involved.

All this progress might lead one to feel that the television assembly mechanization job must be relatively complete and productivity very high as a consequence of the negligible remaining labor. An examination of the labor content in a typical television receiver shows that this is far from the case. Component assembly labor, even without assuming the use of mechanization, is only one of a number of labor-intense areas. Some of the others are instrument assembly, chassis assembly, and testing.

Testing — more automatic

Testing is recognized in the television industry as important both from a quality and efficiency standpoint. Obviously it is important initially to assure that good components are being fed to the manufacturing system. It then becomes essential that the various assemblies be controlled thoroughly and reproducibly to minimize repair, which can become a large labor element in itself, and improve product uniformity and throughput. Test equipment developments have reduced operator dependence and simplified the training task as well as improved quality. The trend in test equipment is to have the test system make the determination on a go/no-go basis or point to the problem area. Tests and adjustments have become more automatic.

Component manufacturing improvements — yokes

In addition to the very prominent developments in assembly mechanization and test methods, substantial progress has also been made over the years in improving the manufacturing productivity of other major components. One of the more interesting developments has been the toroidal yoke winding system and its bonding along with other neck components to the color tube prior to instrument assembly, significantly reducing the final instrument assembly task.

Solid state devices

The solid state business has made almost unbelievable strides in productivity if the measurement were to consider numbers of individual components combined on an IC chip. This progress made in IC manufacturing technology has also dramatically impacted the television business as well as many other industries.

The trend to LSI

Progress from point contact and alloyed junction technology to high-density photolithography, diffusion, epitaxial and ion implantation techniques has been very fast. Many of the important process steps are carried out on a large number of chips simultaneously and some of the ingredients for high productivity are essentially built into the process. But the name of the game in this business, as in the past, is yield, which has become the vital ingredient of LSI productivity.

A number of recent and current developments that will continue to improve manufacturing productivity include the transition to larger wafers and mechanized bonding approaches. Other important factors long recognized in the solid state business have become even more important with the growth of LSI developments. The larger the chip, the greater the need for very clean, defect-free processing. Defects can be introduced throughout the process and are not just from airborne or solution contamination.

The very high resolution necessary during the photographic steps requires that photomasks be in close contact with the wafer during exposure. This process step tends to result in damage to the mask. Developments in alignment and exposure systems have reduced this problem by allowing a gap to exist between the mask and wafer with a reduction in abrasion damage.

Microprocessors in process control

Another important trend has been the improvement in process control made feasible as a result of the availability of mini and microprocessors. Process information feedback for control purposes will continue to have a major impact on manufacturing efficiency and productivity in the solid state business.

Picture tubes

As mentioned above, picture tubes have, by a number of performance improvements over the years, become more difficult to produce — although concurrently those in the business have done an excellent job in improving yields. Picture tube manufacturing economics and productivity are highly dependent on attaining high yield and low material scrap, starting at the glass plant.

A number of the currently used methods and equipment approaches are natural carryovers from monochrome days. Relatively high-volume, efficient mechanization had been developed for mount sealing and a few other of the process steps, but color manufacturing added a substantial screening task that has been further complicated by the "matrix" development. Other product modifications such as 110° deflection and the slotted mask have also made productivity improvement even more of a challenge.

Yield in this process-oriented business is extremely sensitive to control at every point in the process, being similar to solid state manufacturing in this respect. Optical and photographic procedures requiring relatively precise control are involved, and improved yield and quality will require additional use of process control instrumentation and computer capabilities.

Government and Commercial Systems

Manufacturing developments in the Government and Commercial Systems divisions are exploiting automatic testing techniques to reduce the otherwise unmanageable testing task associated with a substantial volume of complex boards and assemblies often containing many LSI's.

Automatic component insertion is increasing as a proportion of total components involved and automatic wire wrap machinery is used extensively. As a specific example, the benefits that can result from Manufacturing Engineering and Design Engineering teamwork in "producibility engineering" is demonstrated vividly by the TR-600 Broadcast Video Tape Recorder. This product, which evolved from the earlier TR-70, was designed with maximum utilization of automatic test and assembly techniques in mind.

Boards were designed to a standard physical configuration for most efficient computer-controlled testing. They were also designed for automatic component insertion. A major portion of the wiring has been incorporated in a back panel designed for automatic wire wrap operations. The wire-wrapped back plane and connector terminated cable harness are also automatically circuit checked prior to assembly.

The combined effect of these manufacturing-oriented developments yields a similar product in terms of performance but requires only 30% of the previous assembly labor to put it together — a prime example of productivity improvement.

The record industry

The record business involves a variety of manufacturing technologies. As viewed from the outside, record pressing appears to be the primary production activity. Actually, pressing is a major activity of Record Division manufacturing, but many other specialized methods and techniques are involved. The Record Division is improving its efficiency and productivity through the use of modern injection-compression presses and is also testing other approaches to automatic pressing.

A good deal of fine work had been done years ago in developing a practical compression press that had remained virtually a standard for the industry for quite some time. The industry is now in the process of gradually replacing this equipment with improved presses of semi-automatic and automatic variety. Also involved in the operations are very precisely controlled plating operations, compound mixing, and printing. The need for improved process control and monitoring in all operations is clearly recognized and undergoing rapid improvement.

Substantial development work has already been accomplished in tape operations where tape duplicating speeds are being increased and assembly and packing operations mechanized.

Carpet manufacturing

The Coronet carpet business was established as a direct result of a basic productivity improvement in carpet manufacturing known as "tufting." This technique allowed an order of magnitude increase in the speed of assembly of yarn into the backing.

Since it began operations in the late 50's, Coronet has been a leader in productivity improvement. Recently, innovations in process machinery operation have provided a substantial increase in throughput capability.

Food processing

The Banquet facilities include many highly mechanized operations, typically operating at cycle rates well in excess of 4,000 an hour.

Chickens are cut up and eviscerated at impressive speeds while traveling on continuous conveyors. Chicken parts are prepared for batter coating and fried via a combination of operator-controlled and automatic process steps.

Food processing machinery has been developed and modified to extend operating speed capabilities substantially for increased productivity. Current developments are aimed at approaches to reduce equipment downtime, increase operating speed and improve quality.

Banquet's operations involve a stimulating combination of automatic processing and handling machinery running smoothly in conjunction with skilled operators.

Conclusions

The comments and background above are basically related to the operations involved. However, there are some general productivity improvement practices that apply across the board:

- Better planning
- More effective management
- Improved processes and procedures
- Better communications
- Effective manpower and personnel policies

At first glance, these factors which have been commonly cited by U.S. manufacturing executives[1] appear to be in the category of truisms or "motherhood" statements. But, as you think about them, you realize there are no substitutes. There are specific solutions to many special manufacturing problems such as new machinery, test equipment and process developments, but for long-range productivity performance the depth and resourcefulness of planning for manufacturing and manufacturing-oriented engineering is critical.

Better management is an obvious requirement. But how is it achieved? Manufacturing management is strengthened by training, selection, and experience in a variety of assignments. Mobility must be improved for talented individuals. Division management is recognizing the importance of training and is establishing training programs for Manufacturing personnel.

Communications is clearly a two-way need. Employees, both salaried and hourly, need to know what is going on and how well they are doing. In addition, if communications are good enough, employees can be an excellent source of ideas for methods to improve productivity and reduce waste. Some Divisions have recognized the value of this source of ideas and installed employee-based programs that have been major contributors to profit improvement. This resource has been a real asset.

Reference

1. Katzell, N.E.; *Productivity: The Measure and the Myth.* American Management Association Survey Report.

Programmable controllers, minicomputers, and microcomputers in manufacturing

J. L. Miller

The need for new techniques in manufacturing has become increasingly critical during the past several years. Factors that contribute to this need are 1) increasing complexity of products, 2) severe pressures of domestic and foreign competition, 3) increasing consumer demand for higher quality, 4) influence of governmental and other agencies for greater safety and reliability, and 5) inability to increase prices to keep pace with increasing production costs. The electronic and other businesses of RCA demand manufacturing development to keep pace with product development so that RCA can retain its competitive position.

James L. Miller, Director, Manufacturing Systems and Technology, Corporate Staff Manufacturing, Cherry Hill, N.J. graduated from Iowa State University in 1948 and joined RCA as an engineer in the Component Parts Department of the Tube Division. During that time he designed printed circuit i.f. amplifiers and rf tuners. In 1953 he transferred to the Home Instruments Division, Color TV, designing i.f. amplifiers, color demodulators and monochrome video circuits. In 1960 Mr. Miller moved to the Computer Division where he worked on high-speed tunnel-diode circuits and later became a manager of peripheral equipment design responsible for card readers and optical character readers. In 1966 he joined the International Licensing organization as the Managing Director of RCA Engineering Laboratories in Tokyo, Japan, and, in 1969, joined Corporate Staff Manufacturing as a manager and later as the Director of Manufacturing Systems and Technology.

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COMPUTERS have been available for many years to provide the speed and capabilities which made many complex and, at times, impossible tasks practical for the first time. Most of these early systems were quite large and expensive and were used in such applications as financial control, scientific and engineering calculations, communications, *etc.* Because of their complexities and cost, only limited use was seen in manufacturing. Introduction of programmable controllers, minicomputers, and microprocessors during the past few years is making it possible for the first time to develop practical manufacturing systems for automatic test, data collection, and process control in manufacturing.

Programmable controllers

Although not as flexible and powerful as a minicomputer or microprocessor, programmable controllers can replace complex relay banks with logic switching that conforms to Boolean expressions. Programmable controllers offer several advantages. They are more flexible and easily changed than static logic or relays. As the complexity of control increases, they offer a cost advantage at about 40 to 100 relays over standard switching logic. Reliability and life of solid-state programmable controllers generally far exceed the expectancy of relay logic. The ability to easily change logic statements

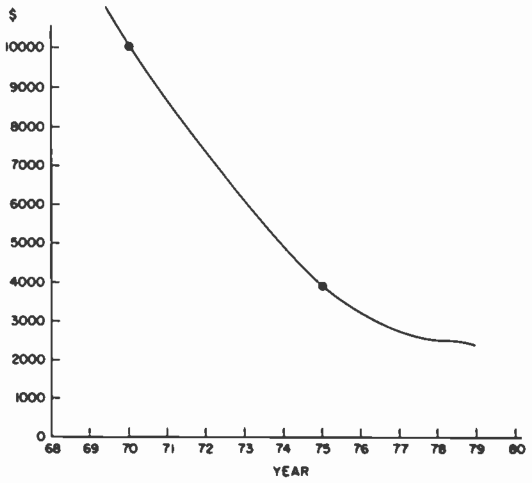

Fig. 1 — Minicomputer prices.

gives the controller greater flexibility when compared with the need to modify wiring in a relay panel. This is especially useful when designing and testing a new system. Since most suppliers provide straightforward methods to program the controller, it can be easily used by personnel familiar with relay switching logic without the need for computer programming skills. Early users were in the automotive and machine tool industries but installations are now being implemented in process control of chemical, petro-chemical, food processing, paper and pulp industries. In some applications, programmable controllers are used as primary control devices with minicomputer backup for the purpose of loading programs, monitoring process conditions and providing more complete control.

Minicomputers

In addition to programmable controllers, minicomputers are being used more extensively in manufacturing applications. One contributing factor has been the drastic reduction in minicomputer prices during the past five years as seen in Fig. 1. In addition, both hardware and software capabilities of minicomputers have been expanding during this same period. Many of the functions previously provided only in large computer systems are now available in these devices. Large core memory at decreasing prices along with such features as hardware multiply/divide, memory protect, automatic restart, etc., have become common. In software, such things as real time operating systems, file management, and process monitor-direct digital control packages are available from one or more of the minicomputer suppliers.[1] In addition, high level languages such as Fortran, COBOL, BASIC, etc., are available on most equipment.

Multiplexing capability permits sensing process conditions, inputting of test results, or entering data manually from many points around a manufacturing floor. The ability to add memory and peripheral devices, as needed, makes it possible to tailor systems to meet specific requirements. This added capability over programmable controllers brings with it the requirement that programming personnel are usually required for effective use of the minicomputer. The most important ingredient of a successful installation is careful planning. A thorough study of the application and its requirements should be completed before consideration of a vendor and the specific software and hardware approach to be used.

Microprocessors

The most recent device to make its appearance in the control scene is the microprocessor. This device has most of the Central Processing Unit (CPU) capabilities of the minicomputer on one or two chips. Added chips are provided for memory, input/output control, etc.

Microprocessors, in general, are lower cost with smaller memories and lower speeds than minicomputers. Early applications appear to be as controllers for testers, process control, and machine tools. Again, with more capability than the programmable controller, they require a higher technical competence to use and maintain. The use of programmable controllers, minicomputers and microprocessors in manufacturing varies over a wide gamut including machine tool control, testing, facility monitoring, process control, automatic assembly, data collection, injection molding, and warehousing.

Applications

New applications in manufacturing and product control are being introduced at a rapidly accelerating rate. It is expected that this trend will continue in the foreseeable future to meet the pressures of cost, reliability, and safety. Two general areas and one specific example from the thousands of specific applications will illustrate the breadth of use.

Automatic warehousing

Automatic warehousing has exploited the minicomputer extensively and is offered by several companies, such as SI Handling, FMC, and GE. These systems include control of trucks for placement and retrieval of product, and range in complexity from operator-assisted to completely automated warehousing.

Injection mold control

Several packaged systems are available using minicomputers from such companies as IBM and Harrel, Inc. These provide monitoring and/or control of cavity pressure, melt temperature, dwell time, etc.

A system developed by the Rochester product division of General Motors Corporation uses General Automation's SPC-16 minicomputers for carburetor adjustment and testing with a group of 31 minicomputers reporting to an IBM System 7 for supervisory control. The System 7 acts as a communication concentrator providing information to a 370/145 at the management level. The System 7s have disc storage in case the 370 goes down.[2]

RCA has been active in the application of minicomputers to manufacturing during the past few years in the areas of automatic test, data collection, and process control.

Automatic test

Some of the earliest computer applications in manufacturing have been for automatic test. The need for thorough and sophisticated testing of components, subassemblies, and complete systems by Government and Commercial Systems has made it necessary to develop rather extensive capabilities in this area. The Government Communications and Automated Systems Division in Burlington, Mass. has extensive experience in this area, and additional capabilities have been developed in the various divisions to meet specific needs.

The test center concept is being used effectively in Camden. A complex of three RCA 1600 computers is used for data input to control testers for logic systems, analog video equipment, and communication equipment; the complex also includes diagnostic capability. Additionally, a General Automation SPC-16 is used for system testing and a DEC PDP-8 for magnetic headwheel balancing. Most modules produced in the Camden Plant are tested at this center.

The semiconductor industry has been another early user of automatic test. The need for high speed, accurate testing of devices has become increasingly important as complexity has progressed from discrete transistors to integrated circuits (ICs) to medium scale integration (MSI) and finally to large scale integration (LSI). One of the first in-house developed test systems was the Computer Controlled Automatic Test equipment (CCAT) for probing of wafers.[3] This system uses an RCA 1600 computer and special equipment controller with three extenders, each of which controls three wafer probe stations. Data from these test systems is logged and taken to an off-line computer for analysis including histograms and wafer mapping.

Hewlett-Packard equipment has been used extensively for testing of power devices. This testing started with the development of a system using the Hewlett-Packard 2114 minicomputer controlling three test stations to qualify components. Since that time, continuous development has been in progress.[4]

One of the first linear testers developed in RCA was the Automatic Dynamic Universal Linear Tester. (ADULT), which uses General Automation's SPC-12 computer as the controller.[5] This system is aimed at specific circuit configurations with separate test stands for each IC type. The SPC-12 provides switching of stimulus and measurement equipment and pass or fail decisions.

General Automation SPC-16 minicomputers are also being used to measure glass faceplates and funnels for color picture tubes. Initially started as a means to measure faceplate contour, it has since been extended to include funnel and other measurements.

Systomation in-circuit testers are being used successfully for testing component values after assembly and dip soldering into printed circuit modules at Consumer Electronics. These machines measure the value of most components to within ±1%. Since the average test time using this equipment for a normal size board is in the order of 5 to 10 seconds, it provides a very powerful tool for testing those devices which do not require adjustment. Since the system provides printout of components not meeting specification, the complicated and sometimes inaccurate troubleshooting steps can be eliminated. Additional work is progressing to use computer control for testing adjustable modules and subassemblies.

The use of an Intel 4004 microprocessor for the testing of horizontal output transformers has been developed by the CE division. Tests performed include control of an indexing table and measurement of inductance ratio, phase and high voltage breakdown with the advantages of reduced test time and increased test accuracy. In addition, the microprocessor keeps an account of good and reject transformers. In all of these test systems, the inherent possibility exists to gather product information and enter it into defect reporting or manufacturing data systems. This provides manufacturing and engineering with a tool to identify repetitive product faults and implement corrective action to further improve product performance and reliability. In most areas where automatic test equipment is being used, plans are progressing to further improve utilization through the use of resulting data output.

Data collection

An early system developed for collecting information from the manufacturing floor is the Defect Reporting System (DRS) developed in Consumer Electronics. This application provides input terminals located at troubleshoot positions on the manufacturing floor tied directly into an RCA 1600 computer. The data is compiled in report format and printout is provided by teletypewriters located at strategic points. These early systems were aimed at collecting defect information as it occurred and presenting it to management in a form making rapid corrective action possible.

Another defect reporting approach being used is Automatic Defect Diagnosis System (ADDS), with manual defect logs used by troubleshooters and inspectors as the source of information. This data is keypunched and entered into a 70/45 computer for analysis. The system is quite flexible and can be configured by each user to fit his own needs. Another feature permits the user to select that portion of data in which he is interested such as specific line number, model, type of defects, *etc.*, by the use of delimiters when requesting reports. These delimiters permit examination of the total data base or specific portions of interest. The ADDS system is very flexible in its application and, therefore, has been or is being used in such places as Consumer Electronics in Taiwan, Government and-Commercial Systems, Consumer Electronics and Appliances in Canada, and Electronic Components in Canada. Applications include analysis of field defect information as well as in-plant use.

Another development providing not only defect reporting capability, but also product tracking through the manufacturing process is the Manufacturing Data System (MDS). This uses a General Automation SPC-16 computer and input terminals similar to those used by the Defect Reporting System (DRS). Greater flexibility is provided as the user can configure the entire system by filling in tables which define data validation routines, input terminal locations, data meaning and data names to be printed in subsequent reports. The user can request reports at any time, giving product status, product flow, in-process inventory, and defect analysis. A unique feature of this system is the X-Y report which permits the user to list any combination of two items, one on the X axis and the other on the Y axis, with the body of the report showing coincidence of the number of counts or quantities summed for these two parameters.[6]

Data collection systems for specific divisional needs have also been developed. Video terminals as input devices are being used by Solid State Division in conjunction with an IBM System 7 processor. The terminals are used in a community mode in which data is entered by clerical personnel as product enters and leaves a functional area such as final test. In addition, data concerning the results of tests can be entered for later analysis. As in most computer controlled data collection systems, the user has the capability of on-line examination of data in a real-time manner.

Although not completely manufacturing oriented, Electronic Components developed an Order Control System (OCS) using a General Automation SPC-16 computer which provides warehousing control throughout the country at various locations. Customer orders are entered by clerical personnel through video terminals at each location and an examination of the data base as to product availability and inventory status is provided. The system printout permits warehouse personnel to select product and also provides billing information to include with the packaging.

Process control

Process control is many times thought of as the complete closed-loop control of a total manufacturing plant such as those systems which have been installed in the petro-chemical industries. Although this type of complete control is usually impractical in most of our manufacturing processes at RCA, it is many times possible to identify small process steps which will yield very effectively to tighter and better control. For some years, certain components have been automatically assembled into printed circuit boards at Consumer Electronics. This approach uses the United Shoe Machine equipment in a continuous line process, assembling one component at each station. Although very effective for high volume runs with few changes, line changeover due to mixtures of products is a time consuming and expensive procedure. Recently, both United Shoe Machine and Universal Instruments Corporation have made available stand-alone component insertion equipment which utilizes X-Y tables to position the workpiece under the insertion head. The insertion head then inserts each component in turn until all insertable components for that board have been put into place. The control mechanism for this device is a General Automation SPC-12 computer which is fed from a paper tape prepared off-line and is used to instruct the machine in the proper sequence of X, Y and Z positions. The computer also adjusts the insertion head to accommodate the size of the component to be inserted. Sequencing machines are used ahead of the insertion equipment to place components on taped reels in the proper sequence so that parts will go into their proper location.

Process control systems using the DEC PDP-8 computer have been developed to adjust to the thickness of latex applied to tufted carpeting and the speed of carpet through drying ovens. Microwave transmitters and receivers are used to sense the amount of moisture in the latex material, since the microwave signals are attenuated as a function of the amount of moisture in the carpet. With this system measuring the moisture content at the output of the drying oven, it is also possible to adjust carpet speed automatically for various carpet styles since the oven temperature is considered a long-term constant. In addition, gas usage monitoring has been added which has proven to be effective in adjusting oven efficiency.

Process control has been developed for the production of photomultiplier tubes at the Electro-Optics and Devices activity in Lancaster. Initially using a PDP-9 and later upgrading to a PDP-11, this system controls the rate of deposition of photomultiplier material on the anodes of the tube and makes specific tests of the product as it is being processed.[7]

In the production of integrated circuits, many critical steps need to be monitored and controlled. Included are the furnace diffusion steps which require tight control of the variables as well as verification that all process steps have been satisfactorily completed. To make these more positive and reliable, many furnace suppliers are developing control systems based on micro- and mini-computers. Solid State Division has recently ordered furnace control systems, one using a microprocessor with card reader input to control insertion and withdrawal rates, setpoints on temperatures, and gases. The second system will include a minicomputer which feeds recipes to the microprocessor and provides a certain amount of supervisory and reporting capability.[8]

Extreme care and careful planning must be exercised when applying process control. People with intimate knowledge of the process and the control system who can effectively communicate and work toward a common goal should be available. In most cases, process variables are interactive; therefore, a period of process monitoring is usually needed to establish correlations to verify intuitive relations established during manual operation. Special attention must also be given to equipment reliability and backup procedures in process control.

Conclusion

RCA is actively involved in many areas of manufacturing technology. The techniques necessary to provide acceptable yield when producing large scale integrated circuits, color picture tubes to extremely tight tolerances, competitively priced tv sets with high reliability, and other quality products have been under development for some time. Only a few of the projects involved with automatic test, data collection, and process control have been outlined in this paper.

Since manufacturing is a major contributor to product cost, performance, reliability, and customer acceptance, increasing attention must be centered on this part of our business.

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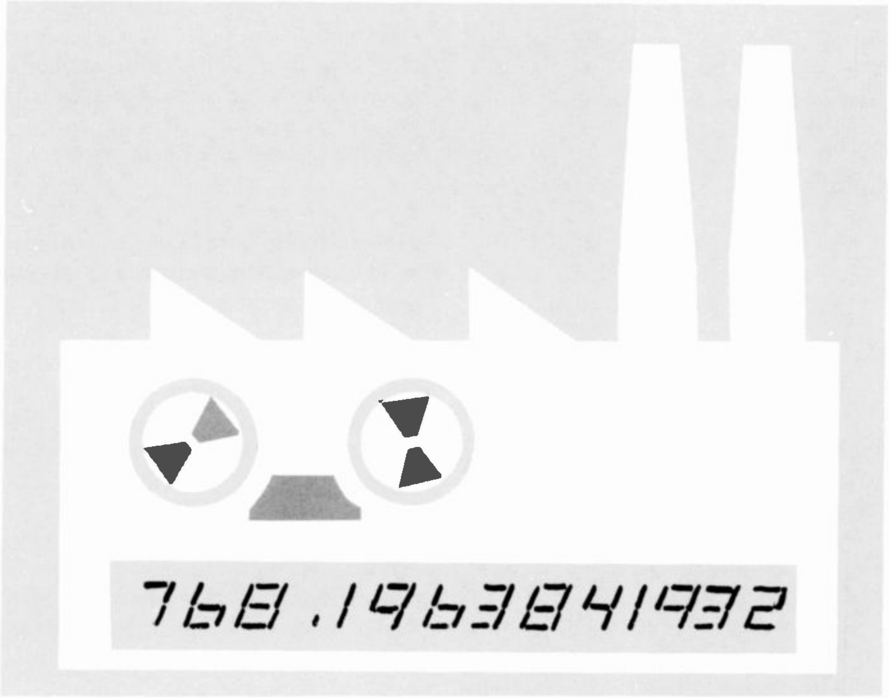

The computer — its use in managing manufacturing operations

R.M. Carrell

Computers have served as a useful tool in the management of manufacturing operations. Such activity has involved big computers, microcomputers — and now the minicomputer gathers data and produces (on demand) the reports that management personnel requires. Such an idealized manufacturing data system provides great management flexibility, reduces defect rates, and provides a convenient easy-to-use, man-machine interface by using a personal input terminal (PIT). A special program called the "XY report generator" can access any file, extract specific data, and provide a "quick look" or a more detailed report for management.

SOMEONE once suggested that significant inventions occur not so much because of the singular genius of the credited inventor, but rather that as events unfold, these inventions are ready to appear. Thus we have steamboats not because of Fulton, but because it was steamboat time, and later, telephone time or moonshot time.

One could say that it is now time for using minicomputers in managing manufacturing activities. What follows may seem obvious; hopefully it is the obvious quality that results from good design. Emphasis in this paper is placed on design principles implemented within RCA; thus, specific applications are not discussed.

Computer universes

Fig. 1 shows three nesting computer universes (big, mini, and micro). We are familiar with the big computer universe, which comes under the control of financial operations in most companies. The computer operation thus tends to operate from a viewpoint which understands a manufacturing operation only in terms of financial statements.

R. Michael Carrell, Administrator, Manufacturing Systems and Technology, RCA Staff, Cherry Hill, N.J. received a BSEE from Iowa State University in 1949 and joined RCA Engineering Products the same year. He became active in the design and development of acoustical transducers, magnetic recording devices, and military keyboards and printers. Mr. Carrell has also participated in system studies of electromagnetic interference problems. He joined the Graphic Systems Division in 1965 as a member of the Product Planning staff. At GSD, he was also active in Systems Engineering. In 1973 he joined the RCA Manufacturing Staff at Cherry Hill where he is working with minicomputers in the collection and retrieval of data concerning manufacturing process-control systems related to production of solid state devices and color picture tubes. Most recently, he has been involved in the process-control studies for the manufacture of the video disc. Mr. Carrell holds six patents and has co-authored and authored twenty-seven technical papers. He was a chairman of NMA's "Computer on Microfilm Quality Standards Committee." Mr. Carrell is a member of the IEEE.

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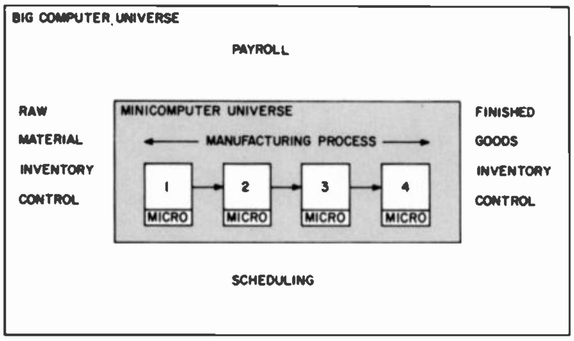


Fig. 1 — Three computer universes.

Actually, manufacture per se has nothing to do with money and if money is used as the *only* criterion the operation will get bent out of shape one way or another.

Most financial computer systems operate in a batch mode using high level languages such as COBOL. Batch operations are frustrating to manufacturing because information isn't available when needed — like now.

Time share business systems are operating at Indianapolis and Information Services at Cherry Hill. Powerful languages and real-time entry/response are possible, but at a cost too high for manufacturing process control involving a continuous flow of data.

Now that it is *minicomputer time*, it is feasible for a manufacturing operation to own a free-standing computer system that gathers real-time data and produces reports that manufacturing management personnel want on demand. Such systems are usually not supported by corporate information systems management. In control applications, it is often necessary to write programs in assembly languages which are unfamiliar to financial programming staffs.

In declaring independence of a big computer operation we are cut off from support as well and must design free-standing turnkey systems. Now the danger is excessive specialization.

Minicomputers were originally used in dedicated, specialized control situations, a function now being taken over the microcomputers. As minicomputer capability rivals the "big computers" of 10 or 15 years ago, there emerges a new application tradeoff.

The idealized manufacturing data system

A manufacturing data system should fit like a glove, not a cast. To tailor a new system for each application is prohibitively costly. Nor can one always afford or use the power of a high-level language in a big computer system to generate specialized application programs to run in a small computer.

A middle path taken in the RCA Manufacturing Data Systems has been to build on an idealized model of a stage of production as shown in Fig. 2.

Here are the elemental actions of production. A message format is provided for each action taken. The terminology may vary, according to local custom, but I think all will recognize these elements. Just as giraffes and elephants have the same number of noses, necks, ears, legs and tails that serve different purposes — so may manufacturing operations differ while containing the same fundamental elements.

If great flexibility is provided in the message structure and nomenclature, we can capture the correct data from any kind of manufacturing operation. This is done by designing a table-driven input system, which I will outline subsequently.

We are approaching a system with real-time data entry through personal input terminals used by inspectors, troubleshooters, movers. *etc.* instead of paper tallies and counters. It is vital that a manufacturing data system enable people in all activities to describe fully their actions. If in any way the system abridges their communication, forces them to lie, or go outside of it, sooner or later the personnel will cause the system to fail.

The most important part of the installation of a data system of this type is the preparation of the messages and nomenclature. Such preparation imposes a salutory discipline on all concerned — a user may for the first time have to think carefully and logically about his operation. Nomenclature must be defined with great care. What, precisely, do we *do* with scrap, rework, reclaim and salvage?

I have seen large reductions in material variances result from the careful preparation for a computer system, before the hardware was installed. The preparation took hard work and dedication — but it was done. There is no magic in a computer system. It is a tool which works as

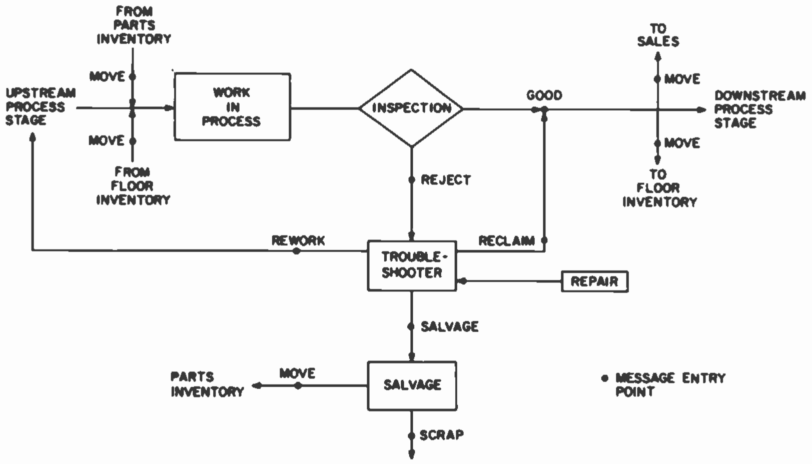


Fig. 2 — MDS generalized manufacturing model.

Fig. 3 — What the manufacturing data system does.

What MDS does:

MDS collects messages
MDS compiles data tables
MDS prepares reports

MDS messages — MDS messages describe the manufacturing process in terms of these basic factors:

a) Count of good product
b) Disposition of product
c) Movement of product
d) Location of product
e) Description of defective product

MDS messages consist of elements and values of elements.

Example:

I pass one good type XYZ
I reject one type XYZ for bent widget
I move 50 type PQR from soldering to location 9

Elements	*Values*
I (operator)	Operator No.
Disposition	Pass, Reject, Move
Quantity	1, 50
Type	XYZ PQR
Defect	Bent Widget
From	Soldering
To	Storage Location 9

Message Formats — Messages are organized into a number of standard formats, beginning with the disposition element, which serves as a title. Examples are:

Message titles	*description*
(Pass) type	Count good product by type and stage
Reject	Record initial defect, type and stage
Reclaim	Product sent downstream to next stage
Rework	Product sent upstream to previous stage
Salvage	Product sent to salvage
Scrap	Product scrapped
Move	Moved to or from floor storage location
Change	Change product identity

Fig. 4 — MDS message elements.

MDS message elements

Element	*Definition or example*
Type	Unit type no.
Disposition	Pass, reject, rework, etc.
Quantity	Number of items
Initial defect	Inspector's defect code
Final defect	Troubleshooter's defect code
Defective item	Code for defective part
Defect class	Code for defect cause
Responsible machine	Number of machine causing defect
Defect zone	Location of defect unit
Inspectors, 1-5	Inspectors handling unit
Terminal No.	Number of entering terminal
Stage	Stage of manufacture
Operator No.	Operator entering data
Time	Hour of message entry
Date	Date of message entry
Shift	Shift of message entry
From	Starting point of a MOVE
To	Destination of a MOVE
Location	Code for a floor storage location, or in special cases, a category

well as it is well designed and well understood.

What a manufacturing data system does

What a manufacturing data system *does* is shown in Fig. 3. We see that each operator action or decision when stated as an English text message will be found to contain elements and values which can be represented by numerical codes. Given a well organized nomenclature, adequate library capacity, and a table-driven input system, a natural and flexible man/machine interface is possible.

An illustrative list of elements is shown in Fig. 4. Each of these is associated with a list of values, which for unit types and defects may run into the hundreds.

Real-time data entry is provided by input terminals widely distributed on the factory floor. Available terminals fall into three classes. There is the very primitive turn-a-knob or small pushbutton terminal. These are slow to operate or very limited in information capacity. The next level of complexity usually includes a badge or card reader. Finally, there is a CRT terminal with a keyboard. These functions all miss the electronics industry as an applications area. They are really designed for heavy industry operations or inventory operations where typing skills are available. Those terminals that are inexpensive enough for wide use on a production line are too slow. CRT terminals are too expensive for wide use,

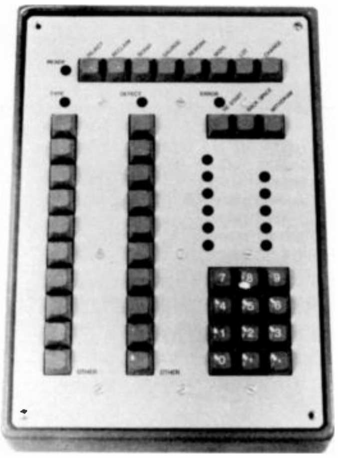


Fig. 5 — Typical layout of a personal input terminal (PIT).

and require typing skills not available in production workers.

Our answer to this problem was the design of a Personal Input Terminal (PIT) which has a free-form button panel interfaced with standard electronics (Fig. 5 shows a typical layout).

Here the buttons are grouped by message elements, with each button representing a value of that element. Lights operated by the computer guide the operator in the correct message-entry sequence. The electronics package has a serial ASCII 20 mA current loop interface. It is intended for use with a minicomputer equipped with a communications multiplexer.

There is extensive use of canned messages where a button represents a part identity or a defect descriptor. The most common messages can be sent by a few keystrokes. Special programs were written for controlling the PITs. A user fills out a series of tables, working from his knowledge of his process. The table formats effectively lead the user into programming-type decisions and translate easily into actual programs.

The PIT control programs validate incoming messages and operate the lamps. Close or loose control of incoming messages is available at the user's option.

Data flow and status reports

Fig. 6 illustrates the data flow through the system. Incoming message elements are distributed into five major data tables, from which five reports are extracted. Fig. 7 shows the current status report. This is a quick look at the operation as it is now. It is available on demand but is printed automatically at the end of the shift. It shows the good output for each type with a breakdown of defects found by inspectors, and the dispositions made by troubleshooters or analysts.

A quick look at manufacturing performance is given by the stage performance report shown in Fig. 8. This report can be summed over a selected recent period retained in the computer data files.

In some operations, material salvage is important and a special report is available to show the source and condition of material flowing into the salvage operation. This too, can be summed over a convenient time period.

A material balance sheet is available for financial analysis. Fig. 9 shows a representative situation where material is being moved about in a complex pattern. Fig. 10 shows a corresponding material input/output report from which a financial analysis can be made.

So far we have discussed convenience features of a manufacturing data system which makes life easier for foremen and reduces clerical burdens.

Savings by defect reductions

Large savings can flow from small reductions in defect rate. The system accumulates detailed descriptions of defective product. The report of Fig. 11 is the output of a powerful data analysis program called the XY report generator.

Any of the data files can be accessed by this report. In any single file any element

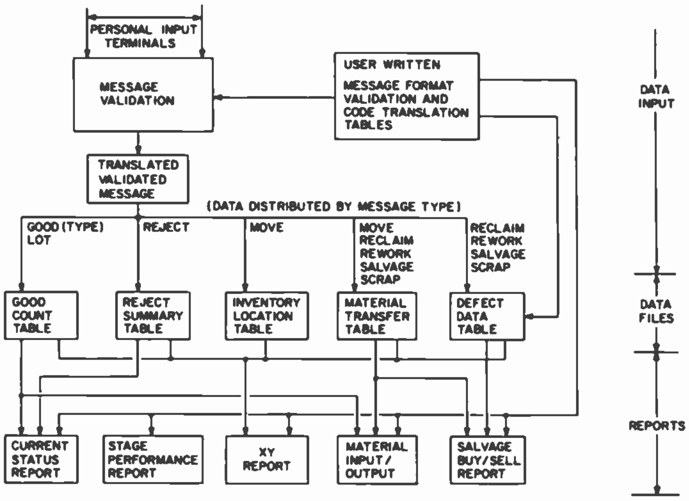
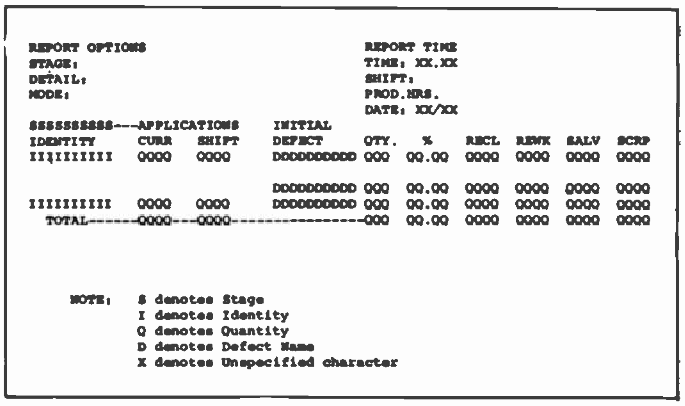


Fig. 6 — Data flow in the manufactuirng data system.



```
REPORT OPTIONS                                    REPORT TIME
STAGE:                                            TIME: XX.XX
DETAIL:                                           SHIFT:
MODE:                                             PROD.HRS.
                                                  DATE: XX/XX
SSSSSSSSSS---APPLICATIONS    INITIAL
IDENTITY       CURR    SHIFT    DEFECT     QTY.   %      RECL   REWK   SALV   SCRP
IIIIIIIIII     QQQQ    QQQQ     DDDDDDDDDD QQQ   QQ.QQ   QQQQ   QQQQ   QQQQ   QQQQ

                                DDDDDDDDDD QQQ   QQ.QQ   QQQQ   QQQQ   QQQQ   QQQQ
IIIIIIIIII     QQQQ    QQQQ     DDDDDDDDDD QQQ   QQ.QQ   QQQQ   QQQQ   QQQQ   QQQQ
  TOTAL------QQQQ---QQQQ-----------------QQQ   QQ.QQ   QQQQ   QQQQ   QQQQ   QQQQ



      NOTE:   S denotes Stage
              I denotes Identity
              Q denotes Quantity
              D denotes Defect Name
              X denotes Unspecified character
```

Fig. 7 — Current status report format.

can be X and any other can be Y. A file extract for a stated period is done, delimited by other elements in the file. The data is arranged in rows of X and columns of Y. Rows and columns are summed, then rank ordered by column totals.

When applied to defect data, the most serious problem rises to the upper left hand corner of the report. Because it is available on demand from the computer, an engineer can easily request a series of reports, slicing the defect data file in different ways to isolate causes of defects.

Computers are not needed to isolate disaters which shut down a line. But in normal operation, defect levels become tolerated which are expensive over a long term. The XY report provides the means to flexibly analyze a large body of data to find what to work on and where to apply corrective effort.

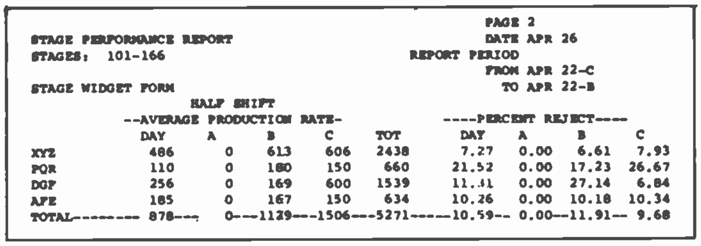
System advantages

The system outlined here has something for everyone. It places no more burden on operators and inspectors than existing paper and counter systems do. It lifts a paperwork burden from foremen and gives them time to supervise, which is their function. Supervision can get a quick look and study summary reports. Scheduling operations has a current look at the location of work in process inventory. Financial operations can get a comprehensive month-end material balance sheet. Engineering and Quality get a powerful defect analysis system.

These report formats may not match local custom for any plant. They do logically present the principal data required. Other special reports can, of course, be written as needed.

Conclusion

In designing a system of this kind there is always a danger of painting oneself into a corner. It is prudent to have enough paint left over to paint a door in the corner through which one can escape. In the present case this is the XY report generator. Because it can access any file, all data collected can be extracted, and there is no risk of some data being lost because it doesn't fit into a preconceived report format.



```
                                                          PAGE 2
STAGE PERFORMANCE REPORT                                  DATE APR 26
STAGES:  101-166                                     REPORT PERIOD
                                                          FROM APR 22-C
STAGE WIDGET FORM                                           TO APR 22-B
                   HALF SHIFT
          --AVERAGE PRODUCTION RATE-                  ----PERCENT REJECT----
           DAY      A       B       C     TOT         DAY      A       B       C
XYZ        486      0     613     606    2438        7.27   0.00    6.61    7.93
PQR        110      0     180     150     660       21.52   0.00   17.23   26.67
DGF        256      0     169     600    1539       11.41   0.00   27.14    6.84
AFE        185      0     167     150     634       10.26   0.00   10.18   10.34
TOTAL-------- 878---    0---1129---1506---5271-----10.59-- 0.00--11.91-- 9.68
```

Fig. 8 — Stage performance report sample showing two shifts of production on same date.

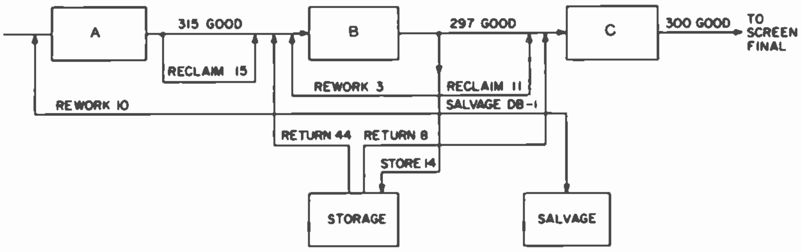
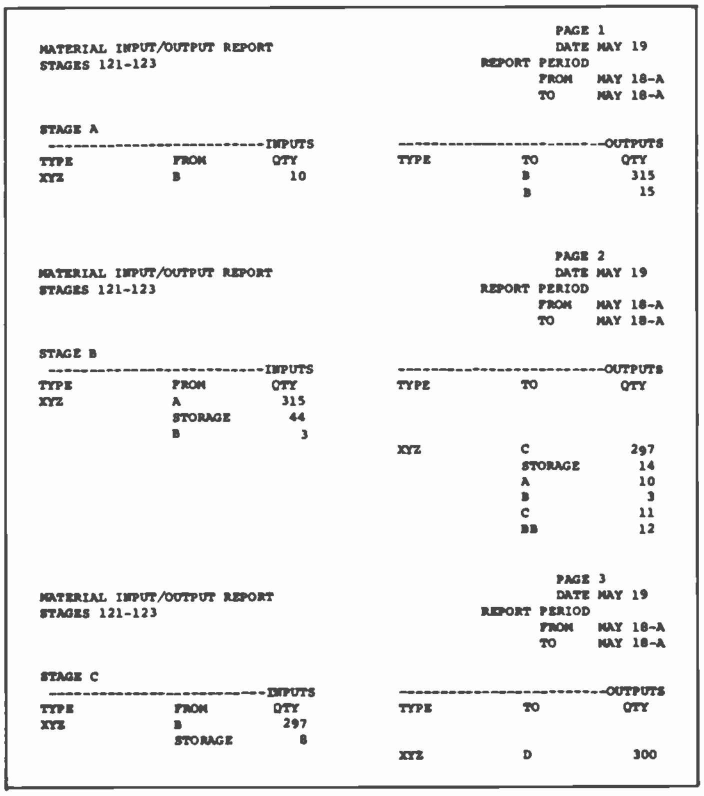
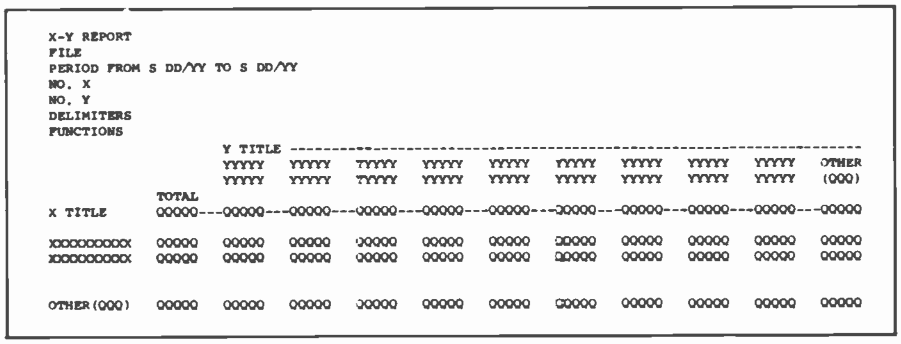


Fig. 9 — Product flow example (see material input/output report sample).



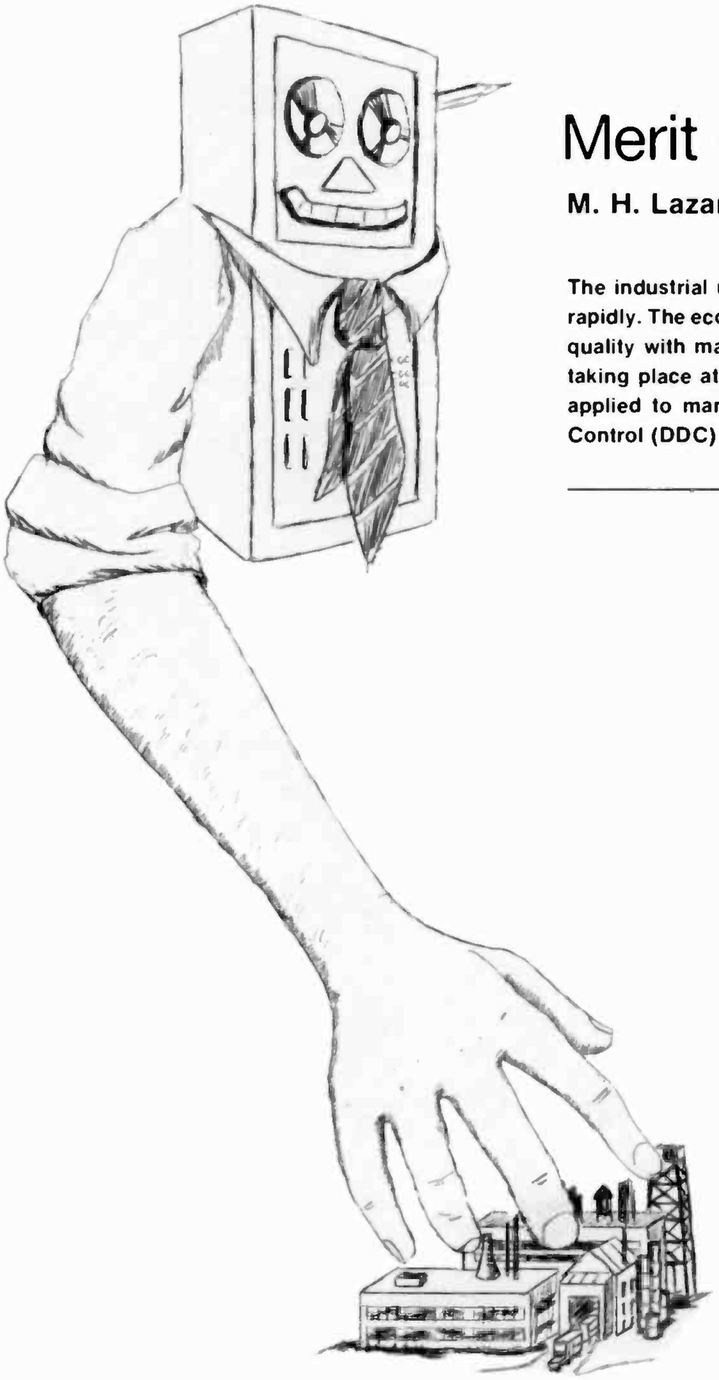
```
                                                        PAGE 1
MATERIAL INPUT/OUTPUT REPORT                            DATE MAY 19
STAGES 121-123                                     REPORT PERIOD
                                                      FROM   MAY 18-A
                                                      TO     MAY 18-A

STAGE A
 ------------------------INPUTS          ------------------------OUTPUTS
TYPE              FROM         QTY       TYPE           TO            QTY
XYZ               B             10                      B             315
                                                        B              15


                                                        PAGE 2
MATERIAL INPUT/OUTPUT REPORT                            DATE MAY 19
STAGES 121-123                                     REPORT PERIOD
                                                      FROM   MAY 18-A
                                                      TO     MAY 18-A

STAGE B
 ------------------------INPUTS          ------------------------OUTPUTS
TYPE              FROM         QTY       TYPE           TO            QTY
XYZ               A            315
                  STORAGE       44
                  B              3
                                         XYZ            C             297
                                                        STORAGE        14
                                                        A              10
                                                        B               3
                                                        C              11
                                                        DB             12

                                                        PAGE 3
MATERIAL INPUT/OUTPUT REPORT                            DATE MAY 19
STAGES 121-123                                     REPORT PERIOD
                                                      FROM   MAY 18-A
                                                      TO     MAY 18-A

STAGE C
 ------------------------INPUTS          ------------------------OUTPUTS
TYPE              FROM         QTY       TYPE           TO            QTY
XYZ               B            297
                  STORAGE        8
                                         XYZ            D             300
```

Fig. 10 — Input/output report sample.



```
X-Y REPORT
FILE
PERIOD FROM S DD/YY TO S DD/YY
NO. X
NO. Y
DELIMITERS
FUNCTIONS
                   Y TITLE -------------------------------------------------------------
                   YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  OTHER
                   YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  YYYYY  (QQQ)
            TOTAL
X TITLE     QQQQQ---QQQQQ---QQQQQ---QQQQQ---QQQQQ---QQQQQ---QQQQQ---QQQQQ---QQQQQ---QQQQQ---QQQQQ

XXXXXXXXXX  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ
XXXXXXXXXX  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ


OTHER(QQQ)  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ  QQQQQ
```

Fig. 11 — X-Y report format.



Merit of direct digital control

M. H. Lazar

The industrial use of computers for all aspects of manufacturing control is advancing rapidly. The economics of people versus machines and the competition for better product quality with mass production dictate it. At the present time there is much investigation taking place at various stages within the RCA divisions on how computers can best be applied to manufacturing. This article discusses one technique called Direct Digital Control (DDC) that has been developed and applied in the continuous flow industries.

MANUFACTURE of electronic products is, for the most part, a discrete process and does not lend itself easily to digital (computer) process control. Although some parts of the process can be automated, such as testing and component insertion, the entire process of creating an electronic product using a computer has not been a reasonable goal.

The opposite has been true for the continuous-flow industries such as petroleum refining where the computer has been applied extensively. As a result, there is a considerable amount of software and hardware technology available today for using the computer for controlling continuous-flow processes. Coupled with this technology is the fact that computer hardware prices have dropped to the point where computer automation in many areas has become economically feasible.

Beyond process technology and economics, several developments are required before any industry can take advantage of automation. One is the interface between the computer and the product that transduces the computer signals to regulate or make the product. In electronics, robotics become important because of the difficulty of replacing the dexterity of the human hand. Another required development is the understanding of the process steps and their interrelation to the extent that the computer can be applied with economic advantage over other methods. In some cases, the process may require some redesign to be compatible with computer control.

Max H. Lazar, Manager, Systems Programming for Corporate Staff, Manufacturing Systems and Technology, Cherry Hill, N.J., received his undergraduate training in Chemical Engineering from Drexel Institute of Technology and did graduate work in Computer Technology at the University of Pennsylvania Moore School of Electrical Engineering. As Manager of Industrial Systems Programming at Leeds and Northrup, he designed and developed real-time process control software for power and cement companies. These developments included Direct Digital Control and Digitally Directed Analog Control. He joined RCA Corporate Staff in 1968 and has been involved in the development of software systems and tools for manufacturing control applications throughout the corporate divisions.

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Types of computer control

Direct digital control

DDC is defined as the use of a digital computer for the closed-loop control of process variables. This means that, at regular intervals, the computer reads in the analog signal such as a temperature or pressure, converts the signal to a binary number representing the engineering units, compares the value to a setpoint, calculates a correction factor and outputs the correction to a device that is the control mechanism for that variable. A flowchart of this process is represented by Fig. 1.

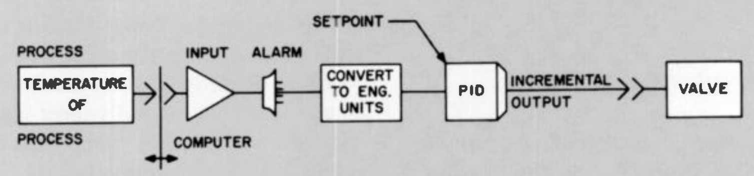


Fig. 1 — Direct digital control (DDC) process flow.

The rate at which signals are read into the computer can vary from once per second to once per minute, depending on the frequency response characteristics of the process.

Digitally directed analog control

DDAC is defined as the use of a digital computer to calculate the corrections to the setpoints of a process. The DDAC flow chart of Fig. 2 shows the setpoint changes.

The setpoints themselves are inputs to analog controllers, one for each point in the process, and these controllers operate independently of the computer. The calculation for the setpoint correction is called a *second level control* program and is based on some higher level decision-making program related either to product volume or product quality. Examples of such calculations are:

1) A power plant where total demand has changed. The second level program calculates the optimum power output for each generator based on its characteristics to meet the total load.
2) A cement plant where an analysis of product feed from the crushing section shows an incorrect ratio of elements. This means that the raw feed content has changed, and the component feed setpoints must be altered to offset this.

DDC second-level control

The control programs that determine the outputs to each process variable and maintain setpoints are generally called the first level of control. The change to the setpoints through stored program calculations rather than through human intervention is generally called the *second level of control.* These setpoint changes are made to a list stored in computer memory. The purpose of second-level control is to determine the setpoint values for the best overall operation of the process. This determination is made by reading input variables and deciding by comparison with some performance index whether the process performance is satisfactory. If it is not, then new setpoints must be derived that will correct the present condition and possibly compensate for the length of time the less-than-optimum performance existed. In some cases, a straightforward second-level control program will not be possible and a trial-and-error situation must be adopted where the setpoints are altered continuously for some period until optimum performance is again attained.

Advantages of DDC

A minor advantage of DDC over regular analog control, if there are sufficient control points in the process, is the cost saving of eliminating each analog controller.

A more important advantage, however, is the capability to customize each control loop with special programming, if required. This feature cannot easily be considered with analog control. But with a computer, the engineers can redesign the control because the possibilities become greater. Thus, DDC offers control flexibility that is superior to analog control.

Feed forward control is more flexible and easier to implement with a computer. Feed forward control is where the examination of product conditions in an early stage of the process dictates a correction in a later stage of the process to offset the possibility of product degradation or even total loss. This can be done with a higher degree of sophistication in DDC than with analog control due to stored program capabilities.

Supervisory control can easily be added to a DDC system with some additional programming. This type of control is used where the computer periodically must interrogate the states of switches through digital inputs, make alarm outputs or printed statements providing a record of change, and generate outputs

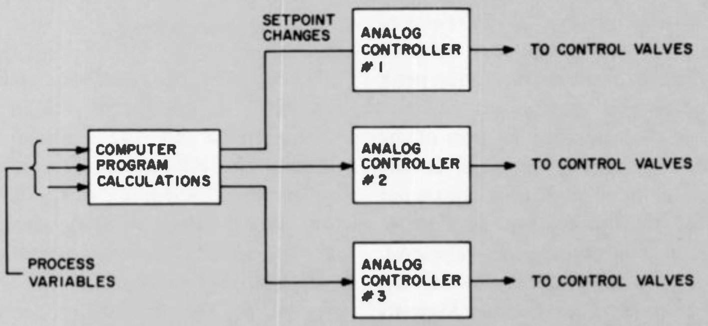


Fig. 2 — Digitally directed analog control (DDAC) process flow.

for changing switches based on a schedule.

Disadvantages of DDC

With one computer controlling a process, backup in case of computer failure becomes an important consideration. One solution is to have complete manual or analog backup. In the case of analog backup, the setpoints that are changed in the computer must also be changed through motorized setpoints as in digitally directed analog control (DDAC). This method effects a bumpless transfer to the process when the computer fails and the system automatically switches to analog control. The drawback for analog control is that the cost of the controllers is not saved. A second method is to have a backup computer that would take over in the case of failure. Mainframes today are low enough in cost that this solution could be attractive. A backup computer requires a link between the two or more computers with a checking system so that if one computer fails, the other can take over the control action after the proper alarms have been sounded.

Microprocessors for automatic backup

A more sophisticated version of DDC with automatic backup can be achieved with the use of microprocessors. The sampling and control functions are performed by one microprocessor for one or more process points. Data is fed back to the central process unit (CPU). If the CPU fails, then the microprocessor maintains the control action. Similarly, if the microprocessor fails, the CPU takes over control. In this way, adequate redundancy is achieved. This type of control distribution using microprocessors becomes advantageous or even required when sampling frequencies are so high that one CPU becomes saturated at peak periods, and when operators must enter information conveniently for part of the process under their supervision. In the latter case, a local intelligent controller can provide communications in place of the CPU and thus share more of the load. This last approach is the most difficult one and requires considerable systems analysis to achieve success. The rule is that the greater the flexibility, the more difficult the design becomes because the possibilities are greater.

Elements of control action

For the purpose of understanding DDC, a brief and simplified explanation of the elements of control action are described here. There are essentially three separate control calculations performed to produce a control action output. These are called proportional, integral and derivative. Mathematically, they are expressed as follows:

Proportional

$$M = K_p(SP - I)$$

Integral (reset)

$$M = K_I \int_0^t (SP - I)dt$$

or

$$dM/dt = K_I(SP - I)$$

Derivative (rate)

$$M = K_D\, dI/dt$$

or

$$M = K_D\, de/dt$$

where:

M is the total movement of the valve or control element from its stable position with the process at setpoint.

SP is the setpoint.

I is the measurement input.

$e = SP - I$, is the measurement control error

K is the gain factor that relates the amount of control action to be taken to the type of control action, proportional (K_P), integral (K_I), or derivative (K_D). This is sometimes called the tuning factor because, in analog controllers, there is one knob or dial for each factor. The process operator uses each dial to tune the controller to the process and achieve the correct amount of control customized to the process idiosyncrasies. Thus, without any mathematical analysis, given a three-mode analog controller (PID), the controller circuitry equations can be fitted to meet the requirements of a process. For DDC, these factors are usually entered into the computer via a terminal.

Proportional control

As seen from the equation, such control provides a corrective action that is proportional to the control setpoint error. The amount of action taken is determined by the size of K_P. When K_P is too large it can cause an overcorrection in the valve position and an overshoot of the setpoint. The process will oscillate around the setpoint and appear unstable. If K_P is too small, valve corrections are produced that require too much time for the process to reach the setpoint after a disturbance. The proper K_P, therefore, is one that will be tuned to the response capability of the process. Such tuning brings the process back to setpoint smoothly with perhaps some minor overshoot and minimal oscillation.

Proportional control is rarely used by itself because it is insufficient for bringing the process back to the setpoint when there is a *sustained* large load change. Since the proportional action is taken with reference to a given amount of load, and a valve position to maintain setpoint at that load, a large sustained load disturbance can cause a permanent control error, or offset. The control equation sees the error but cannot position the valve properly to correct it. Thus, the proportional control alone is not capable of stabilizing a process at setpoint under this condition.

Integral control

In practice, integral control, or reset control, action is used to supplement proportional control in order to adjust the process to the setpoint where proportional alone is not sufficient. As seen from the equation, the amount of valve motion contributed by integral control depends upon the accumulated error over some period called the reset interval or period. If the algebraic summation or integration is zero, then no control action results. As long as a net error exists, however, there will be control action. Thus, where proportional control will permit an offset due to a sustained overlaod or large demand, the reset control will continue to move the valve until the setpoint is reached. In effect, this action tends to 'reset' or 'shift' the proportional control to balance the new demand load with the valve travel.

To see this, it must be remembered that $M = M_F - M_O$, where M_F is the final valve position, and M_O is the initial valve position at setpoint conditions for the previous demand situation. Another insight to integral control may be gained by considering the derivative form of the equation, $dM/dt = K_I\,(SP - I)$. This shows that the rate of motion of the control valve is proportional to the measurement error.

Derivative control

Derivative or rate control is sometimes called booster or anticipating control. It is used where large fluctuations in load are expected and where quick corrective action is needed. Looking at either form of the rate equation, the amount of rate action is determined by the rate of change of either the measured variable or the calculated error. By sensing a sudden large change, rate action is coupled with proportional control to stabilize the process. Rate control will not recognize an error, no matter how large, if that error is steady state. Thus, rate is never used by itself but it is always coupled with proportional, or proportional and integral, control.

Control analogy

To visualize the effects of the different parts of the control equation, it might be helpful to think of a man driving an automobile. Starting out from zero velocity to a setpoint of 50 mi/h, proportional control causes the pedal to be depressed an amount in proportion to the error. Corrections are applied to the pedal in the form of both proportional and reset action to find the correct pedal position for 50 mi/h. As the car approaches a very steep grade, it rapidly begins to lose speed due to the added gravitational pull. The rate action takes effect here, seeing the change in load through the large change in velocity and causes a corrective depression of the pedal. This will be supplemented by both proportional and integral control to readjust velocity to the 50 mi/h setpoint.

Position vs velocity

The preceding discussion for DDC used the position form of the control equations. This means that the final position of the control valve was calculated. The equations normally used in DDC are called the velocity form. The difference is that instead of M, ΔM is calculated. Thus,

$$\Delta M = \Delta P + \Delta I + \Delta D$$

where

$$\Delta M = M_n - M_{n-1}$$

This means that the position of the valve at setpoint is not considered. Only the incremental valve movement is calculated based on data saved from previous readings of variables and the present reading. From this calculation, an output is made to the valve disregarding even its present position, since all that is considered is the change, or ΔM.

Programming DDC

In practice, designing a program to perform DDC in its most elegant form is a complex task because there are many problems to consider. One of them is controller windup. *Windup* is defined as the improper storage or loss of control information (outputs) due to constraints on the controller output. Here, the computer can attempt to output control action at a rate beyond the ability for the actuator to respond. Thus, part of the control information must be saved and merged with the results of the next control calculation.

Bumpless transfer

When a process is *going on* DDC or *going off* DDC to analog or manual control, the process may suffer a 'bump' or sudden change in the variable which could be upsetting to the process dynamics. This condition must be managed carefully in the program design of DDC.

The strategies for solving these problems have been developed by the major vendors of process instrumentation. Algorithms for the conditions of windup and bumpless transfer are not trivial considerations. These algorithms have been incorporated in sophisticated DDC software systems by such companies as Leeds & Northrup, Honeywell, Bailey Meter and Foxboro. More recently, General Automation, a minicomputer vendor, has developed such a full-scale software package called PMS/DDC. This package is currently being evaluated by Corporate Staff, Manufacturing Systems and Technology.

A good package should have all of the programs required for doing straightforward DDC. These include analog input and conversion and input smoothing, digital inputting, control calculations, analog and digital outputting. It should be implemented, for the most part, through table filling for all parameters required to define the system for first level control. Further, all parameters should be easily modifiable on-line via a teletype, CRT, or special communications device. Most important is that the user engineer should not be required to have a programming background or knowledge of programming in order to use the system efficiently.

Applications within RCA

There is potential for the application of DDC in areas within RCA where the manufacturing processes are complex and sensitive to minute variations in process conditions.

In some cases, the process steps and the values of the controlling parameters have been derived empirically, and the operator controls the overall process by experience and intuition. When process upsets occur that cause significant yield reductions, it is sometimes very difficult to restore the process to equilibrium. Then too, even when the process is running smoothly, yields may still be unpredictable or be at such low levels that a 10% increase could drastically alter the process economics. With DDC, better interrelated control might be achieved and at the same time other important tasks could be performed. Some of these are:

1. Evaluation of yields as linked to process parameters.
2. Analysis of process dynamics through the on-line collection of data.
3. Determination of defect sources through correlation with parametric and mechanical attributes.
4. Special reports, alarms and trending.

The evaluations and analyses could lead to the formulation of second-level control programs that would take the 'blind' spots out of the process — those events that cause upsets with no clues as to why. Thus, there could be many advantages and byproducts to the application of DDC to just these areas.

Conclusion

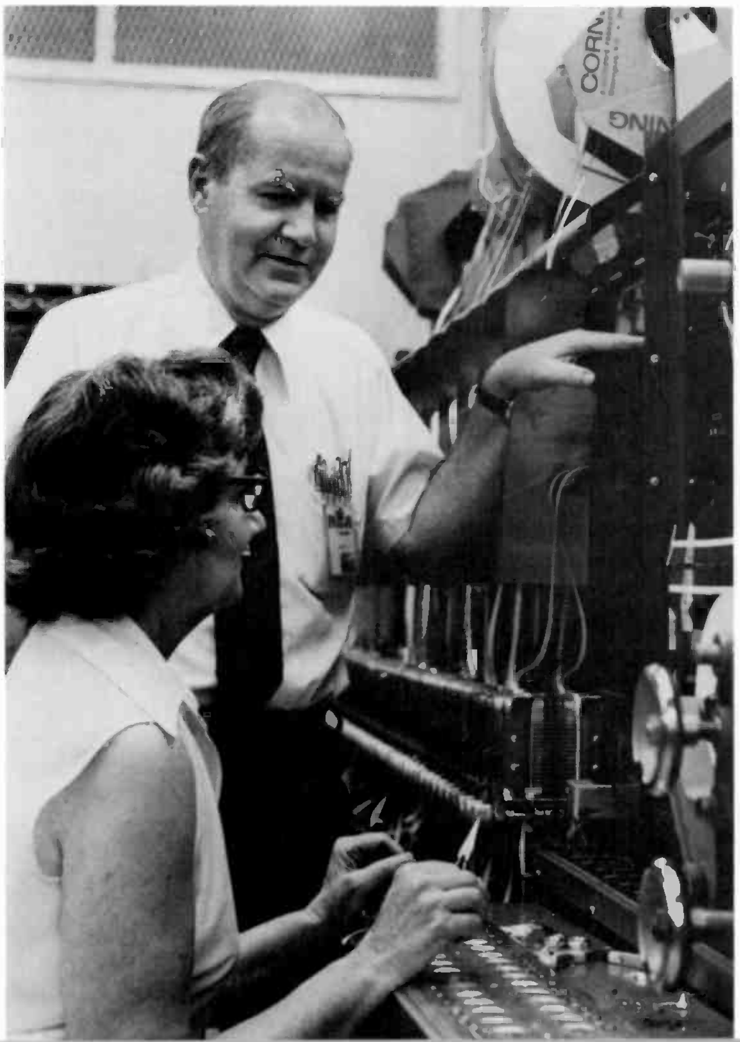
Process control in many forms probably will become a major part of RCA manufacturing in the years to come. DDC is one type of control that will, no doubt, be applied at the proper time in these areas where it makes good economic sense. Because of the cost and complexity, it is advisable to use DDC software supplied from a vendor rather than attempt an internal development. DDC is not a panacea; rather, it is a sophisticated use of a digital computer and must be approached cautiously, understanding what improvements it can bring to manufacturing.

Trend toward standardization and automation in manufacturing

M.J. Gallagher

The design of electronic products has been revolutionized, in recent years, by the introduction of various "state-of-the-art" concepts and technology changes. This continually accelerating trend of technical innovation has, perhaps, had a tendency to cloud the significance and relative importance of some of the fundamental concepts involved in the expression "producibility of design." "Producibility," specifically with respect to the cost connotations implied, is necessarily associated with standardization of materials, components, and operations which, in turn, become the basis for extended mechanization and automation of the operations. Corollary to this process is the necessity for improved data management at the design/manufacturing interface and, in a sense, the standardization and automation of the data and data handling techniques involved.

Maurice J. Gallagher, Mgr., Industrial Engineering, Communications Systems Division, Camden, New Jersey received the BS degree from Temple University in 1958. His experience in the field of Industrial Engineering is varied. Dating from 1946, he has been employed in progressive positions while pursuing his formal degree. In 1952, Mr. Gallagher was promoted to Process Engineer and in 1962 assumed responsibilities of Leader, Manufacturing Engineering. In 1969 he assumed like responsibilities in solving divisional multi-layer printed circuit problems. In May 1970, Mr. Gallagher assumed his present responsibilities of Manager, Industrial Engineering, responsible for all assembly processing, standards and measurement techniques, facilitation, and manpower planning for effective implementation of program goals, Mr. Gallagher is presently a member of the EIA Automated Component Processing and Insertion (ACPI) JC-11 Committee representing RCA.



PRODUCT COST has always been an important consideration in industrial operations, but in the present climate of spiraling material and labor costs, shortages in basic materials and aggressive competitive practices, we can no longer afford the luxury of "back-burner" approaches to such fundamental concepts as standardization and automation. This paper presents the programs undertaken within RCA Camden in recognition of this situation and details some of the accomplishments obtained as a result.

The Camden facility is composed of two separate operating divisions; one broadly chartered for the development and design of government communications systems, and the other with corresponding development and design responsibilities for commercial broadcasting equipment. Both divisions are serviced by a single manufacturing organization.

The product lines of the two divisions are broad and diverse, with unique problems in each product area. Product sizes and complexity cover a spectrum ranging from "manual portability" to major fixed installations. The one point of commonality which exists, however, is that none of the products of either division can be described as a mass production or high-volume product. Because of this basic fact, automation concepts cannot be based on product volumes, but rather on operation volumes across products and product lines. And this, in turn, promotes the desirability of standardization concepts across products and product lines to build and provide the necessary operation volumes (see Fig. 1).

Interdiscipline communication

Development and implementation of programs involving both design and manufacturing disciplines obviously cannot be successfully accomplished by either discipline alone. Thus, it is critically important to establish a working basis within which mutually agreeable approaches to cooperative efforts can be found. Fortunately, at Camden, this fact was appreciated by management levels within both disciplines, and a working relationship, founded upon the necessity for interdiscipline communication and action was established.

The working committees formed to foster this concept were, of course, composed of

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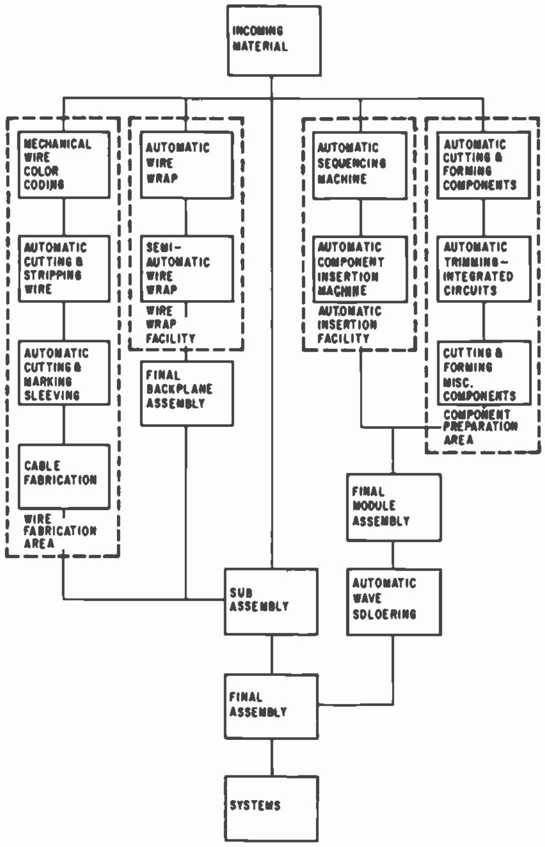

Fig. 1 — General production flow.

representatives from both Engineering and Manufacturing as well as from various Engineering and Manufacturing support activities. The committees were all oriented toward developing and maintaining sets of compatible standards across program lines.

A considerable standardization effort has evolved from these committees including the development and publication of an *Engineering Standards Manual* containing lists of preferred components and related engineering and manufacturing technical data. Significantly, however, it has been found that the committees represent a pooling of knowledge and experience which can be tapped as an information source for the resolution of many "non-standard" problems.

A direct outgrowth of this standardization effort has been the development and publication of an *Industrial Engineering Manual.* This manual serves to document, for continuing implementation control, the specific standardized techniques for transmitting and handling data across the Engineering/Manufacturing interface, and serves as a continuing guide to the Industrial Engineers in the selection of appropriate standard operations and all pertinent data related to them. Information covering all aspects of the Industrial Engineers' function including standard processes, tooling identification, related labor measurement standards, and similar data are all included in the manual.

The *Industrial Engineers Manual* is by no means complete — nor is it ever intended to be completed. It will continue to grow and be updated as additional progress is made. Some of the accomplishments made to date will be detailed in the remainder of this paper.

Data handling

The handling of data is by no means a small part of the overall task. In some cases, simplification and uniformity of data and data handling is a goal in itself; in other cases, successful data handling is mandatory to properly implement and control automated operations.

One of our long-range standardization projects is the development of a format for engineering documentation that will allow the data to be more readily available to other, using activities. To date, with the cooperation of Engineering, material lists have been redesigned to include information that aids in scheduling, purchasing, and manufacturing decisions.

Additionally, by analyzing the documents used by such diverse activities as material ordering, stock disbursement, and manufacturing, certain elements were found that were sufficiently alike as to encourage standardizing efforts in attemps to provide data in a format common to all areas. One of the forms developed, and now computer originated, is capable of serving as a shortage notice for material ordering, a "pull card" for the Stockroom, a dimensional and operational order for the component preparation activity and a bin card for manufacturing areas.

In the realm of manufacturing operations, some functions, essentially because of generated volume considerations, are more conducive to standardization and automation than are others. Wire fabrication operations have provided a fertile field for such efforts — to the point, in fact, that computer operations are utilized to accumulate requirements and to generate appropriate instruction documents. Computer inputs are, of course, standardized and controlled.

Wire fabrication

Wire is cut to length and stripped on automatic equipment. Although the equipment has been in operation for a number of years, recent innovations have improved the overall operation. Due to the automatic nature of the equipment, the restricting dimension affecting production economics is operation quantity and resultant setup time. By utilizing an operations method based on computerized generation of bulk fabrication quantities (by shop order rather than by reference number), and thereby assuring maximum operation output from the equipment, the use of automatic cutting and stripping equipment (see Fig. 2) has not only aided in obtaining dollar savings but has offered the assurance of positively controlled measurements.

An added benefit of this computer

program is that each wire, with its individual dimensions, identification, and fabrication needs, is not only listed, but is also accompanied by a computer card. Once the wire has been cut and stripped, the card functions as a travel tag as the wire progresses through various operations to the point where it ultimately loses its identity by being included in another assembly.

After an analysis of wire color-coding requirements, it was determined that standardization in this area could lead to additional benefits. Equipment has been installed to automatically stripe white wire, using the new standard, in any combination of four colors desired (see Fig. 3). The massive inventory of different colored wire that had to be maintained has now been minimized; yet, the desires of the Design Engineer can be met, often on a more timely basis than before.

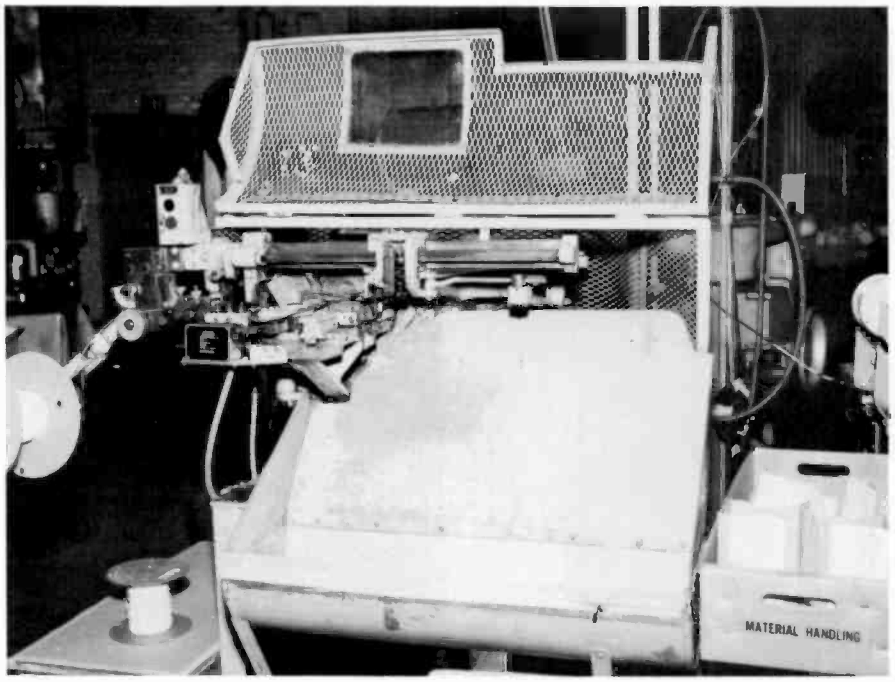

Fig. 2 — Automatic wire cutting and stripping equipment can cut and strip wires up to 30 gauge to predetermined lengths.

Fig. 3 — Automatic wire color-coding equipment.

The wire-fabricating area also has the responsibility of providing assembled coaxial cables to the other assembly areas. It has been the practice of Industrial Engineering to process each program and cable on its own; however, a study of past requirements revealed that, in many cases, connectors and cables used on one program were also used on others. The present method relies on standardized processes for each connector and cable assembly. These processes are compatible to many programs assuring that all connector assemblies are now identical and alleviating the need to prepare processes for new equipment.

Prior to the advent of standardization activities, sleeving was purchased in short lengths of various diameters, thicknesses, material, and colors. This, of necessity, created a large inventory and the cutting and marking by time-consuming manual operations. Now, using automatic equipment, the activity has the ability to cut and mark sleeving in a fraction of the time on the sleeving machine shown in Fig. 4.

As the old three-foot lengths became obsolete and the sleeving machine could be fed from a reel, a program was started to standardize sleeving. Sizes and colors have standardized, allowing for bulk purchasing and processing plus a minimum inventory. As a result, the demands of production are kept at a minimum and savings can be realized.

Wire-wrapping facility

If standardization and automation are to be successfully achieved the utmost cooperation between Engineering and Manufacturing cannot be overemphasized; both activities must realize that the benefits are mutual. An extremely good example of beneficial interface between these two disciplines can be found in the progress made within the Camden wire-wrap facility (see Fig. 5).

The Camden manufacturing activity has a full capability for performing wire-

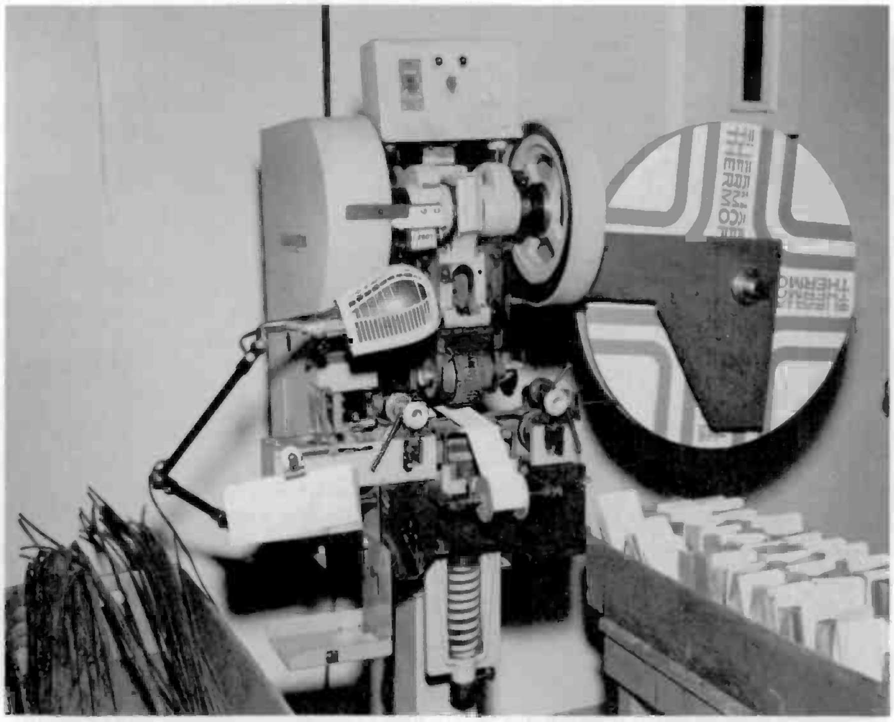

Fig. 4 — Sleeving machine.

Fig. 5 — Automatic wire-wrapping equipment.

wrapping services utilizing either fullly automatic or semi-automatic equipment.

The automatic wire-wrap machine is completely automatic and its sequence of operation, as well as the actual electronic impetus, is controlled solely by the tab card deck. Upon command, the machine will strip and wrap both ends of a wire, cut it to length, and dress it in accordance with a pre-planned program. The machine has the capability of wrapping three levels of wire on panels as large as 22 by 42 in. Although limited to single, solid conductor wires, the machine can handle from 22- to 30-gauge wire. Allowing for such variables as setup time and loading time, the machine has the ability to wrap up to 500 wires/hour.

The automatic wire-wrap machine consists of movable carriages containing wrapping-tool assemblies and dressing fingers that are positioned on modular points to form a desired wire pattern. The commands activating the various machine movements originate with computer inputs. The data utilized to prepare these tapes are the Design Engineering blueprints and specifications which can be easily traced to Design Engineering documents. When Design Engineering prepares their wiring information, an extract of the information is generated which, with minor manufacturing inputs, ultimately becomes the card deck that operates the equipment.

The computer data is supplied on a printout and a deck of punched cards; each card of the deck contains information for one wire; a card reader, in turn, translates the input into mechanical motion. Fig. 6 shows a backplane prepared by the automatic wire-wrap machine.

The semi-automatic machine is also numerically controlled. This equipment is utilized to wrap wires that are beyond the scope of the automatic wire-wrap equipment. For example, twisted pairs are laid in by an operator in accordance with equipment-controlled location patterns. The machine is controlled by a paper-tape input that directs the machine through programmed operations. These operations locate the wrapping head over the particular terminal to be wrapped. The operator then loads the head with the wire and completes the termination. The machine has the capacity for a 30 by 72 in. panel, can be programmed to do point-to-point or path wiring, and can also be converted to two heads (permitting simultaneous assembly of two smaller

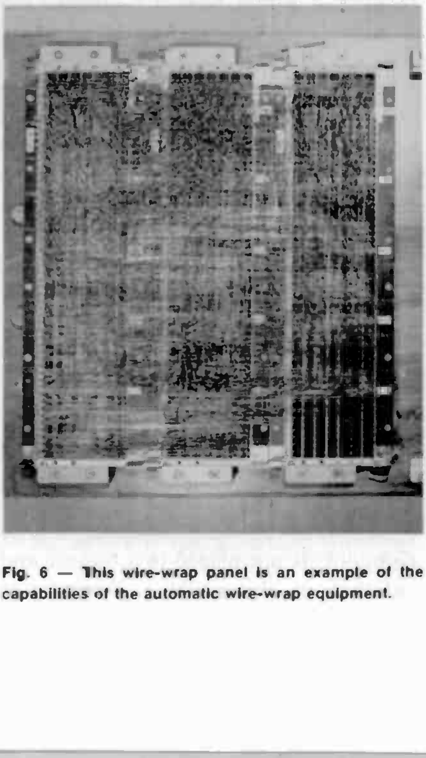

Fig. 6 — This wire-wrap panel is an example of the capabilities of the automatic wire-wrap equipment.

panels). An average of 170 wire terminations/hour can be produced by this equipment.

The key to progress in this area has been the development of feasible, standardized techniques for handling the engineering data, controlling it to prevent significant wiring errors, and development of the computer program which automatically generates the equipment operating instructions in the form of card decks. The wire-wrap facility has proven so successful that additional equipment has been purchased to handle the increasing load. The expansion will include both automatic and semi-automatic equipment. Due to improvements in design, the new equipment will more than double the capabilities of the activity.

Automatic insertion activity

Another facet of manufacturing recently automated in the Camden plant is the assembly of components to printed circuit boards. The automatic insertion equipment (see Fig. 7) contained in the area consists of taping, sequencing and insertion equipment; modules may be assembled in a fraction of the time, with less assembly personnel than previously possible.

Although the automatic insertion technique is not new, standardization concepts have allowed for greatly expanded utilization of this economical manufacturing facility.

In the past, components were assembled to printed circuit boards by hand — a time-consuming operation exposed to operator error. Today, due to the standardization of components, mounting dimensions, and other design considerations, a greater proportion of axial lead components are mounted by automatic equipment. In the Camden activity, the percentage of automatically inserted components has risen from 25% to approximately 75% of the components in recently designed equipments.

For automatic insertion, the normal method of purchasing components is to request that they be on taped reels; however, this is not always possible. The automatic taping machine has been installed to cover this contingency. Loose components are placed in a hopper and fed through the machine, dropping at preset intervals onto tapes that enclose the lead ends; they are then gathered upon reels. The machine has the capability of taping 5,000 components/per hour.

The taped reels of components (either purchased or taped in-house) are placed in position on the sequencing equipment. In operation, the machine is wholly automatic — its commands being dictated by punched tape. This machine has a capacity of 39 reels. The tape, punched (in code) to a pre-determined component assembly sequence, is fed over a scanner which dictates release of one or more parts from one of the 39 reels. The released components travel along a track to a taping unit and are taped and fed onto a reel in the proper insertion order.

Although the machine has the capability of sequencing 5,000 components/hour, it is the limiting piece of equipment in the area. In order to minimize down time for setup, each module utilizing automatically inserted components is scanned for common usage of parts. Those components with the most common usage are assigned to specific locations on the machine. In this manner, only a minimum number of reels need be changed when preparing the sequencer for a new assembly.

The reel of sequenced components is placed on the automatic insertion machine. This machine, also operated by tape, removes the component from the tape and inserts it in its proper position on the printed circuit board. The machine selects the part, inserts it, and clinches it below the board automatically. At the same time, the machine will move its table so that the various locations on the board are correctly oriented to receive the component.

The automatic insertion machine presently in use can insert axial lead components on mounting centers of 0.4 to 0.7 in. It has the ability to insert up to 3,000 components/hour.

Although the present equipment has limitations, such as the necessity to program separately for each mounting center, the automatic insertion area, like the automatic wire-wrap activity, is also undergoing expansion. More sophisticated equipment, increasing the potential of the facility, is being added. The new variable-head insertion machine can insert components on mounting centers ranging from 0.3 to 0.8 in. It can also insert components to more than one mounting center automatically. This, in itself, may be considered a major asset — as it minimizes setup time. Although the equipment has not yet been exposed to production operation, it is estimated that, with setup time, it will insert up to 6,000 components/hour.

A computer program is presently under development that will ultimately control all data needed to operate this equipment. Once the path or sequence of insertion has been plotted on a drawing, the data will be fed into the computer. The computer, using data stored in its library, will

Fig. 7 — Automatic insertion activity.

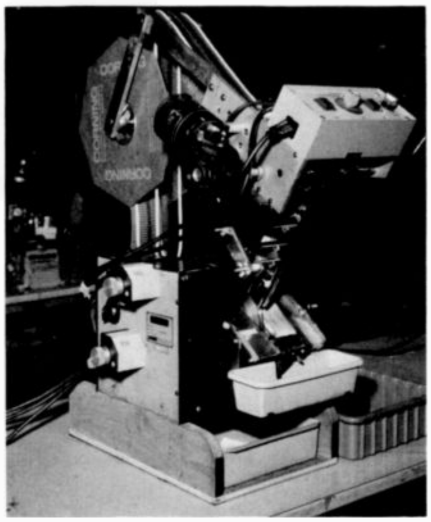

Fig. 8 — Semi-automatic component cutting and forming machine.

then supply all the necessary information for the insertion machines. At the same time, a punched tape will be supplied that will operate the equipment. In this way, the conversion of the Design Engineer's data to production data can be accomplished in a minimum time span.

A new sequencing machine will relieve the capacity restrictions presently experienced and a new variable-head automatic insertion machine has been purchased. Eventually, this facility will be able to process an expanded number of mounting dimensions, components of greater body size and, in addition, integrated circuits.

Component assembly

Almost all printed circuit modules contain components that do not lend themselves to automatic insertion. Usually, this is due to the configuration of the part, although there are other restrictions. Components of this nature must be assembled by hand. To minimize the time needed in actual assembly, these components are pre-formed and cut to length, where possible, on automatic and semi-automatic equipment. Here, too, standardization of components, as well as related design and manufacturing considerations, has allowed automatic approaches which minimize operating costs. Tooling has been designed to preform these components to meet the demands of the Design Engineer. Whether the component be socket-mounted, inserted through a spacer, or raised above the printed circuit board, tooling is available to assure compatibility with the design and guarantee consistency of form.

A semi-automatic machine (see Fig. 8) that can cut and form components to preset dimensions, is capable of processing up to 8,000 axial lead components/hour. The machine can be adjusted to form components to mounting centers of 0.4 to 3.00 in. When desired, this equipment can also form components with loops (to facilitate assembly to terminals) on the ends of the leads.

Other semi-automatic equipment can also process components of various configurations and can be used not only to cut and form axial lead components for horizontal or vertical mounting but to process parallel lead components such as transistors and capacitors.

Another of the semi-automatic machines (see Fig. 9) in the area trims to length the leads of 14- and 16-lead integrated circuits. It is gravity fed; the components fall from one magazine into another, passing over the trimming blades enroute. The machine can trim the leads of 1,000 integrated circuits/hour.

Wave soldering

Upon completion of assembly, whether by machine, hand, or both, the module is then soldered in wave-soldering equipment. The modules are mounted in holding fixtures that are, in turn, suspended between endless conveyors passing through the machine where a coating of flux is applied to the bottom of the module. After the flux has been applied, the module then passes over a cascade of molten solder. In this way, the bottom of the board, just touching the solder, receives its coating. After soldering, the module passes through an area in which it is subjected to a spray of solution that dissolves the residue of flux. From the bath it goes through a drying area, and thence back to the loading station to be removed. The soldering machine is capable of processing 100 modules/hour.

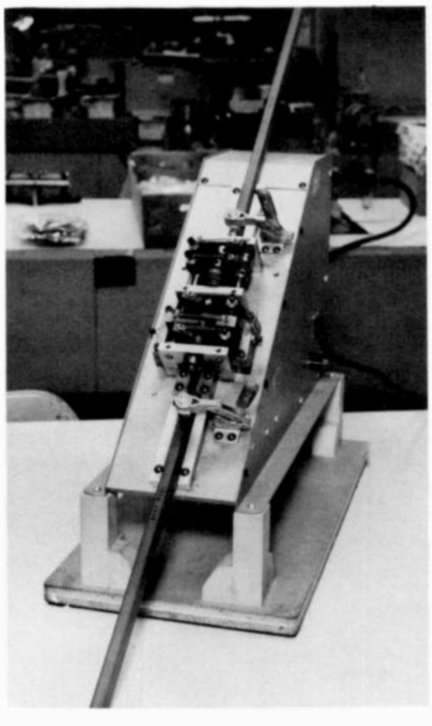

Fig. 9 — Integrated circuit lead trimmer.

Like the previous operations, wave-soldering is also influenced by standardization considerations. Component selection, component density, copper line and space width, even board size and configuration, can influence the basic feasibility and general quality of this operation.

Conclusion

Standardization efforts and the automation of operations made possible through standardization efforts are never-ending jobs. Currently, the Engineering, Manufacturing, and Computer Programming activities are engaged in an investigation into the feasibility of converting raw engineering data into multi-use documents. Working from schematics and logic diagrams, data has been processed that has been beneficial to Drafting and Test Process as well as the two Engineering groups involved. "From and to" lists, cross-reference lists, and DITMCO data have been compiled along with the various numerical control inputs necessary for machine operation. Effort is underway to develop a library of data in the computer that will enable it to furnish additional information such as wire color, type, and part number. A formula that will permit the computer to furnish routing information for use during development of a cable harness, and also furnish the wire lengths needed to fabricate it, is being devised. Additionally, research is presently being conducted into the methods of assembly that will reduce assembly time and yet assure that the design is faithfully being reproduced on a production basis.

Twisted-pair wire dispenser — automatic and programmable

L.D. Ciarrocchi| J.J. Colgan| H.F. Schellack

There has long been a need for twisted-wire dispensing machines that are programmable. To fulfill this need at RCA, the Equipment Development Engineering Section in Camden more than three years ago introduced a prototype machine design. More recently, a second machine (also RCA design) was placed in production. This second machine incorporates many updated innovations. Solid-state reliability, ease of maintenance and product flexibility are the key features of this design. The design provides tangible cost savings in terms of wire prep and production scheduling; also, it provides an alternate wire prepping capability under the direct control of semi-automatic wire-wrapping machines.

THERE ARE a number of reasons why it is not possible to wire wrap certain printed circuit backplanes on currently available sophisticated automatic wire-wrap machines. These include the size of the backplane (some of which fill a standard floor-mounted cabinet), some unusual connector terminations to wire-wrap pins, and the increasing use of twisted wire pairs for most runs. Our original prototype, even though limited to use with a single semi-automatic wire-wrap machine and limited in its flexibility, paid for itself in the first six months of operation.

L.D. Ciarrocchi's and H.F. Schellack's biographies and photographs appear with their other article in this issue.

J. J. Colgan, Equipment Development Engineering, Communications Systems Division, Camden, New Jersey has had 33 years of industrial experience, including 30 years in tooling, machine design, and production engineering. He came to RCA in 1942 as a Tool Designer. He left in 1943 to serve three years in the U.S. Air Force. After returning, he attended Drexel Institute Evening School. He joined the Equipment Devleopment Engineering group in 1949 and had a prime responsibility in facilitating RCA's early introduction to printed circuit fabrication and assembly, tv yoke coil equipment, and the ferrite plant.

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The 'Twister'

The Twisted-Pair Wire Dispenser, illustrated in Fig. 1, is the new production version currently in service. The Twister can be pre-set to dispense a single wire, two single wires or a twisted pair on demand of the semi-automatic wire-wrap machine. The Twister will feed, twist, cut, and strip to the specified length, as programmed on the wire-wrap machine tape. The machine will handle lengths from 5 to 80 in. with turns/in. variable from 1.5 to 5. On a shared time basis (with its built in first-come, first-served memory), the twister will supply wires to two semi-automatic wire-wrap machines which may be operating from entirely different tape programs. The Twister may also be pre-set to deliver two twisted pairs for each wire-wrap machine should there be a requirement to wrap two identical panels on a given program on each wire-wrap machine.

It is an oversimplification to merely state that we feed, twist, cut, and strip the wire. From past experiences in a number of coil winding applications (tv deflection yoke coil winding, etc.) we have been exposed to some of the difficulties in handling wire. Straightening of the wire, as well as maintaining proper tension, is important. In addition, it was necessary to compensate for the "twist" memory and the "spool" memory of the wire.

Twister design

The wire tension and straightening device is designed to operate with all wire sizes with little or no adjustment. It consists principally of clothes lines twisted about the wire to which weights are added for proper tension. A large change can be made by altering the turns; or, a smaller change is made by varying the weights (see Fig. 2).

Threading of the wire is accommodated by removing the clothes line clamp and permitting the lines to unravel, which is a convenient way to reset. The tension is relatively constant and the straightening effects are adequate for the application. There are no complex moving parts, and maintenance will consist of replacing the line possibly in a year or more. The wire dereeling device will handle all known spool sizes up to 18 in. in diameter

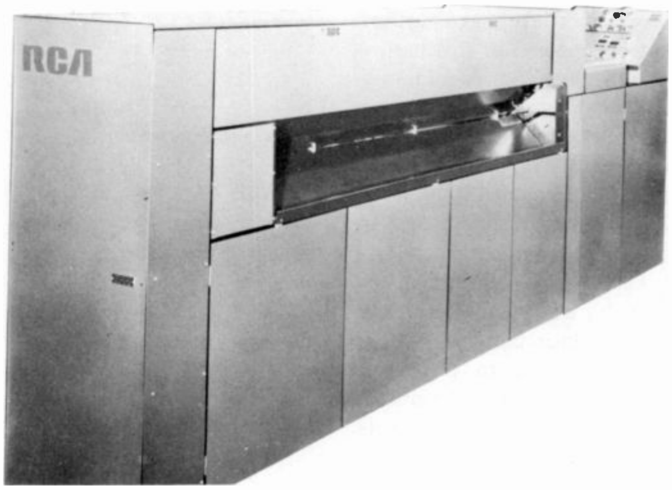

Fig. 1 — Twisted-pair wire dispenser

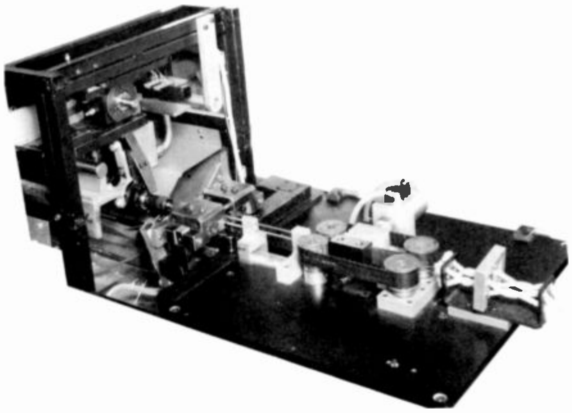

Fig. 2 — Wire-handling mechanics.

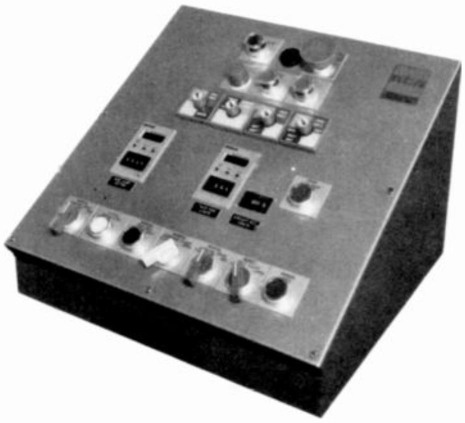

Fig. 3 — Operator control consolette.

without the use of special adapters.

Careful attention was paid also to the other mechanical aspects. The carriage clamp, which holds the wire as the carriage moves to its programmed length, is self adjusting and compensates for variations in the O.D. of the wire. Telescoping tubes are used to cover the path for the wire from the pre-feed belt drive directly to the carriage clamp to prevent possible erratic feeding of the wire. The strip and cut blades are assembled for a particular wire gage and a fixed stripping length. A changeover from one wire gage to another takes only several minutes. The stripping lengths may be altered from 0.100 in. to 1.500 in. through use of a mix of spacer blocks. Since strip and cut blades are assembled as a set, there is no difficulty in alignment when inserting them in the machine (see Fig. 2).

The selection of a stepping motor for the main carriage drive provided the flexibility to obtain the varied functions desired in wire handling. To compensate for the built-in wire memory, which without correction could cause the wire to unravel if released, the stepping motor is programmed to provide varying amounts of stretch, proportional to the wire length. The stepping motor is also programmed for pulsed reversing while twisting is in progress to return the carriage a fixed distance in proportion to the turns/in./unit length of wire.

A vacuum system to draw off the stripped insulation into a collector tank keeps the machine clean and the blades uncluttered. The exhaust from the vacuum system also provides the cooling air for the program controller. The compartment is insulated to reduce the noise to acceptable levels.

Control consolette

The controls provide three modes of operation: manual, semi-automatic and automatic (see Fig. 3).

Each basic motion of the machine may be activated in the manual mode from an array of seven separate pushbuttons to provide capability for setup and checkout.

The semi-automatic mode permits operation as a batch wire-prep unit. Wire parameters can be pre-set for a maximum batch of 9999 wires. The counter will stop the machine at the end of its setting.

The automatic mode is used in conjunction with remote control lines to interact with one or two wire-wrapping machines. The automatic mode will also permit an interruption within the current dispenser cycle without going out of phase. This feature was required to provide for make-up wires and proper sequencing when placing one of two wrapping machines on-line or off-line.

Programmable controller

The sensing devices and the programming controls, as well as, control of the main carriage drive stepping motor are solid state. Mechanical relays are used primarily for isolation of power outputs. There are twenty-nine independent moving functions performed during each cycle, all of which are pre-programmed in a sequence compatible with the condition status of over 30 sensing devices.

As an aid to altering the program, as well as assistance in maintenance, a visual display on the controller indicates the status of the sensing devices. A permanent memory system retains the sequence, once the program is established. The program may be altered in the memory board through other available channels or through use of other pre-programmed memory boards, as shown in Fig. 4.

Conclusion

The new Twister has met the basic design goals in filling the void for wire-wrap support equipment. OSHA safety standards were observed, a fast "pay for itself" was realized, and reliability was enhanced by the unique mechanical features which were incorporated and the use of solid-state controls predominately.

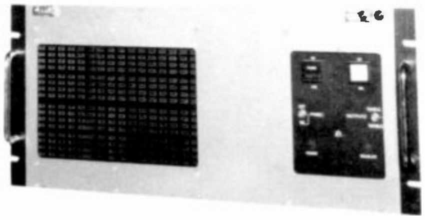

Fig. 4 — Solid-state programmable controller.

18,000-point automatic testing interface machine

L.D. Ciarrocchi | H.F. Schellack

An 18,000-point automatic testing interface machine designed and developed in Camden permits testing of large backplane interconnect systems by interfacing with DITMCO Automatic Test Equipment (DATE). Manual insertion of hundreds of connectors and manual test probing are circumvented with the DATE machine.

THE MOST RECENT TRENDS for very large electronic systems are to make use of cabinet sized backplane wire-wrapped interconnects. Typically, the number of interconnects are in excess of 10,000 points per backplane. The testing of completed wiring is an astronomical task for manual testing. One concept that provides a quick and reliable hookup for an 18,000-point system was designed and built by Camden's Equipment Development Engineering department (see Fig. 1). The concept interfaces with DITMCO Automatic Test Equipment (DATE).

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Louis D. Ciarrocchi, Mgr., Production Engineering Communications Systems Divisions, Camden, New Jersey, graduated from Drexel University in 1937 with a dipolma in electrical engineering. He served in the USAF from 1941 to 1946; his last assignment was Staff Ordnance and Armament Officer for the 9th Air Force. From 1946 to 1956 he was employed as a project engineer by the Baldwin Lima Hamilton Corporation responsible for Diesel-Electric and Electric Motive Power Controls. His latest design covered in-motion automatic switching of locomotive power from third-rail power to diesel electric power and back again to meet environmental pollution limitations in the New York City area. Prior to joining RCA in 1959, he was employed by Selas Corporation as Senior Design Engineer with responsibility for instrumentation and controls in heat treating and fluid processing systems. In his present assignment, in addition to production engineering support for Broadcast and Government Communications Systems Products, he has the responsibility for the direction of the Equipment Design, Development, and Tool Design Engineering Group.

Harry F. Schellack, Equipment Development and Production Engineering, G&CS, Camden, New Jersey received the BSME in 1955 and the MSEE in 1961 from Newark College of Engineering, Newark, New Jersey. In 1955 he joined the Tube Division, Harrison, N.J., as a Design and Development Engineer and worked on manufacturing research in the Methods and Processes Lab. He was granted foreign and domestic patents on tube components manufacturing an delectornic packaging configurations. In 1961, he transferred to the Defense Electronics Products Division, Camden, N.J. His production engineering and manufacturing equipment design assignments were associated with various RCA Divisions in the United States and foreign countries. He has written several magazine articles on manufacturing equipment for printed circuits and in 1969 presented a paper to NEPCON on fabrication controls for manufacturing printed circuits. For several years he taught evening courses in computerized N/C programming at the Camden County Vocational and Technical School. Mr. Schellack is a member of Pi Tau Sigma.

With the system, automatic testing of continuity and shorts, copper-path-networks and hi-potting is accomplished quickly, safely, and accurately.

Need for an interface machine

From past experience, the manual "plug-in" on large systems was found to consume a disproportionate share of the actual testing time. In addition, repeated insertion and removal of wired receptacles introduced errors which required analysis to determine whether the error was in the unit under test (UUT) or the interface cables and connections. The economics of automated testing with DITMCO Automatic Test Equipment dictated development of methods to reduce an operator's time in connecting to a UUT and to improve reliability.

Interface equipment was developed which reduces the operator load-unload time from approximately one-half hour to less than one minute. The machine design utilizes a spring pin contact for each of the 18,000 points (see Fig. 2). This feature keeps all the interconnect wiring from the interface contact pin to the DATE stationary at all times, and, for all practical purposes, eliminates wiring and equipment errors. As such, there are no wear problems as with repeated plug insertion. Spring pin assemblies are rhodium or gold plated for long-term corrosion and wear resistance.

The fact that a plug-in connection of a "card-edge" is not being used to simulate the "final usage" board connection has not been a significant factor. The bulk of faults are concentrated in the wire wrapping operation. The spring pin backside contact to the terminal pins of the UUT's has been extremely effective for DATE interface testing.

Machine description

The machine frame panel A (see Fig. 3) is permanently wired to DATE. Within Panel A, a spring pin is pressed in place at each wire termination and in a spacing

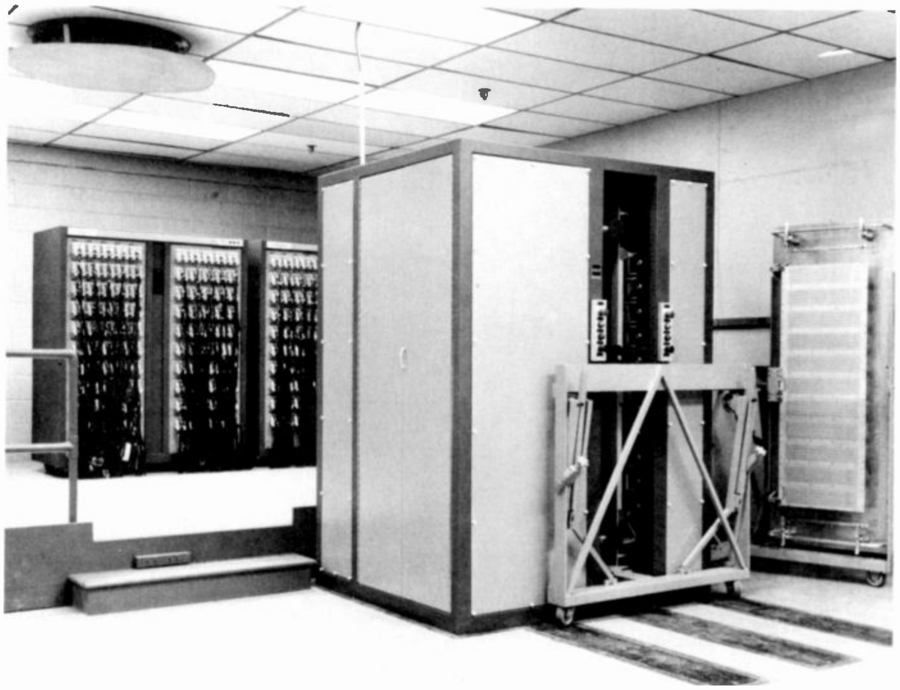

Fig. 1 — Interface machine, in foreground, which connects with DITMCO Automatic Test Equipment (DATE), partially visible on platform in background.

array to match the UUT's (e.g., a grid spacing of 0.125 in., 0.100 in., etc.). The test panel is positioned in a T cart on wheels. The machine has a moveable frame member (B) which travels from the retracted load-unload position to the test position. The T cart, with the UUT backplane accurately prepositioned and secured, is wheeled in and out of the interface machine. Two T carts were furnished with the machine; one with the UUT in the machine undergoing test and a second to permit the operator to load and unload during machine running time.

The second T cart is also used as repair station for the backplane to correct errors recorded while under test.

The operator's function is to place the panel on register pins and clamp. The operator performs this function with the mounting platform in a horizontal position. After clamping the UUT in place, the platform is pivoted and locked in the vertical position for insertion into the machine (see Figs. 4 and 5).

The rear of the backplane mounting plate on the T cart is fitted with T-slots, similar to that found on surface plates of milling machines, that engage T-bars in the machine during loading and unloading. This engagement serves a dual purpose; first, it places the T cart in position for positive alignment with the pins; and second, it prevents damage to the spring pins in the loading-unloading process.

Since the machine is capable of handling a number of types of UUT's the T carts are equipped with sensing actuators which enable the machine to detect the type of UUT and control the closure on the pins accordingly.

During the operating cycle, the movement of frame B also lifts the T cart to accurately align the UUT in relation to the spring contact pins and lock the assembly in place against the B frame before closure with the A frame spring pins is complete. The same closure motive force provides the cam action to align and lock. A permanent stop prevents overstressing of spring pins while permitting positive contact. The travel of each spring is thereby controlled to assure a minimum of 3 oz of pressure contact.

The B frame drive motor is directly coupled to a gear reducer which in turn is connected to a four-post jack screw arrangement that provides positive motion without distortion.

Upon achieving test position, the machine locks up the UUT and disconnects the power drive. OSHA-conforming operating controls and interlocks are provided for operator safety. The typical interface cycle takes about 20 seconds to move the 18,000 points from

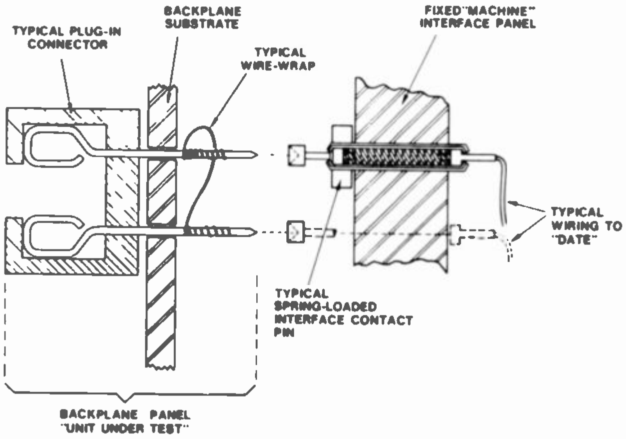

Fig. 2 — Spring pin contact design used in interface equipment.

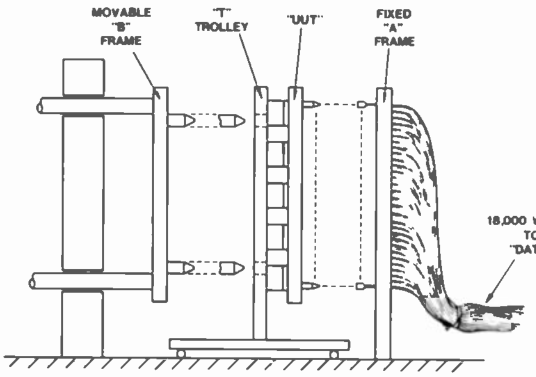

Fig. 3 — Machine interconnection systems.

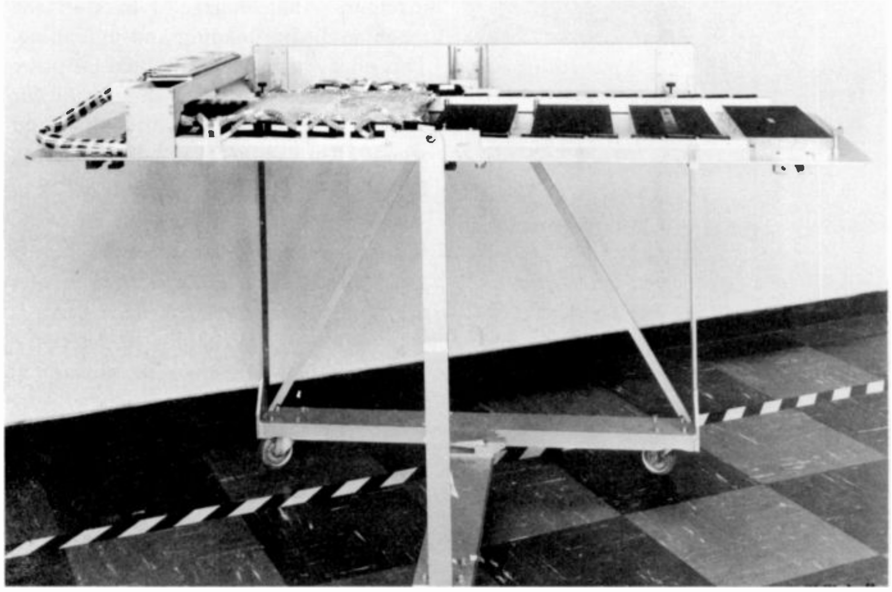

Fig. 4 — A typical backplane UUT is shown with the T cart mounting surface in the horizontal "load-unload" and "repair" position.

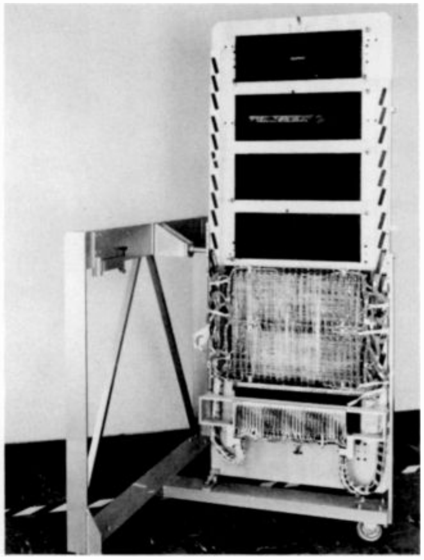

Fig. 5 — A typical T cart with a backplane UUT registered and locked onto the mounting surface which has been flipped and secured into the vertical position preparatory for wheeling into the interface machine.

the load-unload position to the test position. The same time is used to reverse the sequence. Wheeling the T cart into or out of the machine takes 30 seconds.

Tons of force

The frame work of the machine is substantially rugged to cope with the forces required to compress all 18,000 spring pins simultaneously. As can be seen from Fig. 6, the uniformly distributed field of "ounces" of spring pin pressures introduces a possible net force of over 2 tons (up to 4,500 lbs.) in the testing position. As such, the T cart includes backup support for the UUT backplane panel to prevent buckling. Aircraft-type honeycomb sections (see Fig. 7) are used for support of the UUT and to transmit the load through the T cart onto the moveable B frame.

Manual vs. machine reliability

Hand insertion of 18,000 points with 360 connectors (assuming 50 points per connector), at about 10 seconds per plug-in, would take approximately one hour to interconnect to the plug-in side of UUT's.

Conversely, it is never necessary to disconnect the wires that permanently tie-in the interface machine with DATE. Thus, many hours of time to connect DATE, shown in Fig. 8, with the UUT are obviated.

Once the permanent DATE hook-up to the interface machine is made, it is reasonable to expect to approach 100% reliability. Possible operator errors are eliminated by virtue of not inserting hundreds of mating connectors into receptacles.

Most commercially available multipoint interface units are arranged with spring pins in a horizontal plane and usually on a hinged upper panel to provide access for loading and unloading of a backplane. The connecting wires are in motion for

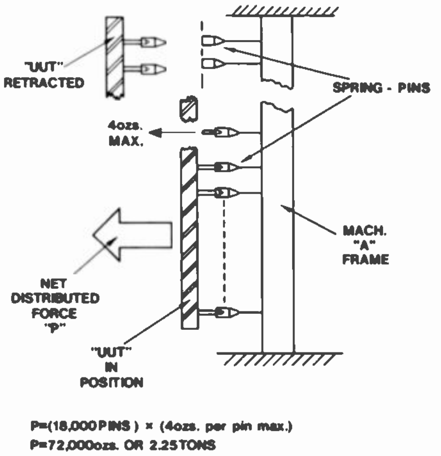

Fig. 6 — Net force distribution with UUT in test position.

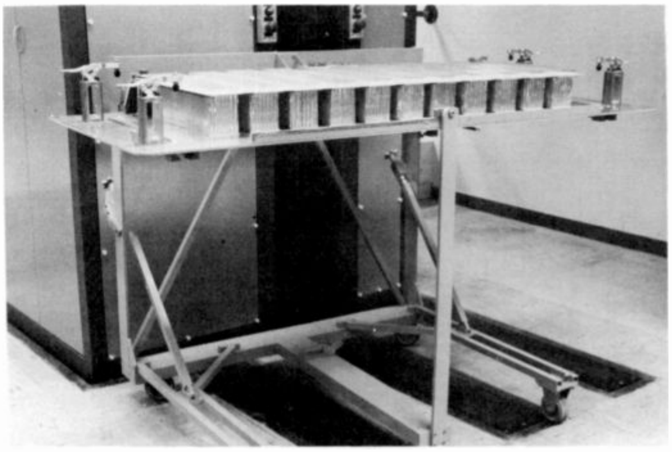

Fig. 7 — Aircraft-type honeycomb structure for prevention of buckling of UUT backplane panel.

each loading and unloading cycle with this design concept. Alignment and maintenance are also more difficult.

The vertical concept provides clear access to both the spring pins and the wiring in the rear and, also, keeps the wiring stationary.

Machine versatility

The machine was designed and built to conform to a fixed grid spacing of pins in a configuration of connectors peculiar to a specific project in process at the time. For other later projects, now in process, conversion units have been developed and furnished for automatic alignment and insertion in the machine, utilizing the same T cart technique for loading. The conversion unit consists of a rigid pin configuration on one surface that is arranged to mate with the basic array of primary spring pins in the A panel of the interface machine.

The opposite surface contains a spring contact pin array to mate with the new UUT spacing (see Figs. 9 and 10).

Installation and removal of a conversion unit is accomplished by using a T cart. The conversion unit is driven under power and automatically alligns with and engages the spring pins in the A panel. The operator locks the conversion unit in position and actuates the drive mechanism to extract the empty T cart in the normal manner as for a UUT. The same procedure is used to remove a conversion unit.

The machine is now ready to accept the new UUT on its T cart, the same as described previously. Again, no wiring is plugged in and out when converting to different UUT requirements. Reliability of making a changeover utilizing the same philosophy approaches that of the basic UUT testing system.

The interface machine has been provided with a long-term stand-alone capability by virtue of its versatility to accommodate different connection point array spacings. It is also evident that the DATE machine presently wired into the interface can be replaced with different automatic testing equipments. Long-term utilization is, therefore, limited only by the creation of new types of "inter-interfaces" (conversion units) that can adapt to the basic framework of the machine.

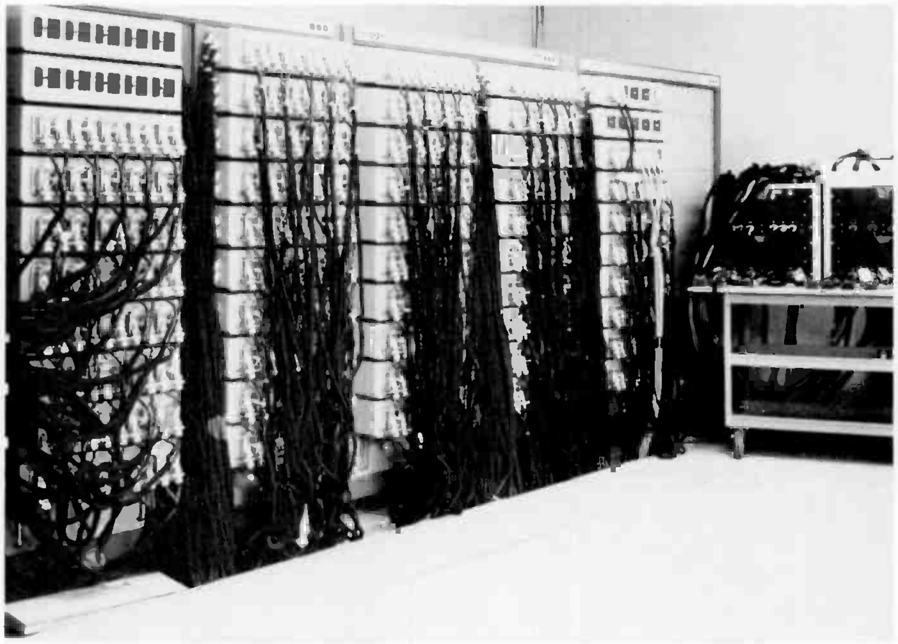

Fig. 8 — DITMCO Automatic Test Equipment and cabling.

Results and conclusions

As of this writing, the machine has been in use for a period of three years and has run an approximate total of 1095 backplanes produced at the Camden facility. An average of 2.5 testings per panel has been typical.

The 2.5 testings per panel is governed by the yield factor on the wire-wrap machines which is constantly improving. It is often necessary to check each level of wiring on the backplane before proceeding with the next level. This would be particularly true on a new project as a means of checking the wire-wrap programs and changes.

For the past 8 months 50 backplane testing per week were run. In the machine's history, there have been a few instances where bent spring pins were caused by distorted wire-wrap pins on backplanes (see Fig. 2). These bent spring pins are replaceable in less than 30 seconds per connection point. There has been an average of less than one such instance per month in the life of the machine.

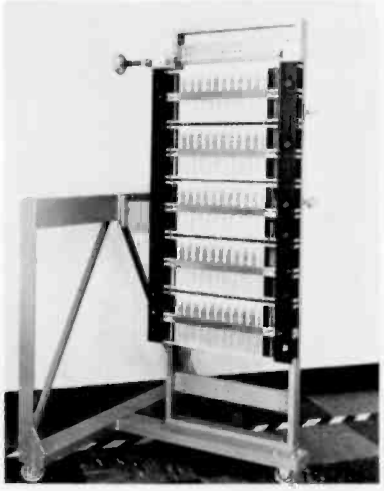

Fig. 9 — Conversion unit on T cart shows how loading-unloading is similar to handling of a backplane UUT.

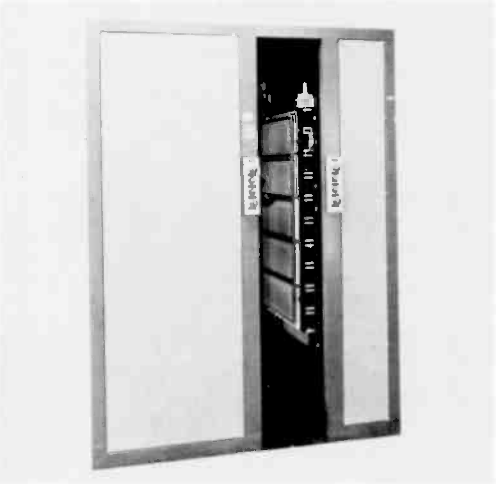

Fig. 10 — Interface machine with conversion unit in place.

Programming for semi-automatic wiring equipment

R. Piscatelli | S. Patrakis

Semi-automatic wiring with its relatively low-cost, highly flexible, quick-reaction, and easily changeable characteristics has opened new dimensions in the field of backplane packaging. Backpanel packaging left to the individual engineer's imagination can present wiring problems for which there is no simple answer. The availability and use of a well-planned, disciplined computer program will allow the engineer to realize all the benefits of semi-automatic wiring.

COMPLEX ELECTRONIC SYSTEMS, primarily but not exclusively digital, require a variety of wire sizes and types (single conductor, twisted pair, triplets, etc.) to be placed down in a point-to-point manner. The characteristics of MSI/LSI circuits and the competitive electronic market require highly flexible, quick reaction, easily changeable wiring techniques. To meet these needs, semi-automatic wiring machines are used. These machines combine the best properties of an automatically directed machine with the versatility of an operator.

The advantages are readily apparent. Semi-automatic wiring machines were developed to fill the gap between fully automatic wiring methods, and manual operations. The machines are in fact post locators that remove this task from the operator and reduce the interconnection errors. The size of panels or boards to be wired is not a problem since the machine's design usually allows panel shifting or dual-head wiring. The various post spacings found in connectors can also be handled. The movement of the machine head does not restrict any grid patterns from being wired. Twisted-pair wires can also be terminated on semi-automatic wiring machines by connecting the ends of paired wires in succession.

Semi-automatic wiring does have some disadvantages. The production rate is solely dependent on the operator. Operator efficiency, attitude, speed, and performance will have a direct effect on

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Robert N. Piscatelli*, Government Communications and Automated Systems Division, Burlington, Massachusetts, received the BS in Physics from Providence College in 1965, the MEd in Secondary Education from State College at Boston in 1966, and the MS in Electrical Engineering from Northeastern University in 1968. He joined RCA in 1969 and since then has performed as a Systems Programmer researching, designing, and implementing methods for improving the efficiency of the MIS Computation Center as well as providing technical assistance to the programming and operation staff with respect to the computer and its software. He also worked on development of a similar program for the generation of integrated circuit and hybrid array masks.

*Since writing this article, Mr. Piscatelli has left RCA.

Stanley P. Patrakis, Mgr., Design Engineering, Products Engineering, Government Communications and Automated Systems Divison, Burlington, Massachusetts, received the BS in Mechanical Engineering from Northeastern University and spent two years in the Army as a member of the Scientific and Professional Personnel program participating in the Army's Special Weapons Program. He joined RCA in 1956 and worked as a mechanical design engineer on the ASTRA and F-108 Program. He provided the engineering-manufacturing liaison and configuration control on the critically scheduled APCHE and Mobile APCHE program (ATLAS missile automatic checkout equipment). Mr. Patrakis was responsible for the electronic packaging design of the Variable Instruction Computer. He was responsible for the electronic packaging design of the RCA-built components on the ADA system and for the aircraft installation design of the complete ADA system. He was active in developing electronic packaging concepts for airborne equipment using medium-scale integrated circuits and in developing the electronic packaging concepts for GCASD's 200 Series Computer. More recently, Mr. Patrakis supervised the Materials Application Laboratory and the Mechanical Design Standards activity.

the output. Some machines require the operator to route wires during the wiring operation which could result in excessive buildup and inconsistent wire routing.

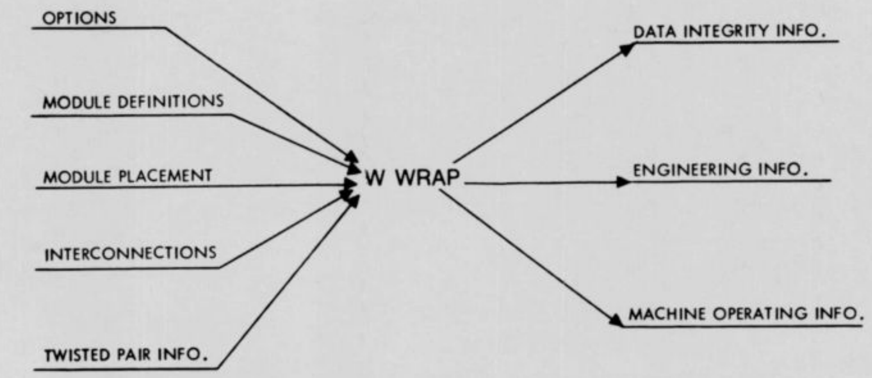


Fig. 1 — WWRAP system overview.

WWRAP programing

At Burlington Operations of Government Communications and Automated Systems Division a computer programming system called WWRAP has been developed which will generate both of the perforated tapes to drive the in-plant numerically controlled wiring machines, provide the engineering information necessary to document the wiring, and test the assembled panels. The typical job uses signal names to denote each string of wires. The actual connection pattern is determined by the computer program. The program is used for a variety of equipment and is therefore general in nature. Provisions are made to input critical dimensions and nomenclature requirements for the various types of backplanes.

WWRAP generates information required for wire-wrapping assemblies on the Hughes Simi-Automatic Wire Wrap machine, available at Burlington. The assemblies can be plug-in cards, backplanes, platters, or any other assembly which will physically fit on the table of the wire-wrap machine. In addition to the numerical control (N/C) paper tapes, the system produces the necessary error wire connection and wire routing listings to insure proper assembly fabrication.

Wire-wrap machines

Before detailing the WWRAP system, a brief description of the Hughes machine and its operation is necessary. The machine is a tandem one consisting of two x-y coordinate tables for holding the assemblies, above which two numerically controlled wrapping heads move. This allows two identical assemblies to be fabricated simultaneously. An operating cycle starts with the reading of two x-y coordinate pairs and a wire size code from a paper tape. This causes the wire-wrapping head to move to the first x-y coordinate pair. In addition, the applicable wire size code appears on the operator console indicating from which wire bin the operator is to take the wire. (The Hughes machine requires that all of the wire for the assembly be pre-cut, end stripped, and stored by size in wire bins before fabrication time). The operator inserts the wire into the wire-wrapping head, positions the head down onto the wire-wrap pin, and allows the head mechanism to wrap the wire onto the pin. The wire-wrapping head, using the second x-y coordinate pair, moves to the position of the other end of the wire where the operator wraps it on the indicated pin. This cycle is repeated until all of the wires called for by the paper tape have been wrapped.

Since the wires are manually placed into the wire wrapping heads, wire shorter than 1.75 in. cannot be handled. All wires smaller than this limit are automatically rounded up with one exception. There are assemblies containing a significant number of wires which connect adjacent pins. These wires, termed 'bus' wires, are wrapped using a numerically controlled Pratt-Whitney drill machine with a custom-designed wire-wrap fixture. If an assembly contains bus wires, they are attached before the assembly is placed on the Hughes machine. The use of bus wires provides for a neater and less congested wire-wrapping package than one which used the 1.75-in. wires in place of bus wires.

WWRAP program

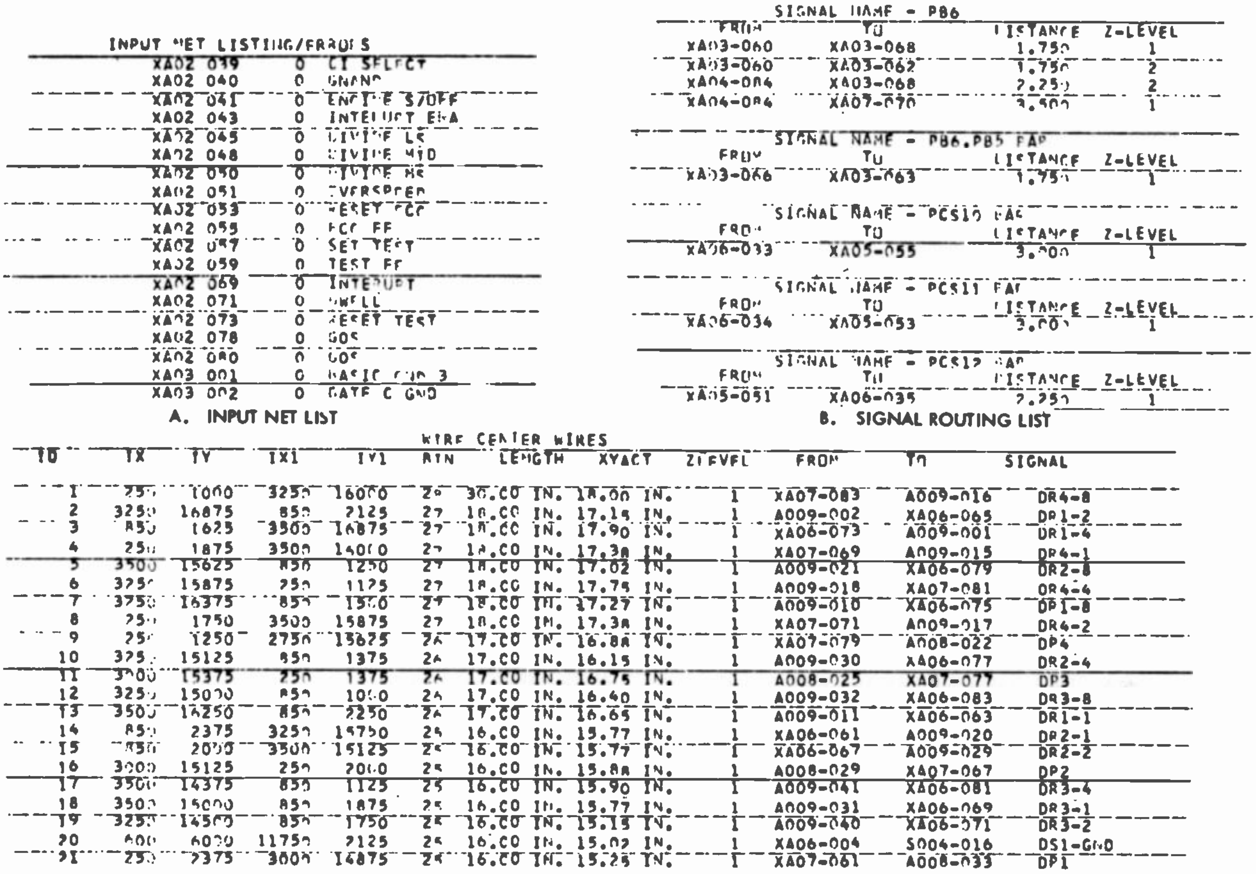
The WWRAP program provides the information necessary for the operation of both of the above machines. Fig. 1 gives an overview of inputs and outputs of WWRAP. The system is controlled by the user via the option parameters, shown below:

- All listings but no N/C tapes.
- N/C tapes only.
- Specific listings only.
- Input error listings only.
- All listings and N/C tapes.
- Option of one or two output tapes. (When this option specifies two output tapes, i.e., two output formats, tape format No. 1 will be used for all wires connecting adjacent pins — 0.100 mil spacing. However, these wires must be included in the overall z-level computations.)
- Selection of bin No. 1 size and incremental increase.
- Option to select order of wiring as long to short or visa-versa.

These parameters allow a great deal of flexibility since they control all of the outputs of the system. The user can suppress unnecessary outputs when they are not required, i.e., when inputing data for an assembly for the first time, suppression of the machine operating information is generally done since the validity of the data has not been established. The module-type definitions and placement information determine the geometric pin matrix for a given assembly while the interconnection and twisted-pair information determine which pins must be wired together.

The outputs of the WWRAP system can be generalized into three areas, data integrity, engineering information, and machine operating information. The following gives a detailed breakdown of the various outputs for each area.

Data integrity information
Module type list
Module placement list
Input net list



```
INPUT NET LISTING/ERRORS
     XA02 039     0  CI SELECT
     XA02 040     0  GNAND
     XA02 041     0  ENGINE S/OFF
     XA02 043     0  INTERUPT ENA
     XA02 045     0  DIVIDE LS
     XA02 048     0  DIVIDE MID
     XA02 050     0  DIVIDE MS
     XA02 051     0  OVERSPEED
     XA02 053     0  RESET FCC
     XA02 055     0  FCC FF
     XA02 057     0  SET TEST
     XA02 059     0  TEST FF
     XA02 069     0  INTERUPT
     XA02 071     0  SWELL
     XA02 073     0  RESET TEST
     XA02 078     0  GOS
     XA02 080     0  GOS
     XA03 001     0  BASIC CUR 3
     XA03 002     0  GATE C GND
```

A. INPUT NET LIST

```
                 SIGNAL NAME - PB6
      FROM             TO                DISTANCE   Z-LEVEL
    XA03-060         XA03-068             1.750        1
    XA03-060         XA03-062             1.750        2
    XA04-084         XA03-068             2.250        2
    XA04-084         XA07-070             3.500        1

                 SIGNAL NAME - PB6.PB5 FAP
      FROM             TO                DISTANCE   Z-LEVEL
    XA03-066         XA03-063             1.750        1

                 SIGNAL NAME - PCS10 FAC
      FROM             TO                DISTANCE   Z-LEVEL
    XA06-033         XA05-055             3.000        1

                 SIGNAL NAME - PCS11 FAC
      FROM             TO                DISTANCE   Z-LEVEL
    XA06-034         XA05-053             3.000        1

                 SIGNAL NAME - PCS12 FAP
      FROM             TO                DISTANCE   Z-LEVEL
    XA05-051         XA06-035             2.250        1
```

B. SIGNAL ROUTING LIST

```
                                       WIRE CENTER WIRES
 ID     TX     TY     TX1    TY1   RTN   LENGTH    XYACT    ZLEVEL    FROM       TO        SIGNAL

  1    250   1000    3250  16000   29  30.00 IN. 18.00 IN.    1    XA07-083   A009-016   DR4-8
  2   3250  16875     850   2125   27  18.00 IN. 17.15 IN.    1    A009-002   XA06-065   DR1-2
  3    850   1625    3500  16875   27  18.00 IN. 17.90 IN.    1    XA06-073   A009-001   DR1-4
  4    250   1875    3500  14000   27  18.00 IN. 17.38 IN.    1    XA07-069   A009-015   DR4-1
  5   3500  15625     850   1250   27  18.00 IN. 17.02 IN.    1    A009-021   XA06-079   DR2-8
  6   3250  15875     250   1125   27  18.00 IN. 17.75 IN.    1    A009-018   XA07-081   DR4-4
  7   3750  16375     850   1500   27  18.00 IN. 17.27 IN.    1    A009-010   XA06-075   DR1-8
  8    250   1750    3500  15875   27  18.00 IN. 17.38 IN.    1    XA07-071   A009-017   DR4-2
  9    250   1250    2750  15625   26  17.00 IN. 16.88 IN.    1    XA07-079   A008-022   DP4
 10   3250  15125     850   1375   26  17.00 IN. 16.15 IN.    1    A009-030   XA06-077   DR2-4
 11   3000  15375     250   1375   26  17.00 IN. 16.75 IN.    1    A008-025   XA07-077   DP3
 12   3250  15000     850   1000   26  17.00 IN. 16.40 IN.    1    A009-032   XA06-083   DR3-8
 13   3500  14250     850   2250   26  17.00 IN. 16.65 IN.    1    A009-011   XA06-063   DR1-1
 14    850   2375    3250  15750   25  16.00 IN. 15.77 IN.    1    XA06-061   A009-020   DR2-1
 15    850   2000    3500  15125   25  16.00 IN. 15.77 IN.    1    XA06-067   A009-029   DR2-2
 16   3000  15125     250   2000   25  16.00 IN. 15.88 IN.    1    A008-029   XA07-067   DP2
 17   3500  14375     850   1125   25  16.00 IN. 15.90 IN.    1    A009-041   XA06-081   DR3-4
 18   3500  15000     850   1875   25  16.00 IN. 15.77 IN.    1    A009-031   XA06-069   DR3-1
 19   3250  14500     850   1750   25  16.00 IN. 15.15 IN.    1    A009-040   XA06-071   DR3-2
 20    600   6000   11750   2125   25  16.00 IN. 15.02 IN.    1    XA06-004   S004-016   DS1-GND
 21    250   2375    3000  14875   25  16.00 IN. 15.25 IN.    1    XA07-061   A008-033   DP1
```

C. HUGHES WIRE LIST

Fig. 2 — Sample output lists.

Spare pin list
Error lists

Engineering information
Signal routing list
Wire connection list
Signal list
Twisted pair vs return list

Machine operating information
Hughes paper tape
Hughes wire list
Bus Paper tape
Bus wire list
Twisted-pair paper tape
Twisted-pair wire list
Total wire list

The data integrity information is used to validate the data input to the system. Obvious errors, i.e., two signals connected to the same pin, are identified on the error lists below, while conceptual errors, i.e., an incorrect module placement, can only be identified by the user from the other lists.

Error listings

1. Duplicate input,
2. Only one pin in net,
3. Pin already assigned to ,
4. Pin not within wiring matrix, or
5. Pin not defined.

The engineering information is used during the test and debug cycle for the assembly as well as for final documentation after design acceptance.

The machine operating information is used by the personnel responsible for the fabrication of the assembly. It consists of the numerical control paper tapes used on the wire-wrap machines and the various listings required by the machine operators. Typical output lists for each area can be seen in Fig. 2.

WWRAP program functions

The WWRAP program performs four major functions (see Fig. 3). The first, as stated earlier, is definition of the geometric pin matrix from module-type and placement information. For the WWRAP system a module can be any collection of wire-wrap pins. The user determines the module types for a particular assembly based on its physical layout. If the assembly is a plug-in card on which integrated ciruict modules are mounted, the 14- or 16- pin IC socket pin configuration should be defined as a module type. If an assemlby is a backplane, the card mounting sockets should be given a module type. When classifying a group of pins as a module type, one pin is chosen as the reference pin for the module and the orthogonal distances of all the other pins from this reference are given. In addition each pin is given a name which is unique within the module. This method of module type definition allows for not only standard component mounting but also for special components or pin configurations (see

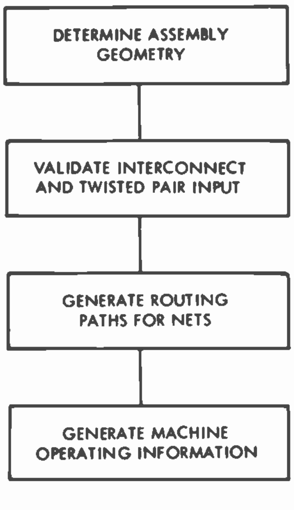
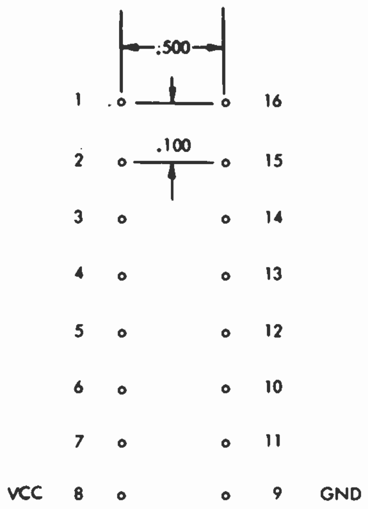
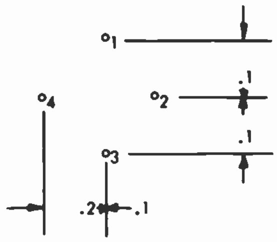


Fig. 3 — Major system functions.

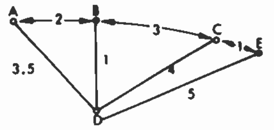


A) 16 PIN IC SOCKET

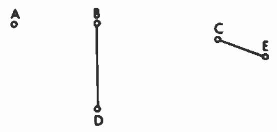


B) IRREGULAR COMPONENT

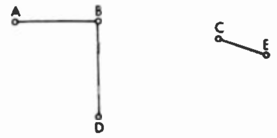
Fig. 4 — Typical module types.



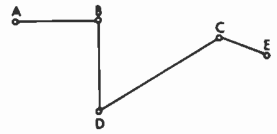
A) PIN PAIR DEFINITION



B) PASS 1



C) PASS 2



D) PASS 3

Fig. 5 — Minimum spanning tree function.

Fig. 4). Once a set of module types are chosen for an assembly, the pin geometry can be fixed by the placement of these types. The user accomplished this by giving a unique name to a module, giving the x-y location of its reference pin, and giving its type. The WWRAP system now constructs a pin matrix for the modules. Each pin is identified via its module name from the placement information and its pin name from the type information. At this time, module conflict errors are detected and reported.

After the geometric pin matrix is established, the processing of the interconnections between these pins is done. It is necessary to differentiate between two kinds of connections — standard and twisted pair. Standard interconnects are single wires connecting two pins while twisted-pair wires are two wires twisted together connecting two pairs of pins. For twisted pair wires one wire is called the signal and the second is termed the signal return. When wrapping twisted-pair wires, the machine operator wraps one end of the signal wire, then the signal return closest to that signal, followed by the other end of the signal wire, and finally the other signal return. It should also be noted that twisted pair wires are wrapped after the standard wires have been placed on the assembly. For the most part standard and twisted pair interconnects are identically processed. As the interconnections are read by the system, the mod-pin in the geometric pin matrix is given the signal name of the interconnection. Cross-connected nets and identified module or pin errors are reported. For twisted-pair wires the signal return is also input and is identified in the geometric pin matrix along with the signal name.

At the conclusion of the interconnect processing, the mod-pins for each signal are collected in preparation for the wire-routing phase. The signal or net routing is performed on each net independent of the others. For the net a minimum spanning 'tree' is found. This is the shortest wire path which will connect all of the pins in the net together. In practice the 'tree' path is not necessarily the minimum due to system constraints. The most significant constraints are the fact that bus wires could be used in the net and that a maximum of two wires per wire-wrap pin are all that are allowed. Thus the minimum spanning tree can be treated as a local rather than a global optimum. The algorithim for the tree follows.

First all possible pairs of wires between all of the mod-pins of the net are found along with their length (Fig. 5a). The paths are now selected starting with the smallest, subject to the conditions that 1) the path does not connect two pins already connected, and 2) there are no more than two wires per pin (Figs. 5b, 5c, 5d). It should be noted in Fig. 5 that wire BC is shorter than DC but could not be used since pin B already has two wires on it.

After the minimum spanning tree is found for a net, the wire paths are defined and saved by the system. The wire-routing information is now generated. This consists of mod-pin pairs and their lengths. If the wire-routing report is requested, the information is outputed. The process continues until all of the nets have their routing determined. It should be noted that routine information does not refer to the actual layout of the wire on the assembly but rather to the determination of which pin pairs in the net are to be connected. The lengths of the pin-pair wires are the straight-line length which are not necessarily the actual wire lengths.

The final system function is the generation of the machine operation information. From the minimum spanning tree information, an orthogonal length for each wire is found. This is used as the length of the wires to be placed on the assembly. Now the records required for paper tape and report generation on the Hughes and bus wire machines can be produced if called for by the user. For ease of wire wrapping and minimum congestion, the wires are sorted by lengths and wire-wrap level. Since each pin can have two wires, one higher than the other, level sorting provides for two separate planes of wires. This produces a neater assembly which is easier to maintain.

Conclusion

The WWRAP programming system provides control of the wiring from design through fabrication and assembly. The programming system represents the application of a computer-aided design technique to improve the efficiency and performance of complex but basically routine tasks required in the wiring of electronics equipment.

A concept of factory automation

R. Walter

Currently, many manufacturing functions are automated through the use of computers and associated equipment. The support of administrative functions such as material and labor control to regulate costs and measure results is aided by the use of medium to large computers at the plant site or through communications to a central computer site. The control of processes, such as testing and assembly, are improved through the use of mini and microprocessors as well as programmable controllers. The engineering problem solving and design now involve the use of hand-held and desk top calculators as well as time-shared and remote processing on a central computer. All of these things have but one basic goal: cost effective manufacturing. This article outlines one possible path for advancement toward that goal, based on existing applications and computer systems capabilities. As always, the final challenge is related in our ability to cost-effectively design and implement the processes which use the tools we have or can acquire.

CONTROL of the manufacturing process can be compared, in many ways, with the organizational structure of such an operation, i.e., the plant manager at the top and the individual worker at the lowest level. From this viewpoint, an effective automation support system must be capable of providing information for all elements of the manufacturing organization and be available where needed. Therefore, one objective of automation support is to ensure that computer power be widely available, and usable. For example, a test system, in addition to applying inputs and measuring outputs in varying sequences, should provide data for statistical summation, for engineering analysis, and for material control. Thus, the information collected is useful to people serving in different capacities and can be used at different levels in the organization for better understanding and control. If this principle is carried throughout the manufacturing organization, then a network of information is developed to support the manufacturing organizational structure. In turn, automated assists for all major functions are distributed among these operations for improved performance.

Existing applications

Minicomputers, microprocessors, and programmable controllers have been used in many major process control applications; this issue highlights several examples.[1,2] In the Picture Tube Division, an Intel microprocessor has been designed into a critical television-picture-tube alignment procedure to alleviate problems resulting from manual adjustments. Such classes of operations could be considered dedicated or worker-level assists which make processes repeatable, accurate, and fast.

Support of Engineering in the design, applications, and production areas has taken some new forms. Time-shared and hand-held calculators have been in use for some time with many applications from artwork design, process control, and problem solving leading the list of applications. Time-shared services have been widely available, accessible, and heavily used. Recently, however, programmable desktop calculators, which can also act as a remote station to a large computer as an intelligent terminal and can interface with laboratory instruments, have placed easily programmed and economical capability into the laboratory. This equipment has replaced certain time-shared applications, while providing readily programmable instrumentation for use with laboratory instruments.

Manufacturing, admisistrative, and control operations—including financial, materials control, warehousing, purchasing, and quality control—are now using some of the capabilities mentioned above plus mini and general class computers. The bulk of these systems use the standard business computer language (COBOL) and are typically batch (scheduled and serially processed) operations. Most of these are run on a local computer or over communications lines to a remote computer. In a smaller number of cases, the users themselves interact directly with the computer through remote terminals to either large or small (mini) computers to request data from a file or input data to a file.

All the above applications are in everyday use but not necessarily at the same factory site. Practically speaking, the need for all of these applications does not appear in the same physical site, but systems in use can often be applied at other sites with reduced development costs.

The benefits of computer aids to manufacturing operations generally include increased productivity, higher quality, faster turnaround of problems, faster machine throughput, and timely information to management. The toughest problem is to apply our

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resources successfully to accomplish these tasks either through automated or manual methods. Future automated systems enhancements are aimed towards better use of our resources—capital and human—to solve our operating problems.

Future

In the near future, primary gains should be in productivity through improved systems development and programming techniques as well as the concomitant gains that accrue to systems users. The bulk of these gains will be through software improvements which account for 80% of 1975 systems costs. This pace will continue over the next decade.[3]

Another future improvement will be reliable and easier communications between humans and the computer and among computers. This will lead to transfer of information to a wider community. For example, dedicated minicomputers regularly and easily acquire data from operations on the factory floor; this information can be passed to a large computer for storage, retrieval, and analysis. Production control personnel would, in turn, be able to monitor factory schedules in real time. The ordering of materials and the status of inventory then could be adjusted to correspond with plant needs.

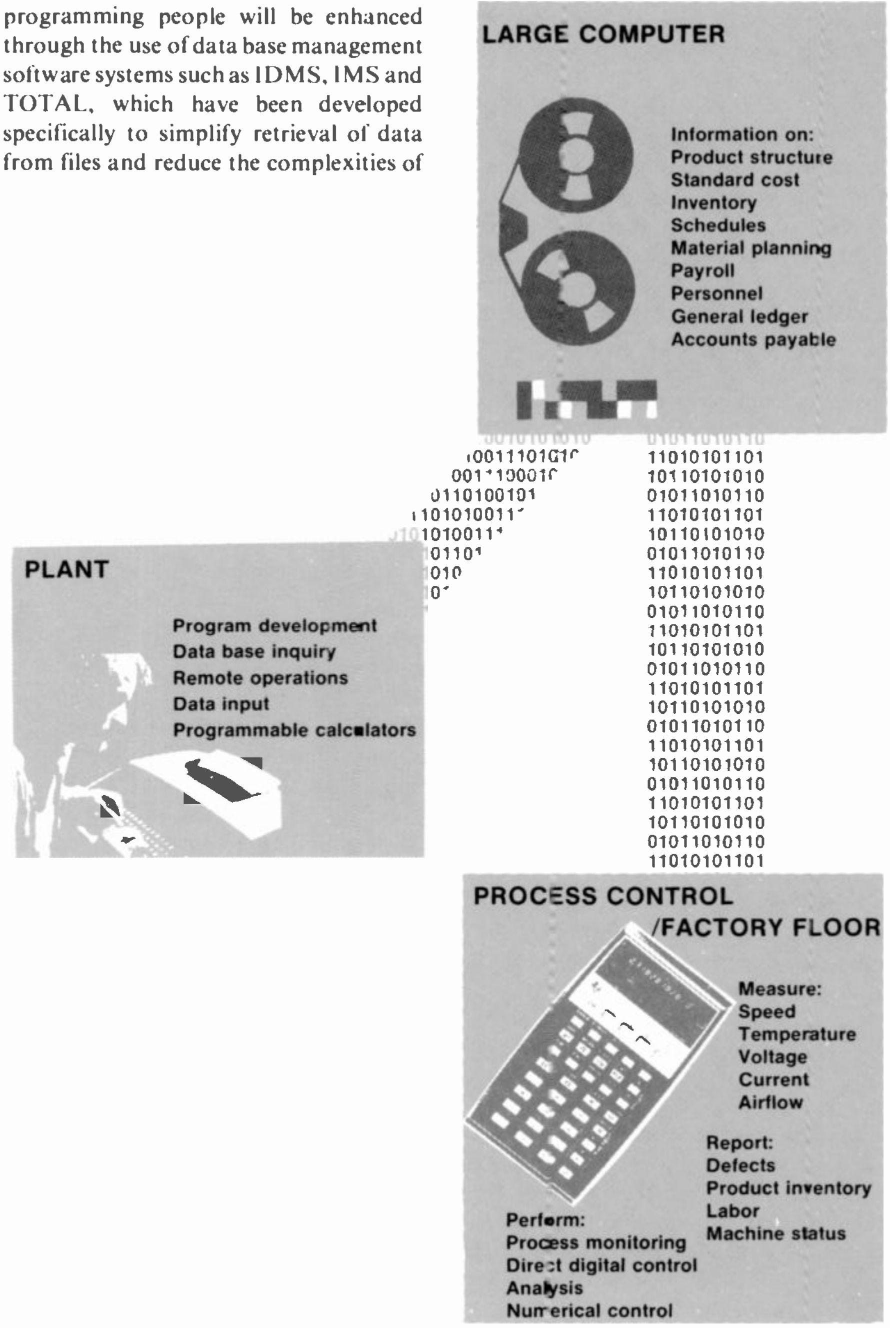
The near future brings these capabilities closer to practicality because of reduced costs. The following material describes a few of the major advancements which should impact the future of automated operations.

Large computers

Large computers with remote accessing capability, cheaper hardware, and better software will be more widely available to users. The processor hardware will be faster and cost less per unit of storage. Also, mechanical peripheral devices will begin to disappear; thus there will be fewer breakdowns, faster access of data, and lower dollar rates per unit of time. High level software, i.e., fewer programming steps to perform an equal task, will become more widely used. In the case of mathematical programming, software systems like APL, which might be considered to be a shorthand notation, will reduce programming costs for the solution of complex mathematical problems. For the end user, simple inquiry programming for the retrieval and manipulation of stored data will also be available for remote use. For example, it would be possible for someone in Personnel to say literally "SELECT *ENGINEERS* EQUAL TO *AGE*> 25 or < 34" resulting in a composed list presented on a video screen; no need for programmer intervention. The file management of data stored for manufacturing operations is another area where software support is improving. The management of files by systems and programming people will be enhanced through the use of data base management software systems such as IDMS, IMS and TOTAL, which have been developed specifically to simplify retrieval of data from files and reduce the complexities of maintaining files. The net effect of these advances is that within the next two to three years, there will be widespread improved turnaround of information to the user, and a reduction in cost.

Communications

Communications between humans and computers have been primarily timeshared. To date, the cost of reliable and accurate transmission from remote areas has been prohibitive with any significant volume of data. As remote capabilities



continue to be enhanced, through both minicomptuers and general-purpose computers, greater communciation volumes can be handled; this in turn, will breed better communication accuracy and reliability.

Other remote capabilities, such as the ability to initiate programs which are not time shared, i.e., the entry of remote processing jobs, will expand significantly. At remote sites people with no more knowledge than is required to operate a time-shared terminal will be able to initiate jobs at will. Normally, these jobs are not suitable for terminal operation because the volume of input data and the volume of output data (printing) are too high.

A communication network inside the plant will also become more actively used. Many times dedicated minicomputers collect data and control machines on the factory floor leaving no capacity for other uses of acquired data. However, enough time can be "stolen" from the work period to transmit data for processing on other machines for other than process-control purposes. Using communications for this purpose will reduce the manual effort, hence the cost for identifying, collecting, and transporting such data.

Documentation

The practical aspects of managing the written word in a technical business are at best a difficult, relatively expensive proposition. There are many cases where the paper version of reports, specifications, and instructions cannot keep up with the activities they support. Because the creation, updating, and composition of text on paper is mainly a manual operation, machine assists become a real possibility not only for better productivity, but for a better product. In the case of composed technical publications, such as manuals and technical data sheets, use of computer-aided file management, editing, and exposed-film output has reduced turnaround times and cost of preparation up to 5:1 per page of final publication. Also, in the realm of the standard typewritten word, equipment specially designed to input, edit, and print is in use for medium to large typing jobs. These so-called word processors enhance typists' productivity by reducing editing and repetitive effort. This capability, coupled to microfilm or microfiche via magnetic tape, and paperless documentation, looks practical. The net effect of these systems will be adequate, timely, and reasonably priced documents along with their maintenance.

Mini/micro computers

The range of electronic calculating devices runs from fixed programmed devices such as hardwired controllers and pre-programmed calculators to large programmable processors. Between these extremes, microprocessors and minicomputers have significant impact on automation. These two types of machines can effectively perform similar overlapping functions. Yet, there are applications where microprocessors are much more inexpenseive to use than minicomputers and applications where the minicomputer can effectively perform tasks where the microcomputer cannot. In any case, there are a wide variety of applications, ranging from machine control with a microprocessor imbedded in the equipment to minicomputers acting as business computers or process control systems. Both categories of processor hardware will continue to decrease in cost. The main expense associated with their use will be in the peripherals — magnetic tape, disks, terminals, interface hardware — and programming.

Microprocessors will fall into two categories based on user capabilities. A class of microprocessors whose end user is skilled in programming (such as equipment manufacturers) would use devices such as the RCA COSMAC for which assembly (low level) software support is provided. On the other hand, people whose prime skill is not programming would use devices such as the INTEL 8080 which use high level (less detailed/somewhat less efficient) programming. These microprocessor developments could affect manufacturing in several ways. Equipment we purchase, such as programmable calculators or remote computer terminals, will provide more pre-programmed and programmable capability to a variety of users, including engineers, data processing, and business personnel. Pre-programmed functions will become more widespread, and simpler programming capabilities will permit more non-skilled programmers to service themselves for more of their needs.

Minicomputers — having evolved to a high degree of sophistication in hardware and software — will play an increasing role in process control and dedicated business operations. Under a distributed computer concept, the application of these machines will permit us to place independent computer capability at the site required. These machines will control processes and provide support for administrative functions such as material and inventory control, word processing, and financial control at the normal place of work. An independent machine is not at the mercy of a single processor at a center site used for other purposes, where conflict of interest could cause delays because of system load. Also, outage of the central computer will not put operations at the remote site out of business.

Minicomputers will continue the trend towards lower hardware costs and more effective software. Minicomputer vendors now are providing the COBOL language on their machines, which is commonly used to support business systems. The machines will also be used for communications switching and as support systems for large computers.[4]

Conclusion

Up until now, the cost of hardware and software has been too high for all but some compelling manufacturing applications. In the next one to three years, there will be substantial reduction in the cost of both human and machine resources to implement computer-supported operations.

In turn, the effectiveness of our manufacturing activities, through more efficient use of our manufacturing people and facilities, will increase. Lower cost and higher quality product will result, thereby adding to the probability that our role in industry will still be dominant.

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DART—open heart surgery on a living factory

**W.R. Guerin, Jr.| M.J. Martin| T.J. Ruskey
T.B. Lyden| G.D. McLaughlin| S.J. Blaskowski**

In August 1973, there was clear evidence that the Solid State Division power business was going to expand to the point where existing manufacturing facilities would not be adequate. The diffusion area, in particular, limited the factory capability, and was in dire need of improvement. Thus, a plan was formulated—the Diffusion Area Rearrangement Task, or DART—to rearrange or replace every piece of equipment in the existing diffusion area of the Mountaintop factory. This task was to be accomplished within the confines of the existing diffusion area and without production interruption. The risk of undertaking the DART program was awesome, but its success represented a projected cost savings of $1 million per year. This describes the planning, design, and execution which culminated in the success of project DART.

WHY PROJECT DART? The projected five-year plan (1973-1978) demanded that the diffusion area increase its capability 58%. However, the present rooms were jammed with equipment located haphazardly—a malady incurred throughout the years of accelerated growth. Since wafer processing evolved as a batch process, no conscious thought had been given to the possible benefits of production-line manufacturing. Preliminary study showed that some wafer types traveled between two and three miles during wafer fabrication. This was a profit leak that had to be plugged.

Furthermore, particulate matter had always been a problem at Mountaintop; particulates contaminate the surface of wafers and, as a result, lower diffusion yields. When the existing diffusion rooms were constructed in 1966, it was felt that removable ceiling-high partitions were sufficient to avoid cross contamination between the n- and p-diffusion operations. These rooms were constructed without drop ceilings and with all the service piping and exhaust ducts exposed, thus contributing to the particulate problem. In addition, the underside of the roof, which is insulating board, caused particulates to be shed into the diffusion rooms whenever the roof loading was changed by snow, rain, or by the movement of people and equipment across the roof. Typical dust counts as determined by Quality Assurance, were 70,000 particles per cubic foot of 0.5 micron size and smaller material, and 500 particles per cubic foot of 5.0 micron size and larger.

The photoresist rooms were designed with similar wall partitions, but did have drop ceilings to aid in the control of temperature and humidity. However, each time Plant Engineering was called to make an emergency repair or a new installation, it was necessary to remove the ceiling tiles to gain access to the piping. This caused the entire room to exceed humidity specifications, and made it possible for particulates to enter the room from above. In summation, when repairs had to be made during production hours, the photoresist rooms operated in an atypical manner or not at all.

Obviously some drastic changes were required if the five-year plan were to be realized. What an opportunity! To conceive an equipment layout to optimize product flow, environment, superviseability, floor space requirements, and equipment design all with the factory in full production. Several alternatives were considered:

1) Obtain additional floor space near the existing Diffusion Area and install the required equipment. This would only cure the capacity problem.
2) Acquire a new building and move and expand the entire area. This would consume two years (an eternity in our business) and expend precious capital.
3) Rearrange and replace the equipment within the existing area—DART.

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The third alternative, DART, was clearly the practical way to accommodate additional capacity within a reasonable time and treat the deformity of the existing area. We had sold ourselves, now we had to sell management. We made the bold commitment.

1) *Production capability could be increased by 58% in the same floor space.*

2) *The job could be accomplished in twelve months.*

We made our proposal and management bet the entire output of the factory and over a million dollars in capital that we could do it!

The objectives

An eight-man task force was organized and a detailed set of objectives was formulated.

1) Increase production capability 58% in the same floor space.

2) Locate 70% of the "new area" within the confines of the present area. Approximately 7000 square feet of empty space was required to start the moves. This space would be returned to the factory at the completion of DART, but in a different location.

3) Provide a clean environment for wafer fabrication.

4) Design an area which would allow for orderly future expansion.

5) Design new chemical processing stations with maximum flexibility.

6) Pursue, to the fullest, process standardization.

7) Pursue production-line philosophy to optimize product flow, decrease space requirements, increase operator efficiency and improve supervisory control.

8) Provide a safe working area (to O.S.H.A. standards) for employees, and one that would motivate through attractiveness.

9) Improve the effectiveness of the existing air conditioning system.

10) Complete the project with no production interruption.

Open heart surgery

It was essential that a master plan be developed to negotiate the required rearrangement with minimum inconvenience to the operating factory.

This plan detailed and sequenced the projected start and finish dates for every element of construction, new equipment installation, equipment debugging, process testing, and movement of operational equipment and departmental inventory.

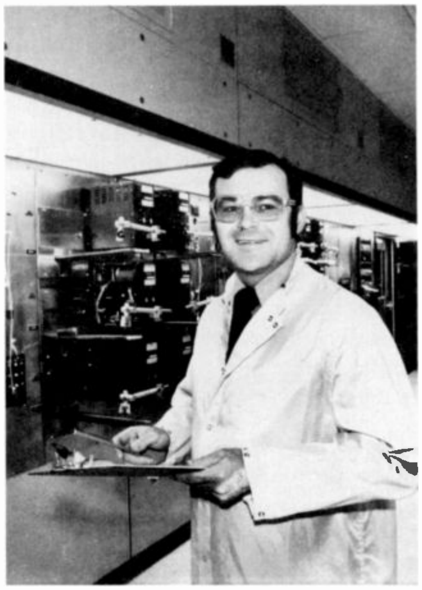
The plan

The plan called for dividing the project construction into five phases. Phase I provided for the simo (simultaneous) diffusion room, a portion of the boron room and about one half the photoresist room. Phase II governed completion of the boron room while Phase II detailed the construction of one half of the phosphorous room. Phase IV provided for completion of the phosphorous room and Phase V the photoresist room and the auxiliary room. With the exception of Phase I, all construction took place in an area vacated by the completion of the

Walter R. Guerin, Jr., Mgr., Project DART, and Ldr., Technical Staff, Mechanical Equipment Technology, Solid State Division, Mountaintop, Pa., attended Newark College of Engineering from 1951 to 1955 and joined RCA Solid State, Somerville in 1963 as an equipment designer. Prior to his transfer to Mountaintop in 1972, Mr. Guerin was engaged in the design of wafer fabrication and assembly equipment—specifically, equipment for chemical vapor deposition, evaporators for metallization, and chemical processing stations. He collaborated in the design of the first cartridge "assembly system" in Somerville and acted as project coordinator for installing and debugging this equipment. Since 1973, he has served in his present position in Mountaintop and has the responsibility for all wafer fabrication equipment used in solid state power-device manufacturing.

Milton J. Martin, Plant Services, Plant Engineering, Solid State Division, Mountaintop, Pa., received the BSME from Newark College of Engineering in 1961. Prior to joining RCA in August 1966, he held various positions in plant engineering, building construction, and field service engineering. One of his active projects at the present time includes the design and installation of a bulk chemical storage facility at Mountaintop. Some of his completed projects include the refurbishing and preparing for occupancy of two buildings in the industrial park along with design and installation of air conditioning and exhaust systems.

Thomas J. Ruskey, Project Coordinator, DART, Solid State Division, Mountaintop, Pa., graduated from Penn State University in 1961 and has attended Rutgers University and Wilkes College. Mr. Ruskey's early experience with Bell Telephone Laboratories, from 1961 through 1965, was primarily in the design of telephone apparatus. In 1965, he joined the Bendix Corporation where he became involved in the packaging and design of aircraft instrumentation systems. In 1966, he joined the RCA Solid State Division at Mountaintop where he has served in various capacities. His initial assignment was in the Equipment Technology Group where he designed and developed numerous automatic and semiautomatic chemical processing and assembly machines. From 1969 to 1972, he served as Facility Planner for the Linear Power Transistor organization where he was responsible for preparing and implementing capital equipment plans. From 1972 to his appointment as Project Coordinator, he has been engaged in the supervision of production departments and the in-process quality control organization.



previous phase; i.e., in Phase I, construction was completed and equipment installed from the Phase-II area; construction relative to Phase II was then completed and the equipment moved into the area from the Phase-III area, etc. New equipment was delivered, installed, and debugged before moving the equipment which was operational, such as silane systems, diffusion furnaces, etc. All operating equipment was moved during the second shift on Friday and was operating again during the first shift on Monday. Fig. 1a shows the diffusion area layout at the beginning of DART, Fig. 1b delineates the active areas for the phases of the program, and Fig. 1c shows the diffusion area at the completion of DART.

The schedule for equipment delivery, which was adopted at the outset of the project, required the selection of an equipment vendor with a minimum of delay. To inform all potential suppliers as quickly as possible of the magnitude, importance, and timing of the project, a vendor conference was called at Mountaintop to which all potential vendors were invited. At this meeting, specifications of typical chemical stations were presented for review, discussion, and quotation. This day-long vendor conference provided the opportunity to give all the interested bidders the same set of information and permitted them to ask questions as the specifications were presented. The vendor conference saved valuable time.

On the basis of the quotations received, some bidders were eliminated; a visit was made to the remaining potential suppliers to evaluate their capability, capacity, and experience in the laminar-flow aspect of the electronics business.

In an effort to assure that the bid prices would be an accurate indication of the ultimate project cost, a more detailed set of modular specifications were drawn up and submitted to the remaining bidders. An advantage of this modular concept was in the resultant pricing structure. Because each unit was priced separately, it was possible to order all stations during the project from one quote and thereby eliminate a time-consuming and detailed quotation procedure when additional stations were ordered.

The final vendor selection was based upon the factors of cost, delivery, quality, proximity of the vendor to the plant, capability and experience.

Phase I

On Monday, May 13, 1974, Phase I began. Eight weeks were scheduled for its completion. A plastic cocoon was built around the area designated as the Phase I area, much as a doctor covers the patient with sheets prior to an operation. The first incision was a three-foot-wide cut into the existing concrete floor for a new trench for acid-drain piping. Unfortunately, the plastic cocoon did not

Thomas B. Lyden, Member, Technical Staff, Solid State Division, Mountaintop, Pa., received the BSME from Youngstown University in 1961. Since joining RCA in August, 1973, he has spent nearly all his time designing, inspecting, installing, and debugging the wafer processing equipment related to the "DART" project. From 1961 to 1965 he was a Test Engineer for the Mobile Hydraulics Department of Commercial Shearing and Stamping Co. From 1965 to 1969 he was a Value Analysis Engineer and a Senior Design Engineer responsible for development of precision custody-transfer turbine flow meters with A.O. Smith, Meter Systems Division. From 1969 to 1971 he was a Project Engineer involved in book-binding equipment design for the Sheridan Corporation, Division of Harris Intertype. Prior to joining RCA, he was Chief Engineer of L.A. Fish Engineering Company responsible for contract machine-design projects, and was introduced to the electronics business as a Design Engineer, with Plessey, Mechanization Division. He is a professional engineer in Pennsylvania.

Glenn D. McLaughlin, Buyer, Equipment and Components, Solid State Division, Mountaintop, Pa. received the BA in Business Administration from Eastern Kentucky University in 1973. Prior to completing his degree requirements he served in the U.S. Air Force's Air Training Council and Strategic Air Council where he was schooled in electronics. During the period from late 1968 through 1970 he remained at the Air Force Electronic Training Center and served as an instructor in solid state electronic theory. Upon receiving his business degree in 1973 he joined RCA's materials training program, and later the same year became a buyer at the Solid State Division, Mountaintop facility. Mr. McLaughlin initially was responsible for purchasing capitalized equipment and related equipment items. During the DART project, he shared with the project director the responsibility for the selection of vendors to supply the clean-room equipment and the selection of the contractor for the room construction. His current assignment is to support the factory raw material requirements by purchasing the glass-to-metal sealed transistor bases for the various power devices manufactured at Mountaintop.

Sy Blaskowski, Designer Draftsman, Solid State Division, Mountaintop, Pa., graduated Penn State University (evening division) with an Associate Degree in Engineering. Early experience with Vulcan Iron Works, Wilkes-Barre, Pa. included design of cement kilns and sugar processing equipment from 1956 to 1959. In 1960, he joined A.C.F. Industries, Berwick, Pa. in design of missile train for guided missiles. In 1961, he joined Foster Wheeler Corporation, Mountaintop, Pa. where he designed fixturing and special tooling for processing of steam generators and boilers. He joined RCA Equipment Technology group in 1965 where he has been responsible for the design of equipment in the Wafer Processing Area.

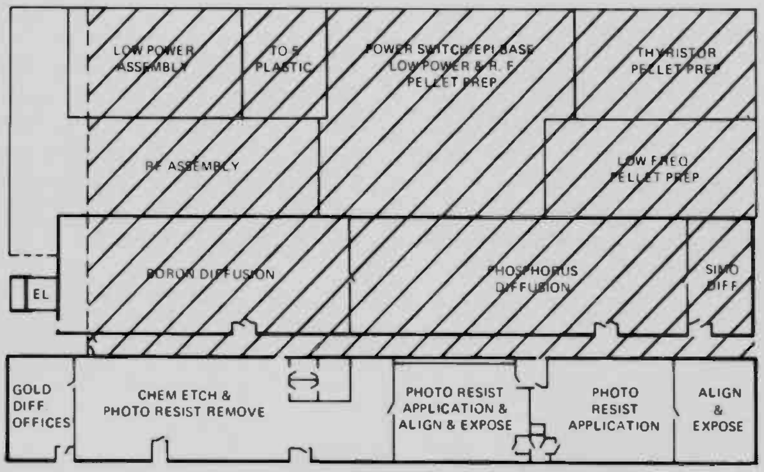


Fig. 1a — Diffusion area before DART—DART now occupies the crosshatched area.

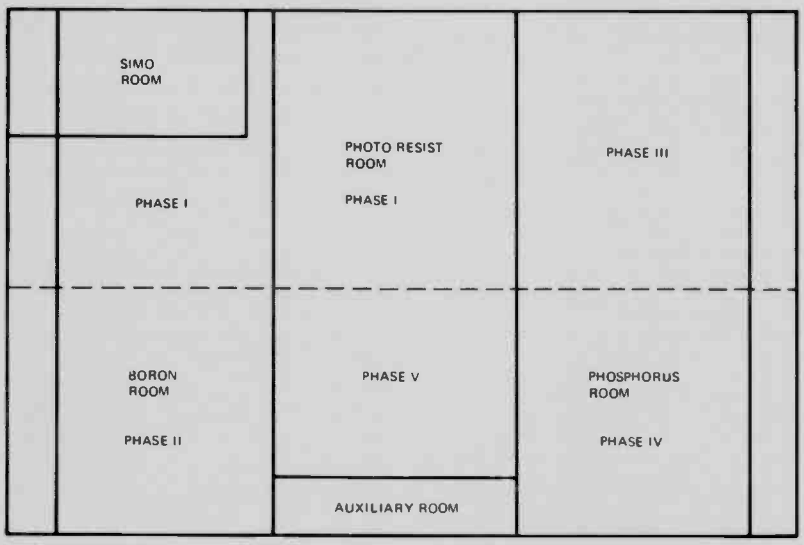


Fig. 1b — The active areas for each program phase.

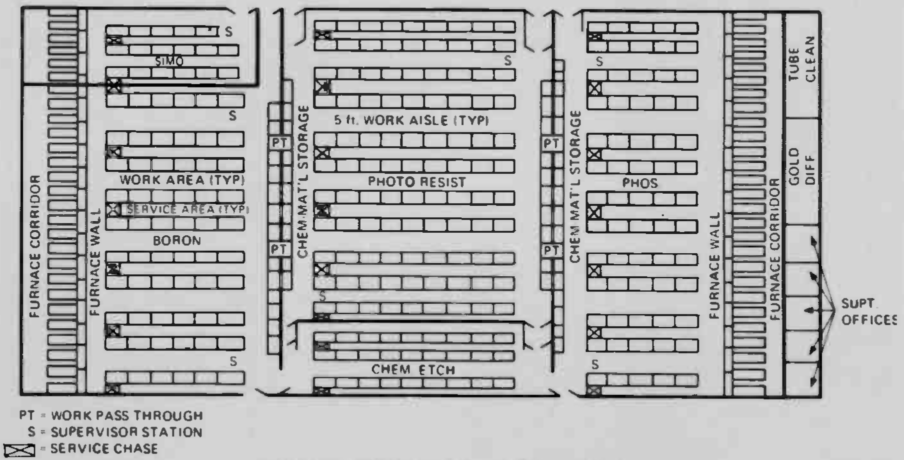


Fig. 1c — Diffusion area at completion of DART.

contain the concrete dust being generated by the jack hammers and an additional tent had to be erected directly over the trench. Upon completion of the new trench, the floor tilers arrived and began installing the new floor. However, only two days after flooring had begun, the Brotherhood of Floor Tile Workers went on strike. Fortunately, the strike lasted only six days, but we were behind schedule already. By working overtime for several weeks, Phase I was quickly back on schedule.

Keeping the project on schedule was imperative since a major air-conditioning rearrangement was required for the new photoresist room, and the July vacation shutdown was the only time that it could be accomplished.

After the floor was complete, the perimeter walls and ceiling steelwork were erected, thus separating the Phase I area from the remainder of the factory.

Room construction

As part of the DART proposal, Plant Engineering seized the opportunity to provide the type of room construction that approximates a clean room, is accessible for maintenance, but yet utilizes the existing air conditioning, main exhaust ducts, and main overhead service piping (see Fig. 2)

For serviceability, the proposal included a structural steel (Unistrut) frame with a 3/4-in. fire-retardant plywood roof. The underside of the roof is lined with an aluminized Mylar vapor barrier to prevent moisture migration. This "walk-on" deck provides accessibility to the overhead area of the diffusion area for service while preventing particulates from entering the room from the dust-generating ducts, pipes, and the insulating boards previously used in the factory ceiling.

The walls of the diffusion area are double-wall constructed using steel-faced gypsum board which has a baked enamel finish on the exposed side. These wall panels are snapped onto steel studs by means of an aluminum filler strip which serves as a fastener as well as a decorative stripe. This non-progressive design makes it possible to remove panels in the center of a wall without starting in a corner.

A suspended ceiling was attached from the steelwork supporting the plywood roof. This ceiling is a drop-in metal-pan type which is located approximately 14 in. below the plywood. This 14-in. area serves as an air-distribution plenum for supplying air-conditioned filtered air to the various rooms in the diffusion area. The ceiling tiles are readily removable, easily cleaned, and non-shedding. Some of the tiles are active to permit the expulsion of air and others are inactive and contain a sealed sound-absorbing batting which prevents the expulsion of air. This system permits an infinite adjustment of air distribution to the area and is readily adjustable for changes in heat loads within the operating areas.

The floor covering selected was a homogeneous PVC tile approximately two-feet square. The seams are beveled and heat welded, which results in a seam-free monolithic floor which is waterproof and chemical resistant.

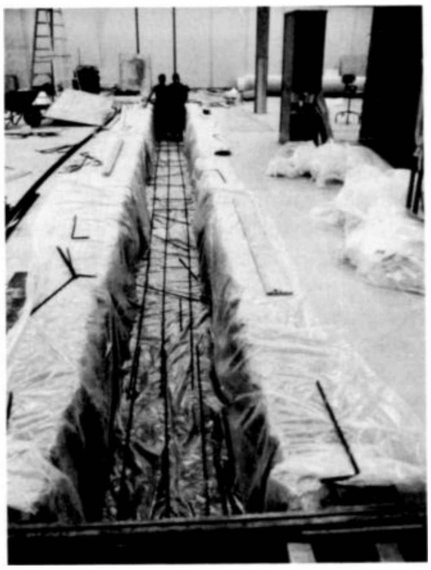
Area lighting was improved from 50 fc to 80 fc and cool white bulbs were replaced with warm white bulbs. The new lighting system has vastly improved working conditions in these areas.

Because of the proximity of the equipment to the ceiling, a new type of flush-mounted sprinkler head was installed throughout the DART area. This head negated the possibility of sprinkler discharge as a result of mechanical damage during the equipment moves.

With the exception of the drain lines, all service piping, electrical conduit, and exhaust ducts enter the rooms from overhead through sealed service chases located between the back-to-back equipment. These "service aisles" make repairs convenient during working hours since the maintenance mechanics do not have to disturb the operators in the production aisles.

Like the pieces of a puzzle, everything began to fall into place—electrical services for lights, service piping, sprinkler systems, air-conditioning ducts, exhaust ducts, new laminar flow equipment—each segment went together as planned. Particular attention was given to the new gas service lines to the area since contamination is a deadly enemy in diffusion. Dust counts were recorded and analyzed periodically to determine contamination both

The incision—start of the trench used for the acid drain piping.



Trench prepared for the pouring of concrete.

Underside of ceiling showing vapor barrier.

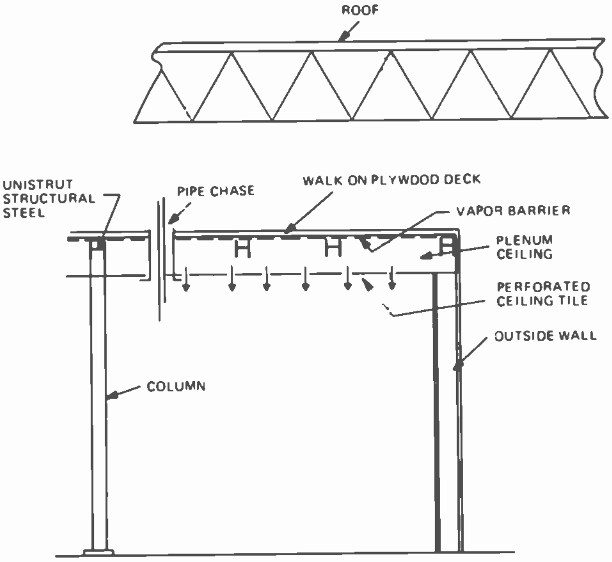


Fig. 2 — Typical room cross section showing construction.

quantitatively and qualitatively. All open lines were covered with plastic each evening and purged with nitrogen when completed.

The construction of the furnace room was completed within two weeks. By consolidating the furnaces, it was possible to incorporate a temperature scanner to measure and to printout furnace-tube temperatures, thus saving hours of profiling by operators. It made the heat recovery system (described later) possible, and avoided adding the furnace heat to the operating portion of the factory, thus reducing the air-conditioning load. It decreased the safety hazard of having furnace pullers extending haphazardly into work aisles, as was previously the case, by positioning them so that an operator always approaches them head on. Since the furnaces were purchased throughout the past ten years, they consisted of several breeds and many vintages. To be able to "hide them" behind a wall also made for a much improved appearance.

It was obvious at this point that, at least, the furnace wall would look impressive. All service piping to the furnaces was terminated in such a way as to minimize the time to reconnect the furnaces in their new location. Now the eight weeks of Phase 1 were over, and all systems were "go". The last major question was soon to be answered. Can we move an entire department over a weekend and have them operating properly by Monday A.M.?

This question had been answered in the affirmative, to some extent, by the careful planning of equipment design and layout.

Furnace wall during construction.

Fig. 3 — Typical DART chemical processing station contains five modular processing units with corresponding front-mounted control panel.

Equipment design

In the design of the chemical processing stations for Project DART, the challenge facing the Equipment Technology activity was to blend equipment standardization and equipment flexibility. In addition, it was imperative to achieve high throughput, clean environment, chemical conservation, ease of maintenance, and operator safety.

The first step was to meet with the production department engineers and foremen to ascertain what processes were being used in the factory. A review of this information yielded many opportunities to standardize these processes. This standardization was to take many additional meetings and many hours of testing. The result was the modular design concept shown in Fig. 3.

The modular design concept developed for the chemical processing stations makes use of a basic laminar-flow structure lined with acid-resistant plastic and containing a plastic drain/exhaust plenum (bath tube) under the work surface. This structure was fitted with the work-top functions required by the processes involved. Each work-top function was designed using common-sized work top "modules" (equal width), which resulted in module interchangeability, and flexibility. To accommodate this modular concept, lot sizes of 2-in., 2 1/4-in., and 3-in. wafers were reduced to a common dimensional denominator and the optimum processing tank size determined. The result is that in a six-foot-long structure, five processing modules and one centrifugal-dryer module can be installed. The rinser-dryer module by necessity is wider than the processing modules, but this combination of five and one makes up a standard station.

Each module consists of a perforated, stainless-steel, Kynar-coated work top, and a processing tank with its associated controls. These controls are mounted on a removable Kynar-coated, stainless-steel panel mounted on the station front. These panels are the same width as the work tops; therefore, work-top modules and electrical control panels can be moved anywhere along the station.

The perforated work tops allow spillage to drain into the plenum, and the laminar flow air, laced with acid fumes, to pass through to the exhaust ports located in the plenum. When a particular process requires something less than five processing modules, or does not require a rinser-dryer, a blank perforated work surface and electrical panel is substituted in its place.

This modular concept was of major value in reducing the number of detailed engineering drawings required during DART. A general equipment specification which covered both general chemical-station structure and individual process modules was generated. This specification, combined with a drawing of the station or module, made it possible to order any chemical station much as one would select dinner from a menu.

Equipment layout

The objectives of the equipment layout plan are optimum product flow, standardized wafer handling systems (jigs, fixtures, etc.), functional space utilization, operator efficiency, and operator safety. It was ascertained that 7000 square feet of factory space would be required adjacent to the diffusion area to begin construction. All new equipment would be uniform in length for complete interchangeability between product lines. The area was oriented in the factory in such a manner that it could be expanded any time in the future. Pass-throughs were provided for work flow between the diffusion rooms (phosphorous and boron) and the centrally located photoresist room to eliminate operator egress from their respective work places.

Space allocations for each room were approximated according to the ground rules to fit within 22,000 square feet (one half of a football field) and preliminary equipment layouts were begun. The product recipes had been prepared by Manufacturing Engineering and were used for these layouts. Meetings were held with the engineers and foreman in each operating area, and the layout was revised on a weekly basis.

The contractors had removed their tools to an assigned area, the clean-up crews had gone over the new area with fine tooth combs (would you believe mops and vacuums?), the manufacturing people were packing their inventory and miscellaneous equipment. The moment of truth was at hand. What a weekend?!! Plumbers, electricians, foremen, technicians, engineers, machine attendants, porters, designers—they were all there doing what they do best. Many hundreds of employees could be affected if this turned into a "long weekend". By Monday morning, everything was in a complete state of confusion—not chaos—confusion. But the furnaces were moved and at temperature by Monday a.m. as anticipated! As Monday wore on, the heartbeat of the factory got stronger and stronger. The area was alive with the sounds of unfamiliar buzzers and alarms. By Tuesday morning, all the vital signs were back to normal.

Phase I was complete, and Phase II had already begun. The process engineers and formen now were fine tuning the new area. The remaining construction phases were much the same as the first; however, each one had its individual crisis, such as a carpenters' strike during Phase II. Project DART was completed on March 1, 1975. The operation was a success, and the patient lives.

Sixth-month checkup

The health of the patient can only be considered improved if this improvement can be measured, in this case, in dollars and cents. The savings realized are sensitive to the production levels in the area; however, below are estimated savings based on the June 1974 production levels.

Material savings—The savings which are attributable to increases in yields and decreased breakages have been estimated to be in excess of $300,000 annually.

Labor savings—The savings directly related to increased labor rates and operator efficiencies will approximate $250,000 annually.

Reduced chemical consumption—This benefit will effect a savings of $250,000 annually despite the fact that chemical costs have been soaring.

Improved distribution of tested units—Improved distribution results in more premium product to be sold at a higher price.

Heat recovery system—This system will save approximately $20,000 annually.

But how are these savings made? The answer is through innovation. A few of the innovative methods that make DART successful are described below.

Particulate control

For particulate contamination control, all processing, loading, and unloading stations are Class-100 (Federal Standard 209A) vertical-laminar-flow stations, and the furnace walls are protected by Class-100 laminar-flow bonnets. The filtered air from loading and unloading sections on the furnace wall is recirculated back into the room, whereas the air which enters the chemical processing stations is exhausted from the rooms. Since the chemical stations comprise about 25% of the number of stations, a typical air mass in the room is HEPA filtered three times prior to leaving the room. This factor has made a significant improvement in the particulate levels in the operating areas. The dust counts in the wafer processing areas under the laminar flow hoods are less than one-third of the level allowed in the class-100 standard. Typical dust counts in the working aisles are averaging 300 particles per cubic foot of the 0.5 micron (and smaller) size (down from 70,000 particles per cubic foot) and 7 particles per cubic foot of the 5 micron (and larger) size (down from 500 particles per cubic foot).

Air conditioning

To reduce the air conditioning requirements in the diffusion area, all the diffusion furnaces were concentrated in furnace rooms, one phosphorous, one boron, and one for simultaneous diffusion. Because of their isolation from the operating portion of the factory, these rooms can be operated at an elevated temperature (90°F). The 145 furnace tubes are located in these rooms and are operating at temperatures averaging 1100°C. Prior to DART, some of the expended heat was absorbed in water

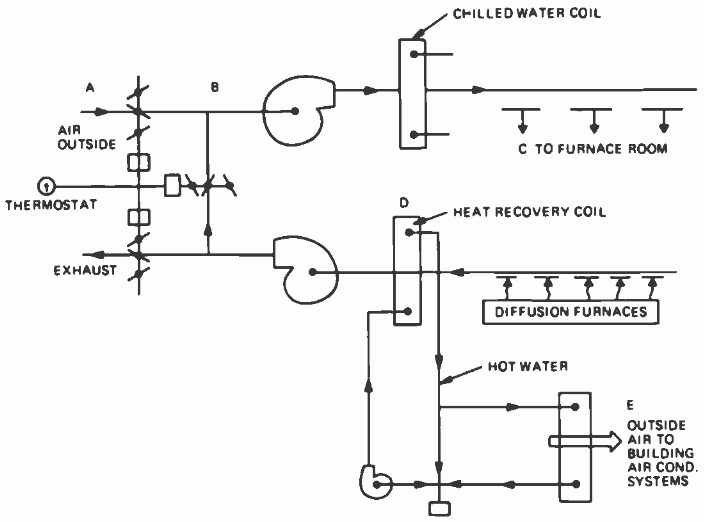


Fig. 4 — Heat recovery system. The outside air is introduced into the space at point A and mixed with return air from the furnace room at point B. Mixing is accomplished by the positioning of the dampers, which are controlled by the space thermostat. In summer, the outside air is modulated by passing it over chilled water coils; the coils are controlled by another thermostat in the space. The air is then distributed to space via ductwork at point C. The air that is removed from the furnace room is exhausted or returned after the heat has been extracted at the water coil, point D. The heated water is then circulated to the main building air-conditioning systems at point E, where it tempers (preheats) the outside air.

cooling coils which were piped to a drain and released to an outside stream. It appeared prudent to utilize this wasted heat to temper the outside air used for exhaust make-up, as shown in Fig. 4.

Based on a recoverable heat load of 8 kW from each furnace, it is estimated that 60,000 gallons of number-six fuel oil can be saved in one year. At $0.30/gallon, this savings amounts to $20,000 a year in fuel cost.

Temperature—controlled etch systems

Several processes require the use of various combinations of nitric, acetic, and hydrofluoric acids. The processes are vigorously exothermic when etching silicon, and the etch rates are extremely temperature sensitive. For this reason, an acid cooling system was installed in a plastic, fume-control, safety cabinet located adjacent to the processing station. The processing tanks are equipped with diffused bottom inlets and an overflow standpipe. This overflow is piped to the acid sump in the cooling system.

A submersible centrifugal pump continuously pumps the acid through a coil of plastic tubing submerged in a controlled-temperature cooling-water jacket surrounding the sump. Overflows are provided to allow over-fills of etchant to run into the cooling-water jacket which overflows into the plant chemical drain line. The pump is constantly recirculating cooled acid to the two process tanks which are used alternately to improve cooling.

When the etchant needs replacement, it is drained into the sump and aspirated to the plant chemical drain using city water. The sump is then filled by dumping etchant into the processing tanks, which drain by gravity into the sump.

These cooling systems have improved product quality by virtue of their repeatable etch times, and have extended the life of the etchants two and one half times. Other process modules were designed for standard organic and inorganic cleanups, cold-water rinsing, hot-water rinsing, ambient-temperature acid dips, and several unique processes involving ultrasonics and heated tanks with reflux condensers.

Process control was emphasized in each module and station layout. All timers used are digital for repeatable setting and all temperature controlled systems have a feedback sensor in the processing liquid to control temperatures.

All pumps and solenoid valves used in the processing modules are fitted with a three-wire pigtail and male plug. These valves are plugged into mating receptacles mounted on the rear of the station, thus allowing a valve change to be made by a plumber only. By supplying one utility receptacle, which is not used in the process, valves can be checked for electrical failure without removing them from the system.

Modules can be prefabricated and added to an existing station in hours, and without the associated construction in the operating area that is usually required when modifying a chemical station.

The uniformity of a given type of module permitted effective training to be given to plumbers, electricians, and machine attendants. All spare parts are stocked and standardized. This measure has greatly reduced the number of component varieties required.

All acid modules are designed with separate drain lines that are run into a common drain manifold in the service aisle. This enables these lines to be segregated in the future if acids can be sold to chemical processers for recycling. This, along with lessening the load in the plant neutralization facility, may prove cost effective. Also, with acid segregation, it may be cost effective to recycle the used deionized water from these process stations. These matters bear further investigation.

This modular construction in conjunction with process standardization has already proven its value in two distinct ways: changes in process sequence can be handled during lunch hours (i.e., through the rearrangement of modules within a station), and operator retraining is simplified when curtailed or increased production causes operator reassignment.

Although, perhaps, the major savings are those listed above and counted in dollars, many other savings and benefits are being realized from DART. These are the intangible benefits, in morale for example, which, while incalculable, affect the total operation, and which are testimony to the communication, detailed investigation, and cooperation shown by all who were involved. The attitude and comments of the people charged with operation of the diffusion area perhaps best reflects the merits of the program:

"The impact of Project DART on the power transistor manufacturing capabilities is in one word—GIGANTIC". Wafer processing capacity of my product line has been tripled. Recent dust counts have shown that the rooms approach Class 100.

Because of this condition and better

process control, Epitaxial processing line yields have improved significantly.

The ability to standardize on processing with quick feedback of data are big pluses. The labor content has been greatly reduced—by better than $.50 a wafer. The DART program allowed for reorganization leading to reduced manpower and improved efficiency."

L.V. Zampetti
Manager
Power Transistor Manufacturing

"The standardization, flexibility, and clean conditions offered by the new chemical cleaning stations and clean room have given me much greater control of the production process. We realized a dramatic yield increase when we started processing in the new area."

C. Jobst
Process Engineer

"The design of the chemical cleaning stations is the single biggest benefit of DART. It allows for pre-diffusion chemical cleaning standardization across all product lines with increased throughput."

E. Vancavage
Production Superintendent

"The new diffusion area has created a professional working atmosphere; safe, clean, orderly, in-line processing, better product flow, and reduced cycle times.

The design and layout of the chemical cleaning stations have had a tremendous impact. Increased volume capability with reduced labor are a reality. The most important accomplishment, however, has been the ability to standardize the chemical cleaning processes. We now process more than 80 types across five product lines in the same shared facilties. The results are improved process control and lower labor and chemical costs."

W. Cuba
Boron Room
Production Foreman

"The advantages of the DART program are many. The room design and the use of laminar flow stations have greatly reduced contamination levels. Standardization of equipment has led to standardization of processing. The order and manner in which the diffusion furnaces are located has enabled us to implement some very sophisticated monitoring systems. We now have the ability to continuously scan all our diffusion furnaces to assure that critical parameters are being met. The result—better control of the actual diffusion process and quicker response to problems."

J. Murray
Process Engineer
Diffusion Furnaces

"The new DART area has given us controlled ambient and atmospheric conditions which are necessary for photoresist processing. The standardized processing stations give us wide flexibility in scheduling work through the area. The solvent disposal systems have eliminated spills and improved safety conditions for the operators."

J. Fadden
Process Engineer
Photoresist Application

"The standardized wafer handling system is responsible for decreasing wafer breakage 5%. Improved cleanliness conditions are directly responsible for increase in yields and distribution. Average yields are running 5% above standard. In addition, a much higher percentage of units show blocking capability of 500 volts, thus improving distribution."

Pat Roman
Engineering Leader
Thy. Manufacturing

"Rate studies of the new diffusion area equipment now underway show dramatic increased rates, thus, lower labor costs. For example, of the ten cleaning rates studied this month, in the linear power area, the average rate increased 250% effecting a $22,000 annual labor savings. Also, the asthetics of the area play heavily on the workers' pride in what they do.

G. Diehl
Industrial Engineer

"Wafer Processing is much simpler to monitor and control with the in-line processing equipment. Product quality has improved and output has increased."

R. Glahn
Production Foreman

"Easy accessibility of standardized components has greatly reduced repair time. The order of the equipment layout puts everything within reach. The atmosphere is pleasant to work in."

R. Draught
Machine Attendant

"Rejection of product due to airborne contamination has dropped to zero. In-process quality checks have been simplified due to process standardization, thus allowing increased frequency of checks with no increase in labor. Wafer breakage and damage has significantly decreased. The order, neatness, and cleanliness of the area have increased the pride of the hourly personnel. The degree of technical competence and sophistication displayed in the DART area can only leave customer survey teams with the impression that RCA is an authority on semiconductors."

H. Richardson
Manager
In-Process Quality

The business end of engineering —an interview with Joe Volpe

Quite a few people were surprised in July 1974 when Max Lehrer, Division Vice President and General Manager of the Missile and Surface Radar Division, announced that Joe Volpe would be the new Chief Engineer.

Few were more surprised than Joe Volpe himself: "I never thought of myself as a Chief Engineer... and I certainly never thought of myself as a replacement for Dudley Cottler as a Chief Engineer."

With a refreshing mixture of self confidence and humility, Joe realizes now that he was being asked to bring a different set of talents to the Chief Engineer's job.

Ever since his youth, Joe Volpe has had the desire to "run things his way." This reflected itself in his aptitude at managing the family business — a retail food store — while he was attending high school in Philadelphia. Later, while he was working part-time testing paper and putting himself through St. Joseph's College, he became supervisor of a group of older and more experienced people. Again, working for the Brown Instrument Division of the Minneapolis Honeywell Regulator Company, he moved naturally into a leading engineering position.

Through almost 17 years with RCA, he has moved through assignments in design and project engineering, and into project management. After almost ten years in project management, and at a point where his career in project management hit its zenith (as AN/SPY-1 Development Project Manager and later as System Project Manager on the staff of RCA's largest Government program — AEGIS) Joe Volpe returned to engineering as Chief Engineer — bringing with him a somewhat different perspective from that of someone who had "grown up" within the Engineering Department.

He shares these perspectives with us in this *RCA Engineer* interview.

The questions were asked by John Phillips, Associate Editor; Bill Underwood, Director, Engineering Professional Programs; and Don Higgs, Manager, Technical Communication, Engineering Operations, MSRD.

You started with MSRD's Engineering Department, then went into project management. Now you're back again in Engineering. The relative perspectives from the various jobs might be interesting. Can you tell us about them?

It was very interesting. I hope I don't get too wordy but this is a favorite subject of mine. And it's been very educational.

When I was in design work I probably had far less appreciation of the total project picture—or even the organizational structure—than I developed later on when I was in Projects looking at Engineering. So I had a little different perspective. I was rather myopic and "Projects" to me meant the individual project engineer, or leader, or manager that we were interfacing with directly; not at all an entity. It was more or less a situation in which if you had a decision to be made that was outside of your scope of work, you just went to Projects. It was the answer to a design engineer's prayer. And it made a design engineer feel very comfortable. He had a job to do that was very technically oriented and not too responsible. He knew that there was a cushion between him and the real world—the real world being the customer and all those nasty things such as overruns. But that was a long time ago.

Didn't the project engineer or manager impose a lot of constraints?

No, not too much. He was the guy you went to for the answers. He would put some constraints on you, but I don't remember any undue pressures. But you have to consider the era. It was different then. The problems were not with overruns, they were the schedules. Get the job done. It wasn't so much a question of how much does it cost; rather, do you need resources here? Then get more resources. Get it done—and get it done right. We didn't have the fixed-price environment and the extremely competitive situation that we have now.

Then when I moved into Projects, I went through a transitional period: it seemed I always picked up the jobs that were in trouble. I would get the tail end of every one of them, either because the guy who had it before me moved off to another job, or —as we did things around here then—if the job was in trouble, the way to fix it was to change the guy who was running it. Sometimes that helps, sometimes it doesn't.

It was in a troubled environment; a lot of the programs were fixed price and had tight schedules, and the relationship with Engineering could have very easily turned into an adversary environment. I don't think it did, in general, but I had to play a very strong directing role as a project manager and I guess I developed much more critical attitudes toward Engineering people, because if they did something wrong, it would reflect back on my success. Then a little further along, in the later 60's on the MPS-36 radar days and the AEGIS days, I started to think a little more . . . I'll call it . . . cooperatively. As a matter of fact, I made it a very basic characteristic of the way in which we operated the MPS-36 program: on a *we*, not a *you* and *they* situation. I tried to establish that there was no such thing as an Engineering problem, it was a program problem and the *modus operandi* was not to prepare for meetings or review so you could throw spears at the other guy, but to try to work it out. And this was a way of life that I tried to develop from there on out; to try to work with people instead of trying to push and shove them.

I tried to establish that there was no such thing as an Engineering problem, it was a program problem and the *modus operandi* was not to prepare for meetings or review so you could throw spears at the other guy, but to try to work it out.

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We need new business to not only survive but to grow, and the challenge to me is to do something different.

What was your reaction to the first move into Projects?

When they asked me to make the transition—even though I had been working very closely with the project group for maybe a year or two—all I could think of was that Projects is a paper organization. All they're doing is dealing with paper and I could see all these directives and policies and I said to myself I don't want a paper job, I want to stay close to hardware.

But I remember going around talking to a few people to get some advice; I've done that a number of times when I've had to make decisions. And the advice I got in general was to look at it from the viewpoint that the people making the decisions think you're qualified and that it's the right place for you to go. I remember the advice because I had opportunities for jobs being offered and sometimes I didn't know what it all meant. But I said, okay, let's see how it works out. And it's worked out well.

Were you pleasantly surprised when you did move into Projects full time?

Yes, I really was. First of all it was entirely different and as I stayed with Projects and went into each of the succeeding projects, I became so enamored with the operation I thought I'd never want to get out. Really, I felt this was the best job in the whole Company for two reasons: one, you get involved in everything; you're working with a customer contact or with Contract Administration, or with Engineering or Materials, and you have such a broad spectrum—if you ever go home thinking you've had a dull day, it's most unusual. Second, as project manager you are able to control, you can plan how you want to run a job, and you can influence it and control it. Not all project managers do, but you have the wherewithal. And I enjoyed that very very much.

When I went into AEGIS, I had a very large organization, and I enjoyed that very much. Certain aspects of that job were very frustrating, but not the project management aspect. So having had that as a background, to me the next obvious stepping stone was (if you can ever get there) to become a General Manager. I never envisioned going back to Engineering—no way.

How did you view the Chief Engineer's job?

Everytime there's a reorganization and the rumor mill goes around as to who's going to what job, I've been uniquely unsuccessful in predicting the results. And prior to this job, if anyone had asked me, I'd be the last one I would have picked for the Chief Engineer's job.

Do you remember the exact moment someone mentioned the Chief Engineer's job?

Oh yes, I can remember that. It was Max Lehrer. We had been having discussions prior to this on my wanting to change positions from the job I had in AEGIS. I had been on the program for five years and I felt I was getting stale. And that was a problem to me in the sense that AEGIS is such a large job, and I couldn't see taking another job that would be a step down, at least in responsibility and problems.

I didn't know it, but an opportunity for Dudley [Cottler] to make a change had come up at the same time. So Max told me to sit tight for a couple of weeks. Okay, so I didn't feel like sitting tight very long but things developed within a couple of weeks and he called me up and said "How about having lunch with me?" On the way into the lunch room he said, "I have a job opening and you're one of several candidates I'm considering"... and I think he implied that if we were mutally agreeable I might be his first choice. But he didn't totally make the commitment. He's a good negotiator. And all the while I was wondering, what the hell job is he going to offer me. He said, "I'd like you to consider taking the job of Chief Engineer." I stopped in the corridor—cold.

It was a traumatic thing for me, and I guess it was sort of a lack of confidence in myself more than anything. Because I never thought of myself as a Chief Engineer, number one, and I certainly never thought of myself as a replacement for Dudley Cottler as a Chief Engineer. And that's probably the most difficult thing I was faced with at that time. Fortunately I didn't try to replace Dudley because I never can. And Max wasn't looking for that. He was apparently as interested in the management and administrative aspects of the job as the technical part. But I couldn't see that immediately, and it was my biggest concern.

Within a few weeks after that, or no more than a couple of months, I got over the feeling of walking in Dudley's shadow (he helped me a lot in this area) and started to develop my own sense of security, and I started to carve out my own niche. And I can truthfully say that of all the jobs I have had, I've never enjoyed a job as much as I've enjoyed this one. What do I enjoy about it? I feel comfortable in the job. I know the people, and that's been a big help. I also know the operation, I know how the people think and work, so I felt comfortable about doing something about it. And I am very pleased with the reactions of the guys who have all pitched in and made me feel comfortable. They could have all gone their private little ways and left me out in the cold. You can't force people to be cooperative, they have to want to do it. They have and it's worked out very well. So I'm enjoying it thoroughly.

Are you enjoying the problems?

We have problems and I thrive on them.

What are they?

I can spell that out very simply: getting new business in the house. We have the situation where we need new business to not only survive but to grow, and the challenge to me is to do something different. That's not a criticism of the way things have been done in the past, but it's a responsibility I feel. I'm trying to do things different but better.

This leaves several questions to be answered. How are you going to generate proposals? What kind of an engineering attitude, or changes in attitudes do you have to get into the organization to generate winning proposals? How are you going to be able to do that so you don't spend all your resources or you spend less of the resources? You have only so much money and it's the old story: the more business you need, the fewer resources you have to go out and get it. It's almost a positive feedback situation. What are you going to do so that your proposals, from the cost standpoint, are more competitive? How are you going to plan and run the jobs differently? What would allow me to put in a cost that's lower and therefore raise my chances of winning? What are the different ways of doing things?

When I came over here I just felt that responsibility to do something better—not just different! I was very anxious not to be different just for the sake of being different. The fact that I came over very open minded surprised a lot of people, because I had been pretty opinionated in my earlier dealings with them. There were probably a few of them who felt they should be writing their resumes right away, based on my prior dealings with them. But it was good that I had an open mind, because in a few months I developed some new ideas and appraisals of the people and the organization. We made some operating adjustments, we made an organization change which was reasonably major, and I started to develop a feeling for how I should run the Engineering Department and how the Chief Engineer's office should operate. I think we're going through another transition now, and we're going to have to start thinking about things in a different light than we have in the past.

What's the transition?

Driving home last night, anticipating perhaps a question like this, I thought of an analogy that might be helpful. The situation we're in now is a little like a martini. In the past, there was quite a bit of emphasis on building up technical skills and abilities, advanced techniques, and advanced technologies; I liken the amount of time and energy and investment that you can put into advanced techniques and technology now to the vermouth in our martini. And right now we're living in an environment of very dry martinis. What can you do for this contract today to get business tomorrow, versus planning the systems of the future and building your skills, your techniques, and your know how to keep advancing the state of the art.

In our present business climate, we have very little to set aside to try the things that don't have an immediate payoff. That makes my job very difficult in trying to keep a balance between keeping our technical skills up and running a business. And right now the business pressures are so heavy that you have to be careful that you don't cut the technical side down to the point where—when you try to revive it—there's nothing left. There is a story my father used to tell about how in the old country (he was born in Italy) they were teaching the donkey to eat less and less and they kept cutting the donkey's food in half every day until they finally had the donkey trained so it wouldn't eat anything at all. And the donkey died.

How do you keep the donkey from dying?

I have ... I won't say pressures ... but I have guidance and inputs that help the balance. On the one hand, I have contacts that keep the business pressure on. We're bidding new jobs, reviewing contracts, and looking at investment plans and bookings reviews; also Max's staff helps keep the business pressure on.

Then there's a different kind of pressure—more like reminders and the like—from G&CS staff, and from the Engineering Department itself: IR&D reviews and things like discussions on what kind of training we should do. It comes up every day in different ways. For example, every time somebody wants to go to a technical seminar, you're faced with making the decision of balancing your overhead budget against your needs. Where do you draw the line? It's not an easy problem in today's environment.

...right now the business pressures are so heavy that you have to be careful that you don't cut the technical side down to the point where—when you try to revive it—there's nothing left.

Given this environment for at least the near future, how do you think you can motivate the technical staff to do a better job than they did before?

One of the things that I set as my goal—that I'm trying to have permeate the organization—is critical to a lot of the things we've discussed so far.

Engineering assignments have to be broadened substantially over what they have been in the past. For whatever reason, we've gotten into an age of specialization and when you have 5000 employees, such as this plant once did, specialization was not a big problem. Because you had 50 of every kind of specialty, you had a variety of resources to handle your assignments. As your resources are reduced, specialization starts to be a real problem. It's a dilemma because, along with the competition, you must be technically innovative. At the same time, you must be very cost competitive, so you can't afford to use all the most senior engineers as your total resource. That might satisfy the first need but not the second.

So to accomplish a major reduction in the engineering content that it takes to do a job, we have to broaden the assignments that we give the individuals. And—as a general statement—I have a great deal of confidence in the ability of individual engineers to take on far broader assignments than they have in the past. They may not do all assignments equally well but they will do them satisfactorily, at least average or above average. A receiver engineer, you know, doesn't have to work on just i.f.'s.

In my own experience, not as a red-hot design engineer, because I'm not (I consider myself an average engineer), I've often had assignments in which I've had no prior experience—and I found I could adapt very readily. You do enough intensive homework and pretty soon you're doing the job very nicely and are able to handle it efficiently. If we can spread out and break down some of the technical cubbyholes, its going to be a big help out of this obsolescence problem we've had. And at the same time from a business standpoint, it's going to have a good impact.

As your staff becomes higher priced and you don't have new business coming in, you can't hire the younger, lower-scale engineer. What kind of a problem is that?

Not easily solved, and I don't have any ready solutions. It's a double problem: It brings your average dollar rates up and it prevents you from getting the fresh blood in, something I think is essential. The young fellows coming out of school now are trained differently. They have fresh ideas, they have energy, they're not fixed in their ways as are some of the older fellows. You need that constant flow into any living, growing, vibrant organization. It's a kind of intangible thing, but you can feel it. You can really feel it. I'm beginning to sound like an old man, now, but I am getting older. Some of these young fellows move a little faster and they have different ideas and it stimulates the rest of us to think a little differently.

Now if you don't have that you're just going to continue into what I would call a decadent way of life. In today's business climate the stimulus must come from shining stars within your organization—the good guys—these high priced but top-notch performers; they are your mainstays. But if you get unbalanced, it's a very difficult situation because invariably these are key people that you could not very casually put out on the street without it having an impact on your organization, your business, and on you personally.

If you remain unbalanced and you're forced to cut back, you run the high risk that you can never grow again because you're going to be low on critical master talent. So more business is the answer. It's like a gambler. You give him cash to work with, he can do something with it, but you send the best gambler into a game without a bankroll, you've really tied his hands and his knowledge of the laws of chance won't help a bit.

How do you feel you relate to your staff? How available is any engineer in the organization to you? How available are your managers?

I've developed a 90/10 philosophy of operation in this job. I soon found that any one of maybe a dozen major aspects of the job would bury the Chief Engineer immediately if he decided to pursue it in depth. So looking at the resources I have available, I got into this 90/10 concept where I will delegate authority and responsibility for say 90% of each job and try to arrange to have the remaining 10% come to my attention.

I've developed a 90/10 philosophy of operation in this job.

Now invariably you find yourself being drawn into a specific assignment that takes a lot of your time. That probably is also a way of life. But with this 90/10 system, I have a lot more time available to specialize, it's not like taking 100% of my time and spending it on the 10-percenters. With that as a background, I try to operate through my own first-level managers if possible, and I say *try* because it's not a very natural thing for me to do. I know so many of the lower-level people, it would be much easier to operate at the engineer level and bypass the management team.

What kind of problems do you think your staff should bring to you?

I'm just going through appraisals and reviews, so we have had a chance to discuss that question, at the first level anyway. The feedback I'm getting—and I'm taking it at face value—is that they like the idea of more responsiblility and authority being delegated to them. This gives them an opportunity, and they are exercising it, of using judgment as to what they think is important to bring to me. We have a very open relationship as far as information flow.

I make special mention of that because one of the constructive criticisms given to me before I took this job was—and I got this from Max and others—"you tend to keep things to yourself and you don't let people know what's going on. People are a little bit cautious about dealing with you because they're not always sure what's in your mind." So I took this to heart and I tried to get this "let's get it out on the table" attitude with the Engineering Department and the same relationship going between Engineering and Projects, and there's a very positive end result I'm aiming for.

There should be less need for having project engineers looking to see what's hidden in the design engineer's shop order. That's the kind of relationship that had existed for ten or fifteen years. That's how I thought when I was a project manager. But I know how they feel, and I can direct assurances to the heart of the problem. And say, "okay, now this is what we are going to do different. I know how you're feeling, I was there a few months ago. Trust me. If I don't do what I'm saying ... if it turns out to be just words, then we'll go back to the old way of doing things." And the Projects people have been very cooperative and it's working out so far.

When you were discussing your early background you mentioned joining RCA here in Moorestown as a B engineer, you said you really didn't know who the Chief Engineer was. In a sense you said the Chief Engineer wasn't even part of your world. I wonder if that's how you feel about the B engineer today? Would it be okay if he said that?

No, it wouldn't, although I have wondered whether they have an awareness of the Chief Engineer—not as an individual, but what he's doing and what he's trying to do. I don't know the answer, but engineers today aren't nearly as far removed from the Chief Engineer, the Marketing Manager, and all the rest of them as I was. One major reason is that there are fewer people here now; it's easier to see through the crowd. We have less than 2000 people now; we had over 5000 when I joined the Company. Also back in those days there wasn't the opportunity for visibility or to meet the Chief Engineer. Now we have, and have had for several years, weekly reviews, so-called Chief Engineer's Line Management Reviews. The principal engineer presents the progress and problems, and he usually has his supporting cast in the audience and they get a chance, not only to get visibility, they get to meet the guy. They know who he is, what he looks like, and talk with him. Other mechanisms for contact have also been built up: awards, patent disclosure honoraria—there's more communication now, so that the guy would really have to be out of it not to know who the Chief Engineer is nowadays.

How accessible do you want them to feel you are? In other words, could a B *engineer walk into your office? For what purpose?*

That one is a little more difficult because the stock answer is motherhood and I've heard a number of managers say it over the years—"my door's always open." And unless you put that in context, it may or may not happen. One of the things I wanted to do when I came to this job was to make sure the managers manage. I'm sensitive about going around them, because I've had some experiences over the past years where some of my bosses tended to go around me and I didn't like it. What happens is that the management people stop managing. Many times they can't manage because they don't know what's going on. And the lower group is working without management.

Okay, what really happens when you slip into that way of operation? You find the business is being operated by the lowest level. This doesn't degrade them by calling them the lowest level, but it's the lowest responsibility level. With this duality ladder at Moorestown, we have some very strong, sharp people at this so-called lower management level, or non-management level. But one of the things we look for in upper management is a broader perspective and balanced emphasis on cost, schedule and administrative aspects. So I am going to expect my managers and management people generally to manage.

To that point, the thing that's coming across very consistently is the sort of naturalness that you feel about authority. In this interview you haven't flaunted it nor have you been humble about it. You just seem to discuss it very naturally as if it's just an ordinary life style. Is that the way you feel about authority?

Yes, I feel an urge to run things or take a position of authority. I guess the most frustrating experience I have is every Sunday at Mass; I watch the inept ushers trying to regulate the flow up to the communion rail. I suppress an urge to get up there and tell them how to do it right. I control myself because I know if I go and do that, the guy would say 'well why don't you join the Holy Name Society and the ushers' committee?' I am not willing to pay that price. But it just seems to happen. When they started a father's club at the local high school my girls went to, somehow or other I got elected president. I didn't know most of the people there, but I just naturally felt the need to take charge. And, of course, I've used meetings to accomplish my goals, but this is a natural thing. I like to participate in groups. I enjoy it. As a matter of fact, I'm more comfortable working within groups than making an after-dinner speech. I feel less comfortable there than if I were in the audience heckling.

What is the role of awards, publishing, and other professional motivational programs?

Well I think they are very important. In a sense, they serve as catalysts to keep up not only the technical image but the capability. It forces some technical discipline. It gives people, if you will, the excuse, the incentive to do that little extra to keep technically sharp. It's not a big deal to get an award, at least certainly not financially, but it's tremendous to the ego and to an individual's well being, and I think it's very important to give recognition, whether it be through publishing a paper or a Technical Excellence Award.

How do you think you relate with the rest of Max's staff. How do you relate to him and his other department managers?

I guess I'll start with Max. I was apprehensive of that relationship. I thought there might just be a little bit of a conflict of philosophies because I consider Max to be a strong guy and I like to think of myself as a strong individual. To be perfectly honest with you (and we can always edit this) it's worked out very well. I think there has been a mutual respect that's been building. He provides a perspective for the business side of the operation. However, you wouldn't know he didn't have a technical background unless I told you because he assimilates technical material very quickly. I haven't found myself overly controlled in time, resource allocation, or in what I'm doing. I've been given reasonable freedom of operation and I've got enough time to do my thing over here. So that's good.

With the other members of the staff I got off on the right foot. Before this job could be announced, I started working with Jim Foran, our comptroller, very closely and he started briefing me in anticipation of the job. So we got a good start in that way and that's an important relationship for the Chief Engineer.

Typical of the relationship is one I've had with one of the project managers who had a way and plan for running his prime program. It was almost 180° out of phase with the way I'm trying to run the Engineering operation. We sat down and worked this thing out. I think I convinced him of 90% of what we wanted to do, and he's willing to go along with it. I think he feels confident that it has the prospects of being a better way of doing the job. And I've given in on a lot of points.

The important thing is that we've done it in a friendly way and not in an adversary atmosphere—even though there were some strong feelings on both sides to get in there and start shouting at one another. That's a different way of life with me—instead of being an arm-waving shouter, I'm trying to be more relaxed and give the other guy a chance to say something.

That's a different way of life with me—instead of being an arm-waving shouter, I'm trying to be more relaxed and give the other guy a chance to say something.

Does arm waving and shouting have its place?

Yes, I think so. I probably wouldn't have gotten this job if I hadn't done some of that earlier in my career.

I still have no compunctions about clearing my throat, but I've tried to do that in a careful, calculated way. A case in point came up a few months back in a kickoff meeting for a proposal; there were 50 to 55 people there—at a time when I was trying to implement a philosophy of cutting costs of doing proposals. It was prearranged for me to set the stage with a little pep talk and ground rules. I sat there stewing and when I got up I don't remember exactly what I said but I really laid it out that this was not the way we were going to run this place with 50 people attending a prop kickoff, and that I was very disappointed and dissatisfied with this as a start. And then I used that opportunity to express some of my philosophy of operating and wound up saying very few words about what I really had intended. And then I left, and the message got through. So you have to come across strong sometimes.

On the other hand, do you think you can bend too much?

Sure. You can become wishy washy and be almost apologetic. The important thing is to be able to take the time and effort to listen to other people's ideas. And then try to make a judgment about which are the best ways of doing it, and be willing to change your mind. Number one, I think you should develop your own ideas and try to improve them or change them. But, if the other guy has a better idea, you must be man enough to say, hey, that's a better idea, let's do it your way.

What are some of your basic personal values? What are the things that you'll stand up and be counted for?

I find it very difficult if someone calls me a liar. And for me to *be* a liar is even worse. That to me is something that is uncompromisable. My father used to make a big issue of this. "If you ever lie," he said, "just once, then I don't know when you're not lying. That's the worst thing you can do and the hardest thing to repair."

So I guess the first word that really comes out in my own mind, is integrity. I like to be extremely frank and above-board with people, but I have no compunctions about trying to strategize how to do things. When you're out to win a proposal, you lay out a strategy; that's not being untruthful, it's not reducing your integrity. I mean, if I want to accomplish something I may have to talk to the right people, make sure they understand what I'm trying to do and vice versa, and so get them on my side. You have to do some of that or things just don't happen. But I have to feel that I'm the guy that people can believe; when I say something I'll stand behind it. That is most important.

Do you think the business is less fun now?

No, surprisingly enough I would have thought that would happen as I kept going up in the ranks and the responsibility became greater. Definitely, if you had asked me that question five or ten years ago, I'd have said there would be less time for fun. My present experience is just the opposite. I think this is more fun than any other job I've ever had. Maybe ten years or two years or two months from now I'll feel differently, but right now it's good.

A good engineer, as far as I'm concerned, is not someone who designs a device that works. He has to fit the rest of the criteria.

There has been a definite trend in your background—of being concerned with monetary aspects of the business. Do you think it's important for all engineers to have such a concern and do you think there is something there that a lot of engineers lack?

Yes, you might say it could be a good or a bad characteristic for a Chief Engineer, depending on what one says the Chief Engineer should be, much less any other type of engineer. As a Chief Engineer, you run the risk of being termed a non-believer or a non-belonger to the engineering cult when you mention cost and schedule. But I am a firm believer that every engineer, not just the Chief Engineer, should have a heck of a lot more cost consciousness. A good engineer, as far as I'm concerned, is not someone who designs a device that works. He has to fit the rest of the criteria.

Engineers often feel that they are to be measured by whether they can make a job work technically—to the exclusion of other parameters. That approach may be all right for the research engineer. But in the environment we work in, that's a very unreal world. And to me, a good engineer is the one who gets the job done technically within the cost and schedule constraints. And that does not mean, necessarily, meeting all those, but doing the best that can be done within those constraints.

You've been in the defense business now for about seventeen years. How has it changed? What does it look like for the future?

When I look back and think of the defense business—the front end of that seventeen years—it was a big amorphous mass to me at that time and it seemed it was the era of big contracts in which I was a very small cog. We're constantly going through cycles in the defense business. I guess a lot of them are driven by whoever is the current Secretary of Defense and by his unique policies, whether they be "fly before buy" or "total procurement," or whatever.

Does the Secretary of Defense himself have that much of an impact?

Oh yes, I think so. It starts usually as a simple little memo or a concept that somehow or other gets propagated in a speech or a very driving directive. And from there it just filters down through the huge community and pretty soon we have new policies. (The current variety is design to cost.) And from there we get directives and seminars and procedures, and you just see it everywhere you turn. Some of these things are just given lip service — something that has to be included in the contract or the contract has to appear to have it; others are intricately involved and you see them infiltrating every aspect of a job.

Where are we now? Now we have different pressures. The economy, or the combination of the economy and the people's will or the reaction to the Government, is influencing defense policy. This impacts in two ways: first, because of inflation we have less real money available for defense or any other things out of the budget. Second, because of the reaction against involvement, people are unsympathetic to defense spending, and this influences congressmen who serve the people.

How can you compete in that environment?

Well, with the shortening of funds that this environment brings out, the services start to reflect this in their procurements. They want off-the-shelf equipment that doesn't require development. They want very competitive price bidding. Then they start to get troubled after they're burned with overruns. Now I wouldn't be surprised to see an era of penalty clauses. They may try to put constraints on to protect themselves. This is going to cause industry to be reluctant to bid in that environment. And then the pressures will mount; you have to bid in order to stay in business and yet you are afraid of being forced into a situation that is unacceptable. I think we're going into a whole new set of challenges in industry. Industry will have to take risks—technical and cost risks—in which the odds are in favor of having financial reverses. And yet the alternative to doing this is to go out of business.

Do you foresee a negative industry reaction? For example, no one responding to a particular invitation to bid?

I say yes quickly, and I guess my second, slower answer would be no. It seems that there are always people who will bid. I can't recall an example where it (a complete industry no-bid response) has happened in the past, no matter how unrealistic the situation. There have been a few not too distant experiences in which I felt that the procurement and the amount of money available for the procurement (this is fairly common knowledge) were just completely unmatched—yet they became closely competitive situations. I think the real end result is that more companies will leave the defense business because it's not profitable. When you add that to the relationship between the defense business and the basic economy, companies will look very critically at each of their defense-oriented entities and peel off the ones that are not good performers.

Do you think that survival is going to depend on the technology or on business practice?

Well, I have an intuitive feeling that survival is going to depend on some combination of innovative technical concepts and implementation, combined with a lot of solid good business rather than on advanced techniques and technology. By innovative, I don't necessarily mean a new type of solid-state device, but a better way of implementing what is available in a very cost effective or performance-producing way that will give you the edge—so that you have something to sell that is better than the next guy's product. I think you will see a tremendous amount of cost vs performance pressure. We are working in a seemingly impossible cost and schedule environment, with usually very difficult technical performance constraints. Some companies are going to fall by the wayside. And possibly we'll go into some other cycle that I can't foresee—hopefully with the economy straightened out, inflation not too bad, and not everybody hating anything associated with defense. We may be able to spend money again, and we'll get back to increasing our technical capabilities. Maybe it'll be something like another moonshot that will be the catalyst. It seems that we need a catalyst. I've never seen people come up with ideas when there's no need for them. There are a few guys who just sit there and think of them, but they're rare. When the pressure is on, though, we make advances.

Given this environment, then, and possible future environment of Government Contracts, where is MSRD today, what are the trends and where are we going to go with those trends?

First of all, we've gotten down to the point where we are lean and hungry. So there's motivation as a starter. It's a challenge getting enough new business in to keep our people employed, but the organization has been pruned down over the years so we're getting close to that critical mass.

Given that as the starting point, what do we have to build on? We've got a pretty good repertoire of product experience. We've built many different kinds of radars and systems; our experience has been broad enough. Basically, our line is radars and big systems. The hooker is, what do we do with all that?

The first thing we are trying to do, is to decide very selectively where we're going to go. We're in that process now. That's probably the biggest challenge we have: looking at the business areas we are in or will pursue and then selecting those on which we can build.

What are the areas we want to pursue? Well, our makeup and structure here in Moorestown help us decide that, at least partially. We have all these skill—and the laboratories and support facilities to go with them. And that means we should probably avoid most of the basic, simple little jobs, because we can't compete in cost with somebody who isn't carrying the expense of our big pool of talent and facilities.

So we have to go after the jobs that are complicated—programs that need us and can afford us. Also, we're going to find ourselves changing our business aperture from one-of-a-kind targets to those that have repetitive payoffs, those that have production followup. And production might be five or ten, or thirty—not thousands. And that business base may swing over to be predominantly manufacturing, but there's always an engineering content.

I think we enjoy a far better situation than a lot of the other Government-business-based firms.

So if we're successful and build ourselves up a certain level of business base, we can afford to think a little more calmly and sanely, to build on that base and go after some new businesses.

Okay, that's one aspect of it. Now, the other aspect is that we're going to have to find a way of doing the jobs with half the engineering content that we've used in the past. Everybody says I'm out of my mind to say that. And maybe I don't really mean that, but it does emphasize the point. It has to be a dramatic change, not just 5 or 10%. To do that dramatically, we've got to be constantly thinking of ways—reorganizing, accomplishing the job—all the things we kind of touched on in various places, so that each one of them may be a 5 or 10%. We have the same situation in manufacturing and all the other parts of a job. But addressing myself just to engineering, which sometimes is a major part of a business, that's one thing we have to do—a big change.

So where does that leave us? Well, we have a reasonable business base that lets us hold our people and gives us a chance to build. I think we enjoy a far better situation than a lot of the other Government-business-based firms. Now, I think we're going to have to turn the corner and build up our base. We haven't been uniquely successful up to now, but I'm confident we'll do it. This may be the year.

Chemical conservation in the Solid State Division

R.N. Epifano | J.R. Zuber | Dr. J.A. Amick

In 1973, the Materials and Processes activity of the Solid State Division began a program aimed at conserving chemicals used in solid state device manufacturing. Through extended use, substitution, and recycling of chemical materials, the Solid State Division has been able to reduce costs, alleviate shortages of critical materials and reduce contaminants in plant effluents. The conservation methods include extended use of buffered etch, continuous addition of hydrogen peroxide to sulphuric acid, and reconstitution of aluminum etch.

INCREASING COSTS, scarcity of critical materials, and ecological considerations necessitate an active chemical-conservation program at Solid State Division installations. Rising production levels require ever-growing volumes of chemicals. This additional demand, coupled with the increased prices of chemical materials will, if no conservation action is taken, have a significant cost impact on Solid State Division operations in 1975 and beyond. The unprecedented and unpredicted growth of the need for chemicals coupled with petroleum shortages and the lack of sufficient new capacity in the refining and chemical-manufacturing industries have combined to produce shortages in materials of critical importance to the Solid State Division. To further complicate the situation, limitations on the composition of plant air and water effluents place additional restrictions on both the manufacturers and users of chemical materials. Chemical conservation through extended usage, substitution, and recycling of materials is important as a means of reducing costs, alleviating the critical materials shortage, and controlling air and water pollutants. As a means of effecting these conservation goals, committees were established in 1973 at the Findlay, Mountaintop, and Somerville locations. Members of the Materials and Processes activity of the Solid State Division, Somerville, were assigned to work in the area of chemical conservation. This article reviews the status of the chemical-conservation program and details selected areas of achievement.

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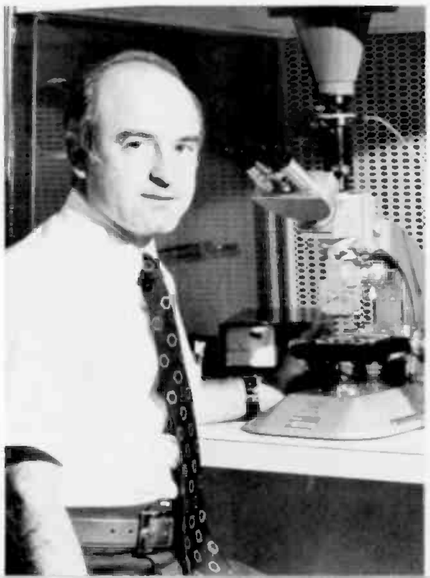
Robert Epifano, Ldr., Materials and Process, Solid State Division, Somerville, N.J., graduated from Lehigh University in 1959 with the BSChE. He completed several graduate level courses in materials technology at Newark College of Engineering. Mr. Epifano joined the Bendix Corporation in 1959 as a materials engineer, and contributed to the development and evaluation of insulation and encapsulation materials for airborne electronics, such as the solid-state inverter used in all Gemini missions. He joined RCA in 1965 and worked in the area of encapsulation of semiconductor devices. Currently he is responsibile for two Technology Groups in the Materials and Processing Department, the Polymer and the Analytical Technology Groups. Mr. Epifano has given many in-plant lectures on plastic encapsulation, and has presented papers at technical seminars on plastic encapsulation of integrated circuits and the evaluation of mask-to-wafer aligners. He holds a U.S. patent.

John R. Zuber, Advanced Materials and Process Laboratory, Solid State Division, Somerville, N.J., received the BS in Chemistry from Fairleigh Dickinson University. He has completed several post-graduate courses at Rutgers University and numerous RCA sponsored courses. Mr. Zuber was employed by the Heyden Division of Tenneco Chemical Corporation in 1952, initially in Research and Development, and then in the Quality Control Laboratory. He joined RCA in 1959 as an analytical chemist in the Materials Laboratory. In 1965 he was assigned to the Advanced Materials and Process Laboratory as a Member of the Technical Staff. He has worked in various areas of process control including clean processing, chemical etching, and pollution identification and control. Most recently, he has been responsible for the initiation, development, testing, and implementation of many chemical conservation techniques. Mr. Zuber has co-authored two papers published in Analytical Chemistry, and has delivered lectures on anisotropic etching and analytical techniques for solid-state process control. He has one patent granted, with others pending, and is a member of the Electro-Chemical Society.

Dr. James A. Amick, Mgr. Materials and Processes, Solid State Division, Somerville, N.J. received the AB in Chemistry from Princeton University in 1949. He then spent a year as a predoctoral fellow at Brookhaven National Laboratory, before returning to Princeton for the MA and PhD in Physical Chemistry in 1951 and 1952. Dr. Amick joined the staff of the RCA Laboratories in 1953, where his starting assignment was to the physical analysis laboratory. In 1955 he began working on Electrofax, and during 1956-57 he was transferred temporarily to the Zurich, Laboratories to continue this research. On returning to Princeton, he was assigned to the Materials Research Laboratory where he carried out research on the stabilization of semiconductor surfaces, and the epitaxial growth of semiconductor elements and III-V compounds. For this latter work he shared in the 1966 David Sarnoff Award for Outstanding Team Performance in Science. In 1963 he joined the Process Research and Development Laboratory where he was head of the Process Research Group. In 1971 he was named Manager of the Materials & Processes Department of the Solid State Technology Center in Somerville, N.J. In 1974 this department was transferred from the Technology Center to the Solid State Power Operations of the Solid State Division. Dr. Amick has three issued patents, has contributed chapters to two published books, and is author or co-author of 26 papers. He is a fellow of the American Institute of Chemists, and a member of the American Chemical Societv, the Electrochemical Society, AAAS, and Sigma Xi. He is listed in American Men of Science.



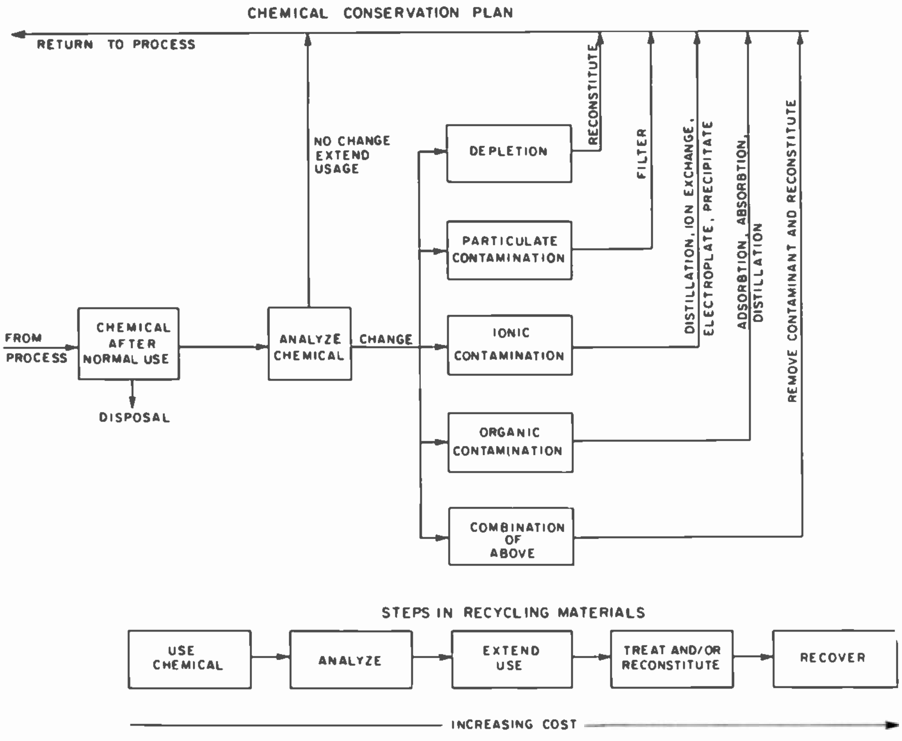


Fig. 1 — An approach to chemical conservation.

Program initiation

The Mountaintop location, which uses more chemical materials than any other Solid State Division location, was the logical choice for initial conservation efforts. As the first step in organizing these efforts, the chemicals used at Mountaintop were grouped as shown in Table I. The percentages are six-month averages for September 1973 through February 1974. A listing of the top nine chemicals on an expense basis gives a better representation of specific materials involved. The materials in Table II account for 75% of total consumed-chemical cost.

Table I — Chemical usage at Mountaintop.

Material	*% of total cost for chemicals*
Group A	
Organic Solvents	36
Group B	
Acids (e.g., Nitric, Sulfuric, Hydrochloric)	43
Hydrogen Peroxide	
Ammonium Fluoride	
Group C	
Silicon Chlorides	11
Group D	
Miscellaneous Chemicals	10

Clearly, chemical conservation efforts should be directed at those materials from which the greatest impact on cost reduction and pollution control can be realized. In addition, certain materials not representing a large dollar outlay, but which are in short supply, also required immediate attention.

The steps in recycling chemicals, in order of increasing cost, are extended usage, reconstitution, and recovery of constituents. The extent to which this progression is followed depends on the extent of change in the material, the ease of reconstitution, relative cost of new versus recycled reagents, value of the constituents, cost of waste treatment, availability of the chemical, and environmental considerations. One approach to chemical conservation is shown schematically in Fig. 1.

Table II — Mountaintop chemical usage—top nine chemicals ranked in terms of decreasing expense.

Fluorinated solvents
Silicon Tetrachloride
Chlorinated solvents
Mixed acid silicon etch
Hydrogen peroxide
Acetone
Buffered oxide etch
Hydrofluoric acid

The success of the chemical-conservation effort depends on an ability to analyze the "spent" chemical materials for the purpose of specifying appropriate recycling action. Analysis has shown that certain processing chemicals (e.g., buffered etch) remain essentially unchanged during long periods of use, and can be conserved simply through extended use. However, many of the other reagents employed in manufacturing become depleted or are contaminated with ionic materials, organics, and particulates during use. After analysis to determine the nature of the change, recycling of these materials requires treatment such as reconstitution, distillation, absorption, or filtration. After treatment, materials are re-analyzed by techniques such as emission spectroscopy, atomic absorption spectrometry, and wet analysis to ascertain the effectiveness of the recovery treatment. In addition, the effects of extended usage or of reclaimed material on silicon wafers is monitored by analyzing the surface test wafers.

Buffered etch

Buffered etch, prepared by mixing ammonium fluoride and hydrofluoric acid, was one of the first chemicals to be studied in the conservation program since the allowed period of use is determined empirically. A laboratory test was performed to determine the effect of extended use of a buffered etch on its ability to dissolve the oxide layer on thermally oxidized silicon wafers. This etch, along with samples of new and discarded buffered etch obtained from manufacturing locations, was subjected to analysis for assay, ionic contamination, and etch rate. Also, calculations were performed to determine how much of the capacity of the etch to dissolve SiO_2 was being used up. These calculations indicated that 5.5% was lost, while at manufacturing locations, the percentage loss ranged from 1.5 to 8.5

These low consumption factors offered considerable encouragement that a reduction in buffered etch volumes could be achieved through extended usage. Further encouragement came in the form of analytical data on the etches from the manufacturing locations. The results of a chemical assay and emission spectrographic analysis of new and used buffered etch from one of the Mountaintop manufacturing areas is presented in Table III. The data show that the characteristics of the used buffered etch were virtually unchanged at the time it was discarded (after normal usage). Prompted by this favorable information, one manufacturing area began triple-usage (three shifts instead of one). At the end of hte triple-usage period, the "spent" etches were submitted to the Materials and Processes Activity for analysis and characterization. In addition to chemical assay and emission spectrographic analysis of the new and triple-used etches, polished silicon slices were exposed to the "spent" etches and examined with a Reichert Differential Interference Microscope in an effort to detect particulate material. Samples were also analyzed at the Princeton Laboratories by spark-source mass spectrometry (SSMS) to determine the presence of surface contamination. Results of the etch analysis are depicted in Table IV. Table V shows the results of SSMS analysis of test wafers exposed to the new and triple-used ("spent") buffered etches.

Comparison of this data with SSMS data for polished silicon wafer controls that had not been exposed to buffered etch indicated that all test and control wafers had similar impurity levels. Based on this information, buffered-etch usage has been extended by a factor of three in production. More recent experiments are directed toward extending the life of buffered etch by an additional factor of three. Initial data indicates that this further extension is feasible.

The successful conservation of this chemical material obviously provides a cost reduction. More importantly, it also reduces material handling and removes

Table III — Buffered etch — normal factory usage before conservation.

ASSAY *Chemical*	*New* (%)	*Used* (%)
HF	7.4	7.4
NH_4F	33.9	33.8

IMPURITIES (by emission spectrographic analysis)

Level (PPM)	*Impurity*	
0.05 to 0.5	None	None
0.005 to 0.05	*Al,Mn,Si,Fe,Ti,Ca,Mg*	*Al,Mn,Si,Fe,Ti,Ca,Mg*
<0.005	*Cu*	*Cu*

ETCH RATE UNCHANGED

Table IV — Chemical analysis of etch solutions used for three times normal usage.

ASSAY *Chemical*	*New*	*Used #1*	*Used #2*	*Used #3*
HF	8.2	7.5	6.5	6.9
NH_4F	35.5	37.4	32.5	35.0

IMPURITIES (by emission spectrographic analysis)

Elements		Level (PPM)		
Cu	<0.005	0.005 to 0.05	0.005 to 0.05	<0.005
B	ND[1]	ND[1]	ND[2]	3.0[3]
Ca	0.005 to 0.05	0.005 to 0.05	0.05 to 0.5	0.05 to 0.5
Al	ND	0.05 to 0.5	0.05 to 0.5	0.05 to 0.5
Ni	ND	ND	ND	ND
Na	ND	ND	0.5 to 5	ND
Fe	0.005 to 0.05	0.05 to 0.5	0.05 to 0.5	0.05 to 0.5
Pb	ND	0.005 to 0.5	0.005 to 0.05	0.05 to 0.5

Other elements not detected or at very low levels

ETCH RATE UNCHANGED

1. Not detected — detection limit 0.3 PPM
2. Not detected — detection limit 0.1 PPM
3. Used to etch boron-doped oxide

Table V — Spark-source mass-spectrometer analysis on wafers exposed to new and "spent" etches.

Element	*New etch* (PPMA)	*Used #1* (PPMA)	*Used #2* (PPMA)	*Used #3* (PPMA)
Cu	21	22	12	6
B	0.4	2.5	0.6	2.4
Ca	1.2	<0.9	<0.7	<1.1
Al	1.1	<0.8	<0.5	<0.8
Ni	<5	<6	10	<9

Not detected - *P, Na, Fe, Pb, Sb, Sm, Zn, Cr, K, Mg, Ag, Pt*

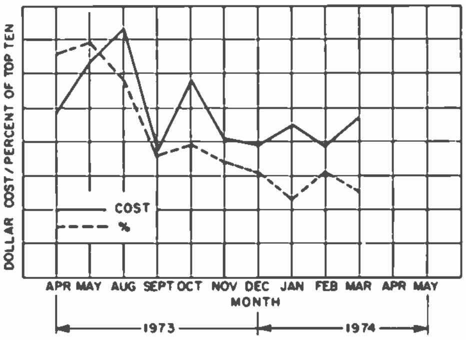


Fig. 2 — Cost of buffered etch in dollars and the percentage of the total cost of the top ten chemicals plotted as a function of the month of use.

part of the load on the plant effluent-treatment facilities. The cost reduction achieved is illustrated in Fig. 2 in which the cost of buffered etch in dollars and the percentage of the total cost of the top ten chemicals is plotted versus the month of usage. Note that both yardsticks show a downtrend. The decrease in cost is, however, partially offset by increasing production requirements. Similar information is plotted for chlorinated solvents in Fig. 3. In this case, both dollar cost and percent of the top ten is rising as conservation efforts have not yet been applied in this area.

The cost reduction achieved with buffered etch can be dramatically illustrated by plotting the percentage costs for chlorinated solvents and buffered etch on the same graph with the total cost for the top ten chemicals, Fig. 4. It is readily apparent that the percent cost which the chlorinated solvents represent remains relatively constant while the percent cost for buffered etch drops markedly because of extended usage.

Caro's acid

In mixtures of sulfuric acid and hydrogen peroxide, commonly referred to as "Caro's"* acid, the sulfuric acid and hydrogen peroxide are mixed in the desired ratio and, because of the exothermic nature of the reaction, a temperature of approximately 100 to 130°C is obtained. The silicon wafers to be cleaned are immersed in the hot solution for 10 to 20 minutes and are then quenched with deionized water. The "spent" acid, now cool and substantially depleted of hydrogen peroxide, is discarded. Sulfuric acid and hydrogen peroxide are widely used in both power and integrated circuit operations and are on the list of the top ten chemicals discussed earlier. Therefore, they rank as prime candidates for chemical-conservation efforts. Experiments performed in the Materials and Processes laboratory have demonstrated that much of the hydrogen peroxide is exhausted in supplying the initial temperature rise; the amount required for the cleaning function is small. To further test this conclusion, sulfuric acid (without any hydrogen peroxide added) was electrically heated to 125°C. A batch of wafers coated with photoresist was then immersed in the hot sulfuric acid. It was found that the hot acid alone was capable of removing the photoresist film; however, carbonized organic residue from the resist turned the solution black, and it would be expected that, without the addition of the hydrogen peroxide, the carbon residue on the surface of the wafer would be high. With the acid still hot, hydrogen peroxide was added slowly until the solution changed from black to clear, indicating complete oxidation of the carbon. The amount of peroxide required for this oxidation was only ten milliliters per liter of sulfuric acid — far less than that required in the normal method in which the hydrogen peroxide also provides the heating action. In addition, it was found that the same bath of sulfuric acid, if kept hot and provided with a continuous infusion of peroxide, could be used for multiple batches of wafers. To determine to what extent the bath life could be extended, a test was devised in which wafers cleaned in standard "Caro's" acid and in the modified mixture prepared from hot sulfuric acid by continuous addition of hydrogen peroxide were compared by analyzing the surfaces of wafers exposed to these solutions. To simulate extended usage in the laboratory, a standard impurity mixture was prepared and added to test solutions at two levels. The standard impurity mixture is described in Table VI.

Table VI — Standard impurity mixture 1000 Mg/liter of the ions listed.

Ag^{+1}	Cu^{+2}
Al^{3}	Fe^{+3}
As^{+5}	Ni^{+2}
B^{+3}	P^{+2}
Ca^{+2}	Pb^{+2}
Cr^{+3}	

An experiment was performed comparing wafers cleaned in standard "Caro's" acid with wafers cleaned in three "continuous addition" Caro's mixtures.

The first of these mixtures was unused; the second contained eleven milligrams/liter; and the third contained sixty-six milligrams/liter of impurities. The third sample should be considered highly contaminated. Following cleaning, the wafers were sent to the Laboratories at Princeton for spark-source mass spectrometric analysis. The results of this analysis are given in Table VII.

From this experiment and others, it can be concluded that the life of sulfuric-acid/hydrogen-peroxide mixtures can be significantly extended by the continuous addition of peroxide to heated sulfuric acid. The resist removal and cleaning effectiveness of these mixtures does not decrease with time, and even large amounts of impurity ions added to the solutions do not adsorb on the silicon surfaces. Equipment capable of continuous addition of hydrogen peroxide to sulfuric acid is commercially available for wafer cleaning and photoresist stripping.

Aluminum etch

A hot mixture of phosphoric and nitric acids is used in semiconductor manufacturing to etch the aluminum metallization patterns on device wafers. The performance of the etch degrades rapidly with time, and it is discarded frequently. As in the case of buffered etch, samples of new and used aluminum etch were analyzed to determine the changes responsible for the rapid degradation of etch performance. The results of the chemical assay are

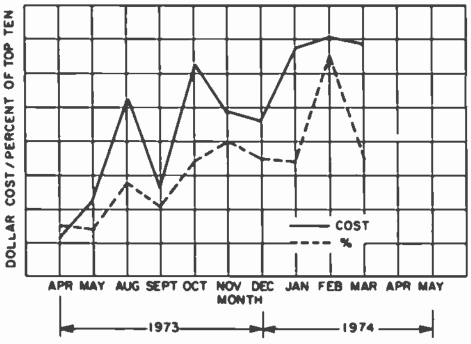


Fig. 3 — Cost of chlorinated solvents in dollars and the percentage of the total cost of the top ten chemicals plotted as a function of the month of use.

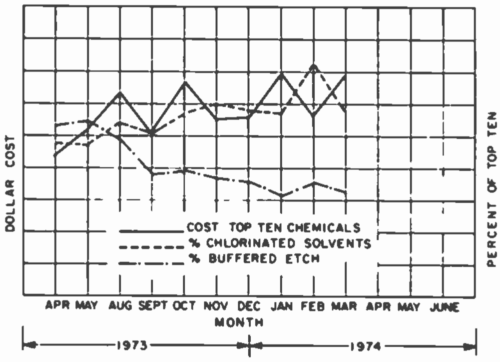


Fig. 4 — Plot of the percentage cost for chlorinated solvents and buffered etch with the total cost for the top ten chemicals.

shown in Table VIII. These data were taken from a factory location and from tests performed in the analytical facilities of the Materials and Processes laboratory. The latter tests involve the controlled addition of aluminum powder to phosphoric-nitric aluminum etch and indicate that the basic degradation mechanism in this etch is the loss of volatile nitric acid and water. Since only very small amounts of aluminum are dissolved in the etch, and virtually no phosphoric acid is consumed, this etch bath can be reconstituted by periodic addition of a one-to-one nitric-acid/water mixture. Such reconstitution permits extended usage of the etch with no perceptible change in etch characteristics.

Table VII — Results of SMSS analysis of silicon wafers exposed to "Caro's" acid samples.

Impurity	*Std*	*Continuous addition "Caro's"*		
	"Caro's" (control)	*New*	*11 Mg/L Impurities*	*66 Mg/L Impurities*
CC	43.	13	87	25
Cu	1.1	0.8	2.0	0.9
Ag	0.6	< 0.7	<1.0	<0.3
B	0.5	0.8	0.8	1.4

Not detected — *Al. As, Cu, Cr, Fe, Ni, P, Pb*

Table VIII — Change of composition of nitric phosphoric acid aluminum etch with use.

Sample	*HNO_3 Grams/Liter*	*H_3PO_4* Grams/liter
New	74	1295
After one hour	30.8	1444
After eight hours	3.1	1620

Solvents

Organic solvents are consumed in large volumes at Solid State manufacturing locations and represent a considerable percentage of the total dollars spent on chemicals. At the Mountaintop plant, for example, fluorinated hydrocarbons as a group represent the single largest expenditure for a chemical. When applying chemical conservation methods to solvents, several additional constraints are introduced, one of which is the large variety of materials utilized; therefore, a more diversified approach to conservation is required. Fluorinated and chlorinated hydrocarbons, aliphatic and aromatic hydrocarbons, ketones, esters, and ethers are all used at various points in the manufacturing process and possess varying levels of flammability and toxicity. Nevertheless, the high cost and scarcity of many solvents required in device manufacturing makes it imperative that conservation be practiced.

Solvents are lost in many operations by simple evaporation, or they are selectively contaminated depending on the application for the solvent; therefore, simple extended usage, as employed for buffered etch, is not an effective means of conserving solvents. Numerous alternatives are being explored to provide cost savings and to alleviate critical material shortages.

Fluorinated hydrocarbon solvents are used in large quantities as drying agents for semiconductor devices. These materials, while not in particularly short supply, are nevertheless costly. It has been found that substantial differences in efficiency exist in drying equipment supplied by competing manufacturers. Equipment now being installed at one factory location will, by reducing volatilization of the fluorinated hydrocarbon, reduce consumption of this material by a substantial margin over that of the equipment being replaced.

In the case of a triple-distilled proprietary chlorinated solvent used for post-mount cleaning of pellets, a cost reduction of sixty percent is achieved by converting to an alternative high purity solvent of slightly different composition having a much lower toxicity. Methods of recovering acetone and photoresist developing solvents (materials which are in short supply) are currently being developed to make possible conservation of these chemicals.

Conclusion

Chemical conservation through extended use, substitution, and recycling of chemical materials is an effective means for reducing costs, alleviating shortages in critical materials, and reducing contaminants in plant effluents. The savings achieved to date attest to the fruitfulness of chemical conservation efforts. It is expected that the level of savings will continue to rise as the chemical-conservation effort gains momentum and as more conservation practices are implemented in the manufacturing plants. In addition to the direct dollar savings, other benefits accrue from the chemical conservation program. Shipping costs, which previously were included in the chemical prices, are now an added cost; thus these costs will also be reduced as smaller quantities of chemicals are purchased. The size of chemical inventories and storage areas may be reduced. Plant effluent-treatment facilities will operate more effectively with the lower volumes of waste materials, perhaps circumventing the need to increase the size of these facilities. Because of the current business environment, chemical conservation warrants the attention of all RCA management as an effective means of contributing to RCA's competitive position through more efficient manufacturing.

Acknowledgment

The authors thank Carlo Grilletto and Alex Gaska of Somerville for their efforts in emission-spectrographic and wet analysis of chemicals in support of this work, and also Efram Botnick of the Princeton Laboratories for spark source mass spectrographic analysis of silicon wafer surfaces. The authors also thank the members of the Mountaintop and Findlay chemical conservation committee who contributed information used in the preparation of this article.

Leased channel with microprocessor control

A. Longo | Dr. P.M. Russo | M.D. Lippman

The use of international teleprinter leased channels has provided the American businessman with the tools he needs to communicate quickly, privately, and economically with offices and correspondents located virtually any place in the world. However, the ever increasing complexity of today's communications systems and the explosive growth in traffic volume coupled with spiraling implementation costs, present a challenge to RCA to effectively meet the goals of efficient, reliable and flexible leased channel service. A stored program approach to system design appears to be the long-term answer to this challenge. This paper describes a stored program approach to leased channel design, based on the RCA COSMAC microprocessor, which satisfies present applications at minimum cost yet can accommodate anticipated future performance requirements.

THROUGH the use of teleprinter leased channels, RCA Globcom provides the American businessman with the tools he needs to communicate quickly, privately, and economically with offices and correspondents located in other parts of the world. Teleprinter leased channels (Fig. 1) are private communications circuits which are interfaced at an RCA Globcom Central Telegraph Office, and are designed to accommodate a subscriber's specific communications traffic requirements. Availability, speed, reliability, and privacy at low subscriber rates are a few of the features which have contributed to the extensive growth of the leased channel service.

Changing system requirements

In the past, implementation of leased channel interfaces to suit subscriber requirements presented no significant problem. However, due to the growing use of sophisticated communications terminals and computer controlled data systems, interfacing requirements have become increasingly complex. Today's leased channel traffic varies among users from simple teletypewriter messages to computer-to-computer communications,

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Authors (from left) Lippman, Russo, and Longo discussing the U.S. — overseas link using a typical leased channel system.

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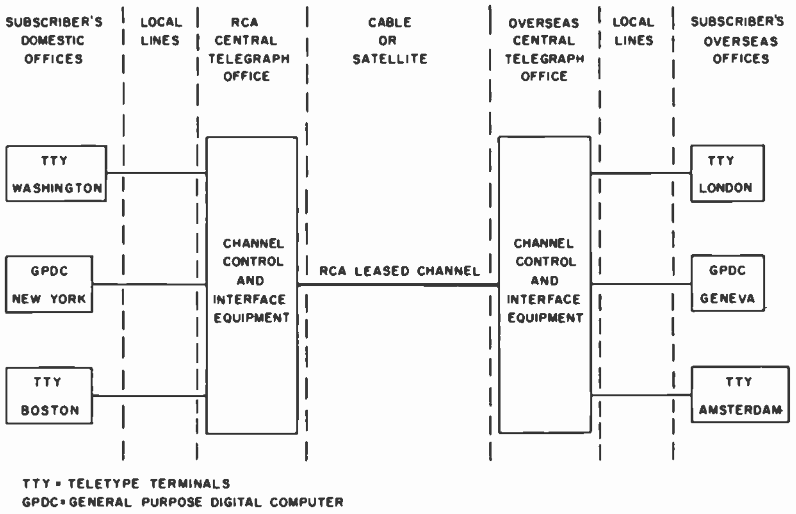

Fig. 1 — Typical RCA teleprinter leased channel configuration.

involving intricate handshaking procedures and line protocols. In addition, functional demands such as code conversions, speed changing, message withholding, line switching, message retrieval and playback have become more commonplace. Code conversion becomes necessary to convert subscriber networks using the domestically common 8-bit ASCII code to the 5-bit international telegraph code used almost exclusively on international links. To reconcile timing differences in data or baud rates within a given network, speed changing factors must be considered. Message withholding techniques, typically the store and forward approach, are used to ensure the receipt of complete cohesive messages. In order to address messages to a specific link within a multiple link subscriber network, line switching capabilities must be included. In networks where circuit path verification is essential, playback circuits must be employed.

Presently, subscriber requirements are met by adapting and integrating available functional "blocks" into a custom-designed system. Often a system comprises as many as five different "blocks". This approach is costly and usually results in long implementation lead times. When subscriber requirements exceed the capabilities offered by the available functional blocks, an intense engineering program is required involving system definition and design, parts procurements, breadboarding, fabrication and debugging, installation, and finally, on-line testing. Each task consumes a substantial amount of time and money.

Projections of future communication demands, even by the most conservative estimates, indicate a continuation of explosive growth both in volume and sophistication. This presents a challenge to RCA Globcom, to effectively meet the goals of efficient, reliable and flexible leased channel subscriber service, in a cost-effective manner. A stored-program approach to system design appears to be the long-term answer to this challenge.

Stored-program approach

The stored-program approach to data communications system design is not new. The past several years have witnessed a large and ever-increasing number of minicomputers and larger processors dedicated to the implementation of a variety of data communication functions. To date, however, the use of computers has been relegated primarily to medium size and larger systems where complex data communication requirements justify reasonably large investments in hardware and software. However, in many low-end applications the high cost of minicomputers and their associated peripherals cannot be justified.

The advent of low cost LSI microprocessors and mass storage devices (e.g., floppy discs) is having a significant impact on the design of new low-end data communications systems. A multitude of systems, that until recently would have required a hard-wired logic implementation, can now realize the many advantages of the stored program approach. These advantages include lower cost, flexibility, improved reliability, ease of maintenance, and the addition of many new system functions which, due to rigid time schedules and cost factors, are impractical or impossible to implement via hardwired logic.

A feasibility model of a leased channel system with RCA COSMAC microprocessor control has been implemented and exhibited at the 1974 International Communications Association show in New Orleans, La.

Microprocessor-system concept

The microprocessor-based system enables designers to provide software that is best suited for the particular functions to be performed using standard LSI chips. The heart of the microprocessor system is the central processing unit (CPU) and its addressing logic.

The microprocessor is capable of performing logical functions under the control of software instructions. Closely tied to the microprocessor is the memory unit, capable of storing data and programmed instructions. Memory contents can be used to identify inputs on multiplexers, enable counters, select ALU (arithmetic logic unit) functions or perform other control functions associated with the design. The rest of the system is made up of peripheral units. Devices such as keyboards, teletypewriters, tape readers, CRT displays, disc memories, and even communications links, are all considered to be peripherals, when they are connected to the processor. Data flows between the processor and the peripherals over a data bus. Individual binary data bits travel on this bus in groups called bytes.

Peripheral interfaces are necessary to convert data from the processor format to one that is acceptable to the peripheral device, and also to perform the required conversion from peripheral to processor data formats. The interface also reconciles timing differences and relays processor instructions in the form of control signals to the peripheral. Flags

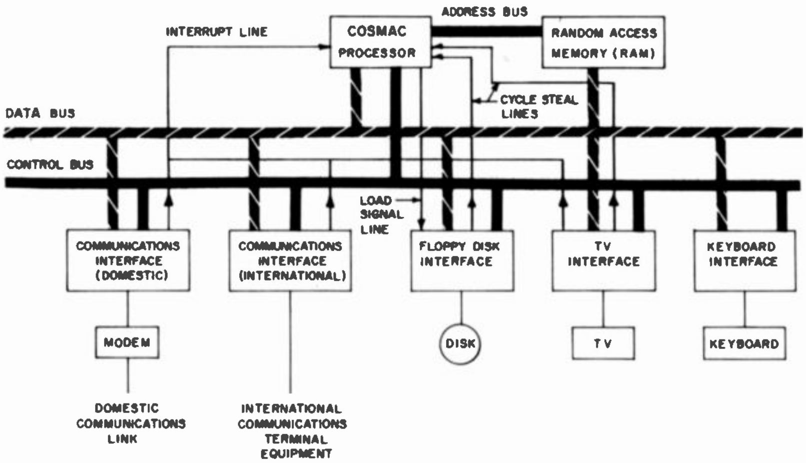

Fig. 2 — Microprocessor-based international leased line communications system.

(usually flip-flops) in the interface are set to inform the processor of significant current peripheral conditions. Interrupt signals generated by the interface force the processor to take immediate action when the peripheral must have priority service.

Microprocessor-based leased channel system

The RCA COSMAC leased channel microprocessor system, as illustrated in Fig. 2, was developed at RCA Laboratories and consists of a two-chip microprocessor, 4096-byte RAM, and peripheral interfaces. Each of the peripheral interfaces serves to connect different devices to the system. Incoming messages enter the system through communications interfaces. Here the messages are converted from a stream of bits into characters, each contained in an 8-bit data byte. These bytes are transferred, one at a time, into the system's random access memory (RAM). When 232 bytes accumulate, they form a block of data. The data block is then moved into the floppy disc memory, where it is held until needed for retransmission. Outgoing data blocks move from the disc to the appropriate communications line via the RAM. The RCA COSMAC microprocessor controls this sequence of events with programs written to satisfy subscriber requirements of the overall store-and-forward communication system.

The microprocessor makes both a data bus and a control bus available to the peripherals. These buses carry most of the information that flows between the processor and the peripherals. Since several different interfaces are connected to these buses, there must be a clear way to indicate which interface is permitted to be active at any given moment. A SELECT instruction performs this assignment function. Each interface has its own unique selection number. For example, a SELECT instruction together with the number 08 on the data bus, will activate the floppy disc interface. Once an interface is selected, it is free to act on further processor instructions.

Three special lines allow the peripheral interfaces to initiate system actions, without first getting permission from the processor. By using the INTERRUPT line, the communication interfaces demand immediate handling of incoming data as it arrives on the communications links, and an immediate supply of outgoing data from the RAM, as it is needed for transmission over the links. With the CYCLE STEAL lines, the floppy disc memory and tv displays gain direct access to the RAM so they can write into the memory, or read from it, without software instruction. Finally, via the LOAD line, the system can be reset and restarted using a disc-stored program after a catastrophic failure or loss of power.

Communications interface

When a communications interface has received an incoming character from its communications link, it raises the microprocessor interrupt line. At the same time, this unit raises an external flag to indicate that a received character is available. At the microprocessor, the interrupt causes the ongoing program to branch to a special software routine designed to service interrupts.

The system allows up to four external flags (EFs) for each peripheral interface. Each of these flags or combinations of flags, when activated, indicates a request for attention by a specific interface. For the communications interfaces, EF4 is set in conjunction with EF1, if the received character is erroneous (bad parity). When an interface is transmitting data, EF2 is set to indicate that the next character can be transferred. Finally, EF3 is used to indicate special conditions, such as abnormal communication line characteristics.

While a given interrupt is being serviced, all other interrupts must wait their turn. Priorities for servicing interrupts are established in the processor's software interrupt routine. For example, the domestic communications interface is always selected first by the routine. Domestic data rates are usually higher than international rates, and therefore, the penalty for keeping the domestic line waiting is greater. Likewise, read interrupts are always given priority over write interrupts, because failure to read may result in loss of data, but the worst penalty for failure to write is time lost on an idle transmission line.

Cycle stealing for more efficient operation

The key feature of the floppy disc interface is its direct access to RAM memory, without need for detailed microcomputer program control. Using this direct memory access (DMA) feature (built into the COSMAC processor) the disc can put data bytes into the RAM or take them out, without receiving even a SELECT command. In fact, it can transfer this data while the processor is occupied with other tasks, such as talking to a communications interface. The direct memory access mechanism used here is called cycle stealing. There are normally two microprocessor cycles for each program instruction; a fetch cycle, followed by an execute cycle. When the cycle steal line comes up during a fetch cycle, the processor will complete that fetch, and the corresponding execute cycle, and then hold its breath for a one-cycle interval before moving on with the next instruction, fetch cycle. It is during these stolen one-cycle intervals that data bytes are moved between the RAM and the disc.

Before the cycle stealing can begin, a DMA address register must be loaded with the first RAM memory address of the data block to be read from, or written on, the disc. Then the register is automatically incremented at each succeeding stolen cycle, until an entire block of 232 data bytes has been transferred. The processor sees only a slight slowdown, usually less than a 1-percent reduction in the time available for ongoing program activities.

As a convenience feature, the disc stores a bootstrap program that can restart the entire system after a power loss, or when some other condition puts the system out of service. Any other program residing on the disc can then be loaded into the RAM using this bootstrap program, thus eliminating the need for auxiliary program load devices such as cassettes or paper tape, and greatly simplifying system recovery.

Less vital to system operation than the floppy disc, but still significant from a maintenance viewpoint, is the tv display.

TV display diagnostics

The tv can display text indicating communication-link fault conditions, and other system status conditions. However, experience has shown that its most useful function is to display memory patterns; bit patterns on the data bus; and other information for diagnosis, test, and maintenance of the system. A standard tv set is used for the display. The display is continuously refreshed from 128 bytes of RAM memory. Like the floppy disc, the tv display uses the DMA (cycle-stealing) capability of the system. Every 60th of a second, the tv interface interrupts the processor and asks for new information. The interrupt routine then points to the beginning of the 128 bytes of RAM memory that contain the tv display information. These data are then sent to the tv interface on a cycle-stealing basis.

The lowest-priority peripheral in the system is the manual keyboard. This device is used to enter data bytes (in the hexadecimal code internally used by the system) into the RAM memory thus facilitating debugging and program modifications when required.

Summary of advantages

In addition to its low hardware cost, a microprocessor-based leased channel system will provide the following functions and features:

- Rapid implementation of subscriber requirements
- Message priority queuing
- Message retrieval capability
- Increased traffic volume capability
- Programmable system parameters
  - data rates
  - character formats & codes
  - character expansion
  - playback/answerback
  - call directory codes
  - transmit select codes
- Maintenance
  - single unit backup
  - fault isolation
  - rapid system recovery

Ongoing development

At RCA Laboratories, a new COSMAC based leased channel control package is currently being developed. In this system, the approach taken will allow minimum cost implementation of present low speed leased channel applications and flexibility to accommodate the anticipated high speed performance requirements of the future. For low speed applications, the bulk of the floppy disc control functions are relegated to software, resulting in reduced controller hardware and related costs. The extended high speed capability is provided by the addition of a second CPU chip which is dedicated to disc control. The addition of a second CPU results in a powerful parallel processing arrangement which relieves the excessive disc control burden from the main CPU thus providing additional processing time. This additional time may be used to implement sophisticated disc management schemes, preprocess data, or to control additional peripheral devices.

The future

The advent of low cost LSI microprocessors will bring about a profound change in the architecture of the next generation of data communications systems. Microprocessor-based data communications, typified by the leased channel system described in this article, will begin to emerge within the next few years.

Many other microprocessor-based data communications systems are now being developed. Intelligent multiplexers buffers, concentrators, interface message processors, and/or any combinations of the above are but a partial list. These systems should stimulate the development of new service offerings to a communications dependent world community.

In addition to the references and bibliographic information cited below, detailed COSMAC information is available from R.O. Winder, Head, LSI System Design Research, RCA Solid State Technology Center, Somerville, N. J. 08876 (telephone 201-722-3200, extension 6005).

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COSMAC — a microprocessor for minimum cost systems

N.P. Swales| J.A. Weisbecker

COSMAC, a microprocessor developed by RCA, is a COS/MOS LSI processor designed for use as a general purpose computing element. The processor architecture described in this paper has been developed to provide maximum flexibility for low-cost computer-based systems. The COSMAC instruction set and input/ouput interface have been designed to minimize memory requirements and system complexity. Experience with this architecture has verified its usefulness over a wide range of potential applications.

MICROPROCESSORS[1] are becoming an important tool for logic and systems designers. Although they will have some impact on the low perfomance end of the minicomputer market,[2] their major successes are being scored in control function applications where microprocessors are being used to replace complicated switching functions which were previously realized with discrete digital logic.[3] The low cost, flexibility, and fast design cycle time which these devices provide are making them increasingly popular with designers. A microprocessor, coupled with a small amount of semiconductor memory and a few inexpensive peripheral devices, can provide a cost effective system for applications where the use of computer technology was previously unthinkable — home entertainment, automobile control, and educational and business systems to name a few.

Microprocessor design

Basically, a microprocessor is a device capable of performing arithmetic, logical, and decision-making operations under the control of a set of instructions stored, either temporarily or permanently, in some memory device. It is capable of communicating with a set of peripheral devices via some defined input/output (I/O) structure. Its operation is slow when compared to large computing devices, such as miniprocessors, but it is implemented on one or a few monolithic integrated circuit chips, and it is not expensive.

The above provides a general framework into which a microprocessor should fit. There are, however, other stringent constraints on the design of a useful microprocessor. The basic design problem is to develop a simple, but flexible, processor architecture which can be used to realize inexpensive systems. It is important to minimize the complexity of the processor itself, with respect to both internal logic and the required number of external connections, so that the device is easy to produce and package. The architecture should possess an efficient I/O structure to help reduce the number of circuits required to interface with external devices and to help increase system performance. In addition, the architecture should provide for efficient use of main memory storage.

It is these latter considerations which have led to the development of the COSMAC microprocessor.

COSMAC architecture

An eight-bit, parallel, register-oriented architecture was chosen for COSMAC as being best suited to the requirements of optimizing performance, memory usage, and processor complexity. An eight-bit machine provides sufficient width to effectively manipulate the standard code and data units of a majority of the communications and information processing fields while providing a significant performance advantage over bit serial and four-bit machines. A 12-bit machine would have provided more performance but it would also have caused difficulties when addressing more than 4K words of memory, and it would have caused inefficiencies when manipulating 8-bit data. Also, both 12-and 16-bit machines suffer from the disadvantages of requiring more logic and more I/O pins — both of which are inconsistent

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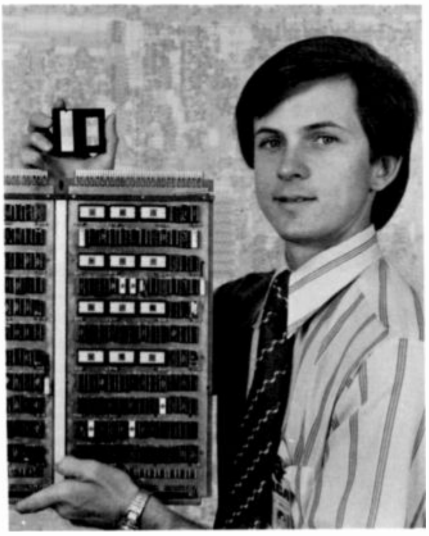

with the desire to minimize the chip area required by the processor. A register-oriented structure was chosen to provide convenience in implementing programs utilizing interpretive subroutine coding techniques, for macro programming, as well as the ability to efficiently manipulate data when programming in the machine language and to effectively implement foreground/background processing using the processor's interrupt facility.

A simple two-step fetch and execute sequence was selected for the basic machine cycle and considerable emphasis was placed on the I/O interface. A total of twenty-three lines, including an eight-bit bi-directional data bus are used to control the I/O. In addition to a data transfer capability, these twenty-three lines provide internal processor state information, an interrupt capability, a device sensing capability, an I/O command code modifier, and controls for a built-in, cycle stealing, direct access I/O facility.

The block diagram of Fig. 1 shows the general architecture of the microprocessor. The register matrix is an array of sixteen 16-bit registers which may be addressed by the P, X, or N registers. The I, P, X, and N registers are all four bits in width. The I and N registers are used to hold the instruction fetched from main memory; the contents of the I register determine the generic instruction type to be executed, and, depending upon the contents of the I register, the contents of the N register are used to select one of the matrix registers, to control the I/O devices, or to provide further definition of the instruction to be executed. The contents of the P register determine which of the 16 matrix registers is being used as the current program counter. The X register is used to address the register matrix to fetch the address of memory operands for certain memory reference instructions. The T register is an eight-bit register used to store the contents of the P and X registers whenever a program state change occurs in response to an interrupt. The A register is a 16-bit register used to temporarily hold the data fetched from the register matrix. A 16-bit increment/decrement network is used to update information fetched from the register matrix. One eight-bit multiplexer is used to gate the contents of the A register to the eight-bit memory address bus and a second multiplexer is used to gate the contents of the A register to the eight-bit, bi-directional data bus.

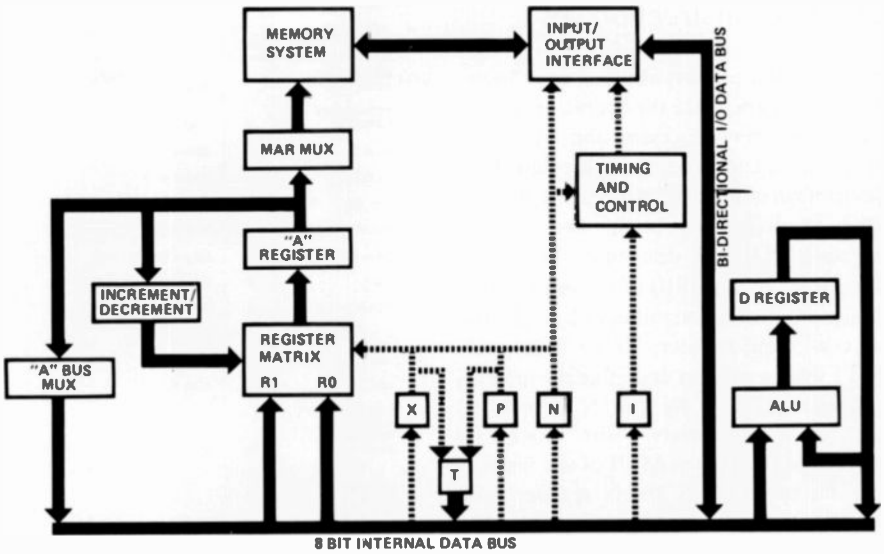

Fig. 1 — COSMAC internal architecture.

The D register is an eight-bit accumulator with associated zero decode and carry, or link, indicator which may be interrogated with the branch instruction. The ALU is an eight-bit parallel arithmetic and logic unit capable of performing binary add, and subtract, logical and, or, exclusive or, and shift operations. One operand is contained in the D register and the other is contained in memory and present on the data bus. The add, subtract, and shift operations may modify the carry indicator.

As shown in Fig. 1, the COSMAC memory system shares the microprocessor I/O interface with the system peripheral devices. Although the memory address is sent to the memory system separately, data is transferred between the processor and memory via the I/O data bus.

As we go to press...

On October 3, the Solid State Division announced the commercial availability of the CDP1800 microprocessor family, including the CDP1801 CMOS 8-bit microprocessor, the "Microkit" hardware support kit, microprocessor manuals, and software development packages. This commercial version of COSMAC is presently available from stock, with the CDP1801 full-voltage (15V) chips available at $56 and the CDP1801C 5-V chips at $40 (quantities of 1-99).

The "Microkit" hardware support kit contains the CPU, 1-k words of RAM, 512 words of ROM, space for additional memory and user-designed interface cards, input/output decoders, an input/output interface for a teletype or other terminal, and power supply. A "Microkit" with a resident editor, assembler and debug board option with a user-supplied terminal provides a complete, independent system for producing debugged programs.

More powerful software development aids are available that offer assembly, editing simulation, and debugging. This program is available either on the General Electric timesharing network or as a Fortran IV tape for installation on an interactive computer. A microprocessor manual, describing the CDP1801's architecture, instruction set, I/O interfacing, and programming techniques is available as well as manuals on the various software design aids.

Futher information may be obtained by writing RCA Solid State Division, Box 3200, Somerville, New Jersey 08876, or by calling William J. Dennehy, Microprocessor Marketing Manager, (201) 685-6713.

COSMAC instruction set

A notation convention has been developed to describe the operation of the COSMAC microprocessor and will now be presented in order to abbreviate the description of its instruction set. R will be used to designate one of the matrix registers; R1 will designate the most significant byte (MSB) of R, and R0 will designate the least significant byte (LSB) of that same register. R(N), R(X) and R(P) will be used to designate the matrix register specified by the N,X, and P registers, respectively. For example, R1(N) represents the MSB of the matrix register specified by the N register and R0(N) represents the LSB. Similarly, M will designate the contents of a memory location, and therefore, M(R(X)) will designate the contents of the memory location addressed by the matrix register specified by the X register. As an example, M(R(N)) → D; R(N) + 1, describes the memory transfer to D instruction (instruction code (I) = 4_{16}). The contents of the memory location addressed by the matrix register specified by the N register are transferred to the D register and the contents of the matrix register are incremented by 1. Using similar notation, the COSMAC instruction set is described in the table of Fig. 2.

All the COSMAC instructions use the same fetch and execute cycle sequence. During the fetch cycle the four-bit address contained in the P register is used to select the matrix register which has been designated as the current program counter. The contents of the selected matrix register are gated into the A register and are then sent to the memory system via the memory address multiplexer. The contents of the A register are incremented by one in the increment/decrement network, and the result is stored in the matrix register specified by the P register. Finally, the contents of the addressed memory location are gated into the I and N registers via the eight-bit bi-directional data bus. In the notation defined above, this operation would be written as M(R(P)) →I, N; R(P) +1. During the execution cycle of the instruction, the digit contained in the I register is decoded and the instruction is executed as described in Fig. 2.

Certain of the microprocessor instructions require further explanation other than that given in Fig. 2.

INSTRUCTION	INST. CODE (HEX)	FUNCTION
INCREMENT REGISTER	1	R(N) + 1
DECREMENT REGISTER	2	R(N) − 1
R0 to D	8	R0(N) → D
R1 to D	9	R1(N) → D
D to R0	A	D → R0(N)
D to R1	B	D → R1(N)
D0 to R00	C	D0 → R00(N)
IDLE	0	IDLE; M(R(N)) → BUS
MEMORY TO D	4	M(R(N)) → D;R(N) + 1
D TO MEMORY	5	D → M(R(N))
LOAD P	D	N → P
LOAD X	E	N → X
CHANGE STATE AND RESET INTERRUPT MASK	70	M(R(X)) → X,P;R(X)+1;RESET IM
CHANGE STATE AND SET INTERRUPT MASK	71	M(R(X)) → X,P;R(X)+1;SET IM
SAVE PRE-INTERRUPT PROGRAM STATE	78	T → M(R(X))
INDEXED MEMORY TRANSFER TO D	F0	M(R(X)) → D
OR	F1	M(R(X)) + D → D
AND	F2	M(R(X)) · D → D
EXCLUSIVE OR	F3	M(R(X)) ⊕ D → D
ADD	F4	M(R(X)) PLUS D → D
SUBTRACT	F5	M(R(X)) MINUS D → D
SHIFT RIGHT	F6	SHIFT D, 1BR → DF
REVERSE SUBTRACT	F7	D MINUS M(R(X)) → D
DATA IMMEDIATE TRANSFER TO D	F8	M(R(P)) → D;R(P) +1
OR IMMEDIATE	F9	M(R(P)) + D → D;R(P) + 1
AND IMMEDIATE	FA	M (R(P)) · D → D;R(P) + 1
EXCLUSIVE OR IMMEDIATE	FB	M(R(P)) ⊕ D → D;R(P) + 1
ADD IMMEDIATE	FC	M(R(P)) PLUS D → D;R(P) + 1
SUBTRACT IMMEDIATE	FD	M(R(P)) MINUS D → D;R(P) + 1
REVERSE SUBTRACT IMMEDIATE	FF	D MINUS M(R(P)) → D;R(P) + 1

INSTRUCTION	INST. CODE (HEX)	TEST FIELD* (HEX)	FUNCTION
TEST AND BRANCH	3	0	M(R(P)) → R0(P)
		1	M(R(P)) → R0(P) IF D ≠ 0/R(P)+1
		2	M(R(P)) → R0(P) IF D = 0/R(P)+1
		3	M(R(P)) → R0(P) IF DF = 1/R(P)+1
		4	M(R(P)) → R0(P) IF EF1 = 1/R(P)+1
		5	M(R(P)) → R0(P) IF EF2 = 1/R(P)+1
		6	M(R(P)) → R0(P) IF EF3 = 1/R(P)+1
		7	M(R(P)) → R0(P) IF EF4 = 1/R(P)+1
		8	R0(P) + 1 (SKIP)
		B	M(R(P)) → R0(P) IF DF = 0/R(P)+1
		C	M(R(P)) → R0(P) IF EF1 = 0/R(P)+1
		D	M(R(P)) → R0(P) IF EF2 = 0/R(P)+1
		E	M(R(P)) → R0(P) IF EF3 = 0/R(P)+1
		F	M(R(P)) → R0(P) IF EF4 = 0/R(P)+1

*Unused TEST CONDITION SHOULD BE CONSIDERED ILLEGAL.

INSTRUCTION	INST. CODE (HEX)	TEST FIELD* (HEX)	FUNCTION
I/O TRANSFER	6	0	M(R(X)) → I/O;R(X) + 1
		1	M(R(X)) → I/O;R(X) + 1
		2	M(R(X)) → I/O;R(X) + 1
		3	M(R(X)) → I/O;R(X) + 1
		4	M(R(X)) → I/O;R(X) + 1
		5	M(R(X)) → I/O;R(X) + 1
		6	M(R(X)) → I/O;R(X) + 1
		7	M(R(X)) → I/O;R(X) + 1
		8	I/O → M(R(X))
		9	I/O → M(R(X))
		A	I/O → M(R(X))
		B	I/O → M(R(X))
		C	I/O → M(R(X))
		D	I/O → M(R(X))
		E	I/O → M(R(X))
		F	I/O → M(R(X))

Fig. 2 — Instruction summary.

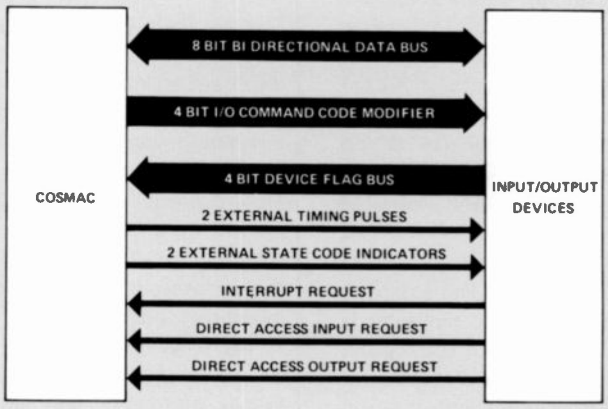

Fig. 3 — COSMAC input/ouput interface.

The IDLE instruction (instruction code (I) = 0_{16}) is used as an instruction halt. Whenever this instruction is encountered in the program flow, the contents of the memory location specified by the matrix register specified by the N field are displayed on the I/O bus. The system will remain in the IDLE state until the receipt of an interrupt or direct access input or output request.

The D0 to R00 instruction (I=C_{16}) places the four least significant bits of the D register into the four least significant bits of the matrix register specified by the N field and therefore may be used to implement single-digit table look-up operations.

The load P instruction (I=D_{16}) causes the contents of the N register to be transferred to the P register, providing a very simple branch and link capability.

The save state instruction (I, N = 7_{16}, 8_{16}) helps provide the capability to store the machine's pre-interrupt state after an interrupt initiated program state change has occurred. The return instructions (I,N = 7,0 and I, N = 7, 1) allow program control of the interrupt mask bit as well as the ability to change the contents of the P and the X registers simultaneously. These last three instructions enable the processor to implement foreground/background programming in an interrupt driven system.

The data immediate instructions (I, N = F, 8 through F, F) provide the ability to easily inject constants from the main program flow into data and address manipulations. These instructions use the contents of the memory location immediately following the instruction code location as one of the operands in the specified operation.

The test and branch instruction (I=3_{16}) tests the condition specified in the N field. If the condition is met, then the contents of the memory location immediately following the instruction are placed into the least significant byte of the matrix register specified by the P register; otherwise, the next instruction in sequence is executed.

Input/output

One area of major concern in any processing system is the computer I/O interface. All of the peripheral devices in a system must use this interface when communicating with the processor, and, therefore, the level of complexity and the efficiency of this interface have a great effect on the overall cost and performance of any given system. This is especially true in systems using microprocessors where the cost of the microprocessor represents a very small portion of the overall system cost and where system performance is limited by the speed of the processor.

In order to extend the useful operating range of the COSMAC microprocessor, considerable emphasis was placed on its I/O structure. The processor interface, physically composed of twenty-three signal lines (see Fig. 3), is capable of supporting devices operating in polled, interrupt driven, and direct access modes. The processor is equipped with a set of very flexible I/O instructions, a built-in direct access I/O capability, and I/O interrupt line, four external flag indicators, a set of external timing pulses, and an eight-bit, bi-directional data bus.

The I/O instruction (instruction code (I) = 6_{16}) is used to control the I/O devices operating in the programmed mode. As can be seen in Fig. 2, there are actually sixteen sub-instructions incorporated into the I/O instruction; eight of these provide for information transfer from the I/O devices to the processor memory; and, and the other eight provide for information transfer from the processor memory to the I/O devices.

During the execution cycle of the I/O instruction, the external state code (ESC) lines of the I/O interface assume a particular state, indicating to the I/O devices that a programmed mode data transfer is to take place. The I/O device which was last selected, using the device select command (one of the eight data output I/O subinstructions), responds by either placing data on the I/O bus or by taking data from the I/O bus depending upon the state of the four I/O "N"(I/O command code modifier) lines.

To avoid confusion on the I/O bus, only one device at a time should communicate with the processor via the data bus. To ensure this condition, a device selection convention has been adopted for use in large systems. The I6 instruction with the N field (and therefore the I/O "N" lines) equal to 1_{16} has been designated the select instruction. All devices in a system are assigned a unique address. Whenever a device detects the I6 condition on the ESC lines and a value of 1_{16} on the I/O "N" lines, it compares the information presented to the data bus by the processor with its assigned address; if these two bytes are the same, the device becomes selected, and, if the two bytes differ, the device becomes or remains de-selected. A device may communicate with the processor in the program mode only while it is selected.

The sixteen I6 instructions provide a very powerful tool when designing control electronics units (CE's) to interface between the processor and its I/O devices. The action taken by any given CE in response to any of the I6 instructions is defined by the CE designer and may vary from CE to CE. These instructions may be used to replace sequencing logic in the CE's, to distinguish between command, status, and data transfer requests, or to control multiple devices through a single CE. In short, they provide a flexible method of implementing simple I/O control procedures for small, dedicated systems. Large systems may be required to use all of the features provided on the I/O interface, but smaller systems can be created using any subset of the I/O signals and conventions.

Four external flag signals are provided on the COSMAC interface to enable the CE's to quickly transfer status information to the processor. These signals may be tested directly by the test and branch instruction.

A single interrupt line is provided to enable any control electronics unit to demand immediate program service from the processor. This line may be treated as a common interrupt bus or as a hardwire priority daisy-chain interrupt facility depending upon the requirements of the system in which it is used. Whenever the processor detects an interrupt condition, assuming interrupts are not masked, it enters an interrupt response state at the end of the instruction which was being executed when the interrupt was received. The ESC lines at the I/O interface assume the interrupt state conditions indicating to the I/O devices that an interrupt is being honored. The contents of the P and the X registers of the processor are transferred to the T register so that the pre-interrupt state of the machine may be saved. Finally, a value of 1_{16} is placed in the P register and 2_{16} is placed in the X register. Normal instruction fetch and execution is then resumed using R1 as the new program counter, effectively causing a hardwired branch and link to the subroutine addressed by the matrix register R1. The machine state instruction (instruction code = 7_{16}, see Fig. 2) may be used to control the interrupt mask as well as to save and alter the state of the P and X registers.

A cycle-stealing direct access I/O facility was incorporated into the COSMAC processor to provide a high-speed data path between the I/O devices and the processor. Two of the I/O signals, Input Request and Output Request, may be used by the I/O devices to initiate a data transfer via this direct access channel. Only one device at a time may operate in the direct access mode.

A direct access device must be selected and activated in the programmed mode. Once activated, the device may initiate a data transfer by signaling the request to the processor via the Input Request or the Output Request lines. The processor responds to the request by entering the Direct Access State after finishing the instruction which was in progress when the request was received. The processor forces the ESC lines to assume the Direct Access State condition to indicate to the I/O device that is processing the transfer request. The CE places data onto the data bus if an input request has been initiated or removes data from the bus if an output request has been initiated. The data is placed into or removed from the memory location specified by the R0 register of the register matrix. At the end of the direct access transfer, R0 is incremented by one byte so that the processor is ready to act upon the next transfer request. A CE need not be in the selected state in order to issue direct access transfer requests. The use of this channel, therefore, does not interfere significantly with program execution or with the simultaneous use of other programmed mode devices. This channel may be employed to communicate with devices which have high transfer rates.

A program load facility using the direct access channel is provided to enable users to enter programs into the COSMAC memory. This facility provides a simple, one step means for initially entering programs into the microprocessor system and eliminates the requirement for specialized ROM's in main memroy to bootstrap user programs into the system.

Chip technology

COSMAC is presently implemented on two chips employing RCA's standard COS/MOS technology. Both chips were layed out manually using standard cell techniques with computer-aided mask generation and checking. One chip contains the register matrix, the increment/decrement network, the A register, and the A register multiplexers shown in Fig. 1; the second chip contains the remainder of the processor elements shown in Fig. 1. The register matrix chip is 236 × 246 mils and the arithmetic and control chip is 256 × 254 mils. Both chips contain approximately 3000 transistors. The COS/MOS technology was chosen because it provides many features which are advantageous in the design of inexpensive systems. The two-chip processor is capable of operating with any supply voltage from 5 to 12 volts; this wide operating voltage range enables direct connection to a variety of circuit types. Inexpensive, unregulated power supplies can be used. The current drain on the power supply is negligible — each chip dissipates only about 100 μW.

The operating temperature range of the devices extends from −55 to +125°C. Most important, the inherent high noise immunity of COS/MOS provides reliable operation even in hostile environments.

Considerable care was taken in the chip circuit design to ensure that the final product would be easy to use and to interface. Only a single phase clock is required. The voltage required to drive the inputs and outputs is not dependent upon the main supply voltage so that the processor can take advantage of the speed benefits of operating at a high voltage, while the inputs and outputs may be operated at lower, TTL compatible levels. Also, all registers in the machine are static, providing the ability to stop the clock generator for indefinite periods without losing information in the processor.

Although the COSMAC devices are new, future enhancements are already being developed. It is anticipated that the processor will soon be implemented on a single chip, and, the implementation of a high-speed version of COSMAC using a silicon on sapphire technology is presently under investigation.

Software and software support

No matter how convenient a computer system is to implement in hardware, it cannot be considered easy to use unless some facility is provided to ensure that the system is easy to program. In order to provide this facility, a complete machine language assembler and simultor/debugger system were created and made available on RCA's corporate time-sharing service. This interactive assembler system provides the ability to easily program the microprocessor using the COSMAC machine language or the repertoire of macro instruction subroutines which were created to simplify the programming of large software systems. The capability is provided for on-line editing of source programs.

A standard Fortran version of the above mentioned assembler/simulator/debugger is being made available for batch processing as well as for use on any IBM time-sharing operating system.

To prove the utility of the COSMAC instruction set, a number of experimental systems have been designed and programmed. The applications which have been studied include word processing, educational and calculator functions, entertainment systems, and communications and real-time device control systems. All of the applications programming done to date, requiring memory sizes ranging from 1K to 16K bytes, have indicated that the COSMAC instruction set does make efficient use of memory and that its processing speed is sufficient to handle a wide variety of processor applications.

Hardware and typical systems

To facilitate the breadboarding of potential systems, a number of standard building block devices and control electronics units have been designed. Processor boards providing a full TTL interface and up to 24K bytes of memory have been implemented. I/O devices and

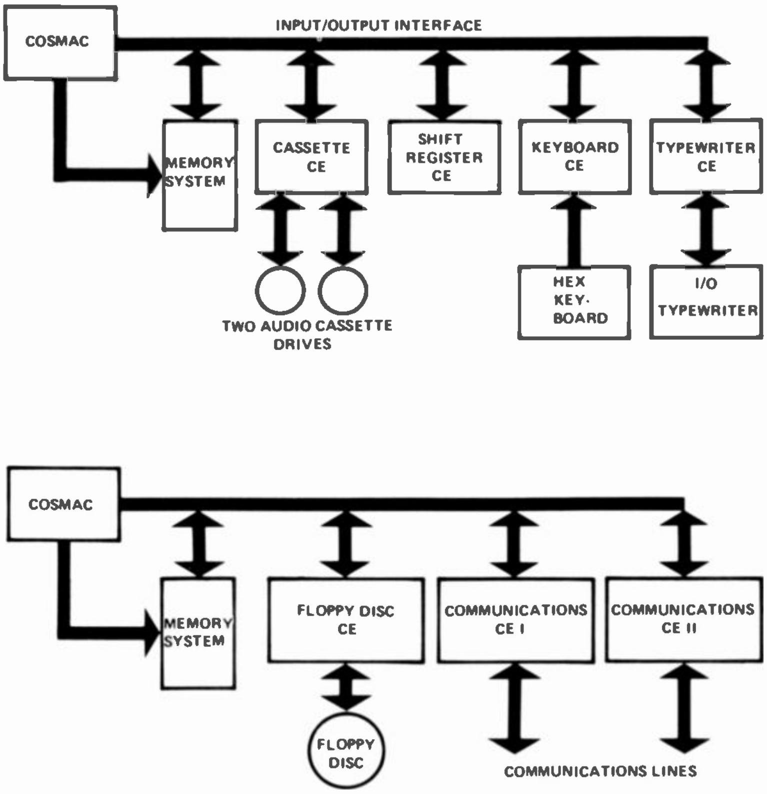

Fig. 4 — Two typical COSMAC systems.

their associated control electronics which have been built include I/O typewriters, tape cassettes, floppy discs, dot matrix tv displays, video data terminals, keyboards, and various communications controllers for teletypwriter equipment and acoustic coupled data terminals.

Fig. 4 illustrate two typical microprocessor systems using some of the above mentioned hardware. Fig. 4a shows a word processing system employing the COSMAC processor and 4K bytes of main memory storage. The system uses inexpensive audio cassette tape recorders as mass storage units as well as for voice system operating instructions. The shift register CE is used as an intermediate storage device for on line data manipulation. The hexidecimal keyboard is used for entering initialization parameters into the system, and the I/O typewriter is used as a hard copy, manual input/output device. The system has been programmed to generate and edit form letters for storage on the tape drives as well as to process the form letters using a recorded mailing list. Programs have been generated to process payroll information and to print paychecks. And, an inventory control and accounts receivable processing system has been investigated.

Fig. 4b illustrates a leased channel communications control system which is currently being developed. The system, consisting of a COSMAC processor with memory, a floppy disc, and two communciations controller, was designed for "turnkey" operation. Both communications controllers are capable of operating in half or full duplex modes. The system is capable of performing the answerback and playback operations required by the telecommunications network line procedures as well as code and speed conversion. The disc unit is used to provide non-volatile storage space for a message store and forward feature and for the storage of all programs. A message forwarding priority weight may be assigned to all messages so that the sequencing of the forwarded messages is independent of the message input sequence.

All of the experimental systems which have been developed to date using the COSMAC microprocessor have shown that it can be used to effectively implement low-cost data processing systems.

Conclusion

The COSMAC microprocessor is an eight-bit, parallel, general purpose computing element designed for use in the implementation of low-cost digital systems. Every effort has been made to make it easy to program and inexpensive to interface.

The COS/MOS technology with which the LSI processor is implemented provides a number of features which are important in the design of low-cost systems. COS/MOS provides a high noise immunity, so, the processor can operate in electrically hostile environments and can be powered by unregulated power supplies. The processor has a wide operating voltage range and the internal voltage supply is separated from the I/O voltage supply so that the processor may operate at maximum speed while interfacing to various external circuit technologies, including TTL. Only a single phase system clock is required; and, the processor power consumption is minimal.

COSMAC posses a built-in matrix of sixteen 16-bit registers and a unique instruction set chosen to make efficient use of main memory. The register matrix may be used to provide multiple program counters as well as address and data storage. Unlimited subroutine nesting is possible, and the instruction set facilitates the use of interpretive subroutine macro instructions. A large amount of support software has been generated to aid the user in programmer and debugging his system software.

The COSMAC I/O interface was designed to provide intimate control of I/O devices so that overall system complexity and cost can be reduced. A direct access I/O capability is included in the processor structure to enable the high-speed transfer of blocks of data without program monitoring.

In short, COSMAC has been designed to help minimize the cost of intelligent digital systems.

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Algorithm for comparison of command and control systems

J.R. LoPresto

In the analysis of Command and Control (C^2) systems, a comparative analysis of the performance of various configurations is important for obtaining cost effective, reliable, and technically adequate systems. This article presents one algorithm that can be employed for such an analysis. Using one of the candidate system configurations as a standard, the result of the algorithm is to obtain relative quantitative indices which measure C^2 performance with respect to the execution of given mission tasks. The article includes a non-mathematical description of the rationale used in the algorithm derivation as well as a sample calculation to illustrate its use.

A COMPARATIVE configuration analysis is important for obtaining cost effective, reliable, and technically adequate system configurations. The algorithm described in this paper can be employed for such an analysis; in its use there are no claims of perfection, total objectivity or infallibility. Although this algorithm was originally conceived to compare military C^2 systems, there is an analogy to commercial process control or management information systems. The expansion of the model to these areas is easily implemented.

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Since this paper was written, Mr. LoPresto has left RCA.

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The algorithm compares the performance of mission execution for various configurations, where *performance* includes associated factors such as reliability, availability, *etc*. The algorithm does not compare technical risk, schedule risk, life cycle costs, or other factors which, in addition to performance, are also important in the analysis of C^2 systems.

The result of the algorithm is a set of quantitative indices which measures the C^2 performance with respect to the execution of given mission tasks. By selecting the best system as a reference standard, *viz*., with an index of 1.0, then as a result of the algorithm computation the systems which are compared produce indices less than or equal to 1.0.

The assumptions under which the algorithm can be used are:

1) The mission/mission phases are clearly defined.
2) The functions to be executed in each mission phase are well defined, *e.g.*, as a result of formal military standard functional flow diagrams and documentation (F^2D^2) analysis.
3) No political or customer bias is involved in the algorithm computation.

The algorithmic model is based on cross correlation involving the following factors:

1) Importance of each functional task during each mission phase.
2) Contribution of the various subsystems toward the execution of each functional task.
3) Degradation of contributing elements, in terms of:
    a) loss of external communication systems,
    b) failure or degradation of subsystems,
    c) smaller allowable operational status in the reduced configuration, or
    d) loss of external information due to the loss of external data sources or degraded reporting procedures.
4) Mutual degradation effects between the above contributing elements.

The weights and values attributed to these factors are, in many cases, value judgments by the analyst and not based on hard and fast known information. The sensitivity of the algorithm to some of these value judgements varies. For example, the weight given to each function within a phase does not have as great an effect as changing the form of the algorithm expression. Special requirements may require special procedures in the definition of tasks for the algorithm use. For example, special reaction time to an extraordinary threat might require the redefinition of a functional task into two functions, one which measures reaction against a "normal" threat, and one which measures reaction against this extraordinary threat.

The remainder of this paper contains a brief functional description of a generalized command and control system that will be used to clarify the algorithmic model description, a non-mathematical description of the rationale of the algorithmic form, and an example to show how the algorithm may be calculated.

Composition of a command and control system

A command and control system is described as a system which senses the data that reflects an environment or a tactical situation, evaluates this data with respect to a specified mission, formulates a reaction to this environmental situation, and initiates and controls this reaction. It then repeats this process until the mission has been accomplished or it can no longer operate in the tactical environment.

As such, the system is composed of a collection of subsystems, *e.g.*, data processing, communications, operating personnel, *etc*., which must perform designated functional tasks during specific phases of the mission. In a general sense, any system may be called a command and control system. Normally, however, it is defined as that portion of a complete system which receives sensor data, formulates the reaction to the environment, and initiates this reaction by interfacing with a subsystem which can change that environment, *e.g.*, weapons systems, process control mechanisms, *etc.* There is a significant similarity between command and control systems and management information systems, the former being the title when applied to military systems while the latter is used for commercial systems.

Assume that a command and control system has been formulated, *e.g.*, through the use of F^2D^2 analysis, to execute a mission which can be subdivided into *m* mission phases. Further, assume that *n* functional tasks must be performed to execute the total mission, but not necessarily each task within each mission phase. To execute the mission, the C^2 system must be composed of *M* subsystems, *e.g.*, data processing, *et al*, which perform these functional tasks. It is important in this algorithm analysis to include the operating personnel as a subsystem since the personnel interact with every subsystem and provide backup for these subsystems when degraded.

Rationale of algorithm

The Mission Execution Tasks (METs) vary in importance with respect to the phases of the mission, *e.g.*, an MET may be more important during *strike* than during *alert*. For any particular mission phase, the importance of a MET can be assigned a numerical value or weight. The more important the MET, the higher the numerical value of the weight. The weight for the r^{th} MET during the j^{th} mission phase is denoted as B_{rj}. Each major subsystem of the C^2 configuration (*e.g.*, communications, data processing, staff) contributes toward the execution of the METs. The importance of any subsystem varies with the MET being executed; *e.g.*, communications may be more important for MET 2 than it is for MET 9. If a subsystem is at full capability, then it can contribute toward a MET at full value of its importance. However, if it is not at full capability, then it can only contribute a proportionate value. Therefore, the basic contribution of any subsystem toward the execution of an MET is a product of the subsystem importance in that MET and the subsystem efficiency compared to full capability.

Up to now, only the effects of the internal capabilities of the C^2 system have been considered, but the performance of the System also depends on the information it receives from external sources. If this information is of poor quality then the whole system is degraded somewhat by this fact. Furthermore, if communications or staff capability is also degraded, then the degradation of external information is amplified in the sense that the system is not as capable of obtaining or using the information which could theoretically be obtained. Therefore the total capability of executing a particular MET can be expressed as:

Degradation factor of subsystem A
× Degradation factor of subsystem B
× Basic contribution of subsystem C
toward MET
= *Effective* contribution of subsystem C
toward MET

The sum of these effective subsystem contributions for all subsystems is the total internal contribution toward the MET execution.

Any subsystem in a command and control center is not independent of the other subsystems. A severe degradation in any one subsystem effectively degrades the others, *e.g.*, if communications is degraded sharply, the staff must spend a great deal more time trying various means of obtaining and evaluating information which normally would have been automatically stored in the data base. For this reason, subsystem degradation factors are used to modify the other basic subsystem contributions. For example, the data processing degradation factor would modify the basic subsystem contributions of communications and staff. When a subsystem has full capability or only slight degradation, then the degradation factor associated with it is 1.0; otherwise it is <1.0. In other words, if data processing were only slightly degraded, a modifying degradation factor of 1.0 would multiply the basic subsystem contributions of communications and staff. If it were severely degraded, a modifying factor of less than 1.0 would reduce the other basic subsystem contributions. In a system composed of three subsystems, A, B, and C, then

Evaluation index of particular MET
= $\sum$ *effective* subsystem contributions
toward the MET
− Degradation of external information
with respect to MET
÷ Degradation factor for staff
× Degradation factor for communications

Notice that for this last term the division by degradation factors of less than 1.0 would tend to increase the negative magnitude of the information quality and thereby increase the total degradation.

The expression above would yield a numerical value for the evaluation index of any MET. However, as stated initially in this section, the METs vary in importance. Hence, to obtain an evaluation index for a total mission phase, a weighted average of these terms, based on MET importance, must be calculated over all the METs. Therefore, the model for the evaluation index for mission phase j (I_j) is generally a weighted average using MET importance, subsystem capabilities and quality of external information all modified by factors that represent the cross-degradation effects of the other subsystems.

Stated mathematically, the model has the form:

$$I_j = \sum_{r=1}^{n} \frac{B_{rj}}{T_j} \left[S_{rj} + \epsilon_{Irj} \right]$$

where I_j is the evaluation index for phase j ($1.0 \leqslant I_j \leqslant 0$); r is the MET number ($1, 2, \ldots, n$); j is the mission phase number ($1, 2, \ldots, m$); B_{rj} respresents the weight for the r^{th} MET during phase j; and T_j is the total weight of METs ($\sum B_{rj}$) during phase j, which is used to normalize the I_m such that $I_j \leqslant 1.0$. Also,

$$S_{rj} = \sum_{k=1}^{M} \sum_{\substack{i=1 \\ i \neq k}}^{M} \rho_{irj} W'_{kr} a_{krj}$$

where ρ_{irj} is a degradation factor for subystem i for r^{th} MET during phase j; ($i = 1, 2, \ldots, M$); M is the number of subsystems which constitute total system; a_{krj} is subsystem k efficiency for r^{th} MET during phase j; $k = 1, 2, \ldots, M$; w_{kr} is the contribution of subsystem k toward execution of r^{th} MET; and

$$\sum_{k=1}^{M} \omega_{kr} = 1.0$$

i.e., numerical values of the subsystem contributions are distributed such that their sum equals 1.0.

$$\epsilon_{Irj} = \max \left\{ \begin{array}{l} \dfrac{Q_{Irj} - 1}{\rho(comm)_{rj}\, \rho(staff)_{rj}} \\ -S_{rj} \end{array} \right.$$

Table I — Sample calculations.

MET # (r)	B_{r4}	$w_{c4}a_{cr4}$	$w_{dr}a_{dr4}$	$w'_{sr}a_{sr4}$	ρ_{sr4}	$S_{r4} = \rho_{sr4}[\rho_{dr4}w'_{cr}a_{cr4} + \rho_{cr4}w_{dr}a_{dr4}] + \rho_{dr4}\rho_{cr4}w_{sr}a_{sr4}$	$\epsilon_{Ir4} = \max\{-S_{r4}, [(Q_{Ir4} = 1)/(\rho_{cr4}\,\rho_{sr4})]\}$	$B_{r4}\,(S_{r4} + \epsilon_{Ir4})$
1.0	10	0.3	0.5	0.10	1.0	0.9	−0.3	6.00
2.0	1	0.4	0.2	0.16	2/3	2/3 [0.4 + 0.2] +'0.16 = 0.56	−0.9/2	0.11
3.0	10	0.3	0.3	0.16	2/3	2/2 [0.3 + 0.3] + 0.16 = 0.56	−0.9/2	1.10
4.0	10	0.4	0.4	0.06	1/3	1/3 [0.4 + 0.4] + 0.06 = 0.3267	max {-0.3276, -0.9} = −0.3267	0.00
5.0	1	0.2	0.3	0.25	1.0	0.75	−0.3	0.45

$\rho_{crj} = \rho_{drj} = 1.0$ for this example

$Q_{Ir4} = 0.7$ for this example

$$T_4 = \sum_{r=1}^{5} B_{r4} = 32$$

B_{r4} obtained in Table II, col. 4

w_{dr} Table III (col. 2 row r) × a_{dr4} Table VI (min. of $\sum$ row r or 1.0)

ρ_{srj} Obtained by using Fig. 1

w_{dr} Table III col. 1, row r) × a_{cr4} Table IV (min. of $\sum$ row r or 1.0)

w_{sr} Table III (col. 3, row r) × a_{sr4} Table V (col. 4, row r)

$$\sum = I_4 T_4 = 7.66$$

$$I_4 = \frac{7.66}{T_4} = \frac{7.66}{32} = 0.239$$

where Q_{Irj} is the quality index of external information for r^{th} MET during phase j;

Note: ϵ_{IIrj} is defined as the maximum of two non-positive values, *i.e.*, the least negative of two values. If either $\rho()_{rj}$ is small, then the term $(Q_{Irj} - 1)/(\rho_{crj}\,\rho_{srj})$ becomes a negative value of high magnitude and would overpower the other terms in the expression for I_j. Therefore, by taking the maximum of this term and $-S_{rj}$, this definition for ϵ_{Irj} bounds the execution index of any particular MET to a value no lower than zero, *i.e.*, $0 \leqslant I_j \leqslant 1.0$.

Illustrative example

As a means of further clarification, this section includes a sample calculation of an index for a reduced configuration for one phase of a mission when the external information is poor ($Q_i = 0.7$). The calculation is based on the following assumptions:

1) The C^2 system is composed of three subsystems — data processing, communications, and staff personnel.
2) The system must execute five mission execution tasks (METs) for mission phase #4.
3) There is no degradation of the data processing or communications subsystems; therefore $\rho_{crj} = \rho_{drj} = 1.0$. The values of ρ_{srj} are derived from Fig. 1.
4) The values of the terms of the algorithm are derived from the tables referenced in Table I. The table entries are arbitrarily selected for this example and no further supporting rationale is given for selecting these numerical values.

Under these assumptions, the algorithm has the form:

$$I_4 = \sum_{r=1}^{5} \frac{B_{r4}}{T_4} [\, S_{r4} + \epsilon_{Ir4}]$$

For the sample calculation, the expression is computed in its equivalent form:

$$T_4 I_2 = \sum_{r=1}^{5} B_{r4}\, [S_{r4} + \epsilon_{Ir4}]$$

The, I_4 is found by dividing both sides of the equation by

$$T_4 = \sum_{r=1}^{5} B_{r4} = 7.66.$$

I_4 is numerically solved in the box at the lower right of the Table I and equals 0.239.

The calculation is generally self-explanatory with remarks beneath each column as necessary. The formal evaluation expression is as given above.

For the system illustrated in the example, the I_j could be called "percent effectiveness" for higher values, say $0.6 < I_j < 1.0$; but below the lower limit this connotation would not hold. The histogram in Fig. 2 gives a qualitative indication of how the index, I_j, might be interpreted. The assignment of these levels was based on qualitative interpretation of performance of METs for which quantitative values could be interpreted with a higher level of confidence. Then these qualitative values were extrapolated to hold for the cumulative indices.

A study of the model parameter definitions and constraints will show that for the given model possible numerical variations in the input parameters will tend to compensate each other to some extent so that the resultant cumulative evaluation indices will not substantially change any conclusions. As an example, in the illustrative computation let the numerical weight given to the most important METs during the phase be halved while the weights of the lesser METs remain the same; then the I_4 will vary in about the third decimal place.

Although reasonable variance of numerical input values will probably not have a great effect on the results, any variance in the form of the model expression may have significant effects.

For example, if the cross degradation effects are eliminated, or if the effect of external information quality is neglected, then the results will probably vary considerably. A cursory explanation of this is

Table II MET weighting matrix (B_{rj}).

MET # (r)	Mission phases (j) 1	2	3	4	5	6
1.0	10	10	10	10	10	10
2.0	10	10	1	1	1	10
3.0	3	10	10	10	10	3
4.0	1	3	10	10	10	3
5.0	1	1	1	1	1	1

Table III — Assignment of w values (W_{x4}).

MET # (r)	Subsystem Weight Comm.	Data proc.	Staff
1.0	0.3	0.5	0.2
2.0	0.4	0.2	0.4
3.0	0.3	0.3	0.4
4.0	0.4	0.4	0.2
5.0	0.2	0.3	0.5

Table IV — Contribution of communications to METs (a_{cr4}).

MET# (r)	Comm. Systems 905	903	904	901	908	181
1.0	1.0	0.1	0.2	0.1	—	—
2.0	1.0	0.1	0.2	0.3	—	—
3.0	1.0	0.1	0.2	0.2	—	—
4.0	1.0	0.1	0.2	—	0.1	—
5.0	1.0	0.1	0.2	—	0.1	0.1

Table V — Staff efficiency/MET (a_{sr4})

MET # (r)	Mission phases (j) 1	2	3	4	5	6
1.0	1.0	0.7	0.6	0.5	0.5	1.0
2.0	1.0	0.7	0.6	0.4	0.4	0.5
3.0	1.0	1.0	0.5	0.4	0.4	0.7
4.0	1.0	1.0	0.4	0.3	0.3	0.8
5.0	1.0	1.0	0.5	0.5	0.5	0.6

Table VI — Distribution of a_{drj}/MET.

MET # (r)	CPU	Main memory	I/O controller	Mass memory	Display Control unit	Mag. tape	Printer/Tab Display control	Comm. data Control console
1.0		0.250		0.300	0.125	0.050	0.075	0.200
2.0		0.200		0.150	0.200	0.050	0.100	0.300
3.0		0.250		0.225	0.200	0.050	0.075	0.200
4.0		0.325		0.150	0.150	0.050	0.075	0.250
5.0		0.250		0.175	0.250	0.075	0.100	0.150

as follows: Changing the form of the model alters the effect of the parameters, (when, how, *etc.*) and therefore can be significant. Any reasonable variation in the numerical values of the parameters, however, affects both the reference standard and the candidate configuration with comparable intensity; hence the index, being a relative value, is not significantly affected.

Conclusions

System performance is one of the most important of the factors that constitute total analysis of Command and Control systems. A quantitative measure of performance is an extremely desirable parameter when a comparison of various system configurations is required. This algorithm establishes a basis whereby a quantitative measure is obtainable.

This model may not be perfectly suited for a given mission — it may be too sophisticated, or conversely, it may ignore pertinent constraints. Nevertheless, the model described in this paper does establish a general rationale which can be applied in tailoring to a given system model. As shown by the illustrative computation, the form of the algorithm is more important than the actual numerical values (within reasonable bounds) entered into the computation.

The implementation of the model may be programmed on a digital computer or time-sharing terminal so that variations and parameter perturbations can be easily assessed. Several variations of models were assessed before the one presented here was selected.

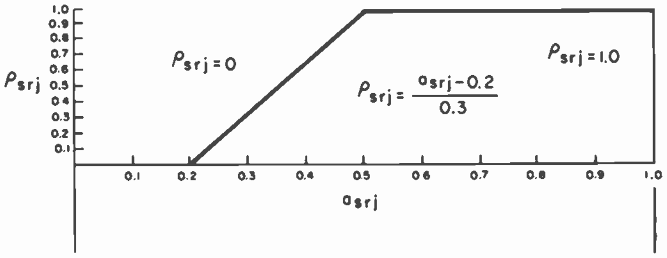

Fig. 1 — Degradation factors due to staff personnel related to subsystem efficiency.

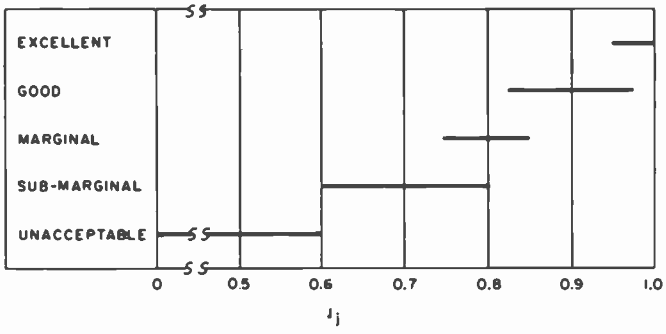

Fig. 2 — System effectiveness.

SARA
— a research planning tool

C. Havemeyer| R.R. Lorentzen

SARA (System for Analyzing Research project Attributes) was developed to aid the management of the Laboratories in the research planning process; it is an amalgamation and extension of systems previously used at the Laboratories.* The purpose of this interactive tool is recording and subsequently retrieving, analyzing, and reporting the allocation of resources to projects and the characterization of these projects by means of user-defined attributes. SARA is designed for use throughout the planning process: to record the characteristics and resources required for proposed projects; to aid in the assigning priorities and in the selection procedure; to help ensure a balance in the portfolio of planned projects; and to assist in the monitoring of resource utilization.

PLANNING of research at the Laboratories is a continuing process. The nature of the planning process has been evolving over the past several years and will continue to change in the future. The process is structured so the Laboratories can be responsive to change -- both internal and external.

The development of the plan for a particular year begins with project proposals that are recommended by the Laboratory Directors based on their evaluation and assessment of various forces which are at work; these include the technological and business needs of RCA divisions, inputs from RCA's corporate staff, the progress and status of the current research program, guidance from the technical staff within the Laboratories, and evaluation of competitive organizations, businesses, and technologies.

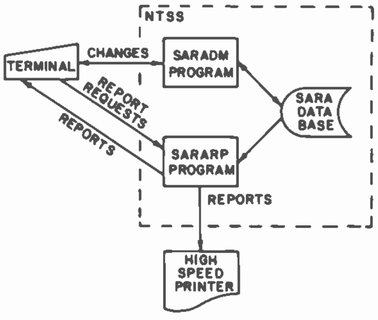

Fig. 1 — SARA system structure.

The next step is an interactive process in which projects are assigned priorities based on their estimated return to RCA. Required resources are compared to the resources likely to be available for the year; resources are diverted from the lower priority projects to those of higher priority. At the same time, it is necessary to ensure that the list of projects is balanced in several dimensions: with respect to the divisons supported, with respect to the time interval until payoff, and with respect to the portion of effort planned for research of various types (e.g., close-in divisional support, exploratory research, etc.).

The research plan at this stage forms a basis for the formal Business Plan submitted to RCA Corporate Management.

The final portion of the research planning process consists of continuous monitoring of actual resource use compared to plan. In addition, the Plan itself is updated during the year in response to changing conditions.

System structure

SARA is a special-purpose data-base system. It consists of:

- A data base for storage of the resource and attribute information for the projects; this includes the allocation of people to projects;
- A data management program (SARADM) for creation and retrieval of the data base and for input, deletion and update of the resource, attribute and other information; and
- An analysis and report generator program (SARARP). Several reports are available. As will be shown, a great deal of flexibility is available to the user in specifying the structure of reports.

Craig Havemeyer, Mgr., Management Information Systems, RCA Laboratories, Princeton, N.J., received the BS in Industrial Engineering in 1966 and Master of Engineering in Operations Research in 1967, both from Cornell University. Upon graduation, he joined RCA as a member of the Operations Research Career Program, which consisted of assignments with several RCA divisions and corporate staff activities. Mr. Havemeyer then accepted a position with the Comptuer Systems Division where he was involved in implementing a large business planning system and other O.R projects. He was promoted to Manager, Operations Research in 1970. In late 1971, he assumed his present position at the Laboratories, directing the development and use of administrative computer systems and management decision aids. Recently his responsibilities were broadened to include the Computer Services organization.

Robert R. Lorentzen, Mgr., Computer Services, Management Information Systems, RCA Laboratories, Princeton, N J., received the BSEE in 1961 and the MSEE in 1965, both from the Newark College of Engineering; he received the MS in Computer Science in May 1975 from the N.J. Institute of Technology. After working at Western Electric, Hewitt-Robins and Federal Telephone and Radio, he joined RCA's Microwave Operations in Harrison, N.J. in 1956, where he held several positions in Equipment Development, Applications Engineering, Staff Planning, and Marketing. In 1972 he became responsible for the computer support and scientific programming for RCA's Thermoelectric Operations. In January 1974, Mr. Lorentzen transferred to RCA Laboratories in Princeton as Manager of the Operations Analysis activity in Management Information Systems. In February 1975, he was given the responsibility for the Computer Services organization at the Laboratories. Mr. Lorentzen has written papers on Microwave and Thermoelectric Devices and Business Planning, and is a member of Eta Kappa nu, Tau Beta Pi, the IEEE, the ACM, and the Institute of Management Science.

Authors Lorentzen (left) and Havemeyer.

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*Earlier systems were PROPP (Project Planning Program) and MAP (Manpower Allocation to Projects). They were used extensively in 1973.

As shown in Fig. 1, both programs are accessed conversationally from a remote terminal. Reports may be directed to either the terminal or a high speed offline printer. Special provisions are made for confidential or sensitive data.

Data base structure

The SARA data base contains four major segments:

general data
dictionary
project data
people data.

Fig. 2 shows these four segments which are linked together through a nickname hierarchy.

The project data segment contains information about each current and planned research project. In addition to identification data (project nickname and title), the resources required for the project and the attributes of the project are stored.

There are twenty predefined resources which can be input for each project. Resources include people, materials, computer costs, and other resources which may be directly allocated to projects. Provision is made for entering overhead (as a percent) and credits.

Of the twenty resources, ten of them represent different people skill and cost categories; the number of people required in each category is input and stored in the data base. Each of these people categories is characterized by a dollar rate which is used to translate the number of people into a dollar cost for the project. The other ten resources are entered either directly as dollars or as a percentage.

Unlike the resources, attributes are defined by the user. The definition of each attribute is contained in the dictionary segment of the data base. Two types of attributes may be specified: value or range. A value attribute has specific allowable values. For example, the user may wish to characterize the projects in terms of Payoff. The attribute nickname might be defined as PAYF and the allowable values defined as: low, medium, and high. A range type attribute allows the user to pre-assign and label various contiguous ranges. For example an attribute, Time to Payoff, might be defined as:

range	*label*
0 to <3 years	short
3 to < 8 years	medium
<8 years	long

In this case, the attribute value for a specific project would be a number of years (e.g., 4). At report generation time, this project would be identified as having a medium time to payoff.

The fourth segment of the data base deals with individual people and their assignments to projects. The project assignments cover a two-year period: the current year and the following year. As can be seen in Fig. 2, the assignment list consists of project nickname, date of beginning of assignment and percent of time spent on this project.

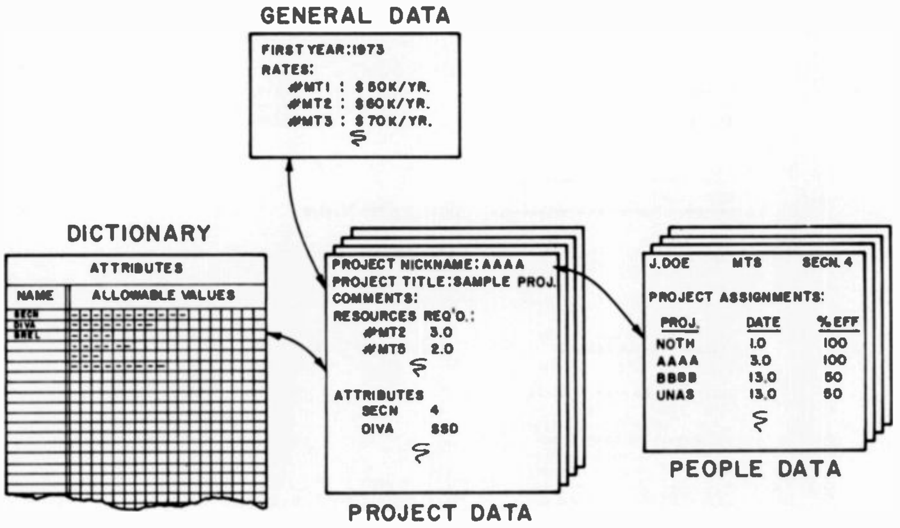


Fig. 2 — Simplified data base structure.

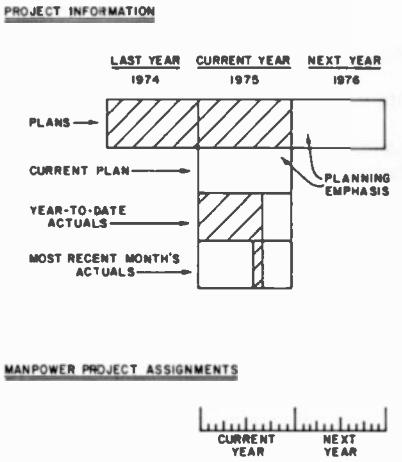


Fig. 3 — Treatment of time in SARA.

The special nickname NOTH indicates that the person is not here during that period (e.g., leave of absence, not yet hired). A second nickname UNAS is used for individuals who are not yet assigned to a project.

Another dimension to the structure of the SARA data base is the treatment of time. As shown on Fig. 3, project data covers a three-year period: last year, current year, next year. In addition, depending on which of these years is being considered, one may also be concerned with business plan data, current plan data, or actual results. Each of the blocks in the matrix shown is called a frame and contains the resource and attribute information for the indicated year/data-status.

The availability of the six frames enables management to make meaningful comparisons of research activity across time and between planned activity and actual results.

SARA reports

At the present time, SARA can produce seven report types grouped in the following categories:

Detail reports,
Resource utilization summaries, and
Research program analysis.

Two detail reports are available — one dealing with project information and the other providing an alphabetical list of people showing project assignments.

Reprint RE-21-3-26
Final manuscript received February 25, 1975.

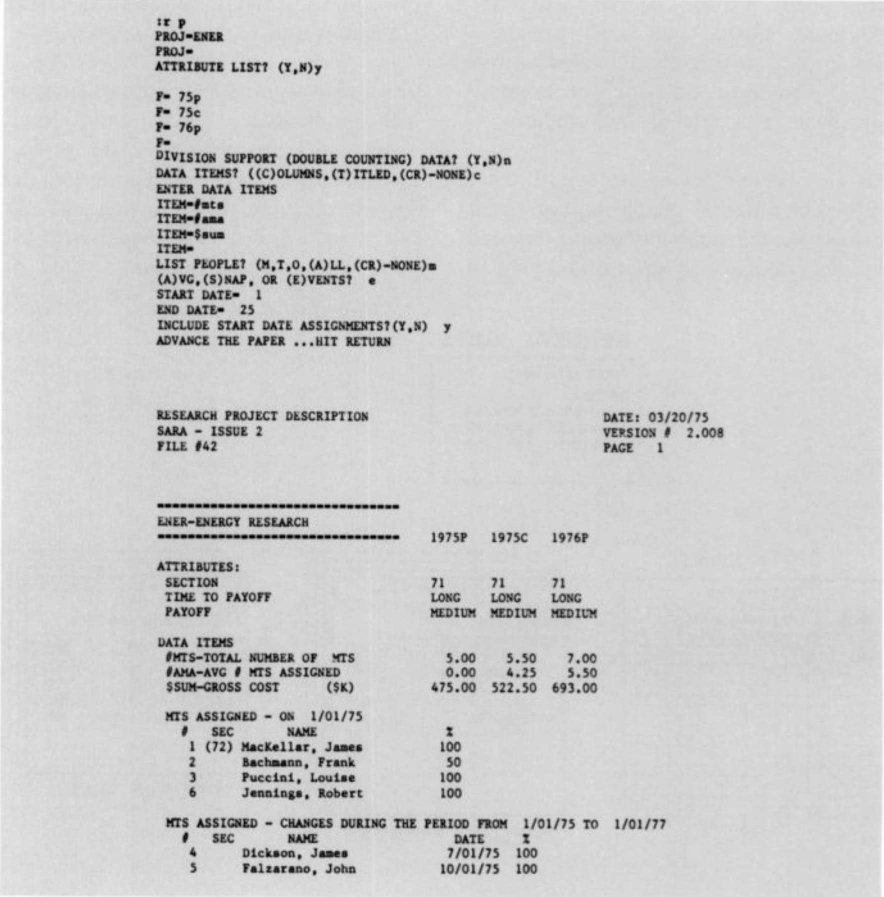
Fig. 4 — SARADM activity commands.

*A D aaaa	add dictionary (attribute)
*A I	add individual
*A P pppp	add project
*C D aaaa	change dictionary (attribute)
*C G gggg	change general item
*C I	change individual
*C P pppp	change project
*D D aaaa	delete dictionary (attribute)
*D I	delete individual
*D P pppp	delete project
*F	frame
*G N	generate new file
*G O	generate old file
*I pppp	in project
*O pppp	out project
*L $\begin{bmatrix}\text{rrrr}\\\text{aaaa}\end{bmatrix}$	list resource or attribute values
*M $\begin{bmatrix}\text{rrrr}\\\text{aaaa}\end{bmatrix}$	Mass (input)
*P D aaaa	print dictionary (attribute)
*P G	print general information
*P I	print individual
*P P pppp	print project
*U	update frames

Fig. 5 — SARARP activity commands.

:C F	change factors
:C M	change mode (terminal/offline)
:G	generate (old) file
:O	offline
:R A $\begin{smallmatrix}\text{M}\\\text{T}\\\text{O}\end{smallmatrix}$	report — alphabetic listing of people
:R P[aaaa][aaaa]	report — listing of projects
:R M $\begin{smallmatrix}\text{M}\\\text{T}\\\text{O}\end{smallmatrix}$	report — matrix (personnel)
:R P[aaaa][aaaa]	report — project descriptions
:R S $\begin{smallmatrix}\text{M}\\\text{T}\\\text{O}\end{smallmatrix}$	report — summary (personnel)
:R S[aaaa][aaaa]	report — totals

where: aaaa = an attribute nickname
M = MTS
T = Technical Support Personnel
O = Other People



```
:r p
PROJ-ENER
PROJ-
ATTRIBUTE LIST? (Y,N)y

F- 75p
F- 75c
F- 76p
F-
DIVISION SUPPORT (DOUBLE COUNTING) DATA? (Y,N)n
DATA ITEMS? ((C)OLUMNS,(T)ITLED,(CR)-NONE)c
ENTER DATA ITEMS
ITEM-#mts
ITEM-#ama
ITEM-$sum
ITEM-
LIST PEOPLE? (M,T,O,(A)LL,(CR)-NONE)m
(A)VG,(S)NAP, OR (E)VENTS?  e
START DATE-  1
END DATE-  25
INCLUDE START DATE ASSIGNMENTS?(Y,N)  y
ADVANCE THE PAPER ...HIT RETURN



RESEARCH PROJECT DESCRIPTION                                DATE: 03/20/75
SARA - ISSUE 2                                              VERSION #  2.008
FILE #42                                                    PAGE    1



--------------------------------
ENER-ENERGY RESEARCH
--------------------------------  1975P  1975C  1976P

ATTRIBUTES:
 SECTION                          71     71     71
 TIME TO PAYOFF                   LONG   LONG   LONG
 PAYOFF                           MEDIUM MEDIUM MEDIUM

DATA ITEMS
 #MTS-TOTAL NUMBER OF  MTS          5.00   5.50   7.00
 #AMA-AVG # MTS ASSIGNED            0.00   4.25   5.50
 $SUM-GROSS COST       ($K)       475.00 522.50 693.00

 MTS ASSIGNED - ON  1/01/75
   #   SEC       NAME              %
    1 (72) MacKellar, James        100
    2      Bachmann, Frank          50
    3      Puccini, Louise         100
    6      Jennings, Robert        100

 MTS ASSIGNED - CHANGES DURING THE PERIOD FROM  1/01/75 TO  1/01/77
   #   SEC       NAME                   DATE     %
    4      Dickson, James             7/01/75  100
    5      Falzarano, John           10/01/75  100
```

Fig. 6 — Project description report.

Two of the resource utilization summary reports show the mix of the portfolio of research projects by grouping projects by attribute values. An example of this will be shown later. A third report in this category displays the variances between project effort required and effort assigned. Another report shows the degree to which projects are staffed by out-of-section people.

The final report shows the results of some special computations which prorate the research effort across RCA businesses.

Each of the seven report types provides the user with a high degree of flexibility as to the nature of the information displayed. For example, the report which groups projects into attribute categories can be generated:

— with 0, 1 or 2 attributes or grouping
— with 1, 2, 4 or 6 frames of information
— with 1 or 2 data items shown.

Using SARA

A key to the use of SARA is the activity command structure. Each of the functions of the two SARA programs is accessed by the user issuing commands. Fig. 4 shows the activity commands for the data management program. Note that in addition to the particular function to be performed, the activity command is used to indicate to the program the specific nickname of the project, attribute, etc. to be added, changed, deleted or displayed.

Fig. 5 shows the activity commands for the report program.

Example

A sample data base consisting of fifteen projects was developed for demonstration purposes.

Fig. 6 shows the terminal prompting and resulting project description report. The degree of flexibility available to the user is evident from the prompting sequence. In this case, information on just one project, nicknamed COLR, is requested. Three frames are shown: 1975P is this year's original plan; 1975C represents the current plan for the year; and 1976P is the latest iteration of next year's plan.

The data items section of the report first shows the planned level of effort on the project, then the average number of people assigned to the project, and finally an estimate of total project cost.

The last section deals with individuals assigned to the project. First, the roster at the beginning of the current year; then changes during the course of the year. In this case, the two additional individuals are scheduled to start full time work on the project on the dates indicated.

A second example, Fig. 7, illustrates how SARA can be used to aid in the analysis of the project portfolio through the use of attributes. The example shows projects grouped by two attributes, time to payoff and payoff. For each project and each grouping, the planned manning level is shown for 1975P and 1976P.

Another version of the same report type is shown in Fig. 8. In this case, projects are grouped by section. This report format is used to help analyze the degree to which actual effort expended on projects is consistent with this year's current plan. The first two columns compare the original plan with the current plan. Then the current plan, factored to represent available effort level, is compared to the actual average effort applied year to date. The last two columns are similar, but focus on last month's effort. The year-to-date and monthly actuals are available to SARA from the Laboratories' Project Cost System.

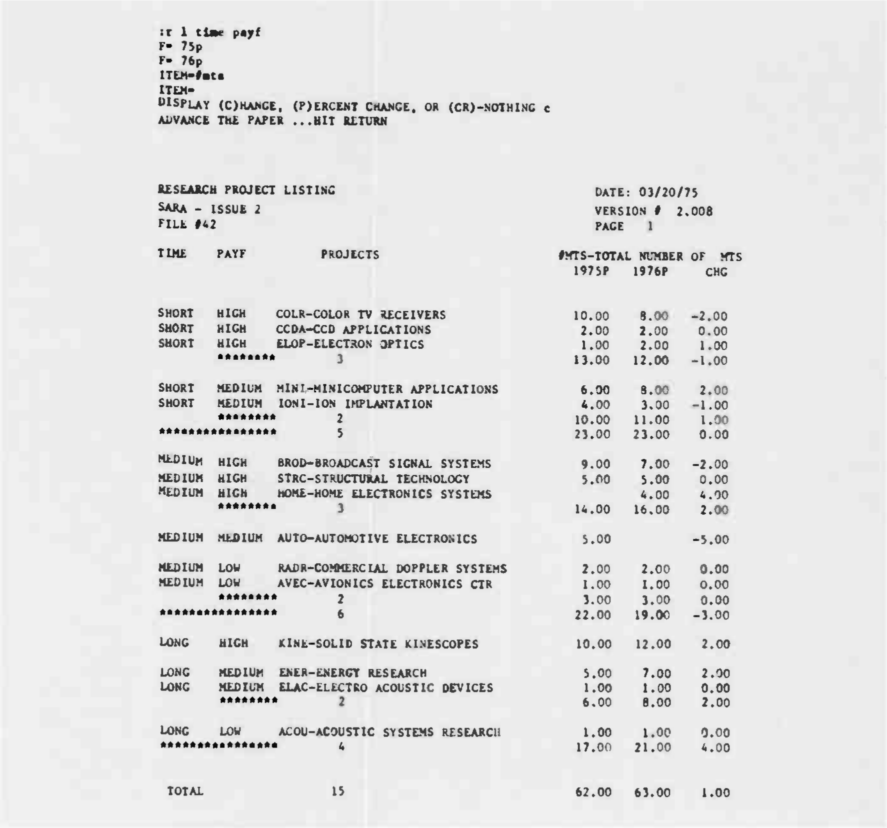
Conclusion

SARA was first used for the 1975 planning cycle, starting in the spring of 1974. It was used heavily during the preparation of the 1975 Laboratories' Business Plan submission. Since that time, actual resource utilization has been compared to the plan on a monthly basis and the plan has been modified in response to changing conditions.

The system itself is viewed as an evolving tool. Several additional capabilities have been added during the past year and others will be added as the participants in the planning process gain experience in using the system.

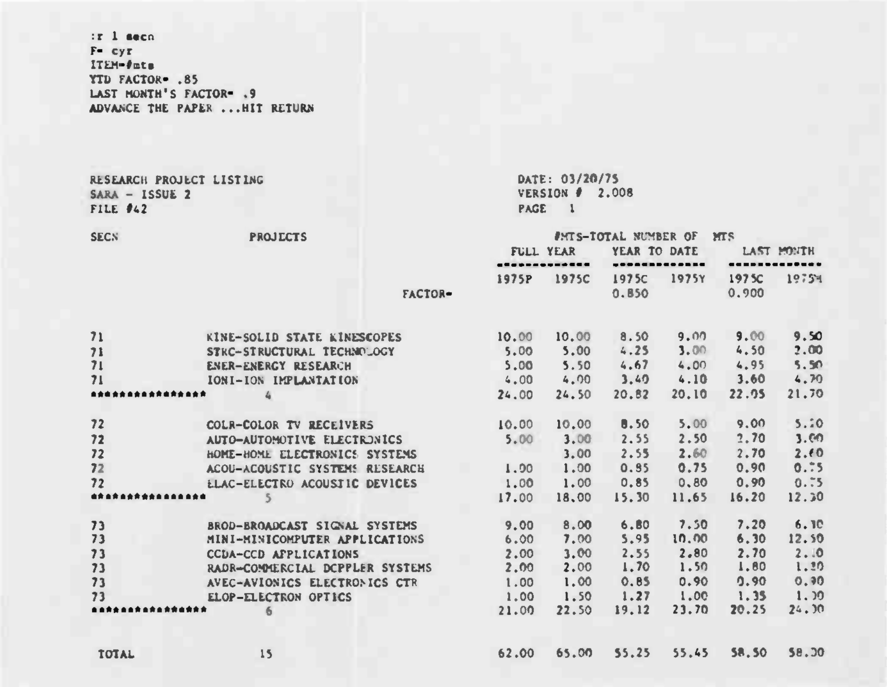
Acknowledgment

For the successful development and continued use of SARA, we are happy to acknowledge the support and guidance of the Laboratories' Management. In addition, we are grateful Barbara Banko and Vince Boccanfuso for their valuable contributions to this project.



```
:r 1 time payf
F= 75p
F= 76p
ITEM=#mts
ITEM=
DISPLAY (C)HANGE, (P)ERCENT CHANGE, OR (CR)-NOTHING c
ADVANCE THE PAPER ...HIT RETURN



RESEARCH PROJECT LISTING                              DATE: 03/20/75
SARA - ISSUE 2                                        VERSION #  2.008
FILE #42                                              PAGE   1

TIME    PAYF           PROJECTS                   #MTS-TOTAL NUMBER OF  MTS
                                                    1975P   1976P     CHG


SHORT   HIGH    COLR-COLOR TV RECEIVERS             10.00    8.00   -2.00
SHORT   HIGH    CCDA-CCD APPLICATIONS                2.00    2.00    0.00
SHORT   HIGH    ELOP-ELECTRON OPTICS                 1.00    2.00    1.00
        ********        3                           13.00   12.00   -1.00

SHORT   MEDIUM  MINI-MINICOMPUTER APPLICATIONS       6.00    8.00    2.00
SHORT   MEDIUM  IONI-ION IMPLANTATION                4.00    3.00   -1.00
        ********        2                           10.00   11.00    1.00
****************        5                           23.00   23.00    0.00

MEDIUM  HIGH    BROD-BROADCAST SIGNAL SYSTEMS        9.00    7.00   -2.00
MEDIUM  HIGH    STRC-STRUCTURAL TECHNOLOGY           5.00    5.00    0.00
MEDIUM  HIGH    HOME-HOME ELECTRONICS SYSTEMS                4.00    4.00
        ********        3                           14.00   16.00    2.00

MEDIUM  MEDIUM  AUTO-AUTOMOTIVE ELECTRONICS          5.00           -5.00

MEDIUM  LOW     RADR-COMMERCIAL DOPPLER SYSTEMS      2.00    2.00    0.00
MEDIUM  LOW     AVEC-AVIONICS ELECTRONICS CTR        1.00    1.00    0.00
        ********        2                            3.00    3.00    0.00
****************        6                           22.00   19.00   -3.00

LONG    HIGH    KINE-SOLID STATE KINESCOPES         10.00   12.00    2.00

LONG    MEDIUM  ENER-ENERGY RESEARCH                 5.00    7.00    2.00
LONG    MEDIUM  ELAC-ELECTRO ACOUSTIC DEVICES        1.00    1.00    0.00
        ********        2                            6.00    8.00    2.00

LONG    LOW     ACOU-ACOUSTIC SYSTEMS RESEARCH       1.00    1.00    0.00
****************        4                           17.00   21.00    4.00


 TOTAL                 15                           62.00   63.00    1.00
```

Fig. 7 — Analysis of project portfolio through the use of attributes.



```
:r 1 secn
F= cyr
ITEM=#mts
YTD FACTOR= .85
LAST MONTH'S FACTOR= .9
ADVANCE THE PAPER ...HIT RETURN



RESEARCH PROJECT LISTING                          DATE: 03/20/75
SARA - ISSUE 2                                    VERSION #  2.008
FILE #42                                          PAGE   1

SECN               PROJECTS                             #MTS-TOTAL NUMBER OF  MTS
                                                 FULL YEAR     YEAR TO DATE    LAST MONTH
                                               -------------  -------------  -------------
                                               1975P   1975C  1975C   1975Y  1975C   1975M
                                   FACTOR=                    0.850          0.900


71           KINE-SOLID STATE KINESCOPES       10.00   10.00   8.50    9.00   9.00    9.50
71           STRC-STRUCTURAL TECHNOLOGY         5.00    5.00   4.25    3.00   4.50    2.00
71           ENER-ENERGY RESEARCH               5.00    5.50   4.67    4.00   4.95    5.50
71           IONI-ION IMPLANTATION              4.00    4.00   3.40    4.10   3.60    4.70
****************     4                         24.00   24.50  20.82   20.10  22.05   21.70

72           COLR-COLOR TV RECEIVERS           10.00   10.00   8.50    5.00   9.00    5.20
72           AUTO-AUTOMOTIVE ELECTRONICS        5.00    3.00   2.55    2.50   2.70    3.00
72           HOME-HOME ELECTRONICS SYSTEMS              3.00   2.55    2.60   2.70    2.60
72           ACOU-ACOUSTIC SYSTEMS RESEARCH     1.00    1.00   0.85    0.75   0.90    0.75
72           ELAC-ELECTRO ACOUSTIC DEVICES      1.00    1.00   0.85    0.80   0.90    0.75
****************     5                         17.00   18.00  15.30   11.65  16.20   12.30

73           BROD-BROADCAST SIGNAL SYSTEMS      9.00    8.00   6.80    7.50   7.20    6.10
73           MINI-MINICOMPUTER APPLICATIONS     6.00    7.00   5.95   10.00   6.30   12.50
73           CCDA-CCD APPLICATIONS              2.00    3.00   2.55    2.80   2.70    2.30
73           RADR-COMMERCIAL DOPPLER SYSTEMS    2.00    2.00   1.70    1.50   1.80    1.20
73           AVEC-AVIONICS ELECTRONICS CTR      1.00    1.00   0.85    0.90   0.90    0.90
73           ELOP-ELECTRON OPTICS               1.00    1.50   1.27    1.00   1.35    1.00
****************     6                         21.00   22.50  19.12   23.70  20.25   24.00


 TOTAL              15                         62.00   65.00  55.25   55.45  58.50   58.00
```

Fig. 8 — Project summary of Fig. 7 arranged by section.

Mechanical design of mobile data processing systems for worldwide use

J. Furnstahl| J. Herzlinger

Modern tactical command and control systems must be automated to a high degree, be transportable anywhere in the world, and operate continuously after arrival. The mechanical design implications are considerable. Specific solutions to mechanical design encountered in the design of the Tactical Information Processing and Interpretation (TIPI) System are described. TIPI is a mobile land-based system designed to apply automatic data processing techniques to tactical intelligence processing. RCA implemented the Display Control/Storage and Retrieval (DC/SR) Segment.

John S. Furnstahl, Manager, Preliminary Design, Government Communications and Automated Systems Division, Burlington, Massachusetts received his Bachelor's degree in Mechanical Engineering from Marquette University in 1950 and his BS degree in Electrical Engineering from Drexel University in 1961. Since joining RCA in 1952, Mr. Furnstahl has been engaged in design and development of light-weight airborne fire control equipment, airborne TV, airborne and space communications, modification of aircraft for equipment flight tests, high-resolution radar, high-speed tape transport, thermo-electric, special electromechanical devices and environmental testing. From 1959 to 1963, his responsibilities included reliability, maintainability, value engineering, drafting coordination, Measurement Engineering Laboratory and design support. Mr. Furnstahl was Manager of Engineering Controls and Support and later was Manager of Computer Product Design. As Manager of Product Design and Installation, he was responsible for design and development of computer, monitoring and control equipment. His most recent assignment consists of equipment product and installation design of the display and control/storage and retrieval system for tactical information and intelligence support for military operations. Mr. Furnstahl is a member of Pi Tau Sigma, ASME, IEEE and AIAA. He is a registered Professional Engineer in the State of New Jersey (No. 11029) and the Commonwealth of Massachusetts (No. 25315).

Joseph I. Herzlinger, Manager, Product Design, Government Communications and Automated Systems Division, Burlington, Massachusetts received his BS in Mechanical Engineering from Newark College of Engineering and his MS in Mechanical Engineering from Drexel Institute of Technology in 1961. Mr. Herzlinger joined RCA following his graduation in 1940. He was engaged in the mechanical design of shipboard radar equipment and television transmitter and antenna equipment until 1946. As Leader of the advanced electromechanical design group, he assumed responsibility for the mechanical design of the Vernier II High Resolution Radar System, overall responsibility for an advanced high-speed tape transport, and responsibility for the development of the Ranger Shutter. At the Aerospace Systems Division, Burlington, Massachusetts, Mr. Herzlinger has had mechanical design leader responsibility for projects involving camera shutters, IR energy detection using fiber optics, and laser applications. He was responsible for the mechanical design of the electronic assemblies of the LM Apollo Rendezvous Radar and Transponder and the mechanical design of the Pulse Doppler Radar System. He was responsible for the mechanical design of the Aegis Orts Equipment and the Walt Disney World Automatic Monitoring and Control System. In his most recent assignment, he had mechanical design responsibility for the configured shelters, bare shelters, environmental control system, passageways, and pallets for the TIPI DC/SR equipment. He has been granted two U.S. patents and is a Professional Engineer in the State of New Jersey.

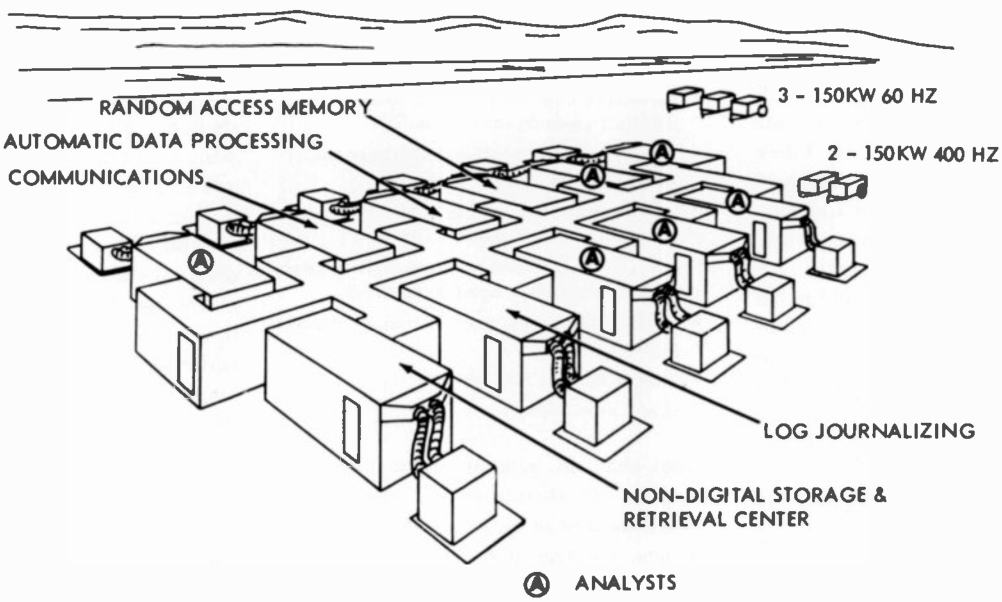


Fig. 1 — Display and control/storage retrieval segment (TIPI)

THE NEED for ease of transport and rapid deployment severely limit size and weight and pose other problems such as how to protect equipment from mechanical shock. Worldwide environmental extremes require that personnel and hardware be protected from heat, cold, and humidity. Reliable and effective use of these complex systems under such conditions demand careful human engineering and maintainability design.

The Display Control/Storage and Retrieval system (DC/SR) assists the intelligence analysts in their tasks of keeping the tactical intelligence data base up to date. The DC/SR segment consists of shelter-mounted equipment, computer software, trained personnel, information, intelligence data and facilities. The DC/SR segment is configured for use by the United States Marine Corps (USMC) and the United States Air Force (USAF), and will interface with other segments of the TIPI System and other existing field systems. The DC/SR equipment is functionally divided into the areas of communications, non-digital materials and automatic data processing. The prime contractor for the development models of the DC/SR segment is the System Development Corporation, Hampton, Virginia.

Physically the TIPI DC/SR segment is configured in a set of 20 ft long by 8 ft high by 8 ft wide shelters. The USAF configuration consists of 11 shelters (Fig. 1). Three basic shelters are the automatic data processing (ADP), random access memory (RAM), and the communications type. There are six intelligence analyst station (IAS) shelters and two non-digital shelters. The USMC configuration consists of 7 shelters, using the same three basic shelters as the USAF (ADP, RAM, and Communications). Three intelligence analyst station (IAS) shelters and one non-digital shelter make up the remaining USMC complement. In addition to the 11 or 7 shelters in a TIPI DC/SR segment there is a set of environmental control units, auxiliary power generation units, and pallets for transporting cables and other ancillary equipment.

A major consideration in selection of equipment was to employ available on-the-shelf designs for integration into the TIPI DC/SR segment with virtually no risk. Some of the equipment already qualified. Other equipment was an enhancement, expansion, or modification of equipment already qualified. In some cases the design had been proven in commercial systems and repackaging was required to meet the TIPI requirements. The size, weight and volume of the selected equipment are consistent with its capacity, performance and environmental capability. Shelter equipments are configured to keep the center of gravity within two feet in the longitudinal direction, within one foot in the lateral direction, and below a distance of four feet above the bottom of the skids to prevent unbalanced loading and upset during handling.

Transportability

The DC/SR segment was designed to be transported by rail, ground, air or sea. The USMC shelters are transported by end-mounted trailers while the USAF shelters are transported by undercarriage trailers. All pallets, including the environmental control system (ECS) and power distribution and cable pallets are transported by a smaller, end-mounted trailer.

The Marine Corps DC/SR segment can be loaded on or off ships, including amphibious vehicles, and C130-type aircraft, with or without the use of the 463L loading system. These shelters and pallet assemblies can use railroad transportation, including humping at 9 mi/h while the shelter is resting on its skids. Each shelter and pallet assembly with trailer attached can be transported by helicopter. The Air Force shelters are capable of the same transportation mode as the Marine Corps shelters except that the trailer must be detached for C-130 type aircraft and railroads.

The shelters have a gross weight of 10,000 pounds, including equipment, in the transport mode. The shelter trailers weigh approximately 4500 pounds. The weights and centers of gravity were monitored constantly during the design cycle; each configured shelter and loaded

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pallet in the transport mode was well within the specified limits.

Special attention was given to maintaining commonality between the DC/SR Marine Corps and Air Force segments as well as to the TIPI Imagery Interpretation (II) segment to facilitate deployment and logistics. The common items include shelter trailers, pallets for the ECS, shelter jacks, shelter and pallet hoist slings. The basic *bare* shelter module structure and overall dimensions are similar including interface shelter hardware items such as fittings for trailer attachements, lifting, and towing rings.

The DC/SR segment was designed so that no dangerous or sensitive equipment or material must be transported. No enviornemntal control during transit or intransit storage of any equipment is required to retain stability or preclude compromise of reliability. The shelters contain pressure relief valve for air transport.

Without special material handling equipment or packaging design, the DC/SR segment can be deployed from a transport to an operational mode or from an operational to transport in two hours or less.

During shelter transport, certain peripheral and ancillary equipment are removed from their normal operating station and secured in transit cases. These items include commercial microfilm reader/printer, paper-tape punch, and communication buffer. The transit cases are secured to tie-down attachments in the shelter floor. Provisions have been made to easily remove any classified equipment and documents during transit and/or storage. Peripheral and ancillary equipment which are not put into transit cases are tied down to the floor or secured for transit. These items include chairs, telephones, telephone switchboards, magnetic tapes, disc packs, disc drives, and plotter. The detailed steps for preparation of shelters for transport are as follows:

- Remove heavy documents from cabinets and pack in transit cases.
- Place certain commercial peripheral equipment items in transit cases.
- Secure all transit cases and loose furnishings in shelter.
- Disconnect and stow all external power and signal cables.
- Disconnect and stow ECS ducts and control cables.
- Disassemble and stow passageway.
- Disconnect and stow ground anchors and electrical grounds on ECS pallet.
- Jack shelter and install undercarriage trailer set (Air Force only).
- Remove and stow shelter and ECS pallet jacks aboard ECS pallet.
- For ADP and RAM shelters, stow digital cables on ancillary equipment pallet.
- Emplace dust covers over shelters ECS duct ports.
- Purge generator fuel systems.
- Attach prime movers.

Note that, in general, items normally outside the shelter in the operational mode are stowed outside of the shelter on pallets, whereas items normally within the shelter are stowed within the shelter during transport mode. This avoids the introduction of dirty cables, jacks, etc. into the shelter, retains documents and equipment specific to a given shelter within that shelter — and avoids the requirement to open a shelter before it is jacked and leveled. Items stowed on the ECS pallets are common to all shelters, permitting ECS pallets to be interchangeable within the DC/SR Segments.

Deployment

The site planning and preparation for deployment are functions of the geographical location, terrain, season of the year, weather and time duration of the segment employment. See Fig. 2, TIPI Segment deployment functional flow diagram.

Prior to the arrival of the DC/SR segment at the site, an area must be selected, surveyed, staked, and planned requisite to emplacement of equipment. The shelters, ECS and passageways are designed to be capable of being jacked to a level altitude for operation on a terrain having a slope up to 10 percent and soil capable of supporting 12 psi. Any individual shelter shall be convertible from a transportable status and from an operational status to a transportable status in 2 hours or less. Fig. 3 shows the emplacement time scheule common to all modules.

The deployed configurations represent essentially the minimum area compatible with all other requirements. Special attention was given to the layouts to minimize lengths of critical signal cables, walking distances for personnel between shelters, and passageway length, weight, and volume. The power generators are located remotely from the shelters to minimize acoustic noise level, fuel odor, and fire hazard. Each ECS is located approximately 10 ft from its shelter and connected to the shelter by flexible ducts to minimize vibration and acoustic noise inside the shelters.

The passageway system is composed of detachable modules to facilitate stowage on the pallets for transport and for erection during deployment. Each major passageway component is capable of being handled by two people. All hardware and tools are captive. Ground anchors are used to secure the passageway against wind.

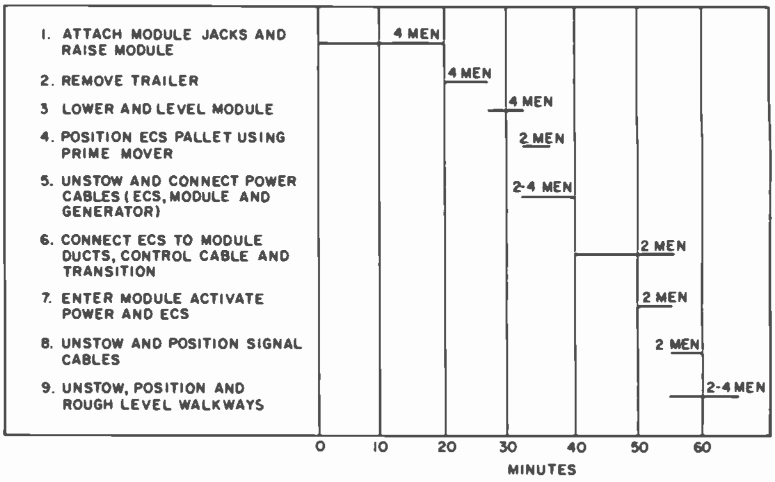


Fig. 2 — Emplacement time schedule common to all modules.

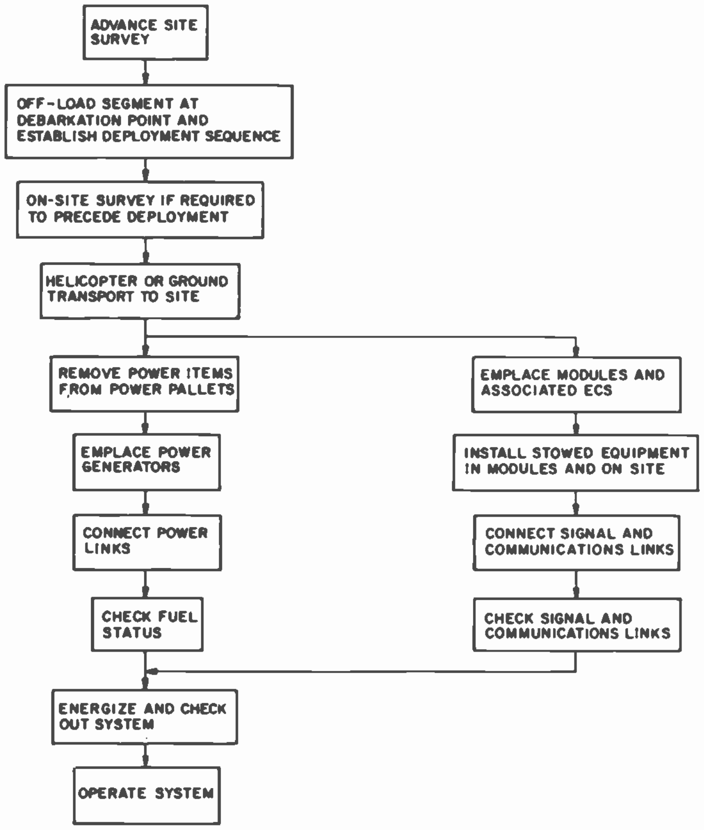


Fig. 3 — TIPI segment deployment functional flow.

The TIPI DC/SR segments can be deployed and put into operation without the passageways, permitting random orientation of the shelters for such purposes as utilization of natural terrain and foliage as camouflage.

Environmental requirements

RCA, as the system integrator, specified the complement of TIPI DC/SR equipment to assure that when installed within the shelter, the configuration would survive the complete range of military mobility hazards. An auxiliary environmental control system maintains the shelter environment within a range enabling operators to work full shifts on a 24-hour basis. The control sytem also assures the proper operating environment for storing magnetic equipment which may be adversely affected by humidity; a minimum of 20% (±5%) relative humidity is maintained.

The Environmental Control System connected to each configured shelter maintains the temperature and maximum relative humidity within human comfort conditions. This temperature and humidity range is also within the safe operating limits of the equipment inside the shelters. The ducts within the shelters distribute the conditioned air at a low uniform velocity, and with small temperature variations at all operator stations.

Humidification is a unique requirement for the TIPI DC/SR system. Three of the configured shelters contain magnetic recording equipment which is sensitive to the extemely low relative humidity which occurs in desert areas and arctic areas in winter. A humidifier is installed in each of these three shelters to maintain the minimim relative humidity at 15%.

The addition of humidity at low temperature causes a moisture condensation problem; thus, all shelter surfaces, in contact with humidifed areas, are either heated or insulated so that the surface temperature is above the dew point. An insulated blanket is provided over the air ducts connecting the shelter to the ECS to avoid condensation.

Structural requirements for the configured shelter design are derived from the rail impact test at 9 mi/h. A pair of elastomeric skids (provided at the base of the shelters) attenuate the shock loads developed during the 12-inch flat and corner drop tests. Elastomeric skids are also provided under the environmental control system pallet to attenuate shock, in addition to acoustic noise attenuation.

The equipment has been designed to withstand steady-state loads of 25g for small components and 15g for large components in the axis of rail impact (both directions) and 25g and 15g in the vertical axis to withstand the drop tests. For lateral loads the design criteria are 8 and 5g. To meet the requirements of the road test, and vibration test, all loose items such as transport cases are fastened down securely with straps.

All doors and openings in the shelter are EMI tight including the rectangular openings which interface with the ECS ducts. Ground stakes and lightning rods are also provided for the configured shelters. A Scotch Tread insulating material is cemented over the shelter floor to provide electrical isolation. Tie-down devices in shelters and the passageway prevent overturning in high winds.

Human engineering

The equipment was designed in conformance with human engineering design criteria. Human factors design requirements are employed to determine operator interfaces which are anthropometrically correct for height, arrangement, illumination, legibility and accessibility. Environments conducive to good operator performance and reduced fatigue are maintained. Functional operator areas provide low acoustic noise levels to enable operators to maintain efficiency.

Safety is designed into the system such that no chassis or assembly with potentials in excess of 70 volts rms is exposed, and appropriate lightning protection is provided. There are no hazards from implosion, gases, acids, alkalis, or fumes. Equipments are designed for two-man carry wherever practicable.

Legibility of displays, printed pages, and control panels is designed to be compatible with normal vision and normal viewing distances in the ambient illumination provided within the shelter. Non-reflective CRT shields are used to reduce unwanted reflections. Control colors are designed to simplify operation and maintenance.

Accessiblility is designed into the shelter configurations to assure operation and maintenance procedures. Equipment controls and indicators are located on the front of the equipments. External cable connection terminal boxes are located on the outside of the shelters to enable rapid set-up and dismantling operations.

The Environmental Contol System (ECS) controls ventilation, air flow velocity, temperature and relative humidity including filtration of the ventilation air. The static airspace per occupant (based on four men per shelter) is approximately 200 ft^3 per man. The minimim ventilation rates of 30 ft^3/m to 45 ft^3/m per man prevent the build up of stale air; *i.e.*, as the effective static airspace decreases, the ventilation flow should be increased. The static airspace was determined as follows: the overall shelter volume is 1280 ft^3 and the static airspace for each of four men is 320 ft^3. It is assumed that the shelter structure, equipment and furnishings displace approximately 120 ft^3/man; therefore, the net allocated airspace per man is 200 ft^3. This is considered the extreme man loading for DC/SR shelter habitability.

The air flow velocities for either cooling or heating is maintained between 20 and 25 ft/m. The discharge louvers are located so that airflow is not directed at the personnel; air flow velocity is controlled by using large area discharge louvers with orifice plates.

The effective temperature is a composite index of dry and wet bulb temperatures which relate humidity and ambient temperature to air velocity. The comfort zone for a sedentary work environment with an air velocity of 20 to 25 ft/m and relative humidity of 30 to 70% is maintained by controlling the dry bulb (ambient) temperature between 68° and 85°F with control of vapor pressure to 7 and 8 mm Hg. The temperature uniformity within the shelters is maintained within 10°F between the floor level and head level and within 5°F at any operator's station.

The general illumination for the shelters is provided by fluorescent luminaries along the center line of the longitudinal axis of the shelter ceiling. Fluorescent luminaries are also provided at the situation maps in the analyst shelters and at the switchboard in the communications shelters. Incandescent lamps are provided at the map stations and work tables in the analyst shelters and at the map tables in the non-digital shelters. Portable lights are provided for maintenance tasks in all of the shelters.

The maximum permissible acoustic noise level in the interior of the shelter when measured at any operators position during self-contained integrated operation with the ECS operating shall not exceed a noise criteria (NC) level of 60. The acoustic noise was minimized by application of one-inch thick acoustical material on the shelter walls and ceiling, location of the ECS up to 10 feet from the shelter, use of soft flexible air ducts, and location of the diesel power generators up to 100 feet from the closest shelter. Noise baffling and acoustic material were used in all peripheral equipments which has a noise source such as fans and mechanical movement of subassemblies. Acoustic noise level of cooling fans and blowers was a major factor in their selection.

Maintainability

The equipment was designed for maintenance by military personnel in the field. Front and/or top access is provided and modular construction enables rapid repair by replacement of plug-in assemblies for 95% of the repair actions. Automatic error detection and fault isolation is provided by either hardware or software. Maintenance is enhanced by illuminated operational status panels, equipment status indicators, and auxiliary maintenance controls.

Installation of the equipment in the shelters, ECS, and power distribution pallet affords maximum access for operation and maintenance. The equipment drawers are mounted on slides provided with locks to secure in open position. Easy and ready access to all assemblies and their interior parts or components for adjustments, checkout, repair and removal, or replacement of parts without damage to adjacent units and without extensive disassembly was a major design consideration. Equipment design relied on the use of standard parts, modular replaceable assemblies, avoidance of special tools, use of captive hardware, adequate physical access, and lifting aides on assemblies.

Interconnections and cabling

Interconnections and cabling are particularly important in the TIPI DC/SR segment because of EMI/EMC, TEMPEST, and the need for secure connections. As a result, the configured shelter internal cables associated with the transmission of control and data signals are considered in the red (secure) category. These cables are separated from the black (unsecure) telephone cables in accordance with the minimum separation and crossover criteria.

Power wiring between each equipment within the shelter and the power entry panel is filtered at the power entry panel. The filtering eliminates the red cable data from being transmitted outside the shelter via coupling to power cables.

Cables within each configured shelter are routed through ferrous metal raceways located near the floor level or overhead above the *dropped* ceiling. The signal and power cables are run in separate raceways (separated by distances dictated by electrical requirements).

The signal and power cables enter the shelter via separate *stepped* entrance panels. Weatherproof connectors are provided for all external connections.

Each different type of cable is keyed to prevent incorrect connections. The numbers and types of cables were kept to a minimum to enhance deployment and logistics. All signal cables except for telephone cables connect to the shelter entry panel. The telephone, power and ECS control cables connect to the shelter power entry panel. This separation provides isolation between secure lines and unsecure power and telephone lines. The signal (digital) cables are routed within the deployment pattern while black telephone cables are routed outside the deployment pattern. This provides physical separation for EMI purposes. Additional EMI security is provided by use of shielded twisted pairs and EMI filters at the communication shelter cable entry panel on telephone lines interfacing with equipments outside the DC/SR segment.

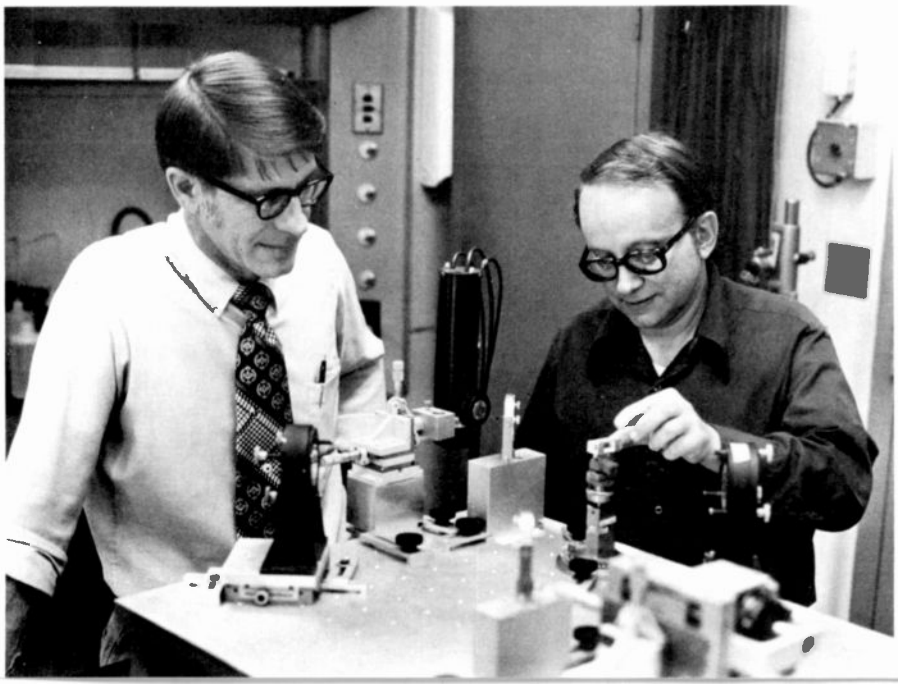
Convenient interferometric method for refractive index determination

M.M. Hopkins| Dr. A. Miller

A Mach-Zehnder interferometer is used for the determination of refractive indices by measuring the change in optical path length through a sample as it is rotated about a vertical axis. The apparatus works equally well with low index as well as high index transparent optical materials. Interference orders are counted electronically. The refractive index of routinely processed samples that are moderately wedge shaped with non-flat surfaces can be measured to better than 1% accuracy.

Maxwell M. Hopkins, Physical Electronics Laboratory, RCA Laboratories, Princeton, New Jersey, joined RCA Laboratories in 1957 as a research technician after three years of schooling at Hanover College, Indiana. He attended night school at Polytechnic Institute of Brooklyn and completed the requirements for the BS in Physics, with the degree being granted in 1961 from Hanover College. Subsequently, he was appointed a Technical Staff Associate. Presently, he is engaged in the study of new materials useful for modulation and processing of light by electro-optic and related effects. Previously he had worked in the field of ferroelectrics. He then helped design and construct a high-temperature carbon-arc imaging system for the growth of single crystals of refractory oxides namely zirconium oxide and hafnium oxide. Later, he was engaged in the spectroscopy of laser materials and designed apparatus for high-temperature differential analysis to determine physical properties relevant to crystal growth from the melt, phase transition temperatures, and the magnitude of energies involved in phase changes. His work on a Bismuth Titanate Display Panel, involved a poling technique to eliminate unwanted domain structures that prevented a uniform optical response in bismuth titanate. The work on non-linear optical materials led to the introduction of optical waveguide in barium sodium niobate. Phase-matched frequency doubling of the cw output of a Nd-YAG laser was demonstrated in such a waveguide. Mr. Hopkins has authored and co-authored five papers and a chapter in a book. One invited paper has been presented at a meeting of the Electrochemical Society. He has one issued U.S. patent and one pending. Also, he is listed in American Men of Science.

Dr. Arthur Miller, Physical Electronics Laboratory, RCA Laboratories Princeton, New Jersey, received the BS in Chemistry, Summa Cum Laude, from Brooklyn Polytechnic Institute in 1951. He attended the California Institute of Technology, where he was granted the PhD in Chemistry in 1957. His thesis research there was on the determination of the structures of intermetallic and organic compounds by x-ray diffraction methods. Dr Miller spent two summers at Brookhaven National Laboratory developing radio-chemical procedures and one summer at Los Alamos Scientific Laboratory performing research in actinide chemistry. Upon joining RCA Laboratories in 1956, he worked mainly in the area of magnetic materials reserach. His studies included spectrophotometric investigations of transition metal cations, elucidating the valence behavior in spinels, formulation of a theory explaining the distribution of cations in spinels, and development of methods for the preparation of new materials for magnetic recording media. In 1964, he initiated a research program in the area of electro-optic materials. He has extended this program to include non-linear optical materials and optical devices. Dr Miller is the author of over two dozen papers dealing with crystallography, radiation chemistry, the crystal chemistry of spinels, and electro-optics. He has been issued eight U S. patents and has a number of others pending. He is listed in American Men of Science, and is a member of the American Crystallographic Association, the American Physical Society, Phi Lambda Upsilon, and Sigma Xi. He is the recipient of two RCA Laboratories Outstanding Achievement Awards



Authors Hopkins (left) and Miller.

GENERALLY, interferometry is thought of when accuracies better than a part in 10^4 or 10^5 in the determination of the refractive index are required. When refractive indices > 1.8 are measured, two of the more common methods used are the Duc de Chaulnes[1] method and the minimum deviation method. The Duc de Chaulnes method is a microscope focus displacement method and has about the same accuracy as the one we are about to describe but requires much more effort for a refractive index determination. The minimum deviation method is the most accurate but requires the fabrication of a large aperture prism.

The method described here is a modification of the technique described by Proctor, von Nardroff,[3] and later refined somewhat by Shumate.[4] They used a double pass interferometer of the Michelson and Twyman-Green type. We use a single pass Mach-Zehnder interferometer to determine the change in optical path length through a plane-parallel plate of material as it is rotated from normal incidence through an angle θ. The change in interference order (fringes) caused by the rotation is noted. From a separate determination of the sample thickness and a knowledge of the wavelength of the incident radiation we have all the information necessary to calculate the refractive index of the sample. Experimentally, we have found the method accurate to better than 1% or typically $\pm \Delta n = 0.007$ ($n = \sim 2$). The limit of the accuracy is determined by the errors in the fringe count and thickness measurement.

Description and analysis of the method

The increase in optical path length through the sample is measured by using a Mach-Zehnder interferometer (Fig. 1). As the sample is rotated away from

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normal incidence there is a resulting change in interference order caused by the increase in optical path length through the sample as a function of rotation angle. The fringes are counted electronically. Others have mainly counted the fringes manually. However, using thicker materials and higher index materials, the counting of possibly 1000 fringes manually would be much too cumbersome.

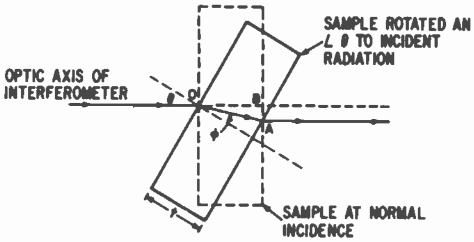

Fig. 2 — Sample shown rotated an angle θ to incident radiation. Smaller samples would require smaller rotation angles.

Fig. 2 shows the sample rotated an angle θ from normal incidence. Assuming that the index of refraction of the reference medium $n_m = 1$, we can readily show in terms of the rotation angle θ, the thickness of the sample t and the refractive index of the sample n, that the net optical path length $P(\theta)$ is

$$P(\theta) = t[(n^2 - \sin^2\theta)^{1/2} - \cos\theta]. \qquad (1)$$

The change in optical path length ΔP *is*

$$\begin{aligned}\Delta P &= P(\theta) - P(0)\\ &= t[(n^2 - \sin^2\theta)^{1/2} - \cos\theta - n + 1], \qquad (2)\end{aligned}$$

where $P(0)$ is the optical path length at normal incidence.

The change in interference order m for a Mach-Zehnder interferometer is

$$m = \Delta P/\lambda, \qquad (3)$$

where λ is the wavelength of the incident radiation. Substituting Eq. 2 into Eq. 3 and solving for refractive index n of the sample we have

$$n = \frac{-x^2 - 2x\cos\theta + 2x + 2\cos\theta - 2}{2x + 2\cos\theta - 2} \qquad (4)$$

where $x = m\lambda/t$.

The interferometer is illuminated with 632.8-nm radiation from a *He-Ne* laser, as shown in Fig. 1. Prior to entering the interferometer the laser beam is expanded to 10-mm diameter by a laser beam expander with spatial filtering. The sample is mounted on a goniometer head[3] attached to a smoothly rotating table that rotates about a vertical axis. The table rests upon a thrust bearing that is responsible for the necessary smooth, vibration-free rotation. Fringes are counted electronically by a photomultiplier tube (PMT) connected to an electronic counter. A 0.43-mm aperture and narrow-band interference filter for 632.8-nm radiation are placed in front of the PMT that allows working in normal room light. A fixed rotation angle of about 30° is used. Since our equipment does not allow us to measure θ with any reasonable accuracy we calibrated the angle by determining n_ω of crystal quartz and using Eq. 4 to find θ. The refractive index n and cos θ are exactly interchangeable in Eq. 4.

The sample is aligned with the front face normal to the optic axis of the interferometer by placing a small aperture between beam splitter S_1 and mirror M_1 and retroreflecting the beam from the front face of the sample upon the aperture. If the sample is not wedged, this position is the extremum in the fringe movement and can also be found by observing the fringe movement, but with less accuracy. Any lack of parallelism in the sample faces can be easily detected because the beam is also reflected from the back face of the sample producing a second spot. Shumate[4] made an analysis of a wedge-shaped sample and found that the error in the refractive index did not exceed 10^{-4} even for a wedge angle of 0.25°.

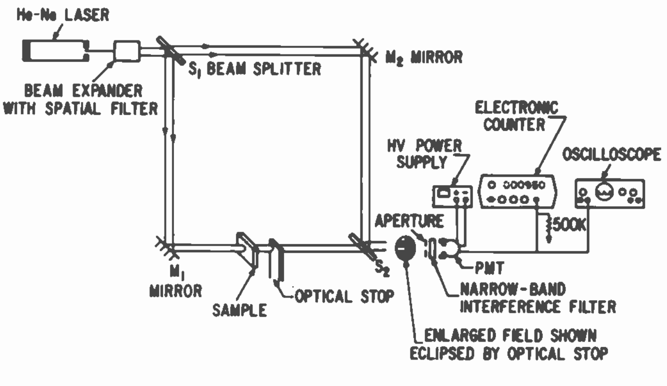

Fig. 1 — The experimental set-up showing the Mach-Zehnder interometer with the location of the sample and optical stop. The inexpensive mirror type beam splitters have inconel coatings. They are flat to approximately one-tenth the wavelength of light and are parallel to 20 seconds.

The angular range over which the sample is rotated is determined by a mechanical stop at one end and a metal vane that eclipses the interferometer beam of light passing through the sample at the other end. The optical stop is used to eliminate spurious fringe counts caused by vibrations from a mechanical stop. When the sample is positioned normal to the optic axis of the interferometer, the optical stop is adjusted to eclipse one-half of the field. The PMT (mounted on an x-y-z translator) with the 0.43-mm diameter aperture is then very accurately positioned just into the eclipsed field at a point where a tap on the laser table will not cause a fringe count. This position is sensitive to 0.001 in. This technique allows us to reliably position the PMT aperture from sample to sample and means all samples are rotated through the same θ. We also found it was particularly important for the electronic counter we used to adjust the PMT voltage from sample to sample in order to keep the photovoltage excursions between fringe maxima and minima about the same for all runs.

Experimentally it was most convenient to initiate sample rotation from the mechanical stop at the extreme angle of incidence and rotate through θ to normal incidence where the optical stop terminates the fringe count by eclipsing the PMT aperture. The sample is rotated in this manner because the fringe density

Table I — Typical values and errors for a plane parallel sample having a refractive index of 2.

Variable	*Typical value*	*Error*	Δn
λ	632.8 nm	Negligible	Negligible
θ'	30°	± 3 min	4.7×10
m	950	± 1	4.6×10
t	0.85 cm	± 13 μm	6.6×10

θ is a fixed rotation angle and has to be calibrated on our apparatus.
Measured with a micrometer.

Table II — Crystal orientations and the refractive index determined using polarized light.

	Orientation	*Refractive index determined*
Isotropic	Any	n
Uniaxial	1. Optic axis parallel to rotation axis (preferred orientation)	Electric vector parallel to optic axis determines n_ϵ. Electric vector, perpendicular to optic axis determines n_ω.
	2. Optic axis perpendicular to rotation axis	Electric vector perpendicular to optic axis determines n_ω.
Biaxial	The principal axis must coincide with both the rotation axis and polarization axis to determine n for that axis.	

is greatest at the maximum angle of incidence and the system would be more susceptable to errors in the fringe count if the optical stop were placed there. We actually rotate the sample through θ by hand in approximately one second.

A degree of optical imperfection of the sample causing poor interference patterns does not appreciably degrade the accuracy of the method if handled properly. When a highly curved or bullseye-type interference pattern is obtained, the center must be positioned over the PMT aperture and remain there throughout the sample rotation. Otherwise, any movement of the center of the interference pattern relative to the PMT aperture as the sample is rotated will cause an error in the fringe count. Two fringe patterns are shown in Fig. 3. Fig. 3a is an interference pattern of a laser quality $LiNbO_3$ crystal. Fig. 3b is a respresentative poor fringe pattern of a good optical quality $LiNbO_3$ crystal that has been poorly processed. However, there was no problem counting the fringes in Fig. 3b. The error in determining n_ω and n_ϵ for both samples of $LiNbO_3$ was 0.6%. Experimentally we find if an interference pattern can be obtained with a fringe spacing greater than the PMT aperture the fringes can be counted. The basic limitation of the accuracy of the experiment is determined by the measurement of the interference order m and the sample thickness t; λ and θ should remain quite constant. Errors in m show up as a variation in n for successive measurements on the same sample, and errors in the measurement of t show up as a systematic offset from the real value of the refractive index. Table I is a list of the variables in Eq. 4, their typical values, and the errors we experience in each and their effect upon n.

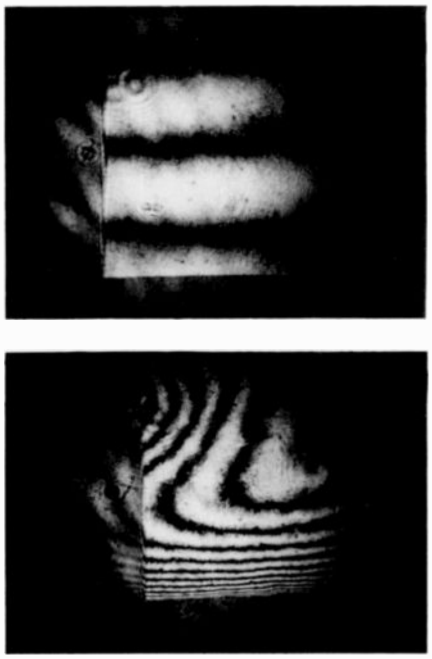

Fig. 3 — Interferograms of lithium niobate. Both crystals are good optical quality but Fig. 3a has been processed to laser quality. Fig. 3b is a typical fringe pattern caused by poor processing.

The method can be used to measure the principal refractive indices of suitably oriented crystals using polarized light. The crystal must be cut with the axis to be measured lying in the plane of the plate. Table II lists different orientations for isotropic, uniaxial and biaxial crystals, and the refractive index determined using polarized light.

The refractive indices of several liquids were determined by using a fused quartz spectrometric cell. Generally, the fringe patterns are very good because of the quality and alignment of the spectrometric cell windows. The procedure is to measure the change in interference order of the empty cell, then measure the change in interference order of the cell containing the liquid. The interference order caused by the liquid is $m_{liq} = m_{liq+cell} - m_{cell}$.

The overall accuracy of the method was determined by measuring the refractive indices of several transparent optical materials and liquids. We covered the refractive index range from 2.3 to 1.33 using crystals of $LiNbO_3$, CdS, fused quartz, crystal quartz, and two liquids, methylene iodide, and H_2O. Errors in determining n were always less than 1%.

Conclusion

The method described for refractive index determinations using a Mach-Zehnder interferometer appears to work equally well for low index as well as high index transparent optical materials. Thin samples as well as thick samples can be accommodated. The interference orders are counted electronically. A particular advantage of the apparatus is that it can handle routinely processed samples that are moderately wedge shaped and still determine the refractive indices to better than 1% accuracy with very little effort.

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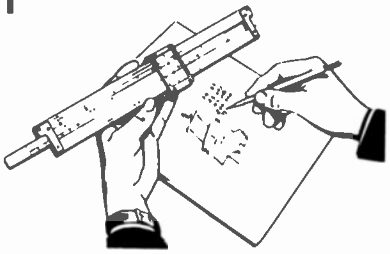

Separating silicon chips to permit chip butting

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Certain electronic systems require integrated circuits that are dimensionally longer than are practical, or possible, to fabricate. Conceptually, it is a simple matter to design submodules on which the circuitry extends to the chip peripheries and then to butt the chips end to end. There is a serious problem, however, in separating the chips (in wafer form) so as to allow them to be butted with fine geometrical precision. Separation of chips on a wafer by scribing and fracture not only leaves ragged edges on the chips but also tends to mechanically stress (diamond scribe) or thermally stress (laser scribe) the circuitry at the edge of each chip. In addition, it is extremely difficult to perform the mechanical alignment (for accuracies and tolerances less than 1 mil) required to accomplish these procedures. This leaves chemical etching as the only practical separation technique where subsequent butting is required.

Chemical etching is routinely used to define integrated circuit patterns on silicon. The etches generally undercut the etch masks to some extent, but the depth of etching is small and the undercutting is negligible compared to the gross definition. In etching through a standard 6 to 10 mil wafer, however, the undercutting would be so severe as to either cause mask failure or at best not be sufficiently reproducible to yield fractional-mil accuracy.

The present technique involves a shallow front side (circuit side) etch wherein the required accuracy is achieved, followed by an oversized deep back-side etch or wire saw cut for which the required tolerance is not so great. Front-side mask alignment is done by conventional means, while back-side mask alignment can be accomplished with an infrared aligner which permits one to see through silicon.

To achieve the front-side etch with fractional-mil accuracy (e.g., control of mask undercutting), one can take advantage of an anisotropic silicon etch. In particular, if a (110) wafer is etched with any of the reported anisotropic silicon etches, and the etch mask is aligned to the vertical (111) crystallographic planes, it is possible to etch long slots with vertical sides. Undercutting is approximately 10% of the etch depth, and it is predictable and reproducible. The slot depth should be deep enough (1 to 2 mil) so that subsequent processing on the back side will not affect or stress the active-side silicon. The slot definition is as good as the IC definition. The circuit should be aligned to the direction of the vertical planes (at least the street area of the circuit). These planes are easily located by etching a shallow slot, with an anisotropic etch, in the general direction of the planes (determined from the wafer flat) prior to circuit fabrication. The etch will undercut the mask along the vertical plane and thus define the exact direction to which the circuit must be aligned. It is expeditious to define both front and back side etch masks to perform the shallow etch on both sides of the wafer. Following the shallow etch, a protective coating is applied on the front surface and the wafer is mounted on a substrate (wax on glass) with the circuit side down. The wafer must be mounted to protect the circuitry from the long etch through the back side.

Either an isotropic or an anisotropic etch may be used on the back side. The back-side slots should be wider than the front slots to ease mask alignments and to assure that the chip edge is defined by the front-side slots.

Alternatively, the back etch may be replaced by a wire sawing technique. The shallow etch is performed on the back to provide wire-saw alignment. The wire diameter of the saw should be larger than the front slot to produce an overhanging or cantilever structure with the edges to be butted defined by the front etch.

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Thyristor trigger circuits employing capacitor-loaded bridge rectifiers

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The circuits of Figs. 1 and 2 provide time-dependent alternating polarity trigger pulses phased to trigger a thyristor in its most sensitive modes (I^-, III^-). The circuits, differing only in the connections of a bridge rectifier and current-sensing resistor, are easily adaptable to provide either of two desired operating modes. The circuit of Fig. 1, for example, provides a momentary turn-on load current upon application of ac power and is useful for energizing the starting winding of an electric motor to provide increased starting torque. The load current can be controlled to vary between an initial full power value and a final half power value which is desirable when driving load devices having variable reluctance magnetic circuits (relays, solenoids, etc.) to provide

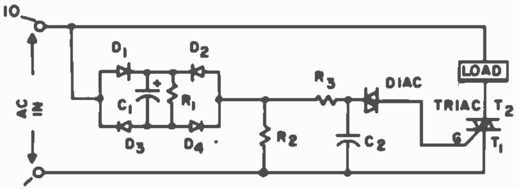

Fig. 1 — Momentary turn-on.

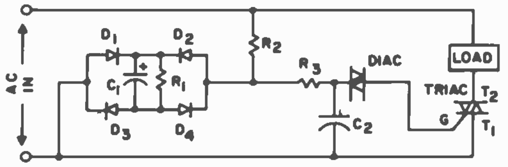

Fig. 2 — Gradual turn-on.

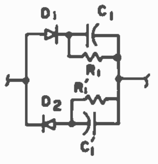

Fig. 3 — Alternative bridge arrangement.

most economic use of available energy. The circuit of Fig. 2 provides a gradual turn-on of load current as needed, for example, to provide a "soft start" for motors used in electric hoists or elevators. In each circuit, the final value of thyristor conduction angle is easily controllable by selection of component values.

In Fig. 1, a current sensing resistor R_2 connected in series with a capacitor-loaded full-wave bridge rectifier (D_1—D_4,C_1) across ac input terminals (10, 12) produces trigger signals proportional to the bridge current. The trigger signals, conditioned by a conventional pulse-shaping network (R_2,C_2, diac) are applied to the gate of a triac for controlling current flow through a load. The connections are such that the trigger signals are of a sense relative to the triac main terminals (T_1,T_2) to trigger the triac in its most sensitive modes (I^+, III^-).

In operation (assuming C_1 is initially uncharged) application of ac power initially causes a relatively large current flow through current sensing resistor R_2 since the bridge impedance is relatively low due to the uncharged condition of capacitor C_1. As C_1 charges, the potential produced acts as a "bucking" voltage which effectively increases the bridge impedance thus lowering current flow through R_2. Eventually, if R_1 were not present, C_1 would charge to substantially the peak value of the ac input signal and thus reduce the current through R_2 to substantially zero. Since the thyristor is triggered in proportion to the R_2 current, its conduction angle and hence the load current varies from an initially high value to substantially zero as the capacitor C_1 charges (assuming R_1 absent).

A discharge path for capacitor C_1 is needed to return the capacitor to its initial uncharged condition when ac power is removed. This could be provided by a relay (not shown) having its coil connected across the ac terminals and the normally closed contacts across the capacitor. A more economic approach is provided by resistor R_1 which, in addition to providing the power-off discharge path, determines (in ratio with R_2) the final value of the triac conduction angle and thus the final value of load current. If R_1 is selected to be very large compared to R_2 the final value of potential developed across R_2 can be made to be less than the diac trigger voltage so that the final value of load current is zero (for motor starting-winding control applications). Choosing a smaller R_1/R_2 ratio can result in non-zero final load-current value (for solenoid or relay-driver applications).

The circuit of Fig. 2 is identical to that of Fig. 1 except that the bridge and current-sensing resistor connections to the ac power terminals are reversed. The operation of these two elements is the same as previously described but since the trigger signals are proportional to the bridge voltage (rather than the R_2 voltage), the triac action is complementary to that of Fig. 1. Here, upon application of ac power, no voltage is produced across the bridge (capacitor C_1 uncharged) so the triac is initially not triggered. As C_1 charges, the potential across the bridge eventually is sufficient to begin triggering the triac at a minimum conduction angle which gradually increases to provide full conduction of the load current. The previous remarks regarding resistor R_1 apply to this circuit as well except that the R_1/R_2 ratio now controls the maximum value that the load current can achieve. By making this ratio relatively large, essentially full power can be delivered to the load. A smaller ratio can be selected to limit the final value of load current to something lower, if desired, or R_1 may be replaced by a relay as previously noted.

The rate of change of conduction angle is controlled in both circuits by selection of the R_2C_1 time constant. The alternative bridge arrangement of Fig. 3 may be substituted for the bridge in either figure to achieve a reduction in the number of diodes (D_3D_4 eliminated) at the cost of requiring an additional capacitor and resistor (C_1',R_1').

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High-dynamic-range, low-noise preamplifier

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A general arrangement for a volume-controlled amplifier having a high input impedance, high dynamic range and low noise is shown in Fig. 1. A specific configuration utilizing an RCA type CA3094 integrated circuit operational amplifier is shown in Fig. 2.

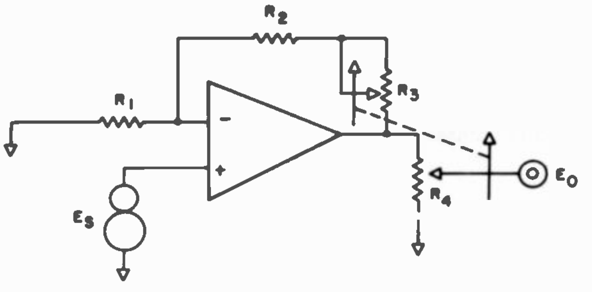

Fig. 1 — High-input-impedance, high-dynamic-range, low-noise amplifier.

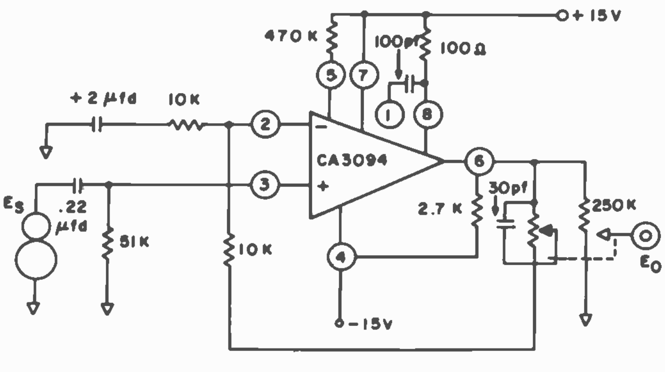

Fig. 2 — Amplifier arrangement of Fig. 1 with CA3094 Op Amp.

This type of amplifier is particularly useful, for example, as a microphone or musical instrument input amplifier where a high dynamic range of input signals is to be expected. The overload characteristics of the amplifier improve as the volume control is decreased.

Specifically, referring to Fig. 1, the variable resistors R_3 and R_4 are ganged together so as to reduce the gain of the operational amplifier at the same time that the portion of the output signal selected from across R_4 is reduced. At the maximum volume setting of R_4, the full resistance R_3 is included in the feedback path of the amplifier so that the voltage gain may be expressed as

$$E_O/E_S = 1 + (R_2 + R_3)/R_1$$

At the minimum volume setting, the portion of R_3 included in the feedback is also at a minimum (e.g., zero). Thus, the output signal level is decreased due to the potentiometer action of R_4 while the gain is reduced because the value $R_2 + R_3$ also is decreased.

At low volume settings, therefore, the overload point of the amplifier is increased while noise output is reduced. The input impedance of the amplifier will be relatively high with the signals applied to the noninverting (+) terminal. Where the potentiometers are linear, the voltage gain may be expressed as

$$E_O/E_S = A^2(R_3/R_1) + A\,(R_2/R_1) + A$$

where A is the fractional rotation of the control. This results in a parabolic variation of signal as a function of the position of the control.

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Automatic pedestal compensation for tv data processing applications

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Television camera systems normally clamp video during horizontal flyback, thereby preserving the dc signal component due to ambient light levels. In commercial television, the camera operator maintains standard signal levels and the consumer (viewer) has complete freedom to manually adjust his received brightness and contrast control to alter the dc and ac signal components to suit his ambient-light viewing conditions. Further, camera lighting in the television studio is adjusted to be uniform over the field of view and to control dynamic range. Any variances which occur are readily manually accommodated by the viewer.

There are many systems, other than commercial television, which employ tv sensors. For instance, in such systems as optical character readers, pattern recognition systems, or as sensors for surveillance systems, tv sensors are frequently used under conditions where it is necessary to process video signals automatically. In such systems, it is generally desirable to process video signals before display and without the aid of an operator making manual adjustments. Further, the low frequency signal component, such as that relating to ambient light conditions, usually contains no useful information and if not removed, imposes a larger dynamic range requirement on signal processing circuits than would otherwise be needed.

A simplified idealized camera video signal is shown in Fig. 1. Although simplified, this waveform is representative of a video signal from a tv sensor used in satellite detection systems where essentially all signals of interest result from point sources. In this case, the ambient light background depends on where the telescope is pointing, being relatively low in looking at the celestial pole and relatively high when looking near a full moon.

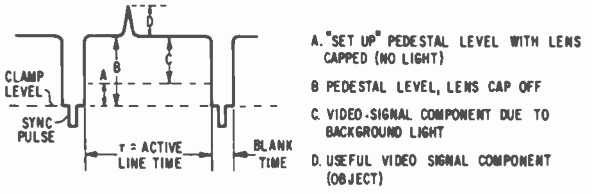

Fig. 1 — Simplified idealized camera video signal.

The object of the circuit shown in Fig. 2 is to remove automatically this variable background, due to variations in ambient light which are of no interest. In so doing, it is important that signal levels are assessed only during the active line time of each tv scan; and that signal levels during the blank interval be excluded. These requirements are met with the circuit shown in Fig. 2, in which a semiconductor switch is closed only during the active line time of each tv scan.

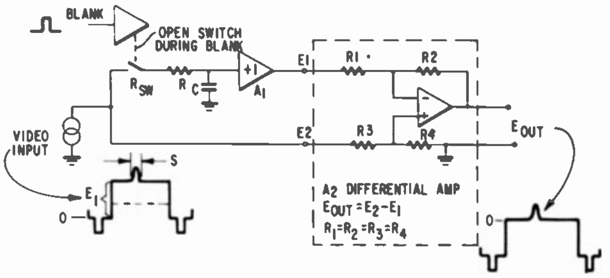

Fig. 2 — Pedestal compensation circuit.

Specifically, if the semiconductor switch has an open resistance $R_{sw\ open}$ in the order of 10^8 ohms and has a closed resistance $R_{sw\ closed}$ only in the order of 10^2 ohms, then the charging time constant of capacitance C through the semiconductor switch and resistance R can be made such that the time constant with the semiconductor switch open is much greater than the active line time τ, while the time constant with the semiconductor switch closed is short with respect to the active line time τ but is still much greater than the duration δ of a video signal component; i.e.,

$$(R_{sw\ open} + R)C >> \tau$$
$$(R_{sw\ closed} + R)C >> \delta.$$

Therefore, while the semiconductor switch is closed, capacitance C will change to the potential E_1, shown in Fig. 2 as the ambient background pedestal level. Further, the ambient background pedestal level E_1 will be maintained from line to line as the tv raster is scanned. The high input impedance of buffer amplifier A_1 assures that capacitance C will not be discharged through this path. The inputs to the differential amplifier A_2 are E_1, the ambient background pedestal level, and E_2, the clamped camera video signal. The differential amplifier A_2 output is $E_2 - E_1$, so that the ambient background component (object) is now always referenced to ground, (0 volts), independent of the background level.

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VIDEO DELTA MODULATION CHANNELS, A technique for correcting transmission errors in — Z. Ali (GCS,Cam) *International Communications Conference Proceedings*, San Francisco, Calif., Session 270, Paper 27E, (June 16-18, 1975).

VIDEO TRANSMISSION, Analog vs. digital anti-jam — C. Haber, E. Nossen (GCS,Cam) National Associates for Remotely Piloted Vehicles, Dayton, Ohip; *Proceedings*, Vol. 1 (June 3, 1975) pp. 1-3.

345 Television and Broadcast

television and radio broadcasting, receivers, transmitters, and systems, television cameras, recorders, studio equipment.

ELECTRONIC JOURNALISM, An NBC view of — R. Mausler (NBC,NY) NAB Workshop, Las Vegas, Nevada (April 6, 1975).

FRAME SYNCHRONIZER, Operational implementation of a broadcast television — R.J. Butler (NBC,NY) *Journal of the SMPTE* Vol. 84, No. 3. (March 1975).

360 Computer Equipment

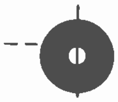
processors, memories, and peripherals.

MNOS/PMOS/SOS MEMORY in space radiation environments, Properties of fully decoded 256-bit — G. Brucker (AED,Pr) IEEE Conf. on Nuclear and Space Radiation Effects, Eureka, Calif., (Jyly 15, 1975).

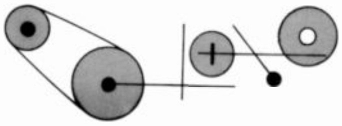
Author Index

Subject listed opposite each author's name indicates where complete citation to his paper may be found in the subject index. An author may have more than one paper for each subject category.

Patents Granted



to RCA Engineers



Consumer Electronics

System for dynamic and static muting — G.D. Pyles (CE,Indpls.) U.S. Pat. 3894201, July 8, 1975.

High voltage protection circuit — P.R. Ahrens (CE, Indpls.) U.S. Pat. 3894269, July 8, 1975.

Electric circuit for providing temperature compensated current — S.A. Steckler (CE,Som.) U.S. Pat. 3895286, July 15, 1975.

Hysteresis voltage supply for deflection synchronizing waveform generator — S.A. STeckler (CE,Som.) U.S. Pat. 3898525, August 5, 1975.

Crystal-lock tuning system for tuning regularly and irregularly spaced channel frequencies — J. B. George (CE,Indpls.) U.S. Pat. 3898567, August 5, 1975.

Dual mode deflection synchronizing system — S.A. Steckler, A.L. Limberg (CE,Som.) U.S. Pat. 3899635, August 12, 1975.

Commercial Communications Systems Division

Spectrum differential noise squelch system — L.C. Schaeperkoetter (CCSD,Meadowlands) U.S. Pat. 3894285, July 8, 1975.

Notch rejection filter — W.J. Hannan, R.S. Singleton (CCSD,Palm Beach) U.S. Pat. 3898375, August 5, 1975.

Government Engineering

Control circuits — G.T. Burton (ATL,Cam.) U.S. Pat. 3895317, July 15, 1975.

Missile and Surface Radar Division

Radar system with a very short pulse length — N.I. Korman (MSRD,Mrstn.) U.S. Pat. 3895383, July 15, 1975.

Integral correlation and transverse equalization method and apparatus — T.V. Bolger (MSRD,Mrstn.) U.S. Pat. 3899666, August 12, 1975.

Insertion and differential phase-trim method — L.J. Lavendan, Jr. (MSRD,Mrstn.) U.S. Pat. 3886501, May 27, 1975; Assigned to U.S. Government.

Average voltage detector for nonlinear waveforms — R.B. Webb (MSRD,Mrstn.) U.S. Pat. 3898551, August 5, 1975.

RCA Limited

Circuit for supplying power to a load — U.M. Van Bogget (Ltd.,Belgium) U.S. Pat. 3898553, August 5, 1975.

Compact frequency reuse antenna — A.R. Rabb (Ltd., Montreal) U.S. Pat. 3898667, August 5, 1975.

Semiconductor radiation detector — J. Conradi (Ltd., Montreal) U.S. Pat. 3898686, August 5, 1975.

Coronet Industries

Adjustable bed — R. Goodman (Cor.Ind., Dalton,Ga.) U.S. Pat. 3898702, August 12, 1975.

Laboratories

Provision of reproducible thin layers of silicon dioxide — A.M. Goodman, J.M. Breece (Labs.,Pr.) U.S. Pat. 3892891, July 1, 1975.

Electron beam recording media — M. Kaplan, E.B. Davidson (Labs., Pr.) U.S. Pat. 3893127, July 1, 1975.

Chemical vapor deposition of luminescent films — J.P. Dismukes, J.Kane (Labs.,Pr) U.S. Pat 3894164, July 8, 1975.

Technique for fabricating high Q MIM capacitors — J. Mitchell, Jr., L.A. Carr, Jr. (Labs.,Pr.) U.S. Pat. 3894872, July 15, 1975.

Method of selectively depositing glass on semiconductor devices — R.B. Comizzoli (Labs.,Pr.) U.S. Pat. 3895127, July 15, 1975.

Method of making a semiconductor device — H. Huang, A. San-Paolo (Labs.,Pr.) U.S. Pat. 3895429. July 22, 1975.

Fabrication of liquid crystal devices — L.A. Goodman, D.E. Carlson (Labs.,Pr.) U.S. Pat. 3896016, July 22, 1975.

Method for epitaxially growing a semiconductor material on a substrate from the liquid phase — S.L. Gilbert, M. Ettenberg (Labs., Pr.) U.S. Pat. 3897281, July 29, 1975.

Method for manufacturing semiconductor devices —J.B. Klatskin (Labs., Pr.) U.S. Pat. 3897627, August 5, 1975.

Method of forming a thin piezoelectric body metallically bonded to a propagation medium crystal — J.J. Hanak, D.M. Stevenson (Labs.,Pr.) U.S. Pat. 3897628, August 5, 1975.

Method of making a transparency of a colored image in a magneto-electric printing system — E.C. Giaimo, Jr. (Labs., Pr.) U.S. Pat. 3898082, August 5, 1975.

Holographic recording media — R. J. Ryan, H.G. Scheible (Labs.,Pr.) U.S. Pat. 3898358, August 5, 1975.

Method of forming pn junctions by liquid phase epitaxy — I. Ladany, W.M. Cannuli (Labs.,Pr.) U.S. Pat. 3899371, August 12, 1975.

Method of electroless plating — N.Feldstein (Labs.,Pr.) U.S. Pat. 3900599, August 19, 1975.

Apparatus for scanning raised indicia — C.T. Wu (Labs.,Pr.) U.S. Pat. 3900717, August 19, 1975.

Apparatus for scanning raised indicia — C.T. Wu (Labs.,Pr.) U.S. Pat. 3900717, August 19, 1975.

Charge amplifier — P.K. Weimer (Labs., Pr.) U.S. Pat. 3900743, August 19, 1975.

Picture Tube Division

Method of setting the 4.5 MHz trap in a television receiver — J.H. Owens (PTD, Dallas) U.S. Pat. 3892913, July 1, 1975.

Self-converging color television display system — A.M. Morrell, W.H. Barkow, J. Gross (PTD,Lanc.) U.S. Pat. 3892996, July 1, 1975.

Cathode-ray tube having lithium silicate glare reducing coating with reduced light tsansmission and method of fabrication — M. G. Brown, Jr.. D.W. Bartch (PTD,Lanc.) U.S. Pat. 3898509, August 5, 1975.

Automated Systems Division

Circuit for determining the time of transitions in an alternating signal — G.B. Dodson, III (ASD,Burl.) U.S. Pat. 3892949, July 1, 1975.

Average value crossover detector — G.B. Dodson, III (ASD,Burl.) U.S. Pat. 3892950, July 1, 1975.

Rapidly accessible optically stored information — B.R. Clay, D.A. Gore (ASD,Burl.) U.S. Pat. 3887276, June 3, 1975; Assigned to U.S. Government.

Valve position indicator — D.O. Blake (ASD,Burl.) U.S. Pat. 3896280, July 22, 1975; Assigned to U.S. Government.

Avionics Systems Division

Computer for threshold of TAU — J.E. Miller (ASD,Van Nuys) U.S. Pat. 3893112, July 1, 1975.

Solid State Division

Multiple cell high-frequency power semiconductor device having bond wires of differing inductance from cell to cell — I. E. Martin (SSD,Som.) U.S. Pat. 3893159, July 1, 1975.

Cathode-ray tube screening correction lens with a non-solarizing material — R.J. D'Amato (SSD,Lanc.) U.S. Pat. 3893750, July 8, 1975.

Megasonic cleaning sysem — A. Mayer, S. Schwartzman (SSD,Som.) U.S. Pat. 3893869, July 8, 1975.

Proximity image tube with bellows focussing structure — G.N. Butterwick (SSD,Lanc.) U.S. Pat. 3894258, July 8. 1975.

Apparatus for non-destructively testing a forwardly biased transistor for second breadkown — R.B. Jarl (SSD,Som.) U.S. Pat. 2895297, July 15, 1975.

Power transistor having good thermal fatigue capabilities — J.E. Wright (SSD,Som.) U.S. Pat. 3896486, July 22, 1975,

Solid State Division

Method of making a junction-isolated semiconductor integrated circuit device — M.A. Polinsky (SSD,Som.) U.S. Pat. 3898107, August 5, 1975.

Government Communications Systems Division

Technique forminimizing interference in video recorder reproducer systems — F.L. Bechly, J.J. Yound (GCSD,Cam.) U.S. Pat. 3893168, July 1, 1975.

Radar recording and reproducing systems — P.F. Muraco, J.S. Griffin (GCSD,Cam.) U.S. Pat. 8993193, June 10, 1975; Assigned to U.S. Government.

Dates and Deadlines

Calls for papers
—be sure deadlines are met

Ed. Note: Calls are listed chronologically by meeting date. Listed after the meeting title (in bold type) are the sponsor(s), the location, and deadline information for submittals.

FEB. 18-20, 1976 — **IEEE International Solid-State Circuits Conference** (IEEE Solid-State Circuits Council, IEEE Phila. Sec. & Univ. of Pa.) Sheraton Hotel, Philadelphia, PA. **Deadline info: (abst & sum) 10/1/75** to D. Koehler, Bell Laboratories/Room 2A131, 600 Mountain Ave., Murray Hill, NJ 07974.

APR. 20-22, 1976 — **Computer Software Engineering: Reliability, Management Design** (IEEE, C&R, PINY) **Deadline info:** (abst) 12/1/75 to M. L. Shooman, Polytechnic Inst. of N.Y., 333 Jay St., Brooklyn, NY 11201.

JUNE 14-16, 1976 — **International Microwave Symposium** (MTT) Cherry Hill, NJ. **Deadline info: (abst) 1/2/76** to Martin Caulton, RCA, Princeton, NJ 08540.

JUNE 21-24, 1976 — **Information Theory Int'l Symposium** (IEEE, IT) Ronneby Brunn, Ronneby, Sweden. **Deadline info:** (ms) 11/15/75 to R.W. Lucky, Bell Labs., Room 1F-532, Holmdel, NJ 07733.

JULY 18-23, 1976 — **Power Engineering Society Summer Meeting** (IEEE, PE) Portland Hilton Hotel, Protland, OR. **Deadline info: (papers) 2/1/76** W. S. Greer, Westinghouse Elec. Corp., 1414 N.E. Grand Ave., Portland, OR 97212.

AUG. 1976 — **Special issue of the *IEEE Transactions on Electron Devices* Deadline info: (papers) 11/1/75** to Mr. Richard A. Kokosa, General Electric Company, Electronics Park, Box 41, Building 7, Syracuse, NY 13201 and/or Dr. Daniel R. Muss, Westinghouse Research Labs., Building 801, Third Floor, 1310 Beulah Road, Pittsburgh, PA 15235.

AUG. 25-27, 1976 — **Product Liability Prevention Conference** (IEEE, R et al) Newark College of Engrg., Newark, NJ. **Deadline info: (paper) 11/1/75** to John Mihalasky, Newark College of Engrg., 323 High St., Newark, NJ 07102.

AUG. 30 - SEPT. 1, 1976 — **Petroleum & Chemical Ind. Tech. Conference** (IEEE, IA) Marriott Hotel, Phila., PA. **Deadline info: (ms) 3/1/76** to J.A. Stewart, FMC Corp., 633 Third Ave., New York, NY 10017.

SEPT. 19-23, 1976 — **Jt. Power Generation Tech. Conference** (IEEE, PE, ASME, ASCE) Buffalo Hilton Hotel, Buffalo, New York, NY. **Deadline info: (abst) 1/29/76** to E.F. Chelotti, Gibbs & Hill, 393 Seventh Ave., New York, NY 10001.

SEPT. 20-24, 1976 — **Int'l Broadcasting Conference** (EEA, IEE, IEEE UKRI Section) Grosvenor House, Park Lane, London, England. **Deadline info: (syn) 11/3/75** to IEE, Savoy Place, London WX 2R OBL England.

SEPT. 29 - OCT. 1, 1976 — **Ultrasonics Symposium**

(IEEE, SU) Annapolis Hilton Hotel, Annapolis, MD. **Deadline info: (ms) 7/1/76** to P.H. Carr, AFCRL, L.G. Hanscom Field, Bedford, MA 01730.

OCT. 25-27, 1976 — **Frontiers in Education** (IEEE and the Ed. Res. & Methods Div. of the ASEE, College of Engrg. Univ. of Ariz.) Ramada Inn, Tucson, Ariz. **Deadline info: (syn) 1/15/76 (final drafts) 6/15/76** to Dr. E.R. Owen, Program Coordinator, FIE '76, Electrical and Electronic Engineering, California Polytechnic State University, San Luis Obispo, CA 93401.

Dates of upcoming meetings —plan ahead

Ed. Note: Meetings are listed chronologically. Listed after the meeting title (in bold type) are the sponsor(s), the location, and the person to contact for more information.

NOV. 3-5, 1975 — **8th Space Simulation Conference** (IES-NASA AIAA/ASTM) Sheraton-Silver Spring Motor Inn, Silver Spring, MD. **Prog info:** Institute of Environmental Sciences, 940 Eut Northwest Highwa1 Mt. Prospect, IL 60056.

NOV. 19-20, 1975 — **Computer Arithmetic** (IEEE, C) Southern Methodist Univ., Dalls, TX. **Prog info:** Dave Matula, Southern Methodist Univ., Dallas, TX.

NOV. 19-21, 1975 — **Nuclear Science Symp.** (IEEE, NPS) Sheraton Palace, San Francisco, CA. **Prog info:** D.A. Mack, Lawrence Berkeley Lab., Univ. of Calif., Berkeley, CA 94720.

NOV. 30 - DEC. 3, 1975 — Int'l. **Electron Devices Meeting** (IEEE, ED) Washington, DC. **Prog info:** C.N. Berglund, Bell-Northern Res. Ltd., POB 3511, Sta. C, Ottawa, Ontario, Can. K1 Y4H7.

NOV. 30 - DEC. 5, 1975 — **96th Winter Annual Meeting** (ASME) Hyatt Regency Houston & Sheraton Houston Hotels, Houston, TX. **Prog info:** Paul Drummond, Director. Meetings and Conferences, ASME, 345 E. 47th Street, New York, NY 10017.

DEC. 1-3, 1975 — **National Tele-Communications Conf.** (AES, COMM, GE, New Orleans Section) Fairmont Roosevelt Hotel, New Orleans, LA. **Prog info:** I.N. Howell, Jr., S. Central Bell Telepnone Co., POB 771, Birmingham, AL 35201.

DEC. 1-4, 1975 — **Signal Filtering** (IEE, IEEE UKRI Section, Inst. of Physics, IERE) IEE, London, England. **Prog info:** IEE, Savoy Place, London, WC2R OBL England.

DEC. 8-9, 1975 — **Chicago Fall Conference on Consumer Electronics** (CE, Chicago Section) O'Hare Inn, Rosemont, IL. **Prog info:** Bob Podowski, Zenith Radio Corp., 6101 Dickens Ave., Chicago, IL 60639.

DEC. 9-11, 1975 — **Electrical Safety in Hazardous Environments** (IEE, IEEE UKRI Section, Inst. of Petroleum, Inst. of Physics) London, England. **Prog info:** IEE, Savoy Place, London W.C. 2 R OBL England.

DEC. 9-12, 1975 — **Magnetism and Magnetic Materials Conference** (IEEE, MAG, also AIP et al) Benjamin Franklin Hotel, Philadelphia, PA. **Prog info:** B. Stein, Univac Div., Sperry Rand, POB 500, Blue Bell, PA 19422.

DEC. 10-12, 1975 — **Decision and Control - Adaptive Processes** (IEEE, CS) Hyatt Regency Houston, Houston, TX. **Prog info:** J. B. Pearson, Dept. of EE, Rice Univ., Houston, TX 77001.

JAN. 12-14, 1976 — **Integrated Optics Topical Meeting** (IEEE, Q-EC, ACM) Salt Lake Hilton Hotel, Salt Lake City, UT. **Prog info:** Optical Society of America, Integrated Optics Meeting, Suite 620, 2000 L St., N.W., Washington, DC 20036.

JAN. 19-21. 1976 — **Computer Architecture** (IEEE, C&ACM) Clearwater, FL. **Prog info:** Oscar Garcia, College of Engrq., Univ. of South Florida, Tampa, FL 33620.

JAN. 20-22, 1976 — **Reliability & Maintainability Symposium** (IEEE, R, et al) MGM Grand Hotel, Las Vegas, NV. **Prog info:** H.L. Wuerffel, RCA Astro-Electronics, POB 800, MS 55, Princeton, NJ 08540.

JAN. 25-30, 1976 — **Power Engineering Society Winter Meeting** (IEEE, PE) Statler Hilton Hotel, New York, NY. **Prog info:** J.W. Bean, American Elec. Pwr. Svc., 2 Broadway, New York, NY 10004.

FEB. 4-5, 1976 — **Modulator Sympoisium** (IEEE, ED & AGED) Statler Hilton Hotel, New York, NY. **Prog ingo:** L.H. Klein, Palisades Inst. for Res. Svcs., Inc. 201 Varick St., New York, NY 10014.

FEB. 17-20, 1976 — **Aerospace & Electronic Systems Winter Convention** (WINCON) (IEEE, AES) Los Angeles, CA. **Prog info:** Dick Harmon, ITT Cannon, 666 E. Dyer Rd., Santa Ana, CA 92702.

FEB. 10-20, 1976 — **Int'l Solid State Circuits Conference** (IEEE, SSC Council, Phila. Section, Univ. of Penna.) Marriott Hotel, Phila., PA. **Prog info:** IEEE, 345 East 47th Street, New York, NY 10017.

FEB. 24-26, 1976 — **COMPCON SPRING** (IEEE, C) Jack Tar Hotel, San Francisco, CA. **Prog info:** Signey Fernbach, Computer Dept., L-61, Lawrence Livermore Lab., POB 808, Livermore, CA 94550.

MAR. 8-10, 1976 — **Industrial Electronics & Control Instrumentation** (IECI) Sheraton Hotel, Phila., PA. **Prog info:** S.J. Vahaviolos, Engrg. Res. Ctr., Western Elec. Co., POB 900, Princeton, NJ 08540.

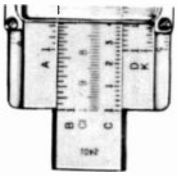
MAR. 9-11, 1976 — **Int'l Zurich Seminar on Digital Communications** (Switzerland Section, ASSP, COMM, C, CAS) Fed. Inst. of Tech., Zurich, Switzerland. **Prog. info:** Albert Kundig, PTT Res. Lab., TZV 907, CH-3000, Bern 29, Switzerland.

MAR. 10-12, 1976 — **Region V Control of Power Systems Conference** (IEEE Region V, Oklahoma City Sec.) Holiday Inn, N.W. Oklahoma City, OK. **Prog info:** M.E. Council, Sch. of EE, Univ. of Oklahoma, 202 W. Boyd, Normal, OK 73069.

MAR. 30-31, APR. 1, 1976 — The **Personal Communications Two-Way Radio Show** (EIA) Las Vegas Hilton, Las Vegas NV. **Prog info:** Mr. Robert Black, The Show Company International, 1605 Cahuenga Blvd., Los Angeles, CA 90028.

APR. 1976 — **Carnahan Conference on Electronic Crime Countermeasures** (IEEE, AES) Univ. of Kentucky. **Prog info:** Office of Continuing Education Engrg., Rm. 779, Anderson Hall, Univ. of Ky., Lexington, KY 40506.

APR 5-7, 1976 — **SOUTHEASTCON** (IEEE Region 3, S.C. Affiliation of Sections) Clemson Univ., Clemson, SC. **Prog info:** J.T. Long, EE Dept., Clemson Univ., Clemson, SC 29631.



Engineering News and Highlights

New RCA management organization

A new RCA management organization was announced by Chairman **Robert W. Sarnoff.** At its apex is the newly created Office of the Chairman. This consists of Mr. Sarnoff, who is Chief Executive Officer; **Anthony L. Conrad,** President and Chief Operating Officer; and the presidents of three major business groups. They are:

RCA Electronics: This consists of the Consumer Electronics Division, the Solid State Division, the Picture Tube Division, the Distributor and Special Products Division, Government and Commercial Systems, RCA Service Company and the "SelectaVision" VideoDisc Project. **Edgar H. Griffiths** becomes President, RCA Electronics. He continues as an Executive Vice President of the Corporation.

RCA Communications: This consists of RCA Global Communications, Inc., Random House, Inc., and the RCA Records Division. **Howard R. Hawkins** becomes President, RCA Communications. He continues as an Executive Vice President of the Corporation.

RCA Diversified Businesses: This consists of Banquet Foods, Coronet Industries, Cushman & Wakefield, Inc., The Hertz Corporation and the Oriel Foods Group. Mr. Griffiths becomes Acting President, RCA Diversified Businesses, pending the appointment of a successor. He has headed this group of subsidiaries since 1971.

The National Broadcasting Company continues to report directly to Mr. Sarnoff. Corporate staff functions that previously reported either to Mr. Sarnoff or Mr. Conrad will now report to the Office of the Chairman.

Mr. Sarnoff said the new, broadened management structure was in response to changes that have occurred in RCA over the past decade.

"During that period our sales have nearly doubled and our assets have nearly tripled," he said. "The combination of our acquisitions and divestitures has changed RCA from a company almost exclusively involved in electronics to a diversified, world-wide enterprise in which the newly acquired businesses have played a vital and growing role."

Mr. Sarnoff said the three major business groups, as well as NBC, will function with maximum operational autonomy. The Office of the Chairman will concern itself with broad policy guidance, the establishment of corporate objectives, the allocation of corporate resources and the coordination of activities among the business groups. The group Presidents, by virtue of their membership in the Office of the Chairman, will participate in top-level decision making for the entire corporation.

Mr. Sarnoff said the primary structural change in the business groups involves the consolidation of all the company's traditional electronic product and service operations into RCA Electronics.

William C. Hittinger, RCA Executive Vice President, continues to be responsible for Consumer Electronics, Solid State, Picture Tubes, Distributor and Special Products, and the "SelectaVision" VideoDisc project. He now reports to Mr. Griffiths.

Irving K. Kessler, RCA Executive Vice President, Government and Commercial Systems, and **Julius Koppelman,** President, RCA Service Company, continue their present responsibilities, also reporting to Mr. Griffiths.

The organization of RCA Communications under Hawkins is: **Robert L. Bernstein,** Chairman of the Board, President and Chief Executive Officer, Random House, Inc.; **Kenneth D. Glancy,** President, RCA Records Division; and **Howard R. Hawkins,** Chairman of the Board and Chief Executive Officer, RCA Global Communications, Inc.

The organization of RCA Diversified Businesses under Griffith is: **Kenneth E. Guebert,** President and Chief Executive Officer, Banquet Foods Corporation; **James G. Gulliver,** Chairman of the Board and Chief Executive Officer, Oriel Foods Group; **Martin B. Seretean,** Chairman of the Board and Chief Executive Officer, Coronet Industries, Inc.; **Leone J. Peters,** Chairman of the Board and Chief Executive Officer, Cushman & Wakefield, Inc.; and **Robert L. Stone,** Chairman of the Board and President, The Hertz Corporation.

"In the years ahead," Mr. Sarnoff said, "RCA, like other companies, will operate in an environment of increasing technical complexity, intensified competition for domestic and international markets, and mounting governmental regulatory requirements. I believe the new organizational structure responds most effectively to the management needs of a large and diversified international company. It will give us the depth and flexibility to react swiftly to new business opportunities. It is a logical and evolutionary response for the management of a changing RCA that faces the future with hope and confidence."

Mr. Griffiths was elected an Executive Vice President of the Corporation in June, 1972, at which time he also was elected to the RCA Board of Directors.

Prior to becoming RCA Executive Vice President, Services, in 1971, Mr. Griffiths was President of the RCA Service Company for three years. He joined RCA at its Camden, N.J., facility in 1948, and a year later he was assigned to the RCA Service Company where he held varied financial positions. In 1963, he was appointed Division Vice President, International Finance, RCA International Division, and three years later was named Division Vice President, Commercial Services, RCA Service Company.

Mr. Griffiths received the BS in Business Administration from St. Joseph's College.

Mr. Hawkins also was elected an Executive Vice President and Director of RCA in June, 1972. Prior to that he served as President of RCA Global Communications since 1966. While an RCA Executive Vice President he continued his leadership role in international communications by serving also as RCA Globcom's Chairman and Chief Executive Officer.

Mr. Hawkins joined RCA Global Communications in 1946 as Assistant General Attorney. He became General Attorney in 1949 and Vice President in 1951. He was elected Executive Vice President and a Director in 1964 and President on June 3, 1966.

A graduate of Indiana University with the BS in Public Business Administration, he received the degree of Doctor of Jurisprudence with Distinction in 1941. He served with the Federal Bureau of Investigation from 1941 to 1946.

Neumann named Chief Engineer for Mobile Communications

Karl L. Neumann has been appointed Chief Engineer for Mobile Communications Systems, Meadow Lands, Pa. In the newly created position, Mr. Neumann is responsible for all product and development engineering activities for RCA's line of two-way radio communications systems.

Neumann

Erickson named Manager, Manufacturing Engineering

Samuel P. Vrankovich, Plant Manager, Meadow Lands plant, announced the appointment of **Dale O. Erickson** as Manager, Manufacturing Engineering, for RCA's Meadow Lands facility. Mr. Erickson is responsible for the planning, operation, and supervision of the Manufacturing Methods Engineering, Test Methods Engineering, and Test Maintenance Activities.

Erickson

Donahue heads Picture Tube Engineering

Dr. D. Joseph Donahue has been appointed Division Vice President, Engineering, Picture Tube Divison. Dr. Donahue is responsible for all engineering activities in the Picture Tube Divison, including research and development. He is located in the Lancaster, Pa., headquarters of the Picture Tube Division.

Donahue

E.O. Johnson named Director of Japanese Laboratories

Appointment of **Edward O. Johnson** as Director of RCA Research Laboratories, Inc. (Tokyo), has been announced by **Dr. Jan A. Rajchman,** Vice President of the RCA subsidiary. Located on the outskirts of Tokyo, RCA Research Laboratories was established in 1961 to foster closer relations between the Japanese and American scientific communities. (See *RCA Engineer*, Vol. 20, No. 3, Oct-Nov. 1974 which contained a profile of the Tokyo Laboratories.) Mr. Johnson is replacing **Dr. Bernard Hershenov,** Director of the Japanese Laboratories since 1972. Dr. Hershenov is returning to RCA in the United States.

Johnson

Laschever appointed Manager, Electronic Warfare and Radar Programs

Dr. Harry J. Woll, Division Vice President and General Manager, Automated Systems Division, has appointed **Norman L. Laschever** as Manager, Electronic Warface and Radar Programs. In his new capacity, Mr. Laschever will be responsible for all electronic warfare and radar products developed and produced by the RCA facility.

Laschever

Bachynski elected V.P.

G. Denton Clark, President, RCA Limited (Canada), has announced that **Dr. Morrel P. Bachynski** was elected Vice President, Research and Engineering. He has been Director of Research since 1965.

(See *RCA Engineer*, Vol. 19, No. 6, April-May 1974 which contains a paper by Dr. Bachynski on "Research and Development in Canada").

Bachynski

Organizational Changes at G&CS

Government and Commercial Systems has made an organizational realignment that includes the re-establishment of its Burlington, Mass., facility as a Division and the consolidation of certain commercial activities.

Irving K. Kessler, Executive Vice President, G&CS, said the Automated Systems Division in Burlington will be headed by **Dr. Harry J. Woll** as Division Vice President and General Manager. Dr. Woll, formerly Division Vice President, Government Engineering, has had acting responsibility for the Burlington operation for the past several months. The Burlington facility was known as the Aerospace Systems Division until March 1974 when it became part of the Government Communications and Automated Systems Division in Camden, N.J.

RCA government activities in Camden have been reconstituted as the Government Communications Systems Division and **Dr. James Vollmer** has been named Division Vice President and General Manager. He succeeds **James M. Osborne** who has resigned.

Dr. Vollmer was formerly the Vice President and General Manager of the Palm Beach Division, Palm Beach Gardens, Florida. That organizational responsibility has been transferred to Commercial Communications Systems Division and renamed Palm Beach Operations.

Commercial Communications Systems Division headed by **Andrew F. Inglis,** Division Vice President and General Manager, now encompasses RCA business in Avionics Systems (Van Nuys, California), Broadcast Systems (Camden), Mobile Communications Systems (Meadow Lands, Pa.), and Data Management Systems (Palm Beach).

Other organizational changes in Commercial Communications Systems Division include the transfer of the Broadcast Systems international business to **Neil Vander Dussen,** Division Vice President, Broadcast Systems. Mr. Vander Dussen also has acquired responsibility for the RCA Film Recording Systems activity in Burbank, California. The international business of Mobile Communications is transferred to **Jack E. Underwood,** Division Vice President, Mobile Communications.

The two international activities formerly were the responsiblity of **Joseph P. Ulasewicz**, a Division Vice President, who has been appointed to a newly created position of Division Vice President, Product Operations. He will be responsible for product management and product engineering activities in Broadcast Systems.

Awards

Government Communications Systems Division

The Technical Excellence Committee of Government Communications Systems Division in Camden, N.J., has made a team award to **Jim Devlin, Al Foster, Jay Hoover, Dick Orr,** and **Dave Sapp** of Recording Systems for their outstanding work in the development of the RCA High Density Multi-Track Recorder (HDMR). Their efforts have resulted in a recent sole source contract from NASA for an engineering model of a 240-megabit per second spacecraft recorder for EOS Program.

RCA Laboratories

Robert A. Gange and **Carl C. Steinmetz,** Materials Research Laboratory, and **Eugene M. Nagle,** Systems Research Laboratory, have received NASA New Technology commendation certificates for their work on a laser actuated holographic storage device.

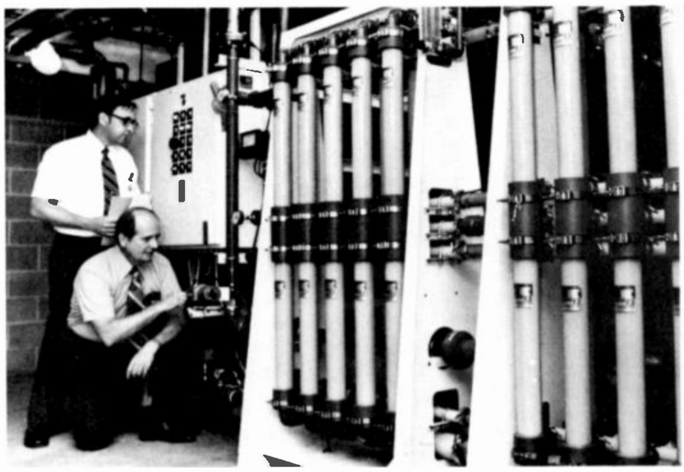
Law and Schade receive SID awards

Dr. Harold B. Law Director, Materials and Display Devices Laboratory, Picture Tube Division, Princeton, N.J., received the Francis Rice Darne Memorial Award of the Society for Information Display "for outstanding contributions to color picture tube development resulting in practical color television."

New equipment at Lancaster

During the plant shutdown at Lancaster, a new Romicon Ultra Filtration water system was installed. This will solve a long-standing problem of providing quantities of high quality water for the CCD operation. The unit supplies 60 gal/minute. It is anticipated that long lifetime operation will be obtained using 0.2-micrometer point-of-use filters.

A Macrodata MD154 large scale IC tester has been installed in the CCD production area in Lancaster. This equipment is one of the most sophisticated pieces of test equipment in the Corporation. It is capable of very wide adaptability in testing all manner of devices incorporating memory, shift registers, and logic circuits. The Macrodata equipment has now been programmed for complete testing of CCD's.



Tom Edwards (left) and Bob Blazek inspecting the new Ultra Filtration water system at Lancaster.

John Schollenberger using the new Macrodata IC tester in the CCD area at Lancaster.

Dr. Harold Law (right) accepts SID award from Robert Klien, President of SID.

Otto H. Schade, Sr. (retired) of RCA Electronic Components, Harrison, N.J., received a special recognition award of the Society for Information Display "for the pioneering applications of frequency response concepts to the analysis and optimization of electrooptic systems."

Hanak receives best paper award

Dr. Joseph J. Hanak, Fellow of the Technical Staff, Materials Research Laboratory, RCA Laboratories, Princeton, N.J. recently received a special Certificate of Recognition from the Mid-Atlantic Chapter of the Society for Information Displays. Dr. Hanak was cited for his presentation, "Electroluminescent Thin Film Displays," as the best paper of the 1974-75 seminar program.

Goodwin, Petrillo win highest Navy award

The Navy's Distinguished Public Service Award, the highest recognition that can be extended to an individual not employed by the Navy, was presented by Rear Admiral **Wayne E. Meyer** to **William V. Goodwin** and **Edward W. Petrillo** "for outstanding...contributions" to the development of AEGIS, the Navy's newest and most advanced fleet air defense system.

The ceremony was held at the company's Moorestown Plant. Also attending were **Anthony L. Conrad,** President and Chief Operating Officer, RCA, and **I. K. Kessler,** Executive Vice President, RCA Government and Commercial Systems.

Mr. Goodwin was cited for his "...dedicated professional participation and innovative engineering leadership" in directing AEGIS "toward its role as the Surface Ship Weapon System of the future."

Mr. Petrillo was commended for "professional and innovative engineering participation" that substantially assisted in the development of AEGIS. As AEGIS Program Manager, he was responsible for delivering a fully integrated AEGIS Engineering Development Model for testing.

Otto Schade, Sr., (right) accepts special SID award from Philip Damon, SID awards/honors chairman.

Professional activities

Commercial Communications Systems Division

A.C. Luther, Chief Engineer of Broadcast Systems, has been named a Member of the Board of Managers of the newly formed Philadelphia Section of the Society of Motion Picture and Television Engineers (SMPTE).

J.R. West, Engineering Leader in Broadcast Systems has been named as the TV program co-chairman of the Philadelphia Section of SMPTE.

Missile and Surface Radar Division

Dr. J.C. Williams was re-appointed to the Scientific Advisory Committee of the Defense Intelligence Agency for the period July 1975 - July 1976 (see June-July 1974 issue which announced the initial appointment).

D.L. Pruitt has been selected to serve on the committee for the Twelfth Modulator Symposium.

Degrees

Government Communications and Automated Systems Division —Burlington

Doug Gore of Electro-Optical Systems Engineering received the MSEE with a major in Electro-Optics from Northeastern University in June.

Errata

To: Editor

Subject: "MOS Array design: universal, APAR, or custom" by R. Bergman, M. Aguilera, G. Skorup

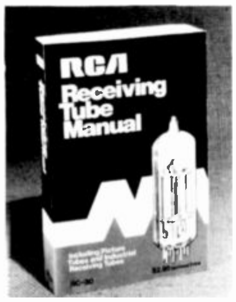
I recently co-authored the MOS array design article which appeared in the June-July issue of the *RCA Engineer*. Due to an oversight on our parts, no acknowledgment appeared in this article.

I strongly feel that professional contributions should be recognized and am requesting that you include the attached in a future issue along with our personal regrets for the oversight.

M. Aguilera

Acknowledgment: Development of the programs referenced in this paper results from the efforts of many RCA personnel. The Advanced Technology Laboratories team under the leadership of A. Feller originally wrote and evaluated the PR2DA and PR2DAE programs and evaluated the supporting standard cell family. The Solid State Technology Center Design Automation group under the direction of Dr. L. French developed the ART, MAP CRITIC and other minor supporting programs necessary for processing custom, APAR and Universal Arrays.

The authors gratefully acknowledge the efforts both of these teams put forth to supply the basic Computer Aided Design programs. The authors especially wish to recognize the efforts of Mr. R. Noto for his writing of PR2DA and PR2DAE the backbone of our present Automatic Placement and Routing system.



New Receiving Tube Manual

A new edition of the widely used *RCA Receiving Tube Manual* is now available. The manual — RC-30 — like its predecessors, has been written for engineers, service technicians, educators, experimenters, and others interested in electron tubes and their applications.

The RC-30 can be purchased from local RCA Family Stores at a special employee price of $2.25 per copy, plus applicable state and local taxes. Orders from the field should be addressed to the attention of Family Stores, RCA Distributor and Special Products Division, Deptford, N.J. 08096.

Oliver is new Ed Rep for Indianapolis plant

C. Wayne Hamilton, Plant Manager, Indianapolis Component Plant, Manufacturing Operations, Consumer Electronics has appointed **James S. Oliver** *RCA Engineer* Editorial Representative for Manufacturing Operations at Indianapolis. Editorial representatives are responsible for planning and processing articles for the *RCA Engineer* and for working with the local Technical Publications Administrator (TPA) to support the corporate wide technical papers and reports program. **Clyde Hoyt** is the TPA for Consumer Electronics.

James S. Oliver received the BSIE from Georgia Institute of Technology and joined RCA at the former Memphis, Tennessee Facility in 1966. Initially hired as a Timestudy Engineer, he later accepted assignment as a Manufacturing Methods Engineer responsible for the generation and maintenance of assembly processes. In August, 1968, he became Manager, Chassis Assembly Process. This position he held until the closing of the Memphis Facility in January, 1971. Transferring to the Bloomington, Indiana Facility, as a Manufacturing Methods Engineer, he assumed processing responsibilities until assigned to the Foreign Operations Support Group in January, 1974. In March, 1974, he was transferred to RCA Electronica, Rio de Janeiro, Brazil. Following the October, 1974, decision to discontinue efforts to develop the Brazil Facility, he was transferred to the Indianapolis, Indiana Facility. He is now engaged in make-versus-buy activities as a Manufacturing Methods Engineer.

Obituaries

Ray Guy

Raymond F. Guy, retired NBC engineering executive and radio-tv pioneer, died on July 12. He was 76. Mr. Guy, whose association with radio dates back to the "spark gap" transmitter and "Quaker Oats" receiver, retired from NBC in 1961 and became a consulting engineer. He started with the Marconi Wireless Telegraph Company in 1916; served in the U.S. Army in WWI; and received the BSEE from Pratt Institute in 1921. That year, he became Engineer, Announcer, et. al. for WJZ — the second radio broadcasting station in the country. In 1924, he transferred to RCA research laboratories at Van Courtland Park, N.Y. He joined NBC in 1929 as Staff Radio Engineer and then became Senior Executive Engineer responsible for all NBC networks, transmitters, and frequency allocations.

Based on his sixty-three years of operation, Ray Guy was one of the oldest active HAMS. He began in 1912 (station 2ANC). His first calls were W2O, W2AK, and, on retiring to Florida, the well-known W4AZ. His professional affiliations included Fellow and Life Member of IRE (President, 1950); Member of FCC Consulting Engineers Assn.; Radio and TV Executive Society; Radio Pioneers; IEEE (Fellow and Life Member); TV Broadcasting Assn.; Radio Club of America (Fellow); Veteran Wireless Operations Assn. (Life Member, President 1939); Radio Pioneers (Vice President 1951-53); NSPE. He was a Professional Engineer in New Jersey and New York; co-author of two books; and author of 150 papers.

Gil Lang

Gilman A. Lang, Manager of Power Engineering at Solid State Technology Center in Somerville, N.J. died on July 20. He was 46. A 1974 recipient of the David Sarnoff Outstanding Achievement Award, Mr. Lang received the BS in Chemistry from the University of New Hampshire in 1951, and served the next four years with the U.S. Air Force. From 1955 to 1958 he was employed as an analytical chemist at the Electronic Tube Division of Westinghouse Electric Corporation in Elmira, New York. He joined the Semiconductor and Materials Division of RCA at Somerville, N.J. in 1958 as an analytical chemist. In 1963 he joined the Industrial Aerospace Projects Department as a process engineer. He transferred to the Industrial Power Transistor Design Department in 1965 as a transistor design engineer with responsibility for the development of high power silicon "overlay" transistors. He was appointed Manager of Power Engineering on October 1, 1974.

Hal Schwartzberg

Harold L. Schwartzberg, Staff System Scientist and a key member of the Astro-Electronics Division organization for 13 years, died on August 23. He was 52. Mr. Schwartzberg received the BSEE from Lehigh Univeristy in 1950 and worked for more than 21 years in engineering and engineering management of spacecraft and communication systems. He was project manager for several satellite programs at AED—most recently the TIROS/ITOS/NOAA Weather Satellite. Prior to RCA, Mr. Schwartzberg was associated with Philco and General Dynamics. He was a Professional Engineer in Pennsylvania; senior member of IEEE; the Association of Old Crows; Space and Range Pioneers; and a member of the American Meteorological Society.

Raymond F. Guy

Gilman A. Lang

Harold L. Schwartzberg

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